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An investigation into commercial aspects of the hard clam fishery and development of commercial gear for the harvest of molluscs : final contract report for the period 1 July, 1970 through 30 June, 1973

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AN INVESTIGATION INTO COMMERCIAL ASPECTS OF THE HARD CLAM FISHERY AND DEVELOPMENT OF COMMERCIAL GEAR FOR THE HARVEST OF MOLLUSCS

Final Contract Report For the Period
1 July, 1970 through 30 June, 1973

Contract No. 3-124 R

by

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Summary, Conclusions and Recommendations

Based on

An Investigation into Commercial Aspects of the Hard Clam Fishery and Development of Commercial Gear for the Harvest of Molluscs.

Project 88-309-3-124-R 1, 2 and 3.

by

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INTRODUCTION

Because of the volumes of data presented in the final report on "An Investigation into Commercial Aspects of the Hard Clam Fishery and Development of Gear for the Harvest of Oysters", we are presenting here a brief summary of the results along with conclusions and recommendations.

DISTRIBUTION AND AVAILABILITY OF HARD CLAMS IN CHESAPEAKE BAY.

Hard clams are widely distributed within Chesapeake Bay, however, moderate to heavy concentrations are found in six areas totaling approximately 19,000 acres (Figure 1). These major areas of hard clam density are: the north side of the lower York River and the Coleman Bridge vicinity, the Tue-Marsh-Back Creek area, Poquoson Flats, the southern section of the Willoughby-Crumps Banks area, Hampton Flats and the lower James River (except in the Craney Island vicinity). No other commercially significant concentrations of clams appear to exist in lower Chesapeake Bay and its tributaries.

Nearly 95 percent of all hard clams landed within Chesapeake Bay are harvested with patent tongs, largely from the areas designated as having moderate to high densities. Some of these areas are old abandoned oyster grounds, or oyster grounds which have remained commercially fallow since 1960 because of MSX. Typically, patent tongers operating on the locations classed as medium on Figure 1 catch

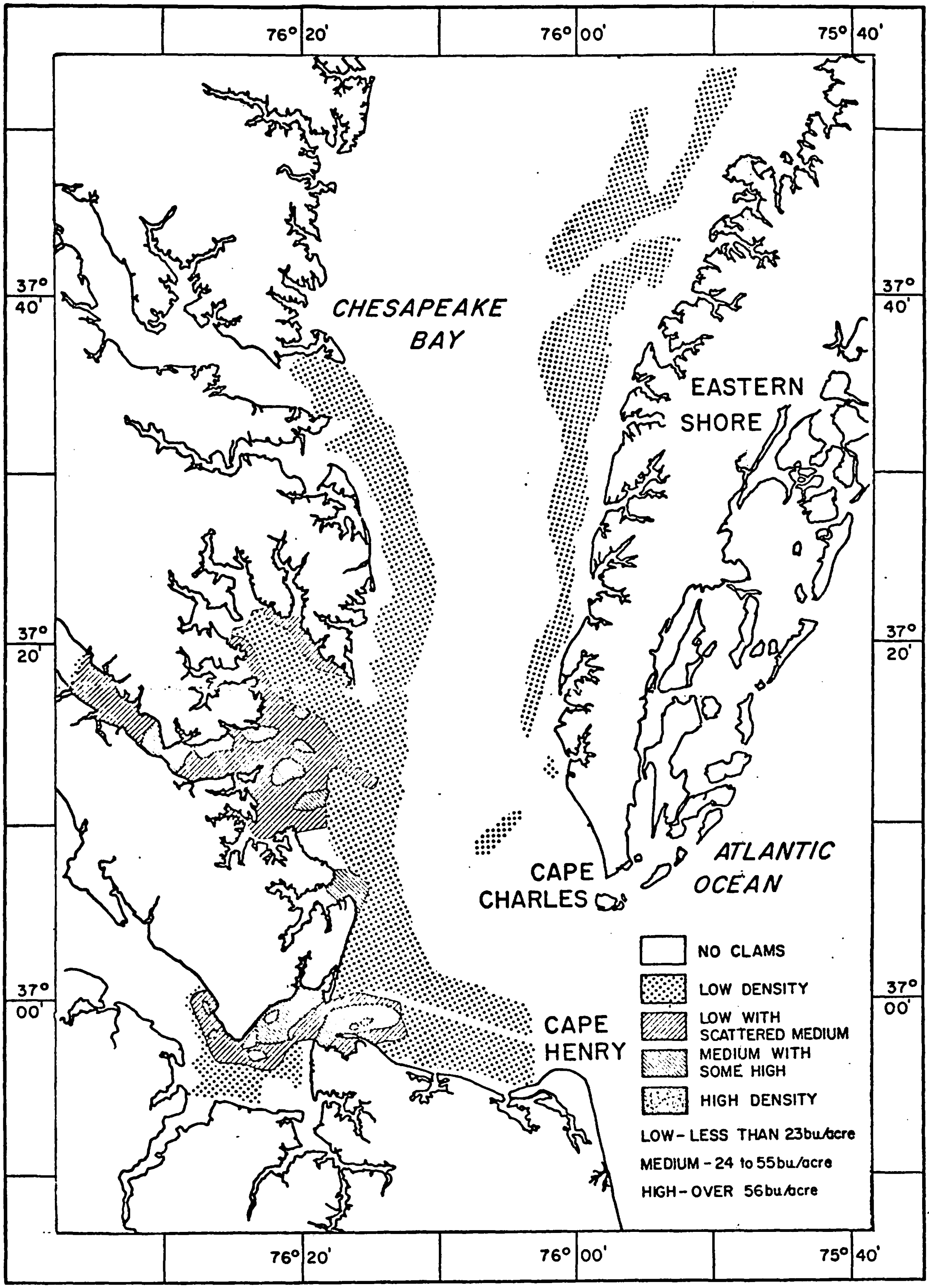


Figure 1. Distribution of Hard Clams in Chesapeake Bay.

from 1000 to 3000 clams per day and up to 7,500 per day in areas shown as high abundance. Patent tong operators state that they cannot make a living in areas shown as low on this chart.

The hard clam industry as it exists today in the bay subsists on only a few small areas. Because the resource is geographically concentrated it is vulnerable to overfishing. Therefore, fishery, scientists and managers must monitor it closely to detect increased natural mortality, reduction in recruitment, or decrease in catch per unit of effort, all warning signs that the resource is in danger of being overfished.

The vulnerability of the hard clam fishery is also indicated by poor recruitment over most of the bay area. Good annual recruitment, as indicated by high abundance, low average length, and high percentages of littlenecks and cherrystones was also limited to the above six areas.

Hard clam growth rates, determined from experimental plantings in the lower James and York Rivers where most of the fishery is located, are slow relative to growth rates reported for clams in higher salinity waters. Littleneck and cherrystone sizes are attained in about 2-1/2 and 4-1/2 years, respectively, by hard clams in Hampton Flats; however, about 4 and 8 years are required in similar areas in the lower York River. Chowder clams may range in age from 8 to 20 years. Thus, clams in this latter size category found in many areas may represent the slow accumulation over many years. Growth is slowed and mortality accelerated when high rainfall depresses salinity below normal.

HARD CLAM LANDINGS AND FISHING EFFORT (1951-1969)

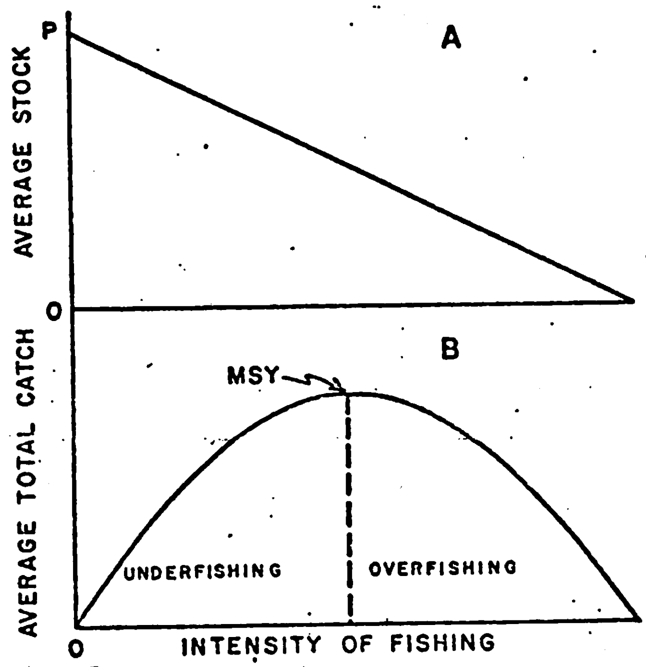
In a hypothetical fishery the population size decreases when fishing commences (Figure 2A) and as the rate of fishing increases, the average catch increases (Figure 2B). The population size will reach a point at some level of fishing effort where the rate of natural increase and the catch are maximal (Figure 2B). The catch at this maximal point is called the maximum sustained yield (MSY). Increased effort beyond this point will result in a decreased catch, and eventually may be biologically detrimental by reducing the spawning stock to, or beyond some critical level. The economics of the industry also are adversly affected when increasing effort yields decreasing catches.

The Virginia hard clam fishery probably has operated near the MSY in recent years (Figure 3). A stronger statement about its position cannot be made on the basis of the data now available; nevertheless, the general trend toward the MSY, or possibly its attainment, is apparent. It is also very apparent that catch per unit effort (weight per license) decreased when effort increased (Figure 4). This is, of course, related to a decrease in the available stock due to fishing.

MANAGEMENT

At this time, it would be prudent management to stabilize effective effort on the stocks now exploited until a more detailed analysis can be made and until goals expected to be accomplished by a management program are specified.

Figure 2. Equilibrium states of a hypothetical fishery.



Source: Shimada, B. M. and M. B. Schafer. 1956. A study of changes in fishing effort, abundance and yields for yellowfin and skipjack tuna in the eastern tropical Pacific Ocean. Inter-Amer. Trop. Tuna Comm. 1 (7): 392.

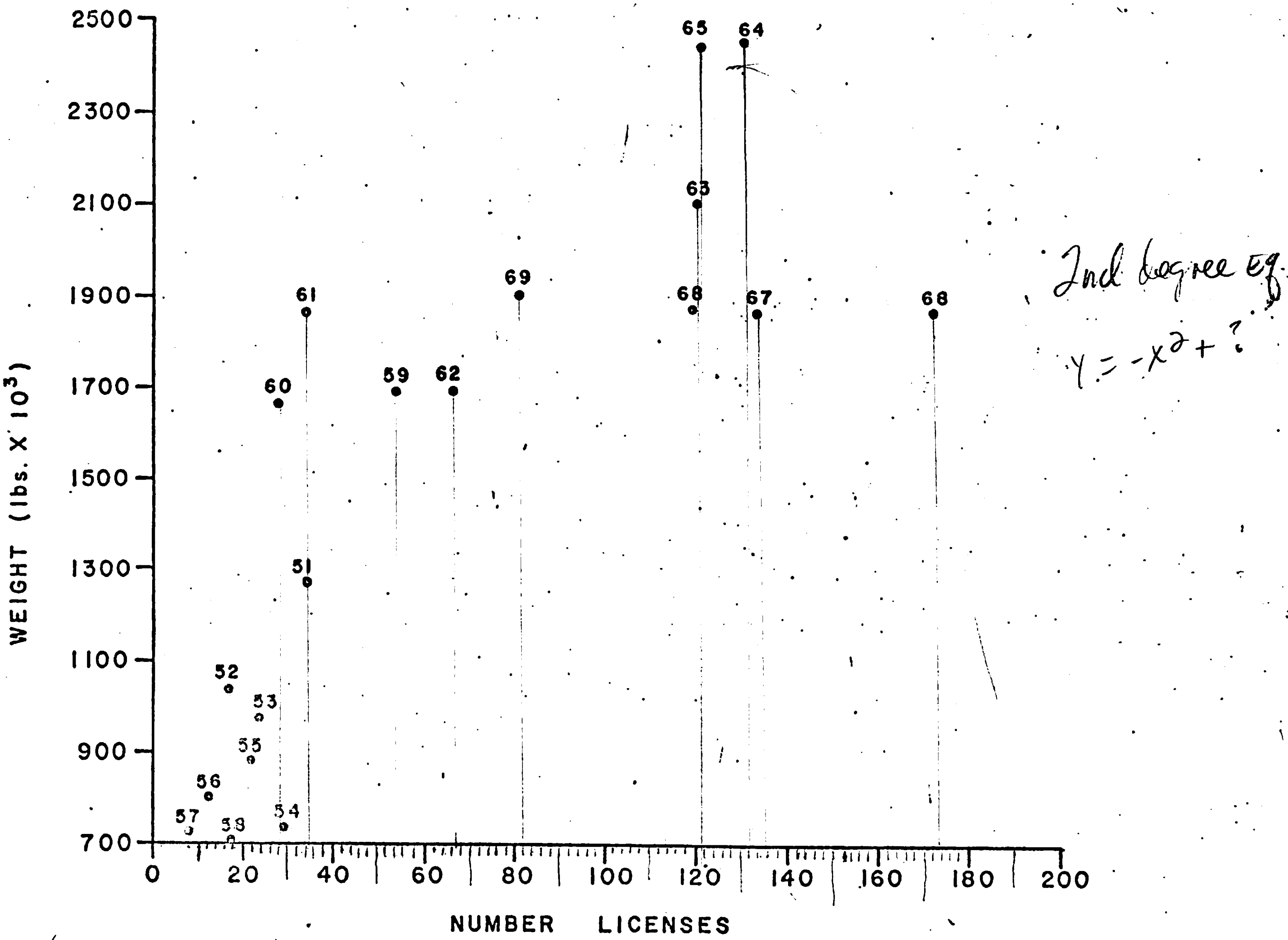


Figure 3. Relationship of hard clam landings (meat weights) to fishing effort (number of patent tong licenses). Numbers indicated respective years (1951-1969).

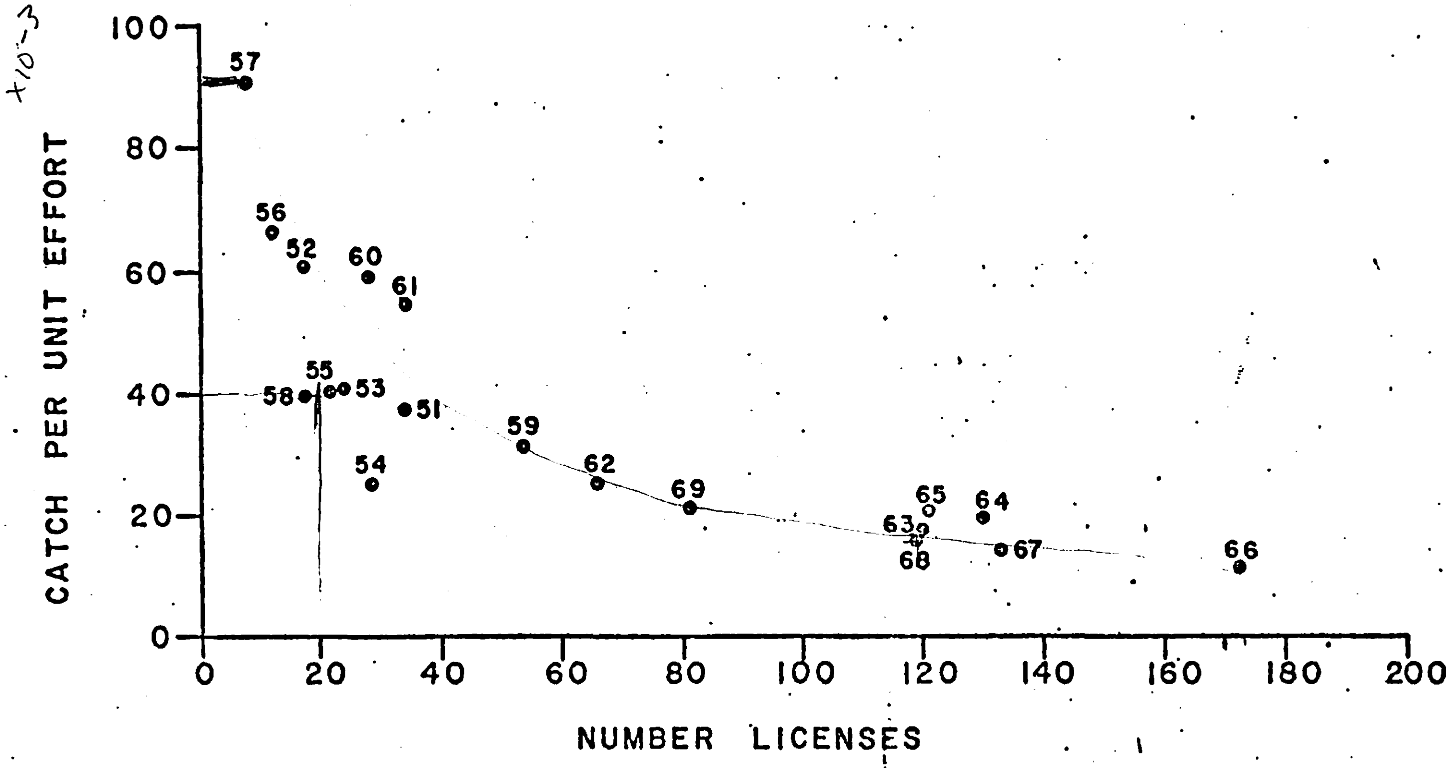


Figure 4. Relationship of catch per unit effort to number of patent tong licenses issued. Numbers indicate respective years (1951-1969).

If socio-economic conditions warrant an increase in landings of hard clams, alternatives exist. The following options would not be detrimental to the stocks presently fished: 1) Permit the use of commercial dredges in Chesapeake Bay in water depths greater than 18 feet (MLW). Presently, it is not economically feasible to fish these low density stocks with patent tongs. The greater efficiency of dredges would offset the low density factor and, presumably, result in a catch cost comparable to that of patent tong fishing in higher density areas; 2) Encourage leasees of MSX-affected oyster grounds having good hard clam resources to enter the fishery; and 3) Encourage and/or support private hard clam mariculture to determine if it is feasible as a commercial operation. Positive results would greatly increase the basic resource. Options 2 and 3 could be exercised on the same grounds.

The extension of the open season in the lower James River is also an alternative for increasing hard clam landings. However, this option would effect stock presently available and, therefore, should not be undertaken unless the evaluation of past catch-effort data indicated that the area is underfished with respect to the MSY.

Harvesting costs could be reduced by allowing the use of more efficient gear, however, to do so would displace men and gear now in the hard clam fisheries or reduce the stocks.

Reliable measures of catch and effective fishing effort in each of the areas are essential to a sound management program. Therefore, it is recommended that an adequate statistical program such as that being developed by the Virginia Marine Resources Commission be implemented as soon as possible.

It is further recommended that the management program once formulated, be reevaluated at least annually on the basis of trends in the vital statistics of the clam population and socio-economic conditions in the fishery. This reevaluation will require a continuing scientific analysis to determine rates of recruitment, growth and mortality, and other parameters of the fishery. This analysis should be accomplished by VIMS with the results and the implications of the results being transmitted in timely fashion to VMRC as a basis for management actions.

AN INVESTIGATION OF CLAM FARMING IN THE YORK RIVER

The idea has occurred to many that it should be possible to raise large numbers of clams, "plant" them in an estuary, and several years later harvest a marketable crop. There are, however, difficulties in this plan. The problems arise when the small clams are planted in an estuary. Often predators such as oyster drills, crabs and fish consume so many that it is not possible for commercial growers to realize an adequate monetary return at the time of harvest.

Under this contract we attempted to develop techniques for protecting small clams during their vulnerable stage (2 to 12 mm). Two methods were tested. One consisted of planting small clams in a gravel substrate, (about 1 cubic yard per 100 square feet). Most effort went into this aspect. A second method (which received only limited tests) consisted of screening off an area with inexpensive 1/4 inch mesh verticle plastic net.

There follows a summation of our results:

1. Plastic net was of no value in protecting developing hard clams.
2. Survival was higher (%) on graveled bottoms at a depth of 5 feet MLW than on natural bottom, but on bottoms shallower than 1 foot MLW gravel was not effective.
3. Hatchery-reared clams protected by gravel grew at the same rate as wild clams on adjacent bottoms.
4. Seldom did more than 10% of the small clams (1-3 mm) survive for one year. Frequently none survived. Survival of larger seed (4-8 mm) was more satisfactory and in one test survival ranged from 33 to 38%, at depths exceeding 5 feet. However, in one test plot none survived.

Clam farming has a definite potential, but at the present state of knowledge, the risk is high. The results of our three year study suggest that caution be exercised by anyone attempting to farm clams on a commercial basis. Care should be taken to obtain the optimum area in respect to survival prior to investing large amounts of capital in this operation. It is suggested that prior to large scale investments, pilot plantings of 1/4 to 1/2 acre be made in an area where depth range is from 10 to 15 feet. It is also recommended that seed be at least 5 mm. In general, the larger the seed planted, the better survival can be expected.

RECOMMENDATIONS

1. Further research on clam farming should be conducted with emphasis on 5-10 mm or larger sizes planted at depths exceeding 10-15 feet to determine if clam farming is practical using the larger sized seed.
2. Determine if "natural gravel or shelly bottom" will protect clams.

MODIFICATIONS OF A MARYLAND TYPE HYDRAULIC ESCALATOR DREDGE FOR HARVEST OF OYSTERS.

An apparatus was developed to fit on the escalator of a Maryland-type soft clam harvester to harvest oysters. In developing this apparatus, we obtained the assistance of Mr. Q. C. Davis, an engineering consultant who specializes in mechanical design.

The initial work on the harvester consisted of building a wooden mock-up of the appatus, and then evaluating several possible designs. After this, work progressed slowly due to the necessity of having the working model constructed from non-standard items in a machine shop. The working prototype, however, was completed in May, 1973 and field trials were conducted in June 1973 on several types of bottoms.

The harvester head consists of a rectangular steel box with an inside width of 36", and an overall length of 36". The "box" narrows from 36" to a width of 18" where it attaches to the escalator. Inside this box are two steel cylinders to which are affixed rows of flexible steel tines. These cylinders are rotated by an underwater hydraulic motor. As the box slides over the bottom ahead of the escalator on steel runners, the tines rake oysters and shells from the bottom and a horizontal jet of water washes them onto the escalator which carries them to the surface.

Initial tests demonstrated that:

1. The mechanical design of the apparatus was satisfactory.
2. The head containing the revolving tines attached satisfactorily to our present escalator system.
3. All bearings, chain drives and motors were fully operable, and the revolving tines dug into the bottom as designed.

As expected, field trials showed that modifications were needed pending further operations, and these are now being undertaken under our new contract.

INTRODUCTION

The following report contains results of our studies from 1 July, 1970 through 30 June, 1973. It also contains some additional data reported in the 1970 final contract report, A Study of the Hard Clam Resources of Virginia, (Contract Nos. 3-77-R-1, 3-77-R-2, 3-77-R-3) which directly pertains to the present report.

Data reported herein relates to four main phases of study, hereafter referred to as jobs: 1) an investigation of the distribution of hard clams in Mobjack Bay and in lower Chesapeake Bay with hydraulic dredges; 2) a study of the rate of growth of the hard clam in various regions of Chesapeake Bay; 3) an investigation of clam farming in the York River, Virginia; and 4) the modification of a Maryland type hydraulic escalator dredge for the harvest of oysters.

JOB NO. 1 - AN INVESTIGATION OF THE DISTRIBUTION OF HARD CLAMS IN MOBJACK BAY AND IN LOWER CHESAPEAKE BAY WITH HYDRAULIC DREDGES.

INTRODUCTION

The distribution and abundance of hard clams was studied with a standard Maryland hydraulic escalator (cf. Mac Phail, 1961) and with a modified hydraulic box tow dredge. The objectives of this study were to define the distribution and abundance of hard clams in the lower Chesapeake Bay region. Of particular interest was the occurrence of commercial densities of hard clams in areas not presently utilized by the fishery.

MATERIALS AND METHODS

Sampling procedures with the escalator harvester are discussed first. Square experimental plots with 150 feet sides (approximately a half-acre area) were initially worked out or harvested for relatively long periods of time. A plot was considered worked out when the harvest rate per hour of hard clams was less than one bushel. When a plot was not completely worked out, operation time varied directly with abundance. This method was employed for those stations listed in Table 1 (part 1).

It was desirable to establish a relatively fast method of subsampling to estimate abundance. In addition to its value for comparisons among areas, an estimate of abundance must be known if it becomes necessary to regulate catch to insure the continued presence of a spawning stock.

The first subsampling attempts to estimate abundance were made by running the boat in the largest possible inscribed circle within the half-acre plot. Due to wind, current and problems of boat handling, preliminary observations indicated that a swath would be cut approximately twice the width of the boat, about 43 percent of the enclosed circled area. A catch curve was established from the swath cut by recording the harvest for constanct time periods. From catch curves, estimates of abundance were made (explanation below). The data listed in Table 1 (part 2) were collected by this method during the winter and spring of 1970. A recent aerial photograph of the shallow water plot at Gaines Point (No. 45) indicated that the estimated swath was adhered to. However, at Hampton Flats (No. 71) where, unlike Gaines Point, strong winds and tides were encountered, measurements made by scuba diving showed the swath to be egg shaped and about 65 percent of the enclosed area worked. An estimate based on a 43 percent work area at this point would lead to an over estimate of abundance. Thus, the method was not applicable to estimating abundance without a time consuming on-site inspection of each plot's swath. The catch rates, however, of these can be compared relative to one another and to the preceding data in Table 1.

It is evident from the preceding discussion that the major problem in subsampling was the establishment of the geometry of the swath covered by the dredge. This problem in subsampling was overcome by developing a third sampling technique. In this last method the previous discrepancies were overcome by operating the hydraulic escalator over the whole surface of the inscribed circle (or near circle) within a half-acre plot. A catch curve was then constructed and an estimate of total abundance made for the circled area. Abundance was then related to the half-acre plot by completely working out (catch $\leq$ 0.3 bushels/hr) the corners and just within the boundary lines of the plot. This catch was then added to the initial estimate to give an adjusted estimate of the total abundance for the half-acre plot. Eight experimental plots were sampled in this manner; seven of these plots were worked out and the estimated total catch compared to the actual total catch (Loesch and Haven, 1973). Data for these eight stations is also shown in Table 1 (part 3) for the purpose of contrasting them with previous sample data.

Abundance was estimated from the observed decline in catch over a time period by the method of Leslie (Leslie and Davis, 1939). A detailed explanation is given in Ricker (1958). A brief sketch is given here. A linear line is obtained by the Leslie method for an observed curvilinear decline in catch per unit effort (C/f) by plotting C/f at time 't' against the cumulative catch (K_t) at the beginning of time 't'. The absolute value of the slope of the line (b, which is negative) is an estimate of the portion of the population harvested by a single unit of fishing effort. This fraction of the population is referred to as catchability (c). The X - axis intercept is the K_t when the C/f has dropped to zero, thus, it is an estimate of the initial population (N_o). The Y - axis intercept is an estimate of N_o times 'c'. The population at any given time (N_t) is equal to N_o less the K_t up to that point in time. The C/f at any time 't' is the product of 'c' and N_t. Substitutions of the expression for N_t into the latter equation give

$$C/f = cN_o - cK_t$$

which has the linear form

$$Y = a + bX$$

Since an estimate of the Y intercept ($\hat{a}$) is equal to CN_o, and when C/f equals zero then $N_o = K_t$, the estimate of the original population is

$$\hat{N}_o = \hat{a}/\hat{c}$$

[A caret (Λ) distinguishes the statistic from the parameter.] Equating X to cumulative catch (K_t) and Y to the catch for a given time interval C_t/f_t then the desired linear expression can be derived from the standard statistical sum of least squares procedure.

The escalator harvester was removed from the R/V Mar-Bel in January, 1971, and the vessel refitted for tow dredging. A box dredge was constructed to fit the Mar-Bel's existing hydraulic pump and auxiliary motor system. This dredge was constructed at the laboratory and was patterned after the larger box dredge used by surf clam operators. The cutting blade of the dredge cuts to a depth of seven inches, presumably undercutting the vertical distribution of the hard clam. The width of the blade is 15 inches; therefore, 1.25 square feet and 0.73 cubic feet of substrate were sampled in each linear foot of tow dredge operation. The collecting bag is approximately three feet long with two-inch stretched mesh. Catch per unit tow is not directly definable as catch per unit area of substrate because of the selectivity of the mesh bag. Mesh size was effectively reduced when large quantities of shell, mud, or eel grass were present. Abundance and mean size estimates, however, were not adjusted for a theoretical minimum size, since varying substrate conditions would be encountered in commercial operations of similar gear.

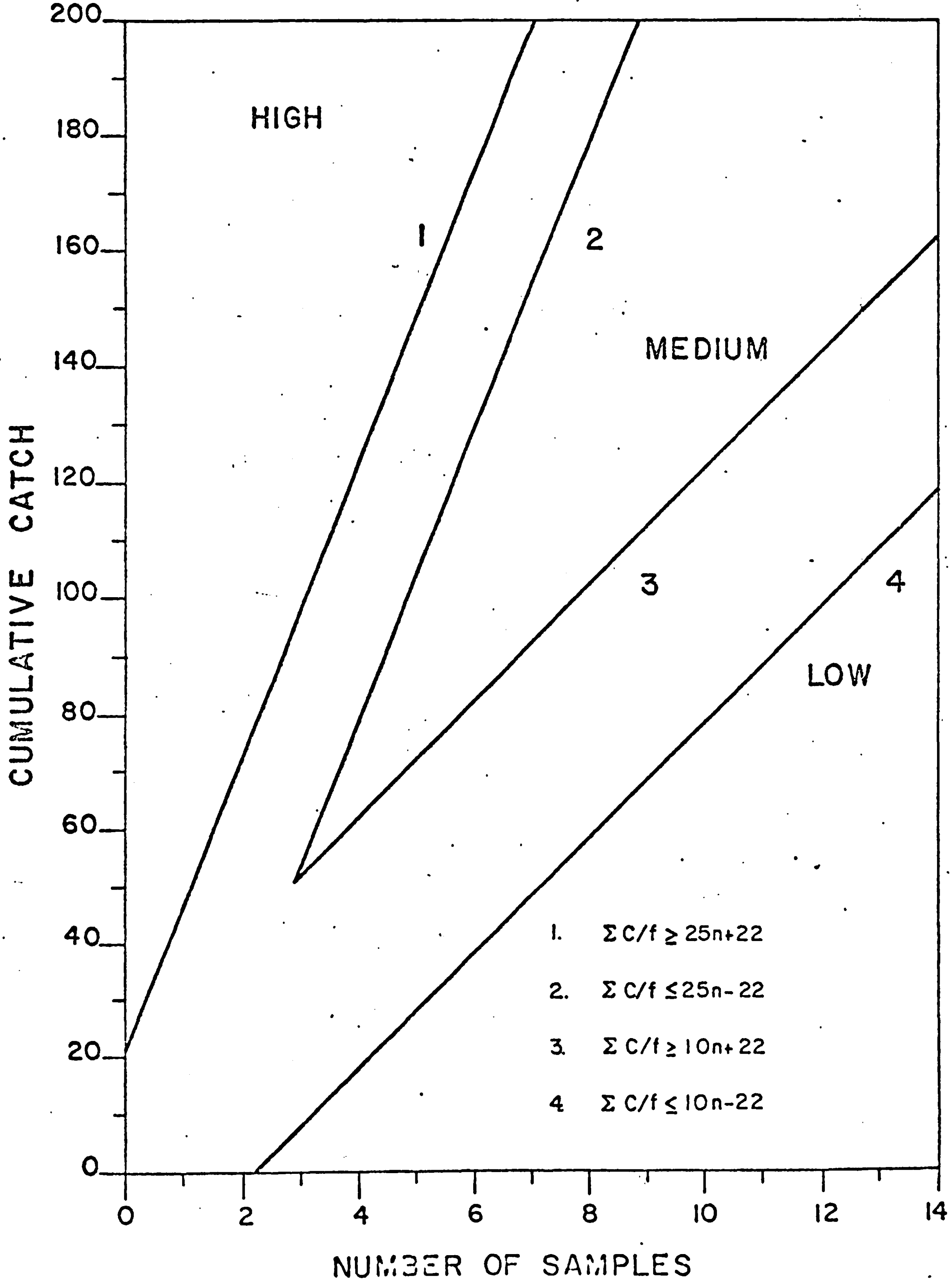
Employment of the hydraulic tow dredge as a research tool permitted sampling beyond the depth limitations of the escalator which was approximately 12 feet. The tow dredge was operated in depths to about 50 feet.

The tow dredge, obviously, could not be operated within an experimental plot in the same manner as the escalator dredge. Instead, a procedure known as sequential analysis was employed to estimate density of clams on the bottom. This procedure, introduced by Wald (1945), differs from "orthodox" sampling methods in that the number of samples to be taken is a random variable and not a predetermined number of sample replications. The actual number of samples taken is a function of the relationship between cumulative catch and the number of samples (tows) taken at that point in time. Fewer observations are needed with a sequential sampling method. Morgan et al. (1951) reported a saving of 25 to 36 percent. The Statistical Research Group, Columbia University (1946) stated that savings are frequently greater than 50 percent. Salia et al. (1965) cited some past biological applications of sequential analysis and demonstrated its applicability for sampling benthic organisms. Their particular examples pertained to Rhode Island hard clams. Dixon and Massey (1969) presented an introduction to sequential analysis; the more concerned reader should consult the above mentioned authors. The procedure permits qualitative probability statements about abundance, in this case, the classification of a study station as one of high, medium or low abundance. Two pairs of parallel lines were constructed from *a priori* knowledge obtained from: 1) previous hard clam escalator sampling data; 2) comparison of pilot tow dredge data with escalator data obtained at common sites; 3) knowledge of commercial patent tong catches; and 4) information obtained from members of the shellfish industry. The intersection of these lines with the abscissa, the ordinate, or each other defined the three areas of abundance and their separating regions of no decision (Figure 1). Sampling continued with cumulative catch plotted against the number of samples taken until the plotted coordinates occurred on a line or within a designated area of abundance. With this occurrence, sampling ceased and the area was classified with respect to abundance at a 90 percent confidence level. If the limits of the graph were exceeded prior to making a decision, sample number (n) and cumulative catch (C/f) were substituted into the inequalities which delimited the areas of abundance (Figure 1) and sampling continued until one of the expressions was satisfied.

Although the outstanding feature of sequential sampling is the reduction in sampling effort, i.e., the number of samples needed to classify data while maintaining the high prechosen confidence level for qualitative statements, it results in an unacceptable degree of inaccuracy for estimating the average number of clams per unit dredge tow when the number of replicated tows at a station are low. This problem is overcome by making such estimates for only stations which required a relatively large number of tows, or by combining the catch data for stations occurring in a given area.

The sample unit employed (with some exceptions) was a dredged length of 50 feet. This represents a sampled area of 62.5 ft^2 or 36.4 ft^3 because the dredge blade is 15 inches wide and cuts to a depth of 7 inches. However, on old, heavily shelled oyster rocks tow distance was only 25 feet because the dredge would completely fill prior to the attainment of the desired 50 feet. The catch data for these stations were still normally distributed (an assumption of the model), but doubling of the catch to estimate that of a 50-ft tow slightly inflates the chosen α probability level (Dixon, personal communication).

Figure 1. Graphical presentation of the two pairs of parallel lines which delimit the areas of high, medium and low abundance, and the areas of no decision.



This could be off-set by initially selecting a smaller α level. It was not considered a serious problem in our survey because at the few stations that required the shorter tow distance, the oyster rocks extended to shallower water and had previously been sampled with a hydraulic escalator. Estimates of abundance by the different sampling methods were always in agreement.

To insure a constant sampling unit of 50 feet, a fathometer was first employed to estimate the average water depth in feet of the area to be sampled; only areas of relatively uniform depth were included in anyone sampling station. Thus, the constant distance of 50 feet and the water depth represented two sides (a and b) of a right triangle. The hypotenuse of the triangle (c) was represented by a marked 1/2 inch rope tied to an anchor. The amount of line to be let out while towing at a station was determined before sampling by solving the equation:

$$(c^2)^{1/2} = (a^2 + b^2)^{1/2}$$

where 'c' was the length of the marked rope and 'a' and 'b' were as defined above. This method was considered superior to the often employed method of using a constant unit of time because substrate composition, wind, and tides affected the boat speed and, thus, the distance dredged. The marked rope was prestretched and repeatedly checked for further stretching. During sampling, it was kept as taunt as possible to justify the assumption that it was a straight line. There was, undoubtly, some curvature in the rope but this error is considered insignificant for the tow distance and water depths encountered in this study. If desired, a correction chart for this error could be constructed by use of a buoy in conjunction with the marked line and anchor. The buoy would be attached to the anchor by a rope equivalent in length to the water depth. A 50-foot length of rope would then be let out across the surface of the water while, simultaneously, the marked rope from the anchor is also let out. Repeated trials at various depths would determine the relationship between water depth and the length of marked rope to be used for 50-foot tows. These data could be plotted and a line of best fit constructed.

Our sampling was conducted by lowering the dredge to the bottom and, prior to towing, the tow line was freely let out until the boat had moved approximately 50-75 feet away from the dredge. The forward motion of the vessel was stopped and the marked-line anchor dropped. The sample tow then commenced and continued until the predetermined length of the marked line was attained. The engine was then lowered to an idling state which caused the vessel to stop because of the weight of the dredge. The vessel was then run back to the dredge as slack lines were gathered.

Because of different market values associated with hard clam sizes, the data was also analyzed with respect to the percentage of littleneck, cherrystones and chowders presented in our samples. Size definition of these groups varies among wholesale markets. General appeareance will also decide what category a clam is placed in; for example, an 80 mm "sharp-billed" clam may be acceptable as a cherrystone, but a thick, blunt one of the same size would be designated a chowder clam. Availability, also, influences the demarcation of these groups. The upper limit for littlenecks and cherrystones may be extended when the supply is limited. This is particularly true during winter in the northern regions when ice inhibits boat operation and accessibility to the clam beds. Consideration of these factors and, in particular, local culling practices resulted in the following arbitrary designation of length groups: 1) littlenecks are $\leq$ 60 mm, 2) cherrystones range from 61 to 80 mm, 3) chowders are $\geq$ 81 mm.

For convenience, the conversion of millimeters (mm) to inches is presented in the Appendix (Table A).

RESULTS AND DISCUSSION

General Distribution and Abundance: Hydraulic Escalator

Eighty-one experimental stations were sampled with the hydraulic escalator for the purpose of determining distribution (Figure 2) and estimating abundance and catch rates (Table 1). Though all sampling data are reported, statistics derived from small samples ($n<75$) must be interpreted with caution. Hard clams were found in the lower Rappahannock River, in the York River up to the Camp Peary-Clay Bank region, and at all areas sampled in the Poquoson and Hampton Flats. Hard clams were also present at all stations in Mobjack Bay. Catch statistics for three of the Mobjack Bay stations are considered reliable because of extensive escalation. At 14 other stations in Mobjack Bay, sampling was conducted for the purpose of establishing distribution (Table 2). Low catch rates at these stations (with one exception) relative to the other three stations were probably related to the limited sampling time because hard sand bottoms, as encountered there, often required some pre-sample work without harvesting to ensure the full engagement of the cutting head of the escalator.

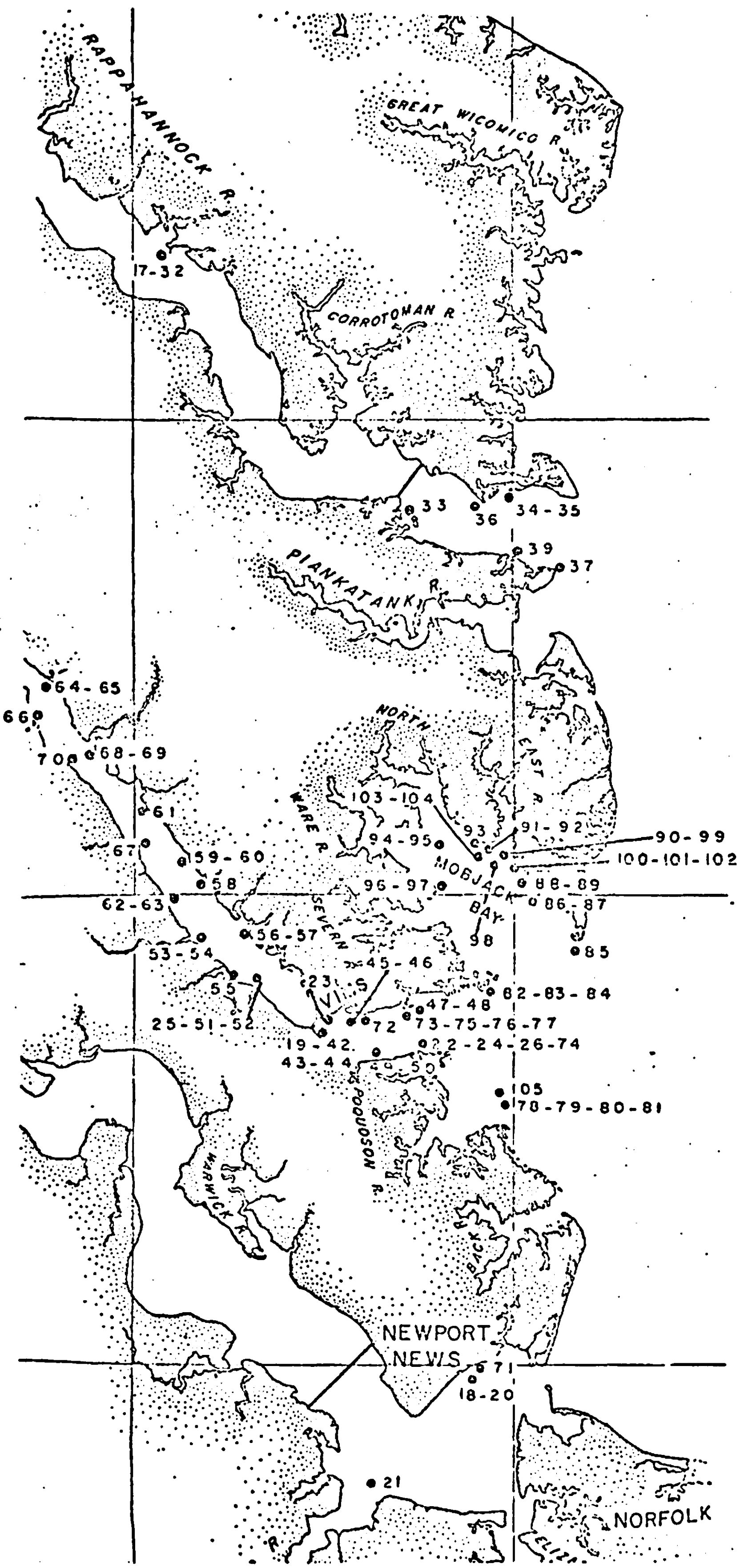


Figure 2. Location of experimental stations sampled with a hydraulic escalator.

Dense concentrations of hard clams were encountered in the lower James River at Nansemond Ridge and Hampton Bar sites. In the latter area where two stations (Nos. 18 and 71) were completely worked out, total catches indicate an abundance ranging from 120 to 157 bushels per acre. A completely harvested half-acre plot at Poquoson Flats yielded 15 bushels.

Relatively heavy concentrations of hard clams were found on the north side of the York River from the mouth to just above the George P. Coleman Memorial Bridge. Catches from the experimental plots at Allens Island and from worked out plots at Gaines Point indicate an abundance of about 50 to 80 bushels per acre, while one at Gloucester Point yielded 17 bushels from the experimental half-acre plot. On the lower south side of the York River clams were less abundant. Two completely escalated sites at Goodwin Island indicate a density of about 18 to 25 bushels per acre. Between the Yorktown and Goodwin Island areas, hard clam density decreased dramatically at two sample stations (Nos. 49 and 50) immediately below the AMOCO oil refinery plant. Distribution was spotty and abundance sparse at sampled sites above the Coleman Bridge. One notable exception occurred at Green Point (No. 57) where 12.5 bushels were harvested in 3 hours from an old oyster rock. An adjacent station (No. 56), however, lacking a heavy shell content in the mud-sand substrate produced about 1 bushel in 2 hours of escalation. No hard clams were found above the Camp Peary-Clay Bank area.

Moderate abundance was encountered at three Mobjack Bay stations which yielded 10.9, 14.0, and 14.8 bushels per half-acre.

TABLE 1. Catch per unit of effort of *Mercenaria mercenaria* harvested in half-acre plots with a hydraulic escalator in 1968, 1969 and 1970 at selected locations.

Coll. No.	River and Location	Month and Year	MLW Depth (ft.)	Effort (hrs)	Total Catch (bu)	Catch/bu/hr Over-all	Catch/bu/hr First 2 hrs.	$\bar{x}$ no. per bu.	$\bar{x}$ wt. per bu. (lbs.)
	Y-Yorktown #1	6/68	6-8	12.0	15		1.5		
17	R-Morattico #1	9/68	7	7.8	0				
18	J-Hampton Flat 1	1/69	9	16.8	78.5	4.7	8.0	285	83.1
19	Y-Yorktown #5	7/68	6	6.0	14.5	2.4	2.5	223	75.6
20	J-Hampton Flats 2	7/68	8	4.5	43.8	9.7	9.5	265	82.0
21	J-Nansemond Ridge	2/69	8	6.0	21.5	3.6	6.0	354	83.1
22	Y-Goodwin Island #1	3/69	4-6	7.5	12.5	1.7	2.0	224	83.6
23	Y-Gloucester Point	3/69	6	9.0	17.0	1.9	3.0	218	82.7
24	Y-Goodwin Island #2	3/69	4-6	2.0	3.7	1.8	1.8	223	84.2
25	Y-Sandy Point	4/69	4-6	1.0	0.7	0.7	0.9	255	86.0
26	Y-Goodwin Island	4/69		3.5	3.4	0.9	0.9	255	86.0
27	ES-Cobb Island #1	5/69	4-6	1.3	1.0	0.8	1.0	612	97.8
28	ES-Cobb Island #2	5/69	4	2.0	2.0	1.0	1.0	330	83.1
29	ES-Terry's Ground	5/69	4	0.3	0.2	0.6			
30	ES			0.8	0.5	0.7		304	86.9
	Y-Yorktown #1 (rework)	6/69	6-8	2.8	0.8		0.3		
17	R-Morattico #1	7/69	7	6.3	0				
32	R-Morattico #2	9/69	10	12.8	0				
33	R-Parrotts Island	8/69	6-8	12.7	0				
34	R-Deep Hole Point	8/69	4-8	4.0	0				
35	R-Deep Hole Point	8/69	4-8	2.3	22 Clams				
36	R-Mosquito Point	8/69	4-8	2.5	101 Clams				
37	R-Deltaville	9/69	4-8	1.0	46 Clams				
38	R-Broad Creek	9/69	4-8	1.0	9 Clams				
42	Y-Yorktown, adjacent	10/69	4	2.0	1.2	0.6	0.6	236	90.0
43	Y-Yorktown, adjacent	10/69	6	2.0	2.3	1.2	1.2	206	85.5
44	Y-Yorktown #3	10/69	9	24.5	24.1	1.0	2.5	232	87.5

Procedure of sampling changed. Clams sampled in 12-foot circular path inside half-acre.

Coll. No.	River and Location	Month and Year	MLW Depth (ft.)	Effort (hrs)	Total Catch (bu)	Catch/bu/hr Over-all	Catch/bu/hr First 2 hrs	$\bar{x}$ no. per bu.	$\bar{x}$ wt. per bu. (lbs.)
45	Y- Gaines Point	1/70	4	2.5	7.0	2.8	3.1	275	89.0
46	Y- Gaines Point	1/70	9	2.5	4.7	1.9	2.0	306	86.5
47	Y- Allens Island	2/70	4	5.0	10.0	2.0	1.8	320	85.0
48	Y- Allens Island	2/70	9	6.4	17.6	2.8	3.5	298	91.9
49	Y-Below AMOCO	2/70	4	2.0	0.5	0.3	0.3		
50	Y-Below AMOCO	2/70	9	5.5	3.4	0.6	0.4	205	
51	Y-Sandy Point	2/70	4	6.0	2.4	0.4	0.6	221	86.2
52	Y-Sandy Point	2/70	9	0.8	8 Clams				
53	Y-Queens Creek	2/70	4	1.5	199 Clams				
54	Y-Queens Creek	3/70	9	3.5	134 Clams				
55	Y-Indian Field Creek	3/70	4	2.5	104 Clams				
56	Y-Green Point	3/70	4	2.0	332 Clams				
57	Y-Green Point	3/70	9	3.0	12.5	4.2	5.2	300	88.3
58	Y-Aberdeen Cr. (Leigh's)	3/70	14	2.0	144 Clams				
59	Y-Camp Peary (Walker's)	3/70	4	2.5	1.7	0.7	0.8	335	90.6
60	Y-Camp Peary (Walker's)	3/70	6	1.0	2 Clams				
61	Y-Allmondsville Whalf	4/70		2.6	0				
62	Y-Camp Peary (Leigh's)	4/70	4	0.5	0				
63	Y-Camp Peary (Leigh's)	4/70	6	0.5	0				
64	Y-Bell Rock (inshore)	5/70	4	0.5	0				
65	Y-Bell Rock (offshore)	5/70	4	0.5	0				
66	Y-Ware Creek	5/70	4	0.5	0				
67	Y-Skimino Creek	5/70	4	0.5	0				
68	Y-Poropotank (inshore)	5/70	4	1.0	0				
69	Y-Poropotank (offshore)	5/70	4	1.0	0				
70	Y-Mt. Folly	5/70	4	0.5	0				
19	Y-Yorktown #5 (rework)	5/70	6	1.0	0.8 (205 clams)				
23	Y-Gloucester Pt. (rework)	5/70	6	1.5	0.5 (88 clams)				
	Y-Yorktown #1 (rework)	5/70	6-8	1.0	0.2 (47 clams)		0.2		

Table 1 Part 3

Coll. No.	River and Location	Month and Year	MLW Depth (ft.)	Effort (hrs)	Total Catch (bu)	Catch/bu/hr Over-all	Catch/bu/hr First 2 hrs	$\bar{x}$ no. per bu.	$\bar{x}$ wt. per bu. (lbs.)
71	J-Hampton Roads	6/70	8-0	22.1	60.4	2.7	5.4	278	87.0
72	Y-Gaines Point	7/70	6-5	20.0	45.8	2.3	4.9	301	89.9
73	Y-Allens Island	8/70	9-0	15.4	26.4	1.7	7.7	357	88.7
74	Y-Goodwin Island	8/70	6-0	6.4	9.2	1.4	4.2	234	88.8
99	Mobjack Bay	9/70	9-0	6.0	10.9	1.5	5.1	241	91.1
103	Mobjack Bay	10/70	9-0	6.1	14.0	2.3	6.2	270	88.4
104	Mobjack Bay	10/70	6-0	5.5	14.8	2.7	7.4	274	94.4
105	Poquoson Flat	12/70	7-0	6.0	15.2	3.6	8.2	310	89.15

TABLE 2. Catch per unit effort of hard clams at 14 selected stations in Mobjack Bay.

Coll. No.	Sampling Time (mins.)	Total Catch	Catch Per Minute
85	5.5	3	0.5
86	4.1	11	2.7
87	11.0	81	7.4
88	4.7	25	5.3
89	2.8	125	44.6
90	8.2	16	2.0
91	5.4	41	7.6
92	6.1	36	5.9
93	7.3	22	3.0
94	5.4	34	6.3
95	9.7	26	2.7
96	4.4	14	3.2
97	6.5	26	4.0
98	7.3	75	10.3

The final sampling method used with the escalator dredge (previously described) for estimating the total number of hard clams present in a half-acre plot produced acceptable results. The error between the estimated total abundance and the actual amount harvested range from 0 to about 8% (Table 3). Catch rate observations were made every hour in areas of high abundance and every half hour in areas of lesser abundance. The number of observations necessary for predicting total catch was arbitrarily decided but the modal value was four. The decision was made when catch per unit effort plotted against time showed a steady decline. The percentage of error in an estimate of the total population was not independent of the number of observations employed. An example of this relationship is presented in Table 4. A total effort of about 22 hours was needed to remove all the hard clams (C/f $<$ 0.2 bushels/hr). An estimate of the population based on 5 hours, about 23% of the total effort, had an error of approximately 9.5%. The percentage of error steadily decreased as the number of observations increased until at 14 hours, about 63% of the total effort, an error was not discernible. The decline in error with increasing time is to be expected since the cumulative catch, from which the estimate is derived, is approaching the total catch. Operational costs and the desired degree of accuracy would determine the amount of effort expended in future sampling by this method.

In the lower Chesapeake Bay area there are many bars, flats, and oyster rocks that throughout their individual expanse are homogenous in substrate composition and other prevailing environmental conditions. Estimates made from randomly chosen plots in each area

TABLE 3. Comparison of the Estimated Total Abundance to the Observed Total Abundance Obtained From Half-Acre Plots With a Hydraulic Esculator

Sample Coll. No.	River and Location	Estimated Abundance (bu./0.5 acre)+	Required Time (hrs.)++	Observed Abundance (bu/0.5 acre)	Required Time (hrs.)	Percent Error
71	J- Hampton Flats	26.2	6.00	27.4 (60.4*)	22.1	4.37
72	Y- Gaines Point	33.6	5.00	32.1 (45.8*)	20.0	4.67
73	Y- Allens Island	24.4	4.00	26.4	15.4	7.57
74	Y- Goodwin Island	9.1	2.25	9.2	6.4	1.08
99	Mobjack Bay	10.9	2.25	10.9	6.0	0.00
103	Mobjack Bay	13.9	5.00	14.0	6.1	0.71
104	Mobjack Bay	15.9	5.50	14.8**	5.5	--
105	Poquoson Flats	14.3	3.75	15.2	6	5.92

\+ Includes total catch from plot corners.

++ Includes time for corner catches (range of 1-2 hrs.)

* Plots nos. 71 and 72 had 33 and 13.7 bushels of clams removed respectively, prior to initiating the sampling method.

** Operation ceased before plot was considered worked out; last observed catch was 1.7 bushels/hr.

TABLE 4. Relationship of the total population estimate error to the number of observational time units. Data for experimental plot no. 71. Total catch 27.4 bushels, harvested in 22.1 hours.

Estimated Abundance (bushels)	Time Units (hrs)	Estimate Error (%)
24.8	5	9.48
26.2	6	4.37
27.1	8	1.09
27.4	14	0.00

would give, on the average, acceptable estimates of abundance. However, in any area where the depth, current, substrate composition, etc. change significantly, estimates must be made for each sub-area type in the overall region.

Average Length and Percentages of Littleneck, Cherrystone and Chowder Clams

Mean lengths, in general, ranged from 64 to 70 mm for hard clam populations sampled at Nansemond Ridge, Hampton Flats, Poquoson Flats, and along the north shore of the York River at Allens Island and Gaines Point (Table 5). The observed average length, increased at Goodwin Island and Seaford sites on the southern shore of the York River; average lengths ranged from 74 to 78 mm. A similar range in mean length was encountered at Yorktown, Gloucester Point, Sandy Point, and Queens Creek. There was a definite decrease in sample mean lengths from Green Point to the Clay Bank area. Averages at these stations ranged from 65 to 70 mm. These statistics, however, are misleading. The small mean sizes are the result of clam stunting, and not good yearly recruitment as is the case in the lower James and York Rivers.

The distribution of relatively high percentages of the desirable littleneck class was associated with the distribution of high abundance and low mean length previously discussed. These statistics, in general, reflect successful yearly recruitment in the areas of their occurrence.

Cherrystones represent the modal class and high percentages occurred even at sites with a low percentage of littlenecks. The

TABLE 5. Mean size (mm) and size frequency distribution of littleneck, cherrystone and chowder hard clams observed in hydraulic escalator samples.

Coll. No.	Station Location	Sample Size	Mean Length	Standard Deviation	Size Frequency (%) Littlenecks	Cherrystones	Chowders
21	Nansemond Ridge	120	64.4	8.2	23.3	76.7	00.0
18	Hampton Bar	278	67.2	14.3	29.1	51.8	19.1
20	Hampton Bar	458	73.0	9.7	8.3	69.9	21.8
47	Allens Island	201	67.4	12.1	21.9	67.2	10.9
48	Allens Island	226	70.2	7.8	8.4	84.5	7.1
22	Goodwin Island	100	77.4	6.8	1.0	71.0	28.0
24	Goodwin Island	80	76.7	8.8	5.0	57.5	37.5
49	Seaford (AMOCO)	104	76.4	10.2	8.6	53.8	37.5
50	Seaford (AMOCO)	202	78.5	6.6	0.5	60.9	38.6
45	Gaines Point	133	73.9	9.9	11.3	60.2	28.6
46	Gaines Point	132	67.1	8.8	19.7	74.2	6.1
19	Yorktown	224	73.3	6.4	1.8	87.5	10.7
44	Yorktown	140	76.2	7.4	2.1	69.3	28.6
23	Gloucester Point	101	76.8	6.9	1.0	66.3	32.7
51	Sandy Point	222	76.0	12.7	11.7	46.8	41.4
55	Sandy Point	99	72.3	11.2	11.1	67.7	21.2

TABLE 5 - Continued

Coll. No.	Station Location	Sample Size	Mean Length	Standard Deviation	Size Frequency (%) Littlenecks	Cherrystones	Chowders
53	Queen's Creek	189	71.7	9.6	10.6	75.1	14.3
54	Queen's Creek	36	78.9	9.6	5.6	47.2	47.2
56	Green Point	157	65.3	14.0	22.3	69.4	8.3
57	Green Point	173	69.6	6.9	9.8	85.0	5.2
58	Aberdeen Creek	138	68.9	7.3	10.1	86.2	3.6
59	Clay Bank	154	67.7	6.6	12.3	85.7	1.9
60	Clay Bank	2	-	-	-	-	-
61	Allmondsville Wharf	0	-	-	-	-	-
62	Camp Peary	0	-	-	-	-	-
63	Camp Peary	0	-	-	-	-	-
64	Bell Rock	0	-	-	-	-	-
65	Bell Rock	0	-	-	-	-	-
66	Ware Creek	0	-	-	-	-	-
67	Skimino Creek	0	-	-	-	-	-
68	Poropotank	0	-	-	-	-	-
69	Poropotank	0	-	-	-	-	-
70	Mt. Folly	0	-	-	-	-	-

TABLE 5 Continued

Coll. No.	Station Location	Sample Size	Mean Length	Standard Deviation	Size Frequency (%)		
					Littlenecks	Cherrystones	Chowders
71	Hampton	229	71.3	13.8	20.1	53.3	26.6
72	Gaines Point	109	73.2	8.2	8.2	75.2	16.5
73	Allens Island	531	65.4	11.4	25.0	70.4	4.5
74	Goodwin Island	107	74.4	16.2	22.4	30.8	46.7
75	Allens Island	73	70.4	12.5	19.2	56.2	24.6
76	Allens Island	124	69.4	11.9	21.8	68.5	9.7
77	Allens Island	66	65.7	16.4	37.9	39.4	22.7
78	Poquoson	94	69.3	19.1	30.9	37.2	31.9
79	Poquoson	35	74.5	21.0	17.1	31.4	51.4
80	Poquoson	98	73.5	13.2	17.3	49.0	33.7
81	Poquoson	24	75.6	17.8	20.8	33.3	45.8
82	Swash	89	71.4	18.4	14.6	48.3	37.1
83	Swash	145	65.6	17.5	39.3	40.7	20.0
84	Swash	64	64.1	16.6	46.9	34.4	18.8
85	Mobjack	3	90.0	4.6	00.0	00.0	100.0
86	Mobjack	11	67.8	23.8	18.2	54.5	27.3
87	Mobjack	81	77.3	8.9	3.7	54.3	42.0
88	Mobjack	25	69.2	19.2	20.0	48.0	32.0

TABLE 5 - Continued

Coll. No.	Station Location	Sample Size	Mean Length	Standard Deviation	Size Frequency (%)		
					Littlenecks	Cherrystones	Chowders
89	Mobjack	125	71.9	7.3	4.0	86.4	9.6
90	East River	16	71.2	11.5	12.5	68.8	18.8
91	Mobjack	41	62.7	15.8	26.8	73.2	00.0
92	Mobjack	36	70.1	14.1	8.3	80.6	11.1
93	Mobjack	22	73.6	14.0	18.2	40.9	40.9
94	Mobjack	34	77.1	14.1	20.6	29.4	50.0
95	Mobjack	26	73.4	17.9	15.4	42.3	42.3
96	Mobjack	14	68.2	17.3	28.6	50.0	21.4
97	Mobjack	26	74.0	14.3	15.4	42.3	42.3
98	Mobjack	75	74.5	8.8	5.3	74.7	20.0
99	Mobjack	121	74.7	9.8	4.1	66.9	28.9
100	Mobjack	185	71.9	5.9	4.1	91.9	3.8
101	Mobjack	120	74.5	9.1	6.7	66.7	26.7
102	Mobjack	145	68.6	8.4	11.7	85.5	2.8
103	Mobjack	120	71.9	11.3	18.3	60.0	21.7
104	Mobjack	121	72.4	9.8	13.2	67.8	19.0
105	Poquoson	259	70.6	14.7	25.1	48.3	26.6

particularly high percentage of cherrystones present in samples from the Green Point to Clay Bank range is again due to stunting and the clams would be marketable only as chowders.

The higher percentages of chowder clams paralleled the distributions of large mean length and low abundance. A range of about 30 to 47%, with a few exceptions, was observed for stations along the north shore of the York River and those in the general vicinity of the Coleman Bridge. Even in some areas where vigorous growth and good recruitment were indicated, a relatively high percentage of chowder clams, approximately 19 to 34%, was present. Areas of good recruit in shoal water ($\leq$18 ft MLW) such as Hampton Flats, Poquoson Flats, Allens Island, and Gaines Point are subject to little or no hard clam harvest by patent tong clammers. It is conceivable that exploitation of these populations would reduce intraspecies competition for food and space. The results would be the enhancement of recruitment and growth (where food is a limiting factor) and a decline in the average size. The latter effect would increase the value of the standing crop. Regulation and study of the exploitation would be necessary to establish a desirable sustained yield.

<u>General Distribution and Abundance</u>: <u>Hydraulic Tow Dredge</u>

Establishment of the Sequential Plan

To distinguish between low and medium hard clam densities the alternative hypotheses established were:

Ho: the catch is 6 or less clams per 50 linear feet.

Hi: the catch is 14 or more clams per 50 linear feet.

To choose between medium and high densities the alternative hypotheses were:

Ho: the catch is 21 or less clams per 50 linear feet.

Hi: the catch is 29 or more clams per 50 linear feet.

In terms of expected harvest per acre the above hypotheses can be approximately equated to: 1) low density $\leq$ 14 bushels/acre; 2) medium density $\geq$ 32 bu/acre but $\leq$ 49 bu/acre; and 3) high density $\geq$ 67 bu/acre. These limits, as previously stated, were established from a priori knowledge. A Virginia patent tong fishery exists (or could exist) in areas of density defined as medium and high in this report. Some low density areas are sometimes worked when only they are accessible during adverse weather conditions, or when a small but dense concentration of clams is discovered.

When one of the paired alternative hypotheses is accepted, two possible errors may (or may not) occur. The first one is called a Type I or α error which occurs when the H_o hypothesis is true but rejected. The second incorrect decision is called a Type II or β error and could be made when the H_o hypothesis is false but accepted. Of course, no error is committed when the correct choise is made. It was felt that a 10 percent risk for both α and β was sufficiently conservative for our survey work.

The decision lines for each pair of parallel lines are

Lower line:

$$C/f = [\sigma^2/(\emptyset_1 - \emptyset_o)] \log_e[\beta/(1-\alpha)] + n(\emptyset_1 + \emptyset_o)/2$$

Upper line:

$$C/f = [\sigma^2/(\emptyset_1 - \emptyset_o] \log_e[(1-\beta)/\alpha] + n(\emptyset_1 + \emptyset_o)/2$$

these equations have the linear form

$$Y = a + b\ x$$

where $C/_f$ is the cumulative catch of hard clams, σ^2 is the variance (estimated by s^2), Ø's are average catch values per sample unit stated above in the hypotheses, α and β are the assigned risks, and n is the number of tows. The lower line of each parallel pair must have a negative intercept, therefore, the fraction $\beta/(1-\alpha)$ was inverted without a change in sign which was the equivilant of taking a negative logarithm. The values for these equations are given in Table 6.

To obtain these values it was first necessary to ascertain the nature of the frequency distribution of the tow dredge sample data. It was suspected because of the findings of Saila et al. (1965) that our sample data would be normally distributed. In addition, though it is well documented that hard clams have a contagious distribution, it was reasoned intuitively that the continuous tow of the dredge in a sample would integrate the catch from group to group. To test for a normal distribution of the sampling data, 90 standard tows were made at Poquoson Flats. The observed catches per 50 linear feet were grouped into nine intervals. The frequency distribution was then statistically contrasted to a theoretical normal distribution for the data by a chi-square "goodness of fit" test. No significant difference could be found between the observed and theoretical frequencies (Table 7); thus, the catch data were reasonably described by a normal distribution.

Table 6. Values for the sequential sampling decision line.

	Low vs Medium	Medium vs High
$\alpha = \beta$	10%	10%
Slope (b)	10	25
Intercept (a)	22	22
Average ($\emptyset_o$)	6	21
Average ($\emptyset_1$)	14	29
Variance (s^2)	79.1	79.1

Table 7. Chi square (X^2) goodness of fit test of the observed distribution to a normal distribution for 90 standard tows ($\bar{x}$ = 26; s^2 = 79.1; α = 0.05).

Catch Interval	End Point	Standard Deviation From Mean	Probability	Expected Frequency	Observed Frequency	Contribution to Chi Square
0 - 9	9	-1.91	0.0280	2.5	2	0.10
10 - 14	14	-1.34	0.0621	5.6	10	3.45
15 - 19	19	-0.78	0.1276	11.5	5	3.67
20 - 24	24	-0.22	0.1952	17.6	23	1.65
25 - 29	29	0.33	0.2164	19.5	21	0.11
30 - 34	34	0.89	0.1840	16.6	15	0.15
35 - 39	39	1.46	0.1145	10.3	7	1.05
40 - 44	44	2.02	0.0505	4.5	5	0.05
45 - 49	49	2.58	0.0167	1.5	2	0.16

Total contribution to X^2 = 10.39 (not significant; $X^2_{0.95(6)}$ = 12.59

Sequential Classification

The sequential sampling method was applied at 215 stations. During the course of the project a few stations were incompletely sampled because of occasional mechanical problems, inclement weather, or time limitations. Those stations which were needed to define a general area were revisited and sampling completed. The distribution and abundance classification of stations is shown in Figures 3, 4, 5, and 6, and catch data are presented in Table 9. Each general area is discussed separately.

Mobjack Bay

A total of 19 stations were sampled in Mobjack Bay ranging from its mouth back to the mouths of the North and Ware Rivers (Figure 3). No samples were taken beyond the mouths of any of the rivers entering Mobjack Bay.

All stations, with the exception of one, were classified as having a low abundance of hard clams. The one excepted station (No. 714) had a medium density of hard clams and occurred near the eastern shore of Mobjack Bay at the depth encompassed by the 6 to 12 ft. contour lines. The findings at this station was in near agreement with the data for three stations previously sampled in this range of depths with the hydraulic escalator. The total abundance at the three sites was 11, 14 and 15 bushels of clams per half-acre. The latter two are just below the lower boundary established for medium classification in sequential sampling. The lower catch would be about midway between a low or medium classification. While the substrate between the 6 to 12 feet depths of the eastern shore of Mobjack Bay, in general, may have a medium density of hard clams,

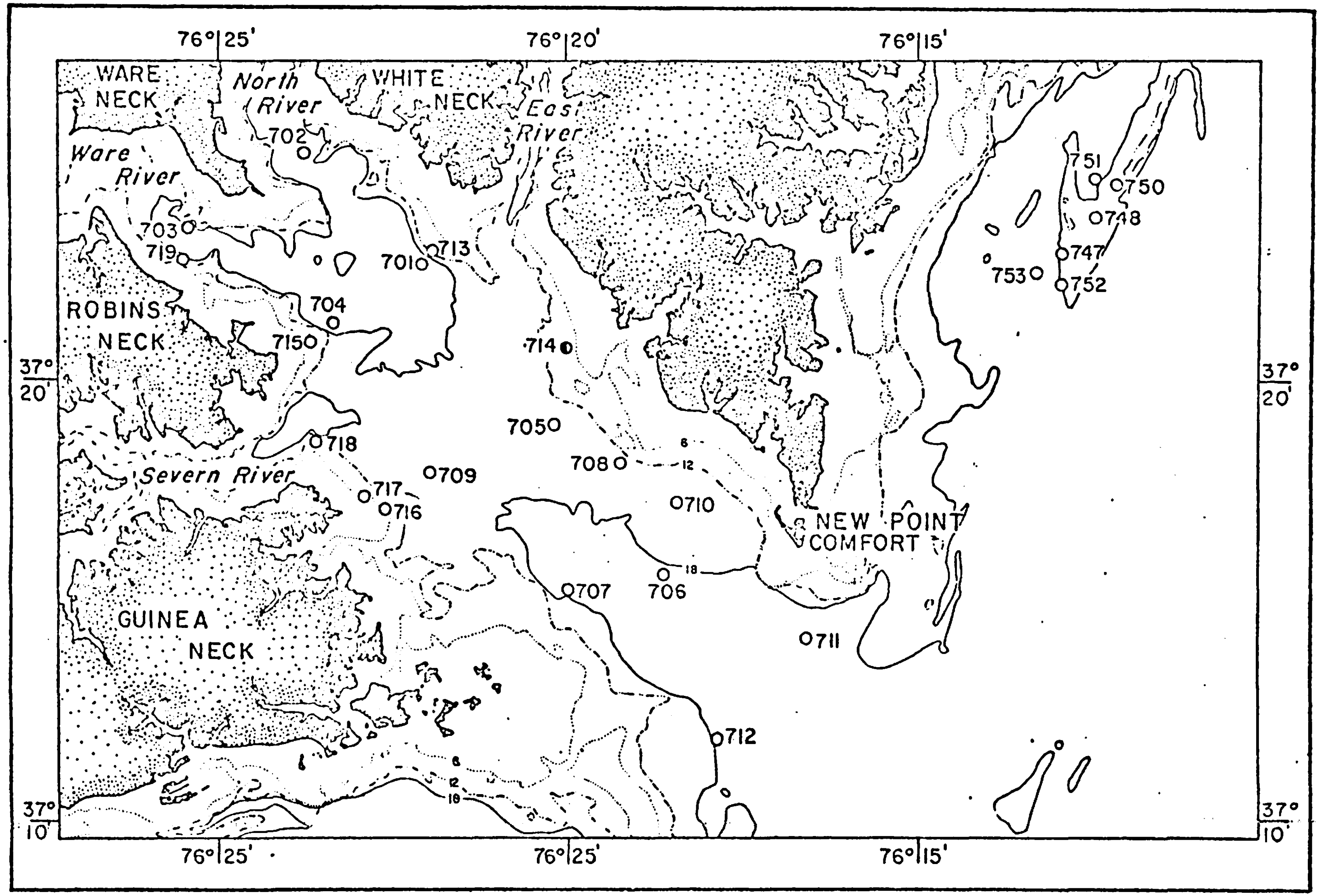


Figure 3. Sequentially sampled stations in Mobjack Bay and Wolf Trap areas. Abundance code: high, closed circles; medium, half-closed circles; low, open circles; and no decision, crosses.

that area constitutes a small percentage of the bay. Most of the bay is of greater depth with a low density of clams.

York River

In the York River and the adjacent areas of York Spit and south along the Poquoson Flats, 67 stations were sampled.

Abundance was generally low in the shoal water (6 to 18 feet, MLW) along the south side of the river with medium abundance encountered only near Yorktown, Goodwin Island and Tue Point (Nos. 612, 609 and 700, respectively).

Medium to high abundance was recorded at the shoal water stations (6 to 18 feet, MLW) along the north side of the York River from its mouth to approximately Sarah Creek. A relatively large percentage of the shoal area from about Sarah Creek downriver to the Perrin River are leased oyster grounds which are no longer productive, with respect to oysters, since the advent of MSX.

The hard clam density distribution defined by sequential sampling in the shoal areas of the lower York River (i.e., downriver of the Coleman Bridge) parallels that previously found with hydraulic escalator sampling.

A commercial hard clam fishery in deeper water ($>$ 18 feet, MLW) presently exists in the vicinity of the Coleman Bridge from about 2 miles above it to approximately 1 mile below the bridge. Our sampling indicated mostly heavy and medium abundance in this area (Figure 4). Downriver, below the fishery, to the mouth of the York River, low abundance was recorded at all deepwater stations, with the exception of No. 754, located just inside the mouth of the river at a depth of

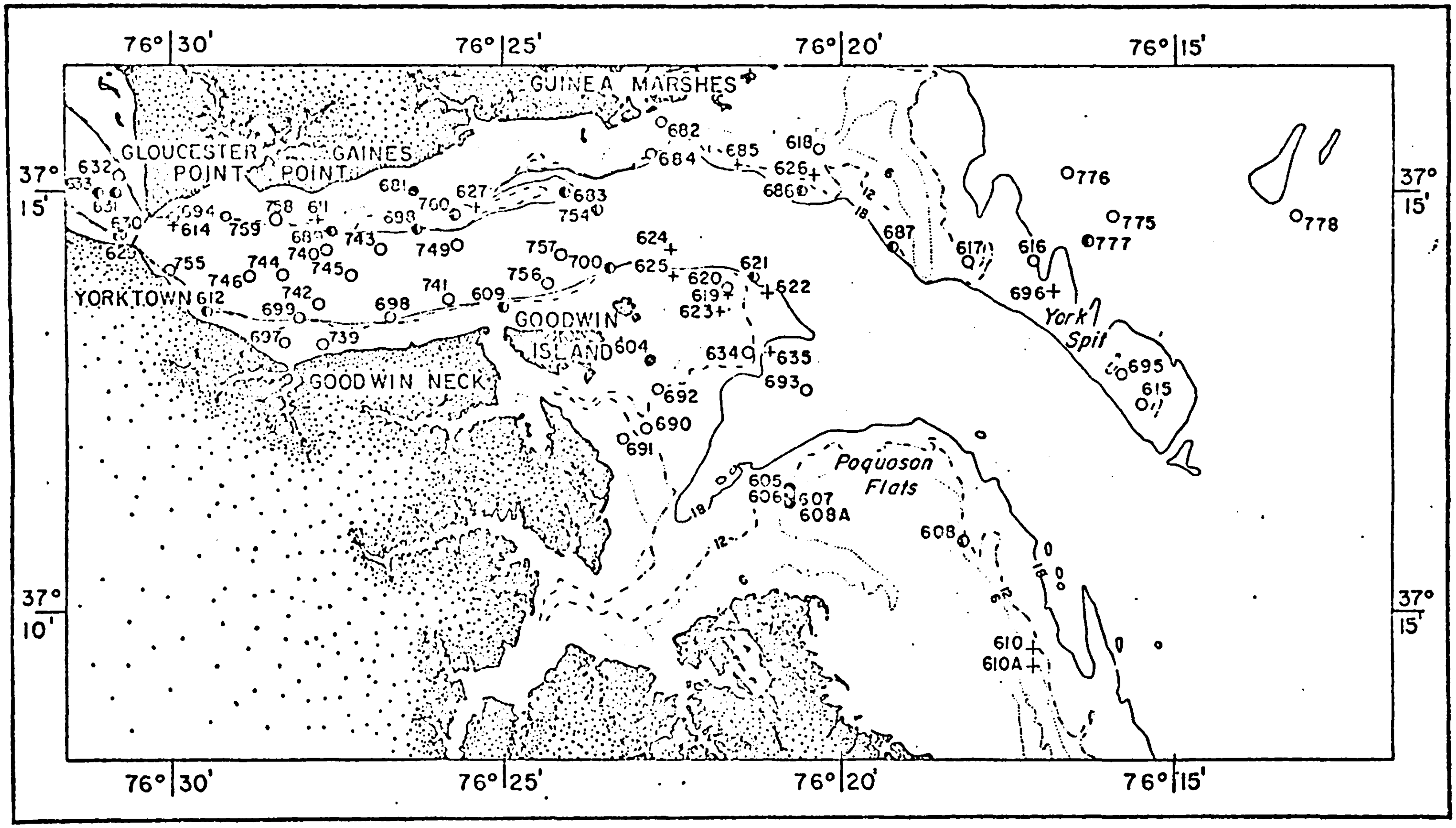


Figure 4. Sequentially sampled stations in the lower York River and Poquoson Flats area. Abundance code: high, closed circles; medium, half-closed circles; low, open circles; and no decision, crosses.

28 feet, which indicated medium density at that site.

Sampling stations at the mouth of the York River, in the area of Back Creek and along the York Spit were predominantly sites of low hard clam abundance. In contrast, most stations in the Poquoson Flats area were classified as high or medium abundance (Figure 4).

Chesapeake Bay

Abundance was low at all six stations sampled in the area just below Wolf Trap (Figure 3). Similar results were obtained at stations 775, 776 and 778 located between New Point Comfort Shoal and York Spit (Figure 4). Station 777 had a medium abundance of hard clams. Patent tongers occasionally work at this site and the immediate surrounding area. All 13 stations sequential sampled between depths from 6 to 18 feet (MLW) at Horseshoe and Thimble Shoal were classified as low abundance (Figure 5). Two adjacent deepwater stations (Nos. 678 and 679) also had a low density of clams. Twelve stations were sampled at Willoughby Bank. Stations toward the entrance to Hampton Roads had a low density of clams, but those south and east near Crumps Bank were mostly high or medium densities of hard clams.

Lower James River (Hampton Roads)

In the area from Old Point Comfort to the Hampton River (Figure 6), 17 stations were sampled and only high and low densities of hard clams were indicated. High abundance was associated with those stations in water depths about 8 feet (MLW) or deeper and not adjacent to

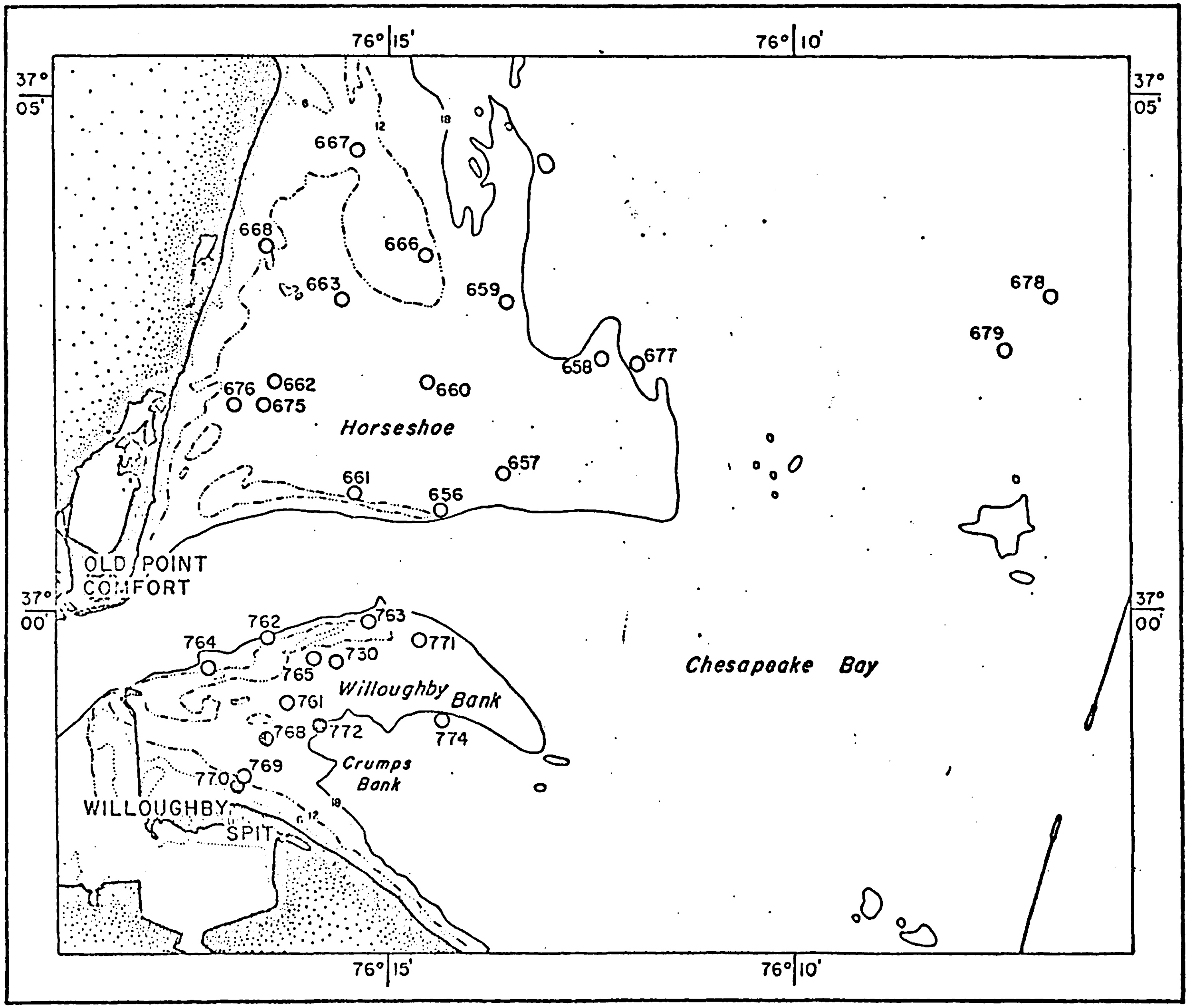


Figure 5. Sequentially sampled stations in the Horseshoe and Willoughby Bank areas. Abundance code: high, closed circles; medium, half-closed circles; low, open circles; and no decision, crosses.

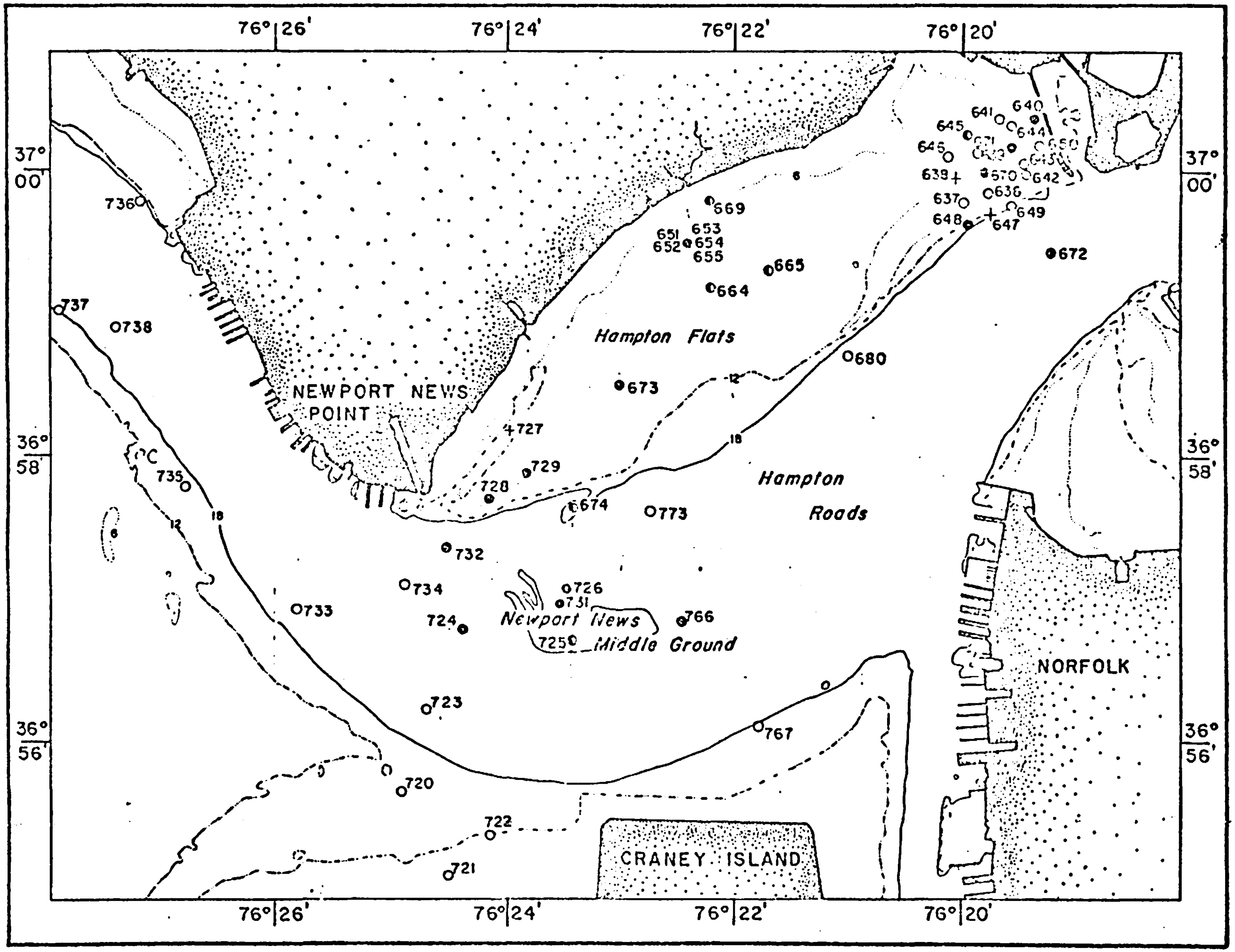


Figure 6. Sequentially sampled stations in the lower James River. Abundance code: high, closed circles; medium, half-closed circles; low, open circles; and no decision, crosses.

channels. Low abundance was associated with stations adjacent to channels (possibly due to siltation). Stations in the shoaler water (> 6 feet MLW) also had low abundance, these sites are subject to freezing and scraping by ice flows when they are exposed in the winter.

Six of nine stations sampled on Hampton Flats between a depth of 6 to 12 feet (MLW) indicated a high abundance of hard clams; the other three sites were classified as medium density. Previous sampling in this area of Hampton Flats with the hydraulic escalator produced between 60 to 80 bushels of hard clams per half-acre. Obviously, there are heavy densities of hard clams in Hampton Flats. Most of this area was privately leased oyster grounds, however, since the advent of MSX, many leases had been abandoned.

In a "corridor" across the lower James River, approximately defined by Salters Creek and upriver to Newport News Point on the north shore, and Craney Island to Streeter Creek on the Portsmouth shore, there were distinct distributions of abundance. High abundance was present, in general, at the stations located between the Newport News shore and the Middle Ground (Figure 6), while at the latter site medium abundance was found. Further across the channel (south) to the Craney Island vicinity only low densities of hard clams were encountered. It is possible that the creation of the Craney Island disposal area is responsible for the siltation in this area, and consequently, the low density of clams.

Upriver from Newport News Point, five stations were sampled and all were classified as low abundance, with the exception of station

738 which was high (Figure 6). The deeper water off Newport News area, however, is fished by patent tongers during the open seasons and their catches indicate a relatively high abundance. Unfortunately, the excessively deep water ($>$ 60 feet) and obstructions on the bottom at some sites prevented tow dredge sampling.

Eastern Shore

The 35 tow dredge samples taken along the bayside of the Eastern Shore were geographically distributed from Cape Charles to Pocomoke Sound (Figure 7) in water depths ranging from 11 to 34 feet (Table 8).

Only one hard clam was taken in the first 21 samples collected from the area off Cape Charles to that off Occahannock Neck (Table 8). Relatively consistent catches of hard clams occurred at stations 22 through 35, located in the area off Nandua Creek to Pocomoke Sound. The estimate of catch per square foot of substrate sampled at a given station on the Eastern Shore is based on only one tow at each site; thus, data for an individual station is not as reliable as when a station is classified by sequential sampling. However, the short range of this statistic, 0.02 to 0.03, and an average catch of 0.036 clam per square foot sampled, and the consistent sampling results among stations in each general area, indicated a sparse population of hard clams existed in the range of depths sampled. An extremely low correlation coefficient ($r = -0.15$), determined from the catch data of 11 stations, indicated no relationship between sample catch per square foot and water depth at the sampling sites.

Figure 7. Location of 35 Eastern Shore tow dredge sampling stations.

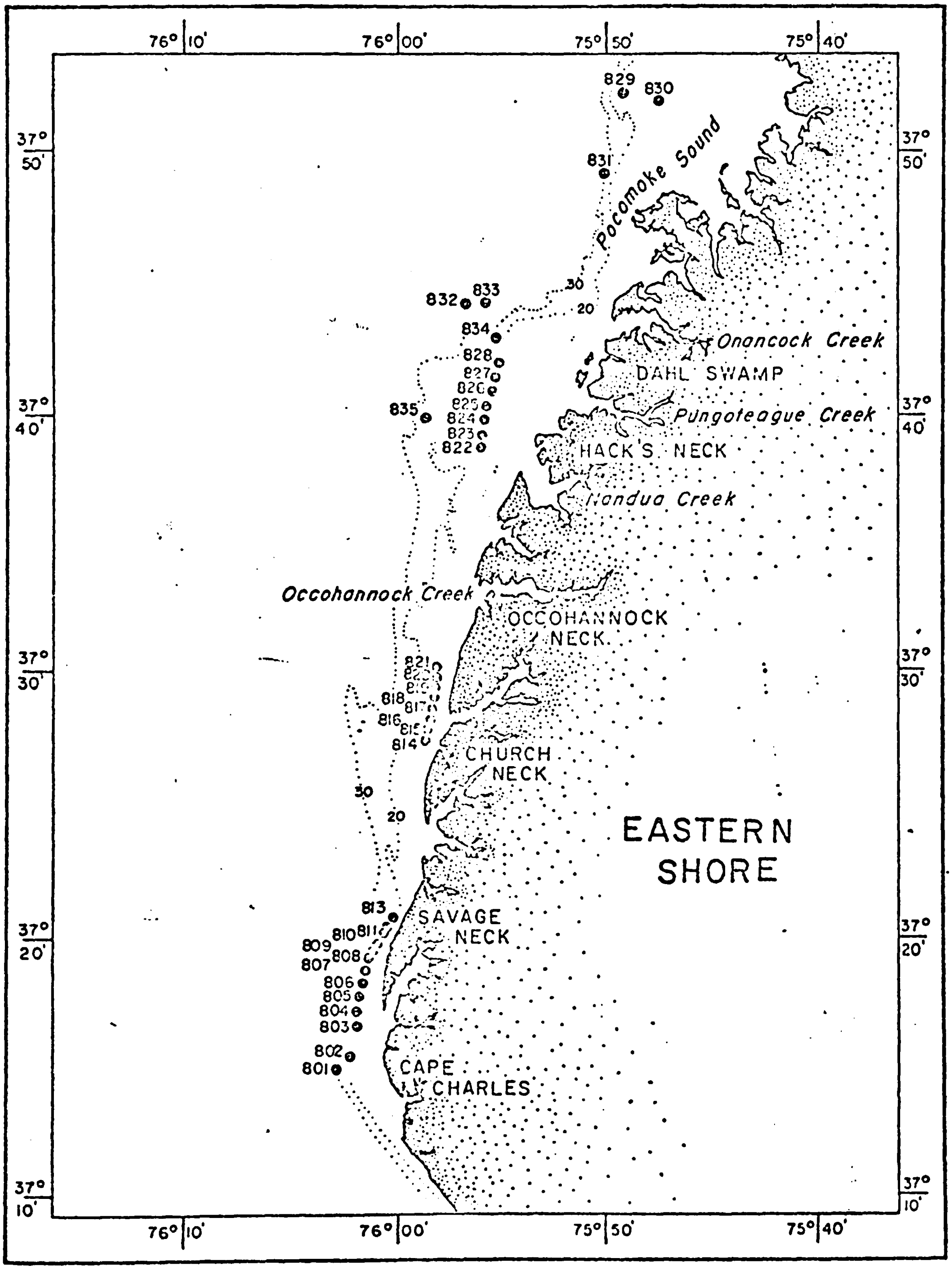


Table 8. Tow dredge sampling data for 35 Eastern Shore stations.

Station Number	Tow Distance (ft)	Water Depth (ft)	Total Catch	Catch per ft.^{2}
1	100	21	0	
2	100	11	0	
3	50	12	0	
4	50	12	0	
5	50	12	0	
6	50	12	0	
7	50	13	0	
8	75	14	0	
9	50	14	0	
10	50	13	0	
11	50	13	0	
12	50	12	0	
13	50	16	0	
14	50	15	0	
15	50	15	0	
16	50	18	0	
17	50	17	1	0.02
18	75	18	0	
19	100	14	0	
20	50	15	0	
21	50	13	0	
22	50	13	0	
23	50	13	1	0.02
24	50	16	2	0.03
25	50	19	0	
26	50	12	2	0.03
27	50	13	0	
28	50	12	3	0.05
29	50	17	4	0.06
30	50	17	0	
31	50	12	2	0.03
32	150	17	9	0.05
33	150	34	6	0.03
34	150	26	5	0.03
35	150	33	5	0.03

Average Length and Percentages of Littleneck, Cherrystone and Chowder Clams

All average lengths and the percentages of the three size categories for each station are reported in the Appendix (Table B). However, statistics derived from small samples ($n \leq 75$) must be interpreted with caution.

Data in Table 9 indicates that the higher percentage of littlenecks and cherrystones was associated with stations sequential classified as sites of a medium or high abundance, conversely, the higher percentage of chowder clams was associated with the station classified as sites of low density. The percentage frequency of the three size classes have arbitrarily been grouped into three relative frequency classes (low, moderate and high) to facilitate discussion (Table 10). Class limits for littlenecks are approximately half those for cherrystone and chowder clams because the efficiency of the tow dredge with respect to small clams is not known, nor is the change in efficiency with a change in substrate type known. Thus, catch per unit effort should not be converted to numbers per unit area without exercising extreme caution when contrasting the latter measure of abundance because of these sources of error. Individual station data have been grouped into 15 general areas to avoid the problem of small samples, and to facilitate comprehension of the data (Table 11). The average length in each general area was compared to a 70.5 mm base-line length, the midpoint of the cherrystone length interval and referred to here after as the M.P.

The average length of hard clams sampled in Mobjack Bay (72.7 mm) exceeded the M.P. Cherrystones occurrence was very high(65%) while littlenecks and chowder clams were low (11 and 24%, respectively).

Table 9. Association of occurrence of littleneck, cherrystone, and chowder clams with sequential classification of abundance.

Relative Abundance	Sample Size	Length Frequency (%)		
		Littlenecks	Cherrystone	Chowders
Low	1911	17	44	38
Medium	3200	19	50	32
High	2256	20	48	32

Table 10. Relative frequency classification of the percentage frequency of occurrence of littleneck, cherrystone, and chowder clams.

Relative Frequency	Percentage Frequency		
	Littleneck	Cherrystone	Chowder
Low	≤ 13	≤ 29	≤ 29
Moderate	14-19	30-39	30-39
High	≥ 20	≥ 40	≥ 40

The low percentage of littlenecks and the high percentage of cherrystones probably reflected poor recruitment and slow growth, respectively. Both conditions are believed to be, in part, a function of the soft, silty substrate encountered at most stations samples in Mobjack Bay.

An average length of 74.7 mm at the six stations sampled just south of Wolf Trap exceeded the M.P. The occurrence of littlenecks was high (25%), but cherrystones were low and chowders were high (28 and 47%, respectively). The high percentage of littlenecks apparently reflected recent recruitment (within the last 3 or 4 years); however, all stations had low abundance, thus, recruitment must be sporadic. The high percentage of chowder size clams and the relatively large mean size were indicative of all old population.

The York Spit and Swash areas had very similar hard clam catch statistics except for the arbitrary classification of littlenecks (moderate and low, respectively). Average lengths in both these low density areas exceeded the M.P.; also both areas had a high percentage of cherrystone and chowder clams (43 and 46% and 40 and 41%, respectively). Recruitment is probably low to moderate.

Along the north shore of the lower York River, the average length (70.3 mm) for samples taken in 6 to 18 feet (MLW), was less than the M.P. This area had the highest occurrence of cherrystones (66%), a moderate occurrence of littlenecks (15%), and a low occurrence of chowder clams (19%) indicating reasonably good recruitment. Stations in this area from inside the mouth of the York River and upriver to Gaines Point were, in general, recorded as medium or high abundance sites. The percentage of cherrystones at these stations was very high, ranging from 63 to 80%, and, conversely, the percentage of chowder clams

Table 11. Average length and size frequency distribution of littleneck, cherrystone and chowder hard clams in hydraulic tow dredge samples. Catch data for individual stations were grouped into general areas.

	Sample Size	Average Length (mm)	Standard Deviation	Size Frequency (%) Little-necks	Cherry-stones	Chowders
Mobjack Bay	511	72.7	10.9	11	65	24
Wolf Trap	214	74.7	19.3	25	28	47
York Spit	295	74.4	15.2	16	43	40
Lower York Rv. (Swash)	545	74.8	14.5	13	46	41
Lower York Rv. (North Shore, 6-18 ft MLW)	817	70.3	12.6	15	66	19
Lower York Rv. (Coleman Bridge area)	732	63.5	14.2	36	56	9
Lower York Rv. (South Shore, 6-18 ft MLW)	285	76.4	9.9	7	57	36
Lower York Rv. (> 18 ft MLW)	168	70.6	12.1	15	65	20
Tue Marsh - Back Creek	1013	72.2	15.8	19	46	35
Poquoson Flats	1063	73.4	15.6	20	43	37
Horseshoe-Thimble Shoals	85	79.4	26.6	24	20	56
Willoughby-Crumps Banks	580	69.7	21.0	23	42	36
Lower James Rv. (Hampton Bar)	766	79.5	15.3	10	36	54
Lower James Rv. (Hampton Flats)	700	75.2	13.4	12	47	41
Lower James Rv. (> 18 ft MLW)	1160	69.4	16.1	23	51	25

was relatively low, ranging from 7 to 21%. Further upriver, however, in this same depth range between Quarter Point and Gloucester Point at stations 758 and 759, no hard clams were taken in six standard (50-ft) tows.

In the general vicinity both above and below the Coleman Bridge where a patent tong fishery exists in the deeper water ($>$ 18 ft MLW), the sample average length, 63.5 mm, and the occurrence of chowder clams (9%) were the lowest recorded. The percentage of littlenecks was, also, the highest recorded (36%) and the occurrence of cherrystones (56%) was exceeded in only four other areas. A reduction in older age groups and, consequently, a decrease in average size is common among stocks commercially fished. It is believed, in addition, because most sampling (and commercial fishing) was conducted in a depth $>$ 30 feet, the higher salinities in this part of the York River estuary favors clam spat set and survival.

Along the south shore of the lower York River the average length for samples taken in 6 to 18 feet (MLW), 76.4 mm, greatly exceeded the M.P. Littleneck catch was the lowest of all areas (7%), while the percentage of chowders was moderate (36%), and cherrystones (57% occurrence) were in the higher part of their assigned length range. Thus, it appears to be an area of poor recruitment.

In the deeper water ($>$ 18 ft MLW) of the lower York River below the Coleman Bridge area the average length, 70.6 mm, was about equal to the M.P. Hard clams in this section of the river are commercially fished to a moderate degree which may account for the high percentage of cherrystones and the low percentage of chowder clams (65 and 20%, respectively). The occurrence of littlenecks was moderate (15%), and reasonably good recruitment is indicated.

The Tue Marsh-Back Creek and the Poquoson Flats area had very similar catch data. Both average lengths (72.2 and 73.4 mm, respectively) exceeded the M.P. The respective occurrence of littlenecks (19 and 20%) and cherrystones (46 and 43%) was high indicating good recruitment, while chowder clams (35 and 37%) were moderate.

Average length and percentage of chowder clams (79.4 mm and 56% respectively) for the Horseshoe-Thimble Shoals area were extremely high. The high percentage of littlenecks (24%) and the low percentage of cherrystones (20%) apparently indicate a reasonable amount of set but poor survival of clam spat. The large standard deviation (26.6 mm) reflected the large variation among average lengths of individual station samples. The average sample lengths ranged from 43 to 106 mm (Appendix, Table B); however, most sample sizes were small and, thus, their accuracy cannot be considered reliable.

The Willoughby-Crumps Banks area had the third lowest estimated average length (69.7 mm). The percentages of littlenecks and cherrystones was high (23 and 42%, respectively) while the occurrence of chowder clams was moderate (36%). The statistics probably reflected the activity of patent tong fishing in this area and, also, good recruitment.

Average length (79.5 mm) for the Hampton Bar samples was the highest of all 15 areas. In addition, the occurrence of littlenecks (10%) was the second lowest estimate and the percentage of chowders (54%) was the second highest. It apparently is an older population of clams which has poor recruitment or survival of clam spat.

The average length (75.2 mm) for the Hampton Flats samples exceeded the M.P. The percentages of cherrystones (47%) and chowders

(41%) were high, while that for littlenecks was low (12%), however, their absolute abundance is high relative to other areas. Nearly all stations on Hampton Flats were sequentially classified as high density sites. These findings substantiated previous data obtained with a hydraulic escalator in which 60 and 78 bushels of clams were harvested from half-acre plots. It is reasonable to assume that at these densities there is intraspecies competition for food and space, and a reasonable harvest would favor clam spat survival and, thus, increase the percentage of littlenecks.

In the deeper water ($>$ 18 ft MLW) of the lower James River an active patent tong fishery operates during the open season. As would be expected, the average length (69.4 mm) was low, and, correspondingly, the percentages of littlenecks (23%) and cherrystones (51%) were high and the occurrence of chowder clams was low (25%). The area is one of good recruitment.

SUMMARY

1. Mobjack Bay: A medium abundance of hard clams was noted at one station in the bay, but 18 other stations were sequentially classified as sites of low abundance.
2. York River: Medium to high densities of hard clams were present at the mouth and upriver along the north side in depths between 6 to 18 feet (MLW) to approximately the mouth of Sarah Creek. These grounds have lain fallow with respect to oysters since the advent of MSX. Abundance was generally low in the shoaler water ($<$18 feet, MLW) along the south side of the river. Sampling stations in deeper water ($>$18 feet, MLW) in the general vicinity from about 2 miles above to about 1 mile below the Coleman Bridge were mostly classified as sites of medium and high abundance.
3. Chesapeake Bay: Low abundance was recorded from just below Wolf Trap south to Willoughby Bank. However, medium and high abundance were noted along the interface of Willoughby and Crumps Banks.
4. James River (Hampton Roads): In general, the north side had an extremely high density of hard clams. The Newport News Middle Ground exhibited both high and medium density stations. South, across Hampton Roads to the Craney Island area abundance dramatically decreases to a near total absence of hard clams.

   Upriver from Newport News Point, four out of five deepwater stations indicated low abundance. However, the area along the docks on the Newport News side which could not be sampled with the tow dredge is commercially harvested during the open season.

5. High percentages of littleneck and cherrystone hard clams were, in general, associated with areas of medium and high abundance, and particularly with areas where clams are commercially harvested. Average lengths were noticably smaller in the latter areas. A relatively large average length and high percentage of chowder clams were associated with areas of low density.
6. An average catch of 0.036 clam per square foot indicated a sparse population of hard clams at the range of depths sampled (13 to 34 feet) along the Eastern Shore from Nandua Creek to Pocomoke Sound. Down bay from Occahannock Neck to Cape Charles only one hard clam was taken in 21 samples.
7. Good recruitment of hard clams as indicated by high abundance, low average length, and high percentages of littlenecks and cherrystones occurred in the areas of the lower York River (north shore), Coleman Bridge vicinity, Tue Marsh-Back Creek, Poquoson Flats, Willoughby-Crumps Banks, Hampton Flats, and the lower James River (except in the Craney Island vicinity). Moderate recruitment. moderate recruitment was indicated for the York Spit, Swash, and lower York River (> 18 ft MLW) areas. Poor recruitment was indicated for the areas of Mobjack Bay, Wolf Trap, the lower York River (south shore), Horseshoe-Thimble Shoals, Hampton Bar, and the bayside of the Eastern Shore.

APPENDIX FOR JOB I

Table A. Conversion of millimeters (mm) to inches by the formula: (mm) (2.937×10^{-2}) = inches.

Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches
60	2.36	71	2.79	82	3.22	93	3.66
61	2.40	72	2.83	83	3.26	94	3.70
62	2.44	73	2.87	84	3.30	95	3.74
63	2.48	74	2.91	85	3.34	96	3.77
64	2.51	75	2.95	86	3.38	97	3.81
65	2.55	76	2.99	87	3.42	98	3.85
66	2.59	77	3.03	88	3.46	99	3.89
67	2.63	78	3.07	89	3.50	100	3.93
68	2.67	79	3.11	90	3.54	101	3.97
69	2.71	80	3.14	91	3.58	102	4.01
70	2.75	81	3.18	92	3.62	103	4.05

Table B. Mean size (mm) and size frequency distribution of littleneck, cherry-stone and chowder hard clams observed in hydraulic tow dredge samples.

Coll. No.	Station Location	Sample Size	Mean Length	Standard Deviation	Size Frequency (%) Littlenecks	Cherrystones	Chowder
601	Poquoson Flats	492	72.2	15.0	19.9	48.4	31.7
602	Hog Island	133	73.2	9.8	8.3	69.2	22.6
603	Tue Point	177	74.6	11.7	9.6	55.9	34.5
604	Tue Point	137	67.7	14.4	32.8	43.8	23.4
605	Poquoson Flats	102	72.0	17.6	23.5	38.2	38.2
606	Poquoson Flats	128	73.0	13.5	22.6	45.3	32.0
607	Poquoson Flats	172	72.6	15.6	21.5	43.6	34.9
608	Poquoson Flats	93	77.1	16.4	12.9	33.3	53.8
609	Goodwin Island	170	76.3	11.0	10.0	51.2	38.8
610	Chesapeake Bay	76	81.3	16.4	10.5	21.0	68.4
611	Gaines Point	146	68.2	10.8	17.1	72.6	10.7
612	Yorktown	86	75.9	8.1	2.3	69.8	27.9
613	Allens Island	150	68.2	9.8	13.3	80.0	6.7
614	Gloucester Point	39	74.2	12.0	15.4	41.0	43.6
615	York Spit	1	-	-	-	-	-
616	York Spit	9	55.4	12.5	66.7	33.3	0.0
617	York Spit	10	61.3	25.3	60.0	0.0	40.0
618	Swash	11	77.9	18.6	9.1	45.4	45.4
619	York Spit	4	89.2	3.9	0.0	0.0	100.0
620	Chesapeake Bay	18	57.6	19.6	50.0	44.4	5.6
621	Chesapeake Bay	98	75.9	17.3	9.2	38.8	52.0
622	Chesapeake Bay	26	63.8	17.3	34.6	46.2	19.2
623	Chesapeake Bay	18	75.6	10.0	11.1	50.0	38.9
624	Chesapeake Bay	23	79.8	5.5	0.0	52.2	47.8
625	Chesapeake Bay	89	72.3	14.0	22.5	44.9	32.6

Table B (Continued)

Coll. No.	Station Location	Sample Size	Mean Length	Standard Deviation	Size Frequency (%)		
					Littlenecks	Cherrystones	Chowder
626	York River (Mouth)	50	71.2	17.5	22	44	34
627	Allens Island	30	77.8	8.4	0	67	33
628	Green Point	30	73.8	5.7	0	93	7
629	Coleman Bridge	149	62.0	13.5	34	63	3
630	Coleman Bridge	78	55.6	12.3	64	36	0
631	Coleman Bridge	205	60.8	14.4	43	51	6
632	Coleman Bridge	54	75.0	9.1	7	63	30
633	Coleman Bridge	187	65.0	11.6	29	65	6
634	York River (Mouth)	42	64.6	17.2	33	57	10
635	York River (Mouth)	96	59.6	17.5	42	52	6
638	Hampton Bar	23	85.3	17.2	13	8	78
639	Hampton Bar	154	81.3	12.7	9	25	66
640	Hampton Bar	93	73.6	14.7	11	64	25
641	Hampton Bar	9	79.3	9.8	0	56	44
642	Hampton Bar	6	72.3	17.5	33	33	33
643	Hampton Bar	4	83.5	21.1	25	0	75
644	Hampton Bar	31	80.2	9.2	3	45	52
645	Hampton Bar	60	76.7	13.4	6	47	47
646	Hampton Bar	28	76.6	12.2	7	57	36
647	Hampton Bar	87	82.0	15.6	8	29	63
648	Hampton Bar	109	78.2	17.4	13	34	53
649	Hampton Bar	13	88.0	6.9	0	15	85
650	Hampton Bar	30	81.1	16.6	13	23	63
651	Hampton Flats	50	73.9	12.0	12	54	34
652	Hampton Flats	56	74.6	11.7	9	61	30
653	Hampton Flats	53	73.9	14.6	21	43	36
654	Hampton Flats	53	69.6	15.3	21	62	17
655	Hampton Flats	43	75.6	16.0	12	42	46

Table B (Continued)

Coll. No.	Station Location	Sample Size	Mean Length	Standard Deviation	Size Frequency (%) Littlenecks	Cherrystones	Chowder
657	Thimble Shoals	3	94.0	16.1	0	33	67
658	Horseshoe	2	91.5	20.5	0	50	50
659	Horseshoe	6	101.8	7.0	0	0	100
661	Thimble Shoals	4	105.5	7.7	0	0	100
662	Horseshoe	24	82.0	27.2	29	4	63
663	Horseshoe	13	89.0	11.7	0	31	69
664	Hampton Flats	53	79.0	7.9	2	51	47
665	Hampton Flats	105	78.9	10.7	7	43	50
667	Horseshoe	2	80.5	37.5	50	0	50
668	Horseshoe	9	82.9	11.2	0	56	44
669	Hampton Flats	70	72.5	15.1	20	44	36
670	Hampton Bar	66	74.5	13.3	11	52	38
671	Hampton Bar	53	88.4	19.9	9	13	77
672	Lower James	150	71.7	19.3	24	37	39
673	Hampton Flats	86	74.4	14.9	14	41	45
674	Hampton Flats	131	76.3	13.2	11	41	47
675	Horseshoe	14	54.8	24.2	64	21	14
676	Horseshoe	8	56.5	34.5	38	25	38
680	Lower James	193	66.9	17.0	32	44	24
683	York River (Mouth)	124	68.7	16.0	21	60	19
684	York River (Mouth)	107	74.5	15.3	12	50	37
685	York River (Mouth)	106	77.8	15.7	13	26	60
686	York River (Mouth)	129	75.4	15.2	16	36	49
687	York River (Mouth)	128	74.9	17.7	19	33	48
688	Gaines Point	69	70.2	10.1	10	78	12
689	Gaines Point	183	73.3	14.5	15	51	34
690	Tue Marsh	2	59.0	18.4	50	50	0
691	Tue Marsh	34	81.4	12.5	6	32	62
692	Tue Marsh	129	80.8	9.8	5	39	56
693	Tue Marsh	5	82.8	10.6	0	40	60
695	York Spit	4	82.8	19.2	25	0	75

Table B (Continued)

Coll. No.	Station Location	Sample Size	Mean Length	Standard Deviation	Size Frequency (%) Littlenecks	Cherrystones	Chowder
697	Lower York River	29	78.7	7.6	0	55	45
700	Tue Point	62	69.3	10.4	14	74	11
703	Mobjack Bay	14	73.2	8.1	14	71	14
704	Mobjack Bay	1	-	-	-	-	-
705	Mobjack Bay	1	-	-	-	-	-
706	Mobjack Bay	1	-	-	-	-	-
708	Mobjack Bay	3	87.7	3.8	0	0	100
711	Mobjack Bay	2	80.8	4.0	0	0	100
712	Mobjack Bay	10	65.4	14.2	50	10	40
713	Mobjack Bay	129	68.2	11.8	16	77	8
714	Mobjack Bay	82	74.6	8.9	6	71	23
715	Mobjack Bay	125	74.1	11.2	11	54	35
716	Mobjack Bay	32	72.7	8.1	6	78	16
717	Mobjack Bay	57	74.2	11.5	9	65	26
718	Mobjack Bay	28	71.0	9.2	14	71	14
719	Mobjack Bay	27	80.2	5.7	0	41	59
721	Lower James	1	-	-	-	-	-
724	Lower James	97	71.9	13.9	20	47	33
725	Lower James	60	70.6	15.4	27	48	25
726	Lower James	75	72.2	10.5	12	68	20
727	Lower James	100	67.5	17.0	30	46	24
728	Lower James	119	65.3	20.6	29	44	26
729	Lower James	59	70.2	16.7	17	58	25
730	Willoughby Bank	48	51.2	29.1	52	29	19
733	Lower James	1	-	-	-	-	-
734	Lower James	18	68.1	12.9	28	56	17
735	Lower James	55	67.6	8.8	18	78	4
736	Lower James	4	62.8	9.2	50	50	0
737	Lower James	1	-	-	-	-	-
738	Lower James	46	67.1	10.0	17	80	2

Table B (Continued)

Coll. No.	Station Location	Sample Size	Mean Length	Standard Deviation	Size Frequency (%)		
					Littlenecks	Cherrystones	Chowder
740	Lower York	25	74.8	12.6	12	52	36
743	Goodwin Neck	2	76.5	12.0	0	50	50
744	Lower York River	4	89.8	5.4	0	0	100
746	Lower York River	3	91.3	8.1	0	0	100
747	Chesapeake Bay	27	72.2	18.5	26	30	44
748	Chesapeake Bay	5	71.4	19.1	40	20	40
749	York River	72	68.2	11.7	18	68	14
751	Chesapeake Bay	1	-	-	-	-	-
752	Chesapeake Bay	92	67.9	19.3	38	33	29
753	Chesapeake Bay	89	83.0	16.4	9	24	67
755	Coleman Bridge	8	70.1	9.6	25	62	12
757	Lower York	1	-	-	-	-	-
760	Allan Island	115	71.1	11.5	16	63	21
761	Willoughby Bank	110	65.3	25.3	28	32	40
764	Willoughby Bank	17	43.0	21.0	82	6	12
766	Lower James	116	73.7	11.4	10	59	30
768	Willoughby Bank	92	79.0	8.4	3	54	42
769	Willoughby Bank	7	80.1	4.5	0	43	57
770	Willoughby Bank	152	68.2	13.1	19	68	13
771	Willoughby Bank	29	83.5	21.6	14	7	79
772	Crumps Bank	81	74.4	18.7	21	31	48
773	Lower James	66	71.1	20.0	20	44	36
774	Crumps Bank	44	77.3	19.5	20	20	59
775	York Spit	49	81.0	7.4	2	37	61
777	York Spit	79	73.7	8.8	6	75	19

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JOB NO. 2. A STUDY OF THE RATE OF GROWTH OF THE HARD CLAM IN VARIOUS REGIONS OF CHESAPEAKE BAY.

INTRODUCTION

The objective of this study was to estimate the growth rates of hard clams and to compare these rates among years and among areas in the lower Chesapeake Bay region. One application of the findings of this study would be to determine if it is feasible to institute "clam farming" on grounds that now lie commercially fallow because of the oyster disease MSX. A second application is the prediction of the average time required in a given area for a natural set of clam spat to reach a commercial size.

MATERIALS AND METHODS

Estimation of Growth

The procedure for measuring clams and estimating growth functions was described in previous reports (3-77-R-3 and 3-124-R) and by Loesch and Haven (1973). A brief review follows.

The annual increment to shell length, i.e., the longest linear dimension was used as an estimate of growth (Figure 1). Individual hard clams, ranging from about 30 to 90 mm, were measured, code-marked with an indelible marker, and planted in the fall of the year at experimental plots. These plots were located at Hampton Flats, the Thorofare between Goodwin Neck and Goodwin Islands, Gloucester Point, Yorktown, and at the mouth of Aberdeen Creek (Figure 2). In

Figure 1. Measurement defined as length for the hard clam, Mercenaria mercenaria.

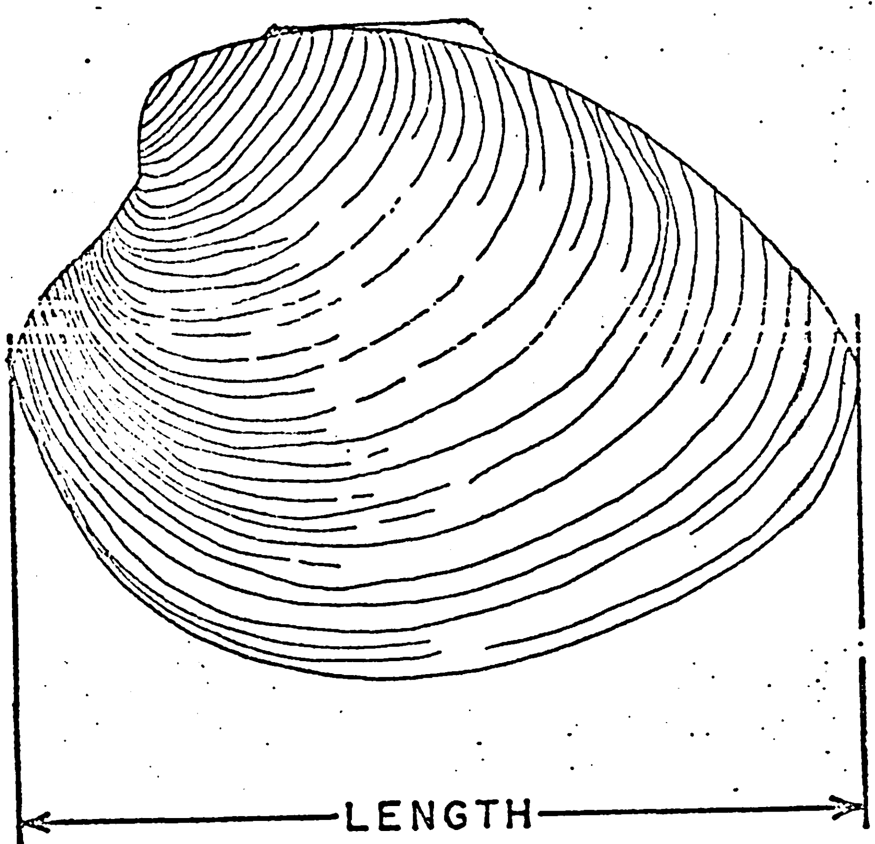
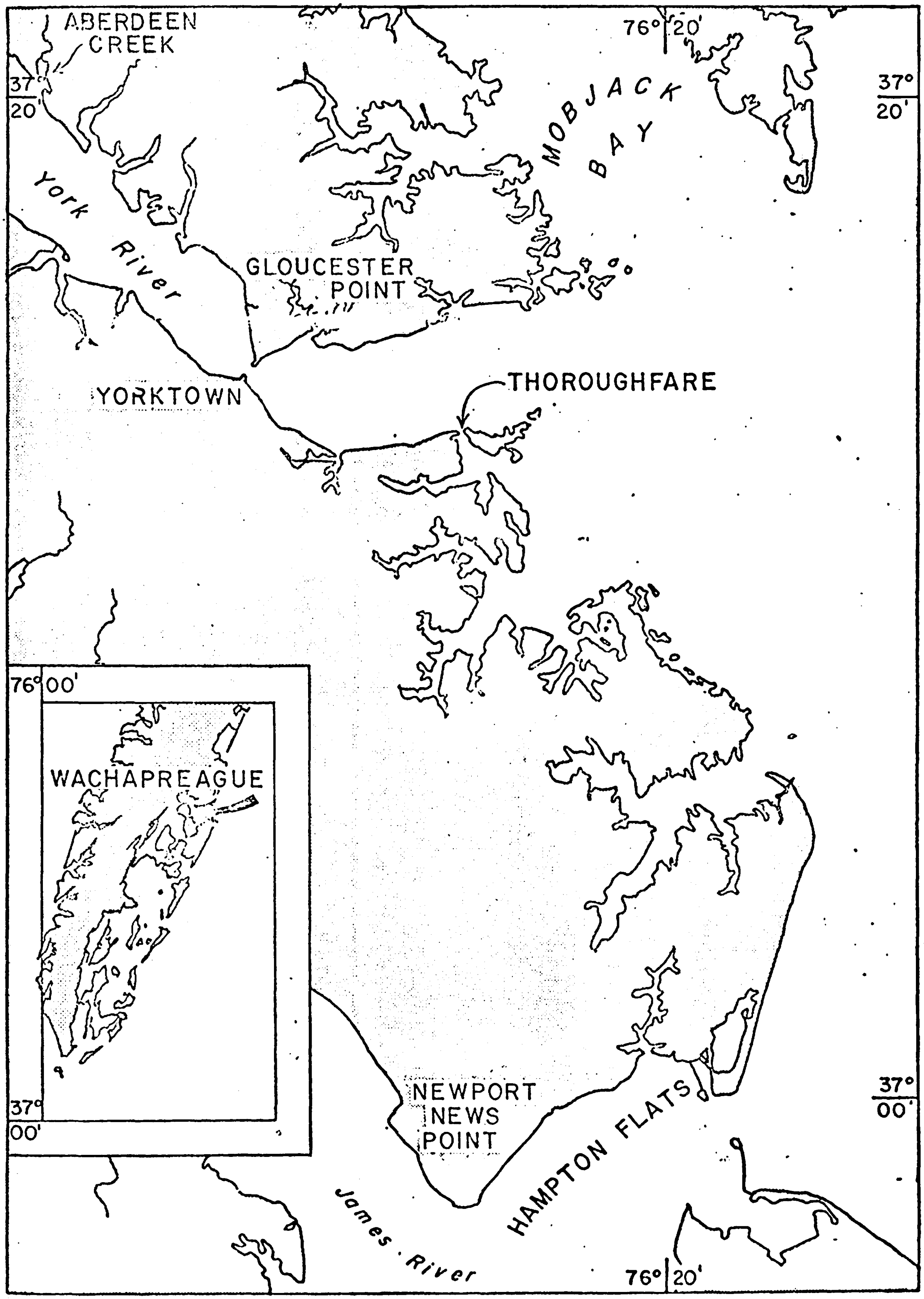


Figure 2. Location of experimental hard clam plots.



order to compare the growth rates of clams in these relatively low salinity areas with those in a high salinity environment, a seaside, Eastern Shore plot was established at Wachapreague, Virginia in 1972. SCUBA was employed for the placement of the hard clams and for their recovery one year later.

Linear growth functions were derived by the method of least squares using initial length (l_t) as the independent variable and length one year later (l_{t+1}) as the dependent variable. This is a variation of the Walford transformation (Walford, 1946) which was first employed by Manzer and Taylor (1947), and was described in more detail in the 1967-1970 final report (3-77-R-1, R-2, R-3). One pertinent fact to be recalled is that the smaller the regression coefficient in the Walford transformation, the faster the rate at which the average maximum size (asymptotic size) is approached. The derived regression equations were, where statistically permissible, contrasted by analysis of covariance. The results of the analyses are reported in terms of the probability (P) of observing a deviation as large, or larger than that observed, solely due to chance.

The growth functions were derived independent of age and the estimated size-age relationship was determined by substituting into the Walford equations the average size at age zero, 0.21 mm (0.008 inch), to obtain the estimated average age one size. Age zero was defined as the time when the clam larvae settle as spat and become part of the benthic community (Loesch and Haven, 1973). The average size at age one was, inturn, substituted into its respective equation to estimate the average two-year old size, and so on.

Salinity Data

It was suspected that prevailing low salinities during 1971 and 1972, which were further depressed to record lows by the occurrence of tropical storm Agnes in June 1972, had adversely affected hard clam growth.

A normal, annual salinity trend for the areas associated with the hard clam experimental plots was estimated from the average values of the respective monthly observations during 1968 and 1969. The salinity values for a common month in each year were obtained on different dates, therefore, their average was arbitrarily plotted on the 15th day of the month. These data were chosen because of their completeness, and were obtained from the VIMS Department of Ecology-Pollution.

Salinity values associated with the Hampton Flats plot for 1968 were determined from James River water samples taken at mile 4 (8 samples), mile 5 (2 samples), and mile 6 (2 samples). The sampled water depth was 3 meters, with exceptions in the months of November and December when salinity was determined from surface samples. In 1969, all water samples in this area of the James River were taken at mile 5, with one exception at mile 4. January and February samples were taken at the surface, but the other 10 monthly samples were at a depth of 3 meters.

The monthly salinity samples associated with the Gloucester Point-Yorktown hard clam plots in 1968 were obtained at mile 4 (2 samples), mile 5 (8 samples), mile 6 (1 sample), and mile 9 (1 sample. All water samples were from a depth of 3 meters, except in December when salinity was determined from a surface sample. In 1969, all samples in this area were taken at mile 5; the first four monthly samples were taken at the surface, but the rest were taken at a 3 meter depth.

The salinities associated with the hard clam plot at the mouth of Aberdeen Creek, located approximately at mile 15 in the York River, are much less percise with respect to the locations at which they were obtained. Ten monthly observations were used from the 1968 data (October and November omitted because of the extreme remoteness of the sampling sites)which were obtained from a range of mile 14 to mile 24, with an average of 18.9 miles. In 1969, the water sampling sites ranged from mile 15 to 23, with an average of 19.8 miles. All samples in both years were obtained at a depth of 3 meters, except for those of December, 1968 through February, 1969, which were taken at the surface.

No salinity data was available for association with the Thorofare experimental plot.

The Eastern Shore area at Wachapreague was unaffected by Agnes; thus, just the 1972 salinity trend is presented. The trend was determined by plotting the values recorded at the VIMS East Laboratory at a depth of 2 meters at approximately weekly intervals from 4 January to 30 August, 1972.

The salinity data of 1972 was divided into two periods, pre-and post tropical storm Agnes which occurred 21 June, 1972.

Pre-Agnes salinity data associated with the Hampton Flats hard clam plot were determined from surface water samples collected by the VIMS Department of Ichthyology at mile 5 in the James River. The salinity data associated with the Gloucester Point-Yorktown and Aberdeen Creek plots were collected by the VIMS Department of Ecology-Pollution at miles 6.4 and 15.5, respectively, at a depth of 2 meters, except in April when surface samples were taken.

Post-Agnes salinity data were more abundant due to the joint effort of all VIMS departments in collecting hydrographic data in the aftermath of Agnes. Salinities associated with the Hampton Flats plot were obtained from water samples taken at mile 3 at depths ranging from the surface to 2 meters. Salinity data associated with the Gloucester Point-Yorktown and Aberdeen Creek plots were obtained from water samples taken at depths ranging from the surface to 3 meters at miles 6.4 and 15.5, respectively.

Although data was not available exactly at the sites of hard clam plantings, they were obtained, with the exception of the Thorofare and Aberdeen Creek plots, reasonably nearby. All data, however, clearly showed the difference between normal and low salinity yearly trends, and, also, the pre-and-post Agnes salinity conditions in 1972.

RESULTS AND DISCUSSION

Hard clam growth rates for a given year, with two exceptions, were not significantly different among the Gloucester Point plots and the Yorktown plot, nor among the Hampton Flats experimental plots. One plot among four in the Gloucester Point-Yorktown area in the 1970-71 growth year had a significantly higher hard clam growth rate ($P<0.05$ but >0.01), again, in this area, for the 1971-72 growth period, clams in one plot among four exhibited a significantly faster growth rate ($P<0.005$). No rationale (other than sampling error) could be offered for this difference, and, accordingly, the growth data for the plots in each respective area were pooled. The growth functions derived from the pooled data, and those for areas which had single experimental plots are presented in Table 1.

The growth years from 1967-68 through 1969-70, which preceeded the unusually low salinities in lower Chesapeake Bay, are discussed first.

In the Gloucester Point-Yorktown area, the growth functions for 1967-68 and 1969-70 are obviously near identical and inferior to the growth function for 1968-69 period. Similarly, in the Hampton Flats area hard clam growth in 1968-69 was significantly greater than in the 1969-70 growth year ($P < 0.001$).

In the 1970-71 period when salinities began to drop due to heavy river discharge, the estimated growth function in the Gloucester Point-Yorktown area was not significantly different from the preceeding year ($P > 0.25$). However, a very large decrease in the growth rate occurred in the Hampton Flats area. It is believed that this was due to the fact that the Hampton Flats area normally has a higher salinity than the Gloucester Point-Yorktown area, and, also, the James River has a larger water basin than the York River. Thus the drop in salinity was more dramatic and salinity reached a lower level in the lower James River. The 1970-71 growth year was the only period observed in which the growth function for the Hampton Flats area was not significantly greater than the Gloucester Point-Yorktown area ($P > 0.10$). The hard clam growth rate at the Thorofare plot was noticable less than at Hampton Flats and the Gloucester Point-Yorktown areas but obviously much greater than that estimated for the hard clam plot at Aberdeen Creek. The latter site is the extreme upper distribution of naturally occurring hard clams in the York River.

Table 1. Estimated growth functions for hard clams in experimental plots.

Station Location	Growth Year	No. Lots	Sample Size	Growth Function
Gloucester Point	1967-68	1	187	$L_{t+1}=12.1+0.848\ L_t$
Gloucester Point-Yorktown	1968-69	3	306	$L_{t+1}=18.5+0.764\ L_t$
Gloucester Point-Yorktown	1969-70	4	1136	$L_{t+1}=12.2+0.854\ L_t$
Gloucester Point-Yorktown	1970-71	4	1172	$L_{t+1}=12.4+0.850\ L_t$
Gloucester Point-Yorktown	1971-72	4	1470	$L_{t+1}=5.52+0.929\ L_t$
Hampton Flats	1968-69	2	495	$L_{t+1}=22.2+0.721\ L_t$
Hampton Flats	1969-70	3	1078	$L_{t+1}=18.5+0.789\ L_t$
Hampton Flats	1970-71	3	1005	$L_{t+1}=12.2+0.862\ L_t$
Hampton Flats	1971-72	3	1762	$L_{t+1}=9.02+0.887\ L_t$
Thorofare	1970-71	1	232	$L_{t+1}=7.13+0.910\ L_t$
Thorofare	1971-72	1	370	$L_{t+1}=9.21+0.875\ L_t$
Aberdeen Creek	1970-71	1	175	$L_{t+1}=3.90+0.946\ L_t$
Aberdeen Creek	1971-72	(100% mortality)		
Wachapreague	1971-72	1		$L_{t+1}=17.1+0.794\ L_t$

The Gloucester Point-Yorktown hard clam growth rate was significantly less than the estimated growth rates for the Hampton Flats and Thorofare clam plots ($P < 0.001$ for both contrasts). Though they appear somewhat similar, the growth function for the Thorofare hard clams was significantly different than that of Hampton Roads clams ($P < 0.005$). It is believed that this was due to the relatively slow recovery from low salinity conditions in the James River associated with the aftermath of tropical storm Agnes which occurred 21 June, 1972 (Figure 3B). Similarly, unusually low salinities occurred in the York River at this time (Figures 4A and 4B). A total mortality occurred among the hard clams in the experimental plot at the mouth of Aberdeen Creek. This occurrence was also attributed to Agnes when salinity in that area of the York River dramatically decreased to about 1.6 $^{\circ}/oo$ and remained low for a relatively long period (Figure 4B). The derived growth expression for the hard clams in the high salinity water at Wachapreague is obviously superior to all the other growth equations for the 1971-72 growth year. It is believed, however, that growth of these eastern shore clams was underestimated because of the relatively low number of smaller size clams recaptured (< 60 mm). The estimated growth rate was weighted and, thus reduced, by the more abundant larger clams which had smaller growth increments. The information is valuable, nevertheless, for a relative contrast of growth between high and low salinity areas. Salinities in the Wachapreague area, unaffected by Agnes, were in their normal range (Figure 3A).

The estimated growth of the hard clams in the Gloucester Point and Hampton Roads lots was significantly less in the 1971-72 period than in the 1970-71 growth year ($P < 0.001$ for both contrasts). The

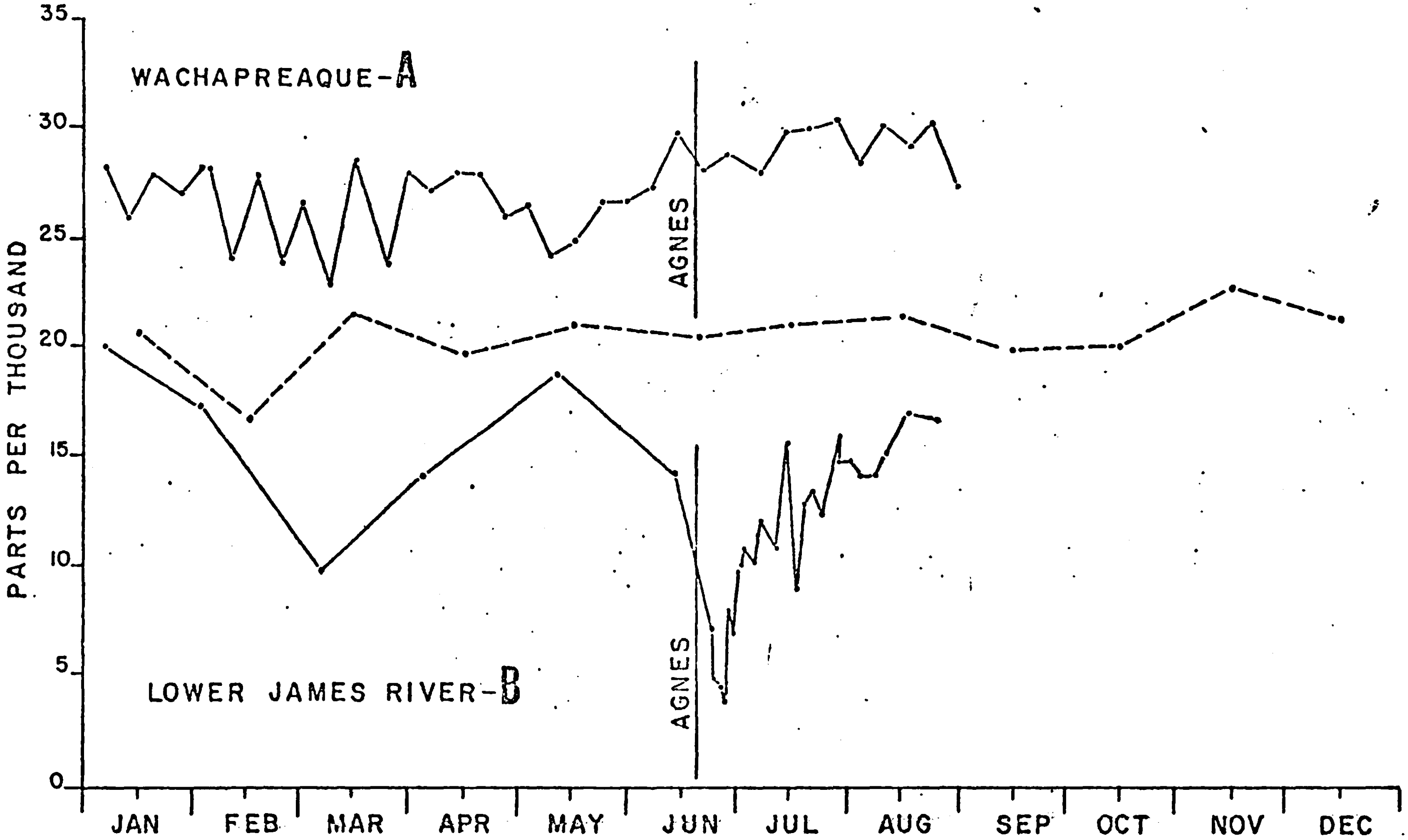


Figure 3. Salinity data: A. Eastern Shore salinities at Wachapreague in 1972. B. Average monthly salinity values for 1968 and 1969 (dashed line) and 1972 salinity trend (solid line) in the lower James River.

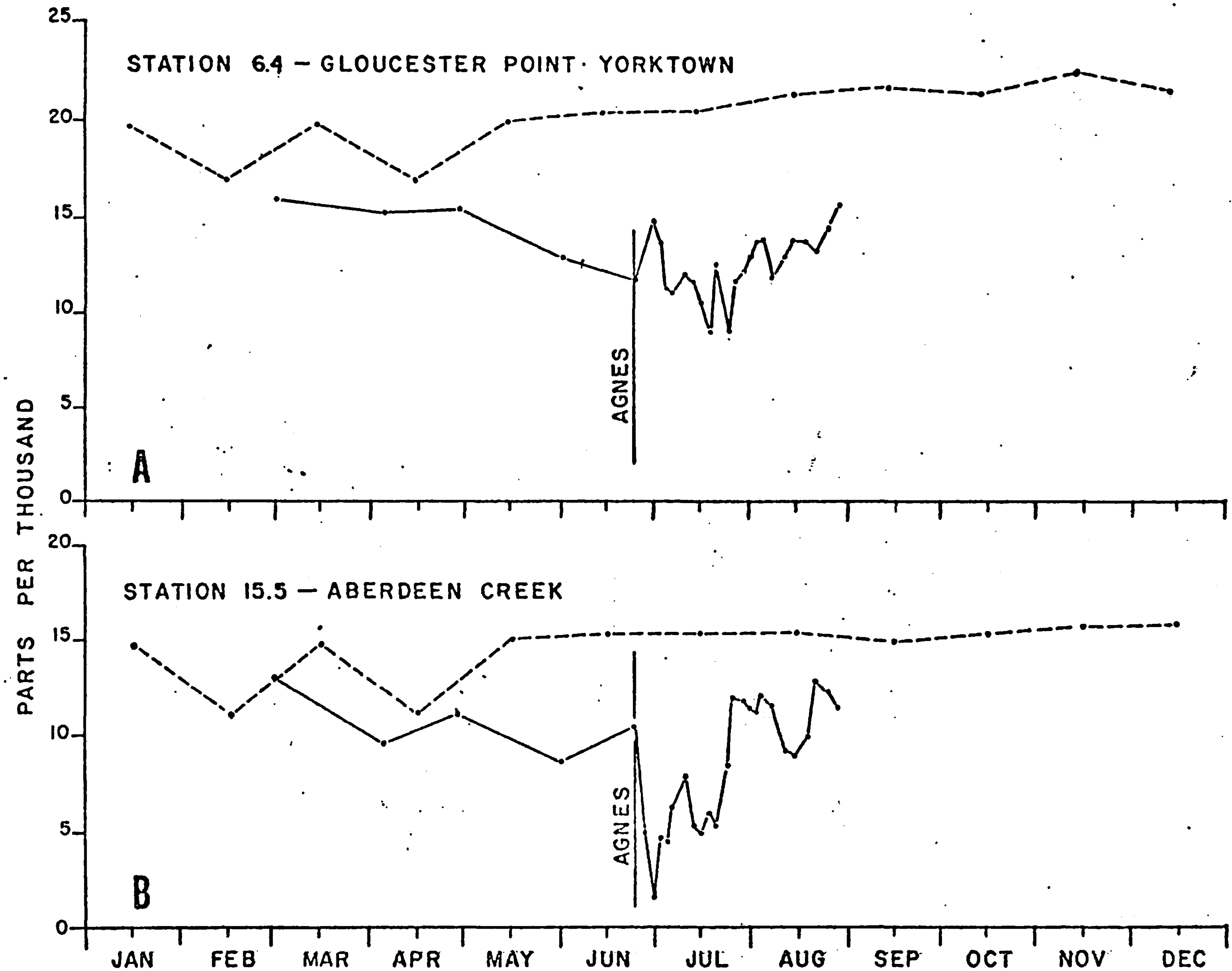


Figure 4. Salinity data: A. Average monthly salinity values for 1968 and 1969 (dashed line) and the 1972 salinity trend (solid line) in the Gloucester Point-Yorktown area. B. Average monthly salinity values for 1968 and 1969 (dashed line) and the 1972 salinity trend (solid line) in the Aberdeen Creek-York River area.

difference between the two growth years is suspected as being correlated to the increased precipitation in the 1971-72 period above the previous high level recorded for the 1970-71 growth year. Both growth years, however, were poor relative to previous estimates. Thus, for the five years of recorded clam growth data for Gloucester Point and four years for Hampton Roads experimental hard clam plots, two yearly growth estimates (1971-72 and 1972-73) were made from clams subjected to the highly adverse conditions of low salinity during their growth periods. The rate of growth of hard clams in the Thorofare lot in 1971-72, though relative poor, was significantly greater than in 1970-71. This apparent paradox was due to the fact that in 1970-71 the clams were in an unsuitable silt substrate but were moved to a more favorable sand-mud-shell bottom nearby for the 1971-72 growth year.

It must be emphasized that any yearly growth expression does <u>not</u> represent the rate at which hard clam populations grow; they are simply one years expression, and overall growth is a function of cumulative growth for a number of years.

To date, our best estimates of the "average" growth in the Hampton Flats and Gloucester Point-Yorktown area were obtained by pooling the data for the 1968-69 and 1969-70 growth years. In doing so, we assume that the high river flows encountered during the 1970-71 and 1971-72 growth seasons and the resulting poor hard clam growth, were rare events not likely to occur again for a relatively long time. The estimated growth functions of the pooled data for Hampton Flats was:

$$l_{t+1} = 21.4 + 0.734\ l_t$$

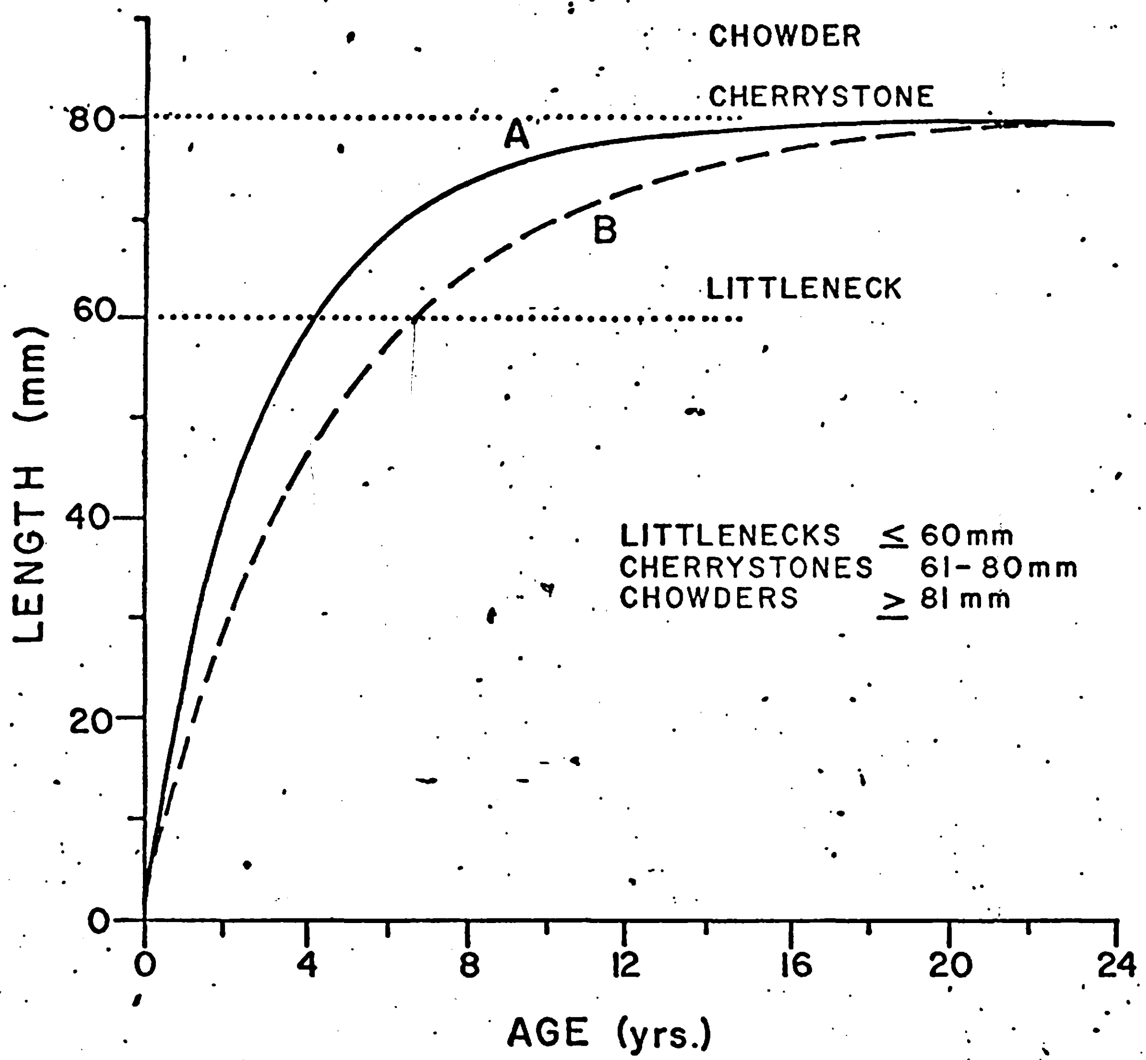
while that for the Gloucester Point-Yorktown lots was:

$$l_{t+1} = 14.8 + 0.816\ l_t$$

where l_{t+1} and l_t are as previously defined and the values 21.4 and 14.8, and 0.734 and 0.816 are the respective y-axis intercepts and regression slopes.

It is estimated from the pooled data that littleneck and cherrystone sizes for clams in the Hampton Flats area would be obtained in about 2-1/2 and 4-1/2 years, respectively (Figure 5). Similarly, in the shoal waters of the Gloucester Point-Yorktown area these sizes would be obtained at ages 4 and 8. An asymptotic size of 80 mm was estimated from the pooled data for hard clams at both locations. At Hampton Flats, however, this average size was predicted by age 17, while at the Gloucester Point-Yorktown area it apparently would not be reached until age 22. The cumulative growth curves in Figure 5 would indicate that chowder size is not attained in these areas. However, the estimated length for a given age is an <u>average</u> size and, similarly, the asymptotic size is the <u>average</u> maximum length which some individual do not attain while others exceed it. Other factors previously cited (Job 1), such as shell thickness, blunting of the vental margin of the valves, availability, and varying size definitions among wholesale markets affect culling (sorting) procedures. For all practical purposes a hard clam fisheries interest in growth would cease before the asymptotic size is reached. Hard clams at Hampton Flats would obtain 90 percent of their asymptotic size by about the 7th or 8th year, and those at the Gloucester Point-Yorktown sites by about the 11th or 12th year. Furthermore, predicted growth increments at the former and latter sites are less than 1 mm after ages 10 and 15, respectively. Accuracy of the above estimates is, of course, dependent upon how reasonable the true average growth was approximated by combining the data for just two years.

Figure 5. Cumulative growth curves derived from the pooled data of the 1968-69 and 1969-70 growth years for Hampton Flats (A) and Gloucester Point-Yorktown (B).



SUMMARY

1. Estimated hard clam growth for the 1968-69 growth period was the highest recorded since experimental planting of clams began in the fall of 1967. Growth is believed to be correlated to the river flow and the resulting increase or decrease in salinity.
2. The observed hard clam growth rates in the Hampton Flats area generally were significantly greater than in the Gloucester Point-Yorktown area.
3. Total mortality occurred among the hard clams in the Aberdeen Creek experimental plot in the upper York River in the 1971-72 period. This apparently occurred in the aftermath of Agnes when salinity dropped to about 1.6‰ and remained relatively low for a protracted period.
4. To date, the best estimate is that littleneck and cherrystone sizes are attained in about 2-1/2 and 4-1/2 years, respectively, for Hampton Flat hard clams; similarly, about 4 and 8 years are required in the shoal water plot areas of Yorktown and Gloucester Point.
5. The growth of planted hard clams at Wachapreague was underestimated because of inadequate harvest returns, but nevertheless, it was far superior to planted western shore clams in the 1971-72 period.

RECOMMENDATION

It is recommended that yearly growth estimates be continued, particularly in areas where oyster planting is no longer feasible because of MSX. An increased number of yearly observations would increase the reliability of an estimated average growth function for a given area. Thus, decisions pertaining to the economic potential of hard clam farming in an area could be made prior to large investments of time and money.

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JOB NO. 3 - AN INVESTIGATION OF CLAM FARMING IN THE YORK RIVER.

INTRODUCTION

With the development of hatcheries for raising small hard clams the idea has occurred to many that it should be possible to raise large numbers of clams, "plant" them in an estuary, and several years later harvest a marketable crop. There are, however, difficulties in this plan. It is true that any good marine laboratory in a high salinity area can spawn hard clams and raise several million larvae to "setting" size (.2 mm). The difficulty comes when the small clams are planted in an estuary. When this is attempted, predators such as oyster drills, crabs and fish often consume so many that it is not possible for commercial growers to realize an adequate monitary return. The solution to the problem seems simple. That is, hold the clams in the laboratory until they grow large enough to resist predators (1/2 inch long). That is possible, but the cost of this practice far out weighs any return which may be realized by the sale of the mature clams.

Job III of this project was an attempt to develop techniques for protecting small clams during their vulnerable stage (2 to 12 mm). Two methods were tested. One consists of planting small clams in a gravel substrate and most effort went into these studies. The second method (which received limited tests) consisted of screening off an area with inexpensive plastic net.

The technique of protecting small hard clams by planting them on gravel substrate was originally tested on the Eastern Shore, at the Wachapreague Laboratory. It consists of spreading about 1 yard of 1/4 to 3/4 inch rounded gravel in a 100 square foot area. This forms a layer about 2-4 inches thick. Two patterns were used: 1) a square 10 X 10; 2) a circular area with a diameter of about 11 feet. After the gravel was in place, clams of various sizes were scattered over the surface by a diver. Gravel is thought to be effective because crabs and other predators simply can not reach in and "dig" out the small molluscs.

Studies on clam farming began at Gloucester Point, Virginia in August 1970 and preliminary results were reported in the annual report for 1970-71 (C.N. 3-124-R).

Most of the small clams for the project were spawned and raised at the Wachapreague division of the Virginia Institute of Marine Science. A few, however, were raised at the laboratory at Gloucester Point. The clams used as spawning stock came from the Eastern Shore, Long Island or from the York River. The original planting density varied from about 5 to 50 per square feet.

Clams were sampled in 1970 and 1971 with a Peterson grab at 6 locations in each plot. It was found out later that this gear did not collect an adequate sample of all clams since the dredge did not penetrate the gravel. Therefore, data obtained with Peterson grab is not used to estimate survival. In 1972 and 1973 a suction apparatus was used which sampled to a depth of 6" in the sediment from 5 to 10 places in each plot. This gear did obtain a representative sample of the bottom. Numbers were purposefully small since it was necessary to sample the area during successive years.

NUMBER OF STUDIES CONDUCTED

A total of 25 separate plots have been planted with clams of various size since the start of the contract period. Seven plots were established in 1970, and others in 1971 and 1972. These areas have been checked at least yearly for survival (Figure 1).

During the 1972 program, tropical storm Agnes which occurred in late June, caused salinities to drop over our experimental beds to about 5 ppt and through most of July salinities were below 10 ppm. These low salinities caused about a 10 percent mortality of large native clams adjacent to our plots. We also observed that clams in our growth study plots nearby (Job No. 2) grew at a lesser rate in 1971 than 1972. High winds occurred at low tide in connection with a second tropical depression in September. This caused excessive "washing" of the bottom on several of the shallow beds. We concluded that the clams on our graveled plots, in 1973 experienced atypical growth and that on several plots clams were "washed" by waves from the area.

There follows a summary of all areas planted during the contract period. In this report, they will be discussed separately under A, B, C and D.

A. Experiments 1 to 17. These studies were conducted at Gloucester Point, Virginia with plantings in 1970 and 1971. These areas were sampled annually. Areas planted were 10 X 10 foot graveled squares or circular areas of the same area. Table 1 summarizes the overall aspects of this series of studies.

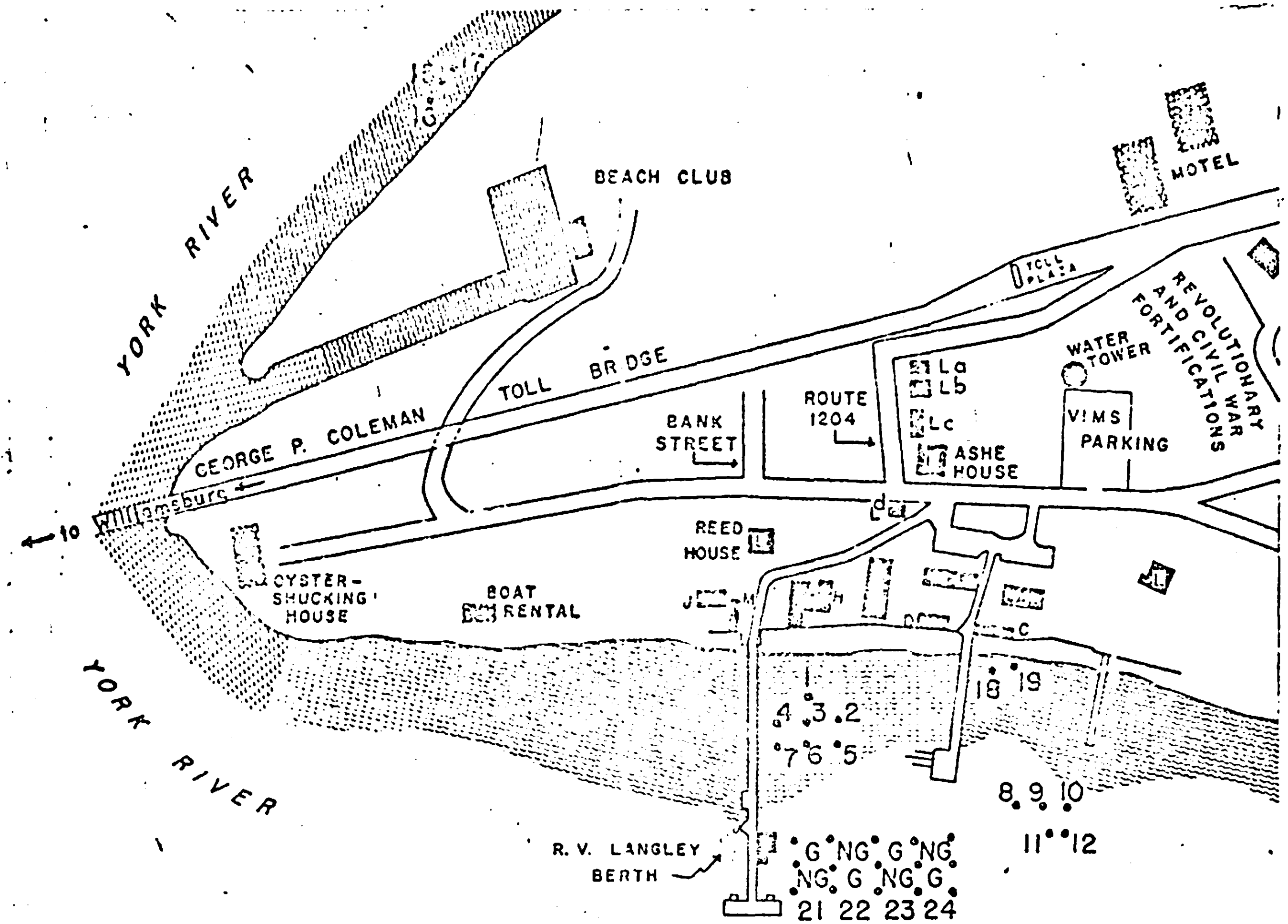


Figure 1. Location of Clam Farming Plots at Gloucester Point.

Table 1. Summation of Clam Farming Plots
1970 - 1973

Plots

	Gravel 1	Gravel 2	Gravel 3	Gravel 4	Gravel 5	Gravel 6	Gravel 7	Gravel 8
Origin	York River Natives	Eastern Shore	L.I. x Y.R. Hybrids	Long Island	Eastern Shore	Eastern Shore	Long Island	Eastern Shore
No. Planted	1800	5200	670	2000	5200	475	3100	5000
Planting Date	27 July 71	17 June 71	13 May 71	13 May 71	17 June 71	17 June 71	13 May 71	15 July 71
Mean length (mm)	2	2	2	2	2	4	3.5	4
Length range (mm)	1-5	1-4	1-3	1-3	1-4	2-7	1-7	2-9
Sampling Date	15 Nov. 71 *	15 Nov. 71 *	1 Nov. 71	1 Nov. 71	15 Nov. 71 *	1 Nov. 71	1 Nov. 71	8 Nov. 71
Mean length (mm)	11	14	16	10	13	No clams	No clams	14
Length range (mm)	4-19	7-23	12-19	7-12	8-19			7-24
Sampling Date	21 Apr. 72	21 Apr. 72	21 Apr. 72	21 Apr. 72	21 Apr. 72	21 Apr. 72	21 Apr. 72	21 Apr. 72
Mean length (mm)	12	17	20	17	No Clams	17	11	11
Length range (mm)	10-17	11-26	14-25	10-26		14-21	8-12	8-12
Sampling Date	21 Feb-May 1973	21 Feb-May 1973	21 Feb-May 1973	Feb-May '73	Feb-May '73	Feb-May '73	Feb-May '73	Feb-May '73
Mean length (mm)	25	1 clam	1 clam	No Clams	No Clams	1 Clam	1 Clam	21
Length range (mm)	15-33	22	24			23	16	18-26

* Grab and suction samples combined.

Table (continued)

Plots

	Gravel 9	Gravel 10	Gravel 11	Control 12	Gravel 13	Control 14	Gravel 15	Control 16	Control 17
Origin	Eastern Shore	Eastern Shore	Eastern Shore	Eastern Shore	Eastern Shore	Eastern Shore	Eastern Shore	Eastern Shore	Eastern Shore
No. Planted	5000	5000	2500	2500	2800	2500	3800a 100b	1250	2750
Planting Date Mean Length (mm) Length range (mm	15 July 71 4 2-9	15 July 71 4 2-9	20 Aug. 70 11 6-18	20 Aug. 70 11 6-18	20 Aug. 70 17 7-21a 2-3b*	20 Aug. 70 17 7-21	20 Aug. 70 17a 23b 7-21a 12-29b	20 Aug. 70 17a 23b 7-21a 12-29b	11 Nov.70 4 2-8
Sampling Date Mean Length (mm) Length range (mm)	28 Nov. 71 14 9-20	28 Nov. 71 12 8-24	29 Dec. 70 17 6-24	29 Dec. 70 No clams	29 Dec. 70 23 19-26a 6b	29 Dec. 70 1 clam 26 mm	29 Dec. 70 15 8-36	29 Dec. 70 29 23-33	29 Dec.70 5 4-8
Sampling Date Mean Length (mm)	NOT SAMPLED	NOT SAMPLED	22 Apr. 71 11 7-18	22 Apr. 71 No clams	22 Apr. 71 15 9-27	22 Apr. 71 No clams	22 Apr. 71 20 8-36	22 Apr. 71 No clams 1 new set 4.2 mm	22 Apr.71 7 5-10
Sampling Date Mean Length (mm) Length range (mm)	28 Nov. 71 14 9-20	28 Nov. 71 12 8-24	28 Nov. 71 30 17-44	15 Nov. 71 11 7-17	11 Nov. 71 31 24-49	NO CLAMS	29 Dec. 71 36 16-52	NOT SAMPLED	NOT SAMPLED
Sampling Date Mean length (mm) Length range (mm)	1 May 72 NO CLAMS	27 Apr. 72 11 7-20	27 Apr. 72 31 21-39	27 Apr. 72 16 16	1 May 72 34 25-43	1 May 72 21 21	21 Apr. 72 35 23-43	21 Apr. 72 NO CLAMS	21 Apr. 72 NO CLAMS
Sampling Date Mean length (mm) Length range (mm)	Feb-May '73 29 29	Feb-May '73 No Clams	Feb-May '73 32 18-41	Feb-May '73 29 23-35	Feb-May '73 30 23-42	Feb-May'73 No Clams	Feb-May '73 No Clams	Feb-May '73 No Clams	Feb-May '73 No Clams

B. Experiments 18, 19 and 20. Two studies were conducted in 1970 and 1971 at Browns Bay about 8 miles from Gloucester Point. This area was planted in 1970 and sampled once in 1971. It was replanted in 1971 and sampled again in 1972. Areas planted were 10 X 10 foot graveled plots or plots of equal size covered with 5 to 6 inches of oyster shells in place of gravel.

C. Experiments 21, 22, 23 and 24. These studies were conducted at Gloucester Point, Virginia with plantings in 1972. Areas planted were graveled and untreated 15 X 15 foot plots. These areas were sampled twice; one in 1972 and one in 1973.

D. Experiment. 25. This study was conducted in Lynnhaven Bay, and at Gloucester Point, Virginia with plantings in 1971 and 1972, respectively. Plots were protected with a "fence" of plastic netting.

A. RESULTS - GLOUCESTER POINT - EX. 1-17

For discussion purposes, in the following paragraphs, examination times are listed at 2 and at 3 years <u>after planting</u>. It is emphasized therefore, that these "years" do not necessarily refer to the age of the clams since their actual age at planting varied from two months to about one year. In most studies, data for 1 year are not listed since the 1971 samples were obtained with a Peterson grab.

Repeated sampling adjacent to test and ungraveled plots showed that in 1970, 1971 and 1972, the natural set of hard clams was practically zero in the vicinity of our experimental plots.

Table 1 shows the essential details of planting dates, mean length, and range in length and in the text which follows complete details of each study are outlined. These data show: numbers of samples taken with the Peterson Grab or the suction sampler, the total area covered by these samples, total numbers of clams collected, mean lengths of clams, range in lengths, increase in mean length, calculated density of clams on the bottom, and estimated survival.

Studies on Clam Farming at Gloucester Point, Virginia
1970, 1971, 1972 and 1973 - (Experiments 1-17).

Experiments 1, 2, 3, 4. These clams were planted in May, June and July, 1971. With a single exception, they were spawned in the Wachapreague Laboratory on the Eastern Shore. They originated from four parental stocks: the York River*, the Eastern Shore, hybrids from Long Island and hybrids of Long Island X York River parents. They ranged in length at planting from 1-5 mm with a mean size of about 2 mm. Station depth was 6' MLW.

Plot	No. Clams in Sample	No. Samples	Total sq/ft in Sample	Range Length mm	Mean Length mm	Increase mm	Density sq/ft	% Survival
				1 Year - 1972				
1	9	20	2.6	10-17	12	10	3.6	20
2	5	20	2.6	11-26	17	15	2.0	4
3	3	20	2.6	14-25	20	18	1.2	18
4	6	20	2.6	10-26	17	15	2.4	12
					Average		2.3	14
				2 Years - 1973				
1	8	14	1.82	15-33	25		4.3	24
2	1	14	1.82	--	22		0.5	1
3	1	14	1.82	--	24		0.5	7
4	0	14	1.82	--	--		0.0	0
					Average		1.3	8

* These clams were spawned at Gloucester Point.

<u>Experiments 5, 6, and 7.</u> These clams were planted in May and June 1971. Two lots, 6 and 8, were from Eastern Shore stock. Lot 7 originated from Long Island stock. All three groups were spawned at the Wachapreague Laboratory on the Eastern Shore, Virginia. They ranged at planting from 1 to 7 mm; mean sizes ranged from 2 to 4 mm. All groups were planted on circular gravel plots around a central stake. Area of gravel was about 100 sq. ft. The following numbers of clams were planted: 5 = 475; 6 = 3,100; and 7 - 5,000. Depth was 6-1/2' MLW.

Plot	No. Clams in Sample	No. Samples	Total sq/ft in Sample	Range Length mm	Mean Length mm	Increase mm	Density sq/ft	% Survival
				1 Year - 1972				
5	0	20	2.6	--	--		0	0
6	3	20	2.6	14-21	17		1.2	4
7	5	20	2.6	8-12	11		2.0	4
					Average		1.1	3
				2 Years- 1973				
5	0	14	1.82	--	0		0	0
6	1	14	1.82	--	23		1.9	6
7	1	14	1.82	--	16		1.9	4
					Average		1.3	3

<u>Experiments 8, 9, and 10.</u> These clams were planted in May and June 1971. They originated from Eastern Shore stock spawned during the fall of 1970 at the Wachapreague Laboratory at Wachapreague, Virginia. They were planted in a circular gravel plot with an area

of about 100 sq/ft. Numbers planted on each plot was 5,000. They ranged in length from 2-9 mm with a mean of 4.0 mm. Depth was 6' MLW.

Plot	No. Clams in Sample	No. Samples	Total sq/ft in Sample	Range Length mm	Mean Length mm	Increase mm	Density sq/ft	% Survival
				1 Year - 1972				
8	5	20	2.6	8-12	11	7	2.0	4
9	0	20	2.6	--	--	--	--	0
10	14	20	2.6	7-20	11	7	5.6	11
					Average		3.6	8
				2 Years - 1973				
8	8	8	1.04	18-26	21	10	7.7	15
9	1	8	1.04	--	29	18	1.9	4
10	0	8	1.04	0	--	--	0.0	0
					Average		3.2	6

Experiments 11, 12. The clams were planted in August 1970, with a range in length from 6 to 18 mm and a mean length of 11 mm. They were spawned at the Wachapreague Laboratory on the Eastern Shore of Virginia, and were about 1 year old when planted. The 10 X 10 gravel plot was located in about 6-1/2' MLW. Numbers originally planted were: Plot 11 = 2,500; Plot 12 = 2,500; Plot 12 was a control and contained no gravel, but was planted at the same rate.

Experiments 11 and 12.

Plot	No. Clams in Sample	Total sq/ft in Sample	Range Length mm	Mean Length mm	Increase mm	Density sq/ft	% Survival
			2 Years - 1972				
11	7	2.5	21-39	31	20	2.7	11
12 (Control)	1	2.5	--	16	5	0.4	1
					Average	2.7*	11*
			3 Years - 1973				
11	11	2.34	18-41	32	21	4.7	19
12 (Control)	3	2.34	23-35	29	18	1.6	1
					Average	3.2	19*

Experiments 13-14. These clams were planted in August 1970. Their length varied over wide limits from 2 to 21 mm, with a mean of 17 mm. They were spawned in the Wachapreague Laboratory on the Eastern Shore of Virginia from Eastern Shore stock. They were planted in a square 10 X 10' plot at Gloucester Point in 1' MLW. This plot was subjected to much wave action; 2800 clams were originally planted in 13. Plot 14 was a control and had no gravel but was also planted with 2800 clams.

Plot	No. Clams in Sample	No. Samples	Total sq/ft in Sample	Range Length mm	Mean Length mm	Increase mm	Density sq/ft	% Survival
				2 Years - 1972				
13	12	20	2.60	25-43	34	17	4.7	17
14 (Control)	1	20	2.60	--	21	4	0.4	1
					Average		4.7*	17*

Experiments 13-14.

Plot	No. Clams in Sample	No. Samples	Total sq/ft in Sample	Range Length mm	Mean Length mm	In-crease mm	Density sq/ft	% Survival
				3 Years - 1973				
13	5	18	2.34	23-42	30		2.1	7
14 (Control)	0	18	2.34	--	--		0.0	0
					Average		2.1*	7*

* Control data not included in average.

Experiments 15, 16 and 17. These clams were a mixed lot of various ages from the Eastern Shore stock. They ranged in length from 2 to 29 mm, therefore, mean length was not calculated. They were planted in August 1970. The habitat of these clams was a broad shallow intertidal flat in 1' MLW which was subject to wave action at low tide. Three plots were established, each 10 X 10 feet. Two plots (15 and 17) received 1 yard of gravel; the third plot (16, the control) was ungraveled. Plot 15 received 3800 clams, Plot 16 received 1250 clams, and Plot 17 received 2750 clams.

Plot	No. Clams in Sample	No. Samples	Total sq/ft in Sample	Range Length mm	Mean Length mm	Increase mm	Density sq/ft	% Survival
				2 Years - 1972				
15	4	20	2.6	23-43	35		1.6	4
16	0	(Control)	2.6	--	--	--	0.0	0
17	0	20	2.6	--	--	--	0.0	0
					Average		0.8*	2*

Experiments 15, 16 and 17.

Plot	No. Clams in Sample	No. Samples	Total sq/ft in Sample	Range Length mm	Mean Length mm	Increase mm	Density sq/ft	% Survival
				3 Years - 1973				
15	0	6*	8.0*	--	--	--	0.0	0
16	0	6	8.0	--	--	--	0.0	0
17	0	6	8.0	--	--	--	0.0	0
					Average		0.0*	0*

* Control data not included in average.

SUMMARY OF EXPERIMENTS 1-17.

A summary of experiments 1-17 is given in Tables 2 and 3. These data indicate:

1. Treatment of the bottom with gravel at approximately the rate of 1-1/2 yards per 100 square feet resulted in higher survival of planted clams than those planted on adjacent ungraveled bottoms. This is shown in experiments 11-12 and in 13-14 for both 1972 and 1973, and to a lesser extent in Experiments 15, 16 and 17.
2. In the shallow water (1 foot MLW) the plots exposed to wave action (stations 15, 16 and 17) survival was very low for 1972, and in 1973 it was zero.
3. Growth and perhaps survival of hard clams in all our graveled and control plots were probably adversely influenced by fresh water conditions and wave action in 1973. Therefore, greater reliance is placed on data for the 1972 season.
4. There appeared to be no consistant pattern for survival among stations (other than at stations 15, 16 and 17) in respect to

size of clams planted, or year planted. This may be associated with the small numbers of clams obtained in our samples.

5. Because of the limited numbers of clams recovered, data from all plots (other than 15, 16 and 17) were combined. From these combined data several generalizations are indicated. In 1972, survival ranged from 3 to 17%; density from 1.1 to 4.7 per square foot; average survival was 10.3%; average density was 2.9 per square foot.

   In 1973, survival ranged from 3 to 19%; density from 1.3 to 4.7 per square foot; average survival was 8.5%; average density per square foot was 2.5.

6. Growth on gravel plots approximated that of natural populations. Estimates of the growth rate of natural populations are described in the preceding section (Job II). These data show that for normal salinity levels at Gloucester Point, hard clams will reach a length of about 15 mm the first year, about 27 mm the second. By the third year, they will be 30 mm long and of a size which may be sold commercially as "nicks".

   Growth rates on our graveled plots was highly variable, and numbers recovered were too small to form good estimates on growth. However, a summation of these data does agree with results obtained from the more definitive study (Job II). Clams planted in 1970 on the gravel plots with lengths ranging from 11 to 17 mm (experiments 11 to 14) reached 11 to 30 mm the first year; 16 to 31 mm the second year; and 29 to 32 the third. For the 2 to 4 mm clams planted in 1971 (experiments 1-10) a mean length

Table 2. Density and Percent Survival for Hard Clam Studies Experiments 1 to 17 - 1970, 1971 and 1973.

Plot No.	Original No. Planted sq/ft	1972 Density sq/ft	1972 % Survival	1973 Density sq/ft	1973 % Survival
1	18	3.6	20	4.3	24
2	52	2.0	4	0.5	1
3	6.7	1.2	18	0.5	7
4	20	2.4	12	0.0	0
	Average	2.3	14	1.3	8
5	4.8	0	0	0	0
6	31	1.2	4	1.9	6
7	50	2.0	4	1.9	4
	Average	1.1	3	1.3	3
8	50	2.0	4	7.7	15
9	50	0	0	1.9	4
10	50	5.6	11	0	0
	Average	3.6	8	3.2	6
11	25	2.7	11	4.7	19
12(control)	25	0.4	1	1.6	1
	Average	2.7*	11*	4.7*	19*
13 (control)	28	4.7	17	2.1	7
14	28	0.4	1	0	0
	Average	4.7*	17*	2.1*	7*
15	36	1.6	4	0	0
16 (control)	12.5	0	0	0	0
17	27.5	0	0	0	0
	Average	0.8*	2*	0*	0*

* Indicates ungraveled control data not included in average.

Table 3. Clam Densities on Plots
1 to 17 1970 - 1973

Plot No.	Approximate Date Planted	Plot Description	Mean Length at Planting	Fall 1971 (Clams/ sq/ft.)	Spring 1972 (Clams/ sq/ft)	Spring 1973 (Clams/ sq/ft)
1 - Gravel	6/71	Circular	2	0.9	3.6	4.3
2 - "	6/71	"	2	0.3	2.0	0.5
3 - "	6/71	"	2	0.7	1.2	0.5
4 - "	6/71	"	2	0.9	2.4	0
5 - "	6/71	"	2	0.7	0	0
6 - "	6/71	"	4	0	1.2	1.9
7 - "	6/71	"	4	0	2.0	1.9
8 - "	7/71	"	4	6.4	2.0	7.7
9 - "	7/71	"	4	1.9	0	1.9
10 - "	7/71	"	4	9.4	5.6	0
11 - "	9/70	Square	11	5.4	2.7	4.7
12 - Control	9/70	"	11	1.1	0.4	1.6
13 - Gravel	9/70	"	17	9.4	4.7	2.1
14 - Control	9/70	"	17	0	0.4	0
15 - Gravel	9/70	"	**	3.4	1.6	0
16 - Control	9/70	"	**	0	0	0
17 - Control	9/70	"	**	0	0	0

* Clams in Fall of 1971 were sampled with Peterson Grab. In 1971 and 1972 they were sampled with the more efficient suction sampler.

** Length 2-29 mm - controls = no gravel.

from 11 to 20 was reached at the end of the first year and from 16-19 mm the second.

7. In respect to survival, our experience strongly suggests that after reaching the size of about 15 to 20 mm hard clams in gravel substrate survive as well as those in natural bottom.

B. Brown Bay Studies - (Ex. 18, 19 and 20).

A series of experiments were conducted in Browns Bay, Virginia. Plantings were made in May 1970 and again in June 1971 when the original plantings failed. The bottom was firm sandy mud. Depth was 1 foot MLW. The plots were located 10 feet off the margin off large grassy marsh, and the environment was completely different from the sandy beach areas at Gloucester Point where the preceding studies took place. Three plots were set out at Browns Bay each 10 feet square. One plot (A) was covered with gravel in the usual manner; a second plot (B) was covered with 4 inches of crushed clam shells; and a third plot (C) was uncovered as a control.

All three plots were planted with small hard clams from the Eastern Shore stock (Table 4).

No clams were recovered from the plants in 1971 or 1972, although almost 1/2 of the top 3 inches of sediment was examined in each plot. It is not known why the Browns Bay area was unfavorable for survival of juvenile clams.

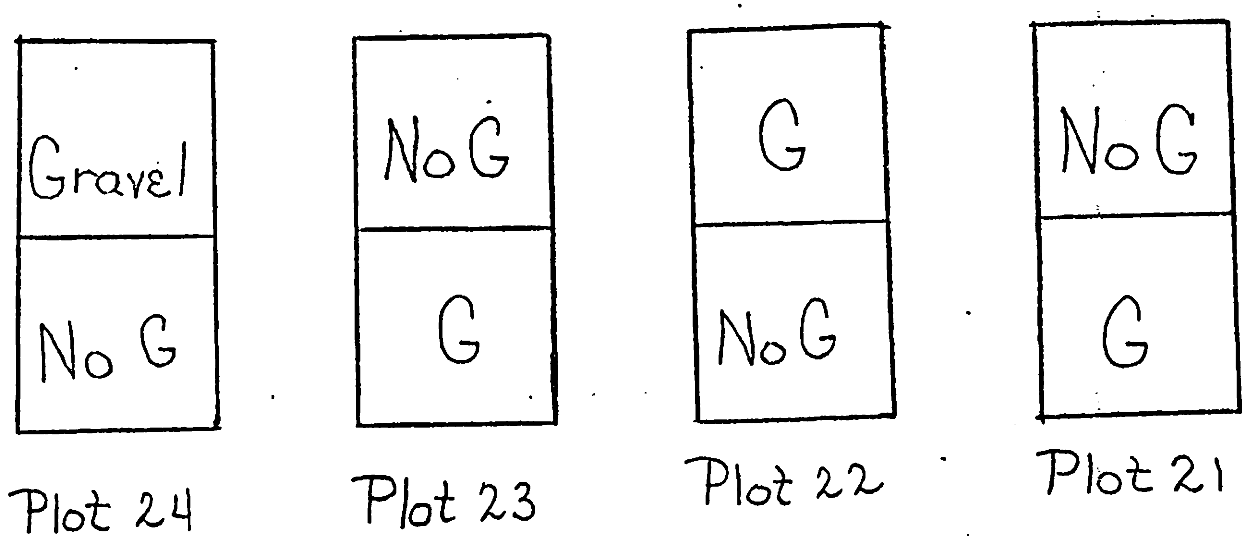
Table 4. Studies on Clam Farming At Browns Bay, Virginia 1970 and 1971.

Plot	Original No. Planted	Clams in Sample	Range Length (mm)	Mean Length (mm)	Increase (mm)	Density sq/ft	Est. Survival %
				1970			
A	2525	0	2-4	3			
B	2525	0	2-4	3		NONE RECOVERED	
C	2525	0	2-4	3		Spring 1971	
				1971			
A	5000	0	2-4	3			
B	5000	0	2-4	3		NONE RECOVERED	
C	5000	0	2-4	3		Spring 1972	

C. Gloucester Point 1972-1973 (Ex. 21, 22, 23 and 24).

Effects of low gravel densities were studied in 1972 and 1973. In these experiments, four gravel plots were prepared each 15 X 15 and these were covered with gravel at the rate of 1-1/2 yards per 225 square foot.

On April 5 and 7, 1972, we prepared 4 gravel plots as shown below. Plot size was 15 X 15; 1-1/2 yards gravel was placed on each gravel plot (G); No G were plots of equal size receiving no gravel.



On May 30, 1972 160,000 Eastern Shore seed *Mercenaria* were divided into eight groups of 20,000 each. These groups were planted as even as possible on each of the control and gravel areas. For orientation purposes while spreading the clams, a line was run diagonally across each plot and the diver traveled across the plot along this line.

A pirtion of these clams were preserved for determining average length; length ranged from approximately 0.5 - 5 mm. There follows the sources of the clams planted:

1. M-NLI-1-72 were spawned 3/20/72 and set between 3/29 and 4/3/72 . Total set 1,074,000. Parents were from Northport, Long Island (NLI). This was the first spawning of this stock.
2. M-PC-1-72 were spawned 1/14/72 and set 1/28 and 1/31/72. Total set 159,000. Parents were from Pellatier Creek, North Carolina. This was first spawning of this stock.
3. M-MG-1-72 were spawned 1/12/72 and set 1/26/72. Total set 20,000. Parents were a mixed group from New York and North Carolina. This was first spawning of this stock.
4. M-PN-1-72 were spawned 1/7/72 and set between 1/14 and 1/19/72. Approximately 5,000,000 set. Parents were from North Carolina and New York.

The planting area was studied 1 November 1972 with the suction sampler and we found that survival was practically zero (Table 5). We attributed this low survival to three reasons:

1. The small size at planting.
2. Tropical Storm Agnes on 21 June brought about excessively

Table 5. Summary of Hard Clam Plots 21, 22, 23 and 24, Gloucester Point, Virginia. Eastern Shore Spawned - Mixed Stock: L.I., N.C., E.S.

Plot No.	6-7 April, 1972 Original Density sq/ft	Mean Size	1 November, 1972 No. Grabs	No. Col-lected	Mean Size mm	Density sq/ft
21 No Gravel	88	0.5-5 mm	15	0	0	---
21 Gravel	88	" "	15	2	4.5	1.0
22 Gravel	88	" "	12	1	5.5	0.6
22 No Gravel	88	" "	12	0	0	---
23 Gravel	88	" "	Not Sampled*		---	---
23 No Gravel	88	" "	Not Sampled*		---	---
24 Gravel	88	" "	Not Sampled*		---	---
24 Gravel	88	" "	Not Sampled*		---	---

* These plots showed no clams in the 20 Feb. 1973 examination (Table 6).

low salinities in the planting area and for several weeks salinities in the area ranged from 3 to 7 ppm.

3. A second tropical storm in September was accompanied by high winds during a period of low water. This caused extensive breaking of waves over the experimental plots and it was felt that many clams were washed away.

On 13 November, 1973 the four 15 X 15 foot experimental plots (21, 22, 23 and 24) were replanted. We did this because we failed to find significant numbers of clams in the squares following Agnes and the subsequent damage due to high winds and surf over the plots in late September. The planting stock consisted of hard clams spawned by the Wachapreague branch of VIMS during the summer of 1972.

Of the clams planted, 100,000 were between 1-3 mm long (2 months old). An additional 29,000 ranged from 4-8 mm and were about 5 months old.

In conjunction with the replanting of plots 21, 22, 23 and 24, we developed a technique of planting very small clams which insured their reaching the bottom. A six inch stove pipe was attached to a 2 X 4 piece of wood so that the bottom of the pipe came within 2 to 3 inches of the bottom. Small groups of clams were dipped up in the beaker and placed into the stove pipe. When the clams had fallen almost to the bottom, the pipe was gently moved over the bottom until all of them were on the bottom. The boat was secured by lines and the descent of the clams was determined with a stopwatch. All of the clams were placed at slack water or under conditions of slight current and little breeze. Approximately one thousand of the 5 month old clams were seeded by casting them into the water because it was slack water and there was no wind. The remainder were placed in the pipe including all of the 3-4 mm clams. When the current increased, we stopped placement for two hours. Placement was started at 0900 and completed at 1600 with a two hour break at 1200.

All of the clams were placed three feet or more in from the edge of the plot and as evenly as possible. It appeared that the larger clams, 5 month old group, was much easier to place on the bottom and were spread more evenly on the plot.

The results of the second planting show excellent survival of the 4-8 mm clams from 33 to 38% and practically zero survival of the 1-3 mm clams.

We conclude that at Gloucester Point, planting of 1-3 mm clams is not practical, but that planting of the 4-8 mm clams does result in survival levels which indicate that clam farming may be economically practical.

D. Experiments Using Plastic Netting To Protect Hard Clams

It seemed desirable to test the use of barrier nets which would exclude animals in addition to testing gravel.

The type of net tested as a vertical "fence" barrier has a mesh 13 mm (1/2 inch) square and is designated as OP 3002 #7 (2x2) Conwed Corp. Two fenced plots were constructed near VIMS during

Table 6. Studies on Clam Farming at Gloucester Point, Virginia. The Replanting of Plots 21, 22, 23 and 24 in November, 1972.

	Planted 13 November, 1972			Sampled 20 February, 1973				
	Total Clams	Size mm	Density sq/ft.	No. Grabs	Number Collected	Mean Size mm	Density sq/ft.	% Survival
Plot 21								
Gravel	14,500	4-8	64	10	32	6.2	24.6	38
No Gravel	None	---	---	10	0	---	----	0
Plot 22								
Gravel	25,000	1-3	111	10	2	3.1	1.5	1
No Gravel	25,000	1-3	111	10	2	3.4	1.5	1
Plot 23								
Gravel	25,000	1-3	111	10	0	---	0	0
No Gravel	25,000	1-3	111	10	0	---	0	0
Plot 24								
Gravel	14,500	4-8	64	10	28	6.0	21.5	33
No Gravel	None		---	10	0	---	0	--

* Each grab of suction sampler took in .13 sq/ft.

the first two weeks of September, 1971 in water 1.2 - 1.5 m (4-5 feet) deep at high tide adjacent to Station 13 (Figure 1).

The plot was approximately 7.5 feet on the side and were delimited by driving deep into the bottom four stout corner stakes. Four additional support stakes were placed midway between each corner. The fenced plots had netting stapled to the stakes at low tide such that the netting extended above the bottom approximately 5 feet with 1 foot fringe at the bottom. Around the perimeter of each plot a trench was shoveled out, and the fringe buried in it. The covered plots had the netting spread out flat over the bottom inside the staked area and fastened down with stakes. Again, a trench was shoveled out and a 0.3 m (1 ft.) fringe buried in the bottom.

Juvenile hard clams with a mean length of 6 mm were planted in two fenced plots along with a control adjacent to one plot.

Date of Planting	Plot Type	Mean Clam Length (mm)	No. Clams Per Plot	Clam Density
9/15/71	2 Fenced	6 mm	870	15 sq/ft
	1 Control	" "	870	" "

In December, 1971, a three-foot long rip developed in one of the fenced plots where the wire staples joined the net to the stake. Previous to this, however, all three plots had withstood several storms without any rips. During the months of January and February, four or five rips developed in the other fenced plots where the net was stapled to the posts. The base of the net, however, was still firmly anchored to the sand in all three plots.

Restoration of the netting on the three fenced plots took place in mid-April 1972, before the blue crabs became active in the inshore areas. New netting was put up using wooden battens 1/16 inch thick and 5/8 inch staples. This was a much more permanent method than simply stapling the net to the stake.

In mid-May 1972, clams were sampled using the water-powered suction sampler which sampled an area 126 cm^2 to a depth of 20 to 25 cm. A minimum of 20 samples were taken within each screened plot and on the control.

There were no clams collected in either the two screened plots or on the control.

It was concluded that netting of the size used offered no protection since it could not exclude the smaller crabs.

Studies at Lynnhaven 1972-1973. On 1 December, 1972, two small experimental plots were planted at Lynnhaven Inlet on bottoms leased to a Mr. Midgett. The two 5x5 foot plots were not treated with gravel but one was screened with 1/4" mesh plastic screen, similar to that used in the preceding study; a secon area was unscreened. These studies were conducted in cooperation with the Institute's Advisory Service by Mr. Jon Lucy and Mr. Robert Dias.

On 1 December, the plots were planted with clams spawned at the Wachapreague Laboratory. They ranged in length from 3 - 12.5 mm with a mean size of 5 mm. Each plot was planted at a density of 241 clams per square foot. Plots ebbed dry at low tide; bottom was firm sand and oyster shells.

On 1 May, 1973, the two plots were sampled with the suction sampler which was used in the preceding studies.

RESULTS

	Original Density sq/ft.	Final Density sq/ft	% Survival	Length mm 1 Dec '72	Length mm 1 May '73
Screened Plot	241	40	16.6	5.0	7.5
Control	241	29	11.9	5.0	7.4

It was concluded that in the Lynnhaven area netting was only marginally successful in protecting clams. However, the 11.0 to 16.6%. However, survival of 40 to 29 clams respectively per square foot was regarded as quite satisfactory from an economic standpoint.

CONCLUSIONS - 1971-72 DATA

Data obtained from our clam farming studies are highly variable, however, certain basic facts do seem clear.

1. The use of gravel does result in higher survival rates than on ungraveled bottoms.
2. The variable and sometimes conflicting results obtained in this study suggest that the location where clams are planted is of major importance. The present study show that shallow areas ($<$1 ft. MLW) subject to wave action,

as well as locations close to protected marshy shore similar to those at Browns Bay are not satisfactory. Survival seemed better in the deeper water (5-6 feet) than in shallow water (1-2 feet). Studies were not carried out in waters deeper than 6 feet under this contract. However, information obtained by Mr. Castagna from the Virginia Institute's Wachapreague laboratory suggests that the deeper water gives better survival than shallow water stations. Future trial plantings should be made at depths of from 10 to 20 feet.

3. Growth in the graveled plots is about the same as that which occurs on the adjacent natural bottom, in "wild" clam populations. This tentative conclusion is based on comparison of growth increments of those cultured on gravel bottom with growth rates in natural populations (Job II).

   If 2 to 4 mm clams are planted in early spring then under normal salinity conditions the clams will reach market size (30 cm) sometime during the third growing season.

   Survival was nearly zero in plots planted with 1 to 3 mm clams. For the 4 to 8 mm sizes survival ranged from 33 to 38%.

5. In our 1971-72 annual report, we were quite optimistic concerning the economic possibilities of hard clam farming. This initial optimism was largely based on

data from plots 1-17 in 1970, 1971 and 1972 where a majority of the clams seeded at a length of 2 to 4 mm lived as well as the larger size. We, therefore, estimated costs of seed on the basis of 2 to 4 mm clams at $2.00 per thousand. Survival in this early report was estimated as exceeding 10%.

A further compliation of data for 1972-73 for plots 1-17, however, suggests that average survival for those plots did not exceed 10%.

In 1972-73 plots 21, 22, 23, and 24 showed zero survival of small seed (1 to 4 mm). Therefore, our initial assumptions as to the economic practicality of small, 1 to 4 mm seed were not valid. The larger 4 to 8 mm seed clams (Plots 21 and 24) gave good survival values ranging from 33 to 38% when measured in late February 1973. This larger seed, however, is more expensive. Mr. Castagna of the Wachapreague branch of Virginia Institute of Marine Science estimates costs at $5.00 per thousand (5 mm seed).

Estimates of cost of clam farming based on 10% and 33% survival and a cost of $5 per thousand follows:

a.	Cost of gravel for 1 acre (minimum amount)	$1,000
b.	Cost of 5 mm clams to plant at the rate of 20 per square foot, at cost of $5/1000 (20 x 43,560 x 1/2¢)	4,356
c.	Cost of planting	50
	TOTAL EXPENSES	$5,406

d. Estimated total gross per acre based on 33% survival and a value of 3¢ each for littleneck clams
871,200 clams x 33% = 287,496 clams
287,496 clams x 3¢ = $8,625

e. However, it is never possible to harvest all of the standing clam crop and it is estimated that only about 70% is harvestable. Therefore, estimates in (4) must be revised as follows:
(287,496 clams x 70% = 201,247 clams)
(201,247 x 3¢) = 6,037

f. From the above value of $6,037 we must subtract the original cost of seed and planting which was $5,406 plus an estimated $200 cost of harvest, therefore, a profit per acre for three years would be:
($6,037 - 5,606) = 431

g. Therefore, annual "profit" on the clam grounds would be about 431 ÷ 3 or $144 per acre per year.

While costs shown in the preceeding paragraph are high and gross profits low it must be recognized that commercial oystermen have long practiced comparable cultural techniques. That is, up to 5,000 bushels of oyster shells are planted per acre as a substrate for seed oysters. Costs and gross profits of this operation are similar to those suggested for hard clam culture.

Costs to Oystermen - 1971

1. Cost of shelling 1 acre of oyster ground with 5000 bushels of oyster shells @ 25¢ per bushel (planted) $1,250

2.	Cost of seed oysters @ $1.50 per bushel and planted at the rate of 500 bushels per acre.	$ 750
3.	Cost of harvest 1 acre	100
	ESTIMATED COST	$2,100
4.	Value of the 500 bushels of seed oysters 3 years later when they reach maturity. (Assuming that 1 bushel of seed will return 1 bushel of market oysters worth $5.00 per bushel). $5.00 x 500 bushels =	2,500
	NET	$ 400
5.	The net for 3 years is $400 or about $133 per year.	

It is pointed out that while the profits from clam farming and for growing oysters seems quite low, they would be higher if successive crops were planted. That is, one shelling of oyster shells will last many years, thus, the expense of shelling is only an initial one. It is equally possible that one application of gravel may be sufficient for several crops of hard clams.

It is concluded that clam farming has a definite potential. The results of our three year study, however, indicate that extreme caution should be exercised by anyone attempting to farm clams on a commercial basis. This is indicated in the present study in studies where all clams died from being planted in the wrong location or at a size too small for survival. Also, prior to planting budgets need to be developed for costs of gravel and seed.

It is strongly suggested that prior to investing large amounts of capitol in clam farming that pilot studies be first made by planting small 1/4 acre plots. It is also recommended that average size of seed be 5 mm or larger.

JOB 4. MODIFICATIONS OF A MARYLAND TYPE HYDRAULIC ESCALATOR DREDGE FOR THE HARVEST OF OYSTERS.

During the 1970-1973 contract period, an apparatus was developed to fit on the head of the Maryland type soft clam harvester so it would be adapted to harvest oysters. It was specifically developed not to utilize a verticle jet of water which would disturb an oyster bottom.

In developing this apparatus, we obtained the assistance of Mr. Q. C. Davis, an engineering consultant who specialized in mechanical design of engineering equipment.

The initial work on the harvester consisted of building a wooden mock-up of the apparatus, and then evaluating several possible designs. After this, work progressed slowly due to the necessity of having the working model constructed from non-standard items in a machine shop. The final working prototype, however, was completed in the 1972-73 constract period and field trials were conducted in June 1973 on several types of bottoms.

The harvester "head" which we have developed consists of a rectangular box of 1/4" cold-rolled steel with an inside width of 36", and an overall length about 36-1/4". The "box" narrows from 36" to a width of 18" where it attaches to the escalator. The box is designed to slide over the bottom ahead of the escalator on steel runners 47" long. These runners are 4" wide at the forward end and 6-7/8" at the end which attaches to the escalator. Two strong I-beam "supports" strengthen the top side of the box, and serve as a place of attachment of the hydraulic motor and for the rotor drive shaft (Figure 1A).

Attached to the inner side of the box are two adjustable eliptical sheets or "arms" of 1/4 inch cold-rolled steel 11-1/4 inches wide at the widest point and 31 inches long(Figure 1B). Affixed between the two arms are two revolving cylinders spaced at equal intervals. Around the diameter of each cylinder are equally spaced six 1-5/8 inch cold-rolled steel bars on which are affixed rows of steel spring "tines" (Figure 1C and 1D). The eliptical arms are attached to the box at one end by a steel shaft going through both the arms and the box (Figure 1A). However, the forward end may be raised or lowered by moving the steel bolts on the side of the box (Figure 1D). The flexible steel tines may be adjusted to dig into the bottom from o to 4 inches below the skids by moving the free end of the arms up or down. The action of the teeth is similar to that of the teeth of hand tongs, and is designed to "rake" shells or oysters from the surface of an oyster bed without penetrating too far into the bottom.

The cylinders are made to revolve by a chain drive driven by a hydraulic motor. This motor operates underwater at full power for 1 to 40 rpm. It is manufactured by Parker Hannifon Company, Model 82-ONF 1UUA-B18B, (Figure 2E).

The hydraulic motor transmits its power to the rear cylinder by a chain link drive. This cylinder in turns drives the second cylinder by a similar chain drive. Tension on this drive chain is maintained by an idler cog and a set-screw (Figure 2H).

The newly developed oyster harvester head was tested during June, 1973 (Figure 3). In the initial tests, it was demonstrated that:

1. The mechanical design of the apparatus was satisfactory.
2. The head containing the revolving tines attached satisfactorily to our present escalator system.
3. All bearings, chain drives, and motors were fully operable, and the tines revolved as designed. Rotation speed of the tines was variable from about 1 to 40 rpm.

As expected, our field trials showed that modifications were needed pending further operations, and these are now being undertaken under our new contract. Modification will consist of the following:

1. Modify the hydraulic winches in the Mar-Bel to accomodate the heavier loads of the present equipment.
2. Strengthen the present escalator system, to accomodate the new head. We will do this by replacing the flat iron structual elements on the present escalator with pipe sections.
3. Add <u>horizontal</u> water jets which will "blow" shell and oysters raised by the teeth <u>onto</u> the escalator belt.
4. Investigate the use of an air tank affixed to the top of the box which will lighten the underwater weight of the apparatus.

Figure 1A-D. Side and Frontal Aspects of Oyster Harvester.

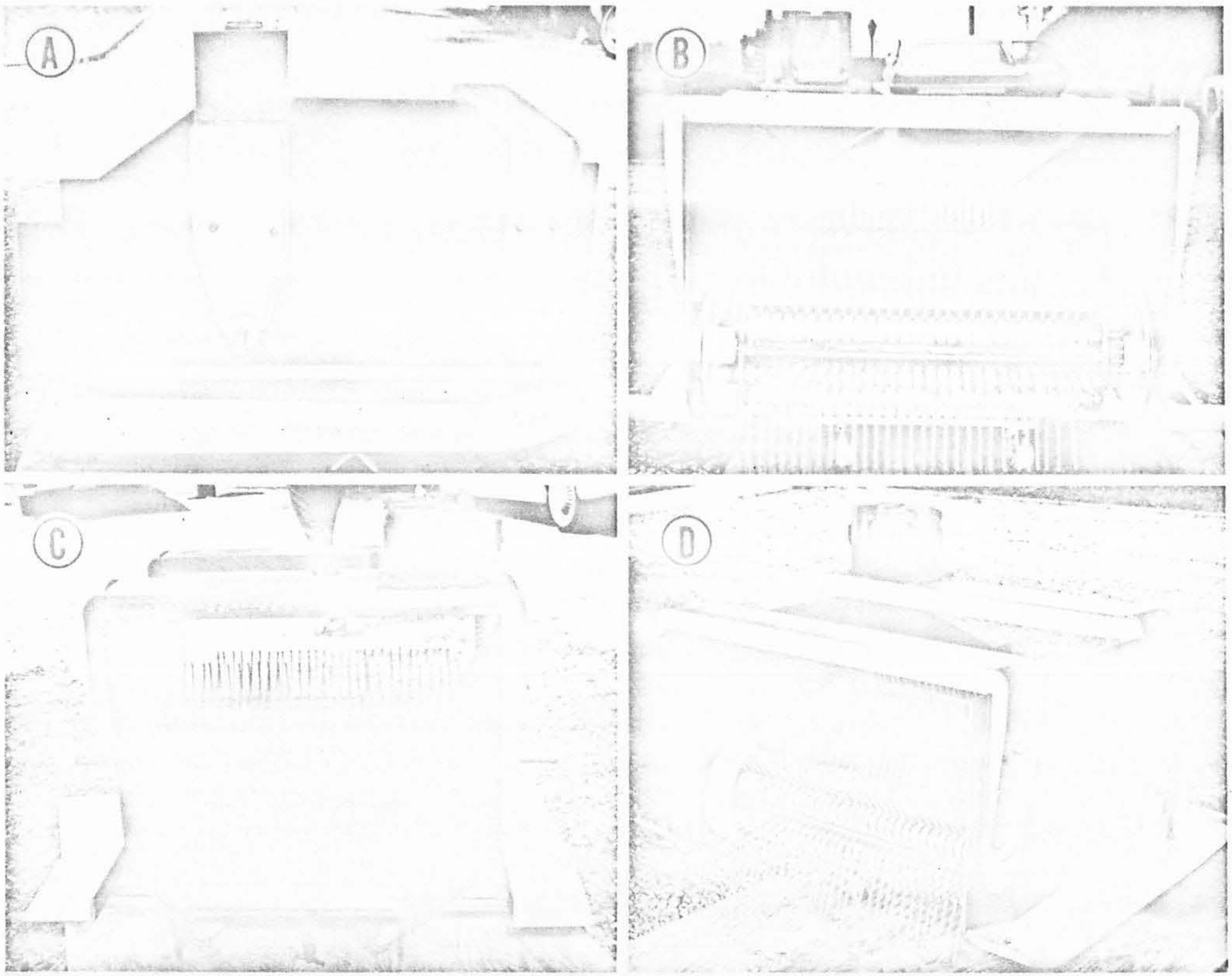
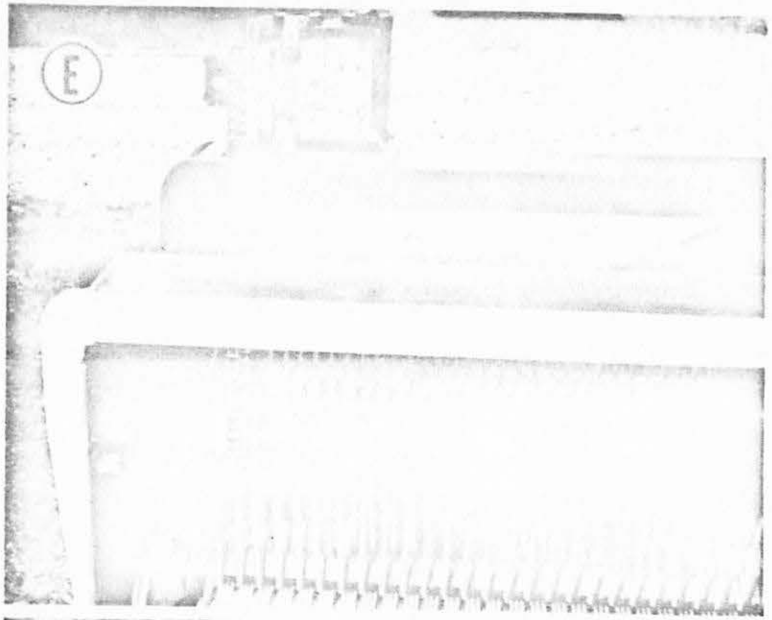

A
B
C
D

Figure 2E-H. Details of Rotating Drums and Tines.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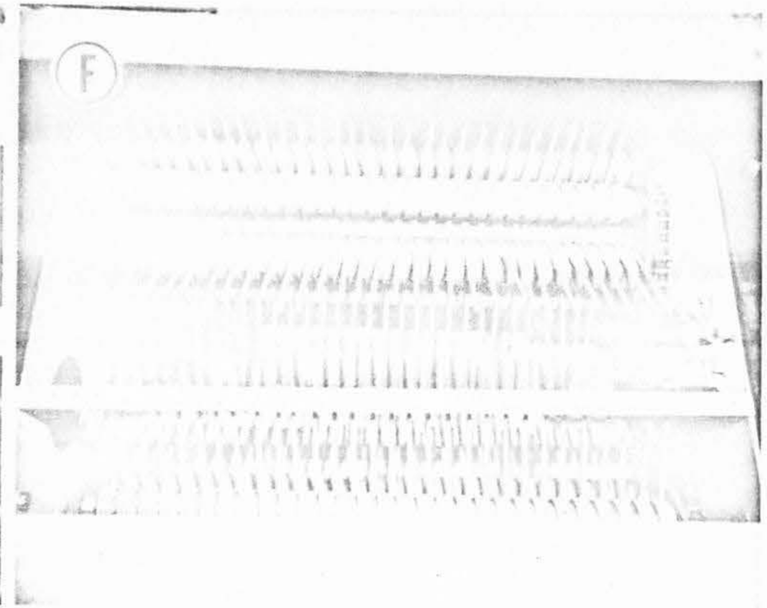
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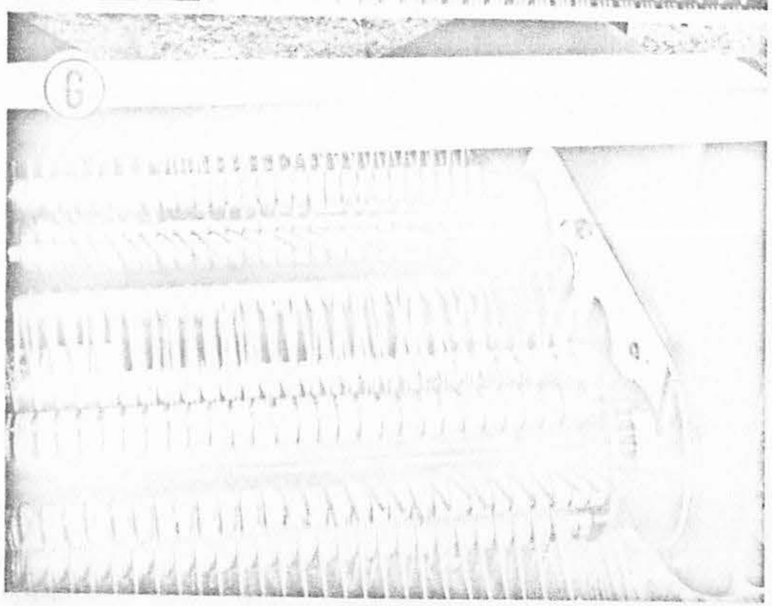
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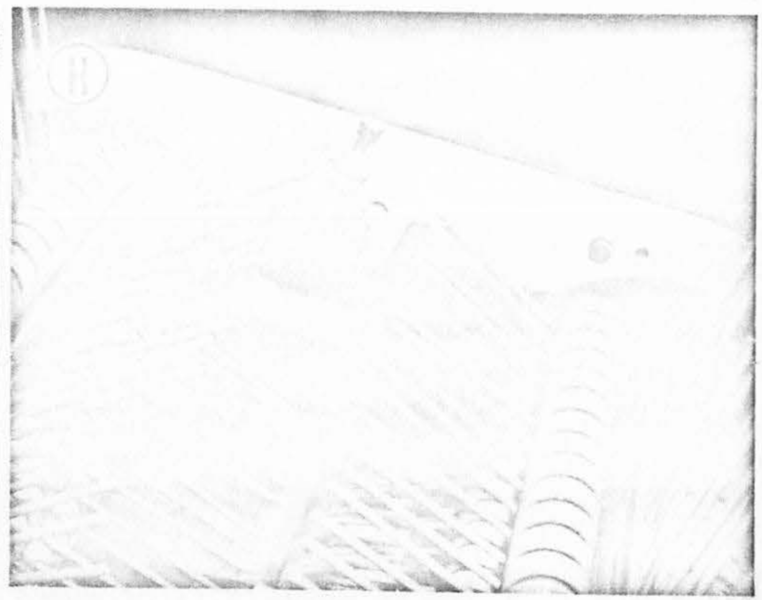
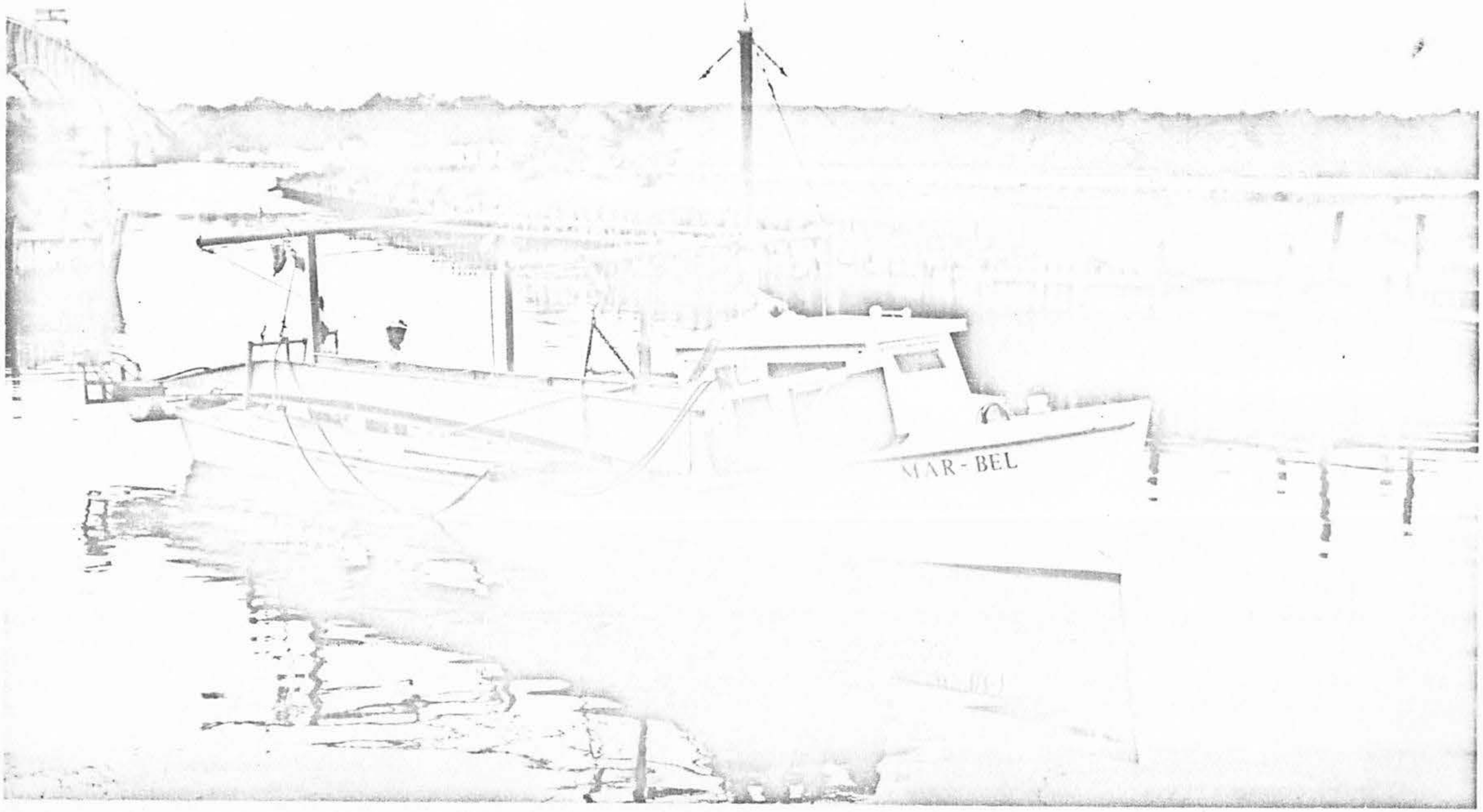

H

Figure 3. Oyster Harvester Mounted on Research Vessel Mar-Bel, Gloucester Point, Virginia.


MAR-BEL

V. SUPPLEMENT - PATENT TONG SURVEY OF THE LOWER JAMES RIVER.

INTRODUCTION

During the course of this contract work, additional data on hard clam distribution was obtained from other surveys the laboratory conducted in 1972 for the Virginia Department of Highways, the Virginia Marine Resources Commission, and the Newport News Shipbuilding and Dry Dock Company. The purpose of these added studies was to determine the possible environmental impact of various construction projects on the hard clam populations.

In the course of these studies, a patent tong boat occupied about 106 stations in the lower James River (Figure 1). At each station the boat was anchored and 10 or 20 grabs were made with the boat being moved slightly between grabs. Each grab of the tongs covered about 10 square feet. Data collected in these studies included number of clams per grab and number per square foot (Table 1).

These data showed heavy concentration of hard clams on the north shore of Hampton Roads and in the area up-river from Newport News.

Figure 1. Location of stations sampled with patent tongs from chartered vessel. Abundance code: high, closed triangle; medium, half-closed triangles; low, open triangles.

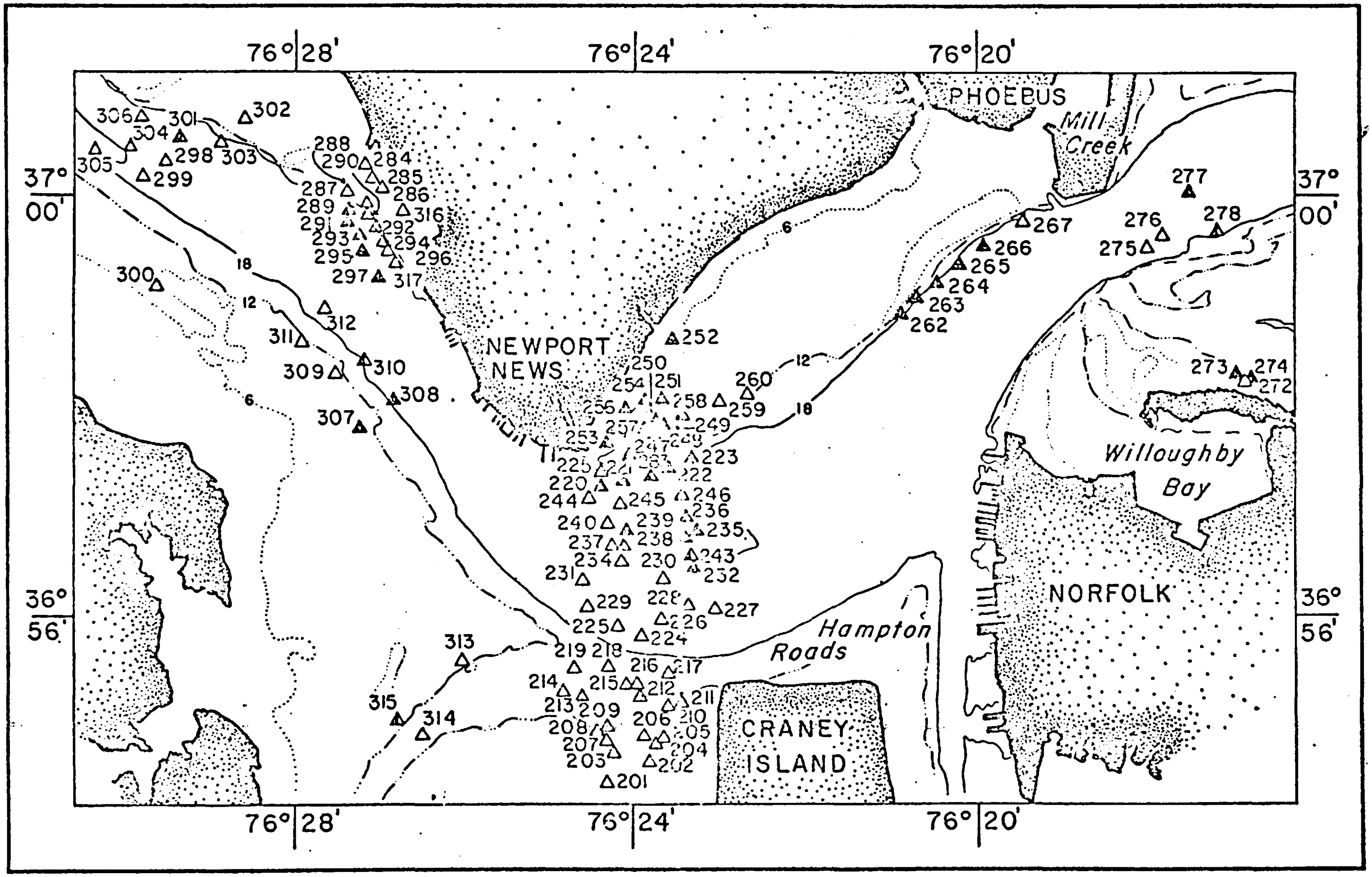


Table 1. Patent tong catch statistics for hard clams sampled in the lower James River in 1972.

Coll. No.	No. of Grabs	No. of Clams	Clams per ft^2
201	20	2	0.01
202	20	0	0
203	20	0	0
204	20	0	0
205	20	0	0
206	20	0	0
207	20	0	0
208	20	0	0
209	20	0	0
210	20	2	0.01
211	20	0	0
212	20	0	0
213	20	0	0
214	20	0	0
215	20	0	0
216	20	0	0
217	20	0	0
218	20	2	0.01
219	20	2	0.01
220	20	232	1.16
221	20	140	0.70
222	20	212	1.06
223	20	128	0.64
224	20	0	0
225	20	2	0.01
226	20	2	0.01
227	20	4	0.02
228	20	0	0
229	20	0	0
230	20	18	0.09
231	20	0	0
232	20	84	0.42
233	20	154	0.77
234	20	6	0.03
235	20	184	0.92
236	20	268	1.34
237	20	16	0.08
238	20	68	0.34
239	20	226	1.13
240	20	188	0.94
241	20	80	0.40
242	20	98	0.49
243	20	74	0.37
244	20	14	0.07
245	20	6	0.03

Table 1 (Continued)

Coll. No.	No. of Grabs	No. of Clams	Clams per ft^2
246	20	2	0.01
247	20	176	0.88
248	20	80	0.40
249	20	102	0.51
250	20	76	0.38
251	20	112	0.56
252	20	132	0.66
253	20	48	0.24
254	20	94	0.47
255	20	0	0
256	10	57	0.57
257	10	57	0.57
258	10	38	0.38
259	10	9	0.09
260	10	11	0.11
261	10	64	0.64
262	10	105	1.05
263	10	84	0.84
264	10	45	0.45
265	10	61	0.61
266	10	49	0.49
267	10	2	0.20
268	10	58	0.58
269	10	47	0.47
270	10	0	0
271	10	4	0.04
272	10	60	0.60
273	10	42	0.42
274	10	45	0.45
275	10	3	0.03
276	10	11	0.11
277	10	49	0.49
278	10	27	0.27
279	10	50	0.50
280	10	74	0.74
281	10	76	0.76
282	10	36	0.36
283	10	36	0.36
284	20	3	0.015
285	20	5	0.025
285	20	0	0
287	20	22	0.11
288	20	0	0
289	20	46	0.23
290	20	2	0.01

Table 1 (Continued)

Coll. No.	No. of Grabs	No. of Clams	Clams per ft^2
291	20	117	0.585
292	20	2	0.01
293	20	216	1.08
294	20	0	0
295	20	188	0.94
296	20	0	0
297	20	209	1.05
298	20	5	0.025
299	20	1	0.005
300	20	0	0
301	20	54	0.27
302	20	16	0.08
303	20	1	0.005
304	20	0	0
305	20	0	0
306	20	9	0.045
307	20	117	0.585
308	20	96	0.48
309	20	0	0
310	20	69	0.345
311	20	14	0.07
312	20	2	0.01
313	20	0	0
314	20	0	0
315	20	40	0.20
316	300	25	0.008
317	900	3139	0.349