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AN INVESTIGATION OF THE SEED OYSTER RESERVES IN VIRGINIA AND TESTING AND MODIFYING OF GEAR TO HARVEST OYSTERS

Final Contract Report for the Period
1 July, 1973 through 30 June, 1975

Contract No. 3-193-R

By

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MANAGEMENT IMPLICATIONS, RECOMMENDATIONS, AND SUMMARY

Management Implications

Great Wicomico River

Few seed oysters have been harvested in this river since the 1972-73 season, although it has produced large volumes of market-sized oysters. From about 1965 to 1971 this system produced about 10% of the total seed output of the state.

There was a significant decline in density of oysters on this bottom from 1973-74 to 1974-75 (Table 1). This indicates that stocks of oysters were being removed by fishing and natural mortality faster than they were being replaced by recruitment. Moreover, during the same period spat set was very low, ranging from 0 to about 6,000 per acre (Table 6). This range was too low to replace the mortality losses. If the trend shown by the data continues, stocks will be depleted.

There is evidence from another source which suggests that stocks have been declining in the river for longer periods. Data on setting (attachment of larvae to shells) obtained by VIMS indicated a very low weekly rate of setting of oysters from 1972 to the present. The supply of seed-sized oysters has diminished because of poor recruitment in conjunction with growth of the existing stocks to market-sized oysters. The Great Wicomico River is presently a market oyster growing area with a low rate of recruitment. Its use as a seed area in the future will depend on occurrence of moderate or heavy sets similar to those in the 1961 to 1971 periods.

The cause of low oyster sets in the Great Wicomico since 1972 may be due to low concentrations of dissolved oxygen (DO) in the deep waters during the warmer summer months. The existance of low DO values in this river has been documented by VIMS in 1972, 1973, 1974 and 1975, and in 1973 and 1974 by the State Water Control Board (SWCB). Laboratory studies by VIMS indicate that low DO's, similar to those observed in the river are lethal to oyster larvae in a few days.

The cause of low DO values in the Great Wicomico River is still unresolved. The SWCB in February 1975 stated in a letter to VIMS that in the Great Wicomico the deeper waters were stratified and were not mixing with the surface layers, and this placed a high demand in the deeper waters on DO. They concluded that since they found low BOD levels in their studies that the demand for oxygen probably came from a factor they termed sediment oxygen demand (SOD).

Piankatank River

This river supplied an estimated 10 to 15% of the seed produced in Virginia in the period of 1964 to 1975, and in 1975 it produced 34,269 bushels of seed and 58,000 bushels of market oysters.

Stocks are now being harvested faster than they are being replaced by recruitment. From 1973-74 to 1974-75 there was a significant decline in density of oysters on the bottom (Table 1). The decline in the spat set in the 1974-75 period (Table 6) in conjunction with the decreased density of the larger size groups indicate that a further decline in stocks will occur.

The Piankatank River contains no known sources of pollution, therefore, the decrease in oyster spatfall must be attributed to natural causes.

James River

Since early in the 20th century, the James River has supplied about 75% of the seed oysters planted on leased bottoms. Without seed from this source, the private sector of the industry, as it operates today, would cease to exist.

Since about 1960, the intensity of spatfall in the James River has decreased about 90% in the area from Wreck Shoals downriver to Nansemond Ridge, and about 50% above Wreck Shoals to Deep Water Shoals. The decline is associated with a reduction in brood stocks in the lower James River because of MSX and increased mortalities of larval oysters due to pollutants or other environmental changes. There has also been a long-term decline in the annual landings of James River oysters. In the period of 1931 to 1960, annual landings ranged from 1.0 to 2.7 million bushels. However, by 1963 annual landings were down to 800,000 bushels, and in 1975, only 317,000 bushels were landed. The reason that shortages of seed from this area have not become critical today is largely due to a lowered demand for seed. If the long-term trend of decreased sets continues, even today's low demand may result in a further decline in existing stocks. Most certainly, if demand increases, then many of the marginally productive areas will be depleted.

The present study showed a significant decline in oyster density between the 1973-74 and 1974-75 sampling periods (Table 1). In addition, the 1973-74 spatfall was low (Table 6). The 1974 spat set, however, was exceptionally high for the post-1960 period. We expect that at the present rate of harvest densities of seed oysters will increase in 1975-76 and perhaps in 1976-77 as a result of this stronger set. The recent past history of the area, however, suggests that this reversal will be temporary.

Management Recommendations

Great Wicomico River

Because of low DO in this system and the inconclusive report of the SWCB, it is recommended that further studies of the hydrography of the area be conducted by VIMS to determine if the low DO levels are associated with industrial pollution and/or natural conditions. In the event they are associated with industry, then remedial action should be taken.

In view of the adverse setting conditions in this river, it is recommended that no large scale shell planting should be made. However, trial plantings (small scale) should still be made at the optimum time of year as shown by VIMS reports on setting.

Piankatank River

This system continues to produce seed, although there has been a decline in setting intensity during the past few years.

It is recommended that this river be planted with shells where density is low (Appendix 1). To optimize the set, shells should be planted just prior to the time of peak setting as indicated on VIMS reports. In the event counts of spat per bushel of bottom cultch are low (less than 400 per bushel) the set should be left in place to grow to market-size oysters. If it is above this value, it should be used as seed.

James River

The James River is the only major source of seed oysters in Virginia. Therefore, it is recommended that VIMS, VMRC, and other concerned agencies make every administrative effort possible to prevent further degradation of this stressed environment.

If it is the intent of the VMRC to increase seed production, it is recommended that repletion efforts be concentrated in the James River. Shell cultch should be planted on bottoms where existing populations are too low to support commercial efforts.

In recommending policies for enhancing seed production for this river, it must be recognized that the James River is divided by law into two sections. The area from Deep Water Shoals downriver to two miles below the James River Bridge is designated as a seed area where all sizes of oysters (seed) may be taken. This downriver limit is called the cull line; below this line only market-sized oysters may be taken.

In the seed areas, the optimal locations for planting shell would be just above the cull line at Naseway Shoals and Brown Shoals and perhaps as far upriver as Wreck Shoals. Below the cull line, however, there are extensive areas of barren bottom which are suitable for seed production since they typically receive a fair to moderate set each year and the oyster drills were killed by fresh water in 1972. We recommend that appropriate measures be taken so that the VMRC utilize all or part of the area below the cull line for seed purposes.

MSX is still present in this area but the oysters have a low degree of susceptibility during their first year. Therefore, if the disease becomes a problem, the seed may be moved at the end of the first growing season.

Shell should not be planted on bars which are presently productive but on areas of firm bottom where oyster density is low. Plantings should be made in early September to take advantage of the maximal set which typically occurs during this month. If shells are planted too early, they may become too fouled to receive a good set.

General

Although there has been a declining trend in seed oyster stocks, demand for seed oysters appears to have governed landings in recent years. In the James River from 1971 through 1974 landings only ranged from about 373 thousand to 459 thousand bushels of seed. There was no consistent decrease; the landings were high in the first and third years relative to those in the second and fourth years. In 1975 landings dropped to 317 thousand bushels but the fishing season was curtailed because of the kepone investigation. The present stock densities apparently can supply a sustained yield within the above stated range of landings. However, rocks in need of repletion should be closed and fishing effort directed to under-fished areas and those capable of sustaining the present fishing effort.

If stock densities continue to decline, a harvest limit should be set for each river system. Initially it could be established as the average landings for the last several years, e.g., in the James River the limit would be approximately 385 thousand bushels. Use of the average would avoid economic hardship in the industry and prevent an acceleration of stock declines due to increased effort.

The VMRC and VIMS should formulate contingency plans for the future management of harvest of seed oysters in the event stock densities decline or increase. To assist in this goal, quantitative data should be collected on a continuing basis. Catch-effort data should be recorded by VMRC, preferably by rocks within the river systems. In addition, quantitative estimates of stock density and structure (size classes) should be made annually by VIMS. The density estimates of spat and yearling oysters would be of particular interest. The latter would be an estimate of recruitment, and the differences between the two year classes would be an estimate of total spat mortality. Dramatic decreases, or a more subtle continuing decline in catch per unit effort and recruitment would be warning signs that a reduction in harvest would be necessary. Conversely, increasing trends of these statistics would warrant an increased harvest.

Summary

The objectives of this two year study in the James, Piankatank, and Great Wicomico Rivers were: (1) Document the densities of seed oysters and spat at representative areas of rocks in order that future changes may be compared to this "baseline"; (2) Consider management implications inferred by the baseline data; (3) Apply standard statistical methods to determine if observed changes were to be considered significant or simply chance differences in observations; and (4) Continue development and testing of a hydraulic oyster harvester.

The following comments are a summary of the contents of this report.

Oyster Density

1. The estimated number of oysters per acre and bushels of oysters per acre significantly declined in all three rivers between the 1973-74 and 1974-75 sampling periods. The decline in oysters per acre in the James River areas ranged from 12 to 70%; in the Piankatank River from 16

to 69%; and, in the Great Wicomico River from 63 to 69%. These declines reflect poor recruitment in recent years (1974 excepted).

2. Estimates of standing crop for each representative area were made in both years but could not be extrapolated for the entire rock because total area of the rocks is not known. These estimates were based on the density statistics and, of course, reflected the general decline mentioned above.

3. The counts of culled oysters per bushel were low ($<$ 1000), with the exception of those at Horsehead. Prior to the early 1960's counts of oysters per bushel were 1000 or more. The reduction in "counts" again reflects, in general, the poor annual spat set which has increased the average age and size of the oysters. It is expected that the count per bushel will increase in the 1975 James River harvest because of the strong 1974 spat set.

4. There was no general trend in average oyster length with respect to location in a given river. Again, Horsehead was an exception. Here, it is believed, that the lower salinity (relative to the other areas studied in the James River) inhibits growth and, thus, is responsible for the smaller size.

5. The percentage of market oysters increased and, correspondingly, the percentage of small oysters decreased in the 1974-75 sampling period. This again reflects the poor spat sets prior to 1974, and growth of small oysters to the next size class.

6. Spat density substantially increased in the James River in the 1974-75 sampling period. In the Piankatank River, spat density dramatically decreased in two areas but density changes were relatively moderate in the other four areas studied. Spat density increased in all three areas in the Great Wicomico River in the second year's sampling, but, nevertheless, remained low.

7. Several statistical programs were constructed by personnel of the VIMS Computer Science Department to aid in the analysis of the oyster data. These and a consideration of optimum sample size are discussed.

<u>Oyster Harvester</u>

1. During this contract period, the oyster harvester was modified and tested in the York and Rappahannock Rivers. The gear was demonstrated in action to members of the press, television, oyster growers, and to State and Federal officials. The trials of the harvester were successful. Harvest rates up to 138 bushels of oysters per hour were observed. Shells were raised at a maximum rate of 906 bushels per hour.

We believe that this gear would be useful to oyster growers and if adopted, would result in a considerable economic benefit.

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Part I: AN INVESTIGATION OF THE SEED OYSTER RESERVES IN VIRGINIA

INTRODUCTION

An urgent need to assess the oyster stocks in Virginia had been generated by declining seed production in the James River in recent years. Since about 75% or more of the seed planted by Virginia oyster growers is harvested from the James River, a knowledge of the stocks to aid managerial decisions is vital. Assessment of stocks in the Piankatank and Great Wicomico Rivers was also included in the study because of extremely poor spat sets there in recent years.

There were two general areas of work in this contract. The first was the stock assessment of the oyster resources at presumably typical sections of oyster rocks in the James, Piankatank, and Great Wicomico Rivers, and to show changes, if detectable, in oyster density from the 1973-74 sampling period through the 1974-75 period. The second aspect of the contract was to test and modify a mechanical oyster harvester.

The following report necessarily includes data from the previous annual report, thus, it is essentially the results of our studies from 1 July, 1973, through 30 June, 1975.

MATERIALS AND METHODS

Study Areas

Representative seed rock study areas determined by members of both the staff of the Virginia Marine Resources Commission (VMRC) and the Virginia Institute of Marine Science (VIMS), were sampled in the James, Piankatank and Great Wicomico Rivers (Figures 1, 2 & 3).

James River

In the James River seven rocks were sampled from Horsehead Bar near the upper limit of the Baylor Grounds to Nansemond Ridge in the lower river (Figure 1). The locations randomly sampled and their representative areas were as follows: Horsehead, 92 acres (Figure 4); Inshore Wreck Shoal, 276 acres; Middle Wreck Shoal, 172 acres; Offshore Wreck Shoal, 172 acres (Figure 6); White Shoal, 57 acres (Figure 7); Gun Rock, 103 acres (Figure 8); and Thomas Rock, 86 acres (Figure 9). Sampling sites at Point of Shoals (Figure 5) and Nansemond Ridge (Figure 10) were selected rather than randomly chosen. This was done because of the noncontiguous nature of the former rock, and because effort at the latter rock was confined to its relatively small crest.

Piankatank River

Five areas were investigated in the Piankatank River (Figure 2). The locations sampled and their areas were as follows: Three Branches, 27 acres (Figure 11); Burton Rock, 65 acres (Figure 12); Capetoon, 58 acres (Figure 13); Palace Bar, 50 acres (Figure 14); Island Bar, 5 acres (Figure 15); and Ginney Point, 18 acres (Figure 16).

Great Wicomico River

In the Great Wicomico River three areas were sampled (Figure 3). The locations sampled and their representative areas were as follows: Marsh West, 57 acres (Figure 17); Ingram Rock, 70 acres (Figure 18); and Whaley's West, 74 acres (Figure 19).

Sampling Procedure

Hydraulically operated patent tongs, installed on the VIMS research vessel Mar-Bel, were used to collect all samples. Nonhydraulic patent tongs are almost exclusively used in the hard clam patent tong fishery, but their efficiency is, in part, a function of the ability of the operator. The use of hydraulic patent tongs in the present study eliminated this variable and, thus, helped to insure a constant sampling unit.

The patent tongs are 131 cm (51.6 inches) long and have a gape of 119.5 cm (47 inches); therefore, each grab sampled an area of 1.56 m^2 (16.8 ft^2). On hard (shelled) oyster rocks the patent tongs sampled to a depth of about 10 cm (4 inches), and tests indicated that the vertical distribution of oysters was encompassed.

A grid system 152 m (500 ft) on a side was superimposed on a chart of the representative areas in the James River. The squares were numbered and approximately 50% of the squares in each area were randomly selected as sampling stations for both years using a table of random numbers. Sample sites were initially located on the representative areas in the James River by means of a sextant and a three-arm protractor in 1973. This method was later replaced by the use of Raydist, a highly accurate electronic navigational system.

A grid system and a random selection of sampling stations procedure was also employed in sampling representative areas of oyster rocks in the Piankatank and Great Wicomico Rivers. However, because the oyster rocks in these rivers are small, a grid system 76 m (250 ft) on a side was used and location of sample stations was exclusively accomplished by use of Raydist.

When sampling commenced in 1973 at Wreck Shoal, five grabs were taken at each station. However, it was soon apparent that this level of effort would not allow sufficient time to sample 50% of the stations in each representative area. Arbitrarily, it was decided to reduce the number of grabs per station, rather than the number of stations per area. Subsequently, two grabs were taken at all sample sites during the remainder of the contract period.

The following catch data were recorded for each grab sample: the total volume in the sample and the subsample volume (generally 0.5 bushel); the total number of oysters in the subsample and the breakdown of the total number of oysters into the descriptive categories of yearling, small and market oysters; the volume of shell and cinder in the subsample and an estimate of the percentage of shell that was exposed; and the number of new and old yearling, small and market oyster boxes. All volumes were measured to the nearest pint (dry) and converted to bushels (nearest 0.01 bushel) by equating 50 quarts, as measured in graduated plastic buckets, to one Virginia bushel.

The subsample was assumed to contain all the constituents of the total sample. Therefore, simple proportions were used to estimate the total volume of oysters, shell and cinder, and the total catch of oysters in a standard sampling unit (1.56 m^2 of substrate).

Appendix 1 contains the catch data for each sample station, the estimated number of oysters per bushel, and the estimated bushel per acre of oysters and exposed shell and cinder. The percentage of exposed cinder was arbitrarily equated to the estimated percentage of exposed shell.

Samples of oysters were returned to the laboratory for length measurements. Length was defined as the longest linear dimension of the upper valve. The average length and the 95% confidence limits of each size class (i.e., market, small, yearling and spat) by stations are presented in Appendix 2. Market oysters were defined as those 76 mm (3 inches). Morphology as well as size was used to define small, yearling and spat oysters.

The separation of yearlings (oysters in their second growing season) was based upon recognizable shell marks, shell striations, barring on the shell, and a raised white knob on the umbone. At any given location, the spat were smaller than the yearling and exhibited a convex upper valve. Similarly, oysters in the small class were larger than yearlings, but $<$ 76 mm (3 inches), and lacked the morphological criteria of the yearlings.

The percentages of market, small and yearling oysters at each station are presented in Appendix 3.

Oyster spat were counted on shell and oysters in one subsample of the station. Wreck Shoal and White Shoal were sampled prior to the cessation of spat set in 1973, therefore, it was necessary to return and obtain separate spat samples from some of the stations. In the second year of the contract, spat samples and oysters for length measurements were obtained in each river when the spat set was completed. Spat data for individual stations are presented in Appendix 4.

The counterparts to Appendices 1 through 4 for the 1973-74 sampling period were presented in the first annual report (No. 3-193-R) and are not repeated here because of their bulk. To facilitate reading and to show general similarities or differences among the areas, data in the appendices for both sampling years were grouped for each representative area of a rock and used to construct tables in the Results and Discussion section.

Bushels of oysters per acre was determined by multiplying the ratio of the average catch per grab to the average number per bushel by 2,589.3. This constant is the number of patent tong grabs equivalent to sampling one acre.

In the James River in the first year's sampling, only Wreck Shoal and White Shoal were sampled prior to the commencement of the annual commercial harvest of oysters. Assuming that oyster tongs harvest market, small and yearling oysters with equal efficiency, their percentage representation would not be affected by the interim between sampling collections. All sampling in the James River in the second year of the contract was completed prior to the commencement of the commercial fishery season with the exceptions of Point of Shoals and Nansemond Ridge. Sampling could not be conducted in the Piankatank and Great Wicomico Rivers prior to the season opening of the fishery. Accordingly, in the second year the representative areas in these rivers were sampled in the same time frame as in the first year, and fishing effort is assumed equal.

Statistical analyses were made using averages of the replicate samples at a station as the basic unit of data, e.g., average catch per grab. When a goodness of fit test indicated that an assumption of normality was reasonable, the parametric paired t test or Students's t test was used. When a normal distribution function could not be assumed, the nonparametric Wilcoxon's Signed Ranks test, the Sign test, or the Mann-Whitney U test was applied.

RESULTS AND DISCUSSION

Oyster Density

The number of oysters per acre (exclusive of spat) in all three rivers decreased between the 1973-74 and 1974-75 sampling periods. Although, as indicated in Table 1, the decrease in the number of oysters per acre was not statistically significant at all stations, nonsignificance was most often associated with small areas averaging only nine sample stations per area. The same differences, if associated with larger sampling effort, i.e., more sampling stations, would be statistically different (optimum sample size is discussed later). The observed decline in oysters per acre in the James River ranged from 12 to 70%; in the Piankatank River from 16 to 69%; and in the Great Wicomico River from 63 to 69%.

The decline in the number of oysters per acre reflects poor recruitment to the fishery since fishing effort has been relatively constant. Because all size classes other than spat are harvested, there is not an accumulation of several young age groups to offset years of poor recruitment. Thus, dramatic changes in oyster density are

Table 1. A comparison of oyster density between the 1973-74 and 1974-75 seasons in representative areas of rocks in the James, Piankatank, and Great Wicomico Rivers.

River and Rock	Oysters Per Acre (X 1000)		Bushels Per Acre+	
	1973-74	1974-75	1973-74	1974-75
James				
Horsehead	255	167*	197	199 NS
Point of Shoals	128	72 NC	164	137 NC
Wreck Shoal				
Inshore	20	6 NS	64	20 NS
Middle	94	48*	210	102*
Offshore	234	129*	356	196*
Thomas Rock	81	71 NS	172	179 NS
Gun Rock	112	88 NS	250	173 NS
White Shoal	233	85*	446	210 NS
Nansemond Ridge	8	48 NC	12++	45 NC
River system	147	85*	242	154*
Piankatank				
Three Branches	88	27*	184	46 NC++
Burton Rock	202	76*	398	175*
Capetoon	228	101*	490	232*
Palace Bar	221	134 NS	520	341 NS
Island Bar	84	42 NC	190	100 NC
Ginney Point	62	52 NS	152	156 NS
River system	148	72*	322	175*
Great Wicomico				
Marsh West	82	26 NS	261	73 NS
Ingram Rock	346	107*	717	220*
Whaley's West	145	53*	385	127*
River system	191	62*	454	141*

+ A function of both density and size of oysters.

++ Only one estimate of count/bu obtained.

* Indicates significant change ($\alpha \leq 0.10$).

NS No significant change.

NC No statistical inference made.

to be expected, particularly if harvest is not adjusted to recruitment.

Data for bushels per acre also indicate a significant decline in oyster density in all three river systems (Table 1). This is, of course, expected since bushels per acre values were derived from estimates of oyster density and the average number per bushel for a given oyster rock. Nonsignificant changes in bushels per acre were, in general, associated with those areas in which the observed change in oysters per acre was also nonsignificant. Two exceptions were Horsehead and White Shoals in the James River. At these two stations, the count per bushel decrease was relatively large (Table 3), indicating a change in the stock comparison, and, thus, increased the estimate of bushels per acre.

Standing crop estimates in bushels of oysters in the representative areas during the two sampling periods are presented in Table 2. Point of Shoals and Nansemond Ridge were omitted because stations were not randomly selected. These data again indicate, in general, the decline in oyster density from the 1973-74 to the 1974-75 sampling periods for a given rock. Differences among rocks with equal or near equal oyster density per unit area in a given sampling period simply reflect differences in the size of the representative area. For example, the density of oysters per acre was highest at Horsehead in both years (Table 1) but in terms of standing crop, it is inferior to several other rocks because of its smaller representative area (Table 2). Total standing crop for an entire oyster rock cannot be estimated because the total area is unknown.

Table 2. Comparison of oyster standing crop in the representative areas of rocks in the James, Piankatank, and Great Wicomico Rivers in the 1973-74 and 1974-75 sampling periods.

River and Rock	Representative Area (acres)	Standing Crop (bushels X 1000) 1973-74	1974-75
James			
Horsehead	92	18	18
Wreck Shoal			
Inshore	276	18	6
Middle	172	36	18
Offshore	172	61	34
Thomas Rock	86	15	15
Gun Rock	103	26	18
White Shoal	57	25	12
Piankatank			
Three Branches	27	5	1
Burton Rock	65	26	11
Capetoon	58	28	13
Palace Bar	50	26	17
Island Bar	5	1	0.5
Ginney Point	18	3	3
Great Wicomico			
Marsh West	57	15	4
Ingram Rock	70	50	15
Whaley's West	74	28	9

Table 3. Average number of culled oysters per bushel in representative areas of rocks in the James, Piankatank, and Great Wicomico Rivers in the 1973-74 and 1974-75 sampling periods.

River and Rock	Average Number Per Bushel 1973-74	1974-75
James		
Horsehead	1,294	837
Point of Shoals	783	528
Wreck Shoal		
Inshore	316	307
Middle	446	477
Offshore	657	660
White Shoal	523	405
Gun Rock	447	511
Thomas Rock	470	400
Nansemond Ridge	600+	1,050
Piankatank		
Three Branches	476	600+
Burton's Rock	507	431
Capetoon	465	434
Palace Bar	425	392
Island Bar	445	424
Ginney Point	410	330
Great Wicomico		
Marsh West	316	356
Ingram Rock	483	489
Whaley's West	376	421

+ Only one estimate obtained.

Number of Oysters Per Bushel

The count of oysters per bushel in the James River was highest at Horsehead, averaging 1,294 per bushel in the 1973-74 period and 837 per bushel in the second year's sampling (Table 3). It was relatively lower at the other locations with averages ranging from 783 to 316 per bushel in the first year's sampling and 660 to 307 in the second year (Point of Shoals and Nansemond Ridge not considered because of nonrandom sampling). Similarly, in the Piankatank and Great Wicomico Rivers the counts were relatively low. In the former river, average counts ranged from 507 to 410 per bushel and 434 to 330 per bushel in the first and second years of sampling, respectively. In the latter river, the range in counts in the first and second years were 483 to 316 per bushel and 489 to 356 per bushel, respectively. Prior to the early 1960's counts of oysters were 1,000 per bushel or more (Haven, unpublished). The reduction in counts in recent years probably reflects, in general, the poor annual spat set which has increased the average age and the average size of the oysters. Thus, while the price of bushels of seed oysters has remained relatively constant, the price per seed oyster has increased and the yield at maturity from a bushel of seed oysters has decreased, thereby increasing the planters overhead. However, the count per bushel should increase in the James River in 1975 if a reasonable percentage of the strong 1974 spat set survive.

Size Composition

Average lengths for the oyster categories of market, small, yearling, and spat are presented in Table 4. There was no general trend in average length with respect to a rock's location except at Horsehead. At this site, the average length of small and yearling oysters was lowest in the James River. These smaller average sizes are, of course, responsible for the high counts of oysters per bushel at Horsehead. Lower salinity at Horsehead relative to the rocks further down the James River is believed to inhibit growth and, thus, is responsible for the small average lengths of yearling and small oysters.

The percentage of market oysters, in general, increased, and, correspondingly, the percentage of small oysters decreased in the 1974-75 sampling period (Table 5). This again reflects the poor spat sets prior to 1974. No pattern was discernable for yearlings, but it is believed their percentage of the catch will improve in samples presently being collected because of the strong 1974 spat set.

Horsehead data present an apparent paradox. No spat set occurred there in 1973 but yearling data are present in Tables 4 and 5 for the 1974-75 sampling period. The only rationale is that stunting of oysters there obscures the morphological criteria used to separate yearling and small oysters, and, thus, there was a misclassification problem.

Table 4 . Average oyster lengths from representative areas sampled in the James, Piankatank, and Great Wicomico Rivers in the 1973-74 and 1974-75 periods.

River and Rock	Average Lengths (mm) Market 1973-74	Market 1974-75	Small 1973-74	Small 1974-75	Yearling 1973-74	Yearling 1974-75	Spat 1973-74	Spat 1974-75
James								
Horsehead	--	--	49.2	51.2	--	32.6	--	--
Point of Shoals	84.6	84.2	55.6	59.2	--	--	--	--
Wreck Shoal	85.2	82.8	60.3	60.1	38.8	36.0	10.6	14.9
White Shoal	84.8	89.2	60.2	64.3	38.4	39.1	12.5	14.0
Gun Rock	87.8	87.6	61.2	65.5	36.4	42.1	10.5	15.5
Thomas Rock	87.0	87.6	64.3	63.8	39.9	37.4	12.2	15.5
Nansemond Rdg.	--	83.2	47.2	61.5	--	39.7	12.9	17.1
Piankatank								
Three Branches	85.0	87.0	56.9	57.3	45.9	--	23.2	22.3
Burton Rock	82.1	88.5	62.9	54.1	48.4	--	25.6	24.9
Capetoon	86.3	88.0	56.2	62.3	--	39.1	21.6	20.0
Palace Bar	86.4	86.4	57.8	57.1	42.0	44.4	27.8	21.4
Island Bar	83.7	90.1	65.6	58.3	44.2	--	24.4	20.3
Ginney Point	85.2	89.8	54.3	63.3	--	--	--	19.4
Great Wicomico								
Marsh West	88.7	88.9	58.2	65.4	--	47.6	--	31.1
Ingram	87.8	90.2	61.3	62.2	--	40.3	28.5	28.9
Whaley's West	88.8	91.3	64.0	62.8	--	--	20.2	29.8

Table 5. Percentages of market, small, and yearling oysters estimated in representative areas of oyster rocks in the James, Piankatank and Great Wicomico Rivers in the 1973-74 and 1974-75 sampling periods.

River and Rock	Sampling Period	Catch Composition (%) Market	Small	Yearling
James				
Horsehead	1973-74	1	99	0
	1974-75	5	84	11
Point of Shoals	1973-74	8	92	0
	1974-75	16	81	3
Wreck Shoals				
Inshore	1973-74	57	41	2
	1974-75	49	45	6
Middle	1973-74	33	66	1
	1974-75	38	59	2
Offshore	1973-74	12	71	17
	1974-75	28	65	7
White Shoal	1973-74	26	67	8
	1974-75	50	48	2
Gun Rock	1973-74	28	60	12
	1974-75	41	49	10
Thomas Rock	1973-74	8	92	0
	1974-75	61	38	1
Nansemond Ridge	1973-74	0	100	0
	1974-75	0	61	39
Piankatank				
Three Branches	1973-74	18	80	1
	1974-75	22	78	0
Burton Rock	1973-74	8	72	19
	1974-75	18	82	0
Capetoon	1973-74	16	83	1
	1974-75	34	62	4

Table 5. (Continued)

River and Rock	Sampling Period	Catch Composition (%) Market	Small	Yearling
Piankatank				
Palace Bar	1973-74	15	83	2
	1974-75	28	67	6
Island Bar	1973-74	29	62	10
	1974-75	56	42	0
Ginney Point	1973-74	9	91	0
	1974-75	68	32	0
Great Wicomico				
Marsh West	1973-74	17	83	0
	1974-75	49	48	3
Ingram Rock	1973-74	23	77	0
	1974-75	49	50	0
Whaley's West	1973-74	37	63	0
	1974-75	43	57	0

Spat Density

The estimates of spat per acre in the James River indicated a substantial increase in the 1974-75 period (Table 6). The one exception at Gun Rock may be more apparent than real because a single large sample greatly influenced the average in the 1973-74 period. When this sample is omitted, the estimate is reduced to less than 1,000 spat per acre. Field observations indicate that spat per acre at White Shoal and Nansemond Ridge may have been underestimated. There were only three spat samples at the former site and four at the latter. In the Piankatank River, there was a dramatic decrease in the estimated spat per acre at Burton's Rock and Island Bar. Estimated changes in spat density at the other rocks were relatively moderate. The estimates of spat density in the Great Wicomico River increased in all three areas in the second year's sampling period, but, nevertheless, remained very low.

Statistical Analysis

Several computer programs were constructed by personnel of the VIMS Computer Science Department to aid in the analysis of the oyster data. A Kolmogorov-Smirnov one-sample "goodness of fit" program was written to test observed frequency distributions against theoretical ones (cf. Sokal and Rohlf, 1969). In conjunction with the K-S one-sample test, a standardized normal distribution function program was written to test for normality of data, and another was written to estimate the exponent parameter in a negative binomial series for its respective goodness of fit test (cf. Elliott, 1971). These tests were necessary to determine if a transformation of data was needed to

Table 6. A comparison of spatfall between the 1973-74 and 1974-75 seasons in the James, Piankatank, and Great Wicomico Rivers.

River and Rock	Spat Per Acre (X 1000) 1973-74	1974-75
James		
Horsehead	0	45
Point of Shoals *	4	13
Wreck Shoal		
Inshore	2	6
Middle	7	117
Offshore	28	294
Thomas Rock	24	162
Gun Rock	148	111
White Shoal	34	63
Nansemond Ridge*	39	78
Piankatank		
Three Branches	25	4
Burton Rock	157	58
Capetoon	30	9
Palace Bar	79	36
Island Bar	136	3
Ginney Point	0	9
Great Wicomico		
Marsh West	0	2
Ingram Rock	1	6
Whaley's West	1	2

* Stations not randomly sampled

approximate normality which is an assumption basic to the most often employed parametric models in statistical inference. Also, a maximum likelihood estimate program was written to determine the probability of given occurrences in a negative binomial series. For cases where nonparametric comparisons were appropriate, a Kolmogorov-Smirnov two-sample test program was written, and the Mann-Whitney U test, the Wilcoxon matched-pairs signed-rank test, and the Sign test were "manually" applied (cf. Conover, 1971).

In general, data for average catch per grab, average number of bushels per acre, and average number of oysters per bushel were normally distributed. This was probably the result of using average values at a station rather than the individual grab sample data. [It is a statistical theorem (very loosely stated here) that averages of samples for a given population approximate a normal distribution regardless of the distribution of the parent population.] The estimates of spat per grab, and thus, spat per acre, were determined for a single subsample. These data were discrete and skewed and the goodness of fit to a negative binomial was generally acceptable.

Probability statements were not made throughout the text because of the obvious trends in decreased seed oyster density and increased spat density during the two sampling periods. Statistical significance or nonsignificance for each area, however, was indicated in Table 1. Summaries of the nature of the distribution functions when ascertained, the statistical models applied, and the resulting statistical inferences are presented in Tables 7 and 8.

Table 7. A summary of the statistical analysis of average catch of oysters per grab in representative areas of rocks in the James, Piankatank, and Great Wicomico Rivers.

River and Rock	Catch Distribution	Test Statistic	Significance
James			
Horsehead	Normal	t	*
Point of Shoals	(No comparison made)		
Wreck Shoal			
Inshore	ND	SRT	NS
Middle	Normal	t_p	*
Offshore	Normal	t_p	*
White Shoal	ND	U	*
Gun Rock	Normal	t_p	NS
Thomas Rock	Normal	t_p	NS
Nansemond Ridge	(No comparison made)		
Piankatank			
Three Branches	ND	U	*
Burton Rock	Normal	t_p	*
Capetoon	Normal	t_p	*
Palace Bar	ND	U	NS
Island Bar	(No comparison made)		
Ginney Point	ND	U	NS
Great Wicomico			
Marsh West	Normal	t_p	NS
Ingram River	Normal	t_p	*
Whaley's West	ND	U	*

Key: *: Indicates significant difference ($\alpha \leq 0.10$)
NS: No significant difference
ND: Distribution not
t_p: Paired t test; t: Students t test
SRT: Signed Ranks test
U: Mann-Whitney test

Table 8. A summary of the statistical analysis of the average number of bushels per acre in representative areas of rocks in the James, Piankatank, and Great Wicomico Rivers in 1973-74 and 1974-75.

River and Rock	Sample Distribution	Test Statistic	Significance
James			
Horsehead	Normal	t	*
Point of Shoals	(No comparison made)		
Wreck Shoal			
Inshore	ND	ST	*
Middle	Normal	U	*
Offshore	Normal	U	*
White Shoal	ND	U	NS
Gun Rock	Normal	t_p	NS
Thomas Rock	Normal	t_p	NS
Nansemond Ridge	(No comparison made)		
Piankatank			
Three Branches	ND	U	*
Burton Rock	Normal	t_p	*
Capetoon	Normal	t_p	*
Palace Bar	ND	U	NS
Island Bar	(No comparison made)		
Ginney Point	ND	U	NS
Great Wicomico			
Marsh West	Normal	t_p	NS
Ingram Rock	Normal	t_p	*
Whaley's West	Normal	U	*

Key:
- *: Indicates significant difference ($\alpha \leq 0.10$)
- NS: No significant difference
- ND: Distribution not determined
- t_p: Paired t test
- t: Students t test
- SRT: Signed Ranks test
- U: Mann-Whitney test

The number of stations randomly sampled at each rock was arbitrarily set at approximately half the number of the grid overlay squares lying within the selected representative areas. Statistically the optimum number of samples needed to estimate a population parameter can be determined. However, this requires (a priori) an accurate estimate of the population variance and a definition of what percentage of error is to be tolerated, i.e., what will be the specified degree of precision when estimating the parameter. The percentage error is expressed as either the standard error of the average or confidence limits of the average. A simple index of precision (D) is the ratio of the standard error to the average (Elliott, 1971):

$$D = \text{standard error/average} = \frac{1}{\bar{x}}\left(\frac{s^2}{n}\right)^{\frac{1}{2}}$$

where $\bar{x}$ = arithmetic average, s^2 = sample variance, and n = sample size. Thus, when D is defined, the equation can be solved for n, the estimated optimum sample size for a specified degree of precision. In the present study, the degree of precision was defined as a standard error equal to 20% of the average catch, thus:

$$0.2 = \frac{1}{\bar{x}}\left(\frac{s^2}{n}\right)^{\frac{1}{2}}$$

and

$$n = s^2/0.2^2\ \bar{x}^2 = 25s^2/\bar{x}^2$$

The above formula, and a variation of it in two instances when a negative binomial series was indicated, was used to estimate optimum sample size for average catch per grab at each representative area.

Sampling effort in the representative areas of the rocks in the James River was, in general, adequate for estimating the abundance of seed oysters (Table 9). Obvious exceptions were at Inshore Wreck Shoal and White Shoal (2nd year). The density of oysters at Inshore Wreck Shoal was low (Table 1, Figure 4), but the variance was large due to a few high density occurrences. It is readily seen in the above equation that a large variance (s^2) and/or a small average ($\overline{x}$) increases the estimate of optimum sample size (n). Sampling effort was not increased in this area because of its unimportance to the fishery. It is likely that four samples at White Shoal are inadequate to estimate sample size, and all seven potential stations should be randomly sampled. In the Piankatank River, Capetoon and Palace Bar were adequately sampled but effort needs to be increased at the other major site, Burton Rock. In the smaller areas, Three Branches, Island Bar, and Ginney Point, where densities were low (Table 1, Figures 12, 16 and 17) the estimates of optimum sample size were high relative to the actual effort. The cost for gains in precision and accuracy by increased effort would not be justifiable unless their future contribution to the fishery were to increase. Except for Ingram Rock (1st year) effort was below the estimated optimum values in the Great Wicomico River.

Another formula, somewhat more involved and not presented (cf. Li, 1964), was used to calculate sample size when statistical contrasts were made. Because of the expanded use of the data, optimum estimates of sample size are greater than when determined by the above simple

Table 9. The number of samples taken and the estimated number of samples based on 95% confidence limits of ± 40% of the average catch of seed oysters in the representative areas.

River and Rock	Number of Samples* 1973-74 Actual	1973-74 Estimated	1974-75 Actual	1974-75 Estimated
James				
Horsehead	7	4	12	7
Wreck Shoal				
Inshore	16	66	16	54
Middle	17	11	26	15
Offshore	19	8	29	5
White Shoal	4	1	4	18
Gun Rock	9	8	9	6
Thomas Rock	8	2	8	9
Piankatank				
Three Branches	7	38	7	169
Burton Rock	17	32	18	26
Capetoon	21	17	22	19
Palace Bar	15	4	23	23
Island Bar	3	40	3	2
Ginney Point	7	34	7	23
Great Wicomico				
Marsh West	12	40	12	27
Ingram	18	14	17	27
Whaley's West	20	26	19	34

* Stations off the rocks were not considered.

formula. The applicability of an estimated sample size (n) is of short duration, as indicated by its change at a given rock from one year to the next. Properly, a sample size is estimated from a pilot test and immediately applied. At best, it should only be a starting point in future sampling. Any change in a population parameter, a change in the size of the sampling unit, or a change in sampling technique necessitates recalculation of n.

Less than optimum effort does not invalidate the data, but simply reduces accuracy and precision, and in the case of statistical contrasts it reduces the ability to distinguish real but subtle differences. In the present study, the trend in change of seed oyster and spat density was so consistent that the reduced ability to detect small differences was of no consequence.

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Elliott, J. M. 1971. Statistical analysis of samples of benthic invertebrates. Freshwater Biological Assoc., Sci. Pub. No. 25 Ambleside, England. 144 p.

Li, J. C. R. 1964. Statistical inference. Edwards Brothers, Inc., Ann Arbor, Michigan. Vol. I, 658 p.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry: The principles and practice of statistics in biological research. W. H. Freeman and Co., San Francisco. 776 p.

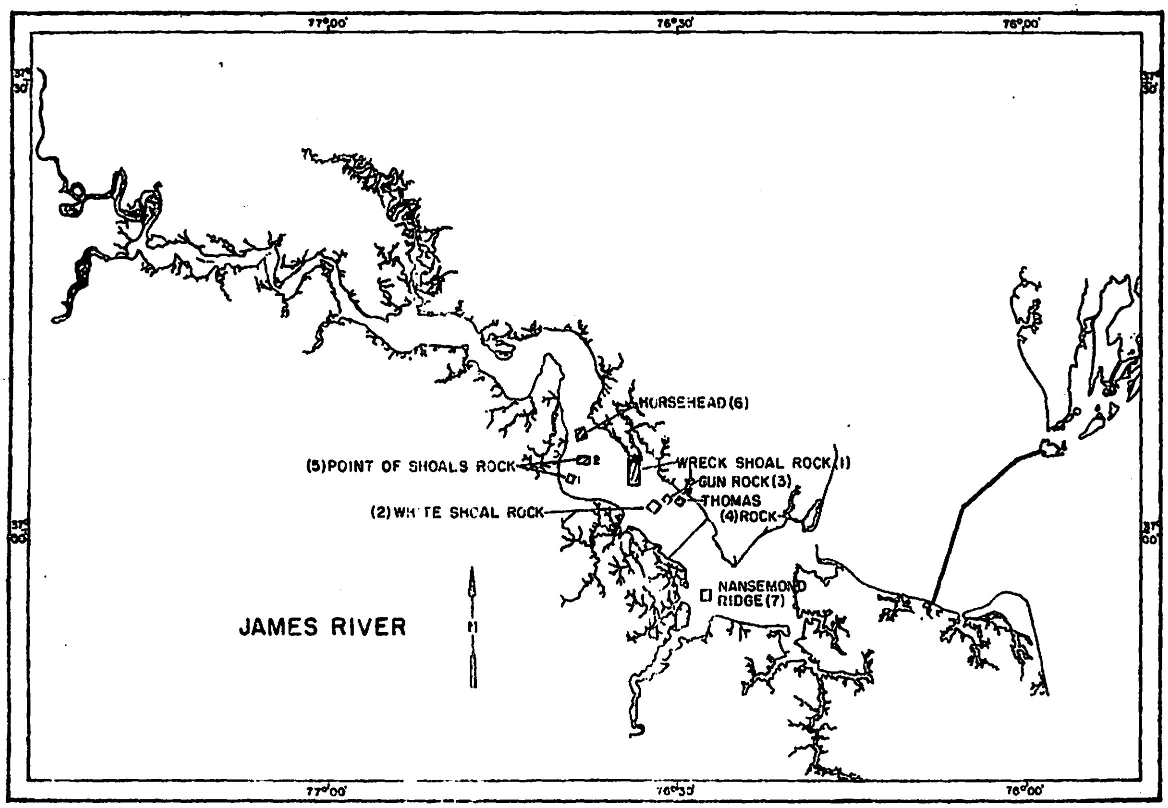


Figure 1.

Location of oyster rocks sampled in the James River, 1973-74. Key: (1) Wreck Shoal; (2) White Shoal; (3) Gun Rock; (4) Thomas Rock; (5) Point of Shoals; (6) Horsehead; and (7) Nansemond Ridge.

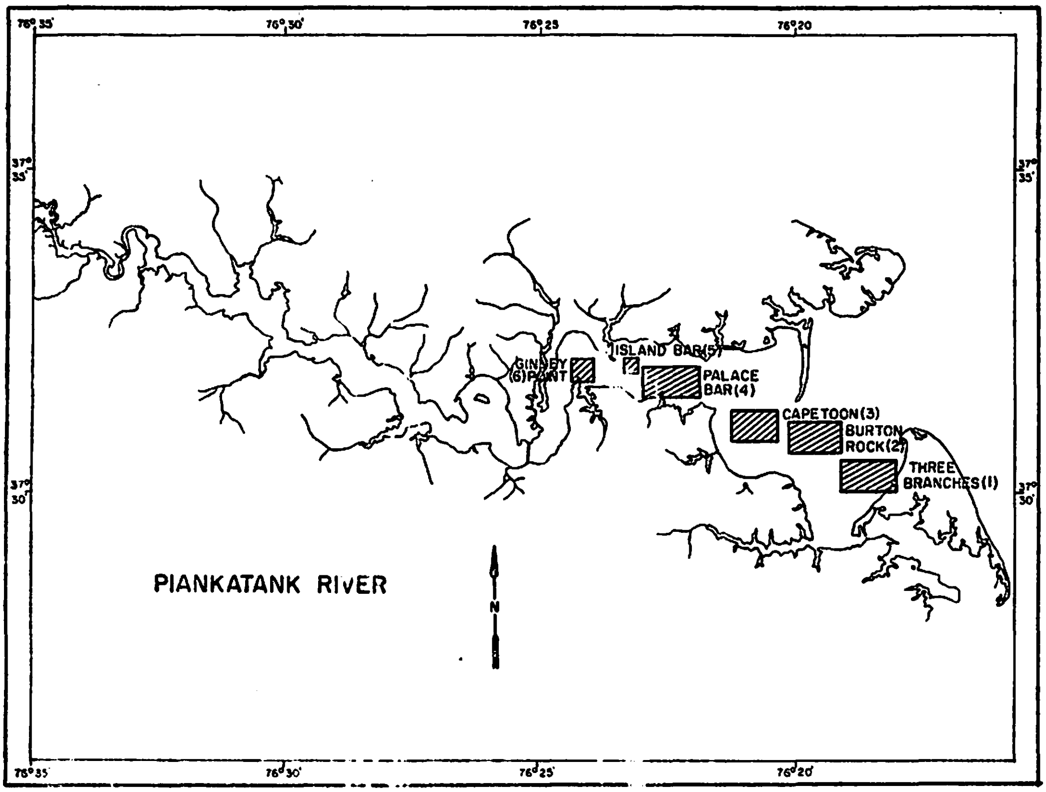


Figure 2.

Location of oyster rocks sampled in the Piankatank River, 1973-74. Key: (1) Three Branches; (2) Burton Rock; (3) Capetoon; (4) Palace Bar; (5) Island Bar; (6) Ginney Point.

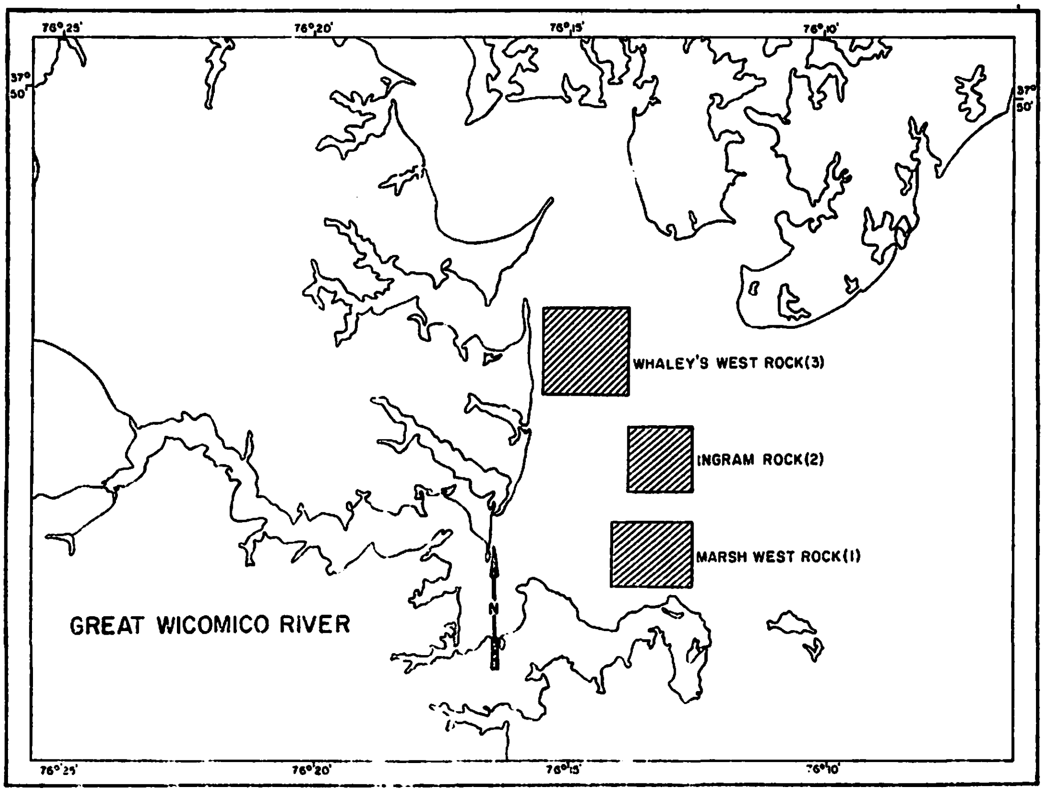
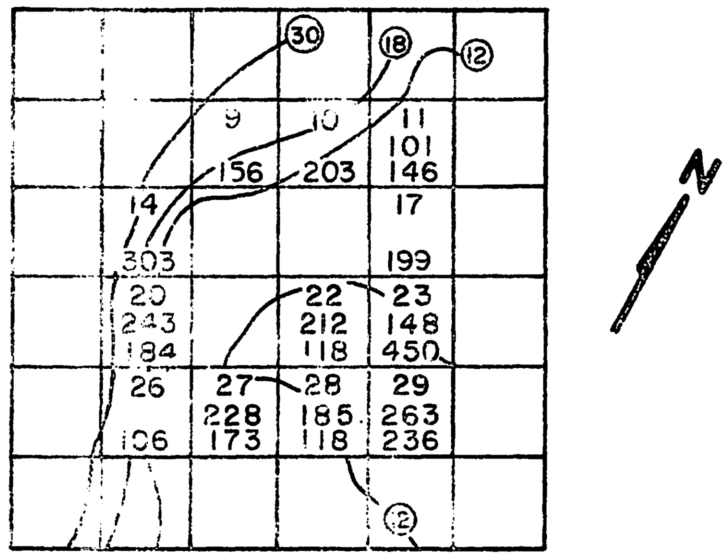


Figure 3.

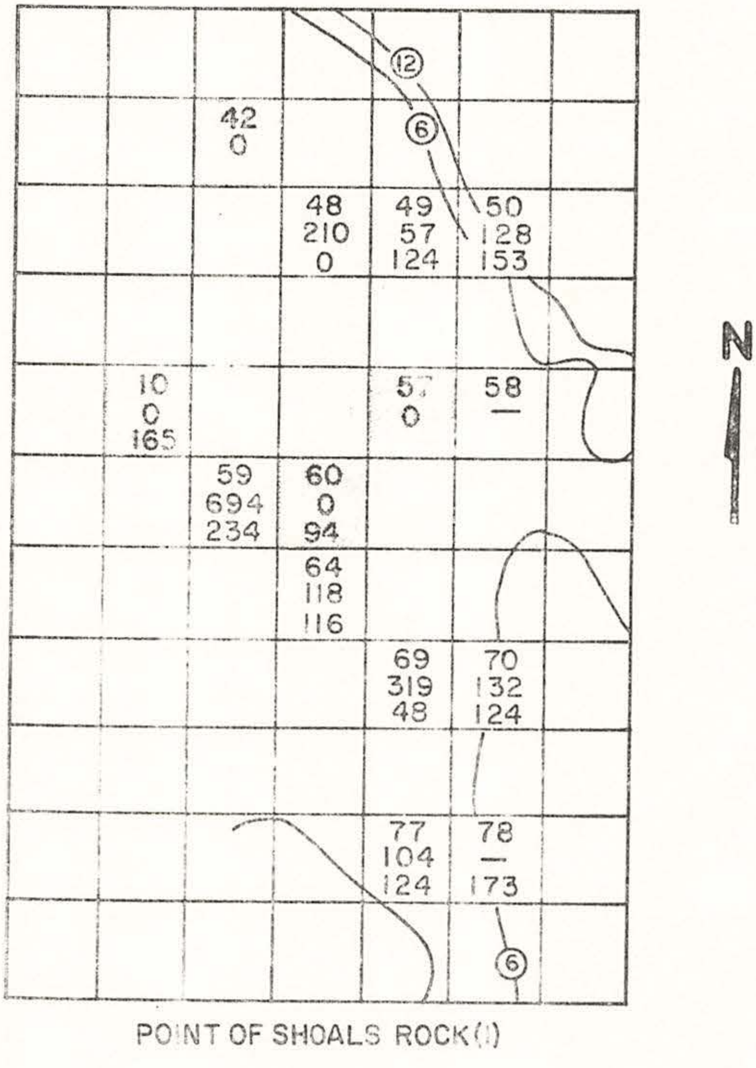
Location of oyster rocks sampled in the Great Wicomico River, 1973-74. Key: (1) Marsh West; (2) Ingram Rock; and (3) Whaley's West.

Figures 4-19. Representative areas sampled. Key to numbers in a grid square: upper is the station number; middle and lower are the estimated bushels of oysters per acre in the 1973-74 and 1974-75 periods, respectively; a dash indicates no estimate; and circled numbers are mean low water depths (ft). Grid squares in Figures 4 through 10 are 500 ft on a side and in Figures 11 through 19 are 250 ft on a side. Shaded stations are not considered to be an integral part of the rock.



HORSEHEAD

Figure 4.



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POINT OF SHOALS ROCK
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Figure 5.

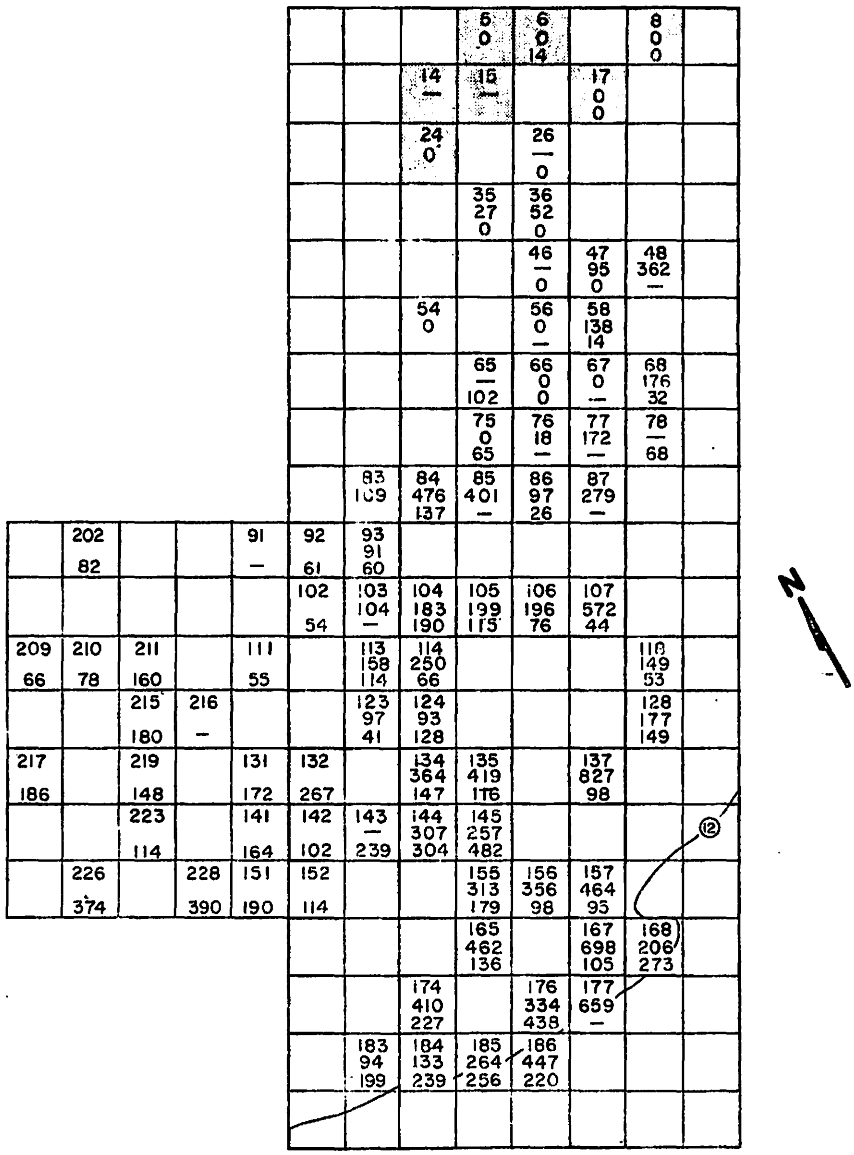
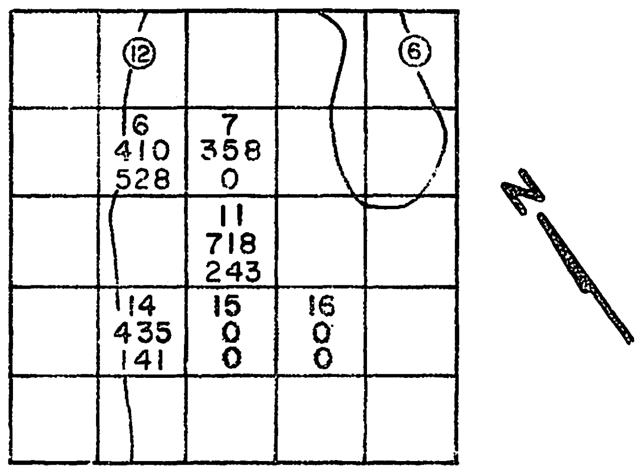
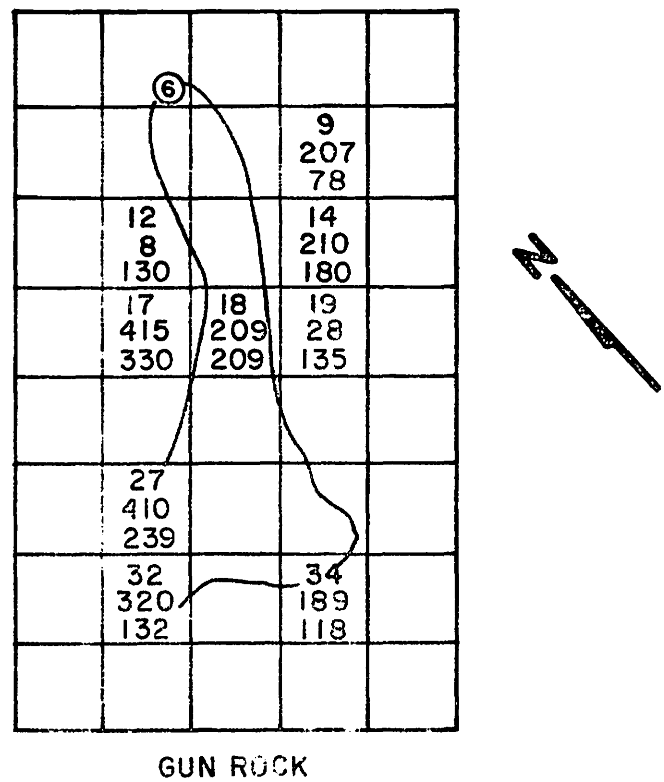

WRECK SHOAL ROCK

Figure 6.



WHITE SHOAL ROCK

Figure 7.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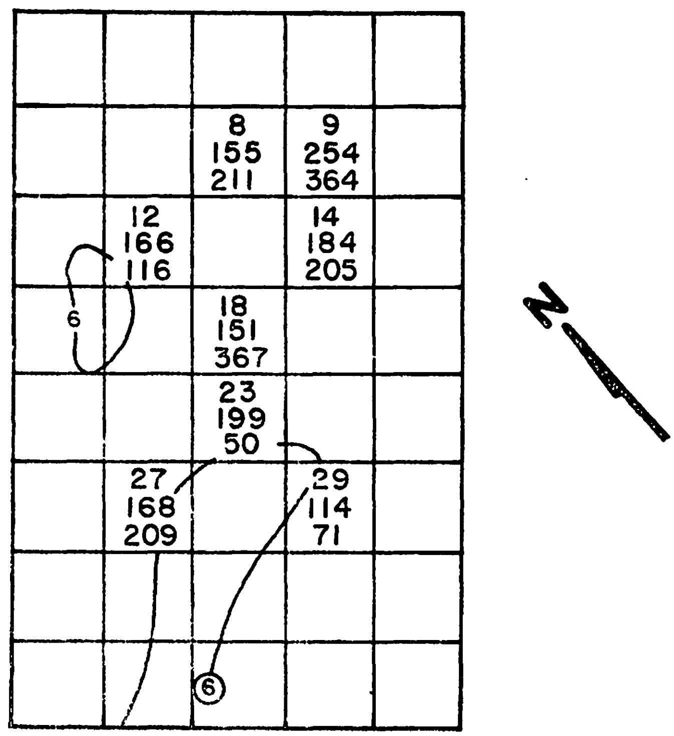
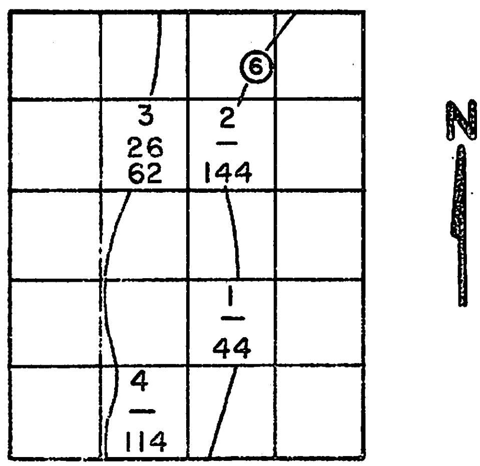
GUN ROCK

Figure 8.



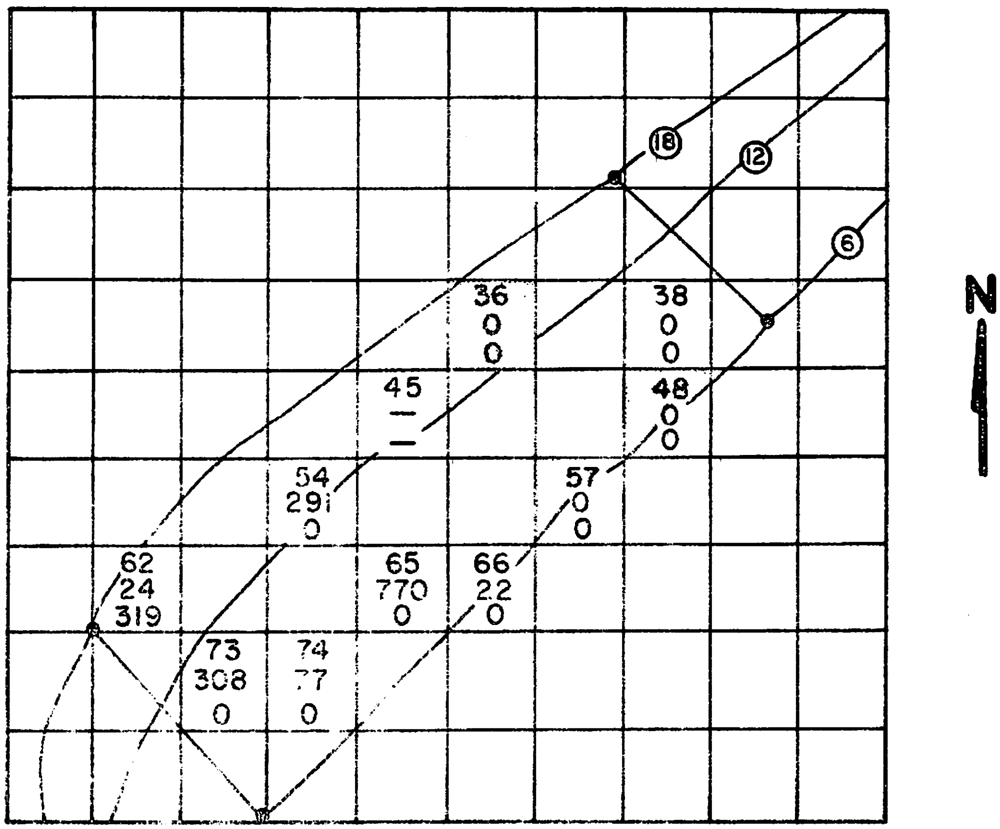
THOMAS ROCK

Figure 9.



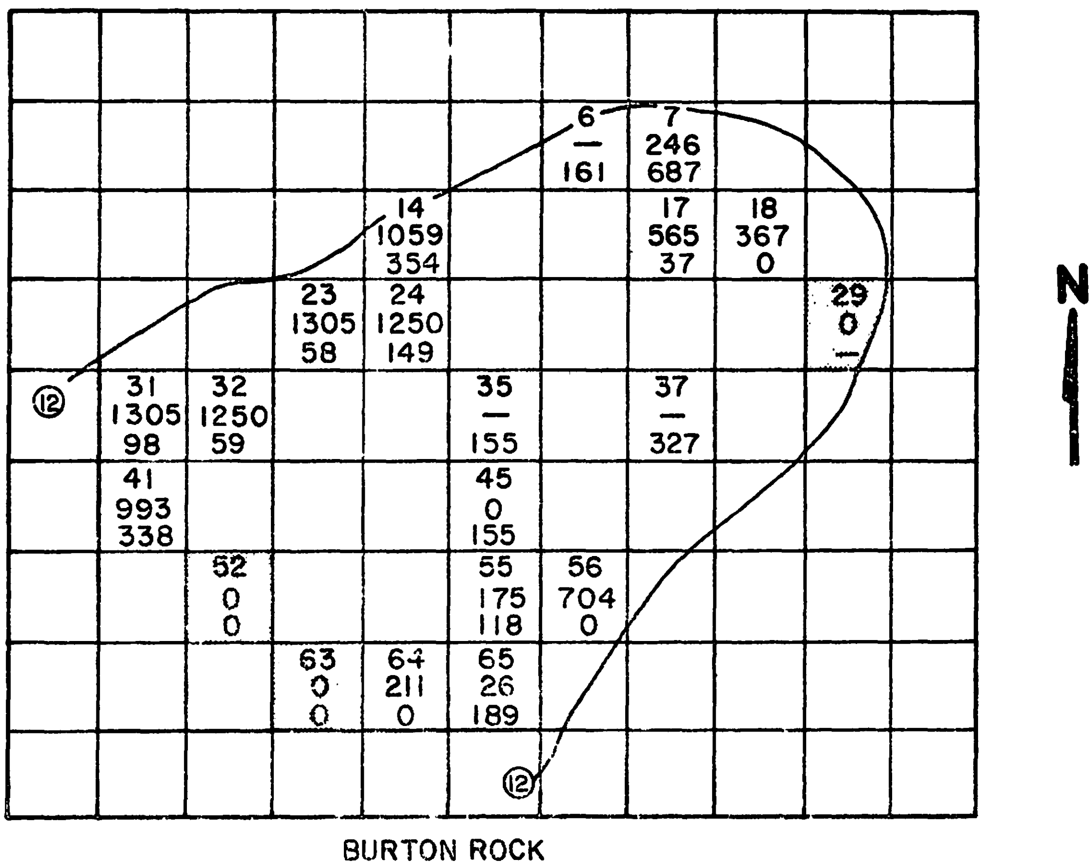
NANSEMOND RIDGE

Figure 10.



THREE BRANCHES

Figure 11.



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BURTON ROCK

Figure 12.

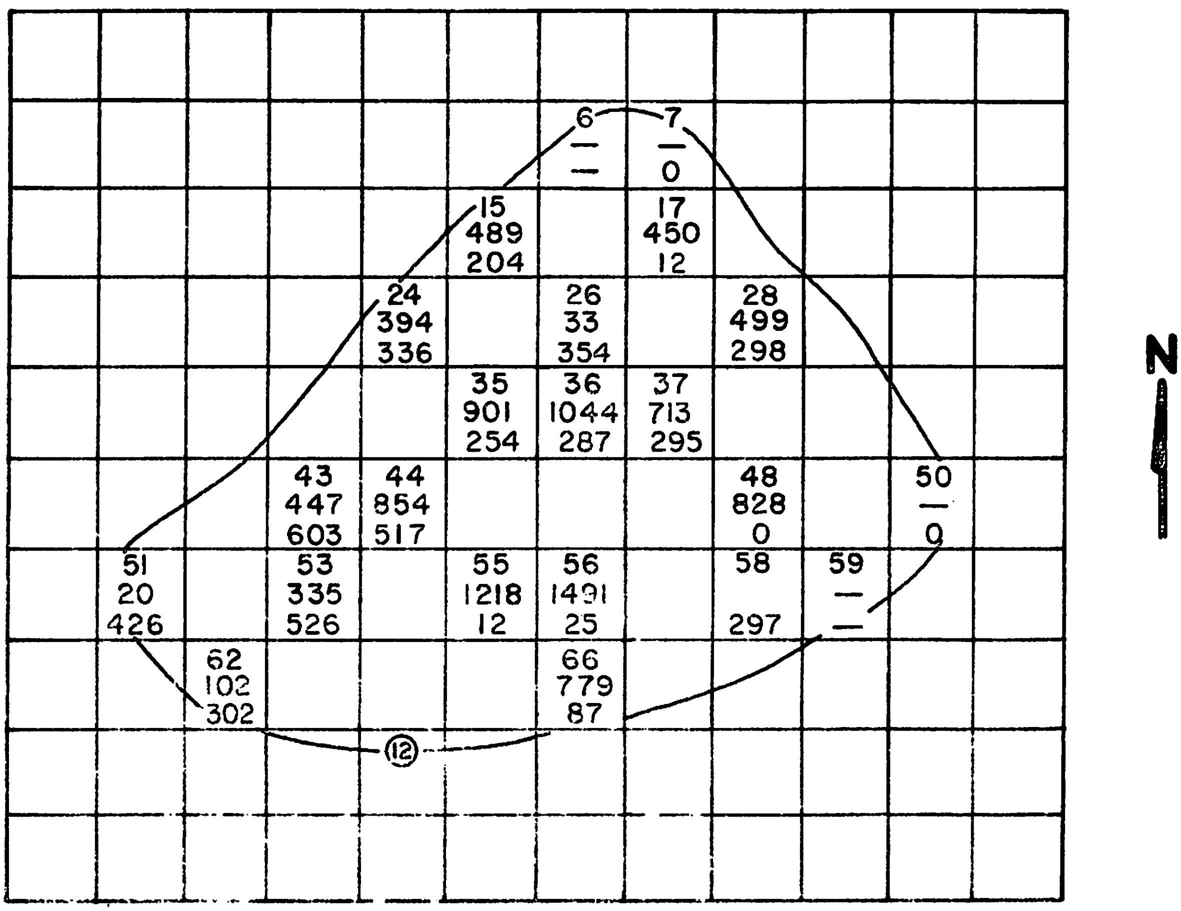

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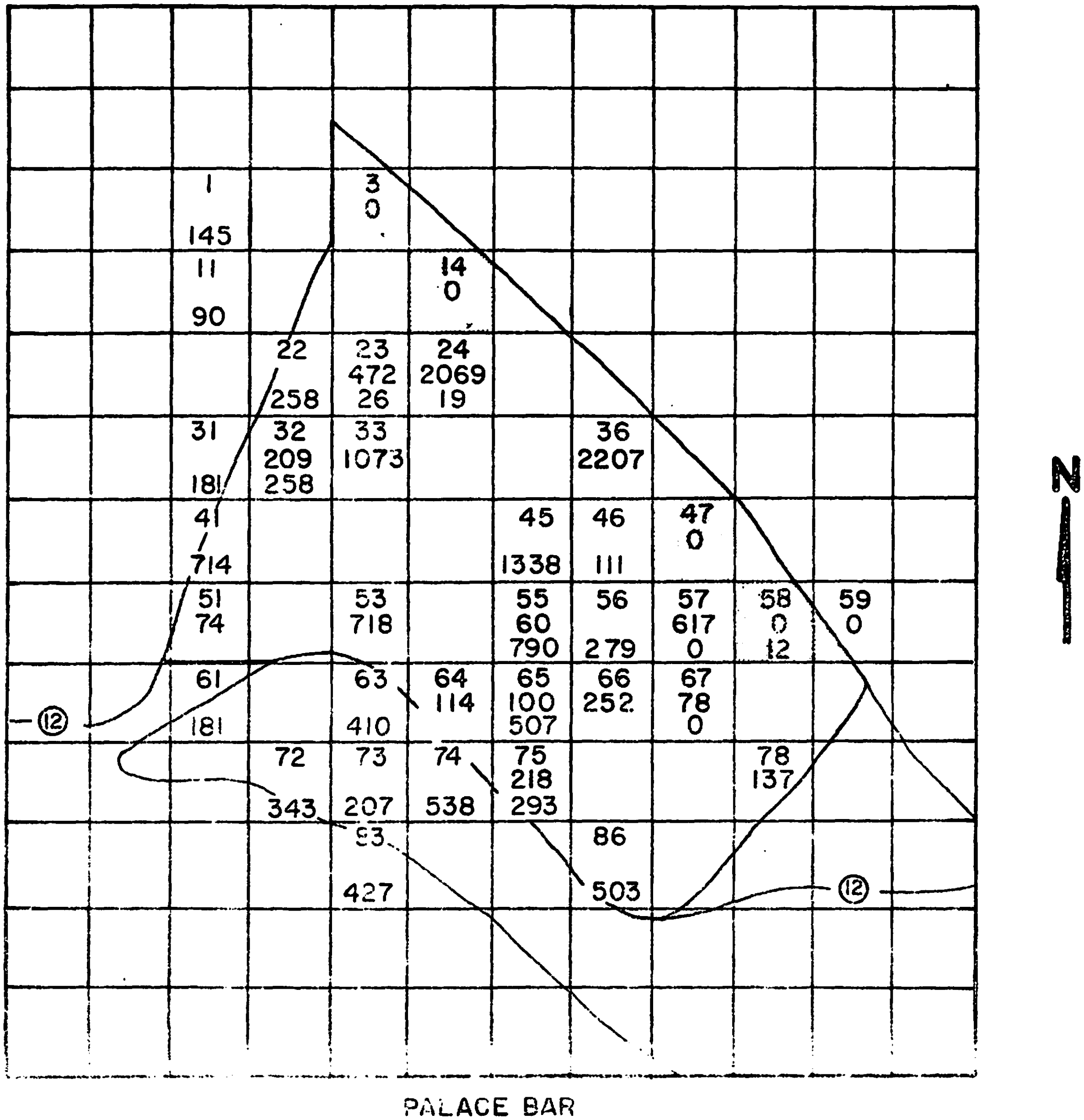
Figure 13.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PALACE BAR

Figure 14.

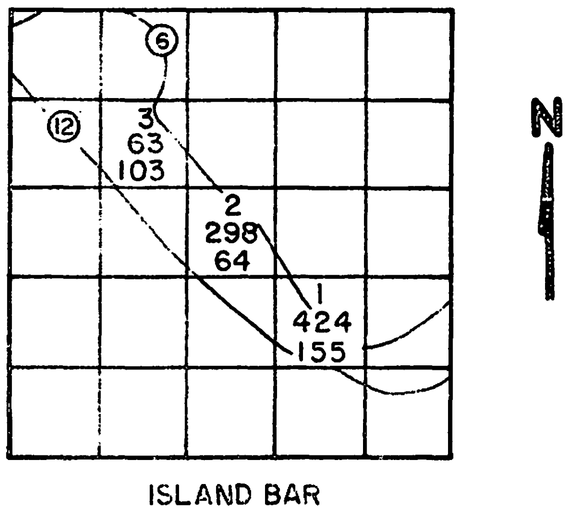
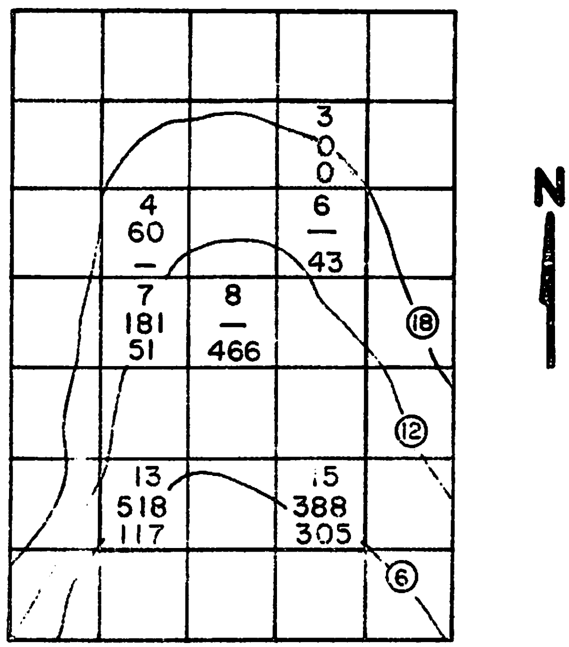


Figure 15.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GINNEY POINT

Figure 16.

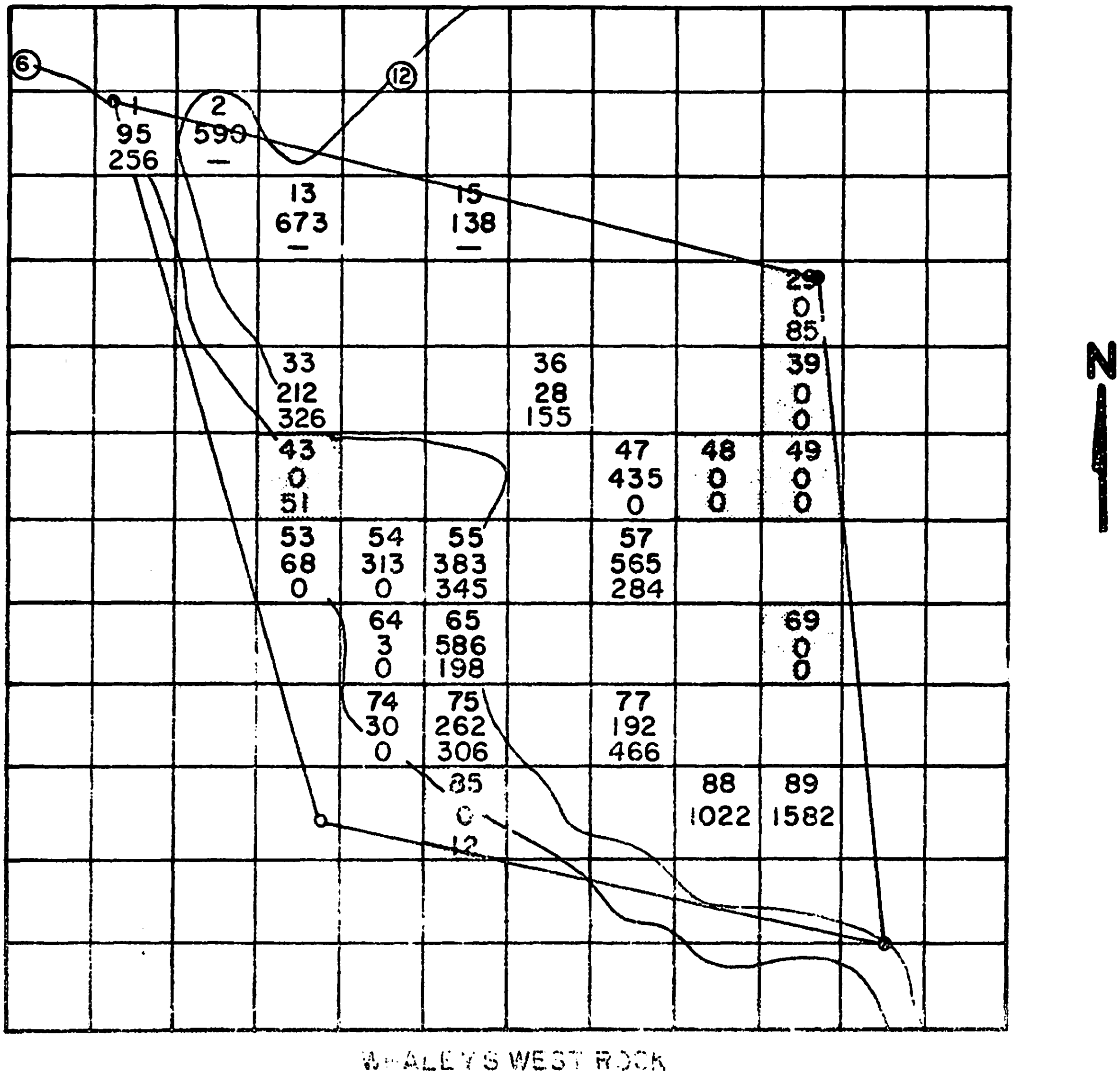
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Figure 17.

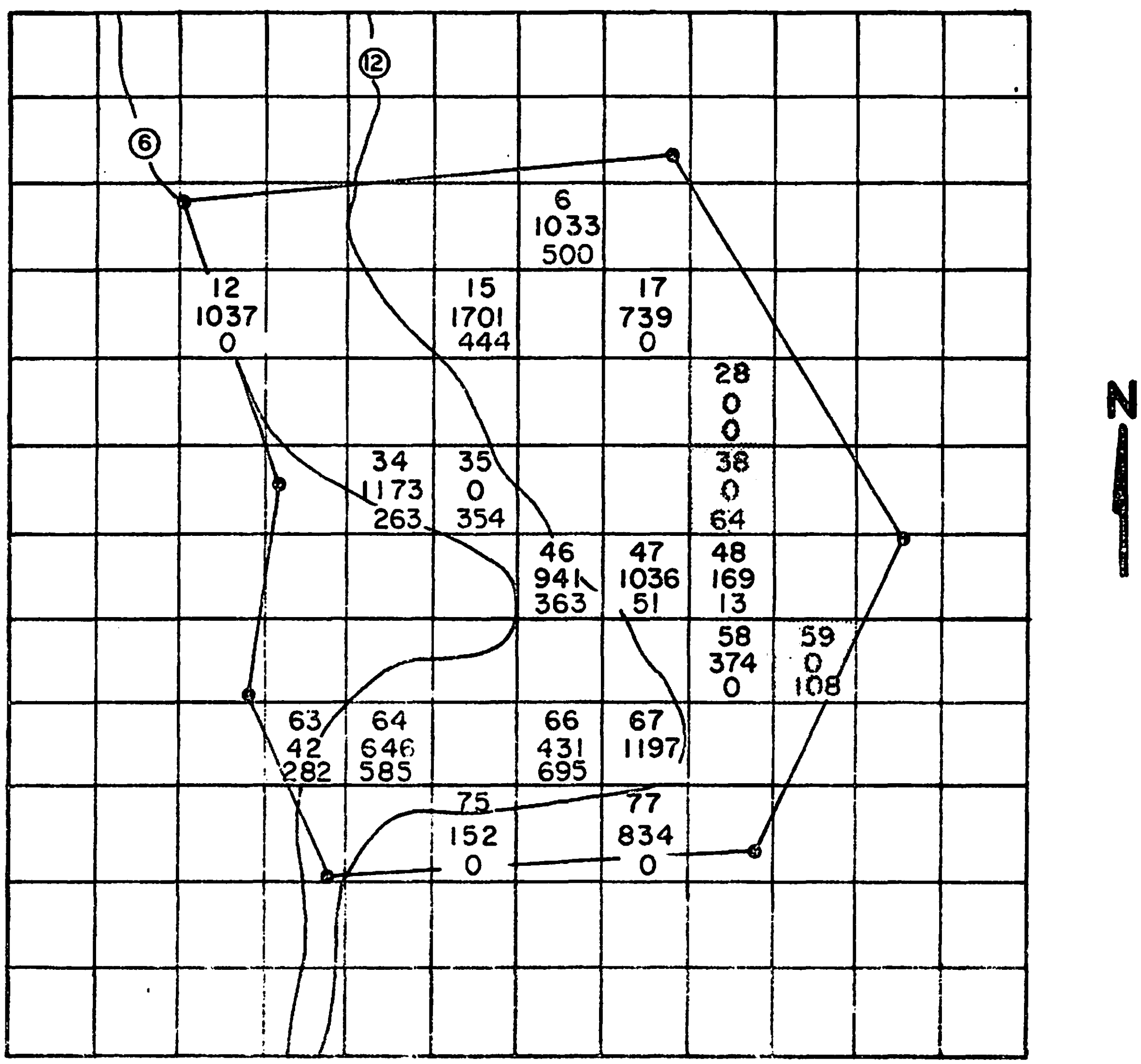

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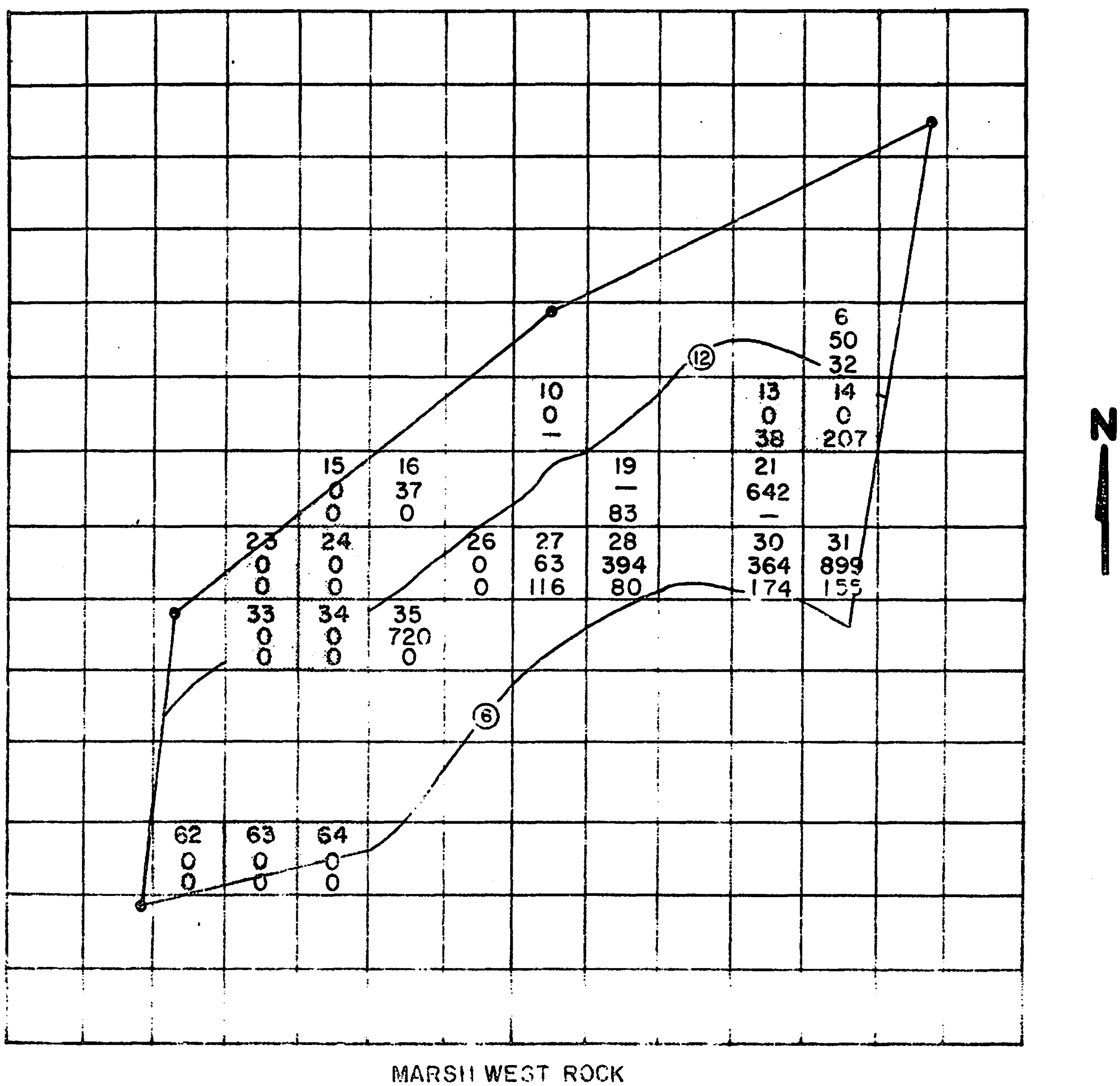
Figure 18.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MARSH WEST ROCK

Figure 19.

Appendix 1. Catch data of oysters, shell and cinder by station in representative areas of rocks in the James, Piankatank, and Great Wicomico Rivers in the 1974-75 sampling period. Adjusted catch is the estimated catch in the total sample volume derived by proportion from the subsample catch and subsample volume. Averages were derived from the pooled data of two samples at each station.

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	OYSTERS Total Adjusted Catch	OYSTERS Average Adjusted Catch	OYSTERS No. per Bushel	OYSTERS Bushels per Acre	SHELL Total Adjusted Catch (bu)	SHELL Average Adjusted Catch (bu)	SHELL Exposed Shell (%)	SHELL Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	CINDER Average Adjusted Catch (bu)	CINDER Bushels per Acre (Exposed)
James River Wreck Shoal															
* 6	2	0.8	0.76	2	2.10	1.05	200	14	0.53	0.26	50	341	0	--	0
* 8	2	1.48	1	0	--	--	--	0	0.12	0.06	50	75	0	--	0
*17	2	1.08	0.72	0	--	--	--	0	0.20	0.10	100	251	0	--	0
26	2	1.24	1	0	--	--	--	0	0.14	0.07	0	0	0	--	0
35	2	0.54	0.54	0	--	--	--	0	0.13	0.06	50	84	0	--	0
36	2	0.42	0.42	0	--	--	--	0	0.05	0.02	0	0	0	--	0
46	2	1.06	1	0	--	--	--	0	0.06	0.03	0	0	0	--	0
47	2	1	1	0	--	--	--	0	0.08	0.04	0	0	0	--	0
48	2	1.66	1	1	1.66	0.83	--	--	0.27	0.13	0	0	0	--	0
56	2	1.48	1	1	1.48	0.74	--	--	0.27	0.14	5	17	0.03	0.02	38.3
58	2	1.1	1	3	3.3	1.65	300	14	0.29	0.14	9	9	0	--	0
65	2	0.9	0.8	13	14.62	7.31	186	102	0.34	0.17	2	11	0	--	0

* Indicates sample station was off the oyster rock.

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
66	2	1.82	1	0	1.82	0.91	--	0	0.26	0.13	2	8	0	--	0
67	2	1.82	1	1	1.82	0.91	--	--	0.26	0.13	2	8	0	--	0
68	2	0.78	0.62	6	7.55	3.77	300	32	0.14	0.07	2	4	0	--	0
75	2	0.42	0.42	15	15	7.5	300	65	0.16	0.08	75	155	0	--	0
76	2	0.64	0.64	3	3	1.5	--	--	0.16	0.08	40	83	0	--	0
77	2	1.22	1	4	4.88	2.44	--	--	0.27	0.13	35	122	0	--	0
78	2	1.32	1	18	23.76	11.88	450	68	0.29	0.14	50	188	0	--	0
84	2	1.32	1	20	26.4	13.2	250	137	0.40	0.20	12	64	0	--	0
85	2	0.32	0.32	2	2	1	--	--	0.16	0.08	15	31	0	--	0
86	2	0.6	0.6	7	7	3.5	350	26	0.3	0.15	45	175	0	--	0
87	2	1.02	0.8	1	1.28	0.64	--	--	0.38	0.19	50	248	0.02	0.01	16
91	2	2.06	1	3	6.18	3.09	--	--	1.44	0.72	20	373	0	--	0
92	2	2.36	1	7	16.52	8.26	350	61	0.42	0.21	22	124	0	--	0

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
93	2	1.56	1	11	17.16	8.58	367	60	0.56	0.28	65	472	0.03	0.02	40
102	2	2.8	1	6	16.8	8.4	400	54	0.62	0.31	40	319	0	--	0
103	2	1.74	1	2	3.48	1.74	--	--	0.45	0.23	35	205	0.04	0.02	45
104	2	2.1	1	21	44.1	22.05	300	190	0.71	0.36	50	462	0.04	0.02	54
105	2	1.78	1	16	28.48	14.24	320	115	0.53	0.27	50	346	0.07	0.04	92
106	2	1.96	1	10	19.6	9.8	333	76	0.71	0.35	55	502	0.04	0.02	51
107	2	1.12	1	9	10.08	5.04	300	44	0.34	0.17	50	218	0.04	0.02	58
111	2	3.22	1	10	32.2	16.1	752	55	0.77	0.39	22	225	0	--	0
113	2	2.2	1	24	52.8	26.4	600	114	0.75	0.37	60	581	0.04	0.02	57
114	2	1.7	1	21	35.7	17.85	700	66	0.51	0.25	70	462	0.03	0.02	44
118	2	2.04	1	17	34.68	17.34	850	53	0.78	0.39	85	853	0.08	0.04	106
123	2	3.18	1	5	15.9	7.95	500	41	1.08	0.54	35	490	0.19	0.10	247
124	2	2.48	1	17	42.16	21.08	425	128	0.94	0.47	50	610	0.15	0.07	193

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
128	2	2.3	1	32	73.6	36.8	640	149	0.74	0.37	90	858	0.09	0.05	119
131	2	2.64	1	30	79.2	39.6	1200	172	0.74	0.37	40	383	0	--	0
132	2	3.44	1	34	116.96	58.48	567	267	1.24	0.62	38	601	0.07	0.03	89
134	2	2.84	1	25	71	35.5	625	147	1.08	0.54	50	698	0.23	0.11	294
135	2	1.8	1	32	57.6	28.8	640	116	0.68	0.34	50	443	0.11	0.05	140
137	2	1.26	1	35	44.1	22.05	583	98	0.40	0.20	60	313	0.18	0.09	228
141	2	1.58	1	33	52.14	26.07	412	164	0.44	0.22	32	186	0.03	0.02	41
142	2	1.96	1	30	58.8	29.4	750	102	0.67	0.33	45	388	0.02	0.01	25
143	2	2.64	1	31	81.84	40.92	443	239	0.95	0.48	80	984	0.32	0.16	410
144	2	2.94	1	41	120.54	60.27	512	304	1.12	0.56	50	723	0.12	0.06	152
145	2	2.66	1	80	212.8	106.4	571	482	1.01	0.50	60	785	0.11	0.05	138
151	2	2.44	1	32	78.08	39.04	533	190	0.83	0.42	35	376	0.12	0.06	158
152	2	2.20	1	21	46.2	23.1	525	114	0.79	0.40	35	359	0	--	0

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
155	2	1.98	1	55	108.9	54.45	786	179	0.55	0.28	30	215	0.40	0.20	513
156	2	1.14	0.9	40	50.67	25.33	667	98	0.30	0.15	20	79	0.23	0.11	295
157	2	2.44	1	27	65.88	32.94	900	95	0.68	0.34	50	442	0.29	0.15	379
165	2	2.1	1	45	94.5	47.25	900	136	0.55	0.27	20	141	0.38	0.19	489
167	2	1.3	0.8	37	60.12	30.06	740	105	0.39	0.20	25	126	0.23	0.11	294
168	2	1.92	1	69	132.48	66.24	627	273	0.77	0.38	40	398	0.08	0.04	99
174	2	2.92	1	45	131.4	65.7	750	227	1.11	0.56	40	575	0.29	0.15	378
176	2	2.82	1	70	197.4	98.7	583	438	0.79	0.40	50	511	0.45	0.23	584
177	2	3.28	1	1	3.28	1.64	--	--	0.92	0.46	8	89	0.72	0.36	934
183	2	3.84	1	33	126.72	63.36	825	199	1.46	0.73	20	378	0.61	0.31	795
184	2	2.64	1	59	155.76	77.88	843	239	0.95	0.48	40	492	0.58	0.29	752
185	2	1.52	1	94	142.88	71.44	723	256	0.24	0.12	45	142	0.43	0.21	551
186	2	1.7	1	57	96.9	48.45	570	220	0.41	0.20	60	317	0.34	0.17	440

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
202	2	2.54	1	12	30.48	15.24	480	82	0.51	0.25	10	66	0.50	0.25	66
209	2	2.54	1	10	25.4	12.7	500	66	0.41	0.20	5	26	0	--	0
210	2	3	1	9	27	13.5	450	78	0.66	0.33	20	171	0	--	0
211	2	4.28	1	15	64.2	32.1	520	160	1.20	0.60	5	78	0	--	0
215	2	3.98	1	22	87.56	43.78	628	180	1.59	0.80	50	1030	0	--	0
216	2	2.04	1	5	10.2	5.1	--	--	0.53	0.26	50	343	0	--	0
217	2	3.44	1.2	24	68.8	34.4	480	186	0.98	0.49	15	189	0.09	0.04	111
219	2	3.8	1	21	79.8	39.9	700	148	1.22	0.61	15	236	0	--	0
223	2	4.4	1	12	52.8	26.4	600	114	1.67	0.84	8	162	0.04	0.02	57
226	2	4.82	1	33	159.06	79.53	550	374	1.25	0.63	25	406	0.10	0.05	125
228	2	4.52	1.2	42	158.2	79.1	525	390	1.81	0.90	25	585	0.08	0.04	98

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
White Shoal															
6	2	2.04	1	66	134.64	67.32	330	528	0.82	0.41	50	528	0	--	0
7	2	2.4	2.4	0	--	--	--	0	0.08	0.04	0	0	0	--	0
11	2	6.26	1	12	75.12	37.56	400	243	1.88	0.94	42	1033	0.63	0.32	810
14	2	1.56	1	34	53.04	26.52	486	141	0.66	0.33	40	339	0.06	0.03	81
Gun Rock															
9	2	1.82	0.9	15	30.33	15.17	500	78	0.44	0.22	50	288	0.20	0.10	262
12	2	1.68	1	31	52.08	26.04	517	130	0.54	0.27	50	348	0.44	0.22	566
14	2	4.88	1.4	12	41.83	20.91	300	180	0.77	0.38	90	893	0.63	0.31	812
17	2	2.32	1	49	113.68	56.84	445	330	0.65	0.32	50	420	0.51	0.26	661
18	2	1.24	1	86	106.64	53.32	662	209	0.35	0.17	45	202	0.32	0.16	417
19	2	4.52	1.3	15	52.15	26.08	500	135	0.76	0.38	32	322	0.56	0.28	720
27	2	1.54	1	78	120.12	60.06	650	239	0.37	0.18	80	383	0.46	0.23	598

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
32	2	1.02	0.9	45	51	25.5	500	132	0.38	0.19	60	299	0.09	0.04	117
34	2	2.28	1	21	47.88	23.94	525	118	0.91	0.46	80	944	0.18	0.09	236
Thomas Rock															
8	2	2.04	1	32	65.28	32.64	400	211	0.78	0.39	50	502	0	--	0
9	2	2.34	1	39	91.26	45.63	325	364	0.98	0.49	50	636	0.05	0.02	60
12	2	1.8	1	15	27	13.5	300	116	0.68	0.34	35	310	0.11	0.05	140
14	2	2.64	1	19	50.16	25.08	317	205	1.06	0.53	45	615	0	--	0
18	2	2.58	1	44	113.52	56.76	400	367	1.03	0.52	85	1136	0	--	0
23	2	1.92	1	11	21.12	10.56	550	50	0.77	0.38	50	497	0.12	0.06	149
27	2	2.02	1	17	34.34	17.17	212	209	0.69	0.34	70	622	0	--	0
29	2	1.58	0.86	21	38.58	19.29	700	71	0.74	0.37	50	476	0.33	0.16	428
Point of Shoals															
10	2	3.18	1	21	66.78	33.39	525	165	1.24	0.62	40	642	0	--	0

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
48	2	3.1	1.5	0	--	--	--	0	0.02	0.01	5	1	0	--	0
49	2	2.4	1	27	64.8	32.4	675	124	0.53	0.26	45	308	0	--	0
50	2	2.96	1	24	71.04	35.52	600	153	1.07	0.53	35	483	0	--	0
59	2	5.06	1.4	28	101.2	50.6	560	234	1.08	0.54	25	351	0.04	0.02	47
60	2	3.62	1	10	36.2	18.1	500	94	0.76	0.38	0	0	0	--	0
64	2	2.98	1	10	29.8	14.9	333	116	0.24	0.12	20	62	0	--	0
69	2	1.66	0.9	13	23.98	11.99	650	48	0.30	0.15	12	48	0.02	0.01	24
70	2	3.18	1	20	63.6	31.8	667	124	0.89	0.44	25	288	0	--	0
77	2	2.4	1	10	24	12	250	124	0.24	0.12	35	109	0	--	0
78	2	4.34	1.3	21	70.1	35.05	525	173	1.34	0.67	15	259	0	--	0
Horsehead															
9	2	1.72	1	46	79.12	39.56	657	156	0.79	0.40	85	871	0.05	0.03	67
10	2	3.92	1	42	164.64	82.32	1050	203	1.57	0.78	35	710	0.08	0.04	102

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
11	2	3.34	1.18	71	200.97	100.48	1775	146	1.76	0.88	45	1022	0	--	0
14	2	2.6	1	53	137.8	68.9	589	303	1.09	0.55	85	1202	0	--	0
17	2	3.08	1	42	129.36	64.68	840	199	1.29	0.65	35	586	0	--	0
20	2	3.56	1	17	60.52	30.26	425	184	0.11	0.05	95	131	0.04	0.02	46
22	2	4.26	1.4	24	73.03	36.51	800	118	1.58	0.79	15	307	0.06	0.03	79
23	2	3.86	1	59	227.74	113.87	656	450	2.08	1.04	40	1079	0	--	0
26	2	3.68	1	30	110.4	55.2	1350	106	1.91	0.96	62	1548	0	--	0
27	2	4.02	1.2	43	144.05	72.02	1075	173	1.34	0.67	25	434	0	--	0
28	2	4.24	1.4	21	63.6	31.8	700	118	1.15	0.58	25	372	0	--	0
29	2	4.56	1.5	51	155.04	77.52	850	236	1.40	0.70	22	407	0.15	0.08	197
Nansemond Ridge															
1	2	1.77	1	11	18.7	9.35	1100	44	0.65	0.32	50	418	0	--	0
2	2	2.22	1	28	62.16	31.08	1120	144	0.71	0.36	50	460	0	--	0

↑ bu/acre value for Nansemond Ridge is computed with Total catch instead of avg. catch

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
3	2	1.84	1	16	29.44	14.72	1231	62	0.68	0.34	50	441	0	--	0
4	2	1.7	0.62	12	32.90	16.45	750	114	0.90	0.45	65	761	0	--	0
Piankatank River Three Branches															
*36	2	3.2	3.2	0	--	--	--	0	0.01	--	0	0	0	--	0
*38	2	2.2	2.2	0	--	--	--	0	0	--	--	--	0	--	0
45	2	1.16	1.0	1	1.16	0.58	--	--	0.26	0.13	5	16	0	--	0
*48	2	3.0	3.0	0	--	--	--	0	0	--	--	0	0	--	0
54	2	3.0	3.0	0	--	--	--	0	0.04	0.02	0	0	0	0	0
*57	2	3.0	3.0	0	--	--	--	0	0	--	--	0	0	--	0
62	2	1.54	1	96	147.84	73.92	600	319	0.68	0.34	95	833	0	--	0
65	2	2.8	2.8	0	--	--	--	0	0.08	0.04	0	0	0	--	0
66	2	2.2	2.2	0	--	--	--	0	0	--	0	0	0	--	0
73	2	0.78	0.78	0	--	--	--	0	0.12	0.06	0	0	0	--	0

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
74	2	2.8	2.8	0	--	--	--	0	0.12	0.06	0	0	0	--	0
Burton Rock															
6	2	1.38	1	26	35.88	17.94	289	161	0.72	0.36	92	859	0.04	0.02	54
7	2	2.04	1	105	214.2	107.1	401	687	0.82	0.41	95	1003	0.04	0.02	53
14	2	1.52	1	113	171.76	85.88	628	354	0.61	0.30	95	748	0	--	0
17	2	0.94	0.66	6	8.54	4.27	300	37	0.40	0.20	10	52	0	--	0
18	2	1.2	1.2	0	--	--	--	0	0.08	0.04	0	0	0	--	0
23	2	1.50	1	20	30	15	667	58	0.63	0.32	95	775	0	--	0
24	2	1.92	1	34	65.28	32.64	567	149	0.96	0.48	95	1181	0	--	0
29*	2	0.4	0.4	1	1	--	--	--	0.03	0.02	50	19	0	--	0
31	2	1.26	1	22	27.72	13.86	367	98	0.45	0.23	90	528	0.02	0.01	33
32	2	1.14	1	14	15.96	7.98	350	59	0.41	0.20	90	478	0	--	0
35	2	0.46	0.46	55	55	27.5	458	155	0.30	0.15	95	369	0	--	0

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
37	2	1.22	0.82	61	90.76	45.38	356	327	0.60	0.30	100	770	0	--	0
41	2	1.56	1	54	84.12	42.12	338	323	0.56	0.28	95	691	0.03	0.02	40
45	2	1.08	0.72	34	51	25.5	425	155	0.54	0.27	100	699	0	--	0
52*	2	1.2	1.2	0	--	--	--	0	0.03	0.02	0	0	0	--	0
55	2	0.86	0.66	9	33	43	471	118	0.42	0.21	95	513	0	--	0
56	2	1.66	0.90	0	--	--	--	0	0.17	0.08	32	70	0	--	0
63*	2	1	1	0	--	--	--	0	0.04	0.02	0	0	0	--	0
64	2	0.6	0.6	0	--	--	--	0	0.02	0.01	0	0	0	--	0
65	2	1.02	0.7	42	61.2	30.6	420	189	0.44	0.22	60	340	0	--	0
Capetoon															
6	2	1.2	1	1	1.2	0.6	--	--	0.13	0.06	0	0	0	--	0
7	2	0.8	0.8	0	--	--	--	0	0.1	0.05	0	0	0	--	0
15	2	1.58	1	43	67.94	33.97	430	204	0.51	0.25	85	556	0	--	0

				OYSTERS					SHELL				CINDER		
Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
17	2	0.8	0.8	3	3	1.5	300	12	0.06	0.03	0	0	0	--	0
24	2	1.3	1	93	120.9	60.45	465	336	0.31	0.16	92	373	0	--	0
26	2	2.28	1	68	155.04	77.52	566	354	0.82	0.41	95	1009	0	--	0
28	2	1.92	1	47	90.24	45.12	391	298	0.4	0.2	50	261	0	--	0
35	2	1.64	1	57	93.48	46.74	475	254	0.52	0.26	92	628	0	--	0
36	2	2.02	1	70	141.4	70.7	636	287	0.52	0.26	82	560	0	--	0
37	2	2.28	1	60	136.8	68.4	600	295	0.68	0.34	80	708	0	--	0
43	2	2.22	1	88	195.36	97.68	419	603	0.67	0.33	95	819	0	--	0
44	2	2	1	85	170	85	425	517	0.52	0.26	95	640	0	--	0
48	2	0.8	0.8	0	--	--	--	0	0.04	0.02	--	--	0	--	0
50	2	1.3	1.3	0	--	--	--	0	0.07	0.04	0	0	0	--	0
51	2	2.06	1	73	150.38	75.19	456	426	0.66	0.33	95	811	0	--	0
53	2	2.54	1	57	144.78	72.39	356	526	0.81	0.41	60	631	0	--	0

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS					SHELL				CINDER		
				Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell(%)	Bushels per Acre (Exposed)	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
55	2	0.5	0.5	3	3	1.5	300	12	0.02	0.01	0	0	0	--	0
56	2	0.5	0.5	5	5	2.5	250	25	0.06	0.03	2	1	0	--	0
58	2	1.64	1	79	129.56	64.78	564	297	0.49	0.25	82	525	0	--	0
59	2	0.6	0.6	1	1	0.5	--	--	0.04	0.02	0	0	0	--	0
62	2	2.34	1	38	88.92	44.46	380	302	0.75	0.37	40	388	0	--	0
66	2	2.26	1	11	24.86	12.43	366	87	0.72	0.36	15	140	0	--	0
Palace Bar															
1	2	2.8	1	14	39.2	19.6	350	145	0.95	0.48	25	308	0	--	0
11	2	0.28	0.28	10	10	5	142	90	0.1	0.05	15	19	0	--	0
22	2	0.86	0.86	64	64	32	320	258	0.28	0.14	68	245	0	--	0
23	2	0.24	0.24	4	4	2	400	26	0.08	0.04	5	5	0	--	0
24	2	1.32	0.86	5	7.67	3.83	500	19	0.28	0.14	18	62	0	--	0
31	2	0.36	0.36	41	41	20.5	292	181	0.1	0.05	85	110	0	--	0

				OYSTERS					SHELL				CINDER		
Station	No. of samples	Total Volume (bu)	Subsample Volume (bu)	Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
32	2	0.88	0.66	47	62.66	31.33	313	258	0.43	0.21	95	525	0	--	0
41	2	2.3	1	104	239.2	119.6	433	714	1.2	0.6	95	1470	0	--	0
45	2	1.98	0.9	171	376.2	188.1	364	1338	0.66	0.33	95	812	0	--	0
46	2	1.72	1	20	34.4	17.2	400	111	0.62	0.31	5	40	0	--	0
55	2	2.18	1	126	274.68	137.34	450	790	0.74	0.37	80	768	0	--	0
56	2	1.66	1	42	69.72	34.86	323	279	0.70	0.35	50	451	0.02	0.008	21
57	2	0.22	0.22	0	--	--	--	0	0.04	0.02	0	--	0	--	0
58*	2	0.10	0.10	4	4	2	400	12	0.07	0.04	2	2	0	--	0
61	2	0.38	0.38	70	70	35	500	181	0.12	0.06	95	148	0	--	0
63	2	1.22	1	91	111.02	55.51	350	410	0.46	0.23	95	570	0	--	0
65	2	2.80	1	69	193.2	96.6	492	507	1.23	0.62	58	917	0	--	0
67	2	1.02	1	0	--	--	--	0	0.44	0.22	0	0	0	--	0
72	2	1.66	1	77	127.82	63.91	481	343	0.80	0.40	100	1032	0	--	0

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
73	2	0.80	0.80	47	47	23.5	293	207	0.26	0.13	58	194	0	--	0
74	2	1.1	0.74	99	147.16	73.58	353	538	0.39	0.19	95	475	0	--	0
75	2	1.02	0.72	62	87.83	43.91	387	293	0.54	0.27	95	662	0	--	0
83	2	1.5	1	104	156	78	472	427	0.63	0.32	98	795	0	--	0
86	2	2.16	1	97	209.52	104.76	538	503	0.95	0.48	98	1199	0.02	0.01	28
Island Bar															
1	2	0.36	0.36	32	32	16	266	155	0.14	0.07	72	131	0	--	0
2	2	0.30	0.30	24	24	12	480	64	0.14	0.07	60	109	0	--	0
3	2	0.32	0.32	42	42	21	525	103	0.14	0.07	50	91	0	--	0
Ginny Point															
3	2	1.06	0.9	0	--	--	--	0	0.25	0.12	0	0	0.15	0.07	198
4	2	0.58	0.58	2	2	1	--	--	0.12	0.06	0	0	0	--	0
6	2	0.9	0.8	12	13.5	6.75	400	43	0.25	0.12	12	40	0.03	0.02	44

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
7	2	0.69	0.69	55	55	27.5	250	51	0.12	0.06	12	19	0.02	0.01	26
8	2	1.4	0.7	52	104	52	288	466	0.64	0.32	50	414	0	--	0
13	2	0.68	0.6	35	39.66	19.83	437	117	0.32	0.16	95	390	0	--	0
15	2	1.18	0.8	44	64.9	32.45	275	305	0.59	0.30	95	726	0	--	0
Great Wicomico Marsh's West															
6	2	3.72	1.50	4	9.92	4.96	400	32	1.88	0.94	6	134	0.02	0.01	32
10*	2	5	5	1	1	0.5	0	--	0	--	--	--	0	--	0
13	2	0.5	0.5	10	10	5	333	38	0.28	0.14	3	11	0	--	0
14	2	0.4	0.4	64	64	32	400	207	0.26	0.13	95	320	0	--	0
16	2	6	6	0	--	--	--	0	0	--	--	--	0	--	0
19	2	0.86	0.8	27	29.02	14.51	450	83	0.45	0.23	95	555	0	--	0
21															
23	2	5.6	5.6	0	--	--	--	0	0	--	--	0	0	--	0

				OYSTERS					SHELL				CINDER		
Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
24	2	5.6	5.6	0	--	--	--	0	0	--	--	0	0	--	0
26	2	5.6	5.6	0	--	--	--	0	0	--	--	0	0	--	0
27	2	0.76	0.76	34	34	17	377	116	0.4	0.2	82	427	0	--	0
28	2	0.8	0.64	15	18.75	9.37	300	80	0.42	0.21	10	58	0.01	0.006	16
30	2	1.68	1	30	50.4	25.2	375	174	0.5	0.2	20	130	0	--	0
31	2	0.42	0.42	26	26	13	216	155	0.3	0.2	25	97	0.01	0.005	13
33*	2	5.6	5.6	0	--	--	--	0	0	--	--	0	0	--	0
34*	2	5.6	5.6	0	--	--	--	0	0	--	--	0	0	--	0
35	2	5.3	5.3	0	--	--	--	0	0.16	0.08	50	104	0	--	0
62	2	1.2	1.2	0	--	--	--	0	0	--	--	0	0	--	0
63	2	0.8	0.8	0	--	--	--	0	0	--	--	0	0	--	0
64	2	0.8	0.8	0	--	--	--	0	0	--	--	0	0	--	0
	[illegible]	56.24	53.12	211	243.09	121.54			6.32 ✓	2.133					

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
				OYSTERS					SHELL				CINDER		
Ingram					1.68 x 81										
6	2	1.68	1	81	136.08	68.04	352	500	0.5	0.2	95	620	0	--	0
12	2	1	1	0	--	--	--	0	0.38	0.19	0	0	0	--	0
15	2	1.56	1	91	141.96	70.98	413	444	0.47	0.23	85	515	0	--	0
17	2	0.6	0.6	0	--	--	--	0	0	--	--	--	0	--	0
28*	2	0.8	0.8	0	--	--	--	0	0	--	--	--	0	--	0
34	2	1.12	0.66	97	164.6	82.3	808	263	0.37	0.19	88	423	0.02	0.008	22
35	2	1.52	1	86	130.72	65.36	477	354	0.46	0.23	90	531	0	--	0
38	2	3.86	3.1	22	27.39	13.69	550	64	0.25	0.12	48	153	0	--	0
46	2	0.92	0.72	125	159.72	79.86	568	363	0.31	0.15	97	385	0	--	0
47	2	1.04	1.04	17	17	8.5	425	51	0.2	0.1	48	123	0	--	0
48	2	3.1	3.1	3	3	1.5	300	13	0.1	0.05	0	0	0	--	0
58	2	5.4	5.4	0	--	--	--	0	0	--	--	--	0	--	0

2630112

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
59	2	3.46	3.3	37	38.79	19.39	462	108	0.13	0.06	25	41	0	--	0
63	2	1.82	1	66	120.12	60.06	550	282	0.62	0.31	65	521	0	--	0
64	2	1.74	1	140	243.6	121.8	538	585	0.45	0.23	90	527	0	--	0
66	2	1.58	1	145	229.1	114.55	426	695	0.28	0.14	85	313	0	--	0
75	2	5.6	5.6	0	--	--	--	0	0.16	0.08	0	0	0	--	0
77	2	5.4	3.3	0	--	--	--	0	0.03	0.02	0	0	0	--	0
Whaley's West			34.62	910			5988		4.71						
1	2	4.96	1	13	64.48	32.24	325	256	1.14	0.57	10	148	0	--	0
2	2	2.76	0.7	2	7.88	3.94	--	--	1.42	0.71	55	101	0	--	0
13	2	2.96	1	1	2.96	1.48	--	--	1.3	0.65	10	169	0	--	0
15															
21	2	3.1	3.1	1	1	0.5	--	--	0.18	0.09	0	0	0	--	0
29	2	3.62	3.3	26	28.52	14.26	433	85	0.18	0.09	42	96	0.01	0.005	14

28 ov 8

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
33	2	1.12	0.8	68	95.2	47.6	377	326	0.48	0.24	98	60	0	--	0
36	2	2.8	2.8	41	41	20.5	341	155	0.06	0.03	48	37	0	--	0
39*	2	5.6	5.6	0	--	--	--	0	0.01	0.005	--	--	0	--	0
43	2	0.44	0.44	23	23	11.5	575	51	0.26	0.13	20	67	0	--	0
47	2	0.4	0.4	0	--	--	--	0	0.4	0.2	35	181	0	--	0
48*	2	5.6	5.6	0	--	--	--	0	0	--	--	0	0	--	0
49*	2	5.6	5.6	0	--	--	--	0	0	--	--	0	0	--	0
53	2	1.1	1.1	0	--	--	--	0	0.06	0.03	50	39	0	--	0
54	2	1.1	1.1	0	--	--	--	0	0.1	0.05	0	0	0	--	0
55	2	1.2	0.9	80	106.66	53.33	400	345	0.35	0.17	95	426	0	--	0
57	2	0.68	0.68	63	63	31.5	286	284	0.22	0.11	95	270	0	--	0
64	2	0.7	0.7	0	--	--	--	0	0	--	--	0	0	--	0
65	2	0.92	0.72	70	89.44	44.72	583	198	0.31	0.15	95	377	0	--	0

Station	No. of Samples	Total Volume (bu)	Subsample Volume (bu)	OYSTERS Total Catch	Total Adjusted Catch	Average Adjusted Catch	No. per Bushel	Bushels per Acre	SHELL Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Exposed Shell (%)	Bushels per Acre (Exposed)	CINDER Total Adjusted Catch (bu)	Average Adjusted Catch (bu)	Bushels per Acre (Exposed)
69*	2	5.6	5.6	0	--	--	--	0	0	--	--	0	0	--	0
74	2	1.2	1.2	0	--	--	--	0	0	--	--	0	0	--	0
75	2	0.9	0.76	100	118.42	59.21	500	306	0.47	0.24	80	491	0.02	0.01	30.66
77	2	2	1	71	142	71	394	466	0.56	0.28	95	689	0	--	0
85*	2	0.7	0.7	5	5	2.5	500	12	0.04	0.02	50	259	0	--	0

Appendix 2. Average oyster length (mm) and 95% confidence interval by stations for descriptive oyster classes. Data obtained from samples in representative areas of rocks in the James, Piankatank, and Great Wicomico Rivers in the 1974-75 sampling period. All measurements are rounded to the nearest millimeter, thus, some intervals are asymetric with respect to the sample average. Class code: Market (Mk); Small (Sm); Yearling (Yr); and Spat (Sp).

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
James	Wreck Shoal	84	Mk	3	79	
			Sm	3	69	
			Sp	1	(15)	
		104	Mk	3	82	
			Sm	8	65	
			Yr	2	39	
		106	Mk	3	79	
			Sm	14	63	58 - 67
			Yr	8	36	
			Sp	3	17	
		124	Mk	1	(80)	
			Sm	26	58	56 - 60
			Yr	16	38	36 - 40
			Sp	9	15	
		128	Mk	16	87	81 - 93
			Sm	28	60	58 - 62
			Yr	10	38	33 - 43
			Sp	10	22	17 - 27
		145	Mk	10	80	78 - 83
			Sm	36	62	60 - 65
			Yr	11	36	34 - 39
			Sp	15	10	8 - 12
		155	Mk	3	83	

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
James	Wreck Shoal	155	Sm	30	55	51 - 59
			Yr	17	32	30 - 34
			Sp	15	13	11 - 15
		157	Mk	7	82	
			Sm	32	57	54 - 60
			Yr	14	36	33 - 39
			Sp	31	14	12 - 15
		165	Mk	13	81	79 - 83
			Sm	61	62	59 - 64
			Yr	4	36	
			Sp	4	16	
		176	Mk	10	84	78 - 89
			Sm	34	60	57 - 63
			Yr	10	38	35 - 40
			Sp	27	16	14 - 18
	White Shoal		Sm	98	64	63 - 66
			Yr	25	39	35 - 42
			Sp	36	14	12 - 16
	Gun Rock		Mk	51	88	85 - 90
			Sm	114	66	64 - 67
			Yr	15	42	39 - 45
			Sp	32	15	14 - 17
	Thomas Rock		Mk	42	88	85 - 90

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
James	Thomas Rock		Sm	89	64	62 - 66
			Yr	12	37	35 - 40
			Sp	35	16	13 - 18
	Point of Shoals	49	Sm	18	54	50 - 59
			Sp	2	37	
		50	Sm	2	63	
		70	Mk	9	84	
			Sm	11	60	56 - 64
		77	Mk	1	(81)	
			Sm	9	59	
		78	Mk	5	85	
			Sm	10	67	61 - 72
	Horsehead	9	Sm	28	52	48 - 55
		20	Sm	50	50	48 - 53
		22	Sm	50	50	48 - 53
		27	Sm	50	49	46 - 51
			Yr	5	32	
		28	Sm	21	60	56 - 64
			Yr	4	44	
	Nansemond Ridge		Mk	4	83	
			Sm	40	62	59 - 64
			Yr	6	40	
			Sp	11	17	14 - 19

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Piankatank	Three Branches	45	Sp	3	13	
		62	Mk	20	86	83 - 90
			Sm	76	57	55 - 59
			Sp	4	29	
	Burton Rock	6	Mk	8	83	
			Sm	18	56	51 - 60
			Sp	45	24	22 - 26
		7	Mk	23	88	85 - 91
			Sm	82	56	54 - 58
			Sp	8	21	
		14	Mk	2	81	
			Sm	99	52	50 - 53
			Sm	12	47	42 - 51
			Sp	7	23	
		17	Mk	4	89	
			Sm	1	(64)	
		23	Mk	2	84	
			Sm	18	55	52 - 57
			Sp	54	23	21 - 26
		24	Sm	34	46	44 - 49
			Sp	13	27	21 - 32
		29	Mk	1	(81)	
		31	Mk	6	89	

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Piankatank	Burton Rock	31	Sm	16	64	60 - 67
			Sp	20	30	28 - 33
		32	Mk	2	84	
			Sm	12	51	47 - 54
			Sp	6	16	
		35	Mk	6	86	
			Sm	49	54	52 - 56
			Sp	9	24	
		37	Mk	1	(82)	
			Sm	60	52	50 - 54
			Sp	9	27	
		41	Mk	14	86	84 - 89
			Sm	40	62	59 - 65
			Sp	16	27	23 - 30
		45	Mk	1	(84)	
			Sm	33	49	47 - 51
			Sp	13	30	26 - 33
		55	Mk	15	90	86 - 93
			Sm	18	60	56 - 64
			Sp	5	35	
		56	Sp	28	23	20 - 25
		65	Mk	28	93	89 - 99
			Sm	14	64	60 - 68

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Piankatank	Burton Rock	65	Sp	5	21	
	Capetoon	15	Mk	15	86	81 - 92
			Sm	28	64	62 - 67
			Sp	5	22	
		17	Mk	1	(91)	
			Sm	2	58	
		24	Yr	2	35	
			Sp	3	19	
		26	Mk	23	85	82 - 88
			Sm	45	60	57 - 62
			Sp	5	19	
		28	Mk	20	84	61 - 86
			Sm	27	61	57 - 65
		35	Mk	17	88	86 - 91
			Sm	35	62	60 - 64
			Yr	5	40	
			Sp	4	20	
		36	Mk	12	86	82 - 92
			Sm	55	60	58 - 62
			Yr	3	39	
			Sp	6	22	
		37	Mk	20	86	83 - 89
			Sm	36	65	63 - 67

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Piankatank	Capetoon	37	Yr	4	40	
			Sp	6	22	
		43	Mk	21	89	85 - 92
			Yr	3	40	
			Sp	3	18	
		44	Mk	28	86	83 - 88
			Sm	52	61	59 - 63
			Yr	5	38	
			Sp	2	22	
		51	Mk	23	88	84 - 91
			Sm	45	61	59 - 63
			Yr	5	39	
			Sp	2	22	
		53	Mk	20	95	88 -102
			Sm	34	58	55 - 61
			Yr	3	38	
		55	Mk	1	(91)	
			Sm	2	54	
		56	Mk	2	80	
			Sm	3	62	
		58	Mk	29	87	84 - 90
			Sm	45	62	60 - 64
			Yr	5	40	

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Piankatank	Capetoon	58	Sp	7	17	
		59	Sm	1	(92)	
		62	Mk	16	85	81 - 88
			Sm	19	66	63 - 70
			Yr	3	40	
		66	Mk	9	93	
			Sm	2	70	
	Palace Bar	1	Mk	6	84	
			Sm	7	68	
			Yr	1	(47)	
			Sp	11	16	13 - 19
		11	Mk	2	79	
			Sm	7	68	
			Sp	5	17	
		22	Mk	36	89	86 - 92
			Sm	18	64	61 - 66
			Yr	10	43	39 - 46
			Sp	25	21	20 - 23
		23	Mk	1	(81)	
			Sm	3	59	
			Sp	3	19	
		24	Sm	4	61	
			Yr	1	(38)	

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Piankatank	Palace Bar	24	Sp	6	23	
		31	Mk	27	85	82 - 87
			Sm	14	67	64 - 70
			Sp	10	21	16 - 26
		32	Mk	9	85	
			Sm	36	53	51 - 56
			Sp	9	24	
		41	Mk	17	86	82 - 90
			Sm	67	63	61 - 65
			Yr	20	44	42 - 46
			Sp	41	21	19 - 23
		45	Mk	71	89	87 - 91
			Sm	99	60	58 - 62
			Sp	4	28	
		46	Mk	2	84	
			Sm	18	61	58 - 65
			Sp	16	20	16 - 24
		55	Mk	44	86	84 - 89
			Sm	82	55	53 - 57
			Sp	3	30	
		56	Mk	24	85	81 - 88
			Sm	18	58	54 - 62
			Sp	5	18	

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Piankatank	Palace Bar	58	Mk	2	79	
			Sm	2	53	
			Sp	1	(19)	
		61	Mk	13	84	80 - 88
			Sm	57	54	52 - 56
			Sp	3	16	
		63	Mk	7	83	
			Sm	49	59	57 - 61
			Yr	35	44	42 - 46
			Sp	12	21	16 - 26
		65	Mk	11	82	79 - 84
			Sm	58	52	50 - 54
			Sp	21	18	16 - 20
		72	Sm	67	54	52 - 56
			Sp	7	20	
		73	Mk	15	94	89 -100
			Sm	32	57	53 - 60
		74	Mk	36	86	84 - 88
			Sm	63	54	52 - 56
			Sp	6	13	
		75	Mk	21	86	80 - 90
			Yr	1	(37)	
			Sp	9	22	

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Piankatank	Palace Bar	83	Mk	7	91	
			Sm	84	59	57 - 60
			Yr	13	47	43 - 50
			Sp	27	24	21 - 26
		86	Mk	16	76	64 - 87
			Sm	81	53	51 - 55
			Sp	13	31	27 - 36
	Island Bar	1	Mk	23	93	88 - 98
			Sm	9	62	
		2	Mk	5	83	
			Sm	19	54	50 - 58
		3	Mk	28	89	86 - 92
			Sm	14	62	57 - 67
			Sp	3	20	
	Ginny Point	4	Mk	1	(81)	
			Sm	1	(75)	
		6	Sm	11	64	59 - 69
			Yr	1	(46)	
		7	Mk	44	95	91 - 98
			Sm	11	57	49 - 65
			Sp	1	(34)	
		8	Mk	39	87	85 - 90
			Sm	13	66	61 - 70

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Piankatank	Ginny Point	8	Sp	5	16	
		13	Mk	19	86	82 - 89
			Sm	14	62	57 - 66
			Sp	11	21	18 - 24
		15	Mk	31	89	85 - 92
			Sm	13	67	62 - 71
			Sp	3	15	
Great Wicomico	Marsh West	6	Mk	2	90	
			Sm	2	52	
		10	Mk	1	(112)	
		13	Mk	8	90	
			Sm	2	64	
		14	Mk	36	90	87 - 93
			Sm	22	68	66 - 70
			Yr	6	48	
			Sp	1	(33)	
		19	Mk	13	88	82 - 93
			Sm	14	64	60 - 68
			Sp	1	(19)	
		27	Mk	12	90	83 - 96
			Sm	22	62	58 - 65
			Sp	2	40	

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Great Wicomico	Marsh West	28	Mk	2	86	
			Sm	13	65	61 - 69
			Sp	1	(30)	
		30	Mk	14	90	87 - 93
			Sm	16	66	63 - 70
		31	Mk	15	99	94 -104
			Sm	11	64	59 - 68
			Sp	2	30	
		75	Mk	56	85	81 - 89
			Sm	44	67	65 - 68
			Yr	1	(42)	
			Sp	1	(25)	
	Ingram Rock	6	Mk	56	95	92 - 98
			Sm	25	57	53 - 60
			Sp	2	28	
		15	Mk	45	88	86 - 90
			Sm	46	55	
			Sp	1	(31)	
		34	Mk	15	88	84 - 92
			Sm	82	55	54 - 57
			Sp	3	28	
		35	Mk	37	89	86 - 91
			Sm	49	60	58 - 62

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Great Wicomico	Ingram Rock	35	Sp	3	27	
		46	Mk	53	86	84 - 89
			Sm	70	67	65 - 68
			Sp	2	13	
		47	Mk	19	98	90 -105
			Sm	20	63	58 - 67
			Yr	2	43	
			Sp	4	34	
		48	Mk	2	97	
			Sm	1	(61)	
		63	Mk	34	83	80 - 86
			Sm	20	71	69 - 73
			Yr	1	(35)	
		64	Mk	54	85	83 - 86
			Sm	67	66	64 - 67
			Sp	1	(33)	
		66	Mk	99	96	93 - 98
			Mk	19	90	86 - 94
			Sm	41	67	65 - 70
			Sp	2	28	
		75	Mk	15	84	81 - 88
			Sm	38	67	65 - 69
			Sp	2	37	

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Great Wicomico	Whaley's West	2	Mk	10	93	87 - 99
			Sm	5	64	
			Sp	1	(39)	
		13	Mk	2	88	
		15	Sm	1	(68)	
		21	Mk	1	(92)	
		33	Mk	18	92	85 -100
			Sm	36	60	57 - 62
			Sp	2	20	
		36	Mk	42	91	88 - 94
			Sm	39	64	62 - 67
			Sp	1	(28)	
		43	Mk	12	90	83 - 98
			Sm	10	70	67 - 72
			Yr	1	(47)	
		47	Sp	5	37	
		54	Sm	1	(72)	
		55	Mk	22	86	83 - 88
			Sm	58	63	61 - 65
			Sp	4	24	
		57	Mk	27	94	90 - 97
			Sm	36	60	58 - 63
		65	Mk	22	89	86 - 92

River	Location	Station	Size Class	Number Measured	Average Length	Confidence Interval (95%)
Great Wicomico	Whaley's West	65	Sm	48	62	60 - 65
		77	Mk	27	95	90 - 99
			Sm	44	63	61 - 65
		85	Mk	3	89	
			Sm	2	64	

Appendix 3. Percentages of market, small and yearling oysters by station in representative areas of rocks in the James, Piankatank, and Great Wicomico Rivers in the 1974-75 sampling period.

River and Rock	Station	Catch	Catch Composition (%) Market	Small	Yearling
James					
Wreck Shoal (Inshore)	26	0	0	0	0
	35	0	0	0	0
	36	0	0	0	0
	46	0	0	0	0
	47	0	0	0	0
	48	1	100	0	0
	56	1	100	0	0
	58	3	67	33	0
	65	13	69	31	0
	66	0	0	0	0
	67	1	0	100	0
	68	6	83	0	17
	75	15	53	33	13
	76	3	33	67	0
	77	4	25	50	25
	78	18	22	78	0
(Middle)	84	20	90	10	0
	85	2	100	0	0
	86	7	29	71	0
	87	1	0	100	0
	91+	3	33	67	0
	92	7	14	86	0
	93	11	73	27	0
	102	6	17	83	0
	103	2	50	50	0
	104	21	62	38	0
	105	16	62	38	0
	106	10	20	80	0
	107	9	33	67	0
	111+	10	20	80	0
	113	24	33	67	0
	114	21	33	48	19
	118	17	18	82	0
	123	5	20	80	0
	124	17	18	76	6
	128	32	34	66	0
	202+	12	25	58	17
	209+	10	50	40	10
	210+	9	22	78	0
	211+	15	53	47	0
	215+	22	23	77	0
	216+	5	0	100	0

+ Station added in 1974-75 sampling period

River and Rock	Station	Catch	Catch Composition (%) Market	Small	Yearling
James					
Wreck Shoal (Offshore)	131+	30	7	70	23
	132	34	32	62	6
	134	25	20	76	4
	135	32	41	59	0
	137	45	31	62	7
	141	33	27	61	12
	142	30	20	60	20
	143	31	29	68	3
	144	41	24	63	12
	145	80	14	81	5
	151+	32	50	47	3
	152	21	10	78	14
	155	55	22	67	11
	156	40	28	68	5
	157	27	18	78	4
	165	45	22	76	2
	167	37	24	68	8
	168	69	30	68	1
	174	45	47	51	2
	176	70	34	61	4
	177	1	100	0	0
	183	33	33	54	12
	184	59	29	52	19
	185	94	30	65	5
	186	57	40	54	5
	217	24	33	62	4
	219	21	14	81	5
	223	12	25	75	0
	226	33	33	58	9
	228	42	17	84	0
White Shoal	6	67	64	36	0
	7	0	0	0	0
	11	12	58	42	0
	14	34	21	74	6
Gun Rock	9	15	73	13	13
	12	31	16	77	6
	14	12	57	17	17
	17	49	41	57	2
	18	86	40	38	22
	19	15	47	53	0
	27	78	36	55	9
	32	45	51	44	4
	34	21	43	57	0

River and Rock	Station	Catch	Catch Composition (%) Market	Small	Yearling
James					
Thomas Rock	8	32	75	25	0
	9	39	62	38	0
	12	15	47	40	13
	14	19	74	26	0
	18	44	52	48	0
	23	11	36	64	0
	27	17	71	29	0
	29	21	57	43	0
Point of Shoals	10	21	19	81	0
	48	0	0	0	0
	49	27	7	93	0
	50	24	0	100	0
	59	28	14	82	4
	60	10	40	60	0
	64	10	40	60	0
	69	13	23	77	0
	70	20	5	95	0
	77	10	60	40	0
	78	21	5	71	24
Horsehead	9	46	22	63	15
	10	42	2	81	17
	11	71	1	86	13
	14	53	2	89	9
	17	42	5	83	12
	20	17	12	88	0
	22	24	0	79	21
	23	59	5	90	5
	26	30	7	67	27
	27	43	7	91	2
	28	21	0	90	10
	29	51	0	94	6
Nansemond	1	11	0	54	46
	2	28	0	75	25
	3	16	0	31	67
	4	12	0	75	25

River and Rock	Station	Catch	Catch Composition (%) Market	Small	Yearling
Piankatank					
Three Branches	45	1	100	0	0
	54	0	0	0	0
	62	96	21	79	0
	65	0	0	0	0
	66	0	0	0	0
	73	0	0	0	0
	74	1	0	100	0
Burton Rock	6	89	20	80	0
	7	99	14	86	0
	14	55	2	98	0
	17	6	67	33	0
	18	4	25	75	0
	23	38	3	97	0
	24	12	0	100	0
	29	13	31	69	0
	31	20	25	75	0
	32	34	9	91	0
	35	76	5	95	0
	37	37	19	81	0
	41	46	17	83	0
	45	15	0	100	0
	52	24	50	50	0
	55	9	33	67	0
	56	0	0	0	0
	64	0	0	0	0
	65	42	67	33	0
Capetoon	6	1	0	100	0
	7	0	0	0	0
	15	43	35	65	0
	17	3	33	67	0
	24	93	45	53	2
	26	68	34	66	0
	28	47	43	57	0
	35	57	30	61	9
	36	70	17	79	4
	37	60	33	60	7
	43	88	24	73	3
	44	85	33	61	6
	48	0	0	0	0
	50	0	0	0	0
	51	73	32	62	7
	53	57	35	60	5
	55	3	33	67	0

River and Rock	Station	Catch	Catch Composition (%) Market	Small	Yearling
Piankatank					
Capetoon	56	5	40	60	0
	58	79	37	57	6
	59	1	0	100	0
	62	38	42	50	8
	66	11	82	18	0
Palace Bar	1	14	43	50	7
	11	10	20	80	0
	22	64	56	28	16
	23	4	25	75	0
	24	5	0	80	20
	31	41	66	34	0
	32	47	21	79	0
	41	100	17	67	16
	45	171	42	58	0
	46	20	10	90	0
	55	126	35	65	0
	56	42	57	43	0
	57	0	0	0	0
	58	4	50	50	0
	61	70	19	81	0
	63	91	8	54	38
	65	69	16	84	0
	67	0	0	0	0
	72	7	13	87	0
	73	47	32	68	0
	74	99	36	64	0
	75	62	34	64	2
	83	104	7	81	12
	86	97	16	84	0
Island Bar	1	32	72	28	0
	2	24	21	79	0
	3	42	67	33	0
Ginney Point	3	0	0	0	0
	4	2	50	50	0
	6	12	0	92	8
	7	55	80	20	0
	8	52	75	25	0
	13	33	58	42	0
	15	44	70	30	0

River and Rock	Station	Catch	Catch Composition (%) Market	Small	Yearling
Great Wicomico					
Marsh West	6	4	50	50	0
	10	1	100	0	0
	13	10	80	20	0
	14	64	56	34	9
	16	0	0	0	0
	19	27	48	52	0
	23	0	0	0	0
	24	0	0	0	0
	26	0	0	0	0
	27	34	35	65	0
	28	15	13	87	0
	30	30	47	53	0
	31	26	58	42	0
	33	0	0	0	0
	34	0	0	0	0
	35	0	0	0	0
	62	0	0	0	0
	63	0	0	0	0
	64	0	0	0	0
Ingram Rock	6	81	69	31	0
	12	0	0	0	0
	15	91	50	50	0
	17	0	0	0	0
	28	0	0	0	0
	34	97	16	84	0
	35	86	43	57	0
	38	22	41	59	0
	46	125	45	54	1
	47	17	41	53	6
	48	3	67	33	0
	58	0	0	0	0
	59	37	57	40	3
	63	66	50	50	0
	64	140	59	41	0
	66	145	60	40	0
	75	0	0	0	0
	77	0	0	0	0
Whaley's West	1	13	69	31	0
	2	2	50	50	0
	13	3	67	33	0
	15	0	0	0	0
	21	1	100	0	0

River and Rock	Station	Catch	Catch Composition (%) Market	Small	Yearling
Great Wicomico					
Whaley's West	29	26	35	65	0
	33	68	44	56	0
	36	41	51	49	0
	39	0	0	0	0
	43	23	52	44	4
	47	0	0	0	0
	48	0	0	0	0
	49	0	0	0	0
	53	0	0	0	0
	54	0	0	0	0
	55	80	28	72	0
	57	63	43	57	0
	64	0	0	0	0
	65	70	31	69	0
	69	0	0	0	0
	74	0	0	0	0
	75	100	55	44	1
	77	71	38	62	0
	85	5	60	40	0

Appendix 4. Estimated oyster spat per acre by station in representative areas of rocks in the James, Piankatank, and Great Wicomico Rivers in the 1974-75 sampling period.

River and Rock	Station Number	Spat/Acre (X 1000)
James		
Horsehead	9	38
	10	48
	11	60
	14	59
	17	48
	20	10
	22	65
	23	39
	26	114
	27	16
	28	0
	29	39
Point of Shoals	49	0
	50	0
	59	0
	64	7
	69	0
	70	0
	77	0
	78	95
Wreck Shoal: Inshore	26	0
	35	0
	36	0
	46	0
	47	0
	48	15
	56	0
	58	5
	65	26
	66	0
	67	5
	68	0
	75	41
	76	0
	77	12
	78	0
Wreck Shoal: Middle	84	77
	85	28
	86	67
	87	62
	91	28
	92	40
	93	50
	102	73

River and Rock		Station Number	Spat/Acre (X 1000)
James			
Wreck Shoal:	Middle	103	51
		104	96
		105	64
		106	80
		107	137
		111	14
		113	116
		114	185
		118	550
		123	111
		124	203
		128	306
		202	14
		209	19
		210	15
		211	0
		215	10
		216	0
Wreck Shoal:	Offshore	131	51
		132	169
		134	228
		135	34
		137	285
		141	27
		142	63
		143	152
		144	238
		145	292
		151	39
		152	78
		155	721
		156	759
		157	318
		165	415
		167	238
		168	542
		174	440
		176	155
		177	2,385
		183	365
		184	491
		185	151
		186	11
		217	56
		219	0
		223	49
		226	23
		228	53

River and Rock	Station Number	Spat/Acre (X 1000)
James		
Thomas Rock	12	214
	14	214
	18	254
	23	174
	27	58
	29	57
Gun Rock	17	44
	18	32
	19	80
	27	257
	32	77
	34	174
White Shoal	6	24
	7	0
	14	166
Nansemond Ridge	1	40
	2	169
	3	76
	4	25
Piankatank		
Three Branches	45	10
	54	0
	62	21
	65	0
	66	0
	73	0
	74	0
Burton Rock	6	142
	7	52
	14	101
	17	0
	18	0
	23	184
	24	62
	31	62
	32	16
	35	23
	37	23
	41	57
	45	57
	55	18
	56	181
	64	0
	65	13

River and Rock	Station Number	Spat/Acre (X 1000)
Piankatank		
Capetoon	6	0
	7	0
	15	23
	17	0
	24	10
	26	26
	28	0
	35	16
	36	31
	37	41
	43	16
	44	10
	48	0
	50	0
	51	13
	53	0
	55	0
	56	0
	58	21
	59	0
	62	0
	66	0
Palace Bar	1	62
	11	13
	22	39
	23	5
	24	16
	31	18
	32	21
	41	205
	45	5
	46	60
	55	16
	56	18
	57	0
	61	8
	63	26
	65	129
	67	0
	72	36
	73	0
	74	16
	75	21
	83	57
	86	54

River and Rock	Station Number	Spat/Acre (X 1000)
Piankatank		
Island Bar	1	0
	2	0
	3	8
Ginney Point	3	0
	4	0
	6	0
	7	0
	8	18
	13	34
	15	13
Great Wicomico		
Marsh West	6	0
	13	0
	14	3
	16	0
	19	3
	26	0
	27	5
	28	8
	30	0
	31	5
	35	0
Ingram Rock	6	10
	12	0
	15	3
	17	0
	34	16
	35	13
	46	13
	47	10
	48	0
	58	0
	59	0
	63	0
	64	5
	66	10
	75	10
	77	0

River and Rock	Station Number	Spat/Acre (X 1000)
Great Wicomico		
Whaley's West	1	0
	2	10
	13	0
	15	0
	21	0
	29	0
	33	0
	36	3
	43	0
	47	13
	53	0
	54	0
	55	16
	57	0
	64	0
	65	0
	74	0
	75	3
	77	0

Part II: TESTING AND MODIFYING OF GEAR TO HARVEST OYSTERS

INTRODUCTION

During the 1974-75 contract period, the hydraulic escalator was modified and tested in the York and Rappahannock Rivers. The harvester was capable of raising large quantities of oysters and shell from various types of bottoms. Moreover, the oysters and shell were not broken or crushed, were almost completely free of adhering silt and sand, also on firm bottom. The apparatus caused only minimal changes in the condition of the bottom.

The modifications were made from January to April. Field testing began in May 1975 in the York and Rappahannock Rivers on public and leased bottom and on several types of substrate. The device was demonstrated for oyster growers, television companies, the press, representatives of the Virginia Marine Resources Commission, the Maryland Department of Tidewater Fisheries, representatives of the National Marine Fisheries Service, and to the staff of the Potomac River Fisheries Commission. Descriptions of the apparatus were published in the VIMS Marine Resources Information Bulletin, Vol. VII, No. 5 and the Marine News Letter, Coastal Plains Center for Marine Development (Vol. 6, No. 6).

Specifications and Construction Details of the Harvester

The essential measurements and operational details of the harvester head are shown in Figures 1, 2, 3, 4 and 5 and reference should be made to these illustrations in this report. The details of the support systems, i.e., water pumps, hydraulic motors, escalator, appear in a series of detailed photographs in the annual report for the preceding year (3-192-R, 1973-74).

A total of 15 trials or demonstrations was completed in the contract period. These are listed chronologically in Appendix 1.

Modifications 1974-75

Modifications consisted of construction of a new escalator frame, and modifying the suspension system of the harvester head.

The construction of the new escalator was necessary for several reasons. The older one was in use for many years and corrosion reduced the thickness of the steel to the point that the structure was unsound. It was also too long and heavy for efficient use with our research vessel, the Mar-Bel. The new escalator was constructed in January and February by the LeMay Welding Company at Greenville, Maryland. It is 29.5 ft long as contrasted to 32.5 ft for the older one and its weight is about 200 pounds less than the one it replaced. The installation and testing of the new escalator was completed during April, 1975.

A second modification was a change in the method of suspending the forward end of the harvester from the boat. It consisted of suspending the harvester head from the end of a steel boom which projected forward at about a 45 degree angle toward the bow of the boat. It is now possible to adjust the height of the harvester head over the bottom with much greater accuracy than previously (Figure 1).

Operational Parameters of the Harvester

Optimal values for water pump pressure, rotational speed of the drums to which the steel tines are affixed, boat speed and escalator belt speed was assessed. A summary follows:

A. Rotational speed of the flexible steel tines. A basic part of the harvester developed under this contract was two rotating drums to which were affixed flexible steel tines. These tines dig or pull oysters and shell from the bottom prior to their being pushed by water jets onto the moving escalator belt which carries them to the surface.

Tests in the York River on various types of bottom indicated that 1 rps gave optimal results. At more rapid rotational speed (up to 5 rps), the harvester took fewer oysters. When the drum revolved at 5 rps or higher, a vortex was created in the water which disturbed bottom sediment.

B. Water pressure of the jets. A water pressure of 50 psi was sufficient to push oysters from the tines onto the escalator belt; moreover, it was sufficient to remove almost all the mud or sand adhering to shells and oysters. In several tests when the water jets were turned off, the harvester would not function.

C. Boat speed and speed of escalator belt. A forward speed of the boat between 1/4 to 1/7 knot gives the best results. At this speed, a belt speed of about 1/2 to 1 ft/sec seems optimum. When the belt speed is increased to 2 to 3 ft/sec, it has the effect of washing shells and oysters back down the belt.

Efficiency of the Harvester

The harvester was successfully operated during May, June and July 1975 on several types of oyster bottom. During these tests it harvested oysters in commercial quantities with few if any mechanical problems. Moreover, it operated satisfactorily with waves 1.5 to 2.0 ft high.

The rate of harvest/hr for oysters was estimated on the basis of the catch over a timed interval and the oysters were picked from the moving belt into a 10 qt measure. Shell was estimated by two methods. The first (when catch was low) was to collect the shell as it fell from the end of the belt into a 10 qt measure. When shell was abundant, the quantity was calculated on the basis of the belt speed in ft/sec (timed), the depth of the shell on the belt, and the belt width.

In the Rappahannock River, near Bowlers Wharf, tests on typical areas of planted bottom indicated a catch rate ranging from 30 to 138 bushels of oysters/hr. The substrate in these areas was originally soft mud, but it had been stiffened prior to planting the seed oysters by planting from 6 to 12 inches of shell.

In the York River near Clay Bank on planted bottoms where the substrate was a moderately firm sand-clay overlain with a thin layer of shell, 27 bu/hr was harvested. On an adjacent harvested portion 6.0 bu/hr were obtained. In the same river, on public oyster grounds at Green Rock where the substrate was very firm and composed of a firm sand-clay shell matrix, the harvester raised up to 7.3 bu/hr from an area tonged the previous year.

In the preceding tests, it was obvious that the rate at which oysters were raised under any given belt speed, boat speed and rotational speed of the harvesting drum was largely a function of density of oysters on the bottom. That is, the higher the oyster density, the higher would be the catch per hour. This study did not evaluate density of oysters on the bottom prior to the tests, but it is typical for growers to plant from 500 to 1000 bushels of seed/acre.

The harvester was efficient in raising shell. In the York River at Green Rock, which is a natural oyster rock, the harvest of shell was from 180 to 774 bu/hr. On a leased bottom with a soft bottom overlain by a layer of shell at Clay Bank, the harvest rate was estimated at 516 bu/hr. In the Rappahannock at Bowlers Wharf on leased bottoms where 6 to 12 inches of shell were used to stiffen the bottom prior to planting oysters, it was estimated that up to 906 bu/hr of shell was harvested.

Quality of Oysters Raised by the Harvester

In all tests the shell and oysters raised by the harvester were largely free of adhering sand and mud. The reason for this is that they are washed free of this material by the jets of water which push the oysters and shell material from the tines onto the moving escalator belt. In addition, the material is washed while it is transported to the surface on the belt. In almost no instances were oysters broken, cracked or fragmented by the action of the harvester under the operational speeds tested.

Effect of the Harvester on the Substrate

The effect of the harvester on the bottom was evaluated. This test was made by first operating the harvester on Green Rock in the York River over a distance of about 200 ft. The bottom in the study area was a natural oyster rock composed of a matrix of sand-clay and shell which extended to a depth of at least 2 ft. During this test the harvester raised shell at the rate of 774 bu/hr and oysters at about 30 bu/hr. The tract covered by the harvester was marked by buoys and stakes and the area was then studied by a diver using SCUBA.

A trench 3 to 4 inches deep was dug by the harvester. This was about the same distance the rotating tines extended below the surface of the runners which slide over the bottom. The width of the track is about 28 inches which is about the width of the rotating drum to which the flexible tines are attached.

The shells and oysters raised by the harvester fell back partially in the shallow trench and also about 2 to 3 ft on each side. The steel runners did not crush or depress the bottom.

There appeared to be no change in the bottom density immediately below the harvested area. The bottom was as firm in the trench as it was 1 to 2 ft outside.

The harvester removed the oysters and shell with only a minimal effect on the bottom layer immediately below that which was removed.

Working Depth of the Harvester

The harvester was tested to a depth of about 10 ft. The escalator used in these tests was 29.5 ft long. If a longer one was used (35 ft), we estimate the harvester might be operated at a depth of about 15 ft.

DISCUSSION

The harvester developed by VIMS has been demonstrated to be efficient in harvesting oysters from planted and natural bottoms. We believe that a modified design might be used to advantage by the private sector of the oyster industry in many East coast areas.

Suggested modifications would include the following:

A. The escalator system should be mounted on a catamaran-type hull with the escalator between the hulls. This arrangement would give the harvester greater stability and would enable it to work in very shallow water. Also, it would make culling more convenient than a side mounted system.

B. Construct the catamaran hull so the end of the escalator belt can be emptied onto a flat-topped barge towed behind. In this way large quantities of shell or oysters could be harvested with a minimum of effort.

C. Construct the harvester head of light-weight alloys.

The advantages of using a mechanical harvester rather than tongs or dredges follow:

A. In using the escalator, the oyster may be culled from the moving belt and the unwanted shell returned to the bottom with no effort on the part of the culler. In contrast, when tongs or a dredge are used, the oysters and shell raised from the bottom are dumped on the deck of a boat or a culling board. Here the oysters and unwanted shell are separated by hand and the unwanted shell is shoveled over the side.

B. A harvester may be operated by two persons. Frequently, a dredge boat must have a crew of three for efficient operation.

C. The oysters raised by the escalator are largely free of adhering mud or sand. This is seldom the case with oyster tonged or dredged from the bottom.

D. Oyster tongers are becoming increasingly difficult to hire because of changing socio-economic conditions. The harvester offers a satisfactory substitute for this type of labor.

E. The harvester efficiently harvested shell partially or wholly buried in the bottom. Neither tongs nor dredges can do this with any degree of efficiency. Shells are used as cultch for attachment of oyster spat. Buried shell is useless for this purpose and oyster growers often pay 25¢/bu for shells. The harvester may harvest up to 906 bu/hr or about 7,200 bushels in a 8-hr day. Therefore, the harvester would be of value in obtaining cultch for the public and private sector of the oyster industry.

Figure 1. The Mar-Bel with the harvester attached. This shows the method of suspending the forward end of the harvester.


VIRGINIA INSTITUTE of MARINE SCIENCE
MAR-BEL

Figure 2. Side view of harvester.

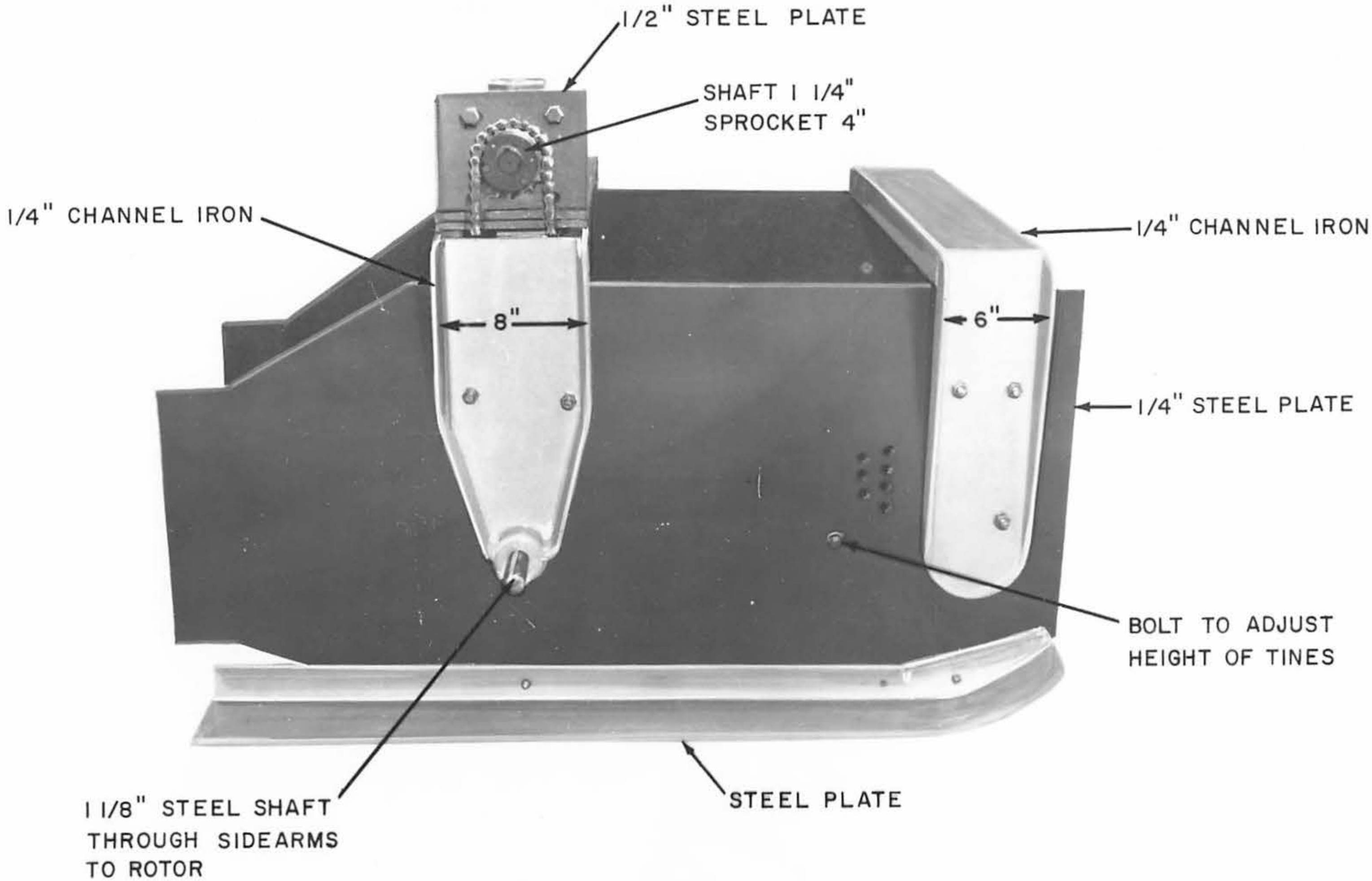

1/2" STEEL PLATE
SHAFT 1 1/4"
SPROCKET 4"
1/4" CHANNEL IRON
1/4" CHANNEL IRON
8"
6"
1/4" STEEL PLATE
BOLT TO ADJUST
HEIGHT OF TINES
1 1/8" STEEL SHAFT
THROUGH SIDEARMS
TO ROTOR
STEEL PLATE

Figure 3. Front view of harvester.

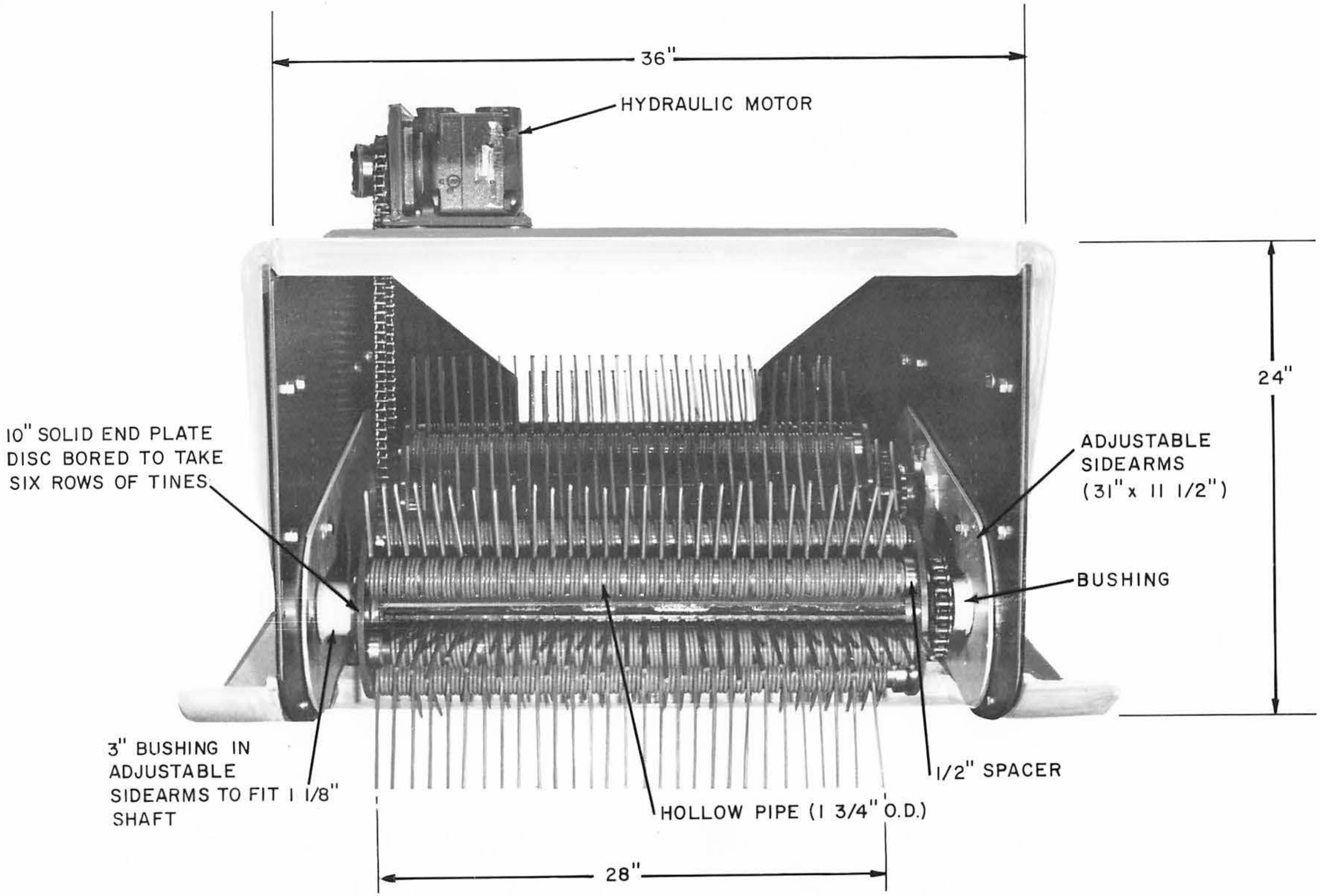

36"
HYDRAULIC MOTOR
24"
10" SOLID END PLATE
DISC BORED TO TAKE
SIX ROWS OF TINES
ADJUSTABLE
SIDEARMS
(31" x 11 1/2")
BUSHING
3" BUSHING IN
ADJUSTABLE
SIDEARMS TO FIT 1 1/8"
SHAFT
1/2" SPACER
HOLLOW PIPE (1 3/4" O.D.)
28"

Figure 4. Details of attachment of tines to harvester and view of holes needed to adjust the working depth of the tines.

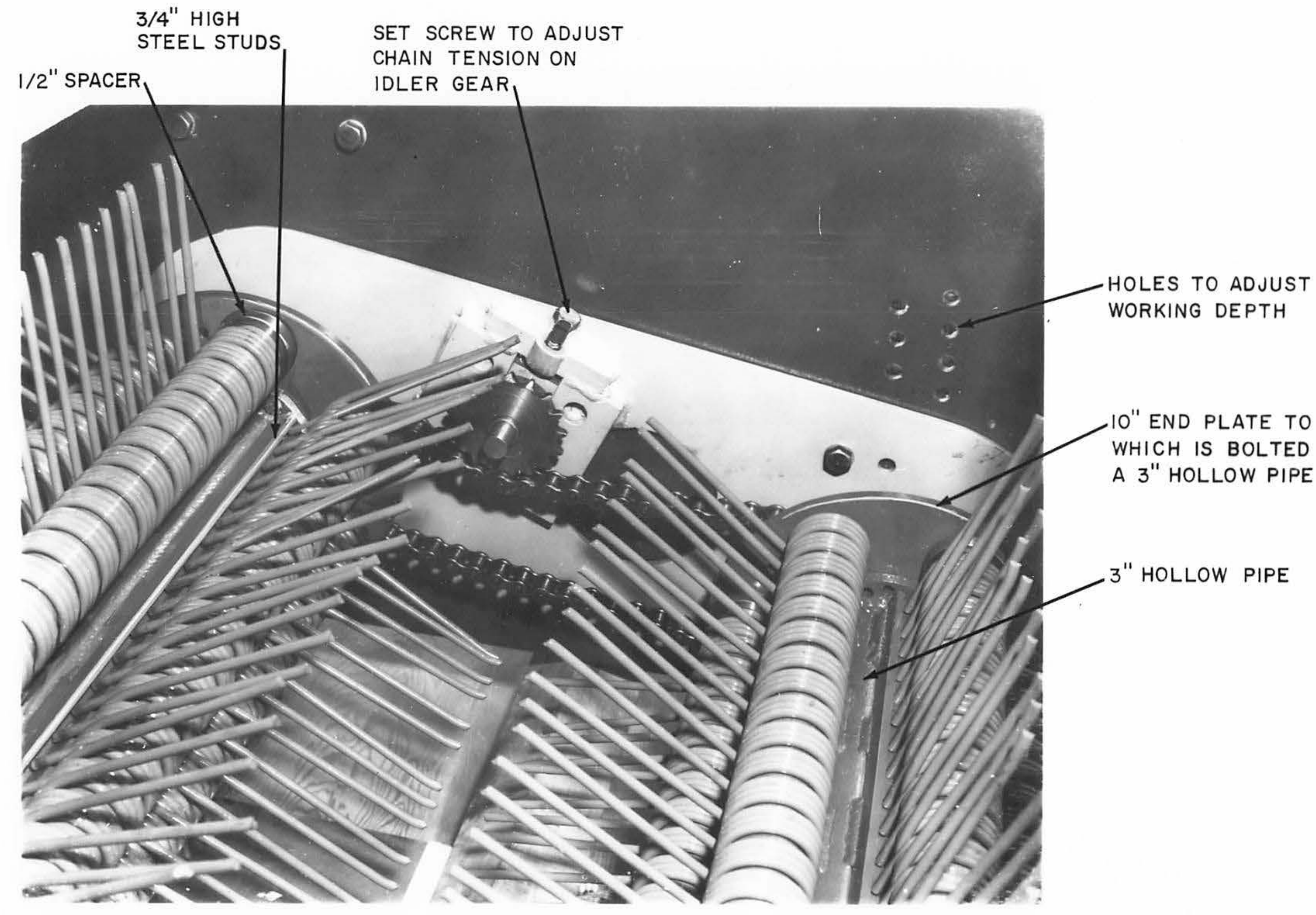
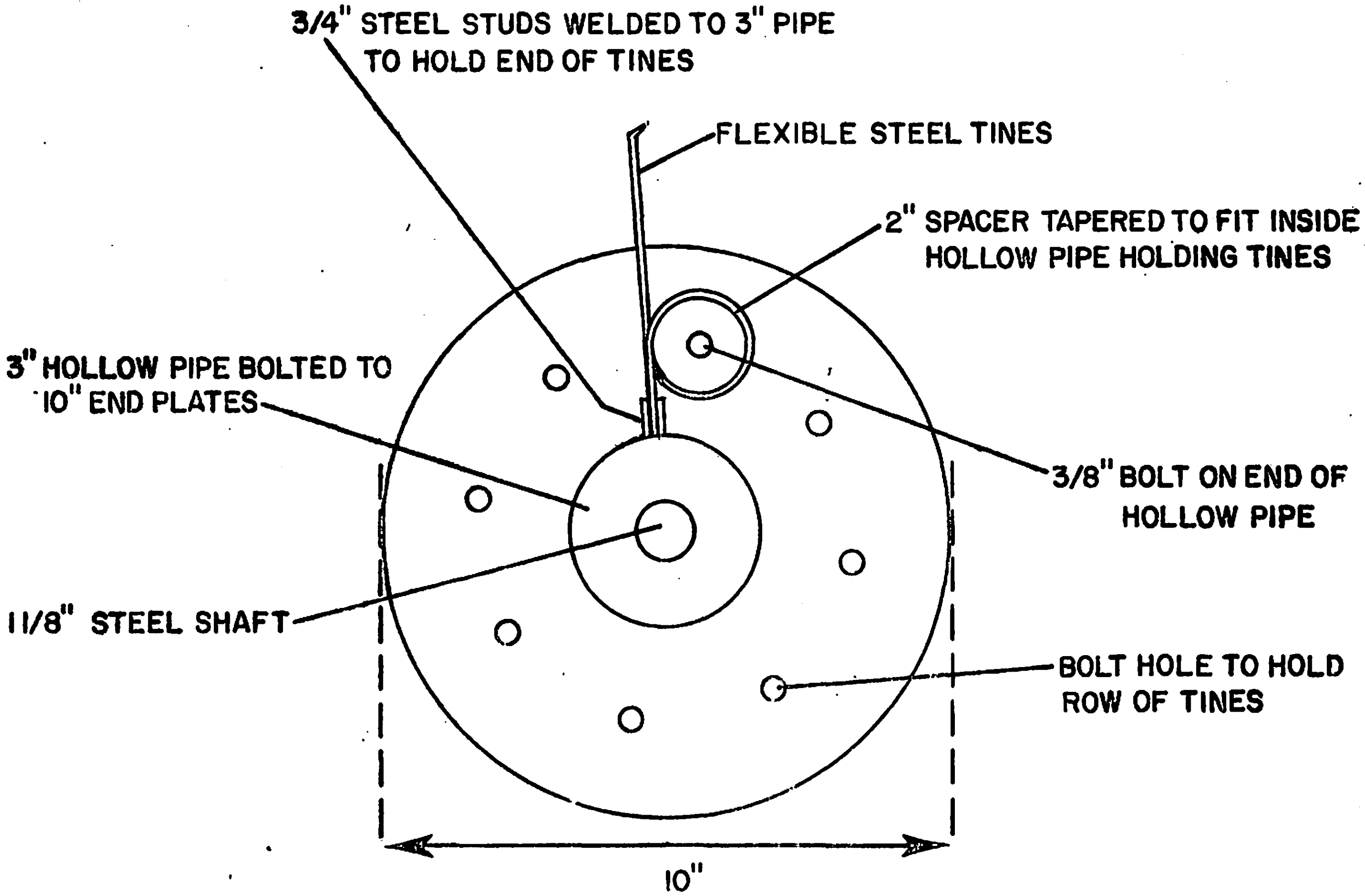

3/4" HIGH
STEEL STUDS
1/2" SPACER
SET SCREW TO ADJUST
CHAIN TENSION ON
IDLER GEAR
HOLES TO ADJUST
WORKING DEPTH
10" END PLATE TO
WHICH IS BOLTED
A 3" HOLLOW PIPE
3" HOLLOW PIPE

Figure 5. Details of attachment of flexible tines to the rotating drum.



3/8" STEEL PLATE

APPENDIX 1

The results of demonstrations and tests of the escalator harvester completed in the 1974-75 contract period follows in chronological order.

23 May 1975

The harvester was operated for about 1.5 hr on a private oyster lease in the York River located about 0.5 mile above Gloucester Point, Virginia. This bottom had not been planted with oysters in about 15 years. It contained scattered oyster shells buried from 1 to 2 inches in a firm sand-clay matrix. The depth was about 9 ft MLW. Test on this date evaluated various rotor speeds and several methods of suspending the harvester from the boom.

27 May 1975

The harvester was operated again on Area I for about two hours to determine the optimum angle of suspending the harvester head from the boom. Shells were raised at rates ranging from 0.5 to 2.0 bu/min (30 to 120 bu/hr). Tests also determined the optimum rotational speed for the drum to which was affixed the flexible steel tines which dug oysters from the bottom. Rotational speeds from 1 to 5 rps seemed to be more efficient than higher rates, but more tests were indicated. During these tests, the belt speed of the escalator ranged from about 0.5 to 1.0 ft/sec.

29 May 1975

The harvester was operated in the York River on leased bottom located about 14.5 miles upriver from the mouth of the river system and about 0.5 mile above Clay Bank (Area II). The bottom was moderately firm sand-clay overlain with a thin layer of shell. The water depth was about 6 to 7 ft MLW. The belt speed was about 1 ft/sec; rotor speed was about 1 rps.

A part of the bottom tested had previously been harvested; the remainder contained oysters 3 to 4 inches long. The oysters brought up in one minute were picked off the escalator belt and their volume measured. The results follow:

	Oyster Catch (bu/min)		
Test Number	Harvested Bottom	Area Not Harvested	Shells
1	0.1		Estimated 1.0 to 3.0 bu/min; about 25% of this was buried shell. Based on collection in a bucket from end of belt.
2		0.3	
3		0.5	
4		0.5	
5	0.1		
6	0.1		
7		0.5	
Avg. min.	0.1	0.45	
Avg. hr.	6.0	27.0	

On the bottom previously harvested the average catch was 6 bu/hr; on unharvested bottom 27 bu/hr. Shell made up about 75% of the catch. The oysters and shell brought up by the escalator were exceptionally free from adhering sand and mud; few if any were broken, chipped or crushed by the action of the harvester.

30 May 1975

The harvester was evaluated on leased bottom on the south side of the York River opposite Gloucester 5.0 miles above the mouth of the system (Area III). This bottom was used to culture oysters about 20 years ago, but it has not been used since. At the time of this test the bottom contained few living oysters but much shell was embedded in a firm sand-clay matrix just below the sediment surface. The water depth was about 8 to 10 ft MLW; belt speed was from 0.5 to 1 ft/sec. Shells ranged from 1 to 3 inches thick on the belt and were almost completely free from adhering sand and mud; few of the shells appeared to be broken by the action of the escalator.

6 June 1975

These tests were made on the south side of the Rappahannock River on leased bottom just inshore of Bowlers Rock Light 25.5 miles above the mouth of the system (Area IV). The four bottoms on which the tests were conducted were made since large quantities of shell (10 to 15 thousand bu/acre) were initially planted on a soft mud bottom. This gave a mud-shell layer on the bottom which ranged from about 6 to 12 inches deep. This was a necessary preliminary step to form the bottom prior to planting seed oysters.

Four areas were evaluated:

A. A shelled area containing few living oysters.

B. A shelled area overplanted with oysters several years ago. However, the oysters were harvested in March 1975 prior to the test. A few live oysters remained on the plot.

C. A shelled area planted in early spring 1975 with James River seed oysters (about 500/bu/acre).

D. A shelled area planted in 1973 with seed oysters. At the time of the test the oysters were mature and ready to be harvested.

The test of the harvester on each of the four bottoms lasted from 5 to 15 minutes. The rotor speed was about 1 rps; belt speed was about 1 ft/sec.

On Plots A and B shell was raised 2 to 5 inches deep on the belt almost continuously; few oysters were obtained. The rate at which shell was raised was estimated by assuming an average depth of shell on the belt of 3.5 inches and a belt speed of about 1 ft/sec. Since the width of the escalator belt was 18 inches, it was calculated that in 1 minute, the belt raised about 45,360 cubic inches of shell (60 sec. X 12 X 18 X 3.5 inches. In a Virginia bushel, there are 3,004 cubic inches, therefore, it is estimated that in one minute the belt raised about 15.1 bushels (45,360 ÷ 3,004) or about 906 bu/hr.

The harvest rate of oysters was determined by picking oysters from the belt during a timed period into a 10 qt measure. On Plot C where four measurements were made, they were harvested at about 0.5 bu/min (30 bu/hr). On Plot D in three trials, they came up at about 2.3 bu/min (138 bu/hr).

The oysters and shell raised were very clean; none appeared to be broken by the action of the harvester.

Mr. Garrett, the leaseholder, witnessed this demonstration.

9 June 1975

The harvester was demonstrated on Area IV to Mr. Cranston Morgan and Mr. Alan Drewer, affiliated with two of the major oyster companies in Virginia. During this demonstration the harvester was operated on the bottom described as A, B, and C on 6 June 1975. Boat speed, rotor speed and belt speed were about the same as during the preceding test. The harvester operated satisfactorily as it did previously on the same bottoms.

10 June 1975

The harvester was demonstrated on Area IV again to Mr. Lawrence H. Couture of the National Marine Fisheries Service and to Mr. Cowart, an oyster grower. Also present was Mr. Howard Hudnall, Chief Repletion Officer of the Virginia Marine Resources Commission. The harvester was operated for about 20 minutes on bottoms A, B and C. The water was quite rough with waves 1.5 to 2.0 ft high. Even under these marginal conditions, the harvester operated successfully and visual observation indicated that the catch of shell and oysters was about the same as on 6 and 9 June.

18 June 1975

The harvester was evaluated on Area V, a leased area, on the north shore of the lower Rappahannock River 8 miles from the mouth. This area was barren and the harvester raised only about 0.5 bushel of oysters in 1 hour.

9 July 1975

The oyster harvester was evaluated at Green Rock in the York River (Area VI). This is a public rock 11 miles upriver from the mouth of the system. It has a firm sand-clay substrate in which shell is embedded to a depth of 2 to 3 ft or more. The water depth is about 6 ft MLW. The area was planted with oysters by the Commonwealth in 1974, but many had been tonged prior to our tests to the point that few watermen worked in the area. Operational parameters during this test were: boat speed about 0.25 knot; and escalator belt speed about 0.5 ft/sec. Shell collected in a 10 qt measure during timed intervals indicated a rate of harvest ranging from about 60 to 120 bu/hr.

A series of tests evaluated harvest rates of oysters at three rotor speeds (1, 2 and 5 rps). The rate of harvest at each speed was estimated by picking them off the belt over a measured interval of time. The results tabulated below indicate that at 0.25 knot, the lower rotational speed gave the highest catch.

Test Number	Minutes required to catch 1 bu oysters	Catch Bu/hr	Rotor Speed rps	Average Catch Bu/Hr
1	12	5	5	
2	10	6	5	5.3
3	12	5	5	
4	10	6	2	6.2
5	9.5	6.3	2	
6	6	10	1	
7	8	7.5	1	7.3
8	10	6	1	
9	9	6.6	1	

The reason why the higher rotational speeds gave lower catches is not too clear. It was observed, however, that at 5 rps the spinning rotors set up a vortex in the water which seemed to erode the bottom beneath the rotating tines.

10 July 1975

The harvester was demonstrated on the south side of the York River on a leased bottom 15 miles above the mouth of the system (Area VII). Mr. Windom Hogge, an oyster grower, and Mr. Andy Jordan from Clemson University were present. The bottom was soft mud over-planted with shells and then with seed oysters. The area, however, had been harvested prior to our trials. The harvester was operated for an estimated distance of 500 ft over the bed and during 8 minutes about 1 bushel of oysters was culled from the catch (7.5 bu/hr).

During this test the belt and rotor speed were operated at about 1 ft/sec and 1 rps, respectively. Shell was from 1 to 3 inches thick on the belt. Calculations similar to those previously presented (Area IV, 6 June) indicate that shell was harvested at the rate of about 516 bu/hr.

15 July 1975

The Institute on this date gave a demonstration of the harvester in the York River at Green Rock for three local television companies which are affiliates of CBS, NBC and ABC, and for four local newspapers. Television coverage of the harvester in operation appeared on all local stations (Newport News, Norfolk, and Richmond) and on programs presented in Rhode Island, Oregon, New Mexico and other locations. Articles concerning the harvester appeared in three local newspapers.

17 July 1975

The Institute gave a demonstration of the harvester to supervisory personnel of the Virginia Marine Resources Commission at Green Rock in the York River (Test Area VI). The following members of the Commission were present:

Mr. James E. Douglas, Commissioner

Mr. Robert Hancock, Chief Law Enforcement

Mr. Herbert Sadler, Supervisor

Mr. Edgar Miles, Supervisor

Mr. Ralph Dameron, Jr., Supervisor

Mr. Ben Daniel, Supervisor

Mr. Howard Hudnall, Conservation Officer

Mr. S. Sewell Headley, Board Marine Resources Commission

The harvester worked well in tests lasting over 1 hour.

<u>18 July 1975</u>

A demonstration was given of the harvester for Mr. George Milton, Dean Oyster Processer, and a grower, Mr. Harold Stine, President, Charles City Maryland Waterman's Association, and Mr. A. C. Carpenter representing the Potomac River Fisheries Commission. The test was conducted on Green Rock in the York River (Area VI). The rate of harvest of oysters was not measured during this demonstration. Shell harvest was estimated, however, by the method used on 6 June for Area VI. Based on a belt speed of 0.5 ft/sec and an average depth of shell, it was calculated at 168 bu/hr.

<u>28 July 1975</u>

A study was made of the effect of the oyster harvester on the bottom substrate. The mechanical harvester was operated on Green Rock and the track over which it operated was marked by buoys and stakes. This track was later examined by a diver using SCUBA.

Operational speeds of the boat and gear were as follows:

Drum speed:	0.5 rps
Water pressure jets:	50 lbs/sq inch
Belt speed:	1 ft/sec
Speed of boat (estimated):	1/7 knot
Shell depth on belt:	2-4 inches (avg. 3 inches)

Under these operating conditions the shells came up on the belt about 3 inches thick. They were clean and free of nearly all sand or mud; few appeared to be broken or fragmented by the action of the harvester. Calculations based on belt speed and depths of oysters on the belt similar to those made on 6 June, indicate that the gear was raised about 6.5 bu/min or 390 bushels of shell and oysters per hour.

A distance of 100 ft was observed along the track with SCUBA gear by Mr. J. P. Whitcomb of VIMS. The width of the track was measured with a yard stick to be between 32 and 36 inches. This is almost the same width as the tines (28 inches) on the rotating drum. The depth of the track varied but in heavily shelled bottom the depth was between 3.5 and 4 inches. Occasionally a depression of 1 to 2 inches deeper was observed. It is observed that the tips of the rotating tines are set to dig about 3 inches below the runners on which the head slides over the bottom and that this was the approximate depth of the trench.

The shell and oysters which fell from the belt back into the water did not appear to fall entirely back into the track. Some fell as far as 2 to 3 ft outside. Within the track the shells appeared to be oriented in a horizontal arrangement. Many of the pieces of shell remaining in the track were small white fragments one to two inches across and there were few black shells. These shell fragments were not shell broken by the harvester but were of the kind commonly found in normal shell substrate 2 to 3 inches below the surface.

Outside the track, in a heavily shelled area, the bottom was covered with a light layer of sediment. Here the angles of the exposed shell surfaces would be described as irregular, making a very rough appearance.

There was no evidence of the runners making a path or crushing oysters and shells. While testing the track area with a 3/8-inch diameter metal rod it was noted that the area inside and outside the track where the rod could be forced into the bottom for a distance of 1 to 2 inches. However, it was usually impossible to penetrate the bottom in any manner within or outside the track.

While transversing offshore toward the channel the depth of the track decreased to about 1 inch in depth about 50 ft from the stake. The bottom at this location appeared to be muddy sand. Closer examination revealed the heavy layer of shell was just below the surface covered with about 3/8-inch of sediment. There were no oysters on the surface in the vicinity of the track. It is assumed that the mechanical harvester lost contact with the upper 3 inches of bottom here due to a slight increase in depth.

In summary, the harvester removes the upper 3 or 4 inches of the substrate without softening or breaking up the bottom below. Shells and oysters are not dumped entirely back into the track but distributed at least 2 to 3 ft outside. The shell in the track was cleaner or whiter than the surrounding bottom. The track was 3.5 to 4 inches deep, although there were fragments of shell in the track it is thought these fragments were caused not by breaking up larger shell but were similar to those which already existed in the substrate.

30 July 1975

A demonstration of the harvester was given for Harold Davis, repletion officer, Maryland Department of Tidewater Affairs on Green Rock in the York River. Also on the vessel were two of his assistants. The harvester worked well as it did in previous tests in this area.