SEABROOK ECOLOGICAL STUDIES
1976-1977

STUDIES ON THE SOFT-SHELLED CLAM, *MYA ARENARIA*, IN THE VICINITY OF HAMPTON-SEABROOK ESTUARY, NEW HAMPSHIRE

TECHNICAL REPORT VIII-2

Prepared for

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August 1978

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1.0 INTRODUCTION

Soft-shell clam investigations at Hampton-Seabrook Estuary (Normandeau Associates, Inc., 1973, 1974a, 1975a, 1976a, 1977) have provided ample documentation of severe adult stock depletion. By 1976, recreational clam diggers had removed approximately 87% of the harvestable clams that had existed in 1971, leaving only an estimated 11.7 bushels per acre remaining (NAI, 1977). This loss might be expected to severely restrict reproductive potential, and, hence, the possibility of repopulating the flats. However, since it has been observed that the planktonic larval stage has a life span of from 2 to 4 weeks (Stickney, 1964; Savage and Goldberg, 1977), it would appear that given favorable hydrographic conditions, it is probable that breeding stocks in estuaries up to 25 miles away (cf. Ayers, 1956) can repopulate the Hampton-Seabrook clam flats. The high flushing rate which characterizes the estuary also leads to the conclusion that Hampton-Seabrook depends heavily on the coastal drift of planktonic larvae for recruitment (NAI, 1972, 1973).

Planktonic surveys (NAI, 1973, 1974b, 1975b, 1976b, 1977) have shown that, in some years, several hundred to a few thousand soft-shell clam larvae per cubic meter appear immediately offshore, in the vicinity of Hampton-seabrook Estuary for brief periods, ranging from several days to one or two weeks. These short-lived occurrences have been primarily concentrated in late summer, from the end of July to mid-September, concurring with other reports of the period of peak spawning activity in this region of New England (Ropes and Stickney, 1965; NAI, 1971; Savage and Goldberg, 1977).

Occurrence of high planktonic larval population densities near the entrance to Hampton-Seabrook Estuary has, however, not always proved to be a totally reliable predictor of spatfall (i.e., primary settling of very young metamorphosed clams) within the estuary itself. For example, high larval densities (averaging 532 per m^3) were observed in late summer of 1975; however, spatfall densities (37 per ft^2) were

(1952) theorized that the species may have been introduced via the bilges of fishing vessels, during a period of expanding trade in lobsters and sardines. Welch (1969, 1975) has demonstrated a positive correlation between green crab abundance in Maine waters and yearly fluctuations in ocean water temperature. His data indicate that the present green crab population boom began about 1970 and had been preceded by an earlier, similar, boom between 1948 and 1954. Clam growth is enhanced by a prolonged growing season generally associated with a rise in sea temperature; however, survival declines drastically under such conditions. The observed inverse relationship between sea temperature and soft-shell clam harvests has been attributed to increased predation pressure from expanding green crab populations (Dow, 1977), as warmer winters also enhance the reproductive success of the green crabs.

The present report continues along the lines of investigation established in previous reports. Notable methodological changes from the previous report (NAI, 1977) include: 1) exclusive use of oblique tows to monitor temporal (seasonal) and spatial (horizontal) larval distributions off Hampton Beach, (2) utilization of aerial photography to enhance precision with which estimates of standing stock can be made, and (3) sampling of intertidal flat sediments to establish grain-size distributions characteristic of clam propagation areas.

2.0 METHODS AND MATERIALS

2.1 LARVAE TOWS

To monitor temporal dist[illegible] of *Mya arenaria* larvae in the vicinity of the Seabrook Station cooling water intake (Figure 1), duplicate, two minute, oblique net tows were made approximately twice weekly, from 27 June to 27 October. A 0.5 m diameter No. 20 (73 μm) mesh net, with a 10 lb. depressor attached, was towed at approximately 1/2 knot. The net was lowered to a depth of approximately 13 m (43 feet), in the first minute and returned to the surface after a second minute had elapsed ending the tow. A General Dynamics flow meter was used to record the volume of water passing through the net; in practice, this volume ranged from 4 to 11 m^3 per tow. Upon recovery, net contents were thoroughly rinsed into a 1/2 gallon glass jar. The live material was transported immediately to the Piscataqua Marine Laboratory, Portsmouth, where it was temporarily stored in a refrigerator.

To separate the live bivalve larvae from the bulk of the plankton, the sample was transferred to 1000 ml dispensing burettes and the contents allowed to settle for 5-12 minutes. The relatively high density of the shells allowed the bivalves to rapidly accumulate at the bottom of the burette column, and to be withdrawn for identification and enumeration. The entire sample concentrate containing the bivalves was enumerated for umboned (length 145-320 μm) *M. arenaria* larvae except when this species was particularly abundant; whereupon, the bivalve larvae were concentrated by a swirling motion, into the center of a round, 100 mm diameter, plastic culture dish. The resulting concentration of larvae was carefully divided into visually equal quadrants using a camels hair probe, viewing the operation through a dissecting microscope at approximately 30x; two diagonally opposed quadrants were then enumerated.

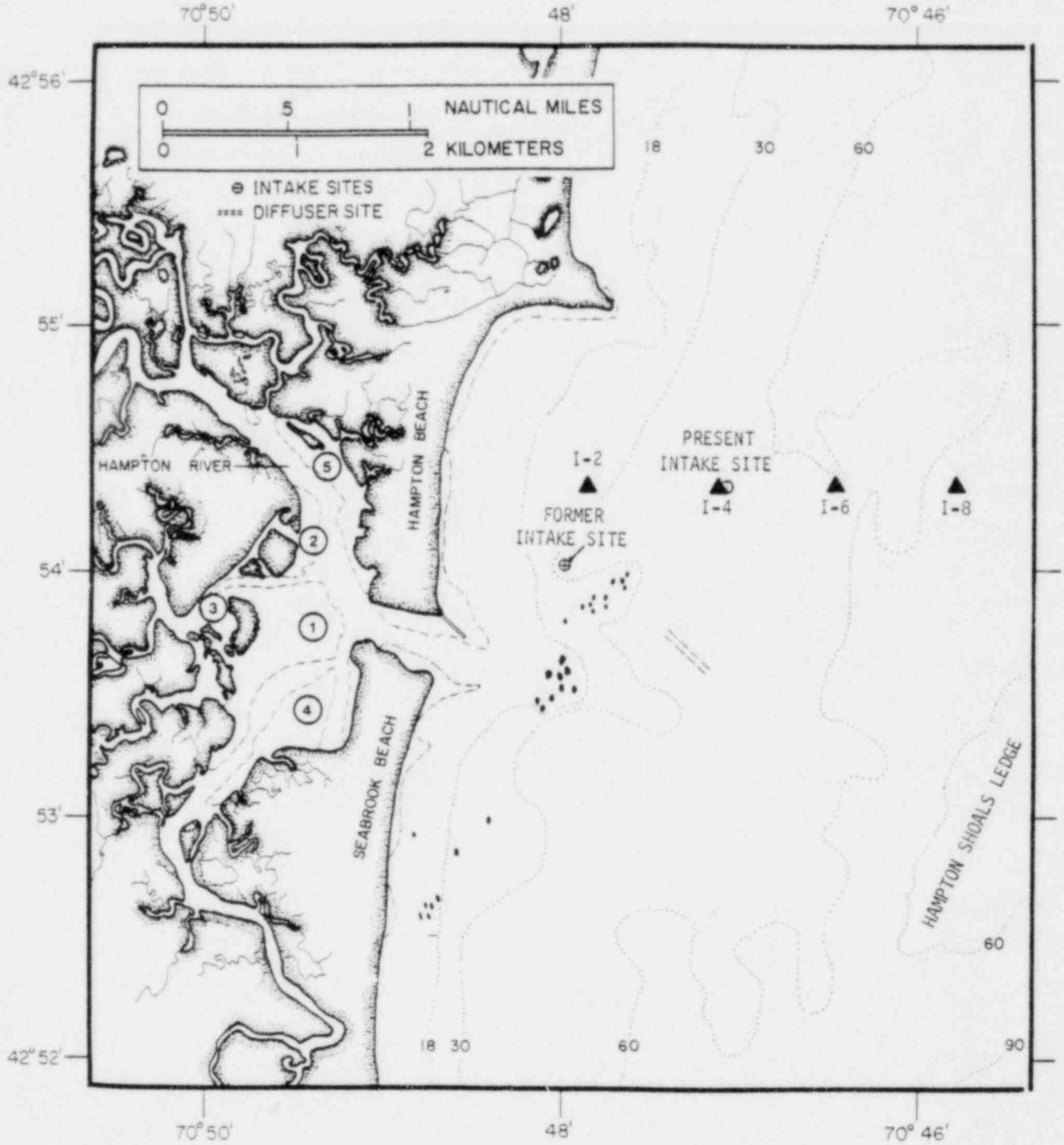

Figure 1. Soft-shell clam, *Mya arenaria*, sampling stations. Seabrook *Mya arenaria* Study, 1977.

The same splitting technique was also used to reduce the amount of larvae, representing other bivalve species, to sample fractions containing a total of 200 to 600 individuals. Depending on original (i.e., field) population densities, this required from one to four successive operations consisting of concentrating the larvae into the center of the dish and then separating and extracting a quadrant. In all cases, two sample fractions were enumerated from each sample, each fraction having originated as one of two diagonally opposite quadrants in the initial (whole sample) larvae concentration. Principal references used as aids in identifying larvae to species were: Sullivan (1948), de Schweinitz and Lutz (1976) and Savage and Goldberg (1976). With few exceptions, only umboned veligers were identified and enumerated. Enumeration of *M. arenaria* straight hinge veligers was carried out only when their identity was reasonably obvious because of the large numbers involved and the paucity of straight hinge veligers of other species.

From 27 June to 28 July, a second larvae monitoring station was maintained at a site which, prior to July 1975, had been designated as the intake site. Collection, identification, and enumeration procedures were as described above for the presently designated intake location.

On those dates when the *M. arenaria* umbone veliger population density was found to exceed 50 per m^3, a special towing program was carried out to define the onshore/offshore *M. arenaria* larval density distribution in the intake vicinity. Oblique tows were made at 1/2 nautical mile intervals along a transect running east to west through the intake site (Figure 1). Data collection procedures were as described above.

2.2 SPAT SURVEYS

To compare population densities of seed clams (shell length: 1.5 to 25 mm) periodic surveys were conducted on Hampton Harbor Flat No.

2 (Figure 1 and Table 1) and on flats in five adjacent estuaries, in New Hampshire, northern Massachusetts and southern Maine (Figure 2 and Table 2). With the exception of the November survey, the stations were fixed in that once established (on the basis of preliminary evidence of high productivity), the same general locality was resampled with each survey. At each fixed collection site, sediment cores three or four inches in diameter, and four inches deep, were extracted in triplicate, using a section of PVC plastic pipe. Sediments from these core samples were washed through a 1 mm mesh screen and the *M. arenaria* spat picked from the screen with forceps. After transfer to small fingerbowls, the spat from each core sample were enumerated and measured to the nearest 1 mm.

Spat samples were also obtained, as described above, during the annual Hampton-Seabrook clam flat survey in November; however, the November stations (Table 1) were chosen at random from a larger set of stations designated for sampling adult clam populations. Whereas the fixed station program, with emphasis on high yield locations, facilitated determination of temporal and relative geographical distribution, the utilization of randomly determined stations in November provided the best estimate of actual spat density over a particular flat, including portions less favorable for spat settlement.

2.3 ADULT SURVEYS

As in past years, the five largest harbor flats (Figure 1) were each surveyed in November 1977 for adult clams. Additional surveys were conducted on Flat #2 in May and August 1977.

In preparation for the actual collection of samples, flats were mapped and contoured. To determine the various dimensions, beach profiles were surveyed using a transit, dumpy level and stadia rod. Transects were laid out in five directions from a central point on the flat. Stadia rod readings were made with the level at one hundred foot intervals. Observed water levels were referenced to mean low water. To

TABLE 1. CLAM SPAT SAMPLING EFFORT, HAMPTON-SEABROOK ESTUARY. SEABROOK *MYA ARENARIA* STUDY, 1977.

LOCATION	DATE	NO. OF STATIONS
	FIXED STATIONS	
Flat 2	January 11	6
Flat 2	April 14	6
Flat 2	June 7	6
Flat 2	August 1	6
Flat 2	October 17	6
	RANDOM STATIONS	
Flat 2	November 16	7
Flat 1	November 15	14
Flat 3	November 15	6
Flat 4	November 16	11
Flat 5	November 14	9

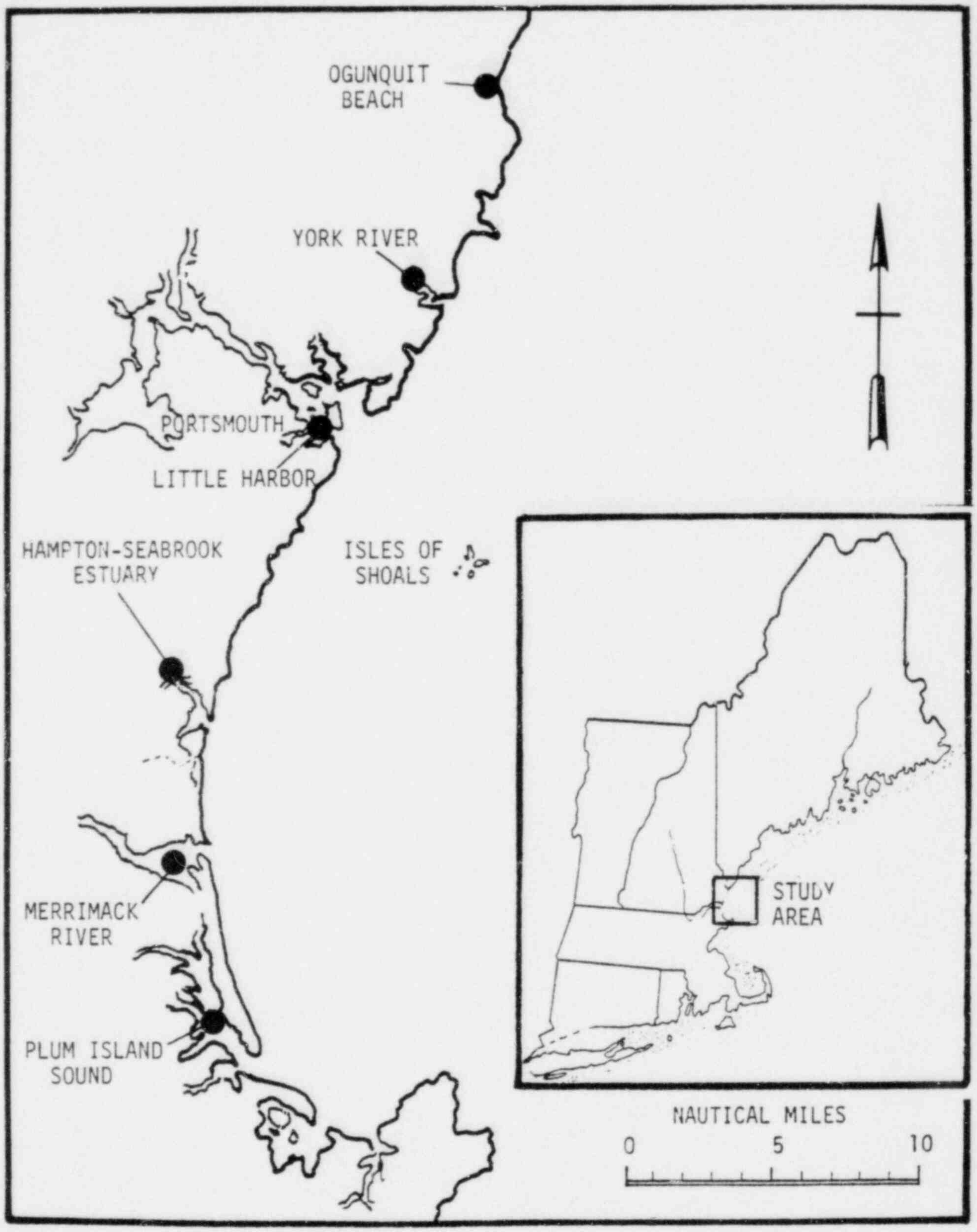

Figure 2. Location of fixed station spat study sites. Seabrook *Mya arenaria* Study, 1977.

TABLE 2. FIXED STATION CLAM SPAT SAMPLING EFFORT, SELECTED ESTUARIES ADJACENT TO HAMPTON-SEABROOK ESTUARY. SEABROOK *MYA ARENARIA* STUDY, 1977.

LOCATION	NO. OF STATIONS	DATES				
Plum Island Sound, MA						
Middle Ground	5	11 Feb	11 Apr	8 Jun	5 Aug	19 Oct
Neck Cove	5	11 Feb	---	---	---	---
Lufkins Flat	3	---	11 Apr	8 Jun	5 Aug	19 Oct
Nut Shoal	2	---	11 Apr	8 Jun	5 Aug	19 Oct
Merrimack River, MA						
Salisbury Flat 3	5	28 Jan	13 Apr	6 Jun	2 Aug	18 Oct
Ball's Flat 1	5	27 Jan	13 Apr	6 Jun	2 Aug	18 Oct
Little Harbor Channel, NH						
Clam Pit Island	5	12 Jan	15 Apr	13 Jun	10 Aug	10 Oct
Flat, opposite side	1	12 Jan	15 Apr	13 Jun	10 Aug	10 Oct
Southern Maine						
York River	5	14 Jan	12 Apr	9 Jun	9 Aug	21 Oct
Ogunquit Beach	6	14 Jan	12 Apr	9 Jun	9 Aug	21 Oct

aid in interpretation of horizontal dimensions given by the transect lengths, important topographic details of the flat were sketched in the field by the survey crew. From these, charts were constructed of each flat surveyed.

Preparation of sampling charts for Flats 1, 2, 4 and 5 was greatly facilitated by the use of aerial photography, which was initiated with the November 1977 annual survey to more accurately measure flat acreage and to provide permanent records of existing flat configuration. Photographic were made on 18 October 1977 at mean low water and at intervals of approximately 1.3 m water-depth increments on the flood tide, making projection of topographic contours possible (Appendix 7.4). Acreage measurements were provided by the aerial survey contractor, employing the "stereotemplate laydown" procedure which is standard for the preparation of tax base maps. The maximum error in computed flat acreage has been estimated by the contractor to be approximately 2-3%. Flats 1, 2, 4 and 5 were done this way; due to difficulties encountered in the overflights; Flat 3 was not fully photographed. Areal estimates were done as in the past for this flat.

Random sampling procedures were employed which minimized unproductive digging in extremely depopulated areas of the flats. Evidence of breathing or siphon holes was used as an indicator of the presence, and conversely the absence, of clams. If, after determining the location of a sampling station, the investigator observed what was thought to be clam siphon holes, a two-square-foot area was dug thoroughly for clams. On the other hand, if no sign of siphon holes was detected within the two square foot sampling area, the investigator in most cases simply noted this fact on a field card and proceeded to the next sampling station. Several stations on each flat which showed no sign of clam holes were randomly selected and dug thoroughly as a check on the effectiveness of establishing the absence of clams by the absence of siphon holes (Table 3).

Total number of samples to be observed for evidence of siphon holes was roughly determined by the surface area of the flat above mean low tide (Table 3). To establish sampling stations, randomly generated rectangular (x, y) coordinates were plotted on charts of each flat.

TABLE 3. ADULT CLAM SAMPLING EFFORT, HAMPTON-SEABROOK ESTUARY. SEABROOK *MYA ARENARIA* STUDY, 1977.

LOCATION	DATE	SURFACE AREA (ACRES)	TOTAL NO. SAMPLE STATIONS OBSERVED	NO. OF POTENTIALLY BARREN STATIONS SUBSAMPLED	NO. OF POTENTIALLY PRODUCTIVE STATIONS DUG
Flat 2	May	25.5	27	4	7
Flat 2	August	25.5	27	4	8
Flat 2	November	25.5	33	8	1
Flat 1	November	55.0	66	13	13
Flat 3	November	11.6	24	4	5
Flat 4	November	50.6	51	6	2
Flat 5	November	23.9	38	5	11
All Flats	November	166.6	212	36	32

Random coordinates were generated until the full quota of stations was attained for the flat. In the field, stations were located by compass bearing and distance from the central reference point established during the beach profile survey. To delineate the sample area, a two-square foot frame was placed on the substrate, with the left hand corner of the frame at the investigator's right foot. The substrate surface outlined by the inner edges of the frame was carefully inspected for evidence of siphon holes. If a sample was to be taken because siphon holes were evident, or if a random subsample of a "no-hole" station was required, the sediment outlined by the frame was dug to a depth of about 16 inches. Adult soft-shell clams found during excavation, or in the spoil, were picked out and placed in a plastic bag along with a tag identifying the station and flat number. In the laboratory, clams were tallied and measured for shell length to the nearest 0.1 mm.

Individual sample counts and shell measurements were converted to biomass estimates (bushels per acre) using a table of clam volumes provided in Belding (1931). The overall biomass estimate for each flat was obtained using the following formula:

$$\bar{X} = \frac{n_1}{n}\bar{X}_1 + \frac{n_2}{n}\bar{X}_2',$$

where: n = total number of sampling stations observed

n_1 = number of stations where siphon holes were observed

$n_2 = n - n_1$ = number of stations where no siphon holes were observed

$\bar{X}$ = average biomass (bushels per acre) estimate for the entire flat

$\bar{X}_1$ = average biomass from n_1 samples

$\bar{X}_2'$ = average biomass from a subset of samples (n_2') representing stations where no siphon holes were observed.

To express results in terms of standing crop (bushels of harvestable clams on the entire flat), the biomass estimate was multiplied by flat surface area (acres). Variance and standard error of biomass estimates were calculated approximately, using formulae given in Hanson *et al.*,

1953. To obtain a rough approximation of 95 percent confidence intervals, standard errors were multiplied by two, as suggested by Hanson *et al.*, 1953.

2.4 SEDIMENT SURVEYS

Clam flats 2 and 4 were each surveyed five times, as shown in Table 4. On Flat 2, sediment sampling stations were randomly distributed and, therefore, were in different positions for each of the five surveys. On Flat 4, fourteen fixed stations were established, and resurveyed each subsequent time.

Either 63 mm or 34 mm, inside diameter, coring tubes were used to extract two approximately 10 cm long sediment cores at each station. The two cores from each station were mixed together in a sealable plastic bag and transported to the Normandeau Associates' Analytical Laboratory for grain-size distribution analysis.

Methods employed for sediment grain-size distribution analysis followed procedures described in Folk (1968) and Carver (1971) including the use of empirically established particle settling velocities (applying Stoke's Law) to determine the proportional representation of particles finer than sand. Particle dispersion was first assured by vigorously shaking a subsample of each field sample with distilled water and sodium hexametaphosphate (dispersing agent). The silt and clay fraction was then separated from the coarser-grained particles by passing the subsample slurry through a 62.5 μm mesh sieve.

Upon separation, the silt-clay fraction was again thoroughly mixed with dispersant and put into a graduated cylinder. At times and to depths determined by formulae prescribed in Folk (1968) and Carver (1971), 20 ml volumes were withdrawn from the cylinder by pipette. These sample aliquots were oven dried and weighed to an accuracy of 1 mg. The coarse particle portion (principally sand) was washed, oven

TABLE 4. SEDIMENT SURVEY SAMPLING EFFORT. SEABROOK *MYA ARENARIA* STUDY, 1977.

LOCATION	DATE	NUMBER OF STATIONS
	Random Stations	
Flat 2	November 1975	4
Flat 2	February 1976	9
Flat 2	August 1976	6
Flat 2	November 1976	10
Flat 2	December 1977	9
	Fixed Stations	
Flat 4	August 1976	14
Flat 4	November 1976	14
Flat 4	February 1977	14
Flat 4	August 1977	14
Flat 4	November 1977	14

dried and sieved through a U.S. Standard Sieve Series, at intervals of 350, 177, 88 and 44 μm. Each of these sieve fractions was weighted to an accuracy of 10 mg.

Weights of the various sieve and pipetted fine-grain fractions, representing each sample, were submitted to a computer program (adapted from Kane and Hubert, 1963) which produced an extrapolated particle distribution curve for each sample. For presentation, and to facilitate interpretation, the graphic mean and graphic standard deviation were calculated for each sample, according to the following formula:

Graphic Mean (Mz)

$$M_z = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

Inclusive Graphic Standard Deviation (σ_I)

$$\sigma_I = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

The value ϕ is the base 2 logarithm of the reciprocal of grain size (in fractions of a mm), such that a 1 mm grain of sand has a ϕ value of 0.0, a 1/2 mm sand grain has a ϕ value of 1.0, and 1/4 mm sand grain has a ϕ value of 2.0, etc. Numbers next to the symbol ϕ, in the above formulae, specify the percentile, e.g., $\phi 16$ means the value of ϕ in the 16th percentile of the grain-size distribution curve.

3.0 RESULTS

3.1 BIVALVE LARVAE: SPECIES COMPOSITION AND ABUNDANCE

Results of twice weekly net tows are presented in Tables 5 and 6 and in Figure 3. Details pertaining to population density estimates for the more abundant bivalve mollusc species, other than *M. arenaria*, are tabulated in Appendix I. Throughout the sampling period, *M. arenaria* umboned veligers never appeared in densities greater than 15 per m^3, with one exception. That exception was on 22 August, when the average *M. arenaria* umboned veliger density, for the two replicate tows, approached 100 per m^3 (Table 5). For the 102 day period from 27 June to 6 October, the *M. arenaria* umbone veliger density averaged only 7.0 per m^3.

Table 7, below, displays the results of the only horizontal distribution tow study conducted:

TABLE 7. DISTRIBUTION OF UMBONED *M. ARENARIA* VELIGERS ALONG THE EAST-TO-WEST INTAKE TRANSECT, 22 AUGUST 1977.

STATION	I_2		I_4		I_6		I_8	
REPLICATE	1	2	1	2	1	2	1	2
Sample volume (m^3)	6.9	7.3	10.0	7.4	9.7	8.2	8.1	9.5
Total count	1506.0	1978.0	1092.0	964.0	2357.0	2065.0	347.0	446.0
Mya Veligers (per m^3)	218.3	271.0	109.0	130.0	243.0	252.0	43.0	47.0

Since this study was not repeated, there being no other date at which *M. arenaria* umbone veligers were present in sufficient abundance, no basis for statistical treatment existed. Umbone veliger total abundance and species composition, on 22 August, is presented in composite for each of

TABLE 5. DENSITIES (/M^3) OF UMBONED *MYA ARENARIA* VELIGER LARVAE COLLECTED BY OBLIQUE NET TOW.

DATE	PRESENT INTAKE REPLICATE 1	PRESENT INTAKE REPLICATE 2	PRESENT INTAKE $\overline{X}$	INTAKE SITE PROPOSED PRIOR TO 1975 REPLICATE 1	INTAKE SITE PROPOSED PRIOR TO 1975 REPLICATE 2	INTAKE SITE PROPOSED PRIOR TO 1975 $\overline{X}$
27 Jun	0.8	0.7	0.8	4.9	2.4	3.6
30 Jun	1.4	0.7	1.0	<.1	<.1	<.1
5 Jul	0.3	0.6	0.4	11.6	3.9	7.8
8 Jul	14.1	12.1	13.1	8.2	10.5	9.4
11 Jul	1.2	0.7	1.0	1.4	3.2	2.3
14 Jul	0.4	2.2	1.3	0.7	0.6	0.6
18 Jul	0.7	0.2	0.4	0.6	0.6	0.6
21 Jul	0.5	0.7	0.6	0.5	0.7	0.6
28 Jul	0.1	0.1	<.1	0.0	0.1	<.1
1 Aug	<.1(53)*	<.1(50)*	<.1			
4 Aug	13.0	15.0	14.0			
8 Aug	1.0	0.4	0.7			
11 Aug	2.1	1.9	2.0			
15 Aug	4.4(5.4)*	2.0(2.4)*	3.2			
18 Aug	4.7	8.1	6.4			
22 Aug	129.0	67.0	98.0			
25 Aug	11.1	13.8	12.4			
29 Aug	3.9	1.4	2.6			
1 Sep	11.7	10.0	10.8			
6 Sep	0.3	0.4	0.4			
8 Sep	0.0	0.1	<.1			
12 Sep	0.6	0.9	0.8			
15 Sep	2.5	3.2	2.8			
19 Sep	14.4	13.8	14.1			
22 Sep	0.7	1.0	0.8			
29 Sep	0.2	0.2	0.2			
6 Oct	0.8	0.5	0.6			
10 Oct	0.0	0.0	0.0			
13 Oct	0.0	0.0	0.0			
20 Oct	0.0	0.0	0.0			
27 Oct	0.0	0.0	0.0			

avg. density: 27 June to 6 October (102 days)
7.0 larvae per m^3

* numbers in parentheses represent straight hinge larval densities

TABLE 6. PERCENTAGE COMPOSITION OF BIVALVE MOLLUSCS IN OBLIQUE NET TOWS IN THE VICINITY OF THE INTAKE SITE. SEABROOK *MYA ARENARIA* STUDY, 1977.

DATE	*M. MODIOLUS*	*M. EDULIS*	*HIATELLA* SP.	*ANOMIA* SPP.	*ENSIS DIRECTUS*	OTHERS	*MYA ARENARIA*
27 Jun	60.6	29.1	8.6	0.4	*	1.2	<0.1
30 Jun	73.7	13.0	11.5	0.1	*	1.7	<0.1
5 Jul	75.3	7.0	12.0	4.3	*	1.4	<0.1
8 Jul	42.8	49.8	5.9	0.1	*	1.3	0.1
11 Jul	72.2	10.7	11.0	5.6	*	0.5	<0.1
14 Jul	55.1	12.7	18.8	12.5	*	0.8	<0.1
18 Jul	33.2	33.7	23.3	7.1	*	2.7	<0.1
21 Jul	15.8	34.1	24.5	22.9	*	2.7	<0.1
25 Jul	39.4	30.5	14.2	12.0	*	3.9	<0.1
28 Jul	43.4	27.3	13.9	13.1	*	3.2	<0.1
1 Aug	24.5	14.6	24.2	25.9	*	10.8	<0.1
4 Aug	19.1	15.4	31.2	24.2	*	9.1	1.0
8 Aug	10.0	50.2	14.7	18.7	*	6.2	0.2
11 Aug	7.9	50.6	18.0	14.6	*	6.7	2.2
15 Aug	7.0	16.1	24.4	45.2	*	6.9	0.4
18 Aug	6.2	19.1	12.7	46.8	*	14.0	1.2
22 Aug	2.7	13.7	18.2	32.7	*	15.9	16.8
25 Aug	10.3	7.2	14.3	54.3	*	13.3	0.5
29 Aug	34.5	8.5	8.4	42.4	*	6.1	0.1
1 Sep	32.0	23.4	10.0	27.5	*	6.9	0.2
6 Sep	26.4	28.4	11.7	24.2	2.3	6.9	<0.1
8 Sep	7.8	53.9	16.9	17.4	0.7	3.3	<0.1
12 Sep	27.1	33.7	15.9	11.9	2.2	9.1	0.1
15 Sep	14.0	33.5	23.9	20.6	1.6	6.3	0.1
19 Sep	8.0	25.5	11.5	31.8	19.6	3.4	0.2
22 Sep	7.7	28.8	5.6	50.7	0.7	6.4	<0.1
26 Sep	4.4	67.9	5.0	14.2	2.0	6.4	<0.1
29 Sep	5.1	35.0	11.9	40.7	1.4	5.9	<0.1
3 Oct	4.1	17.2	4.9	65.2	6.0	2.6	0.0
6 Oct	8.5	32.7	4.5	37.7	8.9	7.6	<0.1
10 Oct	33.7	17.9	6.3	34.2	4.2	3.7	0.0
13 Oct	20.8	3.8	7.0	55.4	9.0	4.0	0.0
20 Oct	22.4	20.4	1.8	46.1	2.2	7.0	0.0
27 Oct	47.0	14.0	4.1	29.4	2.7	2.7	0.0

* Included with "others" category

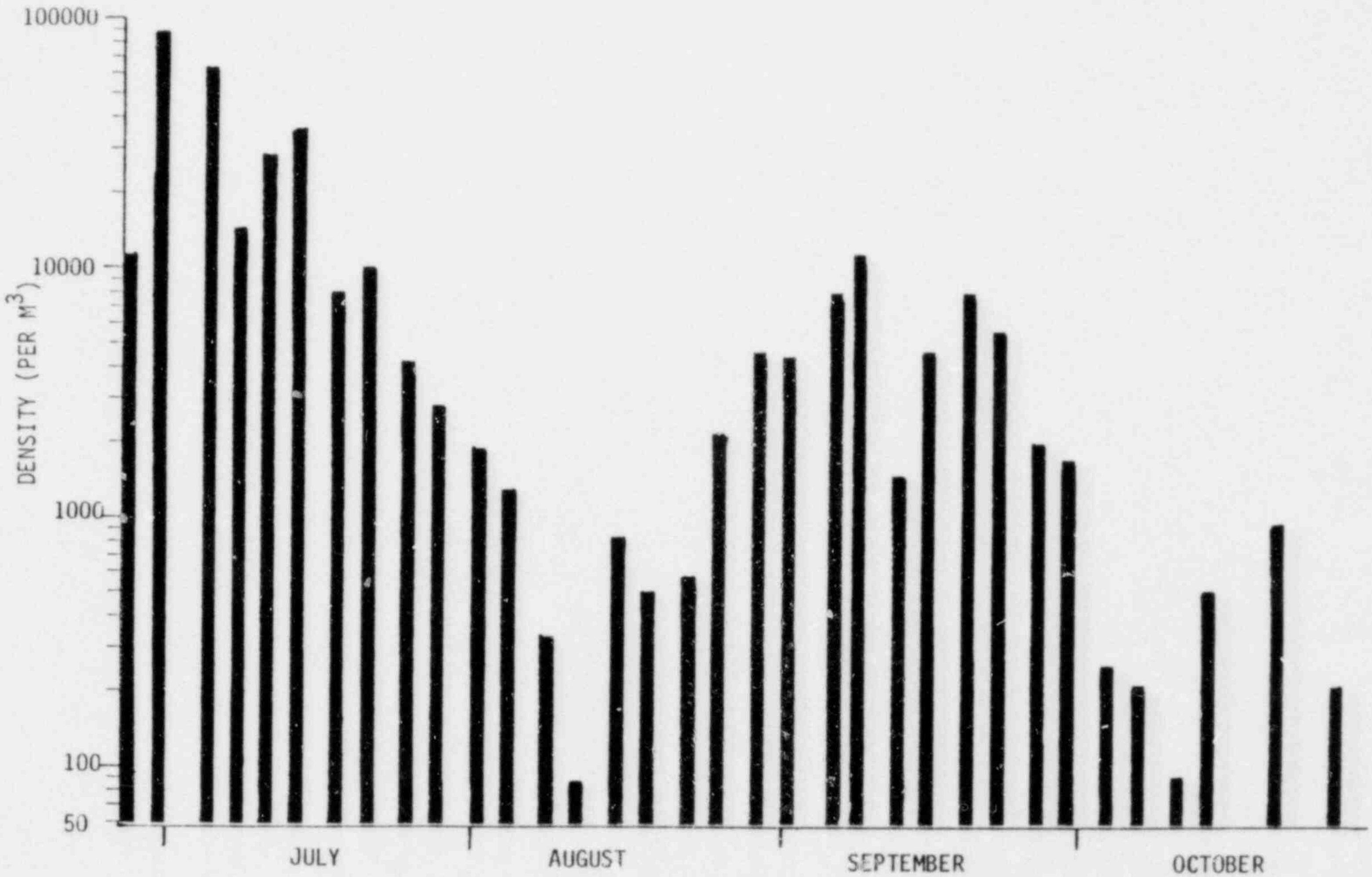

Figure 3. Abundance of veligers of bivalve mollusc species collected in the vicinity of the intake site off Hampton Beach, New Hampshire. Seabrook *Mya arenaria* Study, 1977.

the four stations along the intake transect in Figure 4. These data indicate that, on this date, *Anomia* sp. increasingly predominated the bivalve veliger assemblage in the offshore direction, at least as far out as 2 nautical miles.

Among the other kinds of bivalve mollusc veligers collected in the tows, four species: *Modiolus modiolus, Mytilus edulis, Hiatella* sp.[1] and *Anomia* sp.[2] stood out as being consistently the most abundant throughout the collection period (Figure 3; Appendix I). Total abundance (all species collectively) peaked very early in the collection period, primarily due to the very high density of *Modiolus modiolus* (horse mussel) larvae in the water. On 30 June, estimates of *M. modiolus* density at the previously proposed intake location ran as high as 137,000 per m^3, while estimates from the present site were about half that value (Appendix I).

Several other species, notably, *Cerastoderma pinnulatum* (northern dwarf cockle), *Zirphaea crispata* (piddock clam), *Macoma balthica* and *Placopecten magellanicus* (sea scallop) rarely comprised more than 15% of any of the tow collections, collectively. In early summer collections, *Ensis directus* (razor clam) larvae were also lumped with the low density species; however, as *E. directus* larval populations became relatively more dense in later collections (often exceeding 100 per m^3) these species were enumerated separately. Highest *E. directus* densities (estimates ranged from 1250 to 2000 per m^3) were observed on 19 September (Appendix I).

A secondary peak in total bivalve veliger abundance was evident from late August to late September. Five species: *M. modiolus, M. edulis, Hiatella* sp., *Anomia* sp. and *Cerastoderma pinnulatum* predominated (Figure 3; Appendix I).

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[1]Tentatively, mostly *H. striata* (= *gallicana*)

[2]Tentatively, mostly *A. squamula* (= *A. aculeata*) (spiny jingle shell)

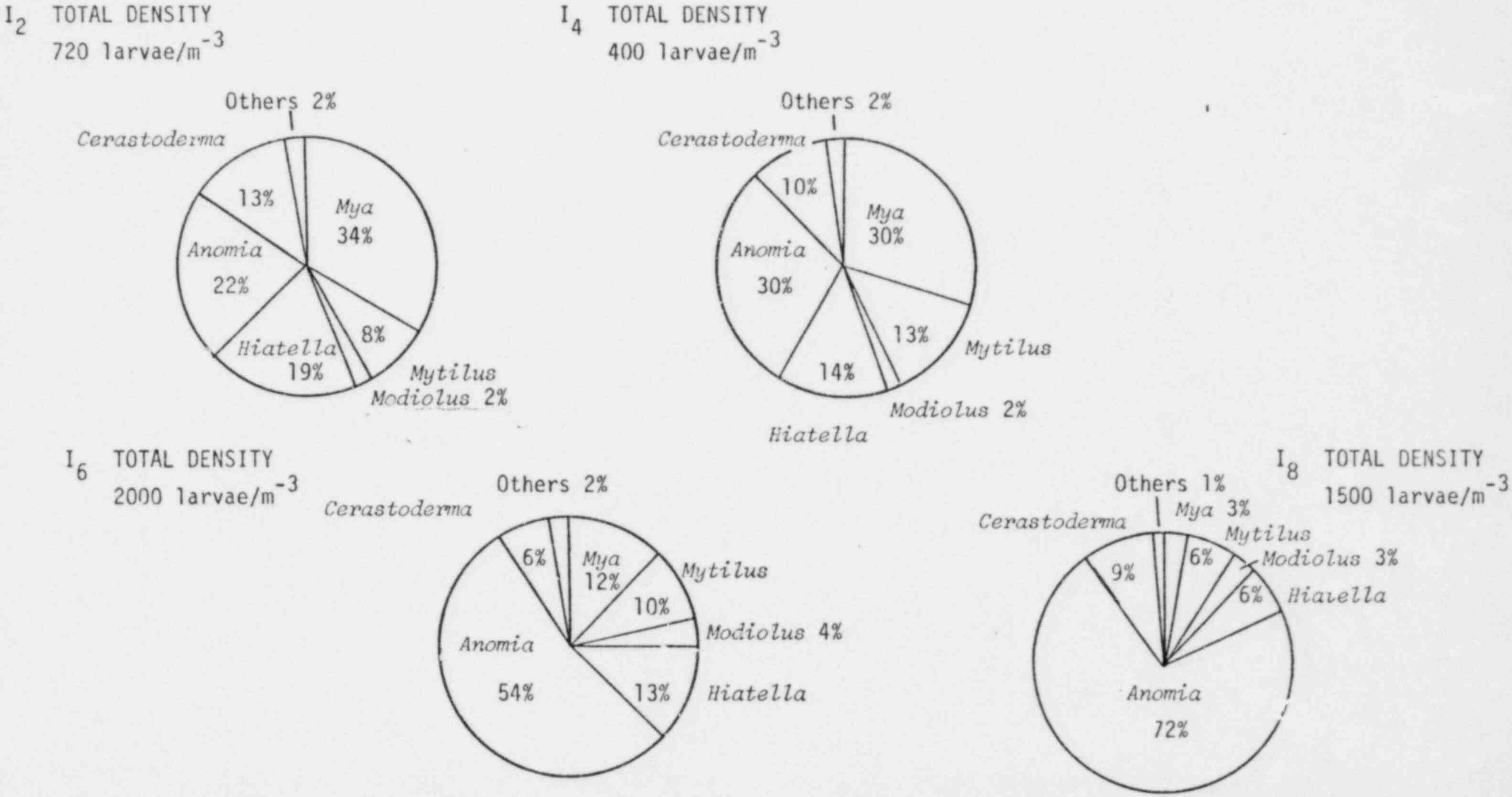


Figure 4. Species composition of tow samples from the intake transect stations, 22 August 1977. Seabrook *Mya arenaria* Study, 1977.

3.2 CLAM SPAT: ABUNDANCE, DISTRIBUTION AND GROWTH

Spat densities recorded for fixed stations in six New England estuaries are presented in Table 8; further detail pertaining to the fixed station survey can be found in Appendix II. Both the Plum Island Sound and Hampton Harbor flats exhibited reasonably good retention of the 1976 spat set, which, as shown in Table 9, represented the highest spatfall density in seven years of study at Hampton-Seabrook Estuary (= Hampton Harbor). Retention was also reasonably high at Ogunquit Beach until October 1977 when densities fell to approximately one quarter of the maximum observed densities. Attrition of the 1976 spat set was almost complete in the Merrimack River estuary, Little Harbor channel, and the York River estuary. Spatfall was relatively modest in 1977 at all of the estuaries studied, except Plum Island Sound, where the 1977 spatfall was even higher than in the previous year.

Shell length data, obtained from the fixed station program, are represented in Figure 5. Shell growth was most rapid at the Plum Island flats. Shell growth at Ogunquit Beach was initially comparatively slow, but later accelerated, particularly between samplings in June and August. By October, 1977, a wide gap was evident between the shell size ranges of the 1976 and 1977 year classes, at both Plum Island Sound and Ogunquit Beach, as Figure 5 clearly shows. To minimize clutter, size-frequency characteristics of the 1977 set were not included in Figure 5 for the October, 1977, Hampton Harbor collection, but were essentially the same as depicted for the same month in the Merrimack River. In October 1977, 1976 year class spat were virtually non-existent in the Merrimack River (Table 8).

Results of the 1976 and 1977 annual spat collections at random stations, are summarized for the five principal flats, collectively, in Figures 6 and 7. These data indicate that median shell size has increased only 6 mm, from 3 to 9 mm, in the 12 month period between surveys. However, clams in the upper 97.5 percentile of shell size have grown approximately 11 mm, from 6 mm to 17 mm, between the two surveys (Figure

TABLE 8. SEED CLAM DENSITIES (FT^{-2}) FOR SIX NORTHERN NEW ENGLAND ESTUARIES. (VALUES DO NOT INCLUDE SPAT LESS THAN 1.5 mm MAXIMUM WIDTH). SEABROOK *MYA ARENARIA* STUDY, 1977.

LOCATION / SAMPLE PERIOD	APR 1976	JUN 1976	AUG 1976	OCT 1976	JAN-FEB 1977	APR 1977	JUN 1977	AUG 1977	OCTOBER 1977 YEAR CLASSES 1976	1977
Plum Island Sound, MA	63	2	17	178	112	212	336	156	101	572
Merrimack River Estuary, MA	33	14	23	228	164	227	149	25	<1	52
Hampton Harbor, NH	113	15	96	1283	614	692	615	363	254	77
Little Harbor, NH	69	19	6	105	85	176	200	60	2	31
York River, ME	181	277	92	105	119	92	416	108	<1	75
Ogunquit Beach, ME	37	2	8	57	101	63	102	108	24	25

TABLE 9. SUMMARY OF *MYA ARENARIA* POPULATION DENSITIES, ANNUAL NOVEMBER SURVEY. SEABROOK *MYA ARENARIA* STUDY, 1977.

LOCATION	YEAR	NUMBER OF SAMPLES COLLECTED		POPULATION DENSITY (#/SQ. FT.)		
		ADULTS	SPAT	SPAT (>1 TO 25 mm)	ADULTS (25 TO 50 mm)	ADULTS (>50 mm)
Flat 1	1971	18	18	48	6.8	2.1
	1972	18	18	110	8.1	3.3
	1973	36	18	44	2.5	1.3
	1974	40	18	2.6	2.8	3.0
	1975	35	18	56	0.4	1.2
	1976	63	18	1084	0.12	0.53
	1977	66	14	819	0.04	0.15
Flat 2	1971	9	9	91	4.8	3.8
	1972	9	9	152	2.2	1.4
	1973	9	9	136	3.8	1.1
	1974	21	9	0.0	2.1	1.9
	1975	21	9	9.1	0.0	0.5
	1976	24	9	351	0.0	0.21
	1977	33	7	86	0.0	0.08
Flat 3	1971	6	6	74	4.7	4.6
	1972	6	6	39	1.6	0.4
	1973	12	6	8	3.6	2.2
	1974	12	6	0.6	0.7	1.7
	1975	12	6	1.1	0.0	0.6
	1976	24	5	560	0.07	0.23
	1977	24	6	75	0.12	0.04
Flat 4	1971	12	12	106	17.6	2.8
	1972	12	12	138	10.6	2.3
	1973	24	12	18	3.8	0.6
	1974	29	12	1.1	2.8	1.8
	1975	29	12	68	0.3	0.7
	1976	81	18	843	0.04	0.16
	1977	51	11	436	0.09	0.01
Flat 5	1971	9	9	176	1.3	1.6
	1972	9	9	196	3.8	2.3
	1973	21	11	23	1.0	0.4
	1974	17	11	2.4	0.0	0.1
	1975	9	11	7.5	0.0	0.01
	1976	24	12	549	0.0	0.14
	1977			114	0.08	0.03

(Continued)

TABLE 9. (Continued)

LOCATION	YEAR	NUMBER OF SAMPLES COLLECTED ADULTS	SPAT	POPULATION DENSITY (#/SQ. FT.) SPAT (>1 TO 25 mm)	ADULTS (25 TO 50 mm)	ADULTS (>50 mm)
All Flats	1971	54	54	92	7.7	2.7
	1972	54	54	130	6.2	2.2
	1973	111	56	47	2.8	1.0
	1974	119	56	2.1	2.1	2.0
	1975	106	56	37	0.2	0.8
	1976	216	62	762	0.06	0.20
	1977	212	47	388	0.05	0.07

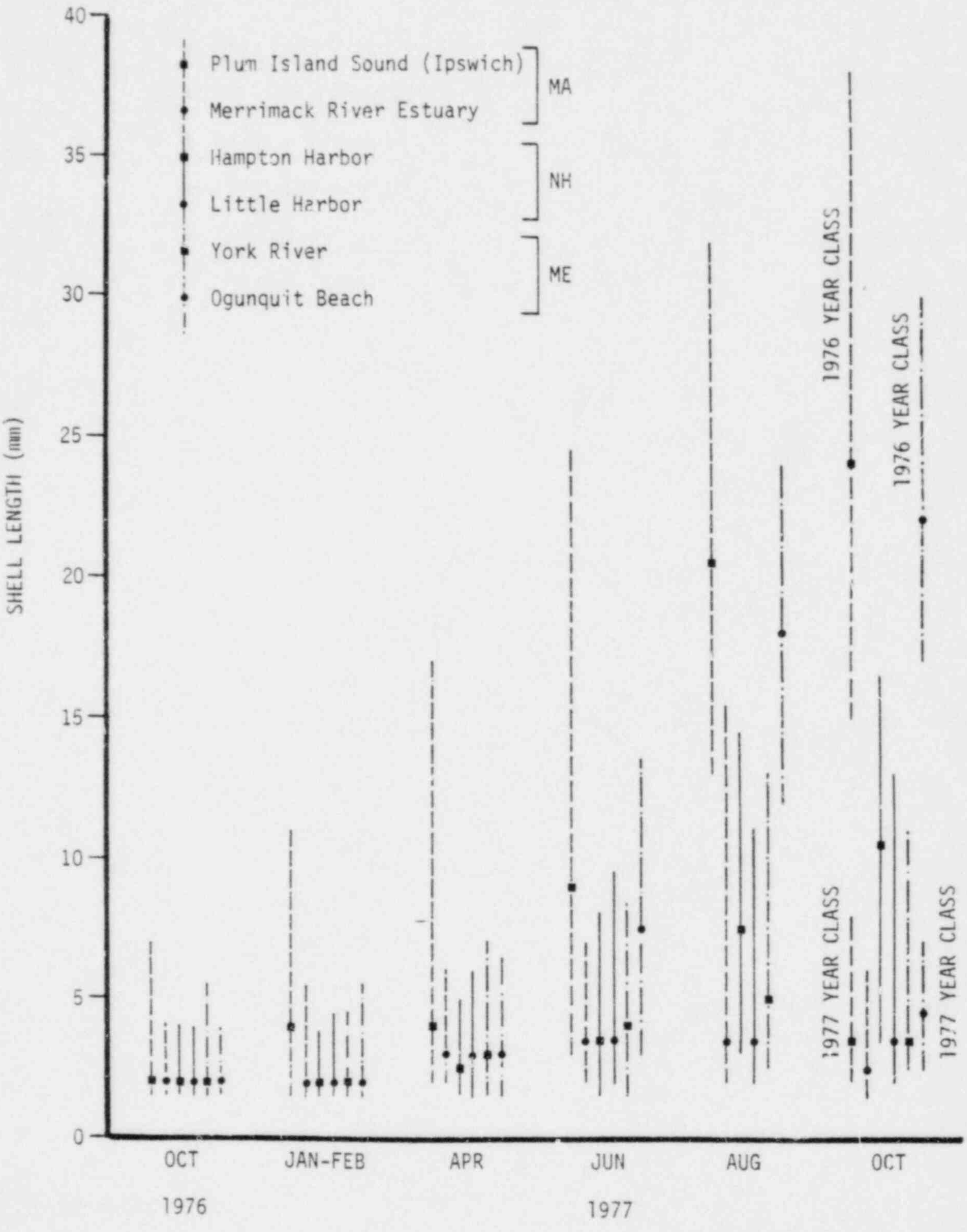


Figure 5. Shell length medians and ranges for juvenile soft-shell clams collected from selected northern New England estuaries. Seabrook *Mya arenaria* Study, 1977.

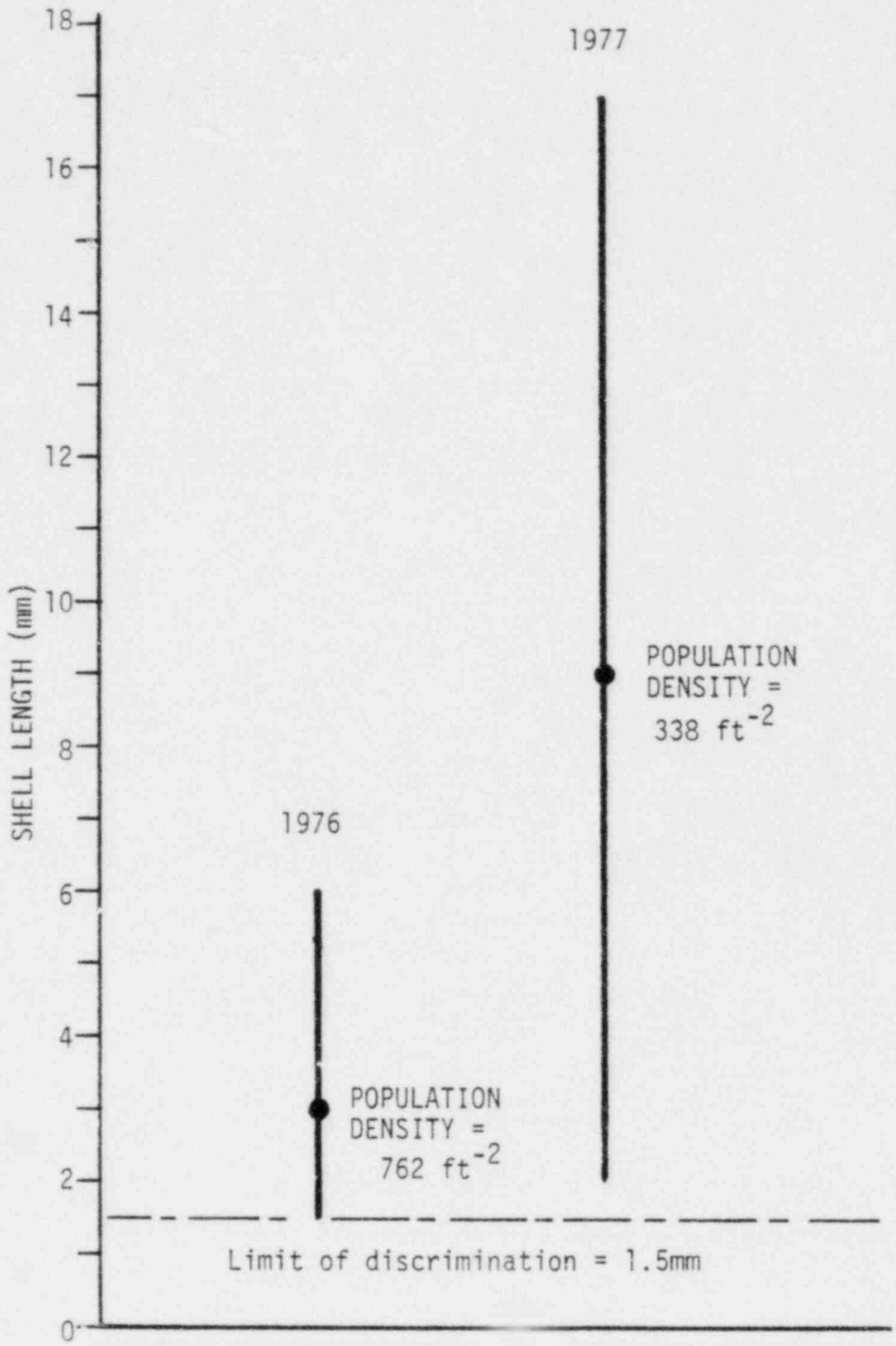


Figure 6. Spat shell length medians and ranges in Hampton Harbor, November 1976 and 1977. Seabrook *Mya arenaria* Study, 1977.

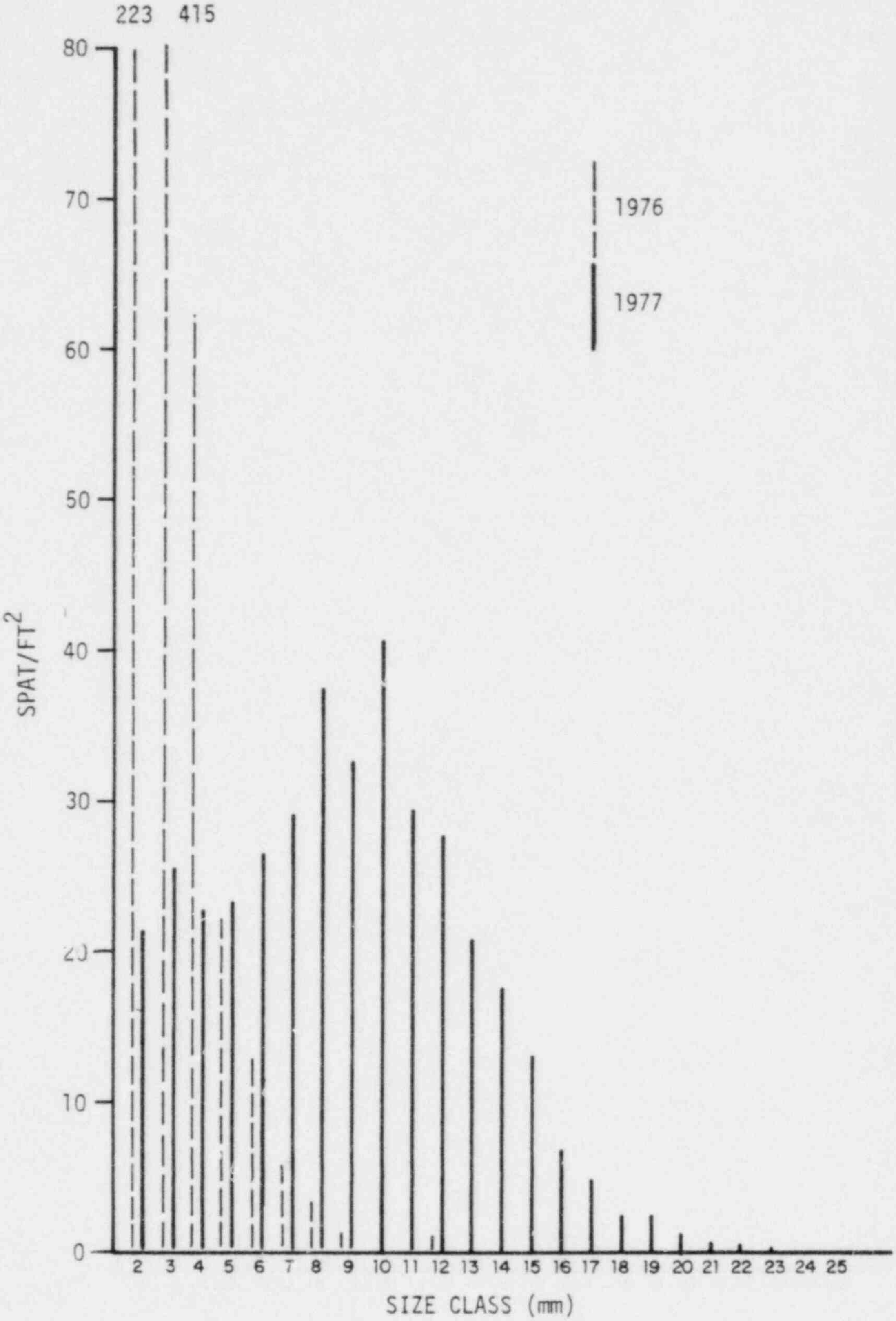


Figure 7. Spat size-frequency distributions for juvenile soft-shell clams from Hampton Harbor, November 1976 and 1977. Seabrook *Mya arenaria* Study, 1977.

6). As of November 1977, approximately 2.5% of all spat were between 17 and 25 mm long (Figures 6 and 7); whereas, there were no spat larger than 12 mm in November 1976 (Figure 7).

Data pertaining to spat density estimates for each of the five principal Hampton Harbor flats is summarized in Table 9. Further details are presented in Appendix 7.3. Flat 1 appears to have retained much of the spat observed a year earlier, in November 1976. Between the 1976 and 1977 annual surveys, densities on Flat 4 have been reduced by approximately one half; while, attrition has been substantially greater on the other three flats.

3.3 ADULT CLAMS: DISTRIBUTION AND ABUNDANCE

Results of Hampton Harbor adult clam surveys conducted throughout 1977 are summarized in Table 10. Considering the entire five-flat area, totaling 167 acres, there has been a 45% reduction in biomass since November 1976 and an 88% reduction since November 1974 (Figure 8). Large declines from the previous year are indicated by the biomass and standing crop values for the individual flats (Table 10), except for Flat 2 which appears to have maintained a fairly stable, albeit sparse, soft-shell clam population for the past two years. As indicated by the relatively large number of stations on Flat 1 where burrows were evident, and the high yield at these stations (see Column $\overline{X}_1$; Table 10), Flat 1 remains an important soft-shell clam propagation area in Hampton Harbor.

Estimates of the percentage of flat area no longer bearing soft-shell clams continued to increase, from 1976 to 1977 (Table 11). By November 1977, 81% of the 167 acres on the five largest flats had become non-productive. The smallest proportion of non-productive area (68%) was found on Flat 3.

TABLE 10. RESULTS OF SOFT-SHELL CLAM (*MYA ARENARIA*) ESTIMATES, HAMPTON-SEABROOK ESTUARY. *MYA ARENARIA* STUDY, 1977.

LOCATION	DATE	SURFACE AREA (ACRES)	TOTAL NUMBER OF SAMPLING UNITS (n)	NUMBER UNITS BURROWS OBSERVED (n_1)	NUMBER UNITS WITH NO BURROWS (n_2)	NUMBER BURROWLESS UNITS SUBSAMPLED (n_2')	MEAN BIOMASS (BUSHELS/ACRE) BURROWS OBSERVED ($\bar{X}_1$)	MEAN BIOMASS (BUSHELS/ACRE) NO BURROWS OBSERVED ($\bar{X}_2'$)	COMBINED ESTIMATE $\bar{X}$ ± STD DEV	STANDING CROP (BUSHELS) ESTIMATED $\bar{X}$ ± STD DEV
Flat 2	May	25.5	27	7	20	4	31.00	0.0	8.04 ± 3.72	205 ± 95
Flat 2	August	25.5	27	8	19	4	27.88	28.0	27.96 ± 12.51	712 ± 318
Flat 2	November	25.5	33	1	32	8	67.00	6.98	8.79 ± 6.76	224 ± 172
Flat 1	November	55.0	66	13	53	13	45.92	0.0	9.05 ± 2.01	498 ± 111
Flat 3	November	11.6	24	5	19	4	13.04	1.08	3.57 ± 1.76	41 ± 20
Flat 4	November	50.6	51	2	49	6	16.15	1.15	1.73 ± 1.15	88 ± 58
Flat 5	November	23.9	38	11	27	5	5.77	1.10	2.45 ± 2.94	59 ± 70
TOTAL ALL FLATS	November	166.6	212	32	180	36	25.78	2.92	6.37 ± 1.64	1061 ± 273

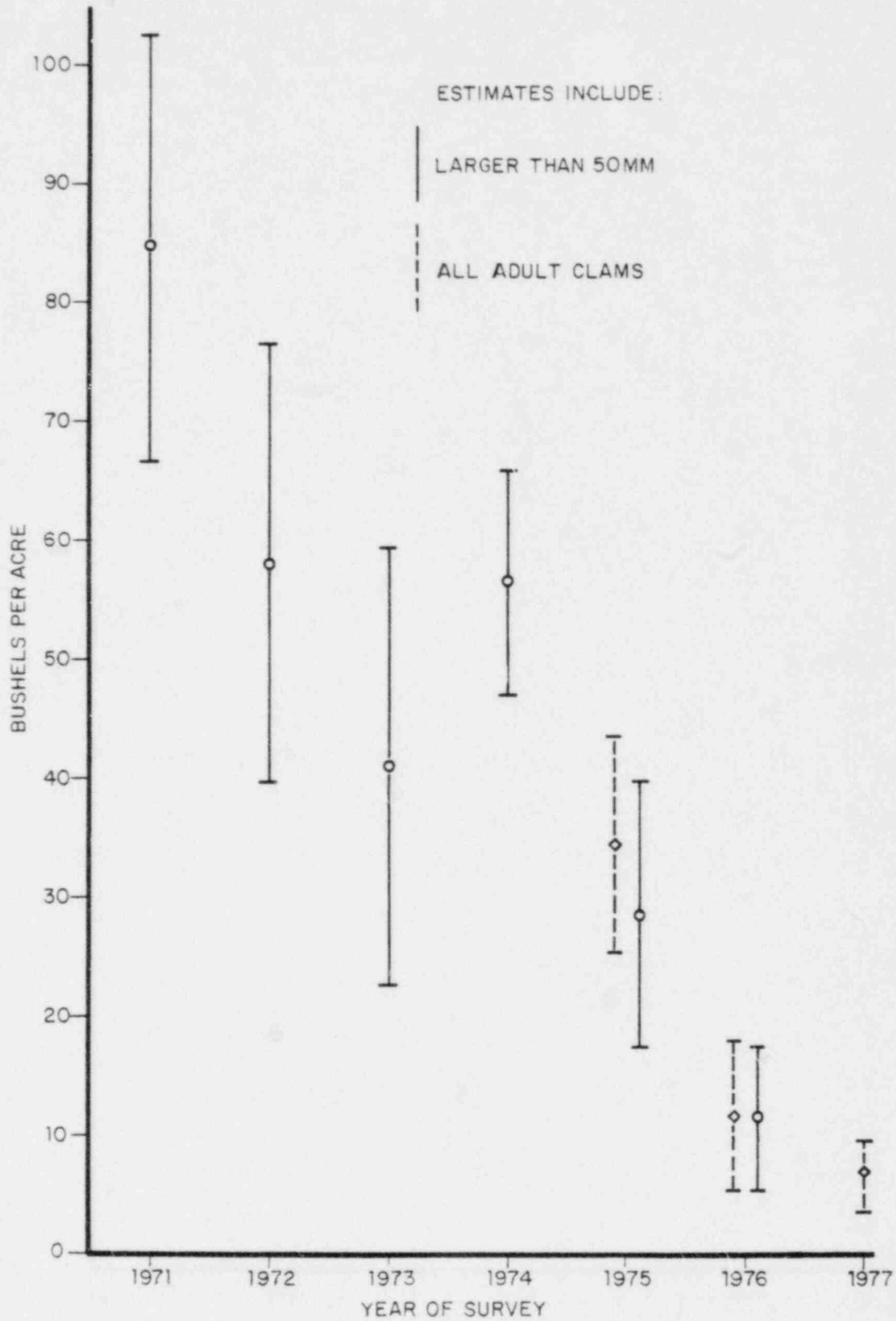


Figure 8. Estimates of soft-shell clam, *Mya arenaria*, biomass for five tidal flats in Hampton Harbor; with approximate 95% confidence intervals. Adult clam populations estimated after 1974. Seabrook *Mya arenaria* Study, 1977.

TABLE 11. ESTIMATES OF NON-PRODUCTIVE CLAM FLAT, HAMPTON-SEABROOK ESTUARY. SEABROOK *MYA ARENARIA* STUDY, 1977.

LOCATION	MONTH	% OF n_1 STATIONS DEVOID OF CLAMS	% OF n_2' STATIONS DEVOID OF CLAMS	ESTIMATED % OF AREA WHICH WAS UNPRODUCTIVE			
				1977	1976	1975	1974
Flat 2	May	29	100	81	43	52	
Flat 2	August	50	50	50	92	52	
Flat 2	November	0	97	85	83	56	37
Flat 1	November	15	100	83	65	47	20
Flat 3	November	40	75	68	52	61	33
Flat 4	November	0	83	80	81	43	12
Flat 5	November	73	80	78	73	96	80
All Flats	November	38	89	81	74	55	34

Length-frequency distributions of clams, collected from the five major Hampton Harbor flats during the past three November surveys, are presented in Figure 9. Compared to the previous year there was an increase in 35 mm size-class density, and a reappearance of clams in the 40 mm size-class. On the other hand, there were no longer any individuals in the 30 mm class, in 1977; a reasonable explanation is that clams in this group (probably representing the 1975 year class) were recruited to the next larger size classes of 35 and 40 mm. From the 45 mm size class upwards, densities declined from 1976 values; this was most marked in the mid-range of harvestable adult clam sizes (size classes 55 to 65 mm). Size frequency records, dating from November 1971, are presented for each of the five principal flats in Appendix 7.3.

3.4 SEDIMENT GRAIN-SIZE DISTRIBUTION CHARACTERISTICS OF FLAT 2 AND 4

Graphic means (M_z) and standard deviations (σ_I) of ϕ values are presented for Flat 2, in Table 12, and for Flat 4, in Table 13. There was little evidence of substantial change in sediment characteristics with time, indicating that large portions of these flats are sedimentologically stable.

Approximately 79% of Flat 2 was composed of fine to very fine sand ($M_z\phi$ = 2.7 to 3.2). Two localities which departed substantially from general Flat 2 characteristics are identified, in Figure 10, as regions of fine sand ($M_z\phi$ = 2.2 to 2.5) and medium sand ($M_z\phi$ = 1.4 to 1.9), respectively. These two areas also tended to be less well sorted than the rest of Flat 2 (Table 12).

Flat 4 exhibited a somewhat more complex sedimentological structure than Flat 2 (Figure 11). The northwestern corner of Flat 4, north of the mussel bed area, was characterized as a medium sand area ($M_z\phi$ = 1.1 to 2.0). Medium sand also prevailed on landward portions of Flat 4 ($M_z\phi$ = 0.9 to 2.3). Sediments associated with the mussel beds and the drainage away from the beds (Figure 11), tended to be the finest

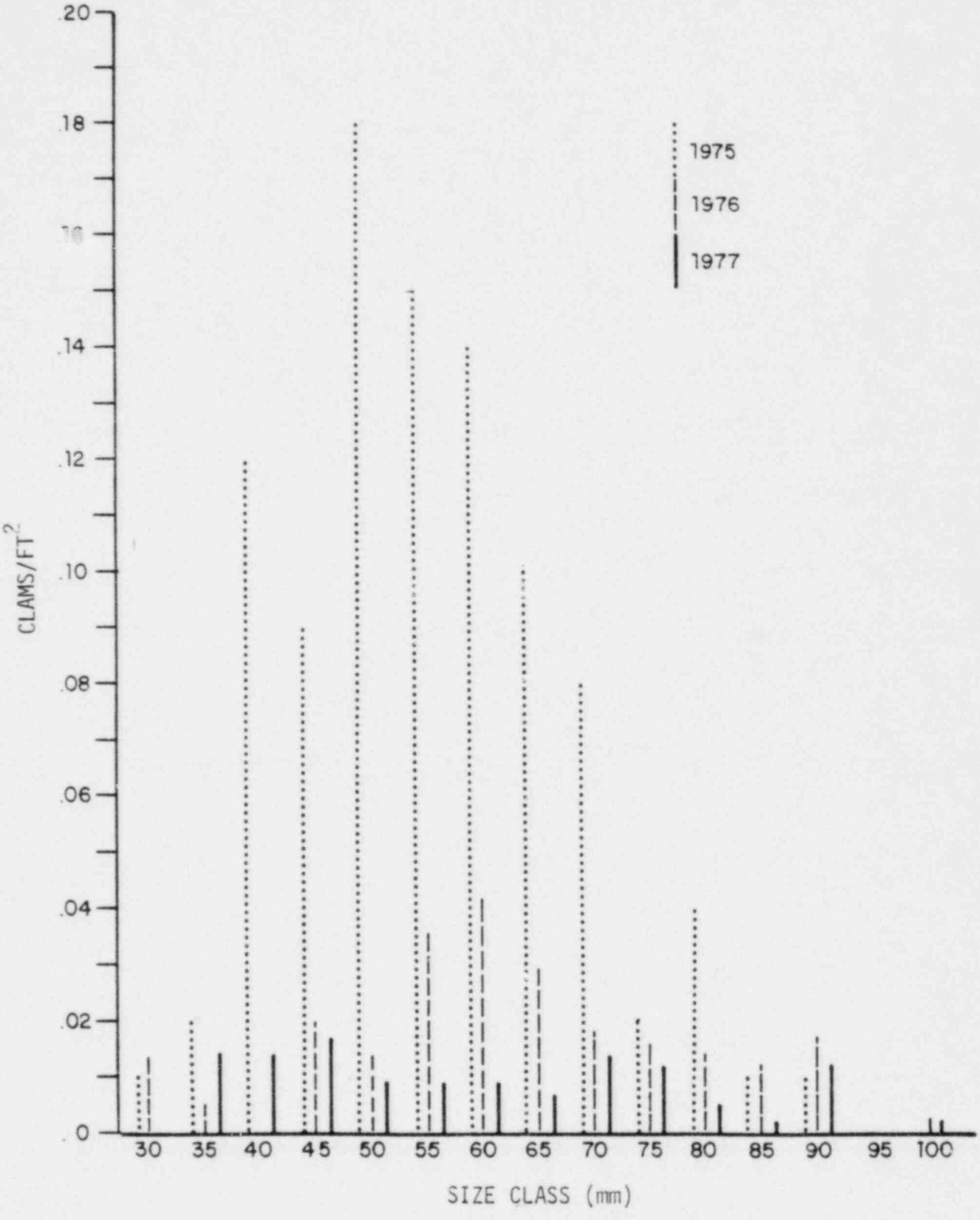


Figure 9. Length-density distribution of adult clams collected from five flats in Hampton Harbor in 1975, 1976 and 1977. Seabrook *Mya arenaria* Study, 1977.

TABLE 12. GRAPHIC MEANS (M_z) AND STANDARD DEVIATION (σ_I) OF GRAIN SIZE (ϕ) VALUES FOR FLAT 2. SEABROOK *MYA ARENARIA* STUDY, 1977.

GRID LOCATION (see Figure 10)	NOVEMBER 1975			FEBRUARY 1976			AUGUST 1976			NOVEMBER 1976			DECEMBER 1977		
	STA	M_z	σ_I	STA	M_z	σ_I	STA	M_z	σ_I	STA	M_z	σ_I	STA	M_z	σ_I
A1							M5	2.5	0.8						
B1				H8	2.9		M4	2.7	0.7	M7	2.9	0.6			
										M5	2.5	0.8			
B2				L3	2.7								5	2.2	1.0
													8	3.0	0.5
C1							H6	3.1	0.6						
C2				H5	2.9		L1	3.1	0.8						
				H1	2.9										
				L7	2.8										
				L8	2.9										
D1	4	3.0	0.46				H1	3.2	0.7				4	3.2	0.7
D2													3	3.0	0.4
													6	2.9	0.4
E2	3	2.9	0.33							H7	3.0	0.5			
E3													2	3.0	0.5
F2										H1	3.0	0.5	9	3.0	0.5
F3	2	3.8	0.48	M4	2.8		L5	1.9	1.1	M1	1.9	1.0	1	1.6	1.2
	1	1.4	1.08												
F4										L1	2.7	0.6			
										L5	1.6	1.1			
G2				M9	2.9					M3	2.9	0.5	7	2.7	0.5
				L6	2.9					L7	2.9	0.5			
										L3	2.8	0.5			

(Continued)

TABLE 12. (Continued)

KEY (INTERPRETATION):

GRAPHIC MEAN (M_z) OF ϕ	PARTICLE DIAMETER (MM)	GRAPHIC STANDARD DEVIATION (σ_I) OF ϕ
1.0	0.500 Medium sand	.35 to .50 - well sorted
1.5	0.350	.51 to .70 - moderately well sorted
2.0	0.250	.71 to 1.00 - moderately sorted
2.5	0.177 Fine sand	1.01 to 2.00 - poorly sorted
3.0	0.125	
3.5	0.088 Very fine sand	
4.0	0.0625	

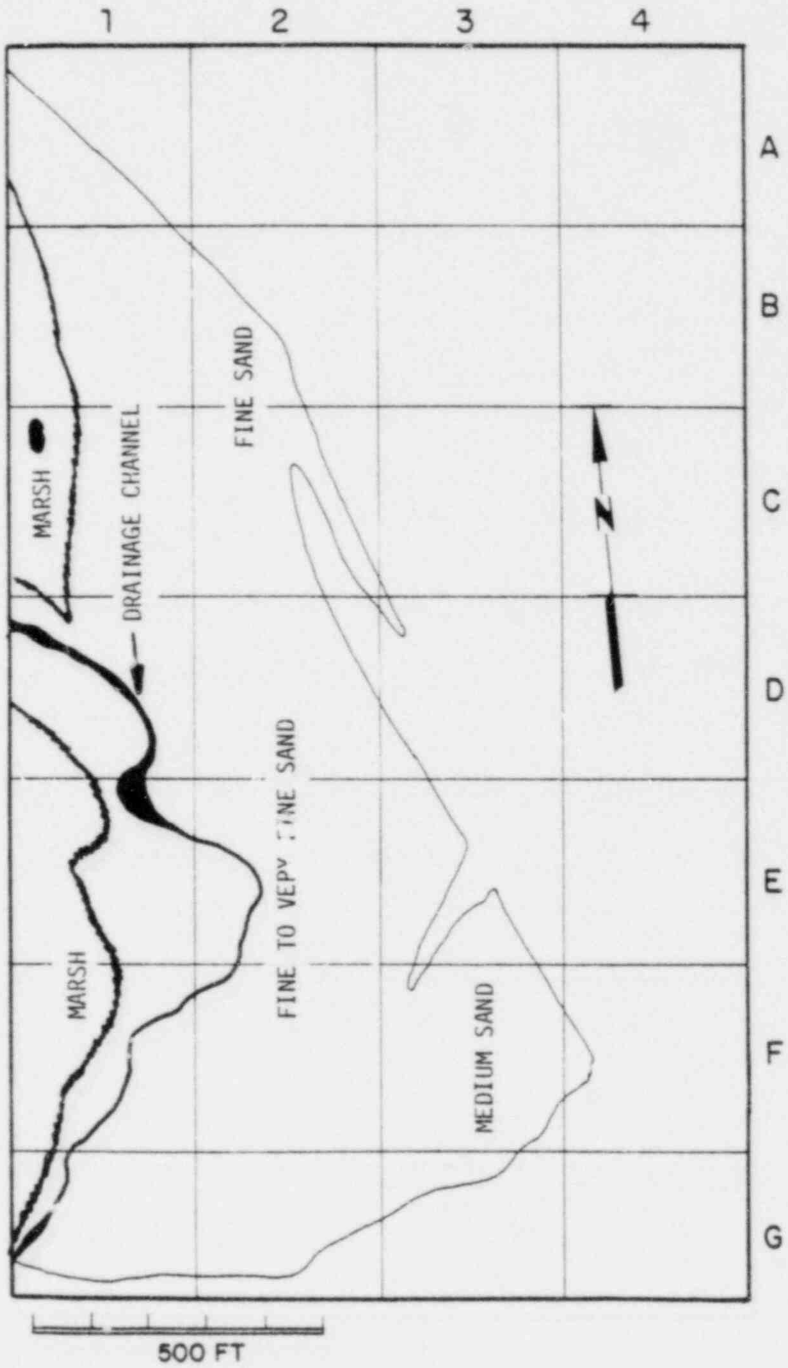


Figure 10. Distribution of mean grain-size classifications on clam flat 2. Seabrook *Mya arenaria* Study, 1977.

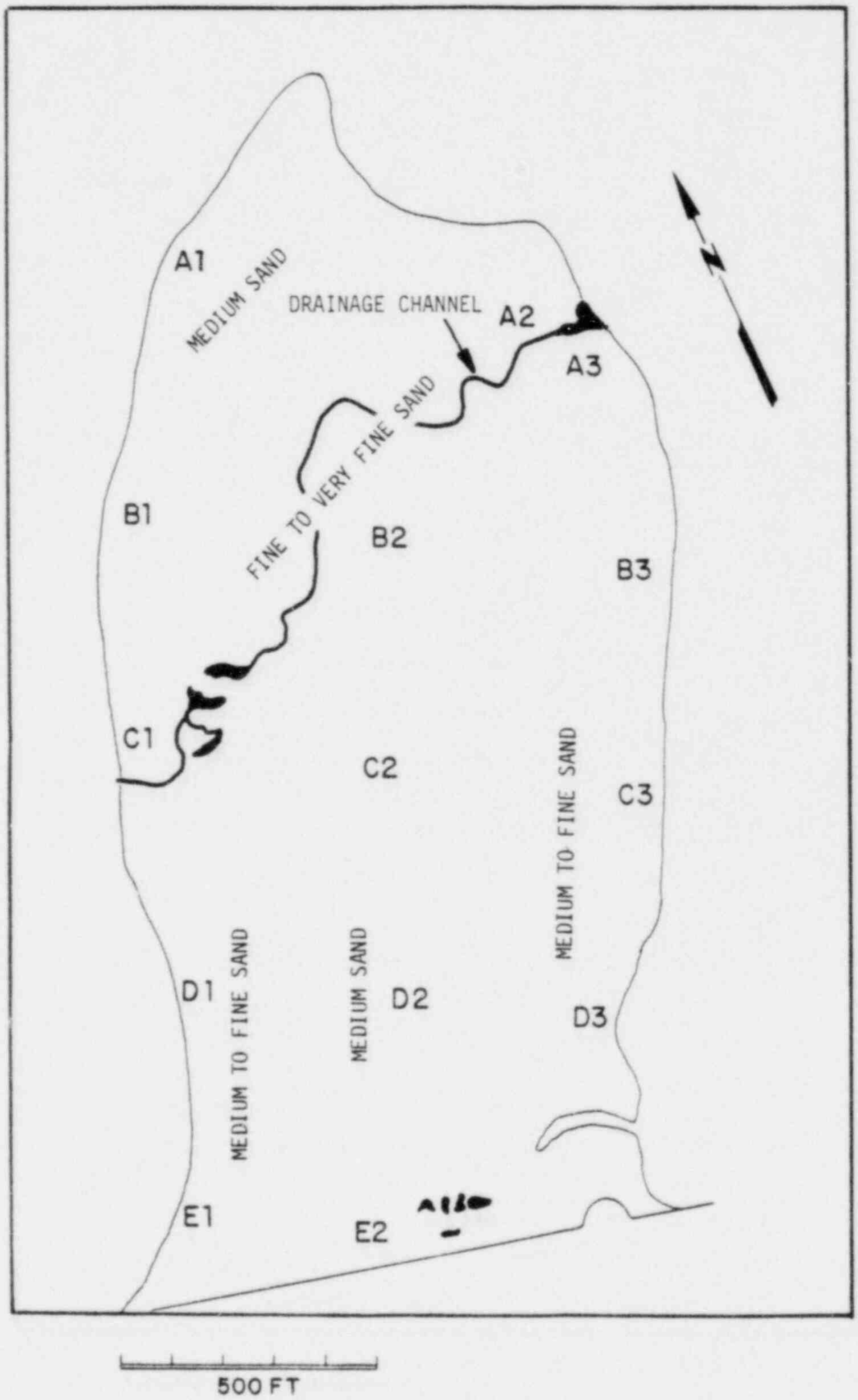


Figure 11. Distribution of mean grain-size classifications on clam flat 4. Seabrook *Mya arenaria* Study, 1977.

grained ($M_z\phi$ = 2.7 to 3.1). The remainder of Flat 4 bordered on fine to medium sand ($M_z\phi$ = 1.8 to 2.5). In general, Flat 4 presented a slightly more poorly sorted situation than Flat 2; this was particularly evident at Stations B3 and D3, in February 1977 and at Station E2, in December 1977 (Table 13).

TABLE 13. GRAPHIC MEANS (Mz) AND STANDARD DEVIATION (σ_I) OF GRAIN-SIZE (ϕ) VALUES FOR FLAT 4. SEABROOK *MYA ARENARIA* STUDY, 1977.

STATION	SUMMER 1976		AUTUMN 1976		WINTER 1977		SUMMER 1977		AUTUMN 1977	
	$M_z\phi$	$\sigma_I\phi$	$M_z\phi$	$\sigma_I\phi$	$M_z\phi$	$\sigma_I\phi$	$M_z\phi$	$\sigma_I\phi$	$M_z\phi$	$\sigma_I\phi$
4A1	1.6	0.9	1.4	0.9	1.5	0.8	1.1	0.9	1.4	0.9
4A2	3.0	0.5	3.0	0.5	3.1	0.5	3.0	0.5	3.1	0.5
4A3	3.1	0.5	2.8	0.5	[illegible].7	0.8	2.9	0.7	2.8	0.8
4B1	1.9	0.8	1.5	0.9	2.0	0.8	1.9	0.7	1.5	0.8
4B2	3.0	0.6	3.1	0.7	2.2	1.2	3.2	0.6	3.2	0.6
4B3	1.9	0.6	1.8	0.7	2.1	2.0	2.1	1.0	2.1	0.8
4C1	2.8	1.0	2.7	1.0	2.7	0.7	2.0	0.7	2.7	0.7
4C2	2.4	1.1	2.5	1.4	2.0	0.9	1.9	1.0	1.9	1.2
4C3	1.9	1.2	2.6	1.0	2.0	1.2	1.7	1.2	2.1	0.9
4D1	1.8	1.0	2.6	0.6	2.3	0.8	2.0	1.0	2.2	1.2
4D2	1.5	0.9	1.7	0.9	1.7	0.9	1.7	0.9	2.1	0.9
4D3	1.4	1.0	1.7	1.0	2.2	1.6	2.0	1.0	1.4	1.1
4E1	1.7	1.0	2.3	0.7	2.3	0.7	1.8	0.9	1.9	0.7
4E2	1.7	0.7	1.4	0.9	1.1	1.0	0.9	1.7	1.5	0.9

4.0 DISCUSSION

4.1 BIVALVE MOLLUSC LARVAE

4.1.1 *Mya arenaria*

As the following table shows, *M. arenaria* umboned veliger densities attained a record low in 1977:

TABLE 14. COMPARISON OF *MYA ARENARIA* UMBONED VELIGER ABUNDANCES OF HAMPTON BEACH, NEW HAMPSHIRE, 1974-1977.

YEAR	PERIOD OVER WHICH LARVAE WERE COLLECTED	MEAN DENSITY (per m^3/day)	DAILY MEAN x SEASON LENGTH (per m^3)
1974	16 Jul to 5 Sep (51 days)	69	3,520
1975	16 Aug to 14 Oct (59 days)	532	31,400
1976	28 Jun to 17 Oct (113 days)	158	17,800
1977	7 Jun to 6 Oct (102 days)	7	714

It should be noted that data presented for 1974 and 1975 were collected by low capacity submersible pumps; however, the previous report (NAI, 1977) demonstrated that, when enumerated under carefully controlled conditions, bivalve mollusc larvae density values obtained from pump collections are approximately equivalent to net tow results.

Horizontal distribution data given in Table 7 (Section 3.1) appears to take some exception to the hypothesis, suggested as early as 1973 (NAI, 1974b) and generally substantiated by subsequent data (NAI, 1977) that *M. arenaria* larval densities decrease with distance from shore. However, the fact that there was only one occurrence of this type in 1977 necessitates reserving any further judgement as to the overall expected spatial distribution of patches of *M. arenaria* pelagic larvae along the New Hampshire coast.

4.1.2 Planktonic Larvae of Other Bivalve Mollusc Species

So far as is known, the present study of bivalve larval abundance and species distribution is unique; no other studies have been identified with which the data presented here can be compared. Bivalve mollusc larvae are usually among the most abundant forms in the meroplankton, and have been enumerated as a generic group (e.g., McAlice, 1972; Lee, 1974); only qualitative species composition information has been given, however. Total densities reported by McAlice (1972) and Lee (1974) averaged one or two orders of magnitude lower than densities reported here.

Species composition off Hampton Beach appears to reflect relative abundance and proximity of adult bivalve mollusc populations inhabiting the study area. The two mussel species are dominants and principal habitat formers on nearby rocky outcroppings. The nestling clam, *Hiatella* sp. is quite frequently found with the *M. modiolus* habitat. *Anomia squamula* are frequently recovered from benthic dredge samples. Many bivalve mollusc species common to the study area were poorly represented in the plankton samples or not found at all. This may be due to a larval demersal habit, or because larvae of certain species tend to remain in the brood chambers of the adults until they are almost ready to settle as spat; the clams *Gemma gemma* and *Nucula* spp. are primary examples of the latter habit.

Data presented in Figure 4 tend to suggest that a density decrease with distance seaward, as hypothesized for *M. arenaria*, may not hold for larvae of other bivalve mollusc species, particularly *Anomia* sp. As was the case with *M. arenaria* spatial distribution (Section 4.1.1), general inferences drawn from a single collection date cannot be evaluated as to reliability.

4.2 SOFT-SHELL CLAM SPAT

The high density of the 1976 spatfall has provided an excellent opportunity to compare soft-shell clam growth and survival in

several estuarine locations. As reported in Section 3.2, virtually complete failure of the 1976 set occurred in three of the estuaries studied. What appeared to distinguish these three estuaries, from those where the 1976 set had substantially survived, was the relative proportion of "disturbed" substrate. In "undisturbed" areas, the substrate was relatively smooth; depressions made by natural and human predators, where present, were widely scattered. "Disturbed" area could be classified as either: 1) ripple marked and coarse sandy areas, predominantly influenced by storm waves and/or strong tidal flow or 2) relatively calm areas of finer sediment, but which were heavily pocketed with predator pits.

By October 1977, substantial acreage of relatively undisturbed substrate was limited almost exclusively to Plum Island Sound and Hampton Harbor, the latter having been closed to digging since May. The second (predator pit) type of disturbed substrate seemed to increase in extent in all six estuaries, throughout the summer. Over the same time interval, the greatest spat loss was apparent (Table 8).

August 1977 sample results from "disturbed" and "undisturbed" areas on Flat #2 were compared in terms of both spat density and size frequency distribution (Figure 12). This comparison indicated that not only were the disturbed areas relatively depleted, but that the survivors were generally smaller in disturbed areas than in the undisturbed area. These observations are consistent with the expectation that those predators which are most active during the summer (namely, green crabs) would detect and devour the larger clams in preference to the smaller ones thereby leaving space for smaller clams to resettle in the areas depleted of larger clams.

At growth rates previously projected for soft-shell clam shell growth (Figure 13) it was anticipated that survivors of the 1976 spat set might attain harvestable size in approximately 3 years. It now appears that this projection was overly optimistic. Only on the Plum Island Sound flats did shell growth even approach projections shown in

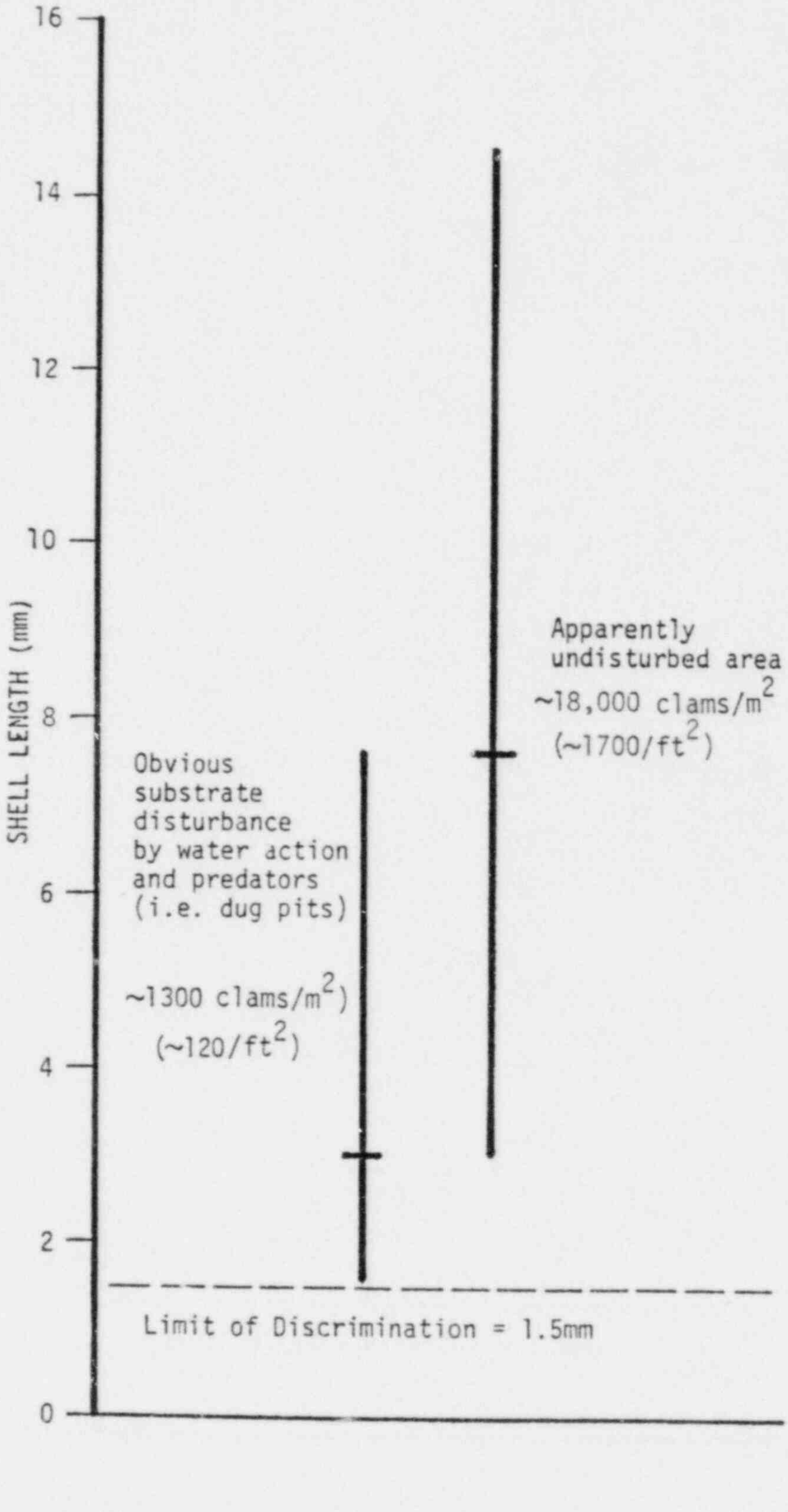


Figure 12. Comparison of size ranges at "disturbed" and undisturbed areas, Flat #2, Hampton Harbor, N. H., August 1977. Seabrook *Mya arenaria* Study, 1977.

Figure 13. One factor which was not anticipated by the Figure 13 projections was the extremely crowded conditions existing on the relatively "undisturbed" substrate areas, particularly in Hampton Harbor. Data presented in Figure 14 indicate an inverse relationship between shell growth and population density.

Causes of the observed interval of several years between highly successful spatfalls at Hampton Harbor (Table 9) remain largely obscure. It is apparent, however, that seasonal planktonic larval abundance was a relatively poor predictor of spatfall success during 1977 (Tables 9 and 14).

4.3 STATUS OF ADULT SOFT-SHELL CLAM STOCKS IN HAMPTON HARBOR

In addition to considerably reducing the uncertainty of clam flat acreage estimates, delineation of natural flat boundaries using aerial photography resulted in the incorporation of about 25% more flat area than would have been practical using ground survey methods described in Section 2.3. (which depend on line-of-sight and therefore cannot include "blind" area obscured behind salt marsh). This increase of 30 to 40 acres to the study area as of November 1977, not included in previous surveys, should be kept in mind when referring to historical standing crop values presented in Tables 15 and 16.

Correcting for the acreage added in 1977, it has been estimated that approximately 950 bushels of harvestable clams were taken from the five principal clam flats in the interval between November 1976 and November 1977; this amounted to approximately 46% of the standing crop as of November 1976. In contrast, approximately 3600 bushels (73% of the November 1975 standing crop) were harvested in the previous 12 month interval (NAI, 1977). Some of the reduction in proportion of harvested to unharvested clams reflects an increasingly diminishing return for digging effort; but much is also due to the fact that the Hampton Harbor flats were closed to clam digging throughout the summer

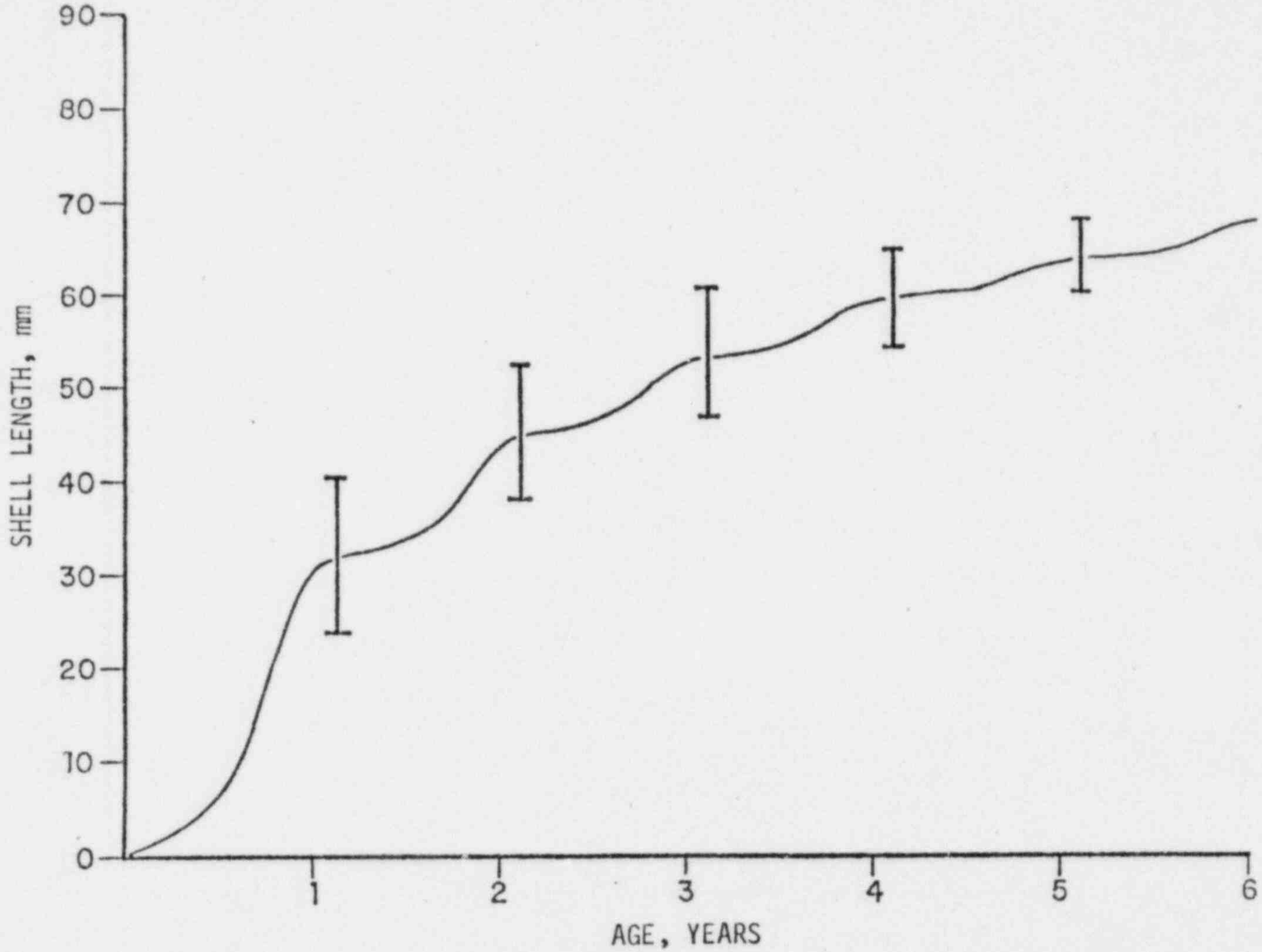


Figure 13. Estimated shell growth rate of soft-shell clam, *Mya arenaria*, with approximate 95% confidence intervals. Seasonal dips in the curve suggest slowing of growth in the late fall and early winter (NAI, 1977). Seabrook *Mya arenaria* Study, 1977.

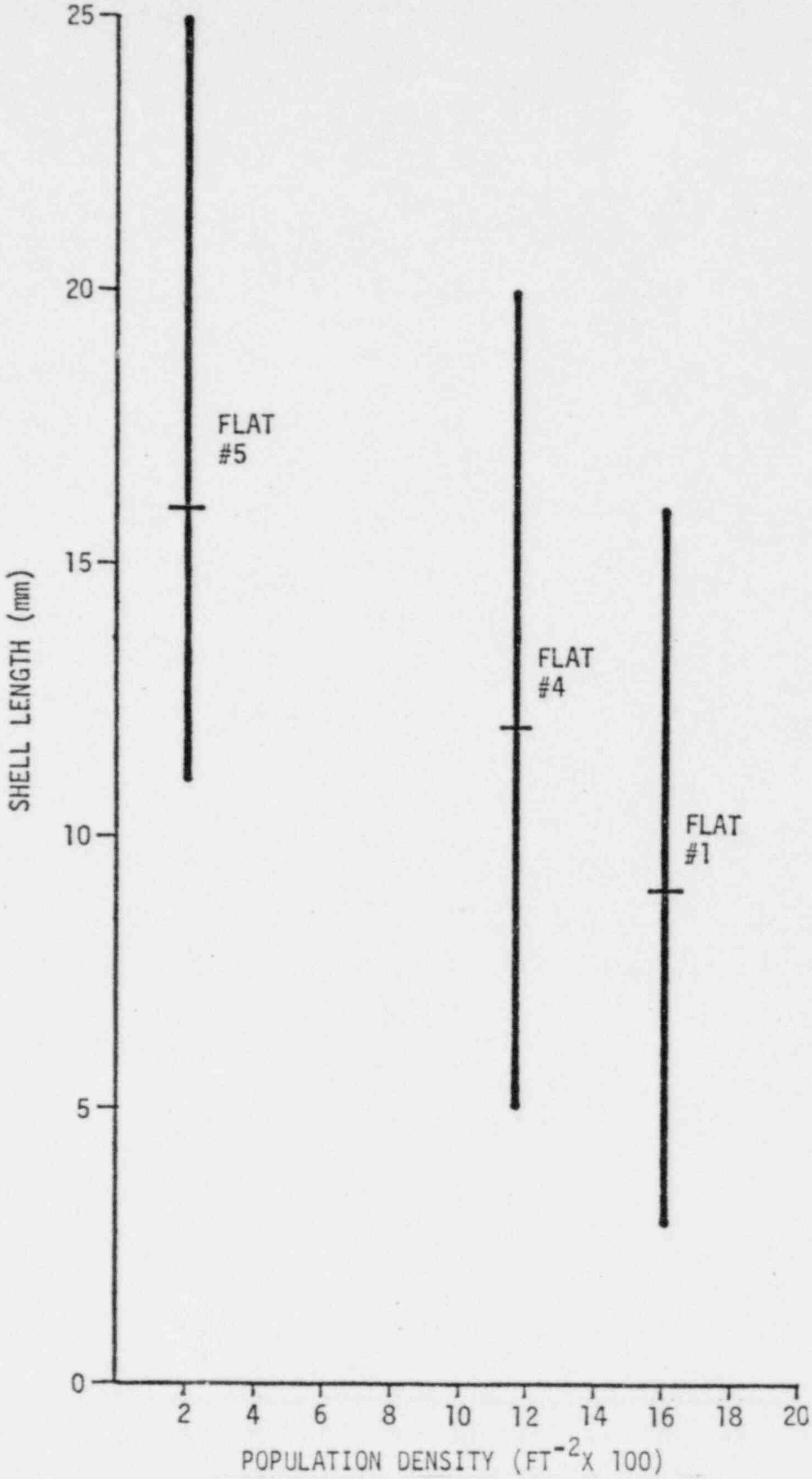


Figure 14. Comparisons of size-density distributions at undisturbed, relatively well-settled areas of selected flats in Hampton Harbor, N. H., November 1977. Clams are approximately 13-15 months old. Seabrook *Mya arenaria* Study, 1977.

TABLE 15. RECENT HISTORY OF THE STANDING CROP OF LEGAL SIZE *MYA ARENARIA* IN HAMPTON HARBOR. SEABROOK *MYA ARENARIA* STUDY, 1977.

DATE	ESTIMATED BUSHEL PER ACRE	TOTAL ESTIMATED NUMBER OF BUSHELS
November 1967	152[1]	23,400[1]
July 1969	103	15,840
November 1971	84	13,020
November 1972	58	8,920
November 1973	41	6,310
November 1974	56	8,690
November 1975	29	4,945
November 1976	11	1,350
November 1977	6	1,060

[1] (from Ayer, 1968)

TABLE 16. RECENT HISTORY OF THE STANDING CROP OF *MYA ARENARIA* (>50 mm LONG) ON FLAT #2. SEABROOK *MYA ARENARIA* STUDY, 1977.

DATE	ESTIMATED BUSHELS PER ACRE	TOTAL ESTIMATED NUMBER OF BUSHELS
November 1967	220[1]	5,500[1]
July 1969	119	2,970
November 1971	139	3,480
April 1972	118	2,960
July 1972	61	1,530
November 1972	55	1,380
February 1973	39	980
May 1973	59	1,480
August 1973	52	1,310
November 1973	63	1,580
January 1974	48	1,200
May 1974	33	825
August 1974	29	730
November 1974	60	1,510
February 1975	71	1,300
May 1975	68	1,060
August 1975	20	355
November 1975	36	785
February 1976	23	385
May 1976	17	260
August 1976	3	50
November 1976	8	140
February 1977	*	*
May 1977	8	205
August 1977	28	712
November 1977	9	224

[1] (from Ayer, 1968)

of 1977. Extrapolating the rate of standing stock depletion prior to 1977 (Figure 8), it appears that as much as 600 bushels might have been added to the 1977 harvest had the flats been open all summer.

Substantial replacement of depleted adult stocks through the recruitment of juvenile clams appears to be a hopeful prospect but still at some distance in the future. At recently observed growth rates, very few of the juveniles now inhabiting the flats can be expected to attain harvestable size by November 1978. A reasonable expectation, based on estimated mortality (NAI, 1977) and densities of 20 to 25 mm clams observed in November 1977 would be recruitment of 150 to 200 bushels by November 1978. This amounts to less than 1/3 of the most recent annual yield, [illegible] suggests an additional "deficit" withdrawal of 550-600 bushels in 1978, leaving perhaps 650-700 bushels remaining on the flats in November, assuming another closed summer season.

4.4 RELATIONSHIP OF SEDIMENT GRAIN-SIZE DISTRIBUTION TO SOFT-SHELL CLAM PROPAGATION POTENTIAL

Results of both the clam and sediment surveys can only be compared qualitatively since the sample sites were spatially and temporally separated. Nevertheless, there appears to be an affinity between areas characterized as containing fine sand sediments and the presence of *Mya arenaria*. Such an association is supported by the observations of Stanley (1970). Very few specimens of *M. arenaria* were found in areas characterized by medium sand; clams that were present were large (8 to 10 cm long) and deeply burrowed (approximately 20 to 25 cm). Exclusion of small soft-shell clams from medium sand areas was probably due to prevalence of somewhat stronger currents (imposing a mechanical disadvantage at these locations) and not due to any aversion to coarser sediments.

In the vicinity of mussel (*Mytilus edulis*) beds, sediments tended to be characterized by very fine sand; here, larger *M. arenaria*

tended to be excluded, probably because of the difficulty soft-shell clams have in clearing their siphons of silt (Stanley, 1970), heavy siltation being a natural result of mussel encroachment.

5.0 SUMMARY

As of November 1977, it was estimated that approximately 1060 bushels of adult clams remained on the five largest flats of Hampton Harbor totalling 167 acres. It was also estimated that since the previous survey (November 1976), clam diggers removed approximately 950 bushels or 70% of the clams present in November 1976. Recruitment of newly harvestable stock from a very modest population of juvenile clams (mostly from the 1972 year class) plus a slight expansion of the study area (i.e., addition of 30-40 acres) accounted for the apparent decrease of only about 300 bushels.

The 1976 year class of clam spat continued to survive in Plum Island Sound (approximately 100 per ft^2), Hampton Harbor (approximately 250 per ft^2) and Ogunquit Beach (approximately 24 per ft^2), but has been virtually eliminated from the Merrimack River Estuary, the York River at Route 103 bridge, and Little Harbor Channel in Portsmouth, New Hampshire. The latest year class (1977) has a population density of 80 to 90 per ft^2 in Hampton Harbor and is exceeded in abundance only in Plum Island Sound (570 per ft^2).

Mya arenaria umboned larvae densities averaged only 7 per m^3 during a 102-day period of observation. This was by far the lowest level of abundance in four years of record. Only on one date (22 August 1977) did larval densities exceed 15 per m^3. On that date densities up to 250 per ft^2 were recorded as far as 1.5 nautical miles offshore. At 2 nautical miles from the New Hampshire coast the larval density dropped to approximately 45 per m^3. Other species of bivalve mollusc larvae associated with *M. arenaria* in the plankton included, in order of decreasing abundance, *Modiolus modiolus* (horse mussel), *Mytilus edulis* (edible mussel), *Hiatella* sp. (a small clam which nestles among the *Modiolus)*, *Cerastoderma pinnulatum* (northern dwarf cockle) and *Ensis directus* (razor clam).

Intertidal flats containing soft-shell clams were largely composed of sand grains ranging in size from .10 to .30 mm. Larger clams (length greater than 10 mm) tended to be excluded from the very fine sandy areas (average particle size less than 0.12 mm); smaller clams (length less than 45 mm) tended to be excluded from areas of medium sand (average particle size greater than .25 mm).

It has been estimated that clams representing the 1976 year class will attain harvestable size in 1981 and 1982. Notwithstanding this projection, restoration of soft-shell clam stocks to pre-1971 levels will require several spatfalls as successful as the 1976 settlement.

6.0 LITERATURE CITED

Ayer, W. C. 1968. Soft-shell clam population study in Hampton-Seabrook Harbor, New Hampshire. New Hampshire Fish and Game Dept. 39 pp.

Ayers, J. C. 1956. Population dynamics of the marine clam. *Mya arenaria*. Limnol. and Oceanogr. 1(1):26-34.

Carver, Robert E. (ed.). 1971. Procedures in sedimentary petrology. John Wiley and Sons. New York, NY.

Dow, R. L. 1972. Fluctuations in Gulf of Maine sea temperature and specific molluscan abundance. J. Cons. Int. Explor. Mer. 34:532-534.

__________. 1977. Effects of climatic cycles on the relative abundance and availability of commercial marine and estuarine species. J. Cons. Int. Explor. Mer. 37(3):274-280.

__________ and D. E. Wallace. 1957. The Maine clam (*Mya arenaria*). Maine Dept. of Sea and Shore Fish. Bull. 35 pp.

Folk, Robert L. 1968. Petrology of sedimentary rocks. Hemphills, Austin, TX.

Hansen, M. H., W. H. Hurwitz and W. G. Madow. 1953. Sample survey methods and theory. Vol. II. Wiley-Interscience. pp. 257-260.

Kane, W. T. and J. F. Hubert. 1963. "A Fortran Program for the Calculation of Grain-Size Textural Parameters on the IBM 1620 Computer". Sedimentology. 2:89-92.

Lee, W. Y. 1974. Succession and some aspects of population dynamics of copepods in the Damariscotta River estuary, Maine. Ph.D. Thesis, Univ. of Maine, Orono. 181 pp.

McAlice, B. J. 1972. Plankton. IN: Survey of the hydrography, sediments, plankton, benthos and the commercially important plants and animals including finfish in the Montsweag Bay-Back River area. Third Annual Report. Ira C. Darling Ref. No. 72-12.

Normandeau Associates, Inc. 1971. Seabrook Ecological Study: Phase I 1969-1970, Hampton-Seabrook Estuary, New Hampshire. Prepared for Public Service Company of New Hampshire. 313 pp.

__________. 1973. Studies on the soft-shelled clam, *Mya arenaria*, in the Hampton-Seabrook Estuary, New Hampshire. Technical Report IV-2.

__________. 1974a. Studies on the soft-shelled clam, *Mya arenaria*, in the Hampton-Seabrook Estuary, New Hampshire. Technical Report V-2.

__________. 1974b. The impact of entrainment by the Seabrook Station. Technical Report V-4.

__________. 1975a. Studies on the soft-shelled clam, *Mya arenaria*, in the Hampton-Seabrook Estuary, New Hampshire. Technical Report VI-3.

__________. 1975b. Spatial and temporal distribution of the larvae of the soft-shelled clam, *Mya arenaria*, in the Hampton-Seabrook Estuary and nearby offshore waters. Technical Report VI-1.

__________. 1975c. *Mya arenaria* confirmational study. Report prepared for Public Service Company of New Hampshire.

__________. 1976a. Studies on the soft-shelled clam, *Mya arenaria*, in the Hampton-Seabrook Estuary, New Hampshire. Technical Report VII-1.

__________. 1976b. Spatial and temporal distribution of the larvae of the soft-shelled clam, *Mya arenaria*, in New Hampshire coastal waters, 1975. Technical Report VI-10.

__________. 1977. Seabrook Ecological Studies 1975-1976. Studies on the soft-shelled clam, *Mya arenaria*, in the vicinity of Hampton-Seabrook estuary, New Hampshire.

Ropes, J. W. 1968. The feeding habits of the green crab, *Carcinus maenas* (L.). Fish. Bull. 67(2):183-203.

__________ and A. P. Stickney. 1965. Reproductive cycle of *Mya arenaria* in New England. Biol. Bull. 128:315-327.

Savage, N. B. and R. Goldberg. 1977. Investigation of practical means of distinguishing *Mya arenaria* and *Hiatella* sp. larvae in plankton samples. Proc. Nat. Shellfish. Assoc. 66:42-53.

Scattergood, L. W. 1952. The distribution of the green crab, *Carcinus maenas* (L.) in the northwestern Atlantic. Maine Dept. Sea and Shore Fisheries Fish. Circ. 8:2-10.

deSchweinitz, E. H. and R. A. Lutz. 1976. Larval development of the northern horse mussel, *Modiolus modiolus* (L.), including a comparison with the larvae of *Mytilus edulis* (L.) as an aid in planktonic identification. Biol. Bull. 150(3):348-360.

Stickney, A. P. 1964. Salinity, temperature and food requirements of soft-shell clam larvae in laboratory culture. Ecology. 45(2):283-291.

Sullivan, Charlotte M. 1948. Bivalve larvae of Malpeque Bay, P.E.I. Fish. Res. Bd. Canada Bull. 77. 36 pp.

Welch, W. R. 1969. Changes in abundance of the green crab, *Carcinus maenas* (L.) in relation to recent temperature changes. U.S. Fish Wildl. Serv. Fish. Bull. 67(337-345).

__________. 1975. Report on the relative abundance of green crabs along the Maine coast, Fall 1975. Maine Dept. of Marine Resources.

APPENDIX 7.1

RESULTS OF BIVALVE LARVAE TOWS
OFF HAMPTON BEACH, NEW HAMPSHIRE

Hampton NH Bivalve larvae 1977 Station I_4 (counts per m^3)

Replicate	Species	27 June		30 June		5 July		8 July		11 July		14 July	
1	Modiolus	5,518	5,319	54,248	55,832	47,594	53,219	9,490	10,902	14,178	18,905	22,168	21,436
	Mytilus	3,157	3,470	5,851	9,143	4,038	1,875	4,149	5,870	11,422	2,560	4,164	8,102
	Hiatella	1,024	910	9,265	9,387	7,788	6,346	1,368	750	5,514	2,462	6,302	7,989
	Anomia	170	P	P	P	721	1,154	P	P	4,431	591	900	3,601
	Others	28	85	1,340	1,340	1,298	865	177	220	98	P	338	394
2	Modiolus	11,859	11,106	77,754	73,068	40,960	49,824	1,854	2,119	34,363	23,828	16,460	20,053
	Mytilus			13,885	17,356	9,017	2,445	9,504	9,446	3,348	8,763	4,533	2,240
	Hiatella	1,902	866	12,149	10,414	8,712	7,642	1,000	441	3,249	2,462	5,973	6,187
	Anomia	P	P	P	P	7,336	1,987	P	P	394	1,772	8,213	5,440
	Others	75	376	1,909	1,562	764	917	294	118	P	590	53	320
	Sample Volumes (m^3):												
	1		9.0		8.4		7.1		5.8		10.4		9.1
	2		6.8		5.9		6.7		8.7		10.4		9.6

		18 July		21 July		25 July		28 July		1 August		4 August	
1	Modiolus	2,488	2,943	1,553	1,812	1,665	2,386	1,560	1,582	239	284	179	187
	Mytilus	3,493	1,890	3,624	3,682	1,255	1,342	827	920	530	388	203	145
	Hiatella	1,770	1,412	2,704	2,618	447	1,193	539	439	317	310	300	249
	Anomia	407	359	3,480	1,093	211	1,441	396	273	601	517	317	209
	Cerastoderma							72	65	317	213	111	91
	Others	167	167	288	316	112	149	36	14.4	26	19.4	22	16.8
2	Modiolus	2,442	2,737	1,743	899	1,556	1,876	517	1,223	733	584	388	265
	Mytilus	2,824	2,678	3,568	2,941	618	887	501	845	148	130	246	220
	Hiatella	2,442	1,971	1,716	2,805	480	436	246	336	668	473	582	498
	Anomia	971	559	926	3,677	313	233	246	459	232	631	304	459
	Cerastoderma						240	33	90	102	102	71	97
	Zirphaea									37	9.3		
	Others	205	324	300	191	218[1]	14.5	25	25	9.3	0.0	52	19.4
	Sample Volumes (m^3):												
	1		10.7		8.9		10.3		8.9		9.9		9.5
	2		8.7		9.4		8.8		7.8		6.9		9.9

P - present in small quantities
1 - mostly Cerastoderma

Hampton NH Bivalve Larvae 1977 Station I_4 (counts per m^3)

Replicate	Species	8 August		11 August		15 August		18 August		22 August		25 August	
1	Modiolus	43	31	4	5	30	70	27	18	13	13	121	199
	Mytilus	211	217	33	75	177	207	143	77	90	90	135	107
	Hiatella	45	53	16	18	262	174	82	62	198	109	370	306
	Anomia	88	78	7	13	390	293	273	155	128	262	1,045	619
	Cerastoderma	16	12	2	3	42	52	58	32	90	67	213	334
	Ensis												
	Others	2	6	7	7	30	9	10	5	19	10	21	28
2	Modiolus	34	27	4	3	27	59	28	15	9	9	386	213
	Mytilus	126	130	44	38	[illegible]	135	121	70	26	121	183	122
	Hiatella	69	32	21	14	160	237	96	66	61	65	345	325
	Anomia	46	41	14	18	210	680	254	234	181	199	1,554	1,625
	Cerastoderma	30	9	2	1	29	29	46	26	52	121	345	173
	Zirphaea							2	9				
	Ensis							7	7				
	Others	14	0	4	4	11	32	0	0	0	13	51	30
	Sample Volumes (m^3):												
	1		7.8		10.4		10.5		9.6		9.8		9.0
	2		7.0		7.9		7.1		8.6		8.6		6.3

		29 August		1 Sept.		6 Sept.		8 Sept.		12 Sept.		15 Sept.	
1	Modiolus	1,203	2,082	1,341	1,097	2,001	2,377	1,074	1,074	137	242	361	392
	Mytilus	213	410	777	716	2,306	3,352	6,744	5,010	522	549	1,687	1,446
	Hiatella	410	341	366	411	965	1,300	2,588	1,844	294	242	1,069	1,024
	Anomia	819	2,594	1,630	1,250	1,524	2,458	1,211	1,266	170	144	1,129	648
	Cerastoderma	136	239	168	152	518	447	275	413	85	52	45	90
	Ensis					183	244	110	110	26	72	45	75
	Others	111	34	107	91	173	142	138	110	26	85	120	181
	Str. Hinge *									5,512	6.060		
	Modiolus	1,180	2,060	1,757	1,580	1,715	1,997	582	785	698	545	999	718
	Mytilus	280	700	1,294	1,389	2,099	1,587	6,662	6,051	487	487	2,217	1,140
	Hiatella	370	460	477	613	794	1,178	1,600	1,629	233	211	1,296	1,093
	Anomia	2,590	1,960	1,226	803	2,176	1,408	2,473	3,084	182	225	1,296	843
	Cerastoderma	290	200	286	354	410	307	204	175	58	51	172	109
	Ensis					154	154	29	58	29	7	78	109
	Others	70	60	41	41	179	102	29	175	65	124	359	125
	Str. Hinge *									6,342	6,065		
	Sample Volumes (m^3):												
	1		7.5		4.2		6.3		9.3		9.8		8.5
	2		6.4		4.7		5.0		8.8		8.8		8.2

Hampton NH Bivalve Larvae 1977 Station I_4 (counts per m^3)

Replicate	Species	19 Sept.		22 Sept.		26 Sept.		29 Sept.		3 Oct.		6 Oct.	
1	Modiolus	758	573	231	42	110	110	60	80	12	7	29	22
	Mytilus	1,495	2,028	1,070	1,070	1,597	1,872	745	645	67	28	94	107
	Hiatella	799	614	462	294	110	26	230	210	12	9	14	12
	Anomia	2,191	2,970	2,665	2,350	358	440	720	740	229	114	76	101
	Ensis	2,007	1,249	42	0	55	55	30	25	10	17	19	25
	Cerastoderma	164	82	147	147	55	26	20	25	-	-	-	-
	Other	123	266	189	42	110	165	80	70	14	3 1/2	19	18
	Str. Hinge					21,251	23,783*						
2	Modiolus	238	449	230	288	62	48	48	103	4 1/2	7 1/2	15	13
	Mytilus	3,088	3,246	2,474	1,266	1,129	1,025	453	670	39	64	44	42
	Hiatella	871	818	288	345	83	55	145	193	7	16	9	8
	Anomia	2,138	3,141	3,969	2,618	179	193	604	821	145	222	93	69
	Ensis	1,399	1,636	56	56	28	21	30	12	7	16	21	13
	Cerastoderma	106	-	259	230	14	7	18	30	-	-	17	13
	Other	158	211	259	201	76	69	72	103	4 1/2	13		
	Str. Hinge					6,[illegible]59	16,654*						
	Sample Volumes (m^3):												
	1		12.5		12.3		9.3		12.8		9.3		13.3
	2		9.7		8.9		9.3		10.6		8.8		10.1

Replicate	Species	10 Oct.		13 Oct.		20 Oct.		27 Oct.	
1	Modiolus	35	30	67	99	218	139	175	40
	Mytilus	12	18	47	27	201	99	36	17
	Hiatella	4 1/2	5 1/2	27	30	28	28	9 1/2	0
	Anomia	32	37	308	295	419	292	79	34
	Ensis	3 1/2	4	56	30	5 1/2	20	5 1/2	5 1/2
	Placopecten					5 1/2	5 1/2	2	4
	Cerastoderma					11	20		
	Other	3 1/2	4 1/2	13	24	23	51	5 1/2	5 1/2
2	Modiolus	35	28	105	93	332	187	51	156
	Mytilus	23	15	50	30	274	224	15	46
	Hiatella	9 1/2	5	47	48	54	50	11	13
	Anomia	32	29	335	287	690	366	42	110
	Ensis	3 1/2	2 1/2	40	25	17	4	0	9
	Placopecten					0	8 1/2	0	2
	Cerastoderma					33	33		
	Other	5 1/2	4 1/2	30	17	58	42	5 1/2	2
	Sample Volumes (m^3):								
	1		9.7		9.5		11.3		8.5
	2		8.5		9.6		7.7		8.7

* 24-48 hr <u>Modiolus modiolus</u>

Hampton NH Bivalve larvae 1977 Station Mrq 5 (counts per m^3)

Replicate	Species	27 June		30 June		5 July		8 July		11 July		14 July	
1	Modiolus	3,013	2,160	112,924	143,644	24,017	33,140	33,858	26,756	17,101	20,992	3,657	2,405
	Mytilus	7,440	6,747	7,111	13,369	14,336	5,399	34,849	47,071	7,270	20,070	1,280	768
	Hiatella	1,200	1,547	3,413	3,129	3,351	2,606	3,468	2,312	3,482	3,174	567	1,125
	Anomia	P	P	569	P	745	465	P	P	307	1,946	128	46
	Others	453	107		569	372	279	495	495	102	102	91	110
2	Modiolus			121,791	137,042	22,499	31,874	43,174	28,783	21,333	11,703	2,654	2,560
	Mytilus			5,882	5,665	13,701	9,807	55,075	58,672	13,653	13,531	1,748	952
	Hiatella			5,229	3,050	3,317	3,461	8,441	1,937	3,291	5,120	1,623	1,733
	Anomia			P	P	577	P	.1,522	P	243	1,219	390	P
	Others			1,089	654	433	288	969	415	243	P	109	156
	Sample Volumes (m^3):												
	1		9.6		3.6		5.5		6.2		10.0		7.0
	2		7.2		4.7		7.1		7.4		8.4		8.2

		18 July		21 July		25 July	
1	Modiolus	1,039	965	2,608	2,198	1,045	1,003
	Mytilus	3,636	2,894	4,903	4,709	2,741	1,664
	Hiatella	1,169	723	1,352	966	320	480
	Anomia	2,319	1,299	604	1,352	245	139
	Others	111	186	313	97	53	96
2	Modiolus	2,848	4,759			1,801	1,291
	Mytilus	8,942	5,661			1,562	1,432
	Hiatella	2,091	1,659			911	597
	Anomia	1,803	649			108	163
	Others	72	36			43	119
	Sample Volumes (m^3):						
	1		6.9		10.6		12.0
	2		7.1		8.7		11.8

P - present in small quantities

APPENDIX 7.2

SHELL SIZE DISTRIBUTION (#/ft^2) OF SOFT-SHELL CLAM SPAT
COLLECTED FROM FIXED STATIONS IN SIX NORTHERN NEW ENGLAND ESTUARIES
1976 THROUGH 1977

PLUM ISLAND SOUND
MIDDLE GROUND

SIZE CLASS (mm)	19 APR 1976	21 JUN 1976	17 AUG 1976	28 OCT 1976	11 FEB 1977	11 APR 1977	8 JUN 1977	5 AUG 1977	19 OCT 1977
1									1.5
2			4.6	47.0	6.1	34.0	0.76		63.0
3	1.5	0.76	4.5	103.0	27.0	37.0	1.5	1.5	206.0
4	0.76		2.3	31.0	24.0	25.0	18.0	3.1	160.0
5		0.76		18.0	25.0	18.0	28.0	0.76	71.0
6	2.3			4.6	16.0	20.0	35.0	0.76	77.0
7	0.76			4.6	3.1	15.0	44.0	0.76	47.0
8	2.3			5.3	2.3	16.0	38.0		25.0
9	1.5				3.1	11.0	31.0		13.0
10				1.5	2.3	5.3	24.0	1.5	3.1
11	1.5				0.76	7.6	18.0	2.3	5.3
12	1.5			0.76	1.5	3.8	21.0	1.5	
13				0.76		3.1	25.0	5.3	2.3
14						0.76	27.0	5.3	1.5
15					0.76	1.5	22.0	8.4	6.1
16	0.76					0.76	12.0	13.0	7.6
17							12.0	17.0	11.0
18						0.76	8.4	15.0	11.0
19							6.1	20.0	8.4
20							6.9	22.0	8.4
21							4.6	15.0	11.0
22							3.1	15.0	6.1
23							6.1	9.1	8.4
24							3.1	11.0	9.1
25							3.1	8.4	8.4
26							1.5	6.1	6.9
27							1.5	3.8	4.6
28								3.1	7.6
29								3.1	5.3
30								2.3	4.6
31									2.3
32								0.76	1.5
33								2.3	1.5
34									1.5
35									1.5

PLUM ISLAND SOUND
LUFKIN'S FLAT

SIZE CLASSES (mm)	11 APRIL 1977	8 JUNE 1977	5 AUGUST 1977	19 OCTOBER 1977
1				
2	25.0	3.8		24.0
3	73.0	25.0	1.3	70.0
4	36.0	36.0	1.3	45.0
5	18.0	36.0	3.8	22.0
6	8.9	46.0	2.5	7.6
7	3.8	22.0	1.3	2.5
8	13.0	45.0	1.3	
9	7.6	20.0		
10	5.1	10.0		
11	8.9	2.5		
12	7.6	1.3		
13	8.9	2.5		
14	6.4	2.5		
15	6.4	1.3		
16	3.8	1.3		
17	6.4	5.1		
18	3.8	1.3	1.3	2.5
19				
20			1.3	1.3
21	1.3	1.3	1.3	2.5
22		1.3	1.3	
23	1.3		3.8	1.3
24	1.3			
25			3.8	2.5
26			2.5	1.3
27		1.3	3.8	2.5
28			3.8	6.4
29		1.3	1.3	3.8
30		1.3		3.8
31		1.3	1.3	5.1
32			1.3	3.8
33				3.8
34			1.3	2.5
35			1.3	2.5
36				3.8
37				2.5
38				1.3
39				
40				
41				
42				
43				
44				
45				1.3

PLUM ISLAND SOUND
IPSWICH RIVER AT NECK COVE

SIZE CLASS (mm)	19 APRIL 1976	21 JUNE 1976	17 AUGUST 1976	28 OCTOBER 1976	11 FEBRUARY 1977
1					
2		0.76	6.9	79.0	79.0
3			9.9	47.0	66.0
4	4.6	0.76	0.76	11.0	12.0
5	0.76		2.3	1.5	6.1
6	3.8		2.3		0.76
7	1.5		0.76		
8	2.3				0.76
9					
10					
11					
12	0.76				
13					
14					
15					
16		0.76			
17					
18					
19					
20					
21	0.76				
22					
23					
24					
25					

PLUM ISLAND SOUND
EAGLE HILL RIVER AT NUT SHOAL

SIZE CLASSES (mm)	11 APRIL 1977	8 JUNE 1977	5 AUGUST 1977	19 OCTOBER 1977
1				
2	13.0		7.6	158.0
3	44.0	5.7	36.0	382.0
4	40.0	5.7	17.0	185.0
5	17.0	3.8	3.8	105.0
6	11.0	1.9	1.9	67.0
7	17.0	5.7	1.9	15.0
8	11.0	7.6		9.6
9	5.7	5.7		1.9
10	1.9	19.0		
11	1.9	11.0		
12	7.6	15.0		
13	3.8	25.0	3.8	
14	1.9	31.0	5.7	
15	1.9	29.0	7.6	
16	1.9	15.0	5.7	
17	1.9	9.6	5.7	
18	1.9	11.0	7.6	
19		5.7	13.0	1.9
20		5.7	15.0	
21		1.9	17.0	3.8
22		1.9	13.0	1.9
23			19.0	11.0
24			5.7	1.9
25			9.6	1.9
26			11.0	5.7
27			3.8	9.6
28			1.9	7.6
29			1.9	1.9
30			1.9	3.8
31			1.9	7.6
32			1.9	5.7
33				
34				1.9
35				
36				5.7
37				
38				3.8
39				3.8
40				
41				
42				
43				1.9
44				

MERRIMACK RIVER ESTUARY
BALL'S FLAT #1

SIZE CLASS (mm)	23 MAR 1976	23 APR 1976	17 JUN 1976	18 AUG 1976	26 OCT 1976	27 JAN 1976	13 APR 1977	6 JUN 1977	2 AUG 1977	18 OCT 1977
1										
2		6.9		1.5	164.0	115.0	47.0	21.0	0.76	27.0
3	0.76	16.0	0.76	11.0	151.0	83.0	201.0	121.0	4.6	37.0
4	1.5	9.9	2.3	3.8	27.0	37.0	89.0	72.0	6.1	13.0
5		5.3	1.5	5.3	6.1	7.6	23.0	25.0	3.1	1.5
6		4.6	0.76		3.8	0.76	4.6	18.0		2.3
7		1.5	0.76	0.76	1.5	0.76	3.1	7.6	0.76	
8		1.5	0.76				2.3	0.76	0.76	
9			3.1					3.1		
10			2.3							
11			0.76							
12										
13										
14			2.3							
15										
16			0.76							
17										
18										
19										
20				0.76						
21										
22										
23										
24										
25									0.76	

MERRIMACK RIVER ESTUARY
SALISBURY FLAT #3

SIZE CLASS (mm)	23 MAR 1976	23 APR 1976	17 JUN 1976	18 AUG 1976	26 OCT 1976	28 JAN 1977	13 APR 1977	6 JUN 1977	2 AUG 1977	18 OCT 1977
1										
2		3.8			56.0	15.0	11.0	1.5	5.3	6.9
3	2.3	5.3		0.76	39.0	29.0	43.0	7.6	20.0	6.9
4	2.3	5.3	1.5	3.1	4.6	26.0	21.0	8.4	5.3	3.8
5	1.5	2.3	1.5	2.3	1.5	9.2	7.6	6.9		3.1
6	1.5	1.5	1.5	3.1		2.3	3.1	2.3		1.5
7			2.3	3.1	0.76			0.76		
8		0.76	1.5	3.1					0.76	
9				0.76			0.76			
10			0.76	0.76						0.76
11			1.5	0.76				0.76	0.76	
12										
13			0.76							
14										
15								0.76		
16			0.76	0.76				0.76		
17										
18				1.5						
19										
20				0.76						
21										
22				0.76						
23				0.76						
24										
25				0.76						

HAMPTON HARBOR, FLAT #2

SIZE CLASS (mm)	12 MAR 1976	21 APR 1976	18 JUN 1976	16 AUG 1976	21 OCT 1976	11 JAN 1977	14 APR 1977	7 JUN 1977	1 AUG 1977	17 OCT 1977
1										
2	119.0	37.0	2.7	57.0	589.0	327.0	167.0	71.0	7.6	3.8
3	44.0	46.0	5.5	18.0	605.0	230.0	361.0	180.0	55.0	18.0
4	4.6	17.0	3.8	3.8	73.0	46.0	124.0	170.0	48.0	23.0
5		9.8	2.2	1.3	14.0	8.3	31.0	99.0	41.0	19.0
6		1.1	2.2		1.9	0.64	5.7	46.0	43.0	26.0
7		0.55	1.6		0.64		1.9	27.0	24.0	28.0
8							0.64	13.0	20.0	25.0
9		1.1	1.1					6.4	20.0	20.0
10								3.2	20.0	18.0
11			0.55						20.0	33.0
12									24.0	23.0
13									21.0	23.0
14									12.0	33.0
15									5.1	20.0
16									0.64	11.0
17										2.5
18									0.64	3.2
19									1.3	
20										0.64
21										
22										
23										
24										
25							0.76			
26										
27										
28										
29										
30										

LITTLE HARBOR CHANNEL FLATS

SIZE CLASS (mm)	24 FEB 1976	22 APR 1976	23 JUN 1976	19 AUG 1976	25 OCT 1976	12 JAN 1977	15 APR 1977	13 JUN 1977	10 AUG 1977	10 OCT 1977
1	1.9									
2	11.0	20.0		2.2	73.0	34.0	40.0	20.0	4.5	2.5
3	0.96	22.0	4.3	2.2	39.0	35.0	82.0	74.0	19.0	11.0
4		15.0	3.3	1.1	4.5	13.0	34.0	40.0	16.0	5.1
5	0.96	5.1	1.9		0.64	1.9	13.0	22.0	10.0	7.0
6		2.5	1.9			0.64	4.5	17.0	5.1	1.9
7		1.3	1.4				1.3	9.6	1.3	1.3
8		1.9						8.9		
9		0.55	0.96					1.3	0.64	0.64
10								0.64	1.3	0.64
11		0.55	0.48					0.64	1.3	0.64
12								1.9	0.64	
13								1.3		1.3
14								0.64		
15										
16									0.64	
17										
18										
19										
20										0.64
21										
22										
23										
24							0.64			
25										
26										
27										
28										
29										
30							0.64			
31										
32										
33										
34										
35										0.64

YORK RIVER FLAT
AT ROUTE 103 BRIDGE

SIZE CLASS (mm)	20 APR 1976	22 JUN 1976	20 AUG 1976	29 OCT 1976	14 JAN 1977	12 APR 1977	9 JUN 1977	9 AUG 1977	21 OCT 1977
1									
2	53.0	30.0	40.0	48.0	49.0	18.0	25.0	1.5	1.5
3	65.0	88.0	34.0	40.0	51.0	41.0	94.0	30.0	17.0
4	30.0	74.0	15.0	11.0	14.0	24.0	126.0	24.0	31.0
5	15.0	38.0		1.5	3.8	2.3	83.0	16.0	14.0
6	12.0	27.0	2.3	2.3	1.5	2.3	33.0	9.9	5.3
7	4.6	9.9				2.3	34.0	7.6	1.5
8		3.1		0.76			11.0	1.5	0.76
9		2.3					4.6	4.6	1.5
10		1.5		0.76		1.5	3.8	6.1	
11		1.5		0.76			0.76	1.5	0.76
12		0.76	0.76					2.3	1.5
13			0.76				1.5	3.1	
14									
15									
16			1.5					0.76	
17									
18				0.76					
19									
20									
21									
22									
23							0.76		
24									
25									
26									
27									
28									

OGUNQUIT BEACH

SIZE CLASS (mm)	20 APR 1976	22 JUN 1976	20 AUG 1976	29 OCT 1976	14 JAN 1977	12 APR 1977	9 JUN 1977	9 AUG 1977	21 OCT 1977
1									
2	6.4		2.5	28.0	48.0	8.9		13.0	
3	13.0		5.1	23.0	26.0	24.0	2.5	5.1	3.8
4	7.0	1.1	0.64	5.7	18.0	16.0	4.5		6.4
5	4.5	0.55		0.64	6.4	9.6	8.9	0.64	5.7
6	1.3				1.3	5.1	17.0		8.3
7	2.5	0.55				0.64	15.0		1.3
8	1.9	0.55					15.0		
9							13.0		
10					0.64		7.6	0.64	
11							5.1	1.3	
12							9.6	1.9	
13							0.64	6.4	
14							3.8	3.8	
15								3.2	
16							0.64	8.9	
17								11.0	1.9
18								19.0	1.3
19								13.0	1.9
20								19.0	2.5
21								6.4	3.8
22								8.9	2.5
23								2.5	1.9
24								2.5	0.64
25								1.3	
26								0.64	1.9
27								0.64	1.3
28									1.3
29									1.3
30									1.3
31									
32									

APPENDIX 7.3

SHELL SIZE DISTRIBUTION (#/ft^2) OF SOFT-SHELL CLAM SPAT AND ADULTS COLLECTED FROM RANDOM STATIONS AT FIVE HAMPTON HARBOR FLATS, 1971 THROUGH 1977

TABLE A. SHELL SIZE DISTRIBUTION OF SOFT-SHELL CLAMS ON FLAT 1 FOR THE NOVEMBER SURVEYS, 1971-1977. SEABROOK *MYA ARENARIA* STUDY, 1976.

SIZE CLASS (mm)	1971	1972	1973	1974	1975	1976	1977
5	19	74	30	2.5	55	1031	283
10	11	9	6		1.14	52	413
15	11	15	3			0.75	117
20	7	11	5		0.02		5.82
25	0.47	2.5	0.16	0.11			0.48
30	1.3	2.3	0.51	0.17	0.02	0.02	
35	1.5	1.2	0.60	0.48	0.04		
40	1.8	1.4	0.67	0.89	0.23		0.01
45	1.8	0.61	0.49	1.1	0.14	0.10	0.01
50	1.0	0.83	0.42	1.2	0.36	0.03	0.02
55	0.64	1.6	0.30	0.82	0.25	0.04	0.03
60	0.36	0.33	0.29	0.42	0.28	0.23	0.02
65	0.08	0.19	0.18	0.31	0.14	0.13	0.01
70	0.03	0.19	0.11	0.10	0.11	0.06	0.04
75	0.03	0.08	0.05	0.10	0.03	0.03	0.02
80				0.02	0.07		0.02
85						0.01	0.01
90						0.01	

TABLE B. SHELL SIZE DISTRIBUTION OF SOFT-SHELL CLAMS ON FLAT #2, NOVEMBER 1971-NOVEMBER 1977. SEABROOK *MYA ARENARIA* STUDY, 1976.

SIZE CLASS (mm)	NOV 1971	APR 1972	JUL 1972	NOV 1972	FEB 1973	MAY 1973	AUG 1973	NOV 1973	JAN 1974	MAY 1974	AUG 1974	NOV 1974
5	37	1.6	2.9	116	138	199	15	114	4.2	7.6	5.9	
10	35	9.7	8.7	26	34	110	20	8	2.0	2.5		
15	11	0.91	5.5	2.4	2.4	13	28	2.6	0.36			
20	9.0	1.5	4.4	0.91	1.0	1.0	42	10	2.0			
25	0.89	0.11	4.7	0.11	0.38	0.42	0.56	0.67	0.91	0.97	0.11	0.50
30	0.44	0.14	4.2	0.44	0.44	0.63	0.27	0.80	0.58	1.4	0.27	0.22
35	0.67	0.19	2.8	0.50	0.38	0.80	0.08	0.66	0.44	1.4	0.61	0.30
40	1.2	0.33	1.6	0.83	0.38	0.97	0.08	0.61	0.38	0.91	0.75	0.40
45	1.6	0.61	0.80	0.27	0.27	0.72	0.08	0.39	0.55	0.83	0.38	0.65
50	1.1	0.53	0.69	0.22	0.22	0.55	0.14	0.36	0.50	0.58	0.56	0.75
55	0.89	0.67	0.56	0.33	0.17	0.32	0.19	0.33	0.19	0.17	0.33	0.32
60	0.94	0.68	0.28	0.27	0.22	0.18	0.08	0.08	0.17	0.25	0.17	0.34
65	0.44	0.36	0.22	0.22	0.08	0.16	0.19	0.14	0.14	0.08	0.06	0.15
70	0.33	0.30	0.19	0.11	0.17	0.12	0.03	0.11	0.14	0.08	0.06	0.19
75		0.08	0.06	0.11	0.06	0.09		0.08	0.14	0.03	0.03	0.06
80	0.06	0.17	0.03	0.06	0.06	0.08	0.06	0.06		0.03		0.06
85	0.06	0.03		0.06	0.03	0.04	0.11		0.06			0.02
90						0.04	0.06	0.11				0.02
95						0.01		0.06				
100							0.03					
105												
110												

(Continued)

TABLE B. (Continued)

SIZE CLASS (mm)	FEB 1975	MAY 1975	AUG 1975	NOV 1975	FEB 1976	MAY 1976	AUG 1976	NOV 1976	FEB 1977	MAY 1977	AUG 1977	NOV 1977
5	5.9	9.8	3.4	9.1	---	---	---	351	---	---	---	83
10					---	---	---		---	---	---	2.9
15					---	---	---		---	---	---	
20					---	---	---		---	---	---	
25												
30												
35	0.13	0.06									0.02	
40	0.32	0.18	0.02			0.11				0.02		
45	0.37	0.28	0.13			0.02					0.02	
50	0.67	0.32	0.06		0.02	0.02		0.02		0.04		
55	0.72	0.52	0.09	0.02	0.02							
60	0.24	0.44	0.02	0.07		0.04		0.02		0.02		
65	0.18	0.18	0.06	0.02	0.02	0.11				0.06		
70	0.20	0.11	0.02	0.09		0.02					0.02	
75	0.04	0.02	0.07	0.04		0.11		0.02		0.02	0.04	
80	0.06	0.04	0.02	0.07	0.02		0.04	0.02			0.09	
85	0.06	0.02		0.02	0.04						0.04	
90	0.02	0.02	0.02	0.04	0.09							0.06
95	0.02	0.02		0.06							0.09	
100		0.04		0.04				0.02		0.02		0.02
105												
110		0.02	0.02									

--- = not randomly sampled; see Appendix II for fixed station results

TABLE C. SHELL SIZE DISTRIBUTION OF SOFT-SHELL CLAMS ON FLAT 3 FOR NOVEMBER SURVEYS, 1971-1977. SEABROOK *MYA ARENARIA* STUDY, 1977.

SIZE CLASS (mm)	1971	1972	1973	1974	1975	1976	1977
5	35	28	6	0.64	1.14	556	67
10	29	4.7	1.0			4.1	3.4
15	5.2	4.0					3.4
20	4.8	2.0					1.13
25	0.17	0.42	1.0			0.05	
30	0.92	0.25	1.0	0.14			
35	0.67	0.17	0.38	0.12		0.02	0.10
40	1.5	0.33	0.62	0.11			
45	1.4	0.42	0.50	0.30		0.02	
50	1.3	0.17	0.29	0.11	0.03		0.02
55	1.1	0.17	0.79	0.08	0.03	0.02	
60	0.83	0.08	0.54	0.18	0.08		0.02
65	0.58		0.46	0.38	0.08	0.04	
70	0.33		0.08	0.42	0.14	0.02	
75	0.25		0.08	0.22	0.03	0.06	0.02
80	0.08		0.08	0.14	0.03	0.06	
85			0.04	0.03	0.08		
90	0.08			0.06	0.08		

TABLE D. SHELL SIZE DISTRIBUTION OF SOFT-SHELL CLAMS ON FLAT 4 FOR NOVEMBER SURVEYS, 1971-1977. SEABROOK *MYA ARENARIA* STUDY, 1977.

SIZE CLASS (mm)	1971	1972	1973	1974	1975	1976	1977
5	38	116	12	2.5	66	830	117
10	11	31	1.0		1.8	13.2	183
15	7	20	3.0				115
20	4	18	2.0	0.64			20.4
25	2.8	1.1	0.52	0.05		0.01	0.62
30	3.5	3.0	1.4	0.26	0.01	0.02	
35	4.6	2.8	0.62	0.58	0.01	0.01	
40	4.0	1.7	0.46	0.96	0.16		
45	2.6	2.0	0.35	0.92	0.16		0.09
50	1.3	1.0	0.38	0.80	0.18		
55	1.1	0.79	0.14	0.50	0.21	0.13	
60	0.25	0.21	0.08	0.29	0.12		
65	0.17	0.04	0.14	0.21	0.14		0.01
70	0.12	0.08	0.06	0.03	0.04		
75			0.02		0.01	0.01	
80		0.04		0.01		0.01	
85				0.01	0.01	0.01	

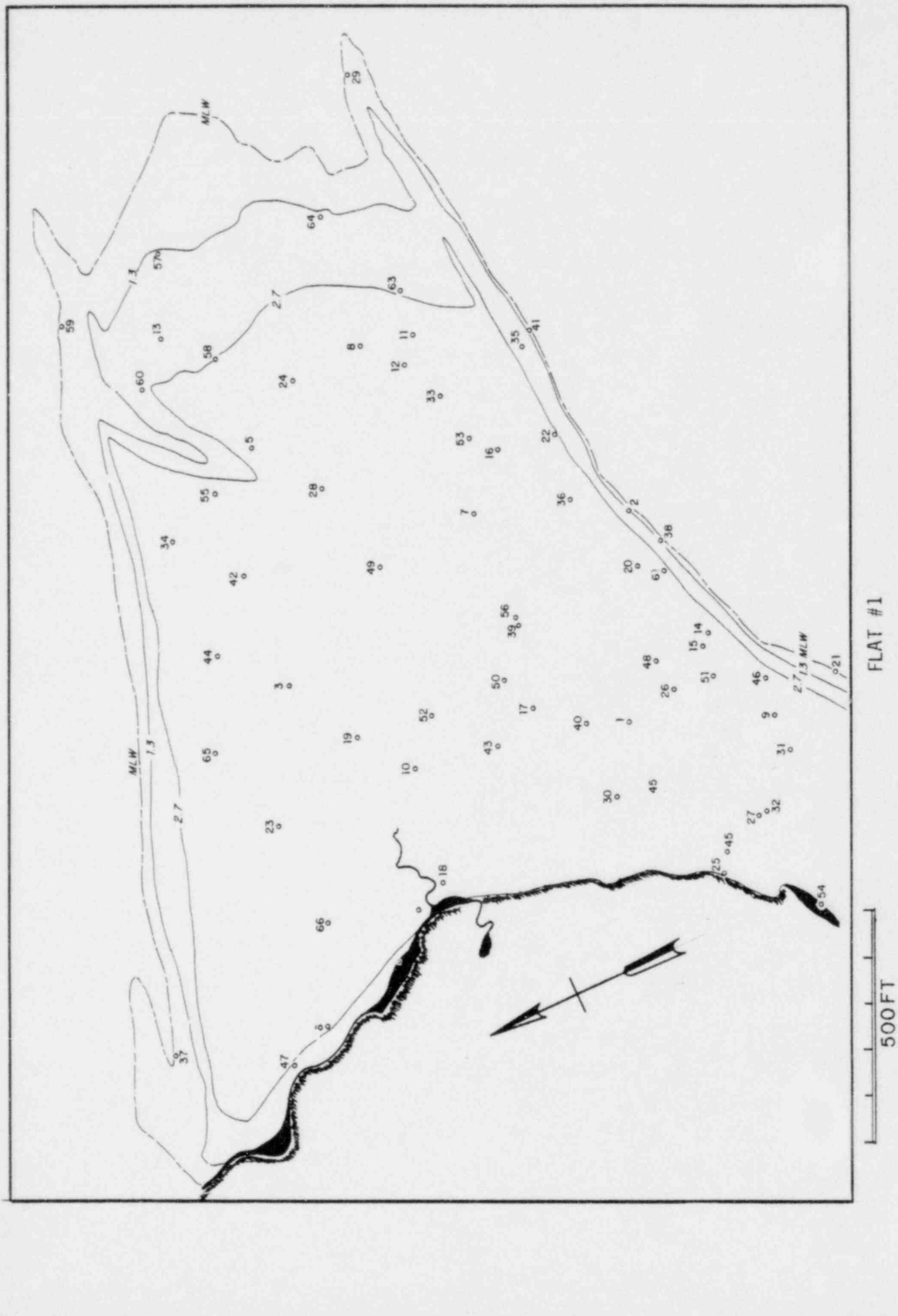
TABLE E. SHELL SIZE DISTRIBUTION OF SOFT-SHELL CLAMS ON FLAT 5 FOR NOVEMBER SURVEYS, 1971-1977. SEABROOK *MYA ARENARIA* STUDY, 1977.

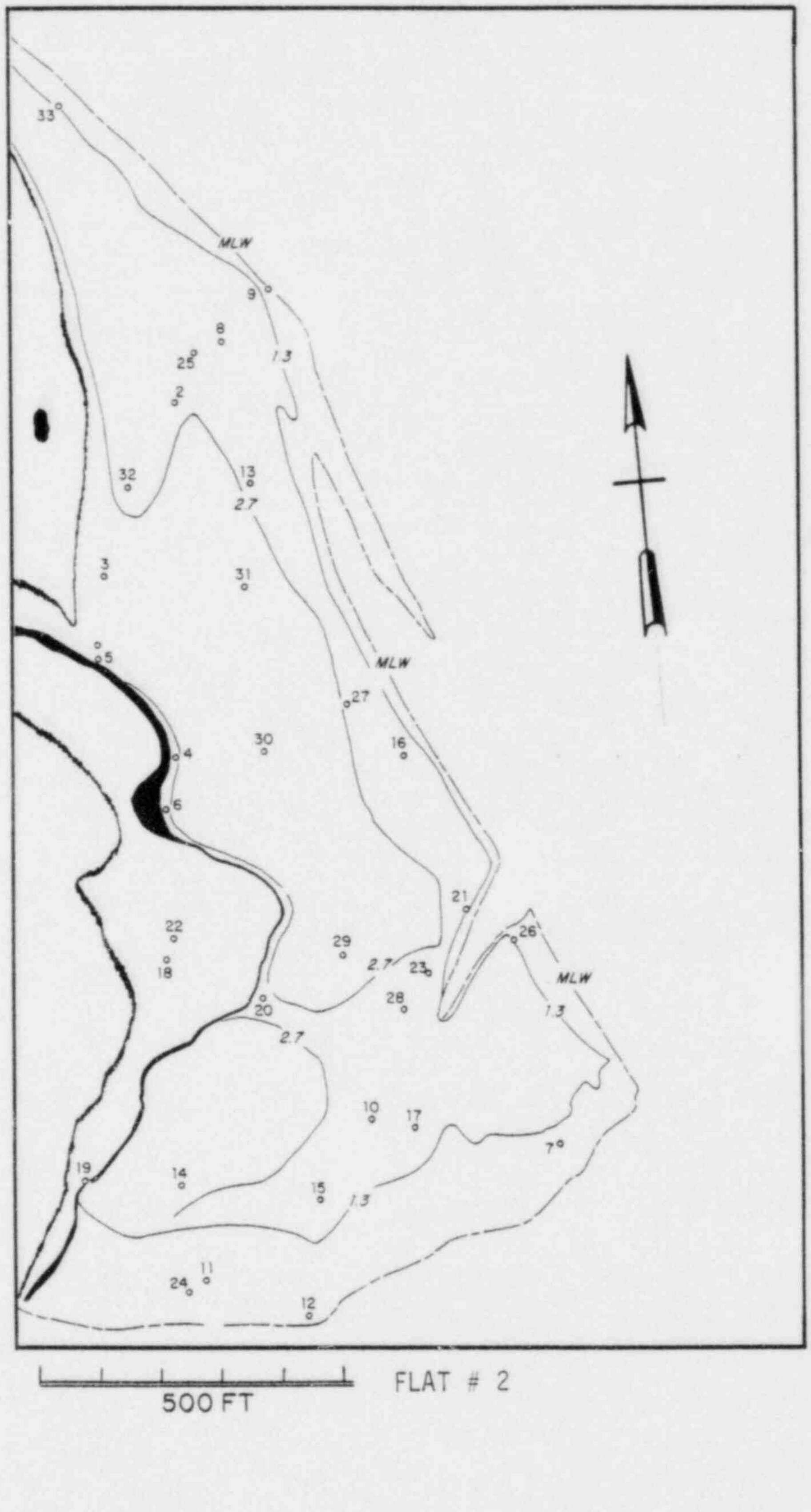
SIZE CLASS (mm)	1971	1972	1973	1974	1975	1976	1977
5	67	136	22	2.4	7.5	546	92
10	38	94	1			2.8	8.3
15	12	16					7.5
20	3	6					5.3
25	0.06	0.55	0.10				0.75
30	0.11	0.89	0.31				
35	0.33	0.61	0.14	0.01			0.01
40	0.44	1.0	0.28				0.07
45	0.44	0.77	0.12				
50	0.94	0.94	0.10			0.02	
55	0.39	0.61	0.12	0.01			
60	0.28	0.50	0.12				
65		0.11	0.05	0.08			0.01
70		0.11	0.05	0.04			
75			0.05		0.01		0.01
80		0.06					
85							
90							0.11

APPENDIX 7.4

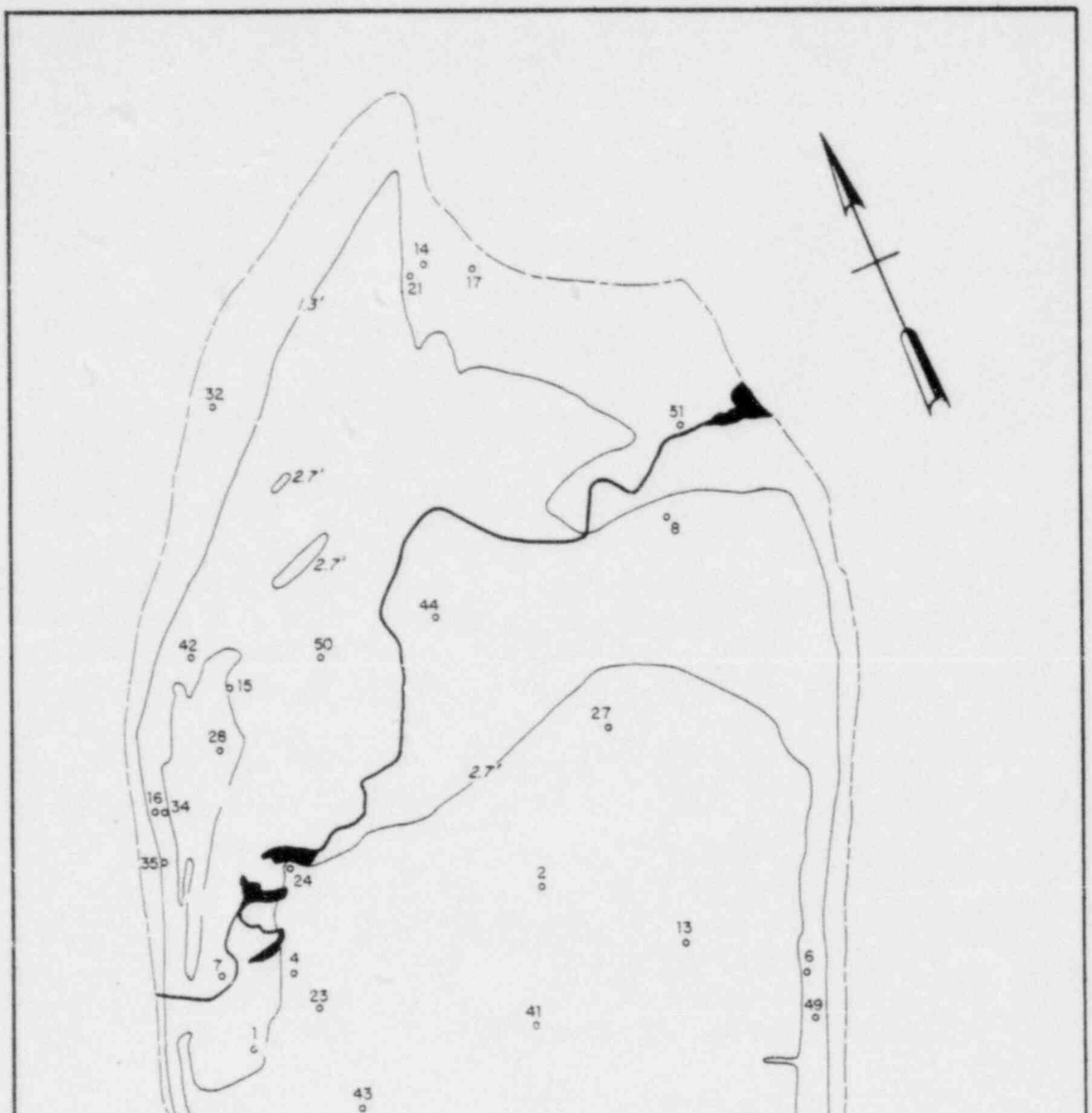
CONTOURED CHARTS OF HAMPTON HARBOR FLATS INDICATING NOVEMBER 1977 SURVEY STATIONS

(Refer to Figure 1 for orientation)


MLW
1.3
2.7
500 FT
FLAT #1


33
MLW
9
8
25
1.3
2
32
13
2.7
3
31
5
MLW
27
30
16
4
6
21
22
29
26
18
2.7
23
MLW
20
28
1.3
2.7
10
17
7
19
14
15
1.3
11
24
12
500 FT

FLAT # 2



1.3'
2.7'
1
2
3
4
6
7
8
9
11
12
13
14
15
16
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19
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22
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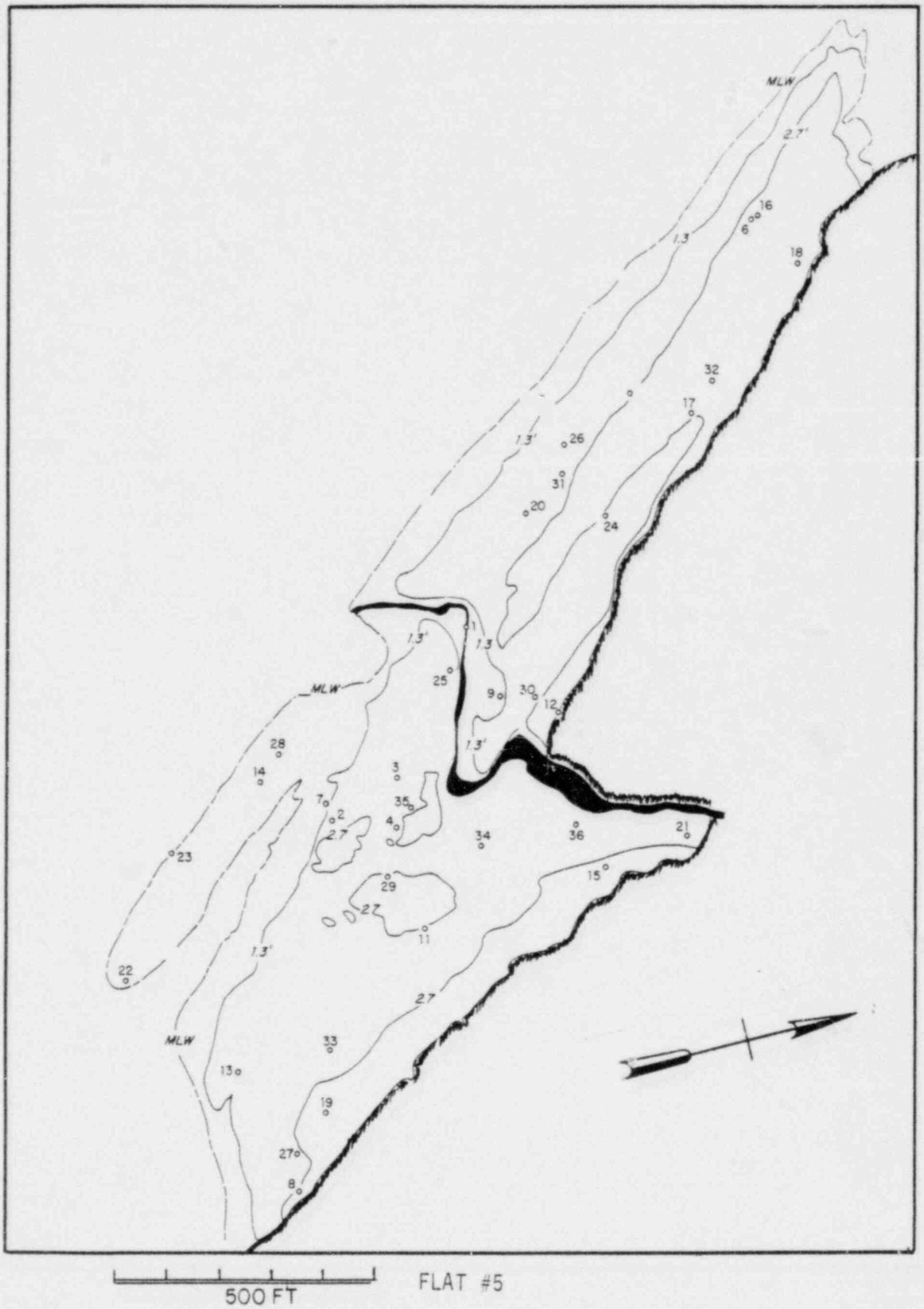
43
44
45
46
47
48
49
50
51
CP
500 FT

FLAT # 4



FLAT #5