Underwater Observations of a Surf Clam, *Spisula solidissima* (Dillwyn), Community and the Relative Efficiency of a Prototype Airlift Clam Sampler

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ABSTRACT—A benthic infaunal community dominated by the surf clam, Spisula solidissima *(Dillwyn), was monitored near Rockaway Beach, Long Island, N.Y., during the summers of 1977 and 1978. In 1978, two distinct size groups were found with shell lengths ranging from 26 to 62 mm ($\bar{x}$ = 42.7 mm, age 2.5 years) and from 104 to 138 mm ($\bar{x}$ = 120.4 mm, age 11.5 years) and densities ranging from 480 to 924 ($\bar{x}$ = 730/m^2) and from 8 to 64 ($\bar{x}$ = 40/m^2) for the small and large modal groups, respectively. The larger clams burrowed to a depth of 12-14 cm with their siphons projecting up between the closely packed smaller clams which were burrowed 2-4 cm below the sediment-water interface. Individual clams burrowed to a depth approximately equal to their shell lengths. A slower growth rate was found in the study area compared with the average for the northeast U.S. coast. There may exist an inverse relationship between clam density and growth.*

An airlift system tested was designed to collect quantitatively a 0.25 m^2 sample. The airlift sampled between 0.25 m^2 and 0.50 m^2 of the bottom (70 percent overestimation) because of sediment slumping and scalloping around the perimeter of the dredge head. This resulted in more small clams being pulled into the sample from outside the quadrat area.

Introduction

The National Marine Fisheries Service's Northeast Fisheries Center (NEFC) began a long-term program in 1977 called Ocean Pulse, designed to monitor periodically selected habitats and resources in the coastal waters of the northeast United States. This paper presents 1) the results of a quantitative survey of a surf clam, *Spisula solidissima* (Dillwyn), population along an inshore-offshore transect in polluted waters of the New York Bight, and 2) a gear calibration study to determine the relative efficiency of a prototype airlift clam sampler. The results of a clam dredge calibration study, initially part of this study, have been published (Meyer et al., 1981). The study commenced in August 1977 to obtain information on the distribution, abundance, and ecology of a surf clam community relative to depth.

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Materials and Methods

Study Area

The Rockaway Beach study area (Fig. 1) was selected as a study site because of an earlier surf clam survey in August 1974 which found a broad size range of surf clams in high densities and in water depths less than 15 m (Franz, 1976). The study area is characterized by high substrate mobility (Harris, 1976) and patches of degraded sand waves during the summer (Freeland et al., 1976). The bottom sediments are fine-medium sands inshore, gradually becoming silty-fine sands offshore (Swift et al., 1976). Bottom currents are generally eastward along the Long Island shore (Charnell and Hansen, 1974), normal to our study transect. The mean tidal range is about 1.4 m (Swanson, 1976). A thermocline exists most of the year with bottom temperatures ranging from 5°C in the winter to 20°C in the summer (Thomas et al., 1976.) On the bottom, salinities range from 30 to 33‰ and dissolved oxygen 10 mg/l in the winter to a low of 1 mg/l in the summer (Thomas et al., 1976). The study area was evidently not affected by the large oxygen depletion and benthos kill of New Jersey in 1976 (Steimle, 1976). Thus, it was felt that a relatively stable population of surf clams exists in the area.

The area is nevertheless impacted by the influence of the proximity of the beds to the high population of the New York-New Jersey metropolitan area. Concentrations of typical heavy metals (ppm in dry sediment; Cu-6, Cr-11, Pb-28, Ni-6, and Zn-53) within the study area NNW of the sewage-sludge dumpsite were 2-3 times greater than sediment samples unaffected by waste dumping (Carmody et al., 1973). Based on high coliform levels (Buelow, 1968), the U.S. Food and Drug Administration (FDA) closed an area (Fig. 1) of about 380 km^2 to shellfishing in May 1970 (Verber, 1976). The closed area was circular, with a radius of 11 km, about the center (lat. 40°25′N, long. 73°45′W) of the New York sewage-sludge dumpsite (Gross, 1976). In April 1974 the FDA, in conjunction with the States of New York and New Jersey, closed a much larger area (Fig. 1) to

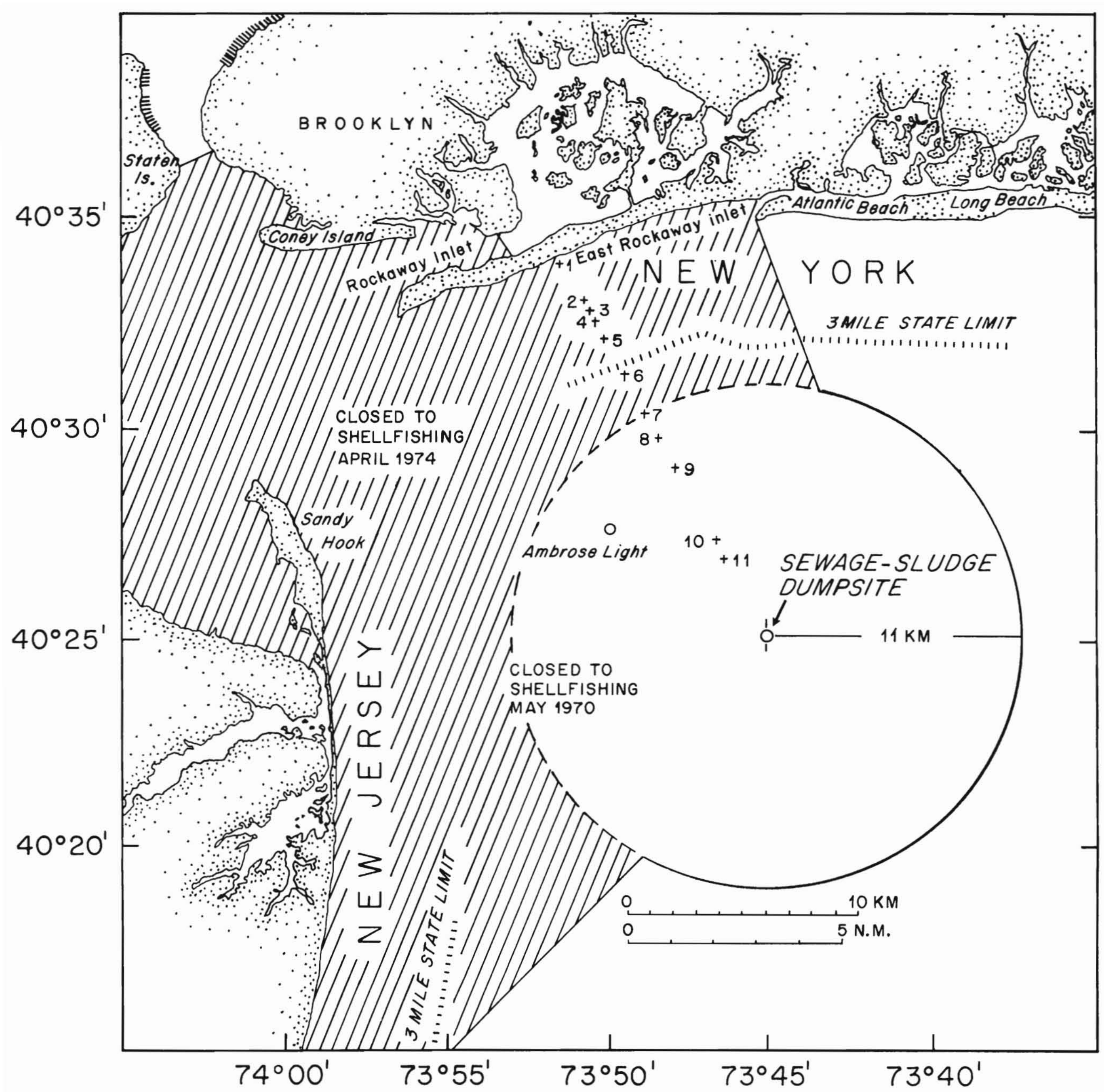

Figure 1.—Rockaway Beach study area.

shellfishing (Verber, 1976). As a consequence, the study area had a wide size range of surf clams within scuba diving depths, had been closed to commercial shellfishing (with the exception of a non-intensive bait fishery) since 1974, and had the potential of containing surf clams in significant numbers and in a relatively undisturbed state to facilitate our study of age and growth, mortality, and settlement.

Diver Transect Study

A NNW-SSE transect was established perpendicular to the Rockaway Beach, Long Island, N.Y. shore between lat. 40°33.9′N, long. 73°51.2′W, and lat. 40°26.8′N, long. 73°46.2′W (Fig 1). Eleven sampling sites on the transect were selected in regard to bathymetry beginning 0.9 km off the beach at a depth of 6.7 m and ending 15.5 km offshore at a depth of 29.6 m (Table 1). Station 11 was located 3.7 km from the center of the

Table 1.—Bottom characteristics.

Characteristic	Year	Station 1	2	3	4	5	6	7	8	9	10	11
Depth (m)	1977/78	6.7	9.8	10.7	12.2	13.4	15.5	18.3	21.3	22.9	27.7	29.6
Substrate	1977/78	Sand-gravel	Fine sand	Fine sand	Fine sand	Fine sand	Fine sand	Silty fine sand	Silty fine sand	Silty fine sand	Silty fine sand	Silty fine sand
Depth of organic covering	1977/78	None	None	None	None	None	None	10 cm	10 cm	18 cm	18 cm	18 cm
Sand waves	1977	10-13 cm high 46 cm length	3-5 cm high 10-13 cm length	(<3 cm) high 6-8 cm length	None	None	None	(<3 cm) high 2-4 cm length	(<3 cm) high 2-4 cm length	None	None	None
	1978	None	None	3 cm high 8-10 cm length	3 cm high 6-8 cm length	None	None	None	None	None	None	None
Shell hash covering	1977	95% Surf clam	5% Surf clam	5% Surf clam	20% Surf clam	50% Surf clam	20% Surf clam	20% Surf clam	5% Surf clam	None	3% Ocean quahog	3% Ocean quahog
	1978	95% Surf clam	15% Surf clam	50% Surf clam	50% Surf clam	50% Surf clam	50% Surf clam	20% Surf clam	5% Surf clam	1% Ocean quahog	3% Ocean quahog	3% Ocean quahog
Bored clams	1977	Yes	None	None	None	Yes	None	None	None	None	None	None
	1978	None	Yes	None	None	None	None	None	None	None	None	None

sewage-sludge dumpsite. The differences in depths between adjacent stations ranged from 1.6 to 4.8 m. Stations 1-6 were within an area closed to commercial clamming by the FDA since April 1974, and Stations 7-11 since May 1970.

Scientists, equipped with scuba, worked in pairs during 1977 from the NOAA Research Vessel *Rorqual* and in 1978 from the NOAA Research Vessel *Kyma*, and collected 20 replicate samples at each transect station using a 0.25 m^2 quadrat grid (Fig. 2) hereafter referred to as a quadrat. Replicate sampling sites were chosen randomly at each station. The grid frame, constructed from aluminum angle stock 4 mm thick, was inserted into the sediment and made stationary throughout the sample collection. The divers worked barehanded. This maximized tactile contact and minimized the loss of clams and other animals in the turbid water above the disturbed sediment. The sediment was passed directly into nylon (mesh size ($\leq$4 mm) collection bags and washed by shaking the bag leaving only coarse fractions of sediment and macrofauna. Care was taken to dig vertically in the grid frame to a sediment depth of about 25 cm. Divers made an approximate 6 m radius circular swim around the center of each station to describe conditions with respect to sediment type, topography, clam and benthic organisms, predators observed, and water visibility.

To determine clam distribution and patchiness in 1978 in the vicinity of Station 2, two quadrat samples were collected at each of 12 locations: 150 feet N, NW, W, SW, S, SE, E, and NE; and 300 feet N, W, S, and E of the center of Station 2. Distance and bearing were determined by marking off 150- and 300-foot lengths on a line and, while keeping the line taut, swimming the requisite bearing using an underwater compass.

In 1978, 53 clams were collected to determine growth rates. This was accomplished by measuring the internal growth lines exposed after thin-sectioning the chondrophore in the hinge (method described by Ropes and O'Brien, 1979). A sample (10 g net weight) of clam foot tissue from Stations 1, 2, 10, and 11 was analyzed on the Perkin-Elmer Model 403 Atomic Absorption Spectrophotometer for heavy metals (method described by Wenzloff et al., 1979). Sediment samples were obtained at Stations 2 and 11 in 1978 using a Smith-McIntyre[1] bottom grab for bottom fauna analysis.

Airlift Bottom Sampler

An airlift system, under development at the University of Rhode Island, was tested as a quantitative clam sampler (Fig. 2). The system was specifically designed to operate in a surface-tended mode and to sample large bivalves, such as surf clams and ocean quahogs, *Arctica islandica*. During our tests, however, the sampler was diver-tended to appraise visually its sampling behavior.

The airlift system had a 0.25 m^2 steel head connected to a 3 m long airlift standpipe of 20 cm inside diameter (Fig. 2). A flexible PVC discharge hose of various lengths, depending on water depth, was attached to the standpipe and conducted samples into a removable nylon mesh collection bag (opening size $\leq$10 mm). Air was supplied to the standpipe through a 2 cm air hose from a low pressure air compressor rated at 40 cfm.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

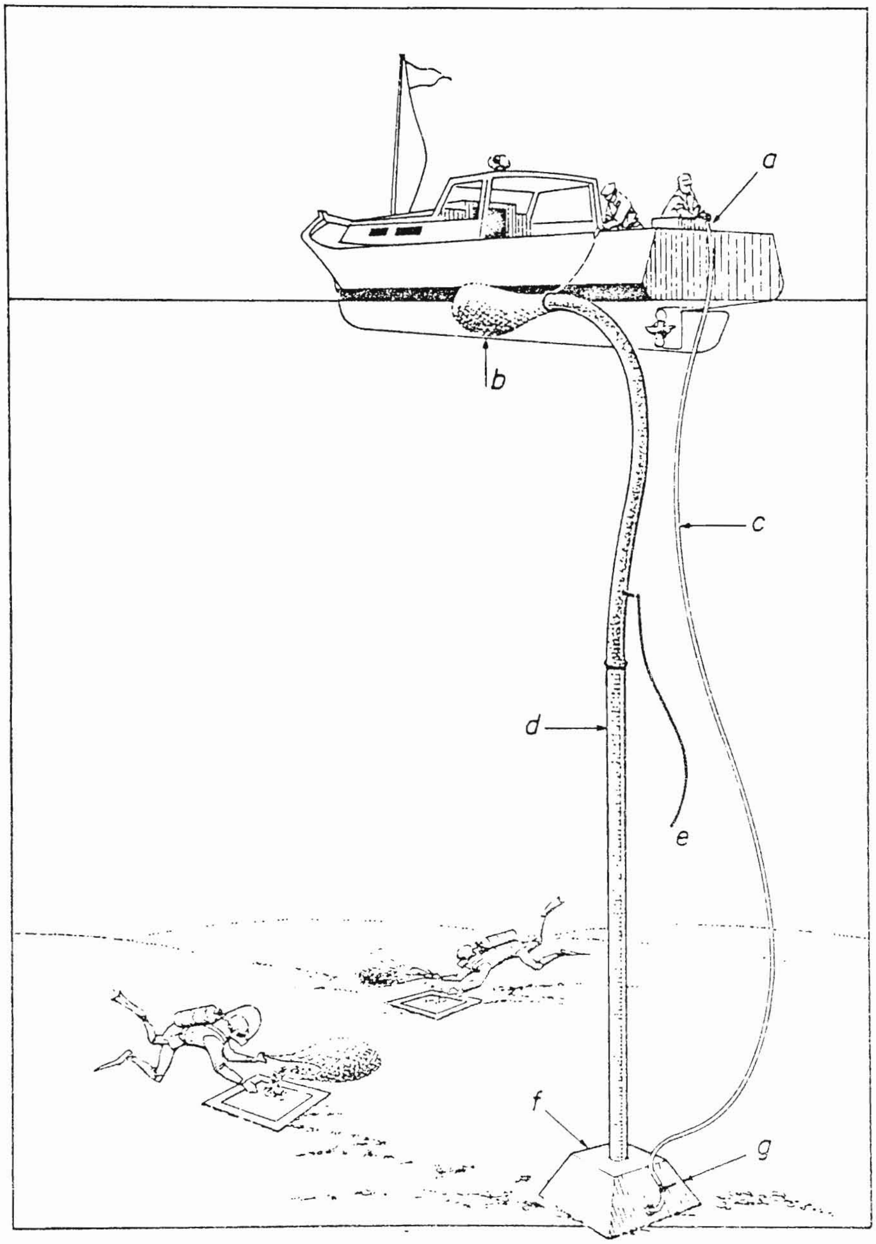

Figure 2.—Airlift system: a = air compressor, b = removable nylon mesh collection bag (opening size ≤10 mm), c = 2 cm air hose to the air compressor, d = 3 m long standpipe with an inside diameter of 20 cm, e = flexible PVC discharge hose in sections for desired water depth, f = 0.25 m^2 steel dredge head, and g = $\frac{1}{4}$ turn ball valve to regulate air flow. Diver system: h = scientist equipped with scuba gear, i = nylon mesh collection bag (opening size ≤4 mm), and 0.25 m^2 aluminum quadrant grid.

In operation, the dredge head and standpipe unit rested on the sediment with the standpipe in a vertical attitude. The collection bag was secured to the support boat at the surface. A diver controlled the volume of air entry through a quarter-turn ball valve on the dredge head. When the air was turn on, the flow into the dredge head caused water, sediment, and infauna to be flushed upward through the standpipe. Materials larger than 10 mm were retained in the collection bag at the surface. The dredge head penetrated to a sediment depth of about 25 cm. With slow bottom currents ($<\frac{1}{2}$ knot) and a stable moor by the surface platform, the discharge hose extended directly upward to the support boat. Recovery time for a sample was minimized in this configuration because the dredge head stayed on the bottom during replicated sampling. Surface to diver communication assured efficient use of the system in this mode.

In 1977 and 1978, the airlift was used to collect 20 replicate samples at Station 2 concurrently with 20 diver-collected samples for further calibration tests. A 90 cfm air compressor was substituted for in 1978 to enable the airlift to dig deeper and faster. In 1978, to determine if the airlift sampler was working efficiently, a sample of clams was marked and placed around the perimeter of the dredge head prior to sampling.

Treatment of Samples

The contents of each diver or airlift collection bag was sorted and the invertebrates removed for identification on board the support vessel. Samples containing large numbers of surf clams ≤65 mm shell length (hereafter defined as small clams) were subsampled to obtain at least 50 individuals for shell length measurements. Remaining small surf clams were counted. The shell lengths of all surf clams >65 mm (hereafter defined as large clams) were measured and the totals were added to the small clam totals for a grand total count per replicate sample. All ocean quahogs were measured for shell length, counted, and categorized with the same criteria used for surf clams. All measurements were to the nearest millimeter using a clam measuring board or calipers.

Results and Discussion

Diver Transect Study

Topography

The bottom topography along the transect was relatively featureless with a

Table 2.—Relative abundance of invertebrates and fish observed along transect. O-no sightings; P-present, ≤3 individuals; C-common, 4-14 individuals; and A-abundant, >14 individuals.

Species	Station and year																					
	1		2		3		4		5		6		7		8		9		10		11	
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978
Hydrozoan	O	O	O	O	O	O	O	O	P	P	O	P	P	P	O	P	O	O	O	P	O	P
Sea anemone, *Cerianthеopsis americanus* (Verrill)	O	O	O	O	O	O	O	O	O	P	P	C	P	P	A	P	A	C	C	C	A	C
Jellyfish, *Cyanea capillata* (L.)	O	O	O	O	O	O	O	O	O	O	O	O	O	P	O	O	O	O	O	O	O	O
Bryozoan	O	O	O	P	O	O	P	C	O	P	P	P	P	P	P	O	O	O	O	O	O	O
Moon snail, *Lunatia heros* (Say)	P	O	C	P	P	C	O	P	P	O	O	O	C	P	P	O	O	O	O	O	O	O
Ocean quahog, *Arctica islandica* (Linné)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	P	O	P	P	C	C
Morrhua venus, *Pitar morrhuana* (Linsley)	O	O	C	C	C	C	O	O	P	O	O	O	O	O	O	O	O	O	P	P	P	P
Surf clam, *Spisula solidissima* (Dillwyn)	P	C	A	A	P	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Razor clam, *Ensis directus* (Conrad)	O	O	O	O	P	P	O	P	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Onuphis worm	O	O	O	O	P	P	O	P	P	P	O	P	O	O	O	O	O	O	O	O	O	O
Annelid (unidentified)	O	O	O	O	O	O	O	O	P	P	O	O	O	O	O	O	O	O	O	O	O	O
Horseshoe crab, *Limulus polyphemus* (L.)	O	O	P	O	P	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Mysid shrimp	O	O	O	O	O	O	O	O	O	O	O	O	C	P	A	P	C	P	C	P	O	O
Pandalid shrimp	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	P	C	P	O	P	A	P
Hermit crab, *Pagurus* sp.	O	O	O	O	O	P	P	P	O	P	O	P	O	O	C	P	O	C	C	P	O	P
Common rock crab, *Cancer irroratus* (Say)	O	O	P	P	P	O	O	O	C	P	O	O	O	P	O	P	P	C	O	P	C	P
Jonah crab, *Cancer borealis* (Stimpson)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	C	P
Lady crab, *Ovalipes ocellatus* (Herbst)	P	O	C	C	O	O	O	O	O	O	O	O	P	O	C	P	O	O	O	O	O	O
Starfish, *Asterias forbesi* (Desor)	O	O	C	P	C	P	O	O	O	O	O	O	C	P	C	P	O	P	O	O	O	O
Skate, *Raja* sp.	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	P	O	O	O
Silver hake, *Merluccius bilinearis*	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	P	O	P	P	O	O
Spot, *Leiostomus xanthurus* Lacépède	O	O	C	O	C	O	O	O	O	O	O	O	O	O	P	O	O	O	O	O	O	O
American plaice, *Hippoglossoides plattessoides* (Fabricus)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	P	O	O	O	O	O	O	O
Winter flounder, *Pseudopleuronectes americanus* (Walbaum)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	P	O	O	O	O	O	P	O
Unidentified fish	O	O	O	O	O	O	O	O	O	O	P	O	O	O	O	O	O	O	O	O	O	O

gradual slope (<10°) from inshore to offshore. The substrate was sand-gravel at Station 1, fine sand at Stations 2-6, and silty fine sand at Stations 7-11 (Table 1). The five deepest stations (7-11), located within 11 km of the sewage-sludge dumpsite (Fig. 1), had a silty organic layer covering the fine sand. This organic layer completely covered the bottom to a depth of about 10 cm at Stations 7 and 8, and to a depth of 18 cm at Stations 9-11. In 1977, sand waves were observed at Stations 1, 2, and 3 with wave height/length profiles of 10-13 cm/46 cm, 3-5 cm/10-13 cm, and 3 cm/6-8 cm, respectively, and less than 3 cm/2-4 cm for Stations 7 and 8 (Table 1). In 1978, sand waves were found at Stations 3 and 4 with wave height/length profiles of 3 cm/8-10 cm and 3 cm/6-8 cm. Sand waves were previously described by Freeland et al. (1976) for this area and indicate a highly mobile substrate.

Surficial Overlay

Shell bits, fragments, and hinged and single valves of surf clams (shell hash) were found at Stations 1-8 with about 5-95 percent shell overlay as determined visually by divers (Table 1). The highest percentage (95 percent) was recorded at Station 1; the remaining seven stations varied from 5 to 50 percent each year. Station 3 showed the largest between-year variation (5-50 percent). Among these shell fragments, bored surf clams were noted at Stations 1 and 5 in 1977 and at Station 2 in 1978; each year, boring moon snails, *Lunatia heros*, were found at the same stations.

Hinged and single valves of ocean quahogs were found each year at Stations 10 and 11 and covered about 3 percent of the substrate. In 1978, an ocean quahog shell to substrate ratio of 1 percent was also found at Station 9.

Species Diversity

The surf clam was the most abundant megabenthic invertebrate collected during both years. Other invertebrates found in lower abundance were the sea anemone, *Ceriantheopsis americanus*; a mysid (unidentified); and a pandalid shrimp (Table 2). The most abundant fish observed was the spot, *Leiostomus xanthurus*. The invertebrates and fish associated with the surf clam population at Station 2 were: Bryozoans, moon snail, *Lunatia heros*; mud snail, *Nassarius trivittatus*; morrhua venus, *Pitar morrhuana*; Atlantic nut clam, *Nucula proxima*; horseshoe crab, *Limulus*

Table 3a.—Transect and airlift statistics: Clam size structure (mm).

Station	No. of diver/air-lift samples collected		Total samples measured		Size structure (range in mm) and mean/standard error					
					Small surf clams (≤65 mm)		Large surf clams (>65 mm)		Ocean Quahogs	
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978
1	20	20	1	14	(42) 42/0	0	0	(66-142) 94.3/-	0	0
2	20	20	1,053/4,732	1,202/3,849	(20-51) 37.9/0.68	(26-62) 42.7/0.7	(104-142) 126.3/0.62	(104-138) 120.4/0.6	0	0
2[1]	20	10	1,060/7,896	532/3,274	(27-50) 38.7/0.63	(30-63) 43.5/0.7	(111-139) 125.3/0.61	(100-132) 120.9/0.7	0	0
3	20	20	1	0	(38) 38/0	0	0	0	0	0
4	20	20	0	0	0	0	0	0	0	0
5	20	20	0	0	0	0	0	0	0	0
6	20	20	0	0	0	0	0	0	0	0
7	20	20	0	0	0	0	0	0	0	0
8	20	20	0	0	0	0	0	0	0	0
9	20	20	1	0	0	0	0	0	0	(87) 87/0
10	20	20	2	3	0	0	0	0	(36-39) 38/-	(84-90) 87/-
11	20	20	9	5	0	0	0	0	(36-43) 38.8/-	(74-95) 83.7/-

[1]Airlift

Table 3b.—Transect and airlift statistics: Clam Density (m²).

Station	No. of diver/air-lift samples collected		Total samples measured		Density (range in m²) and mean/standard error					
					Small surf clams (≤65 mm)		Large surf clams (>65 mm)		Ocean quahogs	
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978
1	20	20	1	14	<1	0	0	3	0	0
2	20	20	1,053/4,732	1,202/3,849	(524-1,368) 934/15.6	(480-924) 730/9.2	(0-48) 10/11.2	(8-64) 40/8.4	0	0
2[1]	20	10	1,060/7,896	532/3,274	(976-2,756) 1,588/22.4	(1,064-1,548) 1,296/9.2	(0-56) 7/11.2	(0-28) 13/5.2	0	0
3	20	20	1	0	<1	0	0	0	0	0
4	20	20	0	0	0	0	0	0	0	0
5	20	20	0	0	0	0	0	0	0	0
6	20	20	0	0	0	0	0	0	0	0
7	20	20	0	0	0	0	0	0	0	0
8	20	20	0	0	0	0	0	0	0	0
9	20	20	1	0	0	0	0	0	<1	0
10	20	20	2	3	0	0	0	0	<1	<1
11	20	20	9	5	0	0	0	0	<1	<1

[1]Airlift

polyphemus; rock crab, *Cancer irroratus*; lady crab, *Ovalipes ocellatus*; starfish, *Asterias forbesi*; and spot.

In 1977, the surf clam was highly concentrated at Station 2, virtually absent from Stations 1 and 3, and not present at Stations 4-11. Shell length measurements made on 22 percent (N=1,053) of the clams sampled by divers at Station 2 (Table 3a) comprised two distinct size groups (Fig. 3B). The small clams were consistently dense ($\bar{x}$ = 934 clams/m²); the large clams occurred at low but variable densities (Table 3b). Large individuals were found in only 5 of the 20 quadrat areas samples. Surf clam (large and small) density was estimated at 944 clams/m². Ocean quahogs were found at Stations 9-11 in 1977 at densities < 1/m².

In 1978, the most abundant species in the quadrat samples was the surf clam and again they were highly concentrated at Station 2. Station 1 yielded 14 live specimens, in two distinct size groups; ten (10) of these clams measured between 66 and 83 mm ($\bar{x}$ = 76.1 mm; SE = 0.6) and four clams measured between 136 and 142 mm ($\bar{x}$ = 139.8 mm; SE = 0.2). At Station 2, shell length measurements made on 31 percent (N=1,202) of the clams sampled by divers (Table 3a) comprised two distinct size groups (Fig. 3D). The small clams were consistently dense ($\bar{x}$ = 730 clams/m²); the larger clams occurred at significantly lower densities (Table 3b). Surf clam (large and small) density was estimated at 770 clams/m². Ocean quahogs were found at Stations 10 and 11 at densities ≤ 1/m².

Surf Clam Community

Distribution and Abundance

In 1978, surf clam distribution was determined by collecting 13 quadrat samples in a grid radiating 150 and 300 feet from the center of Station 2 (Fig. 4). Clam size was consistent throughout the sampling grid. In general, when the small clam density was above the grid mean,

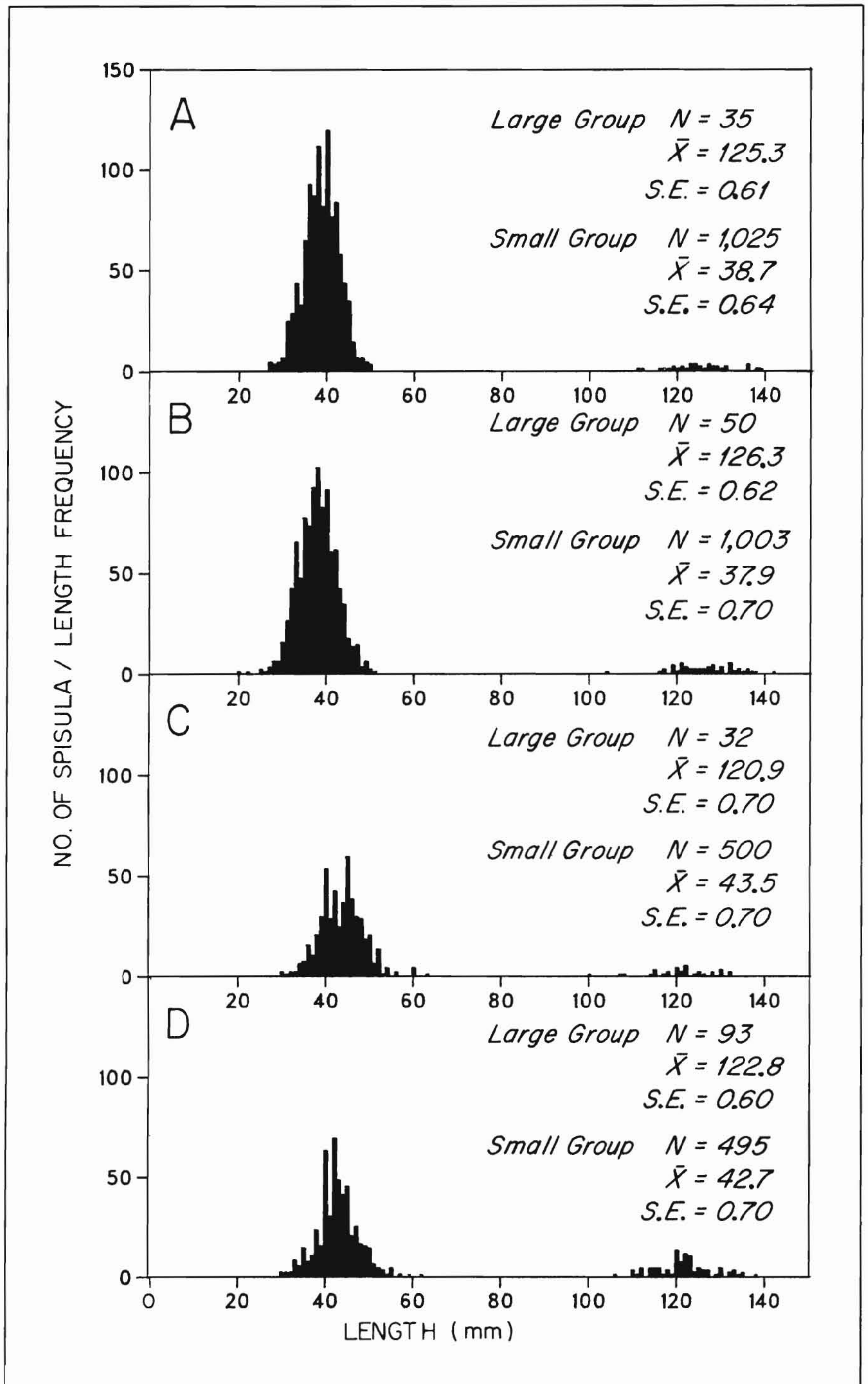

Figure 3.—Frequency distribution of shell lengths of *Spisula solidissima* in: A, 20 airlift collected samples in 1977; B, 20 diver collected samples in 1977; C, 10 airlift collected samples in 1978; and D, 10 diver collected samples in 1978.

the large clam density at the same location was below the grid mean and vice versa. This inverse relationship between large and small clam densities may be due in part to the amount of space available. The larger clams were found burrowed to a depth of 12-14 cm with their siphons projecting up between the closely packed smaller clams which were burrowed to 2-4 cm below the sediment water interface. In general, the surf clams at Station 2 burrowed to a depth about equal to their shell lengths. Divers saw the siphon opening of the larger clams much easier than the smaller ones. Some of the small clams appeared to be in small depressions. Density for the small clams was so high at Station 2 the clams were found physically touching their neighbors.

Meyer et al. (1981) estimated the surf clam density during two clam dredge efficiency tows near our study area. Two distinct size groups with means of about 31 and 112 mm were found. The small group comprised approximately 96.5 percent of the population. Densities ranged from 1,095 to 1,241 clams/m^2. During this study, densities were some 300 clams lower and means were about 10 mm higher. The proportion of small clams was virtually identical.

Age and Growth

In 1978, 12 surf clams (8 small, 4 large) from Station 1, and 41 (10 small, 31 large) from Station 2 were analyzed for age and growth (Table 4). Small clams in 1977 and 1978 at Station 2 increased in mean size from 37.9 to 42.7 mm; mean size of the large clams decreased from 126.3 to 120.4 mm (Table 3). This would suggest that the larger clams suffered some mortality. Since very few empty shells were found, the larger clams apparently either emigrated from this area or were moved by storm surges. The study area is characterized by an extremely high substrate mobility (Harris, 1976). This can be seen in the high percentage (up to 95 percent) overlay cover of surf clam shell hash found at Stations 1-7, and in sand waves which appeared at different stations each year; this also probably accounts for the occasional massive beaching of surf clams during winter storms (Jacot, 1919), and in the findings of Franz (1977) that living surf clams were always available on Rockaway Beach during his study. Apparently, the high substrate mobility and unknown environmental factors in this

Table 4.—Surf clam age and growth statistics, 1978.

	Station 1						Station 2					
	Small clams			Large clams			Small clams			Large clams		
Year of life	No. of clams	Mean size (mm)/S.E.	C.I. 0.05	No. of clams	Mean size (mm)/S.E.	C.I. 0.05	No. of clams	Mean size (mm)/S.E.	C.I. 0.05	No. of clams	Mean size (mm)/S.E.	C.I. 0.05
1	8	17.3/0.34	0.78	4	13.8/1.58	4.39	10	16.7/0.58	1.29	31	11.7/0.39	0.80
2	8	50.3/1.38	3.18	4	48.6/2.30	6.38	10	34.4/0.89	1.98	31	32.6/0.63	1.29
3				4	69.7/0.99	2.75				31	53.6/1.39	2.84
4				4	81.7/1.53	4.25				31	72.2/0.99	2.02
5				4	89.8/2.02	5.61				31	87.2/1.02	2.08
6				4	96.1/3.57	9.91				31	98.6/1.17	2.39
7				4	100.7/4.69	13.02				31	106.2/1.26	2.57
8				4	103.6/5.04	13.99				31	111.2/1.30	2.65
9				4	109.0/4.88	13.55				31	112.7/1.20	2.45
10				4	118.7/4.12	11.44				12	113.8/1.32	2.69
11				4	127.7/3.51	9.74				2	116.0/4.56	9.30
12				4	135.3/2.26	6.27						
13				4	140.3/1.28	3.55						
14				3	144.1/1.08	3.00						

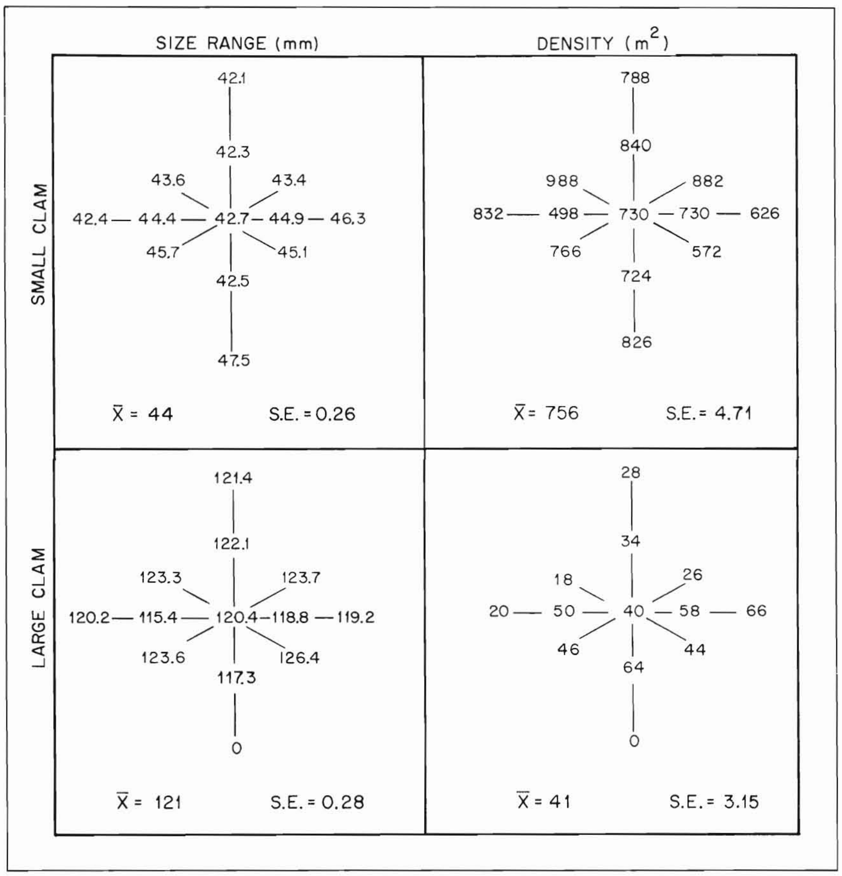

Figure 4.—Surf clam distribution and abundance 150 and 300 feet from center of Station 2.

area can partially or totally eliminate a clam bed during a 1-year period.

Age and growth were determined for clams from Station 2 by measuring internal growth lines. These clams were part of the group which showed the 4.8 mm increase. Measurements from the umbo to each annulus permitted back calculation of growth (Table 4).

The small clams found at Stations 1 and 2 in 1978 were about 2.5 years old (Table 4). During year one, these clams showed similar rates of growth, 17.3-16.7 mm, respectively. In year two, clams from Station 1 grew 33 mm; at Station 2 they grew 17.7 mm. Assuming this growth differential is real, and not an artifact of small sample size, the apparent difference may have resulted from the high density of small clams found at Station 2 and, therefore, less available food per clam and a slower growth rate. There may exist an inverse relationship between clam density and growth, especially in areas of high clam concentrations. For improvement in small clam growth at Station 2, a significant degree of thinning would have to occur. In addition to thinning, some of the larger members of the small clam group could burrow deeper where space does not appear to be limiting.

The large clams found at Stations 1 and 2 in 1978 were estimated to be 14 and 11 years old, respectively (Table 4). The back calculated growth (Fig. 5) curve for Station 1 clams demonstrated greater variability in rate than for Station 2, probably due to the small sample size.

Surf clams reach full sexual maturity during the second year with the smallest fully mature clam being about 45 mm long (Ropes, 1979b, 1980). The small clam population at Station 2 averaged 42.7 mm which is nearing sexual maturity. Spawning off New Jersey in 1962 to

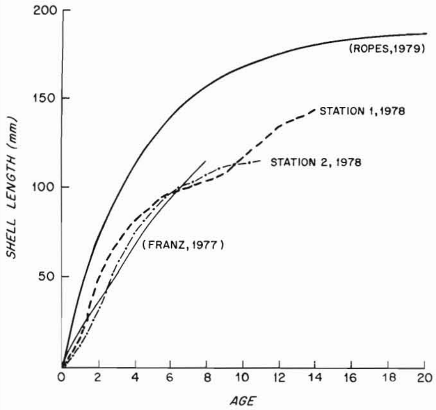

Figure 5.—Surf clam age and growth.

Table 5.—Mean heavy metal concentrations (ppm, wet weight) found in surf clams and ocean quahogs by station along transect in 1978 and results of Wenztloff et al. (1979).

Study	Station	No. of clams	Cd $\bar{X}$	Cd S.E.	Cu $\bar{X}$	Cu S.E.	Cr $\bar{X}$	Cr S.E.	Pb $\bar{X}$	Pb S.E.
Our study	Surf clams									
	1	11	0.03	0.007	0.73	0.16	0.48	0.19	0.39	0.19
	2	21	0.04	0.009	0.57	0.23	0.59	0.22	0.16	0.15
	Ocean quahogs									
	10	3	0.36	0.11	1.83	0.47	0.70	0.13	3.5	0.26
	11	5	0.27	0.05	1.56	0.64	0.72	0.28	2.9	0.67
Wenztloff	Surf clams									
et al. (1979)	41°00′-40°30′	3	< 0.12		3.83	0.78	< 0.62		< 0.7	
	Ocean quahogs									
	40°30′-40°00	15	0.42	0.34	5.33	0.40	< 1.23		1.0	

1964 began in mid-July to early August (major) with a second spawning (minor) in mid-October to early November (Ropes, 1968).

Franz (1976) determined distribution and abundance of the inshore surf clam population at 0.5, 1.5, and 2.5 n.mi. offshore along 47 transects normal to the Long Island shore from Rockaway Beach to Montauk. He found that adult abundance in July 1974 increased sharply west of East Rockaway Inlet and from offshore shoreward (Fig. 1). Franz (1976) measured surf clams near our study area and showed one modal group at about 86 mm, representing a 5.5-year-old clam by his growth data. Our results at Station 2 in 1978 showed two modal groups; one 42.7 mm and another 120.4 mm with mean ages of about 2.5 and 11 years respectively. In addition, Franz found relatively high densities of juveniles west of Fire Island, especially in areas where adults were sparse, with the highest juvenile densities occurring along Rockaway Beach at the 0.5 N.Mi. stations with densities decreasing substantially offshore. During our study, no juveniles were found.

Franz (1977) estimated surf clam growth from live specimens washed up along Rockaway Beach in May 1976 (Fig. 5). Both Franz's and our large clam age and growth curves (Fig. 5) when compared against Ropes (1979a), who calculated the general age and growth of surf clams along the northeast coast of the United States, indicate that the Rockaway Beach surf clam growth rate is considerably below the average for the northeast (Fig. 5). This slower growth rate is probably due to the high densities in combination with higher summer water temperatures at the very shallow study area.

Heavy Metals

Heavy metals in surf clams and ocean quahogs have been measured at 151 stations in 1974 from Cape Hatteras, N.C., to Montauk Point, N.Y., (Wenzloff et al., 1979). Heavy metal analyses of clams collected at Station 1 (11 surf clams), Stations 2 (21 surf clams), Station 10 (3 ocean quahogs), and Station 11 (5 ocean quahogs) in 1978 (Table 5) indicate no significant differences in a comparison of Station 1 with Station 2 or Station 10 with Station 11. Our surf clam and ocean quahog values for cadmium, chromium, copper, and lead appear to be below those presented by Wenzloff et al. (1979), except for lead in ocean quahogs which was about 2.5 times higher at Station 10 and 11.

The National Health and Medical Research Council (NHMRC) of Australia has recommended maximum allowable concentrations for some heavy metals in seafood (Mackay et al., 1975). The FDA is currently developing acceptable levels for heavy metal concentration in U.S. fishery products. The maximum concentrations (in ppm, wet weight) presented by NHRMC were: Cadmium 2.0, copper 30.0, and lead 2.0; chromium was not listed. Our values are below the NHMRC recommended maximums, except for lead in ocean quahogs at Stations 10 and 11. These values may have been high because of the proximity of these stations to the center of the sewage-sludge dumpsite (Fig. 1).

Table 6.—Analysis of bottom grab samples.

Species	Station 2 No. of individuals	Station 11 No. of individuals
Aschelminthes		
Nematoda		
Unidentified spp.		3
Mollusca		
Gastropoda		
Mud snail, *Nassarius trivittatus* (Say)	2	
Bivalvia		
Atlantic nut clam, *Nucula proxima* (Say)	2	46
Ocean quahog, *Arctica islandica* (Linne)		1
Verrill's diplodon, *Diplodonta verrilli* (Dalli)		2
Northern dwarf cockle, *Cerastoderma pinnulatum* (Conrad)		2
Surf clam, *Spisula solidissima* (Dillwyn)	5	1
Northern dwarf tellin, *Tellina agilis* (Stimpson)		1
Annelida		
Polychaeta		
Pherusa affinis (Leidy)		4
Arthropoda		
Crustacea		
Amphopod, *Leptocheirus pinguis* (Stimpson)		1
Common rock crab, *Cancer irroratus* (Say)	1	2

Infauna

Analyses of the infauna in bottom samples collected at Station 2 and 11 in 1978 indicate a higher species diversity at the deeper station; from 4 to 10, respectively (Table 6). The most abundant species was the Atlantic nut clam with 46 individuals. Other invertebrates averaged from 1 to 5 individuals.

Airlift Sampler

In 1977, shell length measurements made on 13 percent (N = 1,060) of the clams sampled by the airlift at Station 2 (Table 2) comprised two distinct size groups (Fig. 3A). Small clams were consistently dense ($\bar{x}$ = 1,588 clams/m^2), larger clams occurred at low but variable densities. Large individuals were found in only 6 of the 20 quadrat samples collected. Surf clam (large and small) density was estimated at 1,595 clams/m^2. The airlift overestimated the density of small clams by 70 percent and underestimated the large clams by 43 percent; the overall population was overestimated by 69 percent. A significant difference was found in the mean number of clams sampled by the airlift and diver methods; no significant difference was found in the mean lengths.

In 1978, shell length measurements made on 16 percent (N=532) of the clams collected by the airlift in 10 quadrat samples at Station 2 (Table 2) comprised two distinct size groups (Fig. 3C). The small clams were consistently found in extremely high densities ($\bar{x}$ = 1,296 clams/m^2); the larger clams occurred at low but variable densities. Large individuals were found in 9 of 10 quadrat samples collected. Surf clam (large and small) density was estimated at 1,309 clams/m^2. After collecting 10 airlift samples in 1978, the results were compared with the first 10 diver collected samples (Fig. 3C, 3D). The airlift overestimated the density of small clams by 78 percent and underestimated the large clams by 68 percent; the overall population was overestimated by 70 percent. Shell length measurements were similar (0.8 mm difference). To confirm that the airlift was oversampling, 115 small clams and 5 large clams were marked and placed around the immediate outside perimeter of the dredge head as it rested on the bottom. The airlift then collected a sample; 79 of the small marked clams (69 percent) and 1 large clam (20 percent) were captured. Overall, 67 percent of all marked clams outside of the airlift head were captured. Because of the marked clam result and the apparent 70 percent overestimation of the first 10 airlift samples, the remaining 10 airlift samples were not collected. This large overestimation of the clam density, the closeness in shell length measurements, and the similarity in results between 1977 and 1978, made statistical tests unnecessary.

The overestimation of the surf clam population by the airlift sampler was also observed by divers over the 2-year study. The airlift collected between 0.25 m^2 and 0.50 m^2 of the bottom by overestimating small clam density (those oriented close to surface) and underestimating large clam density (those deeply burrowed). An airlift sample hole showed it to be mounded in the middle and the sediment became slumped and scalloped around the periphery upon removal of the dredge head. All larger clams near the inside periphery of the dredge head had been collected, but some of the larger clams remained in the middle. All of the smaller clams were collected. As the density of larger clams increased, so did the magnitude of underestimation. Nevertheless, both collecting methods sampled the clam population by shell length without bias.

The prototype airlift sampler, in its present configuration, is a complex system requiring at least a 15 m long surface support platform, three people on deck, and a tending diver to sample benthic macrofauna. It samples to a sediment depth of about 25 cm, collects replicate samples at a rate of 1.0-1.5 minutes per sample, and qualitatively collects macroinvertebrates down to a size of $\leq$ of 7 mm with less than 1 percent breakage.

The airlift sampling system tested shows promise as a surface-operated bivalve sampling tool. It has been successfully tested in a surface tended mode to a depth of 25 m. Through further modifications, specifically with regard to the overestimation of clam density, the airlift sampler should be capable of quantitative sampling. Once this capability is attained, the support required should be no more complex than other surface sampling systems.

Summary

The bottom topography in the study area was relatively featureless with a gradual slope (<10°) from inshore to offshore. The substrate was fine sand with an organic covering at the five deepest stations (ones nearest to the sewage-sludge dumpsite). A 1-95 percent shell hash overlay was found at the various stations.

Invertebrates and fish found directly associated with this surf clam community were: bryozoans, moon snail, *Lunatia heros*; mud snail, *Nassarius trivittatus*; morrhua venus, *Pitar morrhuana*; Atlantic nut clam, *Nucula proxima*; horseshoe crab, *Limulus polyphemus*; rock crab, *Cancer irroratus*; lady crab, *Ovalipes ocellatus*; starfish, *Asterias forbesi*; and spot, *Leiostomus xanthurus*.

The surf clam community measured in 1978 showed two distinct size groups. Shell lengths ranged from 26 to 62 mm $\bar{x}$ = 42.7 mm, age 2.5 years) and from 104 to 138 mm ($\bar{x}$ = 120.4 mm, age 11.5 years); densities were 730 clams/m^2 and 40 clams/m^2, respectively. No juveniles were found. There appears to exist an inverse relationship between the densities of large (>65 mm) and small ($\leq$65 mm) clams. In general, as the density of one group increases, the density of the other decreases and vice versa. This is probably due in part to the amount of space available.

Large clams burrowed to a depth of 12-14 cm with their siphons projecting up between the closely packed smaller clams which were burrowed to 2-4 cm below the sediment water interface. Surf clams burrowed to depths about equal to their shell length. Smaller clams were found to be physically touching their neighbors.

Analyses of in between-year growth increments and back-calculated growth suggests that larger clams suffered some form of mortality. Since very few empty shells were found, the larger clams apparently either emigrated from this area or were moved by storm surges. In 1978, comparison of growth statistics for small clams at Station 1 and 2 indicated similar growth rates for year one, 17.3-16.7 mm. In year two, clams at Station 1 showed a faster rate of growth of 33-17.7 mm. The slower growth rate of the small clams found at Station 2 may have resulted from high densities and less available food per clam.

Rockaway Beach surf clam growth

rate is considerably below the average for the northeast coast probably due to the high densities and the high summer water temperatures. An inverse relationship may exist between clam density and growth especially in areas where there are high concentrations of the clams.

Heavy metal concentrations for cadmium, chromium, copper, and lead measured in surf clams from Station 1 and 2 were below those recommended by Australia's NHMRC. Ocean quahogs, measured from the two deepest stations, showed lead values slightly higher than the recommended maximum allowable concentration for that metal in seafood by NHMRC. The value for lead may have been higher because of the closeness of the stations to the center of the sewage-sludge dumpsite.

Infauna samples collected from Station 2 and 11 in 1978 indicated a higher species variability at Station 11 (the deepest station), 4 and 10, respectively. The most abundant species was the Atlantic nut clam, *Nucula proxima*, with 46 individuals found at Station 11. Other invertebrates averaged from 1 to 5 individuals.

The airlift system tested shows promise as a surface-operated bivalve sampling tool. It was designed to quantitatively collect 0.25 m^2 samples, but it overestimated the small clam density by 78 percent and underestimated the large clam density by 68 percent, with an overall overestimation of 70 percent. The airlift sampled between 0.25 m^2 and 0.50 m^2 of the bottom by pulling in small clams into the sample from outside the quadrat area. The resultant hole was mounded in the middle and the sediment became slumped and scalloped around the periphery upon removal of the dredge head. All of the larger clams near the inside periphery of the dredge head had been collected, while some of the larger clams remained in the middle. All of the smaller clams were collected. Through further modifications, specifically with regard to the overestimation of clam density, the airlift sampler should be capable of quantitative sampling. Once this capability is attained, the support required should be no more complex than other surface sampling systems.

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