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Fishery independent standing stock surveys of oyster populations in Virginia 1996

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Roger Mann - file copy

Annual Report for the period October 1, 1993 - September 30, 1996
with general commentary and **Summary Report**
for the funding period October 1, 1993 - September 30, 1996

for the program entitled:

Fishery independent standing stock surveys of oyster populations in Virginia

submitted to:

The Chesapeake Bay Stock Assessment Committee:
attention: M. Elizabeth Gillelan, Division Chief
NOAA Chesapeake Bay Office
National Marine Fisheries Service
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by

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Introduction

The Virginia oyster resource and the need for stock assessment

Extensive description of the Virginia oyster resource and history of its utilization has been given by Haven, Hargis and Kendall (1981), and more recently reviewed by Hargis and Haven (1988). These contributions, among many others, describe a state of continuing decline. The James River, Virginia has served as the focal point for the Virginia oyster industry for over a century, being the source of the majority of seed oysters that were transplanted for grow-out to locations within the Virginia portion of the Chesapeake Bay and much further afield in the Middle Atlantic states (Haven et al, 1981). The Rappahannock River in Virginia was, for many years, a source of large and valued oysters for both the shucking and half shell trade. Other subestuaries and embayments in the Virginia portion of the Chesapeake Bay have served variously as both seed oyster (e.g. the Great Wicomico River) and market oyster (Mobjack Bay and Pocomoke Sound) sources for the once substantial historical fishery. It is surprising that comparatively little effort has been previously expended to estimate standing stocks of oysters in the Virginia subestuaries, especially the James and Rappahannock Rivers, given the acknowledged need for such data in fishery management and the comparative ease of data collection compared with mobile fish populations. Continuing losses of productive oyster reef over the past three decades to Haplosporidium nelsoni, commonly known as MSX, and Perkinsus marinus, commonly known as "Dermo", in the higher salinity regions of the Bay and the subestuaries, combined with increased fishing pressure on all remaining stocks, have emphasized the need for working estimates of standing stock. This need has been further exaggerated in the James River by a change in emphasis in the past decade from the harvesting of "seed" oysters to larger "market" oysters, and the reduction in size limit of the latter from three to two-and-one-half inches maximum dimension for the 1988 through 1994 public oyster fishing seasons. The fishery continues to exploit the limited remaining broodstock from the James River in order to retain a viable fishery for "market" oysters, while simultaneously threatening the long term future of the river as the only functional seed producing location in the Virginia portion of the Chesapeake Bay.

The oyster fishery of the Eastern Shore of Virginia differs significantly from that of the Bay, being based on predominantly intertidal stocks that fringe the extensive reef systems between the barrier islands and the peninsula shoreline. While attracting less attention than the Bay fishery the Eastern Shore oyster fishery has also suffered significant decline in the past three decades with disease, harvest and environmental degradation all contributing to the demise. As with the Bay stocks, prudent long term management is required to stabilize the resource and future production.

Intensive, fishery independent estimates are rare but pivotal to examination of spawning capabilities of broodstock supporting commercial fisheries and related requirements for establishment of fishery catch quotas. This is especially the case with oyster stocks. To facilitate resource management of the Bay and Eastern Shore oyster stocks a fishery independent survey was proposed to and subsequently supported by the Chesapeake Bay Stock Assessment Committee of NOAA in 1993. The first year of activity focused on the James and Rappahannock Rivers in the Bay and the annual report covering that material was submitted in November, 1994. That report contained commentary on both fishery independent and fishery dependent data as tools to assist oyster fishery management in Virginia. One disappointing conclusion of that report was that fishery dependent data collected prior to 1994 was of very limited value in stock assessment because of the habit of "two piling" - the simultaneous harvest of seed and market oysters - with the confounding effect that effort data were practically impossible to generate for each directed fishery product. Consequently subsequent efforts focused exclusively on fishery independent survey methods. The second year of activity began in the Fall of 1994 with further examination of the James and Rappahannock, but was expanded in the Spring of 1995 to include the resources of the Eastern Shore of Virginia. The report describing activity under the 1994-1995 funding year was submitted in October, 1995. In the third and final year of scheduled support (1995-1996) efforts were again expanded to further include a number of subestuaries in the Virginia portion of the Chesapeake Bay. This report presents this third year of new data, but does so in the context of a three year presentation of fishery independent data covering the entire 1993-1996 funding period.

Fishery Independent Sampling

The objective of the study was to effect a fishery independent study of the standing stock of oysters, both market and seed, in the Virginia portion of the Chesapeake Bay and the Seaside of the Eastern Shore.

1. Methods: Subestuaries of the Virginia portion of the Chesapeake Bay

General comments on selection of sample locations and sample numbers

Spatial variability in distribution of oysters within an oyster reef system, and distribution of reefs in the intertidal and/or subtidal regions complicate fishery independent estimation of standing stock. For all Bay locations we designed a quantitative sampling program using a stratified random grid with the documented oyster reefs or rocks forming the strata. The sample locations in each of the estuaries or regions sampled is illustrated in the following maps. A further list of all rivers sampled, the oyster reefs by name (as commonly used in historical documents and current fishery descriptions) and estimated reef area in acres is given in Table 1 in the Results and Discussion section. Table 2 in the Results and Discussion section gives additional information on dates of sampling for the 1995-1996 effort. Although use of metric values is generally preferred and adhered to in the present document the acreage value is given because of common use in management discussions.

In the James River the area surveyed is described in extensive surveys made by VIMS and reported by Haven and Whitcomb (1983), and briefly in the 1993-1994 and 1994-1995 reports of the current investigators. These areas have been subjected to regular survey by VMRC and VIMS personnel for at least two decades by dredge. The limits of the known oyster reef were mapped by the Surveying Engineering Department at VMRC and the grids for sampling set with Loran coordinates (Loran was checked daily when in the field from known markers at both the beginning and end of the day). The James River public oyster grounds (Baylor grounds) currently supporting oyster populations are illustrated in Figure 1.1 as an overlay of a map of bottom type (oyster rock, shell and mud, shell and sand, sand, and soft mud). The purpose of this figure is to illustrate that the reef systems as identified in the Baylor surveys are not uniform in substrate, and therefore not expected to be uniform in oyster distribution within a single reef. The reef areas sampled in 1994-1995 and 1995-1996 are illustrated in Figures 1.2, this being a modification of Figure 2 from the 1993-1994 survey to include new reef areas examined. The legend of Figure 1.2 identifies the sampled reefs by number. These numbers are often cross referenced with reef names in this report where convenience dictates, and are the suffix in the figure numbers for Figures 2.1 through 2.19, size distribution data for reefs 1 through 19 respectively as illustrated in the Results and Discussion section. Sampling areas 1 through 11 in Figure 2 represent the limits of hard oyster rock strata selected, mapped and sampled within the larger public oyster grounds in those regions. The limits of hard oyster rock strata within sampling areas 12 through 23 were not mapped separately because of the large areas involved; consequently, we knew beforehand that sampling grids selected in areas 12 - 23 would include both oyster rock strata as well as bare sandy or muddy strata. Sampling sites were picked by random numbers within the grids and oysters were sampled with a hydraulically operated patent tong. In this manner a total of 825 stations on 19 reefs were occupied in the James River in 1993-1994, 786 stations on 23 reefs in 1994-1995, and 815 stations on 23 reefs in 1995-1996.

The sampling protocol for the Rappahannock River was as for the James River and employed a quantitative sampling program using quadrats located in a random grid placed over a map of the known oyster resources. Although once extensive, these are now mostly limited to the upper part of the Rappahannock above Bowlers Rock and Morattico Bar. The only commercially exploited reef of any consequence is Russ' Rock. In 1994-1995 and

1995-1996 surveys were extended to include reefs below the Rappahannock bridge at White Stone in an area bounded by Mosquito Point and Windmill Point to the north, and Grey Point and Stingray Point to the south. This section of the river lies approximately 15 nautical miles downstream of the region first surveyed in 1993-1994 and resurveyed in 1994-1995. The regions sampled in the Rappahannock are illustrated in Figure 1.3. The reefs were again the basis for stratified random sampling. The area surveyed is described in Haven and Whitcomb (1989). The limits of the known oyster reef were mapped by the Surveying Engineering Department at VMRC and the grids for sampling set with Loran coordinates. Loran was, again, checked daily when in the field from known markers at both the beginning and end of the day. Sampling sites were picked by random numbers within the grids. 47 stations were occupied on 5 reefs in the Rappahannock in 1993-1994, 193 stations on 7 reefs were occupied in 1994-1995, and 113 stations on 12 reefs in 1995-1996.

The 1995-1996 sampling also included the Piankatank River (62 stations on 8 reefs, Figure 1.4), Great Wicomico River (45 stations on 6 reefs, Figure 1.5), the Coan River (a small tributary of the Potomac River, 29 stations on 4 reefs, Figure 1.6), the Yeocomico Rivers (a larger tributary of the Potomac River, 21 stations on 3 reefs, Figure 1.7), Tangier Sound (60 stations on 8 reefs, Figure 1.8) and Pocomoke Sound (41 stations on 5 reefs, Figure 1.9). Stratified sampling for all locations was based on surveys by Haven et al (1981) as later archived at both VIMS and VMRC in digital format using ARCINFO software, and random grid applications as for James and Rappahannock surveys as described earlier.

Sampling gear

Both tongs and dredges are commonly used to examine oyster populations; however, only the former are good quantitative tools (see Chai et al, 1992). In 1993-1994 we examined a standard patent tong of known area; however, tests proved this to be an unpredictable sampling tool in that penetration into the hard bottom on the reef surface was inconsistent resulting in high variability in replicate samples on the same site. We replaced the tong with an hydraulically operated tong which separates the closing actions of the tong from the retrieval action. This has proven to be vastly superior in providing consistent penetration of the bottom and replication sampling and was retained as the only sampling tool for all stations in the Bay and its tributaries in all years of the study. Tong design insured that the tong opening was consistent during operation and that an area of one square meter was sampled. None the less two sources of concern accompany the use of patent tongs for quantitative surveying. These are :(1) does the tong consistently penetrate the bottom to sufficient depth to sample the entire oyster population at the surface, and (2) is any portion of the sampled material lost by "spilling over" the top of the tong during the retrieval process in passage to the surface? Both can be addressed in the current application. All of the reefs surveyed in the current surveys using tongs are relatively thin, that is they are a superficial crust of live oysters and shell overlaying an anoxic layer of underlying substrate (comments relating to limited oyster shell resources in the following section address this subject in greater detail). In sampling the tong contents consistently included a layer of underlying anoxic material indicating penetration of the living oyster layer. The tong was equipped with a basket like upper cover which retained surface material during retrieval. The common observation of worm tubes in the surface of tong samples prior to washing for retrieval of oysters indicated the absence of consistent loss of material during retrieval. The hydraulic tong was installed on the VMRC vessel R/V Wolftrap for 1993-1994 surveys, and transferred to its successor, the R/V Baylor for 1994-1995 and 1995-1996 surveys.

Data collection

The open dimensions of the tong were such that it sampled one square meter. Upon retrieval the sample was washed on the cull board and processed for counts of live oysters as spat (young of the year), small oysters (less than 3 inches = 76 mm), and market (greater than 3 inches) oysters. The 3 inch size limit was applied in both 1994-1995 and 1995-1996 surveys in agreement with the size limit enforced by VMRC regulation. Prior to that period a 2.5 inch (= 62.5 mm) size limit was employed for the Fall 1987 - Spring 1994 period, thus a 2.5 inch limit was employed in 1993-1994 surveys. In addition, the opportunity was taken to collect data on dead oysters with paired valves (boxes, indicating recent mortality). The volume of shell retrieved in each tong was also recorded as an index of the quantity of cultch material present at each station. Between six and nine people were on board on each day of sampling, and all were trained to avoid inconsistency in categorization of oysters. This process was labor intensive, with between 30 and 60 samples being processed each day depending on weather conditions, crew size and the time required to wash and separate samples.

Adequacy of sampling in design of surveys

In the initial stages of analysis of the 1993-1994 data sets questions relating to sampling design and adequacy were addressed, mostly because of a lack of previous quantitative assessment data for this resource. Although thorough discussions of these questions were a component of the 1993-1994 annual report a brief recapitulation is appropriate here for completeness. The two primary questions addressed were:

1. Are there strata reasonable? The background behind this question is that recent surveys by Haven and Whitcomb (1983, 1989) illustrate varying bottom type within the chosen strata - from mud to hard shell bottom. This could present a significant sampling problem in that strata are sufficiently heterogeneous to be of limited ecological and statistical value.

2. Assuming 1 (above) is not a problem, are there sufficient samples to adequately represent the strata and allow estimates of abundance per unit area and, subsequently, total standing stock.

Bros and Cowell (1987) offer a good discussion of methods of estimating sample size in situations where minimum detectable difference cannot be specified a priori, as is the case in this situation. Their proposed method incorporates use of resolving power as a primary factor and sampling feasibility (an issue here with time and cost) as a secondary factor. They suggest the standard error of the mean be used as a measure of appropriate sampling effort. We have adopted their suggestion. Questions 1 and 2 above were primarily addressed by a single analysis in which data were examined collectively within each strata. A plot was generated of mean number of oysters per patent tong (one square meter) sample and standard error of the mean versus number of samples included in the calculation. This calculation was repeated ten times for data within a strata with samples being chosen at random from those available. Random sampling eliminated any bias that resulted from sequential data entry in accordance with sampling in the field sampling (the latter may have resulted, inadvertently in temporally focused sampling on a particular substrate type). In a regime where variability with bottom type was high and the sample size was low then the mean would not stabilize, and where sampling was insufficient the standard error of the mean would not demonstrate a **stable** trend of decreasing value - remembering of course that the standard error value will eventually continue to decrease with increasing number of samples included in the calculation because the standard error is inversely proportional to the square root of the number of observations of the mean. Increasing sample size will eventually solve both these problems, but the number of samples required might be very large. The same criteria were applied in sampling in 1994-1995 and 1995-1996 as in 1993-1994. In no instance did we encounter suggestions of inadequate sampling on major reefs. Adequacy of sampling can be more problematic on very small reefs (see Table 1) simply because there is less "room to move"

Figure 1.1. Outline of areas sampled in James River oyster stock assessment surveys in Fall 1993 (1993-1994 funding), Fall 1994 (1994-1995 funding), and Fall 1995 (1995-1996 funding) superimposed over a chart of bottom type modified from Haven et al (1981). Areas in white represent predominantly mud.

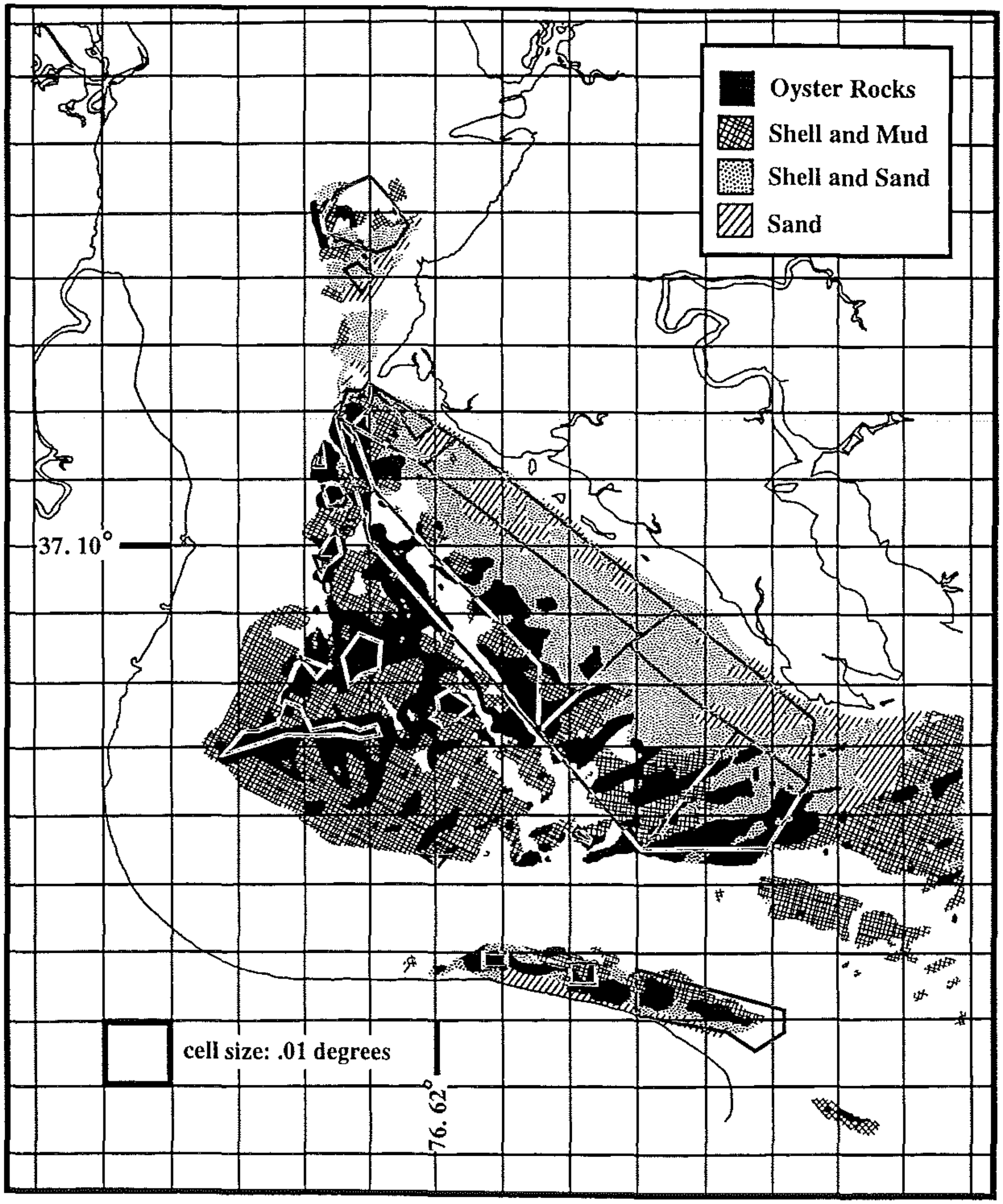


Figure 1.2. Outline of areas sampled in James River oyster stock assessment surveys in Fall 1993 (1993-1994 funding), Fall 1994 (1994-1995 funding), and Fall 1995 (1995-1996 funding). Areas are identified by number in the side bar. The same numbers are used for reference in the text and in the series of figures illustrating size class distribution in section 2.

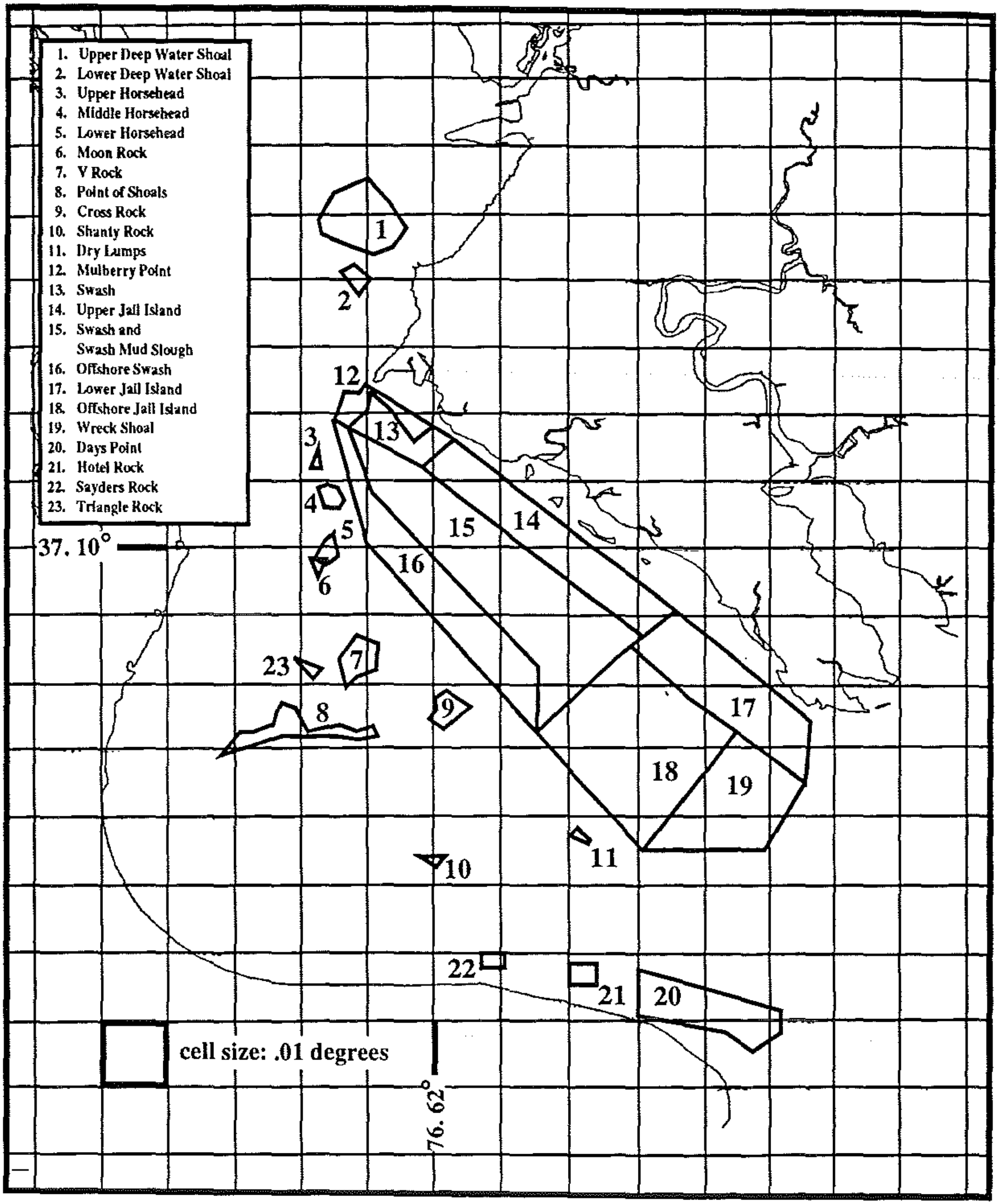
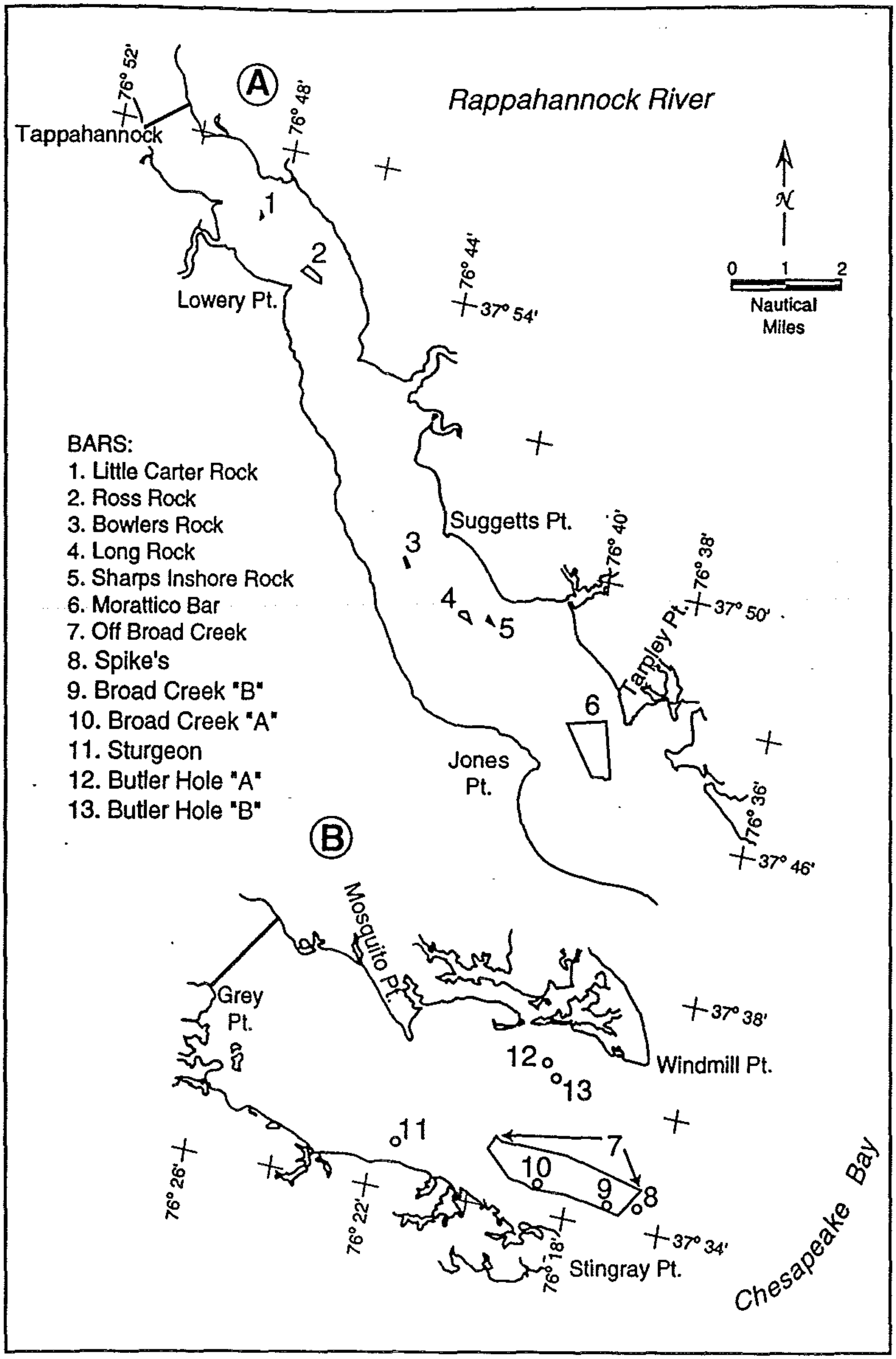
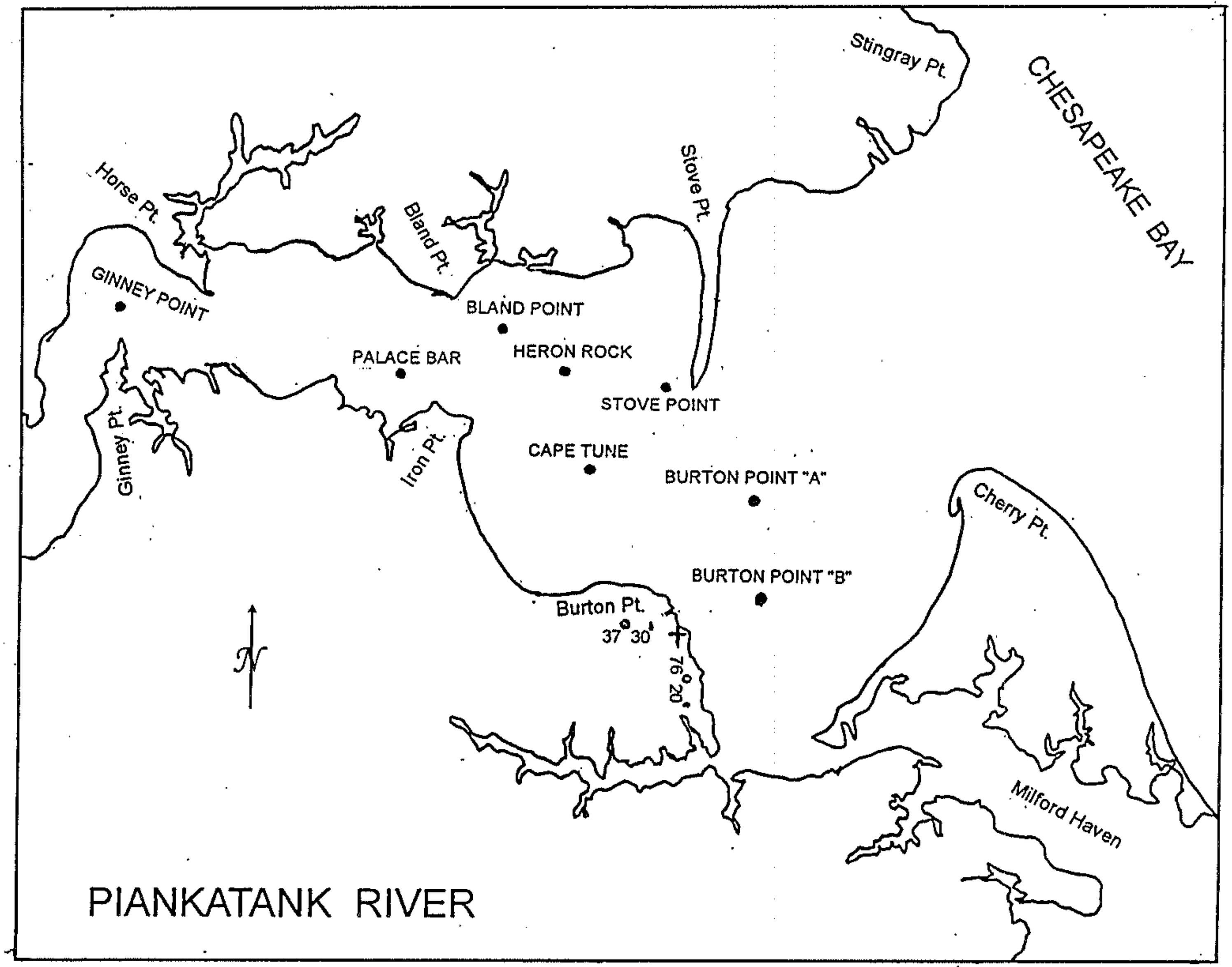


Figure 1.3. Outline of areas sampled in Rappahannock River oyster stock assessment surveys in Fall 1993 (1993-1994 funding), Fall 1994 (1994-1995 funding), and Fall 1995 (1995-1996 funding).



A
Rappahannock River
Tappahannock
76° 52'
76° 48'
76° 44'
37° 54'
Lowery Pt.
Nautical Miles
0
1
2
N
BARS:
1. Little Carter Rock
2. Ross Rock
3. Bowlers Rock
4. Long Rock
5. Sharps Inshore Rock
6. Morattico Bar
7. Off Broad Creek
8. Spike's
9. Broad Creek "B"
10. Broad Creek "A"
11. Sturgeon
12. Butler Hole "A"
13. Butler Hole "B"
Suggetts Pt.
76° 40'
76° 38'
37° 50'
Tarpley Pt.
Jones Pt.
76° 36'
37° 46'
B
Mosquito Pt.
Grey Pt.
37° 38'
Windmill Pt.
76° 26'
76° 22'
76° 18'
37° 34'
Stingray Pt.
Chesapeake Bay

Figure 1.4. Outline of areas sampled in Piankatank River oyster stock assessment surveys in Fall 1995 (1995-1996 funding).



Stingray Pt.
CHESAPEAKE BAY
Stove Pt.
Horse Pt.
Bland Pt.
GINNEY POINT
BLAND POINT
PALACE BAR
HERON ROCK
STOVE POINT
Ginney Pt.
Iron Pt.
CAPE TUNE
BURTON POINT "A"
Cherry Pt.
BURTON POINT "B"
Burton Pt.
37°30'
76°20'
N
Milford Haven
PIANKATANK RIVER

Figure 1.5. Outline of areas sampled in Great Wicomico River oyster stock assessment surveys in Fall 1995 (1995-1996 funding).

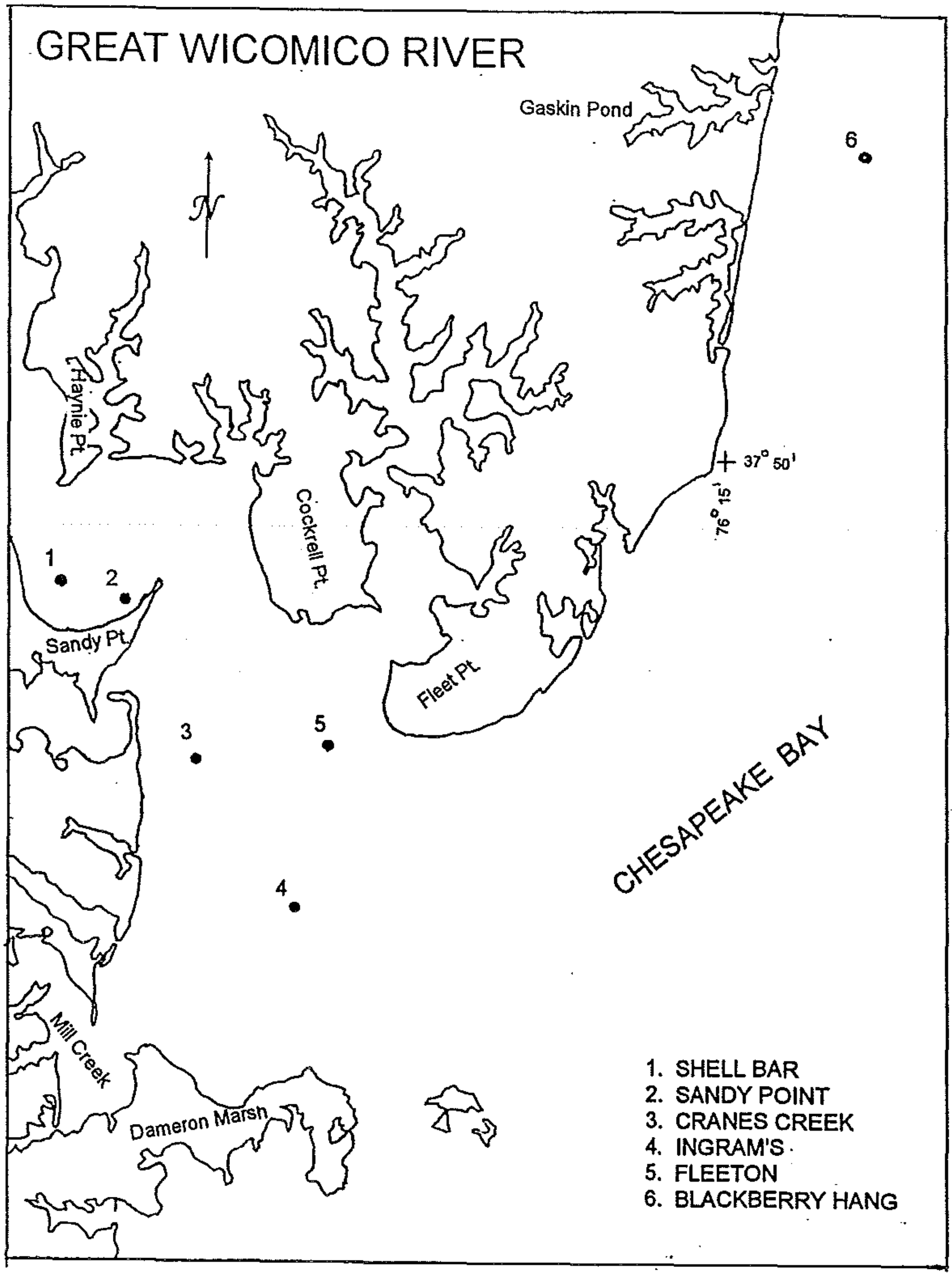

GREAT WICOMICO RIVER
Gaskin Pond
6
Haynie Pt.
37° 50'
76° 15'
Cockrell Pt.
1
2
Sandy Pt.
Fleet Pt.
3
5
CHESAPEAKE BAY
4
Mill Creek
Dameron Marsh
1. SHELL BAR
2. SANDY POINT
3. CRANES CREEK
4. INGRAM'S
5. FLEETON
6. BLACKBERRY HANG

Figure 1.6. Outline of areas sampled in Coan River oyster stock assessment surveys in Fall 1995 (1995-1996 funding).

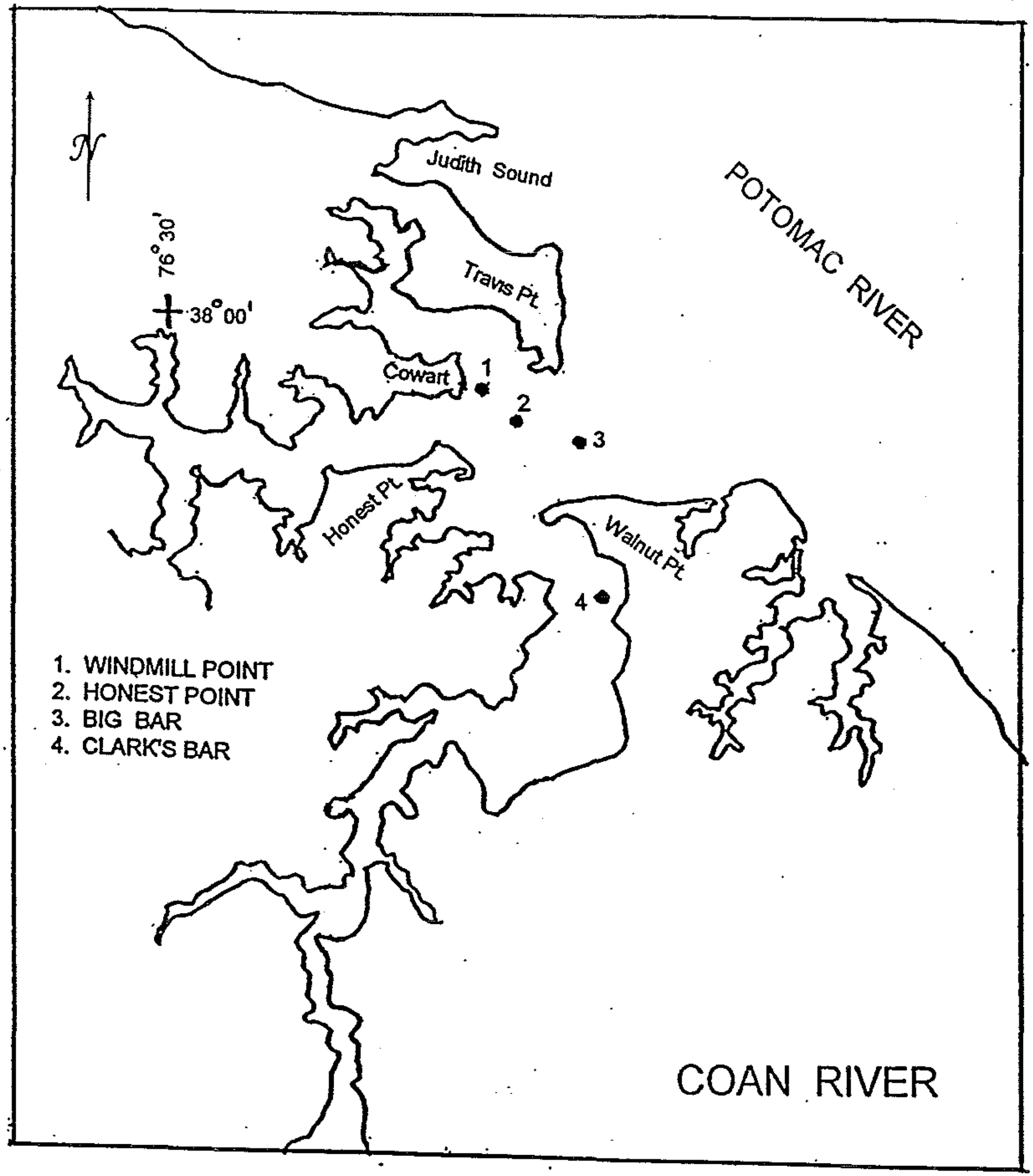

N
76° 30'
38° 00'
Judith Sound
Travis Pt.
POTOMAC RIVER
Cowart
1
2
3
Honest Pt.
Walnut Pt.
4
1. WINDMILL POINT
2. HONEST POINT
3. BIG BAR
4. CLARK'S BAR
COAN RIVER

Figure 1.7. Outline of areas sampled in Yeocomico River oyster stock assessment surveys in Fall 1995 (1995-1996 funding).

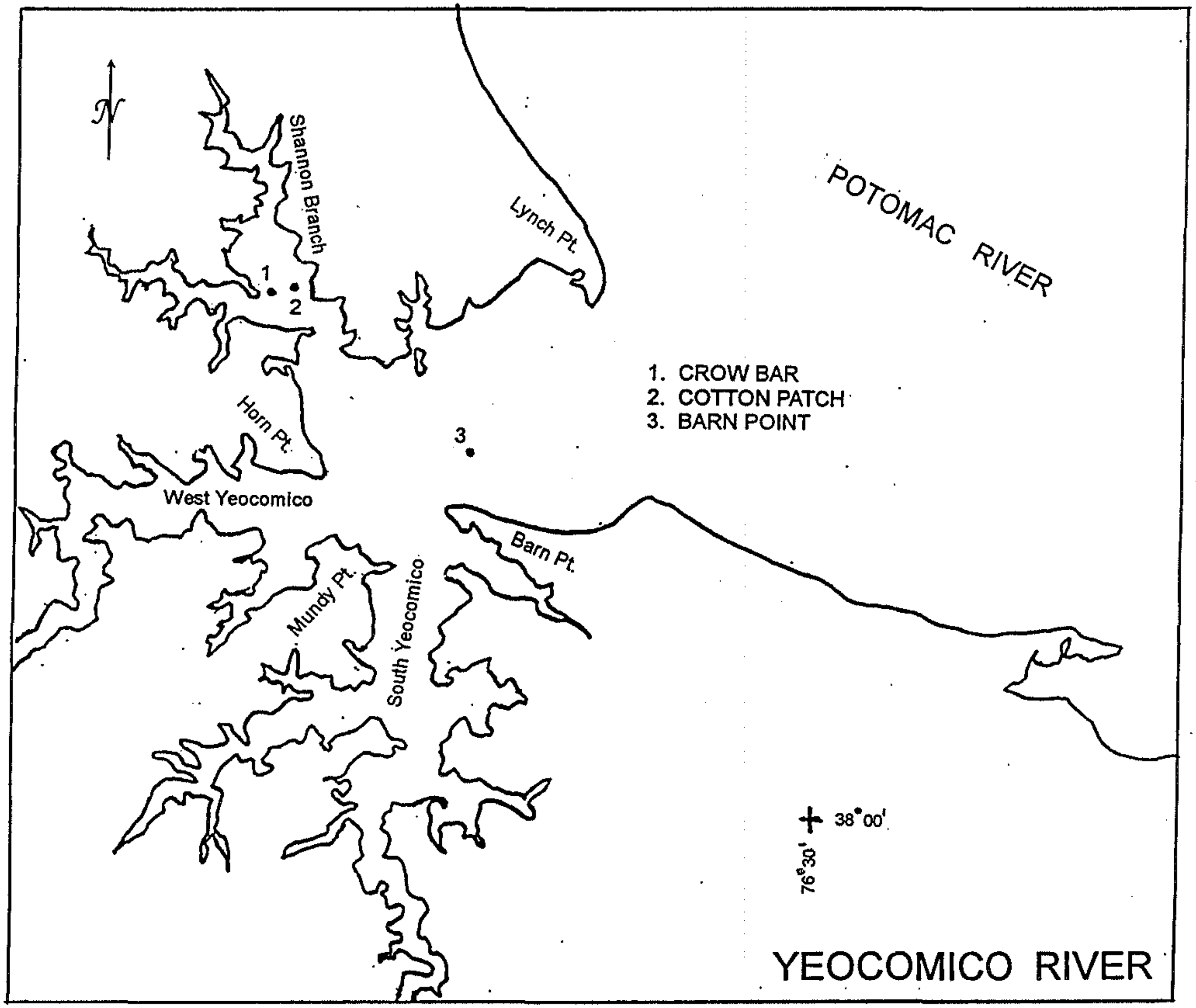
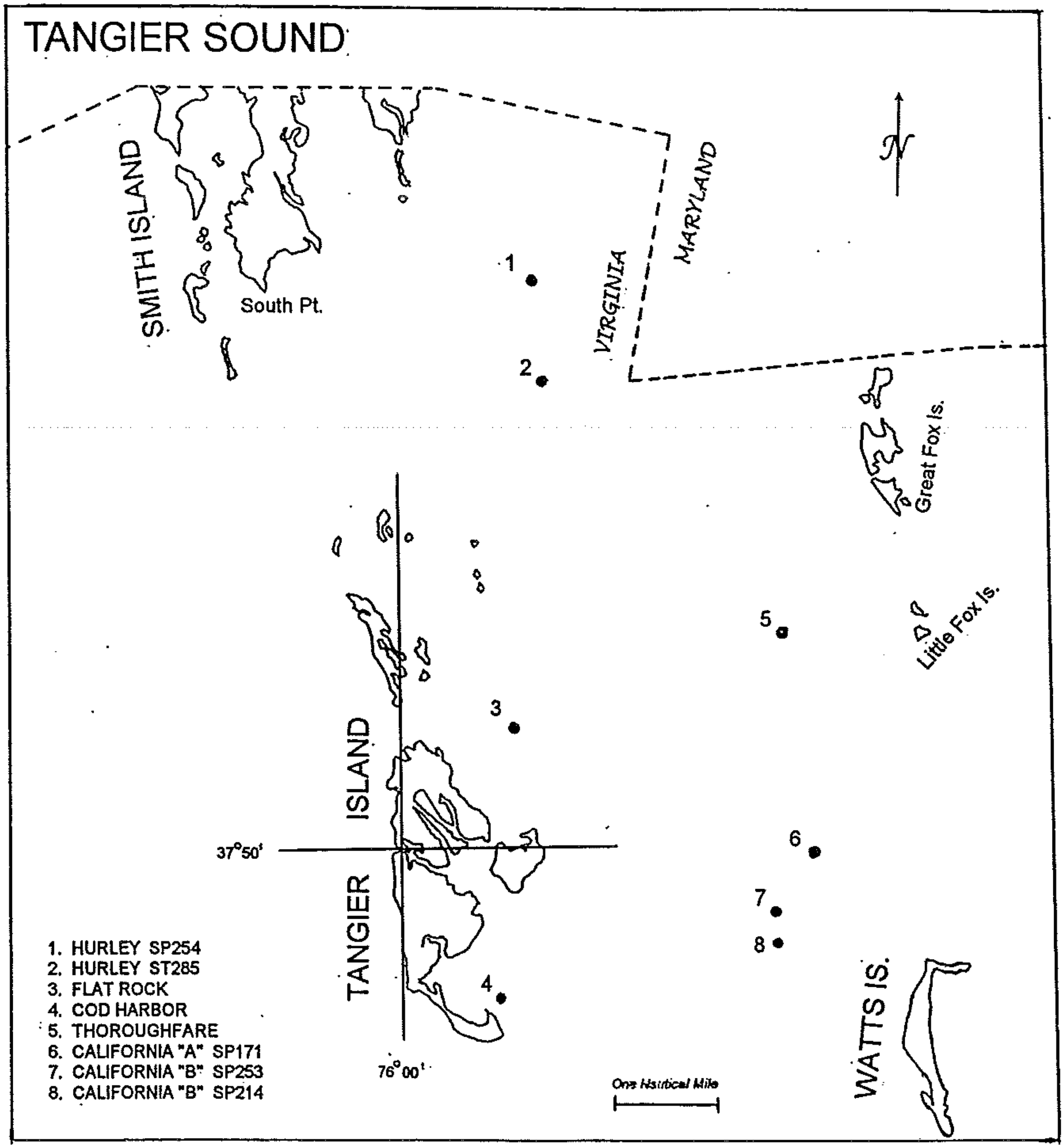

N
Shannon Branch
Lynch Pt.
POTOMAC RIVER
1
2
1. CROW BAR
2. COTTON PATCH
3. BARN POINT
Horn Pt.
3
West Yeocomico
Barn Pt.
Mundy Pt.
South Yeocomico
38°00'
76°30'
YEOCOMICO RIVER

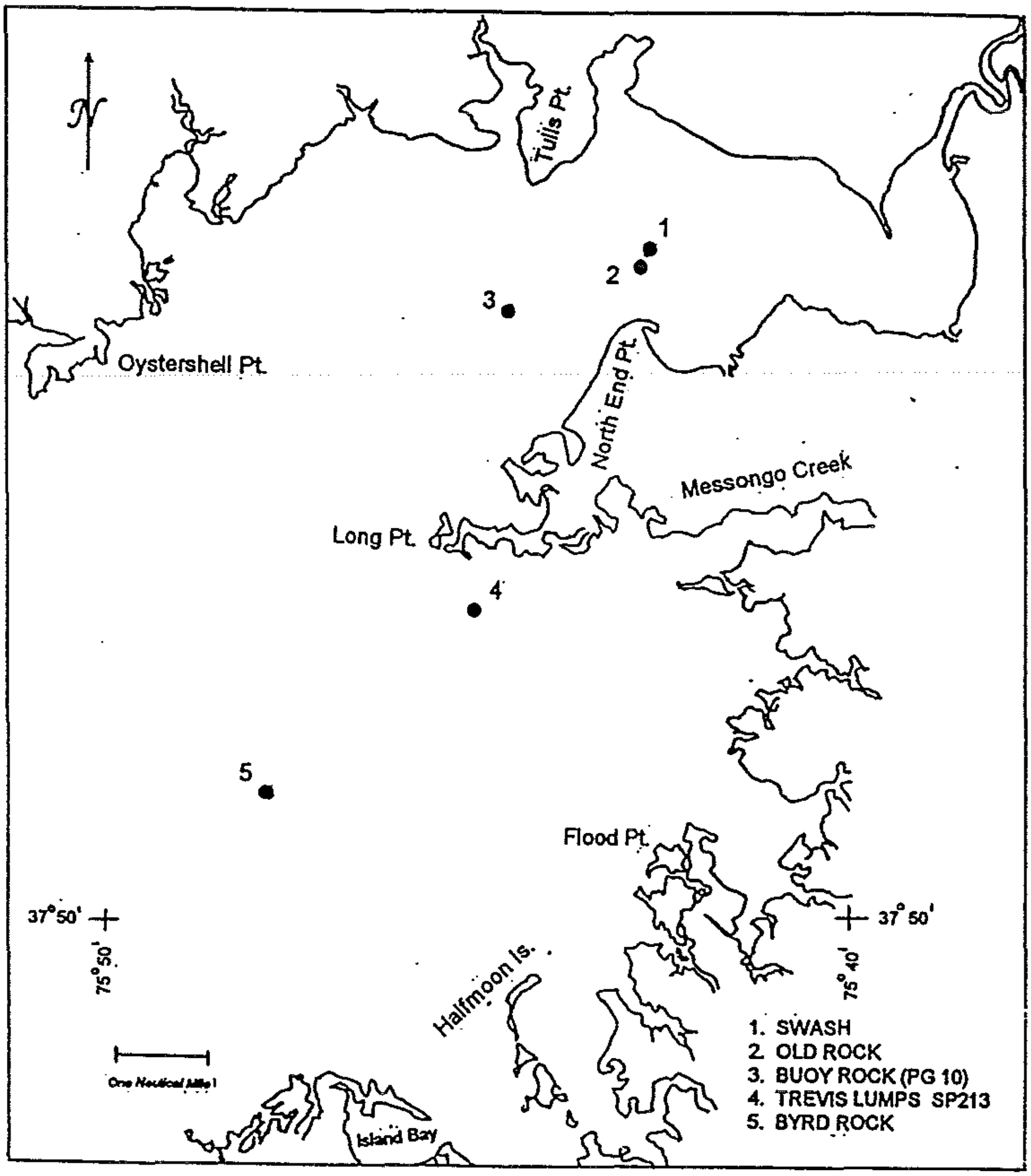
Figure 1.8. Outline of areas sampled in Tangier Sound oyster stock assessment surveys in Fall 1995 (1995-1996 funding).



TANGIER SOUND
SMITH ISLAND
South Pt.
VIRGINIA
MARYLAND
N
Great Fox Is.
Little Fox Is.
TANGIER ISLAND
WATTS IS.
37°50'
76°00'
One Nautical Mile
1
2
3
4
5
6
7
8
1. HURLEY SP254
2. HURLEY ST285
3. FLAT ROCK
4. COD HARBOR
5. THOROUGHFARE
6. CALIFORNIA "A" SP171
7. CALIFORNIA "B" SP253
8. CALIFORNIA "B" SP214

Figure 1.9. Outline of areas sampled in Pocomoke Sound oyster stock assessment surveys in Fall 1995 (1995-1996 funding).

POCOMOKE SOUND



over the reef and lower numbers of samples were collected, but we are confident that collected data are good representations of the populations at hand.

Data reduction and archiving

A custom database program for field data was developed by the Fisheries Data Management Unit (FDMU) in the Department of Fisheries Science at the School of Marine Science and Virginia Institute of Marine Science. A database program in Microsoft Access was also developed by FDMU for raw count data for all information classes for all stations. Size distribution data was archived and analysis effected using Microsoft Excel before eventual transfer to the FDMU archive. Archived material is available in either hard copy or digital form on request.

2. Results and Discussion

General summary of population sizes and size distribution data

Stock assessment estimates are given in Tables 1 and 2, with Table 1 providing information on live oysters by size class and Table 2 providing information on boxes and residual shell. Given that the James River remains the only commercial public fishery of any note within the Virginia portion of the bay, Table 3 provides a comparison of small and market oyster standing stock in the James River by reef for the Fall 1993 (funding year 1993-1994), Fall 1994 (funding year 1994-1995), and Fall 1995 (funding year 1995-1996) surveys.

As in previous years there remains a high variability in mean oyster density among the sampled reefs in the James River (Tables 1 and 3); however, the most notable change in stock data since the previous examination is the remarkable decrease in market oyster standing stock by approximately 50% (see Table 3). Very little of this is directly attributable to commercial harvest which accounted for less than 4000 bushels in the 1995-1996 season. Two other major factors combined to cause the observed decrease in large oysters. The first was an exceptional year for disease related mortality in the summer of 1995 with elevated salinities accompanying low runoff - an ideal situation for progression of both P. marinus and MSX in an upriver direction. The second factor was a freshet in the month of June adding the insult of a short duration, low salinity event when water temperature was at its annual maximum with resulting mortality. Simply stated, reefs in the higher salinity areas suffered disease losses, while reefs in low salinity areas suffered freshet losses. These losses are particularly evident at Deep Water Shoal (#'s 1 and 2), Horsehead, V-Rock, and Point of Shoals upriver, and Offshore Jail Island and Wreck Shoal downriver in multi year comparisons of Table 3 and the "old box" count (paired oyster valves exhibiting some fouling, thus not a recent mortality) given in Table 2.. Included in this list are reefs that support the major fishery for market oysters. Despite these losses Horsehead, Moon Rock, V Rock, Point of Shoals and Cross Rock maintain reasonable populations in bu./acre measure, in part because of the sustained or even increased contribution from small oysters. Apparently these suffered smaller relative losses in freshet conditions, possibly because of lower compounded stress from disease. P. marinus typically has incremental effect with increasing age (= size) and thus older (= larger) oysters in upstream locations typically harbor sublethal infections that will contribute to mortality with compounding stressors like low salinity. Ironically, the freshet was not without benefit. Spat settlement on the clean shells of recently departed market size oysters provided good substrate for settling larvae in the August - September period, resulting in spat abundance of 68 - 194 / sq. m at Horsehead, Moon Rock, V Rock Point of Shoals and Upper Deep Water Shoals. It will be three to five years, generally nearer five years, before these animals will contribute to the public fishery if the current three inch (76 mm) minimum size limit is maintained (estimate based on continuing growth studies in situ at Horsehead). Also, the survival of these spat in a year otherwise noted for modest settlement on shellstrings used in weekly monitoring by VIMS staff supports conclusions offered in prior annual reports that substrate in the James is limiting. A statement made in the 1994-1995 annual report is worth reiterating and updating. Ten liters of shell uniformly spread over the surface of one sq. m represents a layer one centimeter thick - or about a single layer of shells. Only two of the sampled reefs in the James, Shanty Rock and Dry Lumps (both very small reefs), had a mean shell volume in sampling in excess of 10L per sq. m. Note that none of the sampled reefs was uniform with respect to bottom type and therefore shell coverage, and that reefs numbered 1 through 11 in the James represented a uniformly better bottom type for oyster growth. Despite this qualification, consideration of a mean value of 5.36 L shell per sq. m of bottom on Point of Shoals suggest that even if only 20% of the reef area were oyster shell covered then this shell layer would still only be about one inch (2.5 centimeters) thick! Further, the current data include partially buried shell as available, thus slightly inflating the "real" values! Again, the necessity to maintain shell replenishment on the productive reefs, not around them, cannot be understated.

Figures 2.1 through 2.19 illustrate size frequency distribution data for reefs 1 - 19 as mentioned earlier. They serve mainly to reinforce the conclusions of the previous paragraph. The graphics illustrate the drastic loss of all size classes at Deep Water Shoal (2.1 and 2.2), reduction of larger oysters at Horsehead and V Rock but a promising trend in small oysters (2.3 through 2.5, 2.7), only marginal changes at Moon Rock (2.6), increasing numbers of small oysters at Point of Shoals and Cross Rock (2.8 and 2.9), but less notable increases at Shanty Rock and Dry Lumps (2.10 and 2.11). Within this list of reefs it is important to note that where shell applications were made **to the reefs** (as opposed to the previous practice of shell planting in areas distinct from the reefs) to facilitate settlement the 1995 year class is well represented (Mid and Low Horsehead, V Rock, Point of Shoals and Cross Rock); however, the notable exception is Moon Rock where no shell enhancement was made and the 1995 year class is comparatively poor. These observations provide strong support for the practice of light applications of shell **to productive reefs** , rather than peripheral areas, on a continuing basis to maintain a clean substrate that is conducive to spat settlement. The Mulberry Point and Swash areas, Jail Island and Wreck Shoal (2.12 through 2.19) show moderate, generally downward changes in abundance over the three year interval illustrated. Some minor consideration is required in comparison of 1993-1994 data with later data sets because of the change in size limits of markets oysters as described earlier. Again, the 1993-1994 survey used a 2.5 inch separation for small versus market oysters, whereas the 1994-1994 survey used a three inch separation. This would result in moving animals formerly in the market class (from 2.5 to 3 inches) to the small oyster class, and possibly contributes to the discrepancy in the values for the size classes in respective years. Despite all of this the alarming reduction in available market oysters to the fishery and to serve as broodstock (noting the disproportionate value of large oysters to egg production) is cause for concern, especially given the fact that the major losses are from natural events that are beyond direct management control. Recent implementation of market only reefs, such as Point of Shoals, where all small oysters are returned for potential future harvest as market oysters are efforts to be applauded. None the less constant vigilance and respect for stock assessment data in annual management decisions must be sought.

Oyster populations remain low in density throughout the Rappahannock River, indeed the data of Tables 1 and 2, and the commercial harvest of less than 200 bushels for the 1995-1996 season, suggest decreasing stocks. In the 1994-1995 surveys (Fall 1994) Ross' Rock, Bowlers Rock, Long Rock and Sharps Inshore locations exhibited 12, 10, 8 and 32 bu. / acre of small oysters and 3, 15, 22 and 66 bu. / acre of market oysters respectively. In the Fall 1995 survey these had changed to 15, 5, 48 and 8 bu. / acre of small oysters and

9, 9, 10 and 14 bu. / acre of market oysters respectively. These oyster densities are consistently well below the values of actively exploited reefs in the James River (see Table 1) and give little hope to a recovering fishery resource, a conclusion emphasized by the general lack of good spat settlement at all Rappahannock River reefs (Table 1).

The extended survey area of the 1995-1996 effort covered areas that recently supported fisheries of varying characters, or are maintained as seed production areas. The Great Wicomico was once a significant seed producing river, and has been the subject of some repletion activity in recent years. Very modest spat and small oyster densities were observed, but market oysters were essentially absent. The Piankatank River has been maintained by VMRC as a seed oyster producing region for a number of years and is closed to market oyster harvest (hence the marginally higher shell residual values associated with shell planting). Very modest spat and small oyster densities were recorded. Pocomoke Sound remains devoid of recent settlement with very low densities of small and market oysters. The Coan, and to a lesser extent the Yeocomico Rivers have been examined as potential low salinity sanctuaries from disease, but their modest (at best) oyster densities and small areas offer little hope of extended production on public oyster bottom. Like other areas in the Bay, Tangier Sound also has few oysters in all size classes; however, the voting majority of the Marine Resources Commission who recently voted to open this region to harvest by dredging. There is little question that the few remaining oysters in the region, having survived continuing challenge by disease, represent valuable broodstock. The Commission, after much debate, made the laudable decision to buy back these oysters from the commercial watermen and relocate them to a high density sanctuary on a shell reef in the Great Wicomico River. This sanctuary region had a history of good spat settlement prior to recent disease events, and we await with interest the outcome of planting of a high density population of large and reproductively capable animals in this location.

Table 1: Living Oyster Resources, 1995-1996 Surveys

	StationName	n	Spat mean / sq. m	Small mean / sq. m	Market mean / sq. m	Small + Market / sq. m	Reef area acres	Small whole reef bu.	Small bu. / acre	Market whole reef bu.	Market bu. / acre	Small + Market whole reef (bu)	Small + Market bu. / acre
James River	Upper Deep Water Shoal	72	194.10	7.17	1.60	8.76	233.92	6784	29	3024	13	9808	42
	Lower Deep Water Shoal	8	17.63	0.75	0.25	1.00	19.93	60	3	40	2	101	5
	Upper Horsehead	7	68.43	253.00	15.00	268.00	3.01	3082	1024	365	121	3447	1145
	Middle Horsehead	10	116.70	346.60	12.10	358.70	19.47	27310	1403	1907	98	29216	1501
	Lower Horsehead	12	110.17	273.33	9.33	282.67	19.47	21537	1106	1471	76	23008	1182
	Moon Rock	8	118.00	263.38	13.25	276.63	3.95	4210	1066	424	107	4634	1173
	V-Rock	21	73.29	198.09	8.68	206.77	72.05	57759	802	5063	70	62822	872
	Point of Shoals	33	78.36	200.15	14.03	214.18	131.71	106684	810	14957	114	121641	924
	Cross Rock	21	13.10	182.81	3.71	186.52	36.69	27144	740	1103	30	28247	770
	Shanty Rock	7	8.86	78.71	2.86	81.57	3.58	1140	319	83	23	1223	342
	Dry Lumps	7	4.71	22.14	0.43	22.57	5.93	531	90	21	3	552	93
	Mulberry Point	31	12.77	22.16	2.90	25.06	48.43	4343	90	1138	23	5481	113
	Swash	22	5.68	10.86	1.64	12.50	201	8837	44	2662	13	11499	57
	Upper Jail Island	65	0.66	8.60	1.57	10.17	611.8	21293	35	7770	13	29063	48
	Swash Mud Slough	125	2.14	20.51	2.49	23.00	1244.9	103339	83	25069	20	128408	103
	Offshore Swash	101	3.21	38.33	1.98	40.31	626.51	97174	155	10041	16	107216	171
	Lower Jail Island	62	0.47	9.71	3.32	13.03	628.93	24713	39	16913	27	41627	66
	Offshore Jail Island	102	1.27	6.77	0.67	7.44	1017.2	27887	27	5489	5	33376	33
	Wreck Shoal	50	0.82	6.64	0.34	6.98	584.76	15713	27	1609	3	17323	30
	Days Point	30	1.67	6.60	0.10	6.70	300	8013	27	243	1	8256	28
	Hotel Rock	7	2.14	12.14	0.14	12.29	13.53	665	49	16	1	681	50
	Snyders	7	0.86	16.00	1.29	17.29	10.54	682	65	110	10	792	75
	Triangle Rock	7	50.86	112.57	18.86	131.43	7.33	3339	456	1119	153	4458	608
	total	815										0	0
Rappahannock River	Bowler's Rock	19	0.00	1.16	1.05	2.21	5.87	28	5	50	9	78	13
	Broad Creek A	7	13.29	2.00	0.57	2.57	10.22	83	8	47	5	130	13
	Morattico	20	0.25	1.40	0.80	2.20	142	805	6	919	6	1724	12
	Ross Rock	10	0.80	3.60	1.10	4.70	31.88	464	15	284	9	748	23
	Spike's	7	11.14	1.43	0.14	1.57	11.84	68	6	14	1	82	7
	Sturgeon	7	6.00	1.29	0.14	1.43	13.7	71	5	16	1	87	6
	Long Rock	10	0.30	11.90	1.20	13.10	15.39	741	48	149	10	891	58
	Sharp's Inshore	7	0.29	2.00	1.71	3.71	2.46	20	8	34	14	54	22
	Carter's Rock	5	0.20	0.20	0.00	0.20	5.68	5	1	0	0	5	1
	Butler's Hole A	7	3.00	1.14	0.14	1.29	7	32	5	8	1	40	6
	Broad Creek B	7	13.71	1.29	0.71	2.00	12.73	66	5	74	6	140	11
	Butler's Hole B	7	2.14	0.14	0.00	0.14	10	6	1	0	0	6	1
	total	113											

	StationName	n	Spat mean / sq. m	Small mean / sq. m	Market mean / sq. m	Small + Market / sq. m	Reef area acres	Small whole reef bu.	Small bu. / acre	Market whole reef bu.	Market bu. / acre	Small + Market whole reef (bu)	Small + Market bu. / acre
Great Wicomico R.	Cranes Creek	10	6.50	12.20	0.80	13.00	67	3308	49	434	6	3742	56
	Fleeton	7	13.43	4.43	0.29	4.71	25	448	18	58	2	506	20
	Sandy Point	7	10.29	22.14	1.57	23.71	11	986	90	140	13	1126	102
	Shell Bar	7	11.14	4.14	0.14	4.29	11	184	17	13	1	197	18
	Ingram's	7	8.29	7.00	0.43	7.43	40	1133	28	139	3	1272	32
	Blackberry Hang	7	6.71	0.43	0.29	0.71	21	36	2	49	2	85	4
	total	45											
Piankatank River	Bland Point	7	31.43	5.29	0.14	5.43	25	535	21	29	1	564	23
	Burton Point A	9	11.11	5.00	0.33	5.33	37	749	20	100	3	849	23
	Cape Tune	9	11.44	7.56	0.00	7.56	42	1284	31	0	0	1284	31
	Ginney Point	7	15.71	1.71	0.00	1.71	6	42	7	0	0	42	7
	Palace Bar	9	17.67	5.22	0.11	5.33	41	866	21	37	1	903	22
	Stove Point	7	25.43	2.43	0.14	2.57	5.23	51	10	6	1	57	11
	Heron Rock	7	16.00	3.86	0.00	3.86	12.45	194	16	0	0	194	16
	Burton Point B	7	15.00	3.29	0.43	3.71	7.57	101	13	26	3	127	17
	total	62											
Pocomoke Sound	PG10 (Buoy Rock)	14	0.07	1.00	0.29	1.29	70	283	4	162	2	445	6
	Byrd Rock	7	1.71	5.43	1.86	7.29	20	439	22	301	15	740	37
	Old Rock	7	0.00	1.43	0.00	1.43	25	145	6	0	0	145	6
	Swash	7	0.00	3.14	0.57	3.71	50	636	13	231	5	867	17
	SP213 (Trevis Lumps)	6	0.50	1.33	1.00	2.33	7.81	42	5	63	8	105	13
	total	41											
Potomac River	CoanR./Windmill Pt.	8	1.38	0.38	0.38	0.75	6	9	2	18	3	27	5
	CoanR./Big Bar	7	3.14	4.00	3.43	7.43	6.58	107	16	183	28	289	44
	CoanR./Honest Pt.	7	2.29	1.43	2.00	3.43	10	58	6	162	16	220	22
	CoanR./Clark's Bar	7	4.71	10.57	6.29	16.86	2.91	124	43	148	51	273	94
	total	29											
Tangier Sound	Hurley SP254	10	0.00	0.00	0.10	0.10		0	0	74	1	74	1
	Hurley SP285	7	2.43	3.29	0.57	3.86	58.04	772	13	268	5	1040	18
	Flat Rock	7	2.71	2.43	0.43	2.86	12.7	125	10	44	3	169	13
	Thoroughfare	8	1.00	3.38	0.38	3.75	24	328	14	73	3	401	17
	Cod Harbor	7	9.71	6.71	0.43	7.14	18.62	506	27	65	3	571	31
	California A - SP171	7	6.71	6.14	1.43	7.57	11.27	280	25	130	12	410	36
	California B - SP253	7	0.71	2.43	0.86	3.29	53.66	527	10	372	7	900	17
	California B - SP214	7	2.14	7.29	1.43	8.71	18.28	539	29	211	12	750	41
	total	60											
Yeocomico River	Crow Bar	7	1.14	1.00	0.86	1.86	9.7	39	4	67	7	107	11
	Cotton Patch	7	0.86	0.86	0.86	1.71	5.61	19	3	39	7	58	10
	Barn Pt.	7	1.14	0.43	0.14	0.57	3.55	6	2	4	1	10	3
	total	21											

Table 2: Shell Resources: 1995-1996 Surveys

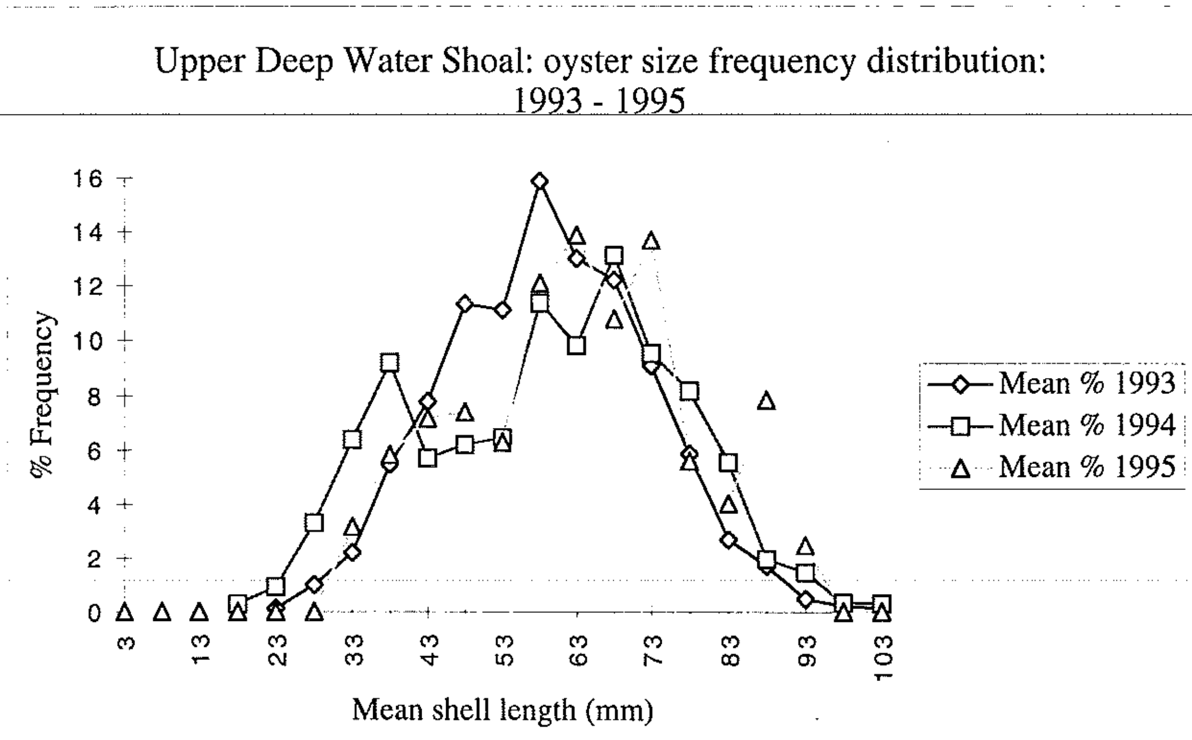
River	StationName	date	end date	n	Old box mean	upper C.I.	lower C.I.	min	max	New box mean	upper C.I.	lower C.I.	min	max	Shell vol L
James River	Upper Deep Water S	27-Nov-95	13-Dec-95	72	52.58	66.79	38.38	0	290	1.10	1.57	0.62	0	12	3.78
	Lower Deep Water	27-Nov-95		8	18.13	29.38	6.87	0	36	1.25	2.72	0.00	0	5	3.25
	Upper Horsehead	27-Nov-95		7	36.00	51.79	20.21	21	64	3.00	4.41	1.59	1	5	2.36
	Middle Horsehead	27-Nov-95		10	55.20	68.88	41.52	18	84	11.70	17.24	6.16	3	23	5.50
	Lower Horsehead	04-Dec-95		12	55.08	78.60	31.57	8	154	4.17	6.45	1.89	1	11	7.50
	Moon Rock	04-Dec-95		8	64.13	100.86	27.39	14	162	4.63	9.82	0.00	0	19	6.38
	V-Rock	28-Nov-95		22	54.05	63.63	44.46	15	104	9.50	12.80	6.20	1	28	4.95
	Point of Shoals	28-Nov-95	05-Dec-95	33	77.12	90.55	63.69	3	177	10.36	12.35	8.38	1	26	5.36
	Cross Rock	08-Dec-95		21	44.43	53.29	35.57	0	80	6.19	8.38	4.00	0	15	9.23
	Shanty Rock	08-Dec-95		7	33.29	40.32	26.25	22	47	2.86	4.81	0.90	1	6	11.00
	Dry Lumps	08-Dec-95		7	11.43	14.58	8.28	6	15	0.71	1.41	0.02	0	2	10.14
	Mulberry Point	29-Jan-96		31	20.97	32.01	9.93	0	112	0.23	0.43	0.02	0	2	2.65
	Swash	05-Dec-95		22	11.05	16.51	5.58	0	41	0.23	0.46	0.00	0	2	1.15
	Upper Jail Island	05-Dec-95	08-Dec-95	65	9.69	13.52	5.86	0	68	0.28	0.51	0.04	0	7	1.28
	Swash Mud Slough	14-Dec-95		125	9.89	11.83	7.94	0	60	0.63	0.82	0.44	0	6	2.15
	Offshore Swash	12-Dec-95		101	9.35	12.29	6.41	0	74	2.03	2.82	1.24	0	26	3.47
	Lower Jail Island	30-Nov-95	04-Dec-95	62	10.05	14.44	5.65	0	89	0.58	1.06	0.11	0	11	2.80
	Offshore Jail Island	30-Nov-95		102	4.94	6.14	3.75	0	33	0.69	0.99	0.38	0	9	3.66
	Wreck Shoal	14-Dec-95		50	5.24	7.25	3.23	0	38	0.20	0.32	0.08	0	1	6.79
	Days Point	30-Jan-96		30	3.57	5.43	1.70	0	19	0.30	0.50	0.10	0	2	5.53
	Hotel Rock	29-Jan-96		7	4.43	7.63	1.23	0	11	0.14	0.49	0.00	0	1	5.57
	Snyders	30-Jan-96		7	3.14	5.89	0.40	1	9	0.14	0.49	0.00	0	1	5.21
	Triangle Rock	29-Jan-96		7	43.14	74.24	12.05	0	82	3.43	6.76	0.10	0	10	5.57
Rappahannock R.	Bowler's Rock	31-Oct-95	18-Jan-96	19	0.00	0.00	0.00	0	0	0.05	0.16	0.00	0	1	4.11
	Broad Creek A	01-Nov-95		7	3.86	7.29	0.42	0	8	0.29	0.74	0.00	0	1	9.86
	Moratico	31-Oct-95		20	0.95	1.87	0.03	0	7	0.20	0.53	0.00	0	3	9.40
	Ross Rock	31-Oct-95		10	1.10	1.81	0.39	0	2	0.10	0.33	0.00	0	1	8.50
	Spike's	10-Nov-95		7	5.14	11.05	0.00	0	17	0.14	0.49	0.00	0	1	8.57
	Sturgeon	01-Nov-95		7	0.43	1.16	0.00	0	2	0.00	0.00	0.00	0	0	5.50
	Long Rock	31-Oct-95		10	2.90	4.94	0.86	0	8	1.30	2.31	0.29	0	4	8.50
	Sharp's Inshore	31-Oct-95		7	0.43	1.16	0.00	0	2	0.14	0.49	0.00	0	1	11.29
	Carter's Rock	31-Oct-95		5	0.20	0.76	0.00	0	1	0.00	0.00	0.00	0	0	13.00
	Butler's Hole A	01-Nov-95		7	1.00	3.07	0.00	0	6	0.43	1.16	0.00	0	2	3.59
	Broad Creek B	01-Nov-95		7	2.86	7.14	0.00	0	11	0.29	0.74	0.00	0	1	3.14
	Butler's Hole B	01-Nov-95		7	0.14	0.49	0.00	0	1	0.00	0.00	0.00	0	0	1.57

River	StationName	date	end date	n	Old box mean	upper C.I.	lower C.I.	min	max	New box mean	upper C.I.	lower C.I.	min	max	Shell vol L
Great Wicomico R.	Cranes Creek	01-Nov-95		10	7.00	9.80	4.20	0	12	3.00	4.78	1.22	0	7	15.40
	Fleeton	01-Nov-95		7	6.14	9.45	2.83	1	12	2.29	3.67	0.90	0	4	5.71
	Sandy Point	01-Nov-95		7	12.29	18.99	5.58	3	22	3.71	6.72	0.71	0	10	11.57
	Shell Bar	01-Nov-95		7	3.57	5.89	1.25	0	6	0.86	1.50	0.22	0	2	13.86
	Ingram's	01-Nov-95		7	6.00	9.29	2.71	1	12	1.14	2.13	0.15	0	3	17.71
	Blackberry Hang	09-Nov-95		7	1.57	2.97	0.17	0	4	0.29	0.98	0.00	0	2	6.71
Piankatank River	Bland Point	30-Oct-95		7	23.43	35.30	11.56	2	39	2.71	6.48	0.00	0	11	14.29
	Burton Point A	30-Oct-95		9	38.00	62.87	13.13	0	86	2.22	3.65	0.80	0	4	11.67
	Cape Tune	30-Oct-95		9	43.78	70.78	16.78	0	96	3.78	5.57	1.98	0	7	17.89
	Ginney Point	30-Oct-95		7	2.00	3.31	0.69	1	4	0.29	0.74	0.00	0	1	11.00
	Palace Bar	30-Oct-95		9	13.33	20.52	6.14	2	28	0.44	1.12	0.00	0	2	16.78
	Stove Point	30-Oct-95		7	5.14	9.62	0.66	0	13	0.71	1.41	0.02	0	2	8.71
	Heron Rock	30-Oct-95		7	9.29	14.37	4.20	1	18	1.29	2.56	0.01	0	4	10.57
	Burton Point B	30-Oct-95		7	14.71	26.91	2.52	0	40	0.86	1.98	0.00	0	3	8.14
Potomac River	CoanR./Windmill Pt	09-Nov-95		8	0.38	1.00	0.00	0	2	0.13	0.42	0.00	0	1	1.31
	CoanR./Big Bar	09-Nov-95		7	4.14	6.84	1.45	1	8	0.43	1.16	0.00	0	2	12.86
	CoanR./Honest Pt.	09-Nov-95		7	1.71	2.99	0.44	0	4	0.00	0.00	0.00	0	0	7.50
	CoanR./Clark's Bar	09-Nov-95		7	3.57	6.34	0.80	0	8	0.29	0.74	0.00	0	1	6.71
Pocomoke Sound	PG10 (Buoy Rock)	10-Nov-95		14	4.57	8.28	0.87	0	21	0.50	0.94	0.06	0	2	5.36
	Byrd Rock	10-Nov-95		7	6.57	9.90	3.24	0	11	0.71	1.87	0.00	0	3	15.57
	Old Rock	10-Nov-95		7	3.71	7.12	0.31	0	10	0.57	1.30	0.00	0	2	3.93
	Swash	10-Nov-95		7	8.57	14.61	2.53	0	18	0.57	1.30	0.00	0	2	4.14
	SP213 (Trevis Lum	10-Nov-95		6	2.33	6.82	0.00	0	11	0.00	0.00	0.00	0	0	2.83
Tangier Sound	Hurley SP254	06-Nov-95		10	1.10	1.96	0.24	0	3	0.00	0.00	0.00	0	0	5.50
	Hurley SP285	06-Nov-95		7	3.86	9.10	0.00	0	15	0.86	1.98	0.00	0	3	4.14
	Flat Rock	06-Nov-95		7	4.29	9.90	0.00	0	14	1.14	2.69	0.00	0	4	2.64
	Thoroughfare	06-Nov-95		8	2.38	6.47	0.00	0	14	0.63	1.62	0.00	0	3	5.75
	Cod Harbor	06-Nov-95		7	4.14	6.89	1.40	0	9	1.29	3.33	0.00	0	6	7.29
	California A - SP17	06-Nov-95		7	3.86	8.43	0.00	0	11	1.43	2.83	0.03	0	4	6.29
	California B - SP25:	06-Nov-95		7	0.57	1.07	0.08	0	1	0.57	1.30	0.00	0	2	5.43
	California B - SP21	06-Nov-95		7	5.29	10.51	0.06	0	13	0.29	0.74	0.00	0	1	7.14
Yeocomico River	Crow Bar	09-Nov-95		7	0.71	1.41	0.02	0	2	0.29	0.98	0.00	0	2	3.86
	Cotton Patch	09-Nov-95		7	1.14	2.78	0.00	0	5	0.14	0.49	0.00	0	1	3.00
	Barn Pt.	09-Nov-95		7	0.43	1.16	0.00	0	2	0.14	0.49	0.00	0	1	4.93

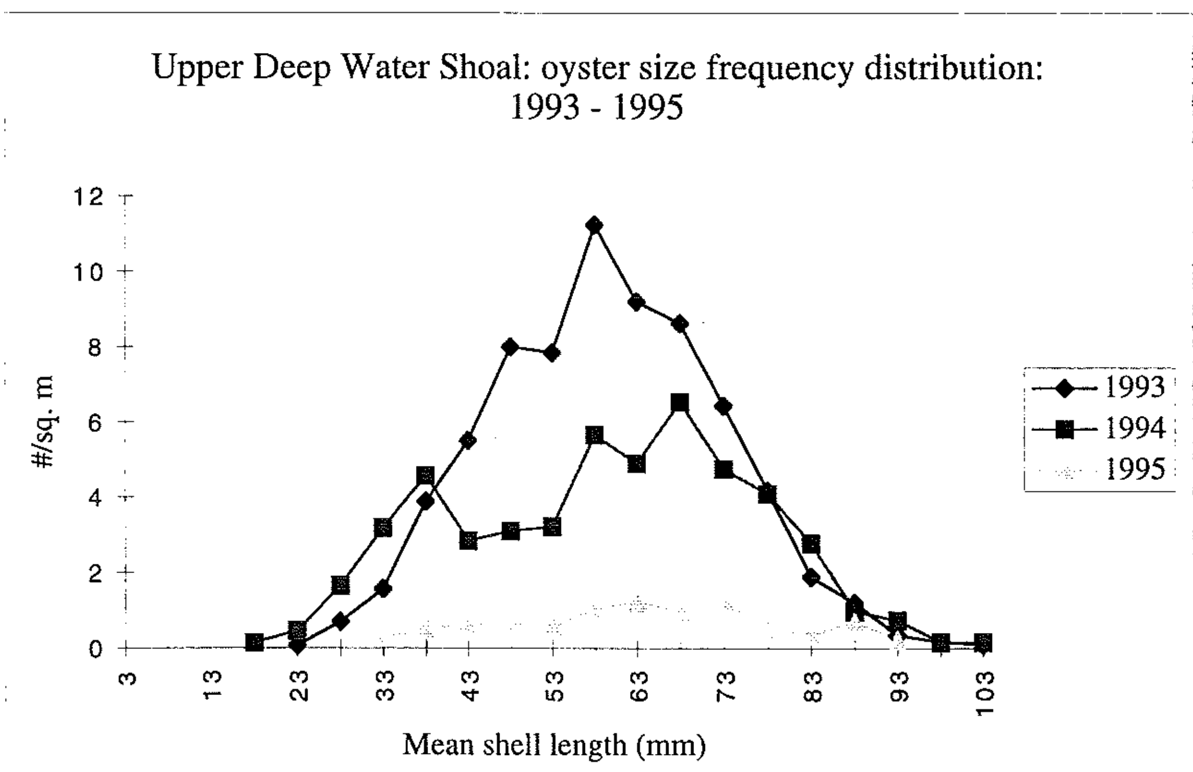
Table 3: James River Oyster Resources by reef: 1993 -1995 Fall surveys

JAMES RIVER REEF #	REEF NAME	ACRES	small bu. 1993	small bu. 1994	small bu. 1995	market bu. 1993	market bu. 1994	market bu. 1995	Total bu. 1993	Total bu. 1994	Total bu. 1995
1	Up D Wtr Shl	234	46472	34866	6784	37579	24214	3024	84051	59080	9808
2	Low D Wtr Shl	20	798	871	60	1371	1792	40	2169	2663	101
3	Up Horsehead	3	3588	2127	3082	1348	885	365	4936	3012	3447
4	Mid Horsehead	19	16877	13938	27310	1158	2606	1907	18035	16544	29216
5	Low Horsehead	19	19963	20068	21537	2954	5843	1471	22917	25911	23008
6	Moon Rock	4	3948	4505	4210	791	1186	424	4739	5691	4634
7	V-Rock	72	45950	40969	57759	11842	12433	5063	57792	53402	62822
8	Pt of Shoals	132	55906	73923	106684	25463	26984	14957	81369	100907	121641
9	Cross Rock	37	11151	10289	27144	2329	2494	1103	13480	12783	28247
10	Shanty Rock	4	471	1490	1140	65	103	83	536	1594	1223
11	Dry Lump	6	360	1197	531	40	29	21	400	1225	552
12	Mulberry:upriver	87	6436	10544	4343	3937	2390	1138	10373	12934	5481
13	Mulberry & Swash	165	2356	8466	8837	1687	4340	2662	4043	12806	11499
14	Upper Jail Is	612	13560	30785	21293	27578	29618	7770	41138	60403	29063
15	Swash Mud	1245	104703	122151	103339	56092	30558	25069	160795	152709	128408
16	Offshore Swash	627	62175	72713	97174	28911	13866	10041	91086	86579	107216
17	Lower Jail Is	629	23571	20200	24713	24936	16833	16913	48507	37034	41627
18	Offsh.Jail Island	1017	31884	53615	27887	20117	25473	5489	52001	79088	33376
19	Wreck Shoal	585	15188	19321	15713	10671	6194	1609	25859	25515	17323
20	Days Point	300		23223	8013		1063	243		24286	8256
21	Hotel Rock	14		2012	665		239	16		2251	681
22	Snyders	11		770	682		102	110		872	792
23	Triangle Rock	7		3086	3339		1413	1119		4498	4458
	TOTAL										
	REEFS 1-19 INC	5517	465357	542038	559543	258869	207841	99149	724226	749880	658692
	REEFS 1-23 INC			571129	572242		210658	100636		781787	672878

Figure 2.1

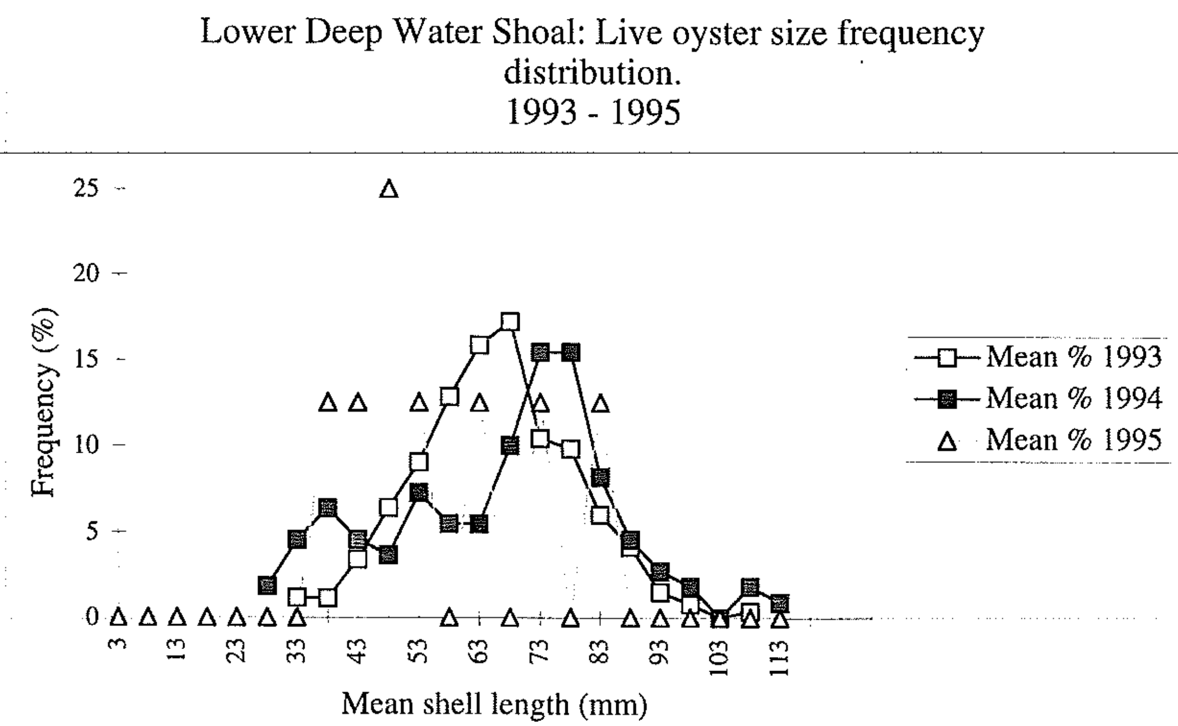


Upper Deep Water Shoal: oyster size frequency distribution: 1993 - 1995
% Frequency
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995



Upper Deep Water Shoal: oyster size frequency distribution: 1993 - 1995
#/sq. m
Mean shell length (mm)
1993
1994
1995

Figure 2.2


Lower Deep Water Shoal: Live oyster size frequency distribution.
1993 - 1995
Frequency (%)
25
20
15
10
5
0
3
13
23
33
43
53
63
73
83
93
103
113
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

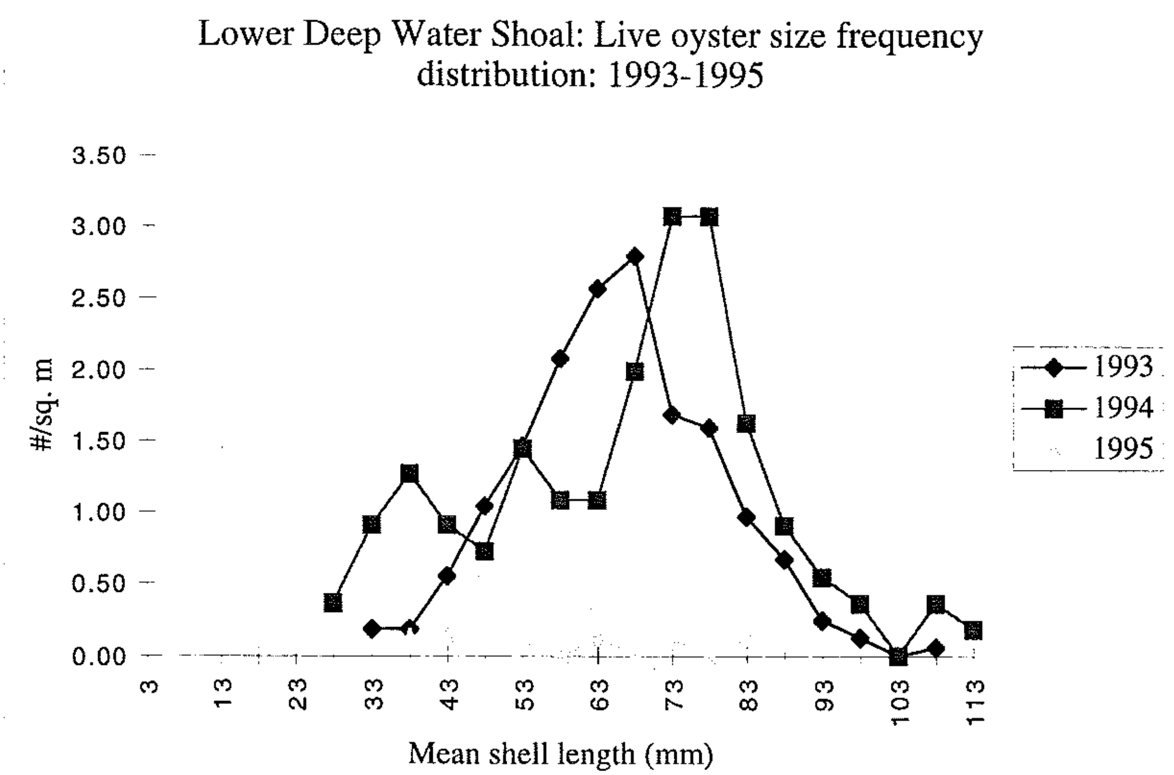
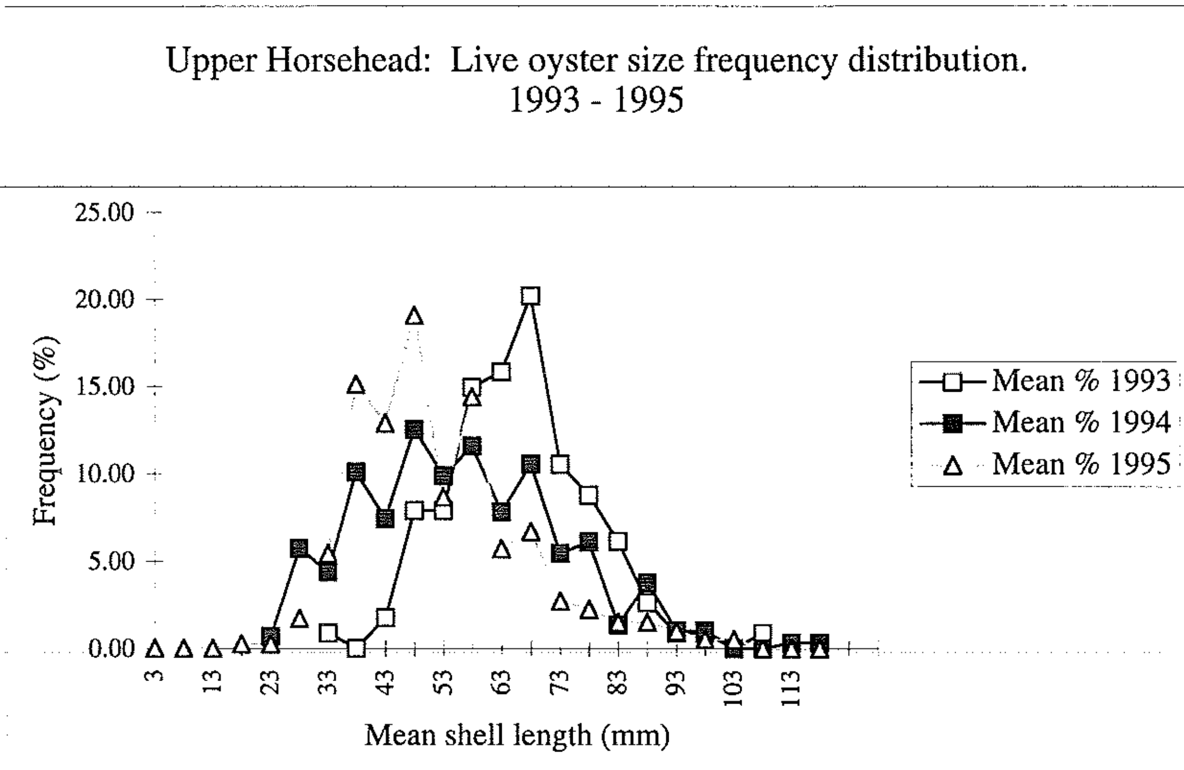

Lower Deep Water Shoal: Live oyster size frequency distribution: 1993-1995
#/sq. m
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3
13
23
33
43
53
63
73
83
93
103
113
Mean shell length (mm)
1993
1994
1995

Figure 2.3


Upper Horsehead: Live oyster size frequency distribution.
1993 - 1995
Frequency (%)
25.00
20.00
15.00
10.00
5.00
0.00
3
13
23
33
43
53
63
73
83
93
103
113
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

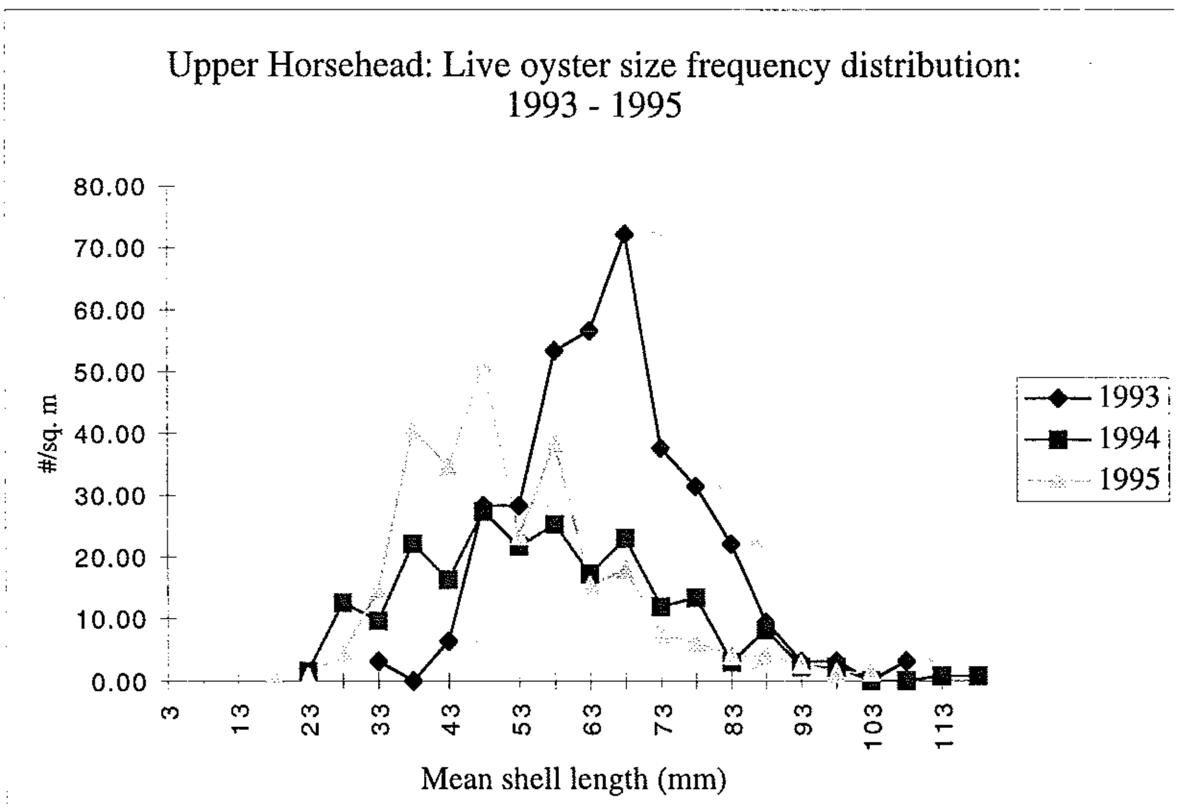
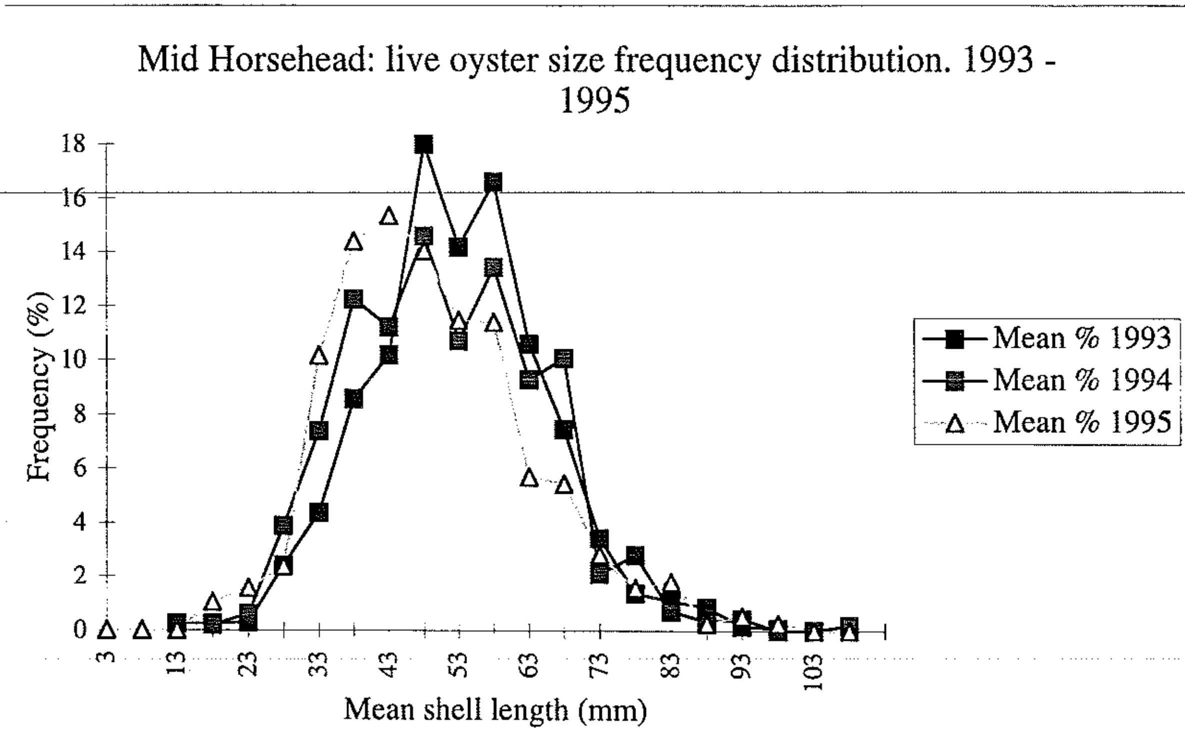

Upper Horsehead: Live oyster size frequency distribution:
1993 - 1995
#/sq. m
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
3
13
23
33
43
53
63
73
83
93
103
113
Mean shell length (mm)
1993
1994
1995

Figure 2.4


Mid Horsehead: live oyster size frequency distribution. 1993 - 1995
Frequency (%)
18
16
14
12
10
8
6
4
2
0
3
13
23
33
43
53
63
73
83
93
103
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

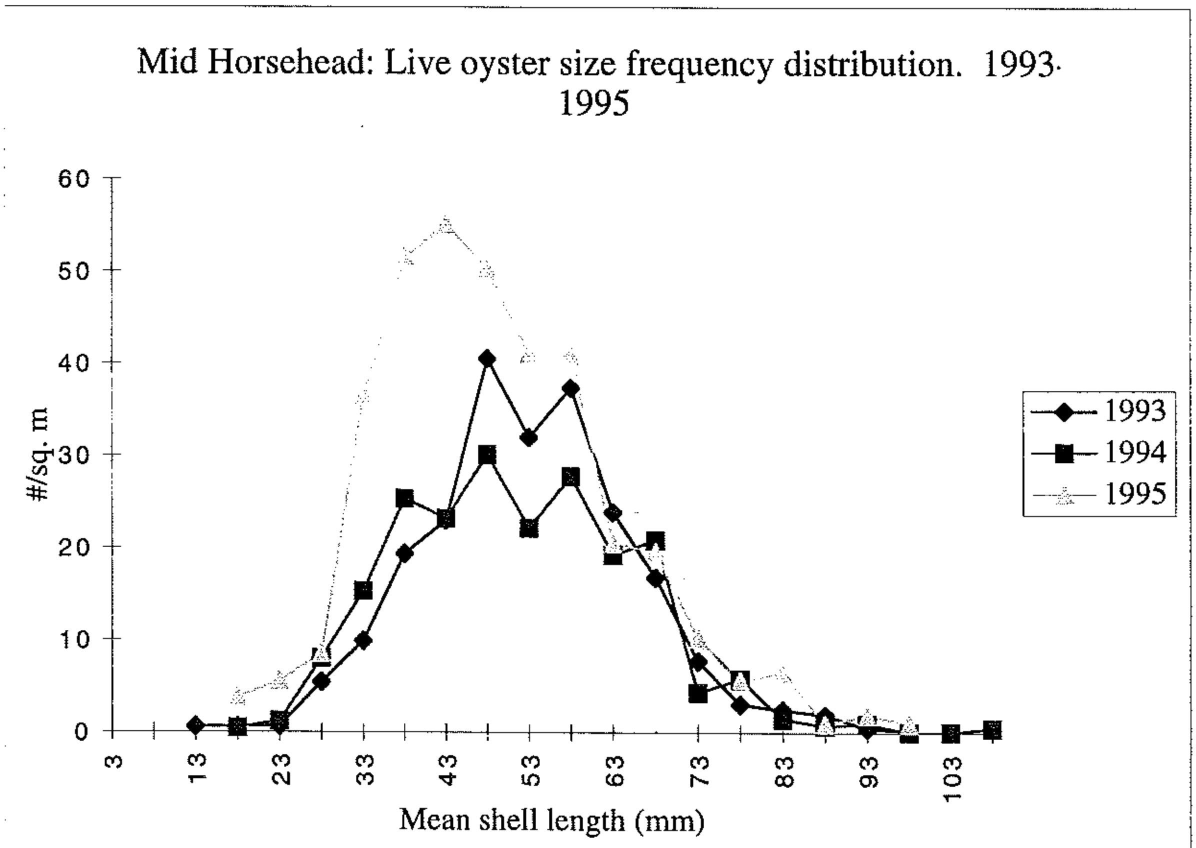
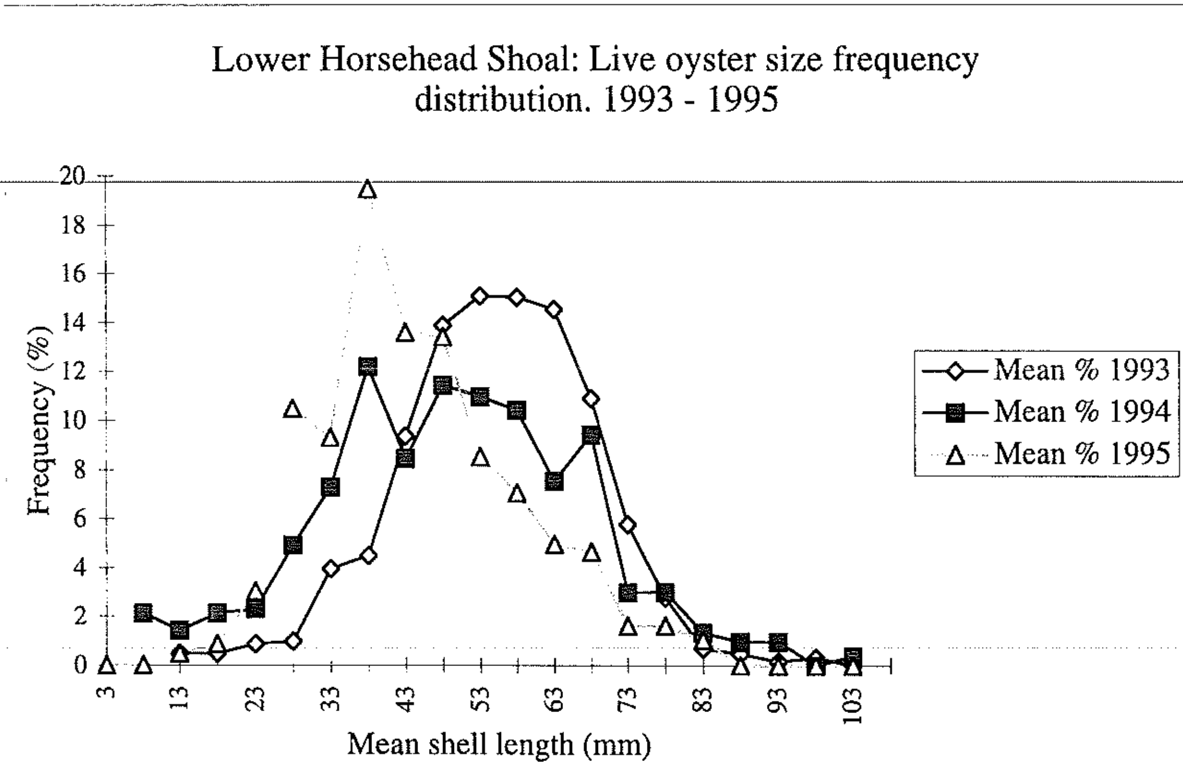
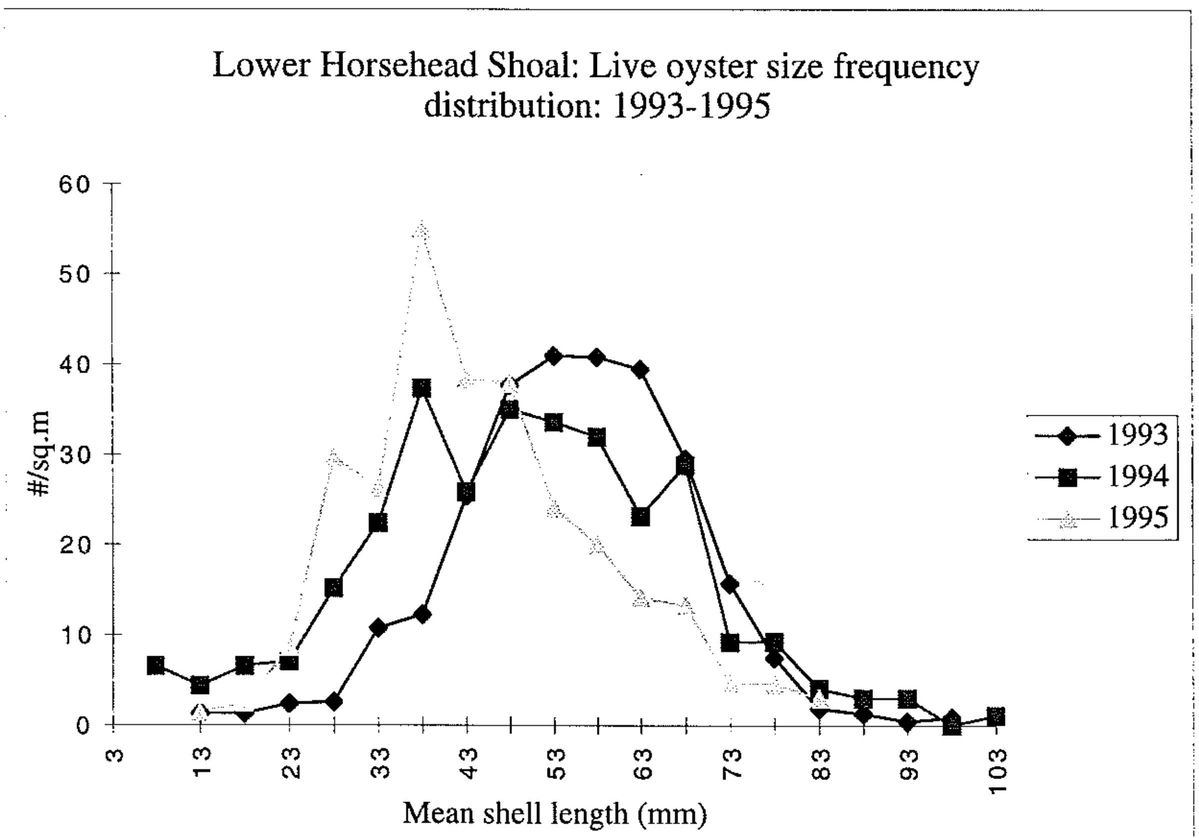

Mid Horsehead: Live oyster size frequency distribution. 1993- 1995
#/sq. m
60
50
40
30
20
10
0
3
13
23
33
43
53
63
73
83
93
103
Mean shell length (mm)
1993
1994
1995

Figure 2.5

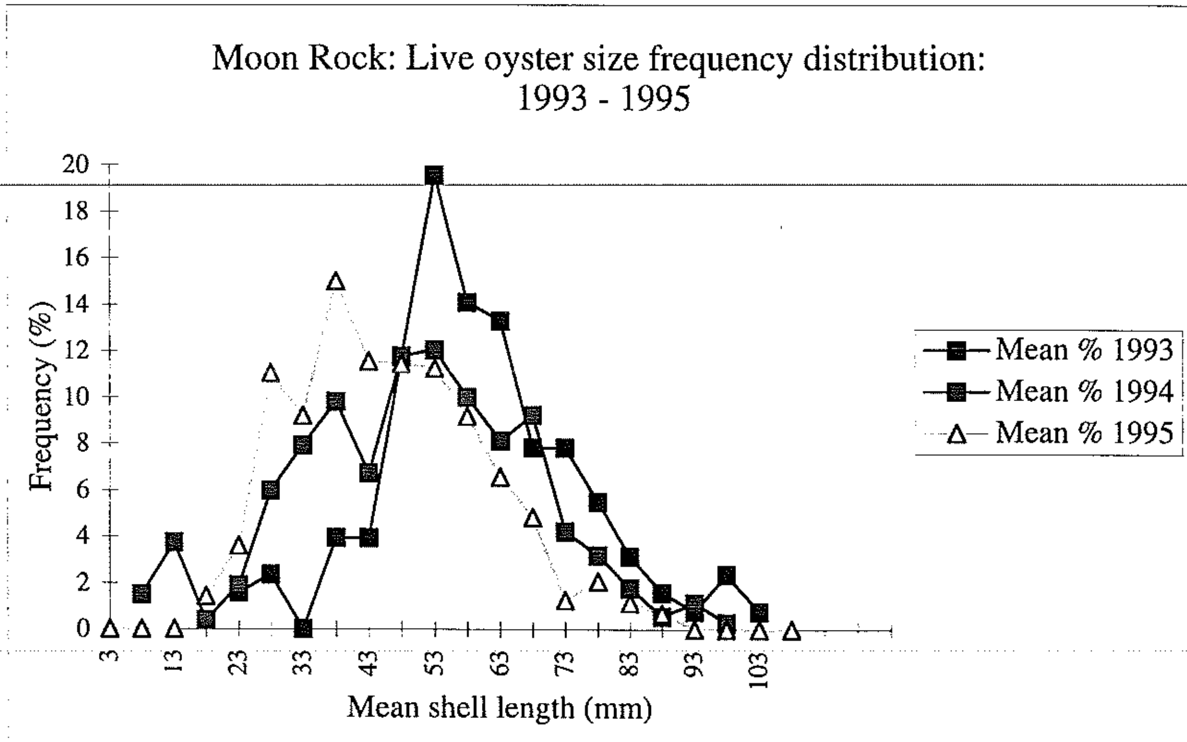


Lower Horsehead Shoal: Live oyster size frequency distribution. 1993 - 1995
Frequency (%)
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

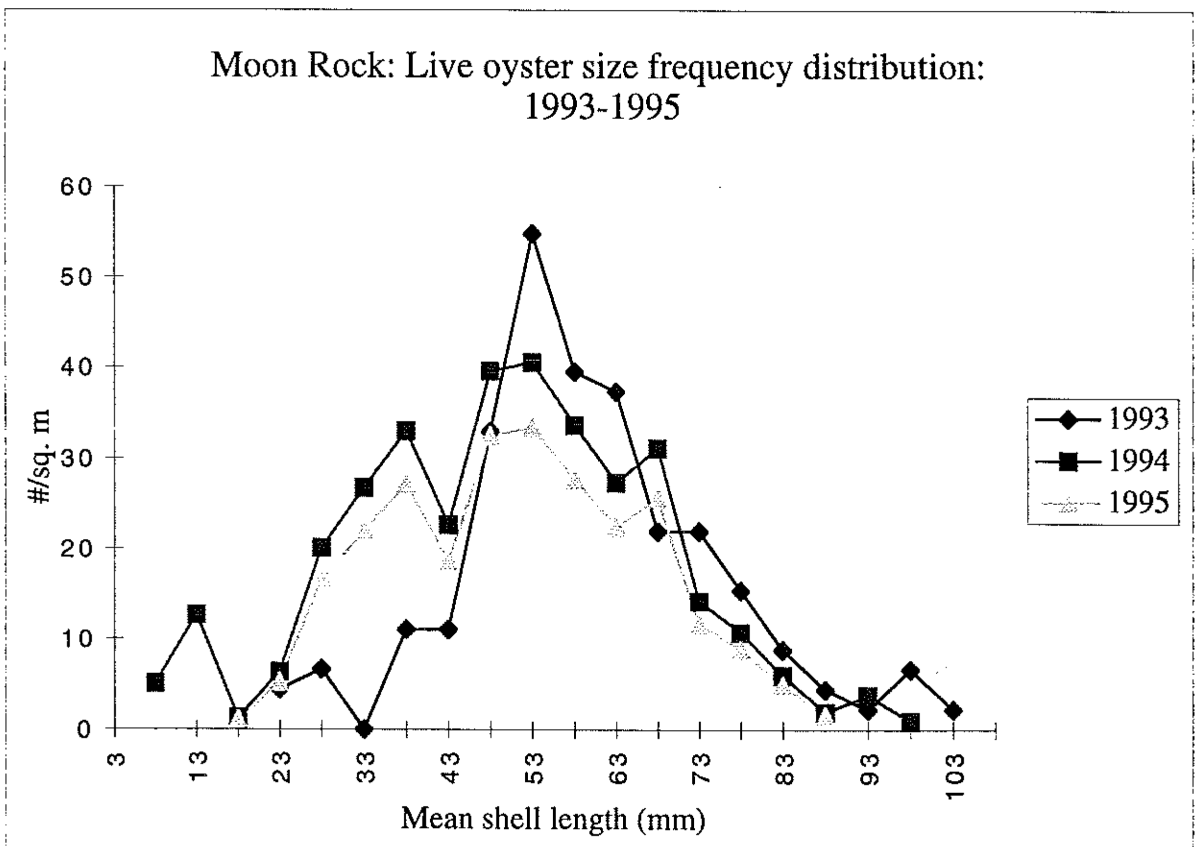


Lower Horsehead Shoal: Live oyster size frequency distribution: 1993-1995
#/sq.m
Mean shell length (mm)
1993
1994
1995

Figure 2.6

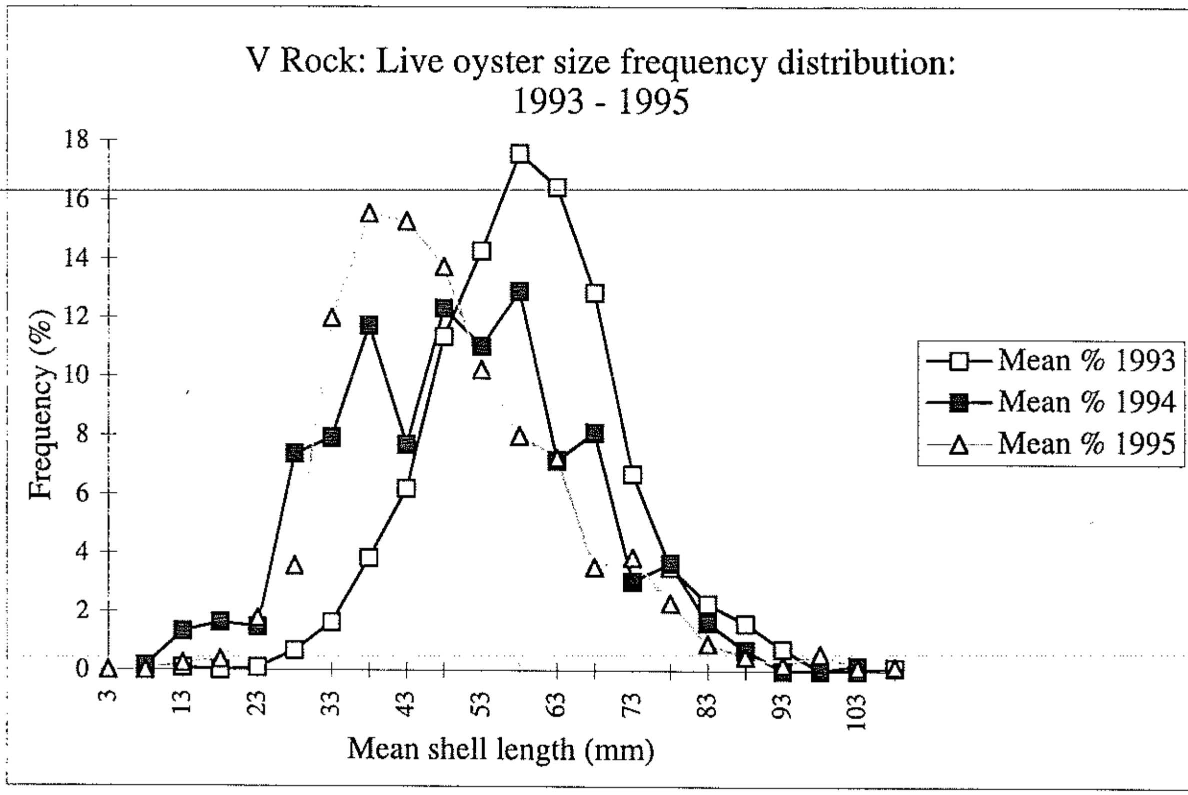


Moon Rock: Live oyster size frequency distribution: 1993 - 1995
Frequency (%)
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995
20
18
16
14
12
10
8
6
4
2
0
3
13
23
33
43
53
63
73
83
93
103



Moon Rock: Live oyster size frequency distribution: 1993-1995
#/sq. m
Mean shell length (mm)
1993
1994
1995
60
50
40
30
20
10
0
3
13
23
33
43
53
63
73
83
93
103

Figure 2.7


V Rock: Live oyster size frequency distribution: 1993 - 1995
Frequency (%)
0
2
4
6
8
10
12
14
16
18
3
13
23
33
43
53
63
73
83
93
103
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

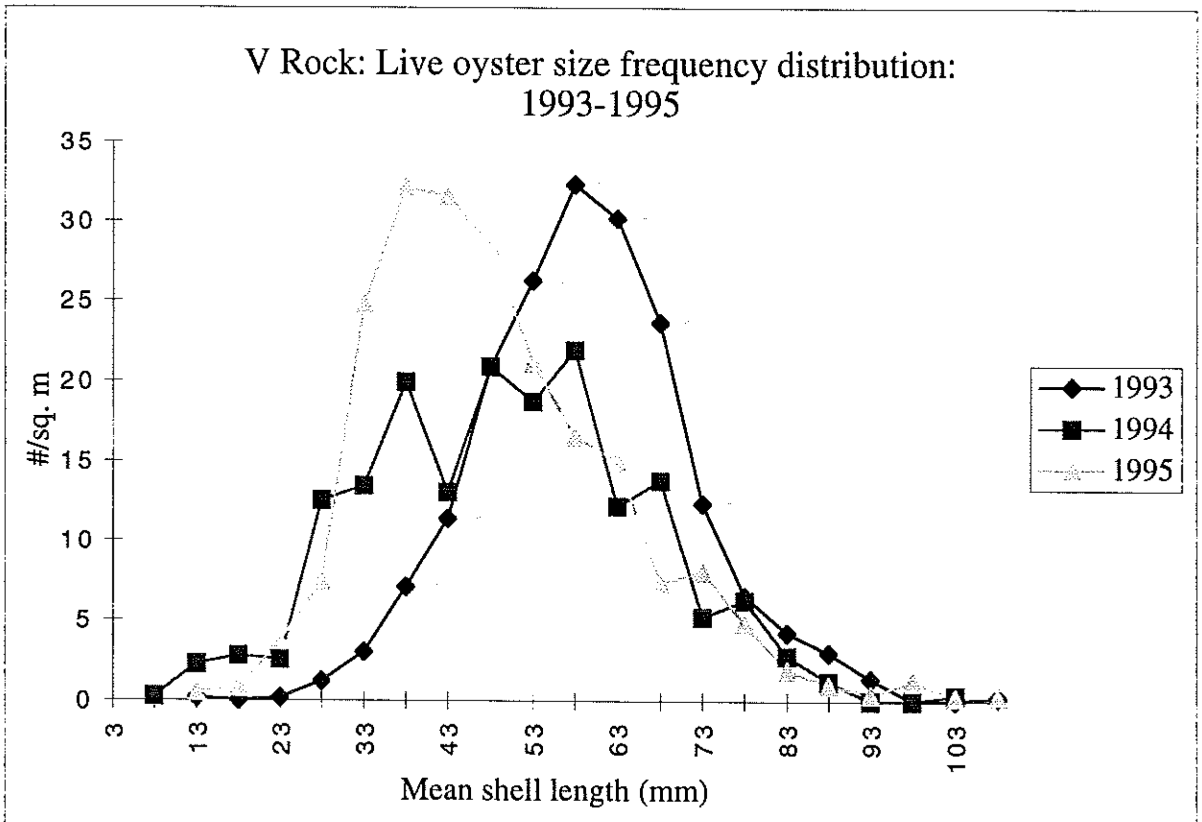
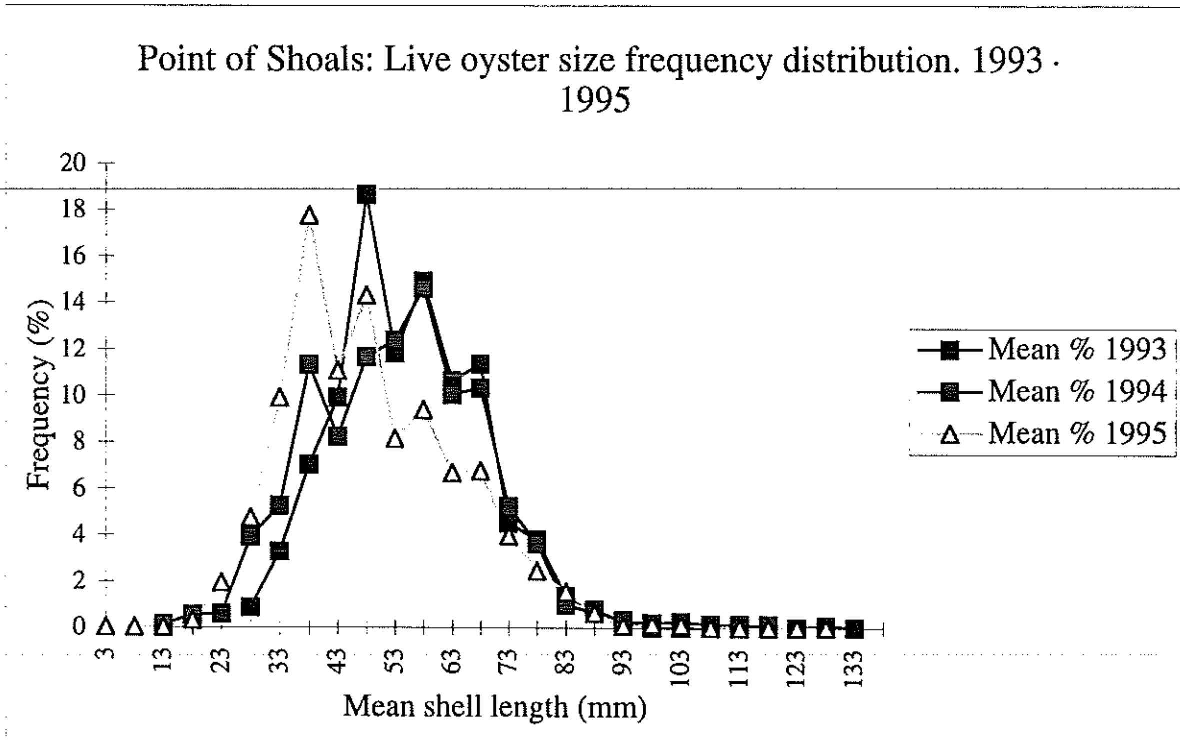

V Rock: Live oyster size frequency distribution: 1993-1995
#/sq. m
0
5
10
15
20
25
30
35
3
13
23
33
43
53
63
73
83
93
103
Mean shell length (mm)
1993
1994
1995

Figure 2.8


Point of Shoals: Live oyster size frequency distribution. 1993 - 1995
Frequency (%)
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

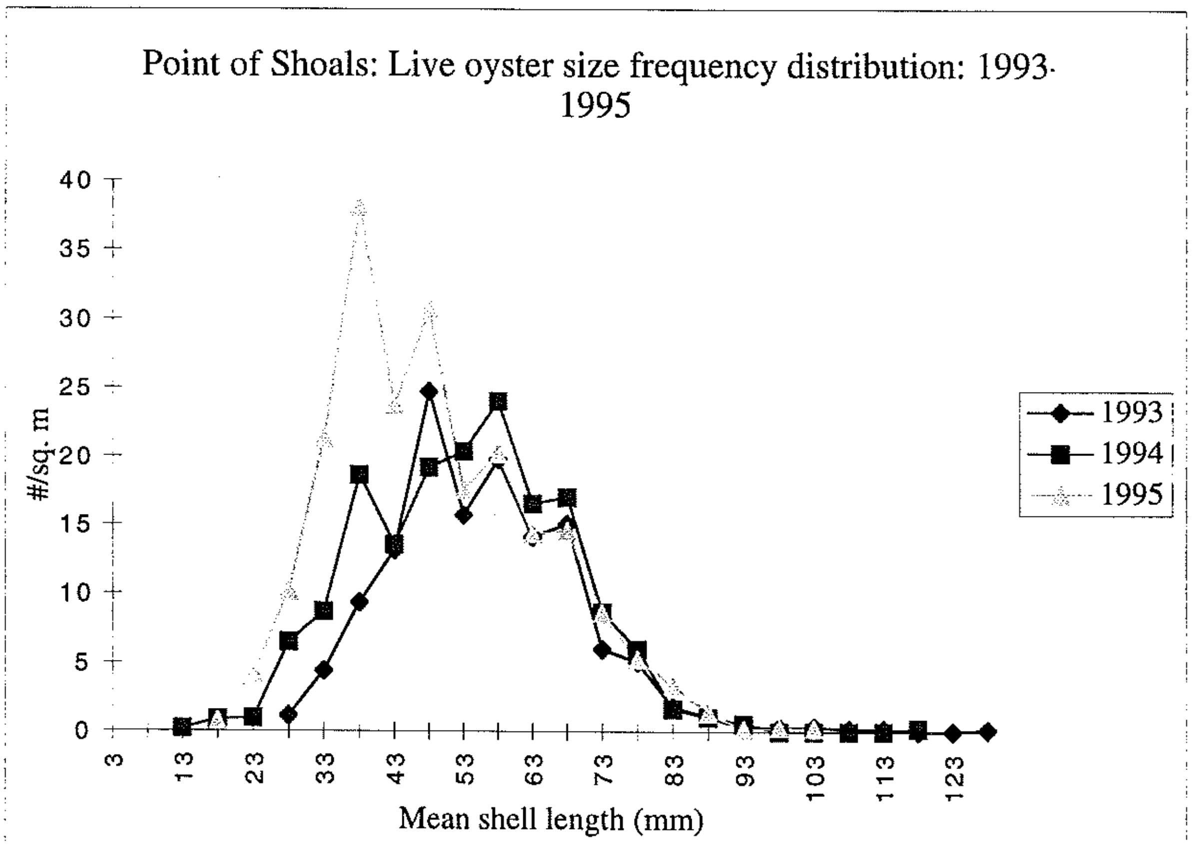
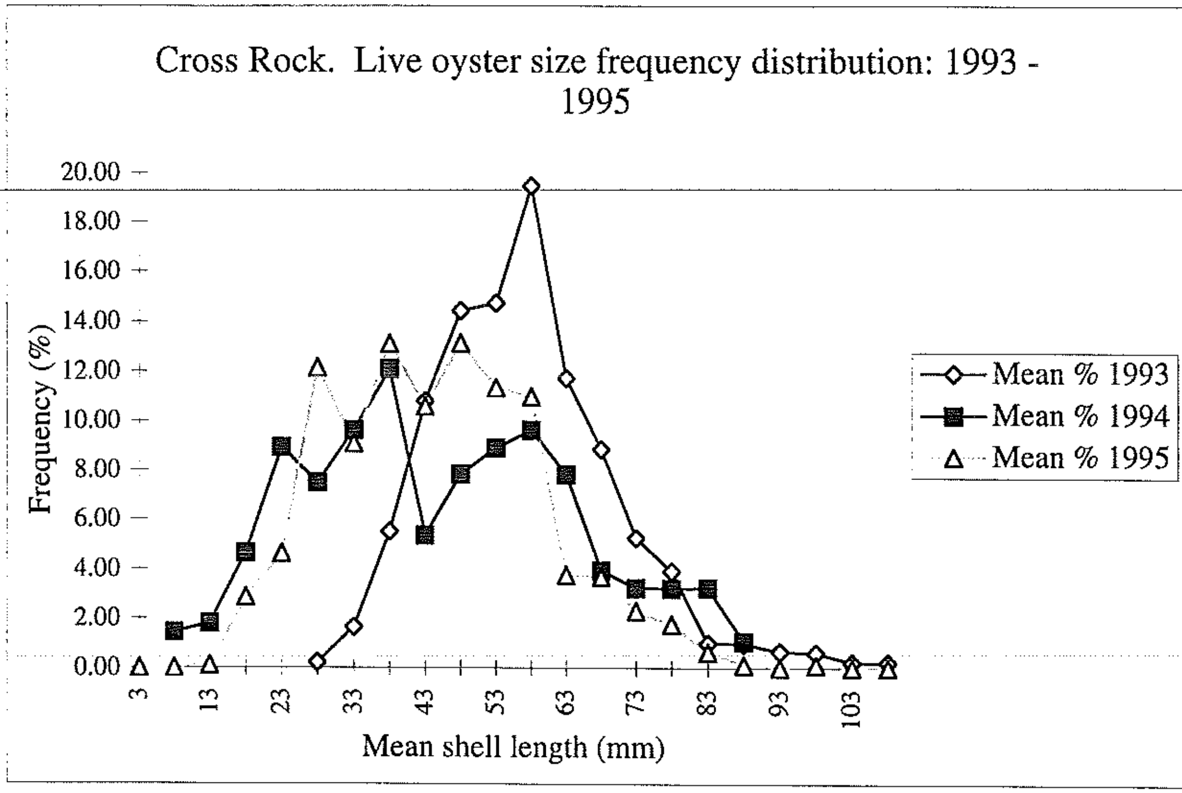
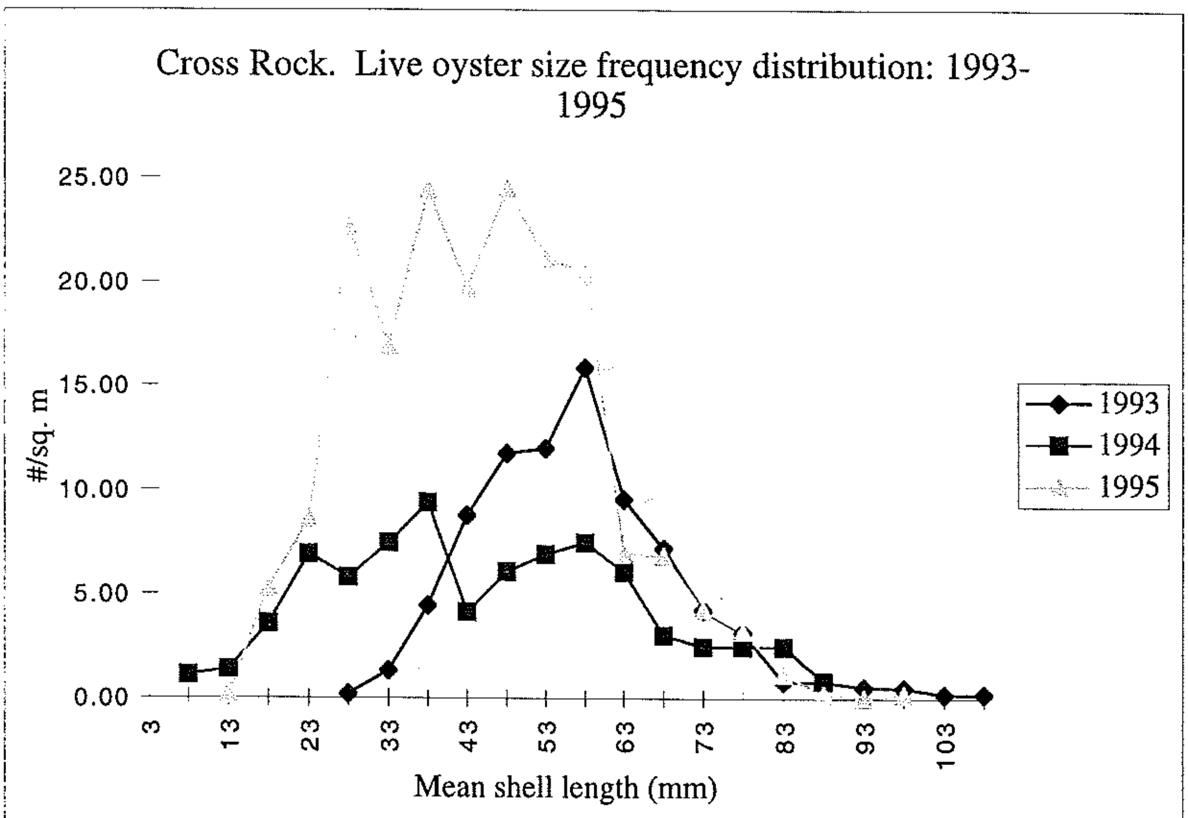

Point of Shoals: Live oyster size frequency distribution: 1993-1995
#/sq. m
Mean shell length (mm)
1993
1994
1995

Figure 2.9

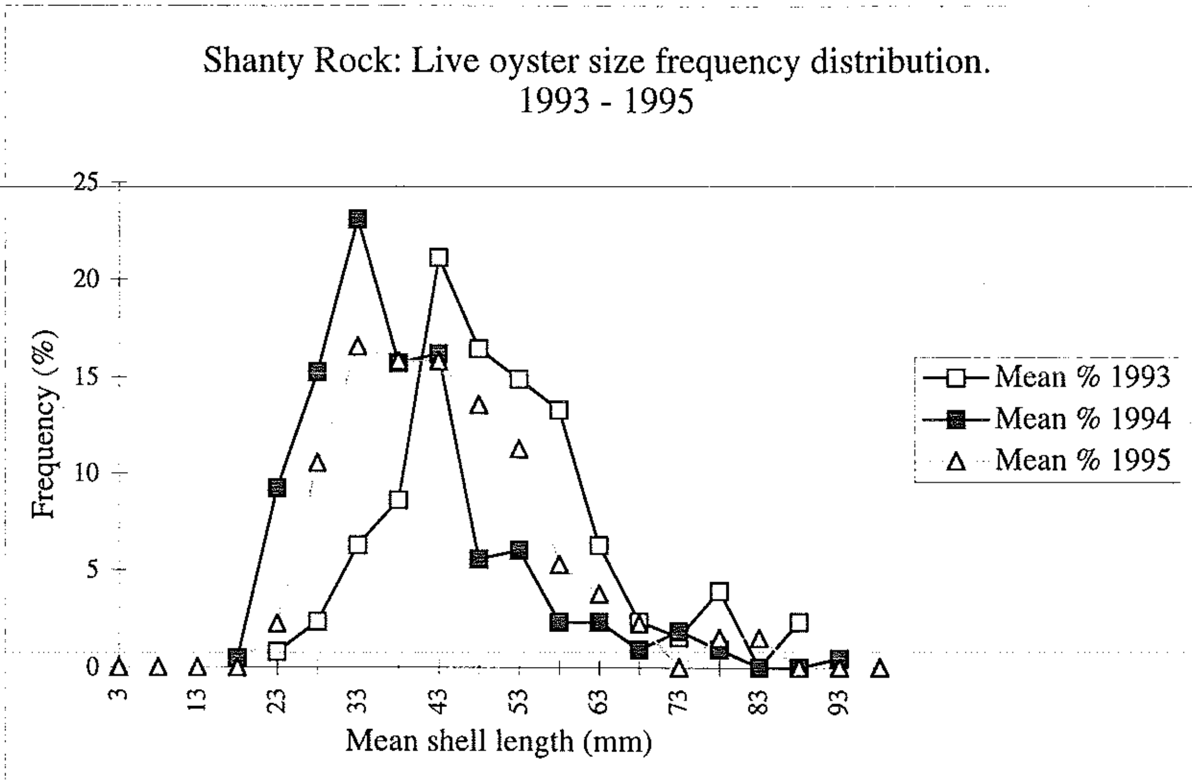


Cross Rock. Live oyster size frequency distribution: 1993 - 1995
Frequency (%)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
3
13
23
33
43
53
63
73
83
93
103
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995



Cross Rock. Live oyster size frequency distribution: 1993-1995
#/sq. m
25.00
20.00
15.00
10.00
5.00
0.00
3
13
23
33
43
53
63
73
83
93
103
Mean shell length (mm)
1993
1994
1995

Figure 2.10


Shanty Rock: Live oyster size frequency distribution.
1993 - 1995
Frequency (%)
25
20
15
10
5
0
3
13
23
33
43
53
63
73
83
93
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

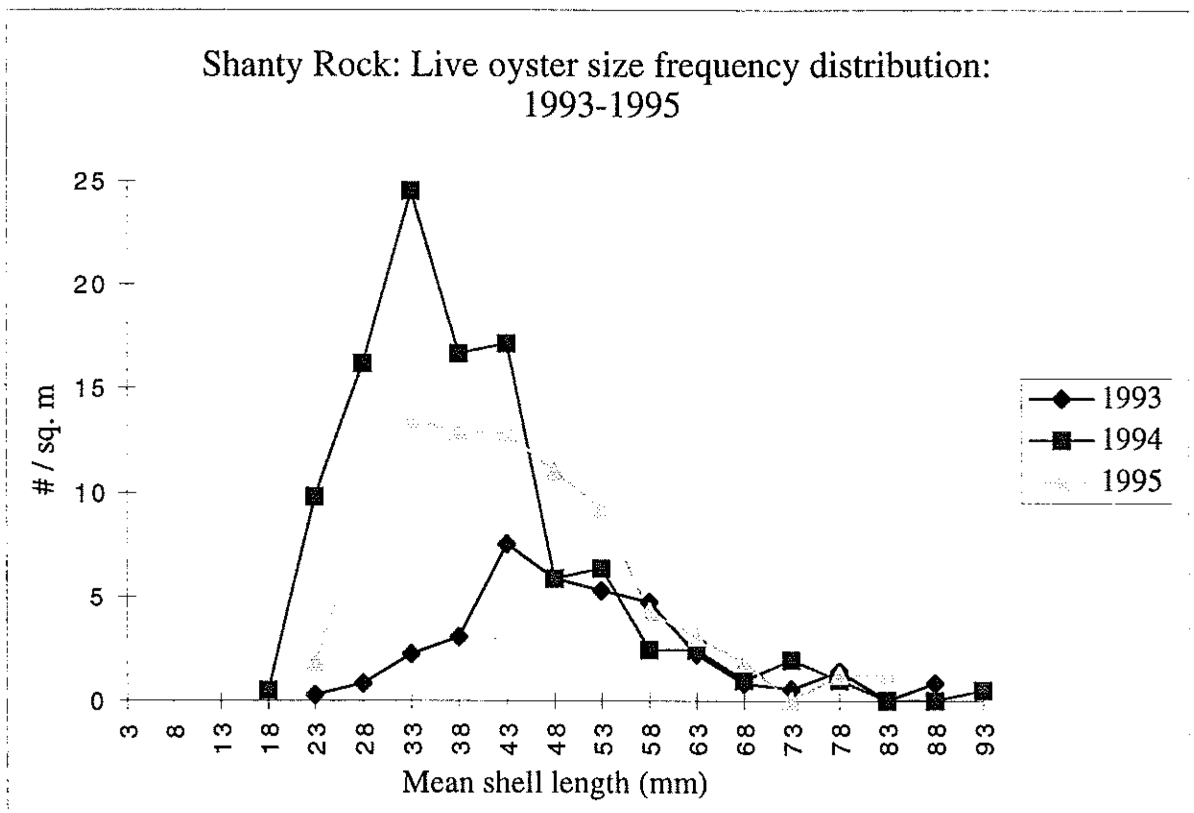
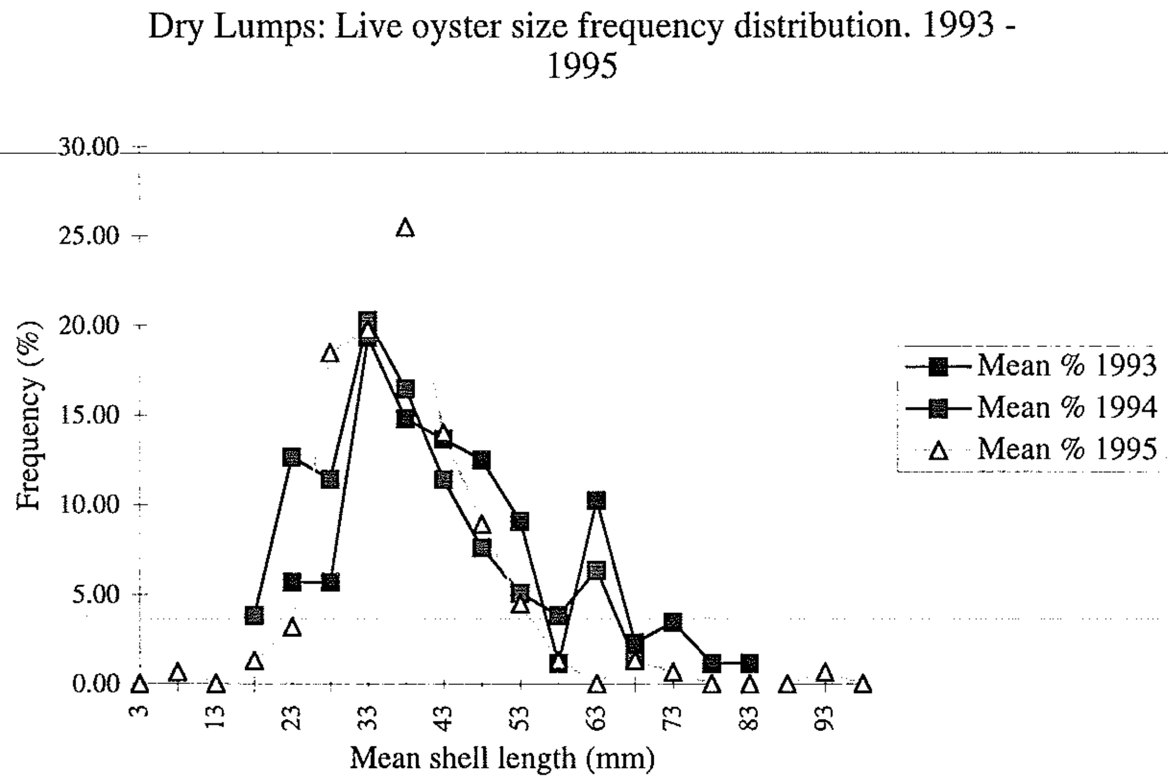
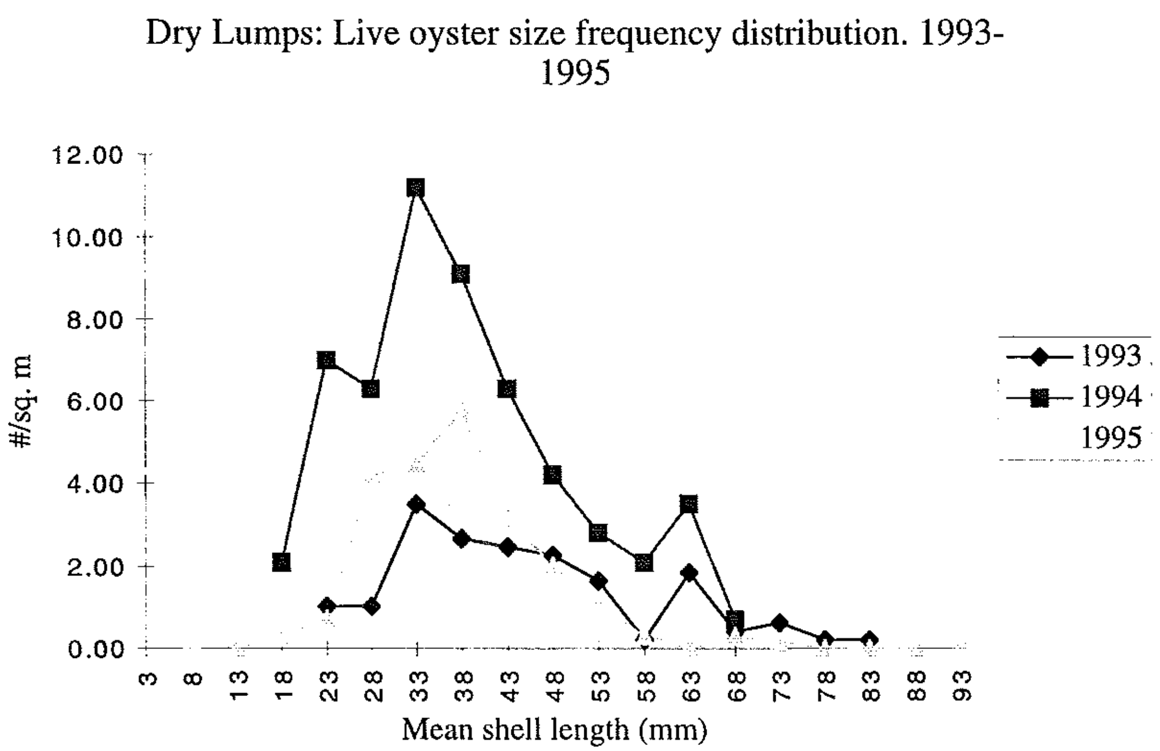

Shanty Rock: Live oyster size frequency distribution:
1993-1995
/ sq. m
25
20
15
10
5
0
3
8
13
18
23
28
33
38
43
48
53
58
63
68
73
78
83
88
93
Mean shell length (mm)
1993
1994
1995

Figure 2.11

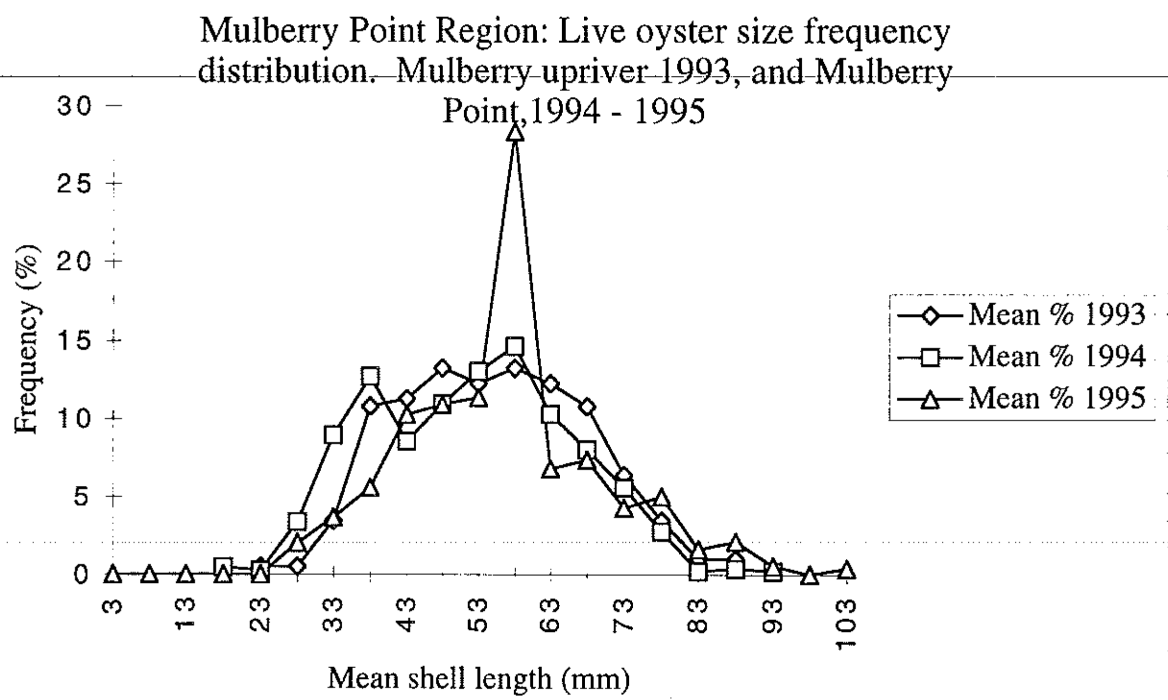


Dry Lumps: Live oyster size frequency distribution. 1993 - 1995
Frequency (%)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
3
13
23
33
43
53
63
73
83
93
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995



Dry Lumps: Live oyster size frequency distribution. 1993- 1995
#/sq. m
12.00
10.00
8.00
6.00
4.00
2.00
0.00
3
8
13
18
23
28
33
38
43
48
53
58
63
68
73
78
83
88
93
Mean shell length (mm)
1993
1994
1995

Figure 2.12


Mulberry Point Region: Live oyster size frequency distribution. Mulberry upriver 1993, and Mulberry Point,1994 - 1995
Frequency (%)
30
25
20
15
10
5
0
3
13
23
33
43
53
63
73
83
93
103
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

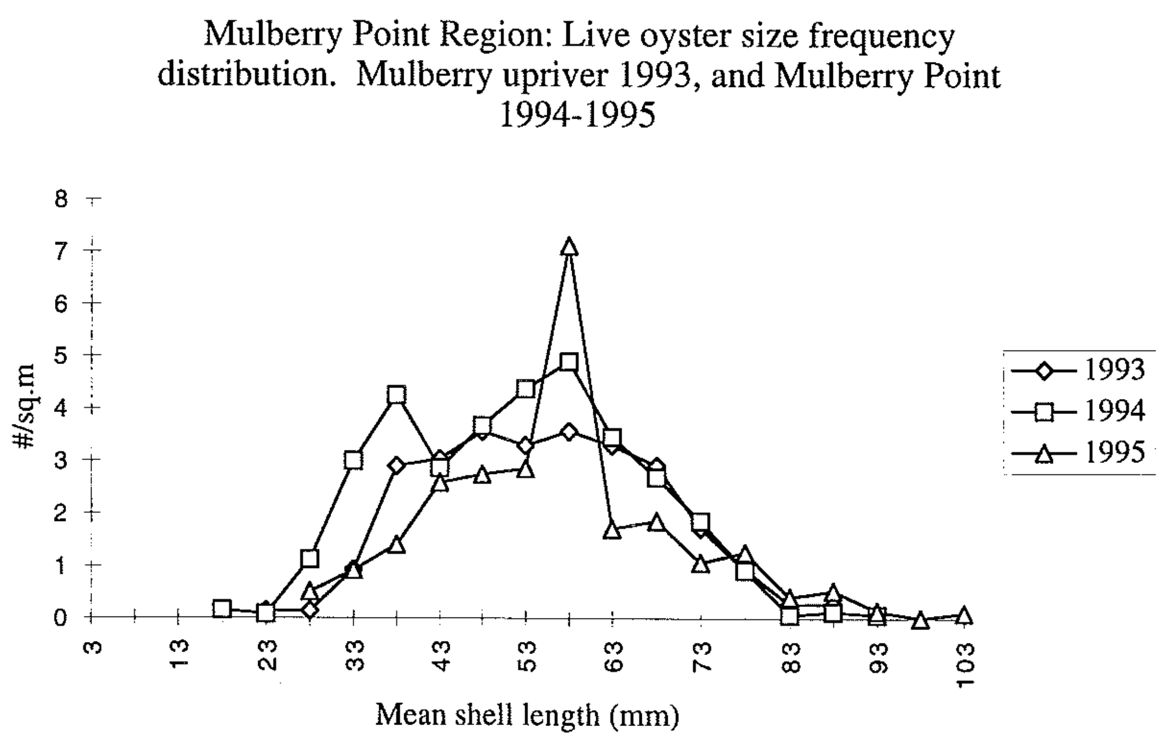
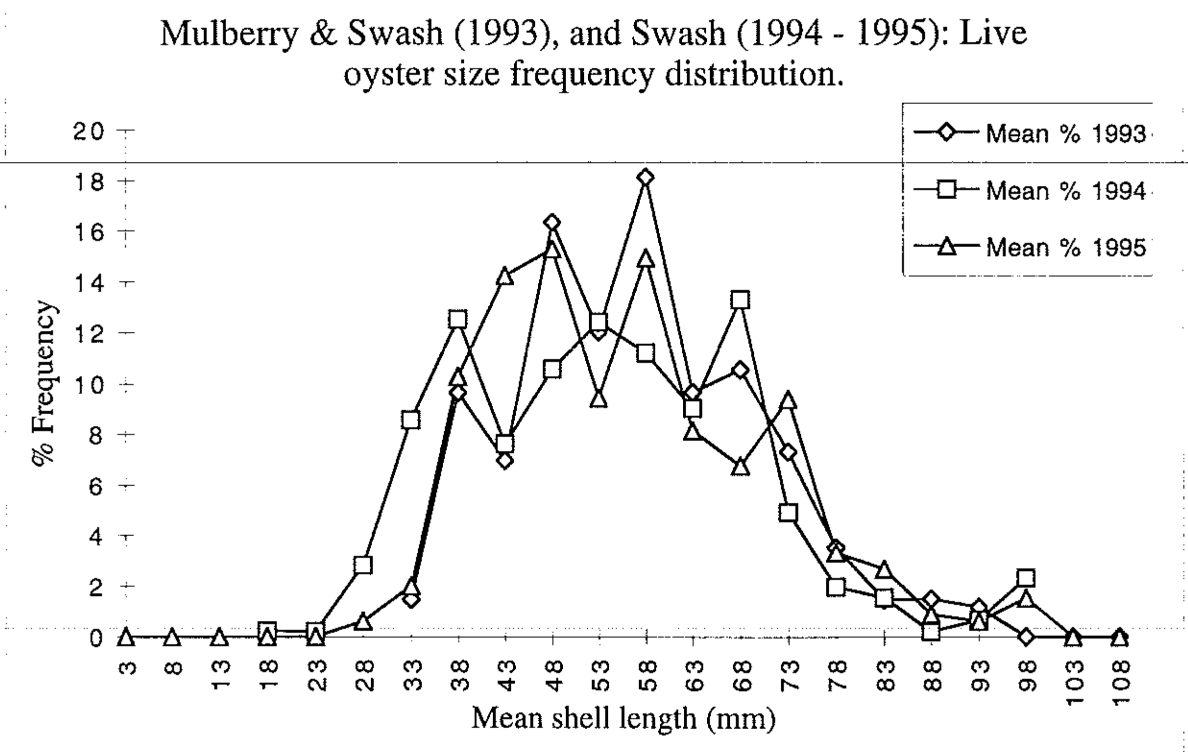
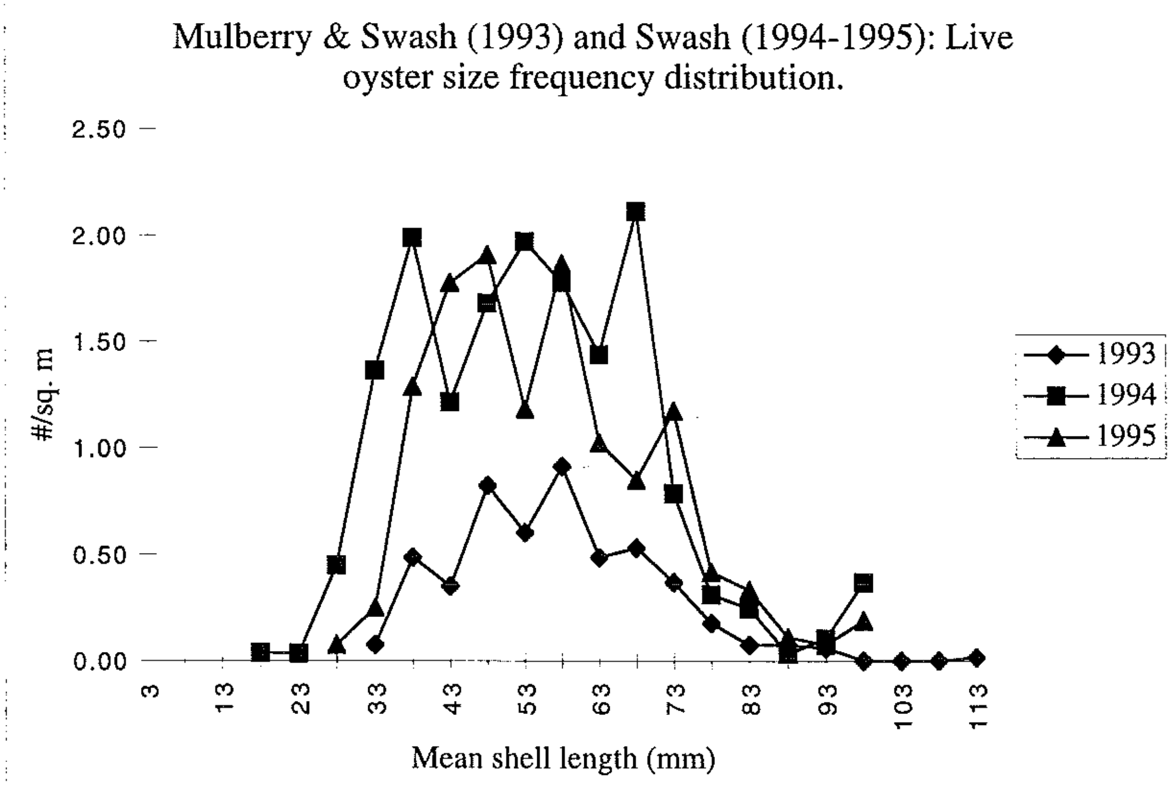

Mulberry Point Region: Live oyster size frequency distribution. Mulberry upriver 1993, and Mulberry Point 1994-1995
#/sq.m
8
7
6
5
4
3
2
1
0
3
13
23
33
43
53
63
73
83
93
103
Mean shell length (mm)
1993
1994
1995

Figure 2.13



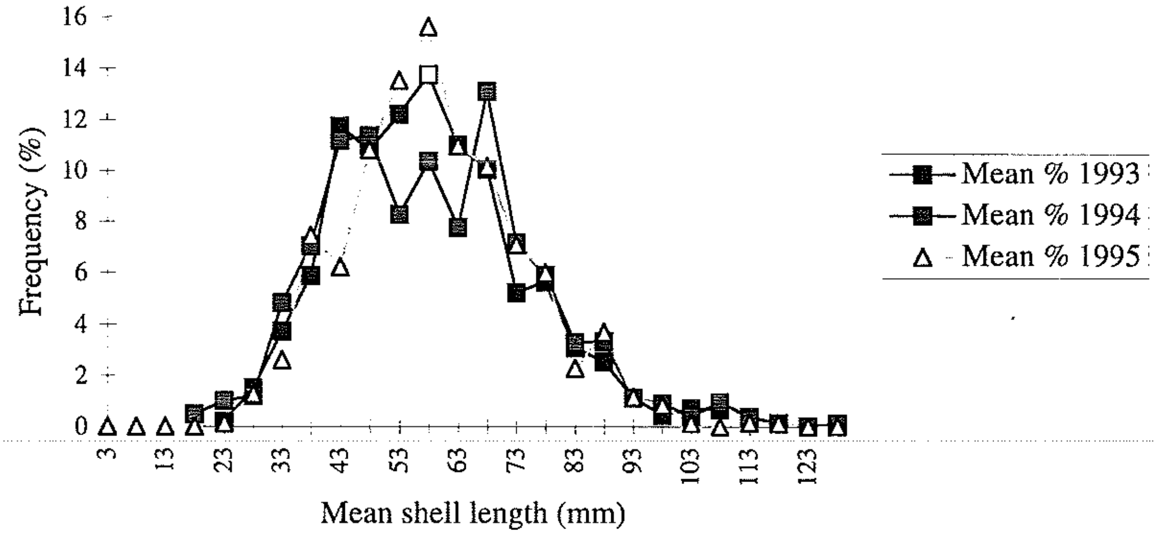
Mulberry & Swash (1993), and Swash (1994 - 1995): Live oyster size frequency distribution.
Mean % 1993
Mean % 1994
Mean % 1995
% Frequency
20
18
16
14
12
10
8
6
4
2
0
3
8
13
18
23
28
33
38
43
48
53
58
63
68
73
78
83
88
93
98
103
108
Mean shell length (mm)



Mulberry & Swash (1993) and Swash (1994-1995): Live oyster size frequency distribution.
1993
1994
1995
#/sq. m
2.50
2.00
1.50
1.00
0.50
0.00
3
13
23
33
43
53
63
73
83
93
103
113
Mean shell length (mm)

Figure 2.14

Upper Jail Island: live oyster size frequency distribution.
1993 - 1995



Upper Jail Island: Live oyster size frequency distribution:
1993-1995

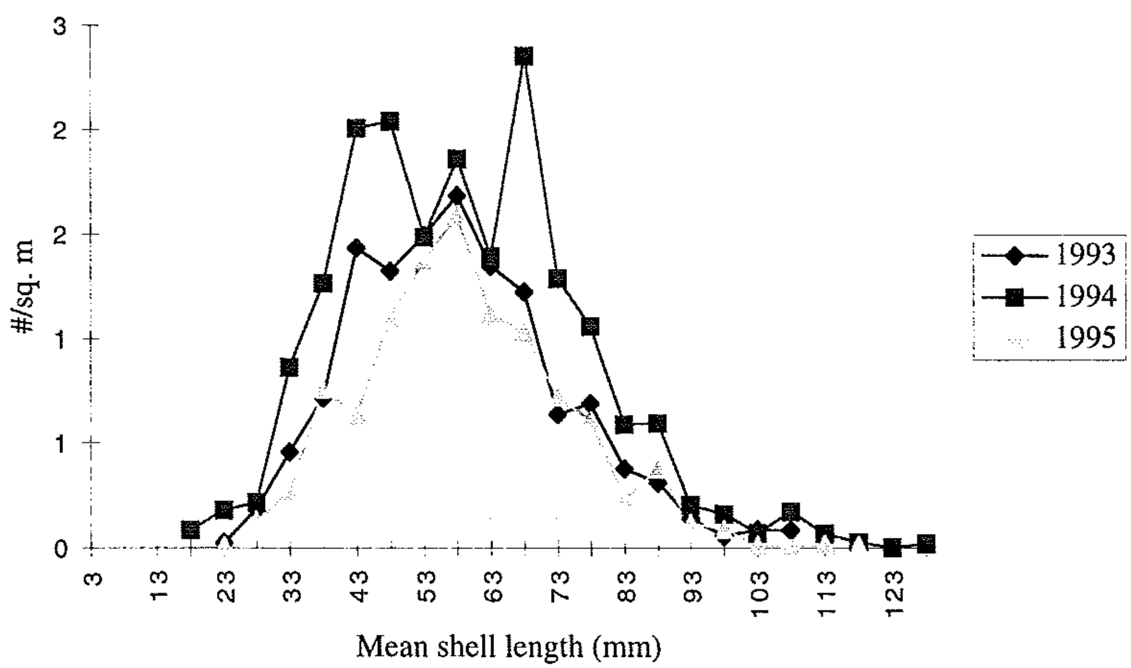
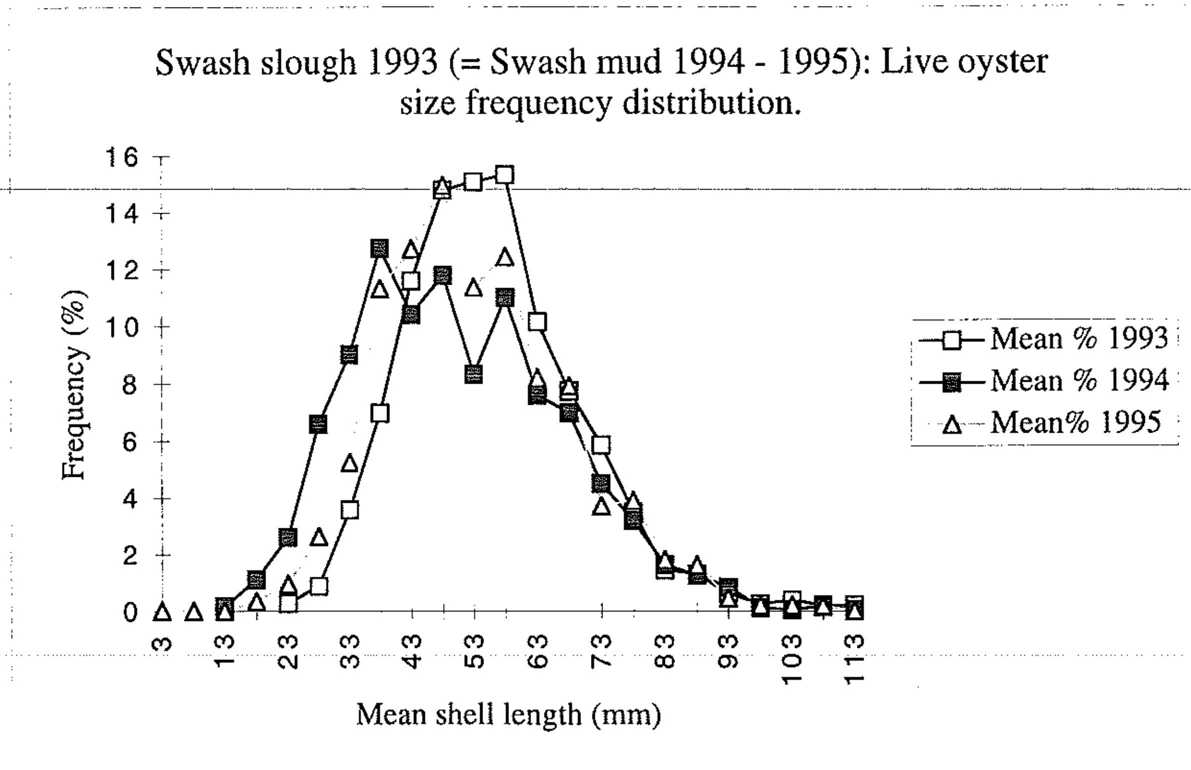
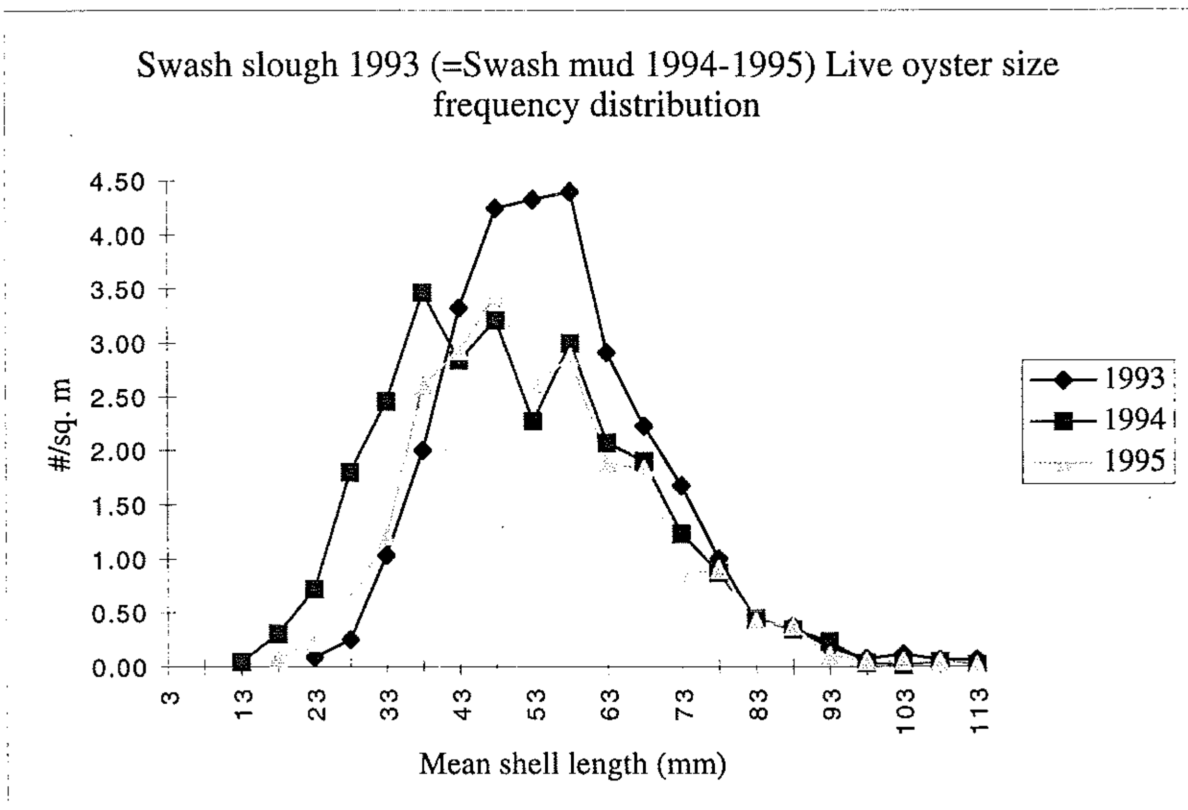


Figure 2.15

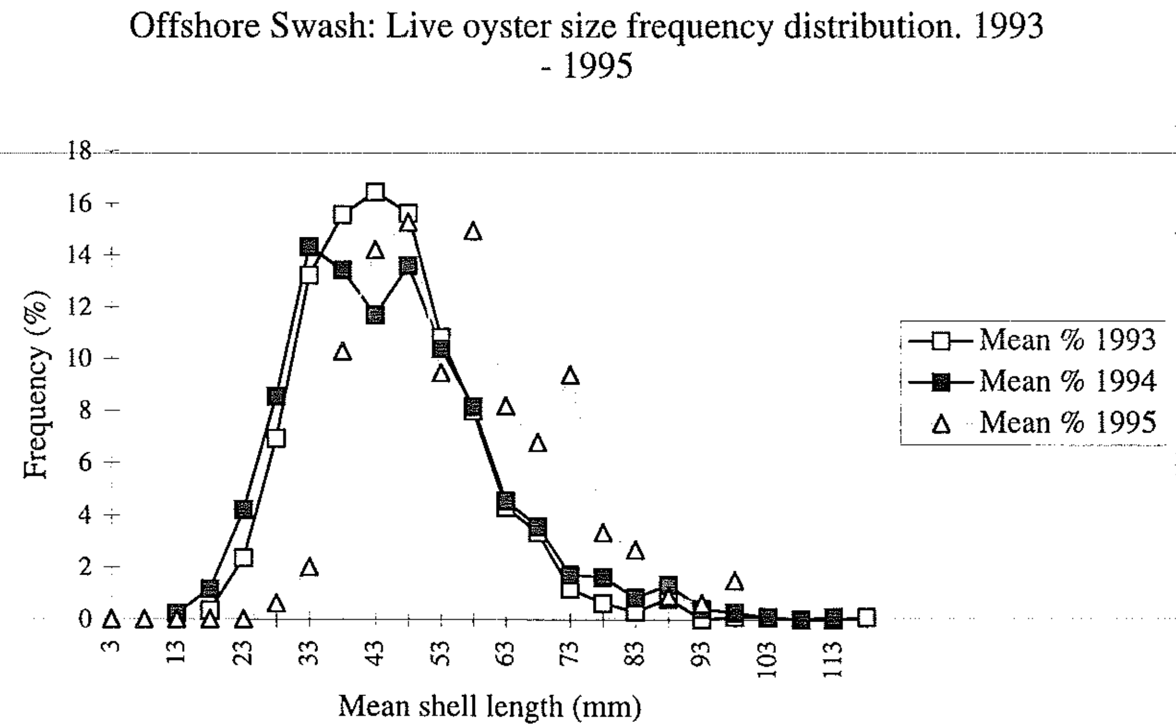


Swash slough 1993 (= Swash mud 1994 - 1995): Live oyster size frequency distribution.
Frequency (%)
16
14
12
10
8
6
4
2
0
3
13
23
33
43
53
63
73
83
93
103
113
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean% 1995



Swash slough 1993 (=Swash mud 1994-1995) Live oyster size frequency distribution
#/sq. m
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3
13
23
33
43
53
63
73
83
93
103
113
Mean shell length (mm)
1993
1994
1995

Figure 2.16


Offshore Swash: Live oyster size frequency distribution. 1993 - 1995
Frequency (%)
0
2
4
6
8
10
12
14
16
18
3
13
23
33
43
53
63
73
83
93
103
113
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

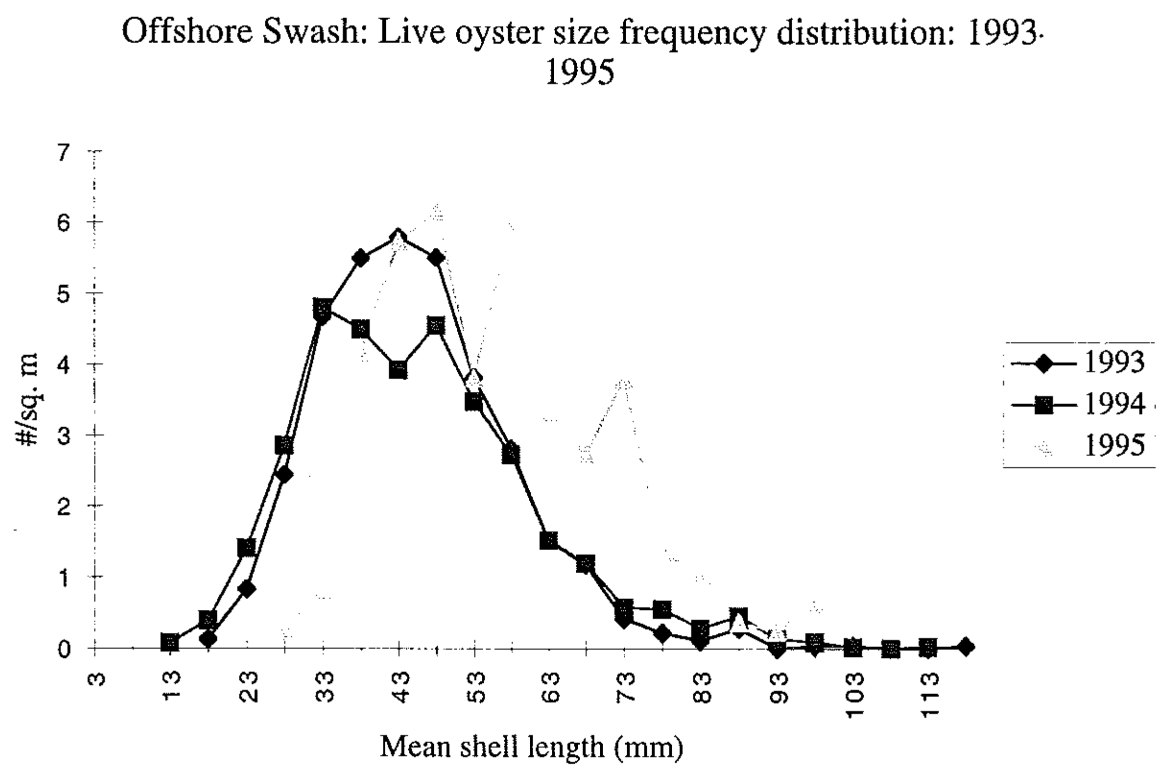
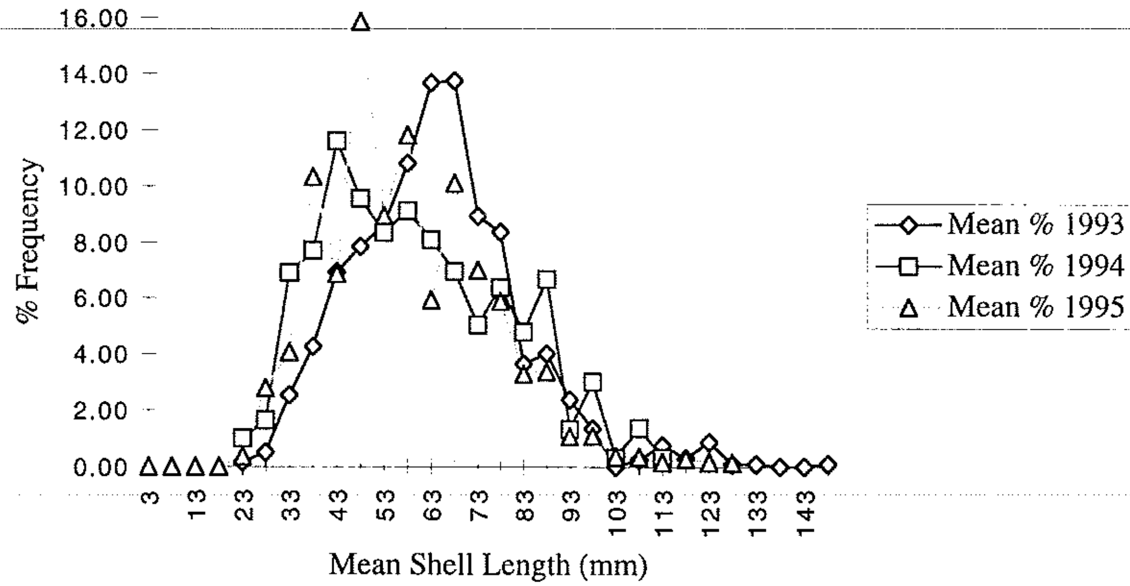

Offshore Swash: Live oyster size frequency distribution: 1993-1995
#/sq. m
0
1
2
3
4
5
6
7
3
13
23
33
43
53
63
73
83
93
103
113
Mean shell length (mm)
1993
1994
1995

Figure 2.17

Lower Jail Island: Oyster size frequency distribution.
1993 - 1995



Lower Jail Island: Oyster size frequency distribution:
1993-1995

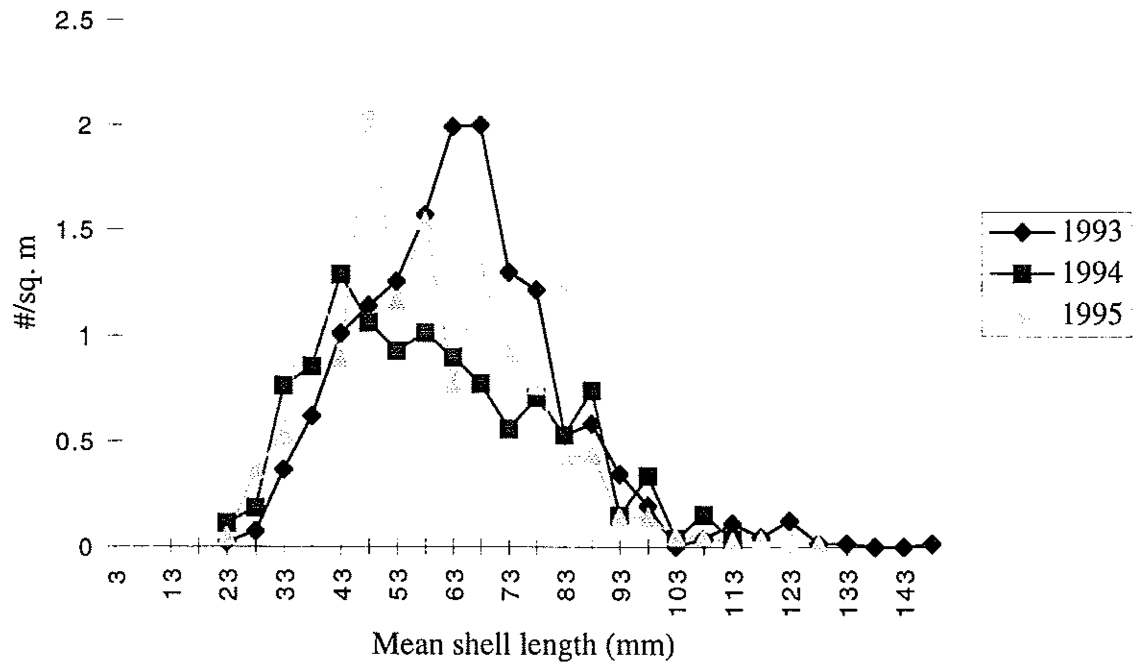
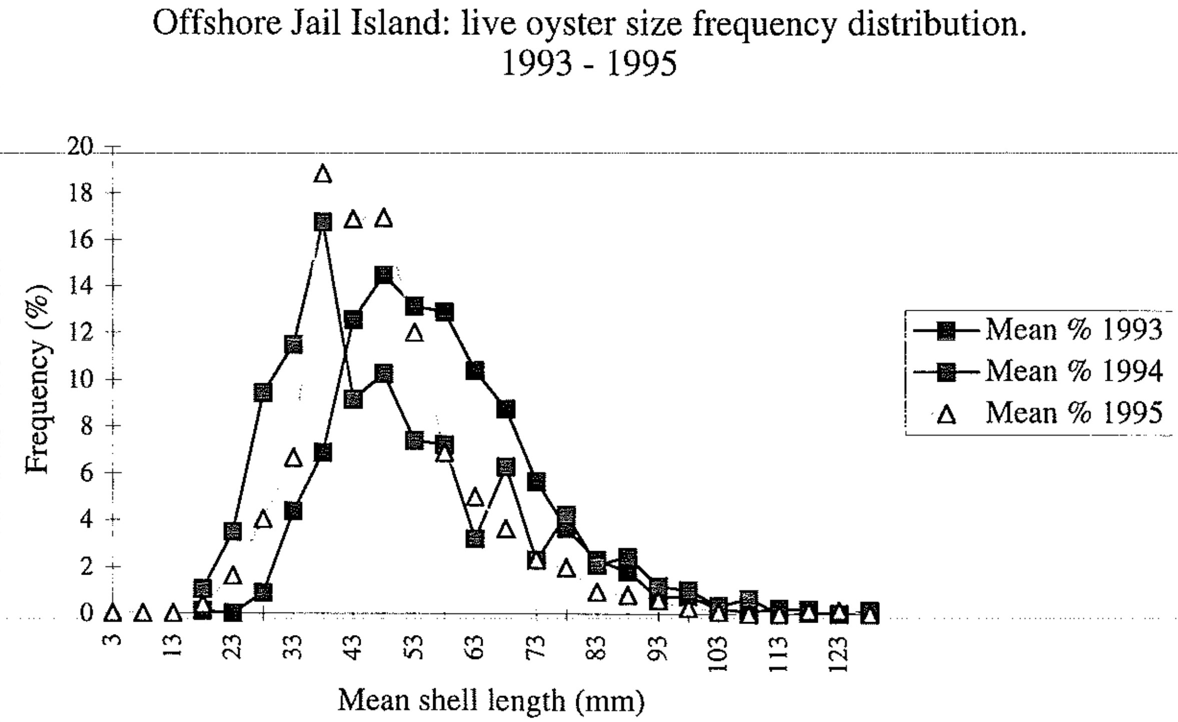
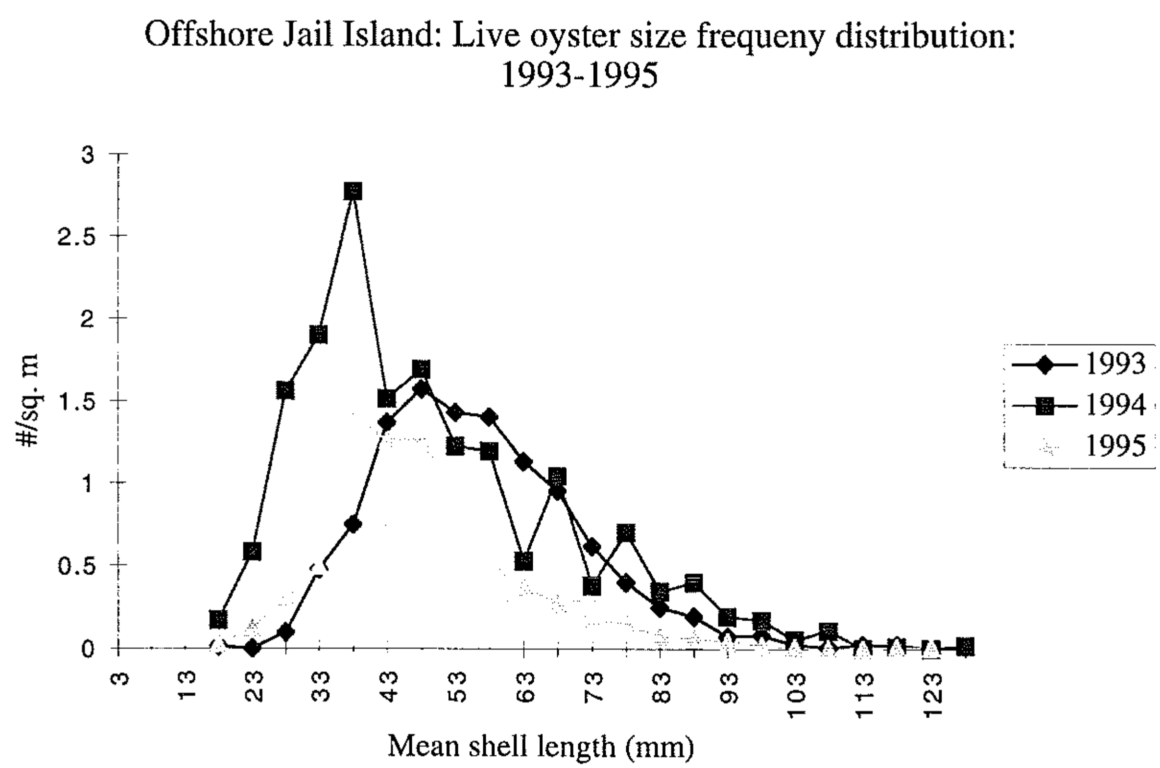


Figure 2.18

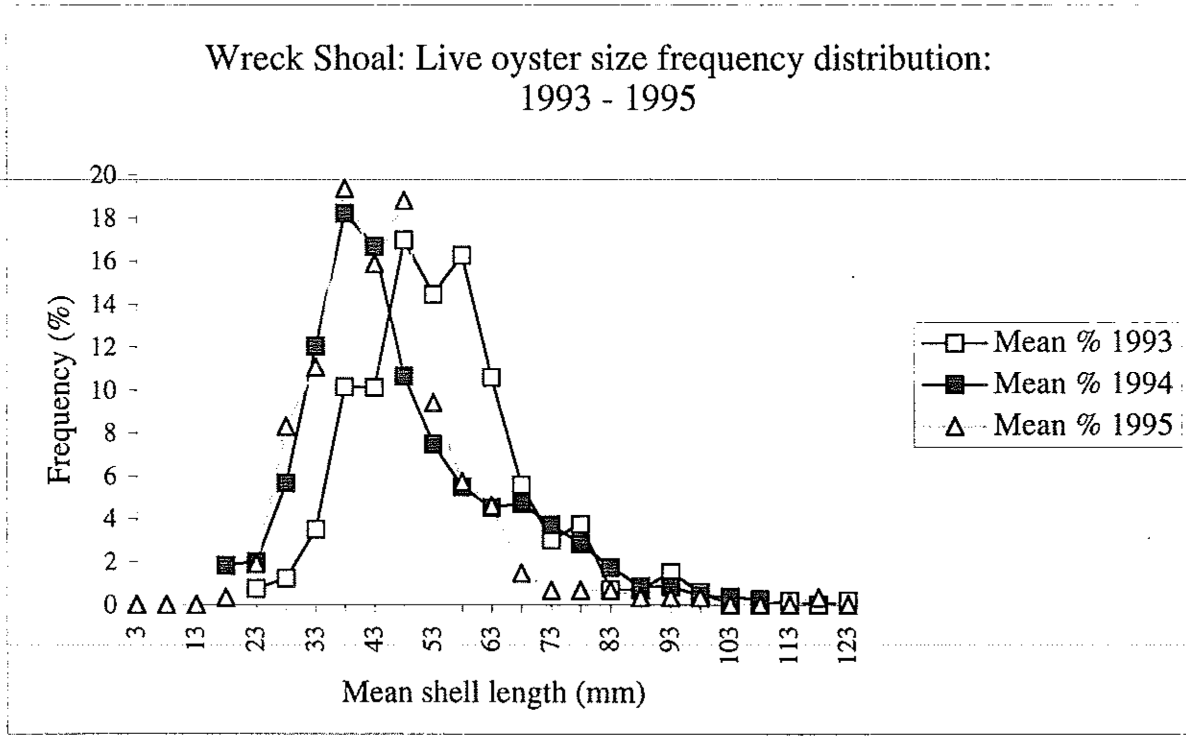


Offshore Jail Island: live oyster size frequency distribution.
1993 - 1995
Frequency (%)
20
18
16
14
12
10
8
6
4
2
0
3
13
23
33
43
53
63
73
83
93
103
113
123
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995

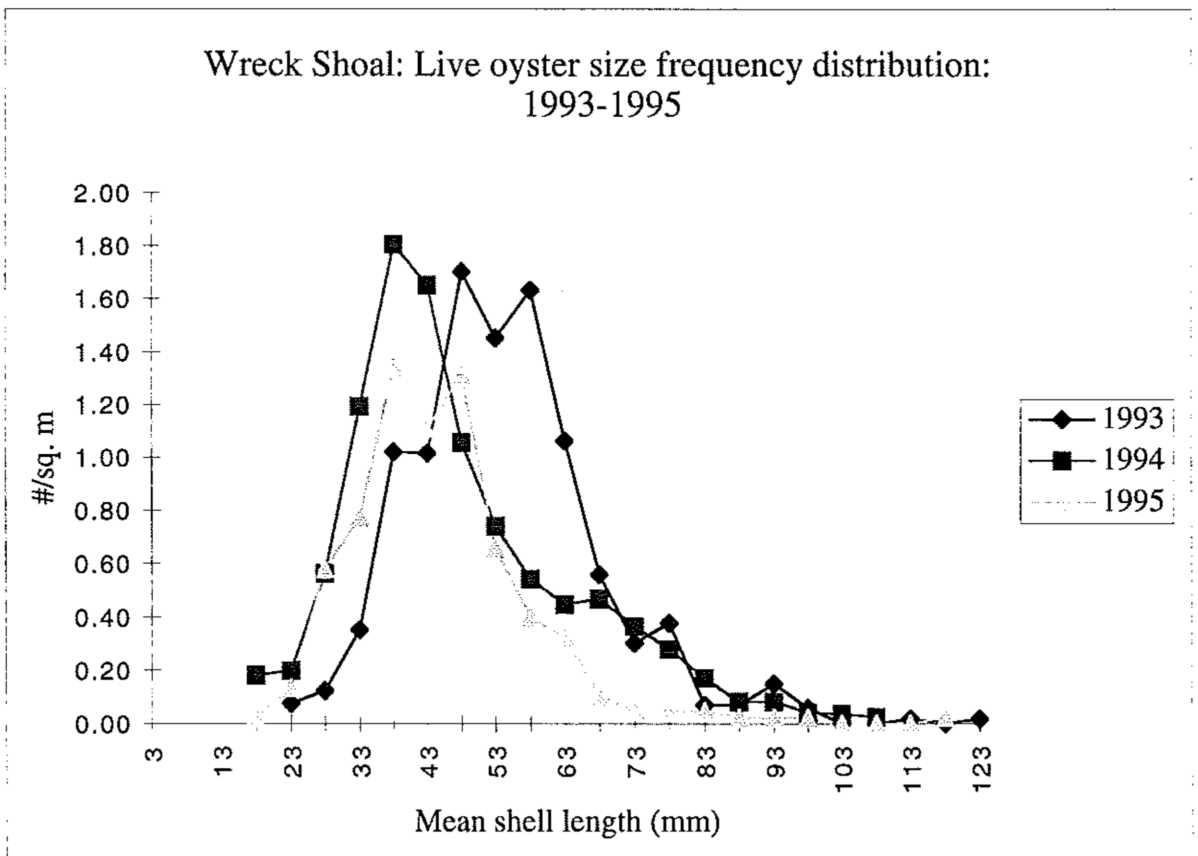


Offshore Jail Island: Live oyster size frequeny distribution:
1993-1995
#/sq. m
3
2.5
2
1.5
1
0.5
0
3
13
23
33
43
53
63
73
83
93
103
113
123
Mean shell length (mm)
1993
1994
1995

Figure 2.19



Wreck Shoal: Live oyster size frequency distribution: 1993 - 1995
Frequency (%)
20
18
16
14
12
10
8
6
4
2
0
3
13
23
33
43
53
63
73
83
93
103
113
123
Mean shell length (mm)
Mean % 1993
Mean % 1994
Mean % 1995



Wreck Shoal: Live oyster size frequency distribution: 1993-1995
#/sq. m
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
3
13
23
33
43
53
63
73
83
93
103
113
123
Mean shell length (mm)
1993
1994
1995

3. Methods: Seaside of Eastern Shore of Virginia

The selection of sample locations, numbers and sampling gear

The shallow intertidal reef systems of the Seaside if the Eastern Shore of Virginia represent a much different sampling problem to the subtidal reefs of the Chesapeake Bay. The Seaside reefs are vast in number but generally small in size - many are in the range of less than one acre to two acres. Many exist as fringing regions of reef as the reef progresses into high marsh grass regions. Few have been adequately surveyed. The shallow reef systems are found along the entire Virginia shoreline from Chincoteague in the north to Fisherman's Island at the southern tip of the DelMarVa peninsula. Given the limited resources in time and personnel available to us we determined that the optimum approach to the task of stock assessment was to select identified reefs in a limited number of areas along the coastline. For the Spring 1995 survey (1994-1995 funding) five areas were examined. From north to south these were Chincoteague, Wachapreague, Quinby, Hog Island, and Oyster. For the Spring 1996 survey (1995-1996 funding) this was reduced to sampling in the Oyster region on February 13, 1996, and the Oyster region on February 14, 1996. These locations are illustrated in Figure 3.1. In each area reefs were chosen based on recent (1992 and subsequent) replenishment activity by the VMRC Shellfish Replenishment Program. It is important to emphasize that assessment in these locations focus on regions that have been subjected to replenishment activity rather than just natural reefs or rocks. Thirty one reef systems were identified for examination in 1995. Twenty one reef systems were identified in 1996. Initial attempts in 1995 to survey these reefs to provide "overlays" for random sampling proved difficult, time consuming and to all intents impractical, so we resorted to haphazard sampling. This consisted of sampling at low tide with a quarter meter square quadrat. At low tide these reefs illustrate that oysters optimally inhabit a very narrow depth range in the intertidal. The sampling quadrat was literally thrown haphazardly into the air above the reef and the sampling location determined by where it landed. All material in the quadrat was collected in mesh bags (one bag per quadrat) and returned to the VIMS Wachapreague laboratory for examination. Protocols for sample evaluation were as for samples collected in the James and Rappahannock Rivers: market, small and spat size oysters, mortality estimates from "boxes", and residual shell volumes. Seven quadrats were collected from each reef sampled for a total of 217 samples in 1995, and 147 samples in 1996.

4. Results and Discussion: Seaside of Eastern Shore of Virginia

Data analysis

Unlike surveys in the James and Rappahannock Rivers the sampling of the seaside was limited in statistical rigor by the choice of a haphazard sampling protocol with a fixed number of samples per sampling area. No attempt was made to investigate optimal sample numbers per sampling area prior to sampling, although modest standard deviations in the resultant groups suggest representative coverage. Also, the small size of the sample area and the large number of areas to be sampled dictated an efficiency in effort at each location.

General summary of population sizes

For comparison purposes Both 1995 and 1996 data are given in Table 4. 1995 sampling has been discussed in detail in the previous annual report. Discussion here will focus on comparison of 1995 and 1996 data for the Quinby and Oyster sampling areas. 1995 data from Quinby stations was characterized by relatively low spat abundance but high abundance's of small oysters. Given that the 1996 surveys were effected in January it is probable that a high proportion of the 1995 small oysters grew through summer of 1995 and were harvested

Figure 3.1. Location of the areas sampled during the Spring 1995 (1994-1995 funding) and Spring 1996 (1995-1996 funding) oyster stock assessment surveys on the Eastern Shore peninsula of Virginia. A list of individual bars in each area is given in Table 4.

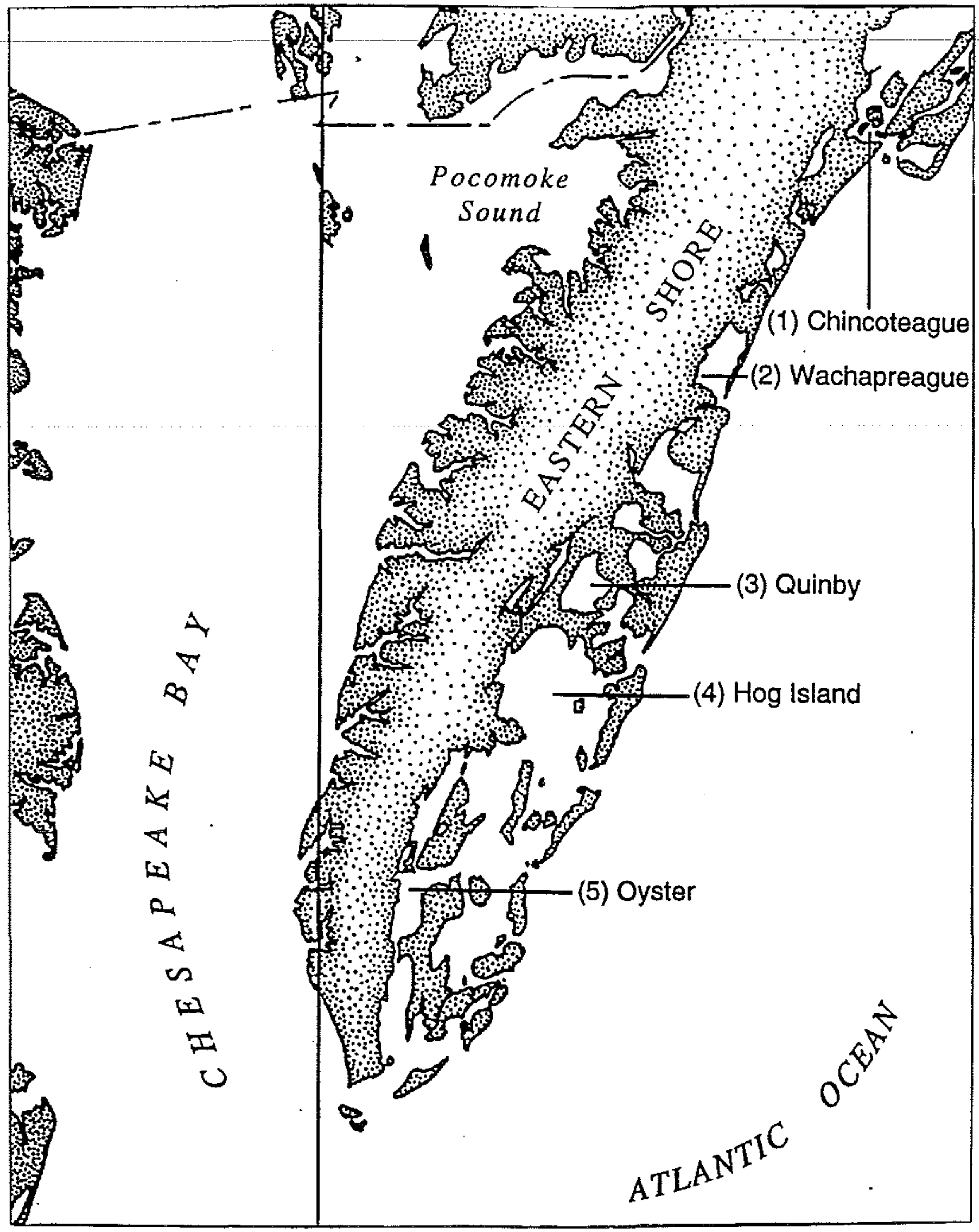


Table 4: Seaside of Eastern Shore of Virginia Oyster Stock Assessment: Spring 1995 and Spring 1996
All values are the mean number per sq. m (based on seven collections from randomly deployed 0.25 sq. m quadrats)

Area and Station Location	Oysters				Boxes			Residual
	Spat	Small	Market	Total	New	Old	Total	Shell L
(1) Chincoteague, 1995								
Watts Bay high	18.3	133.7	33.1	185.1	3.4	8.6	12.0	9.1
Watts Bay low	4.6	1.7	0.0	6.3	0.0	6.9	6.9	19.4
(2) Wachapreague, 1995								
Bradford Bay 1993-94 shell plant	4.6	129.7	4.6	138.9	13.7	8.6	22.3	16.6
Bradford Bay 1993 turnover east	1.7	45.1	2.3	49.1	10.3	9.7	20.0	27.4
Bradford Bay 1993 turnover west	0.6	40.6	0.6	41.7	6.9	16.0	22.9	22.9
North Hummock 1993 & 1994 shell plant	11.4	9.7	0.0	21.1	1.7	0.0	1.7	18.3
North Hummock 1993 turnover & 1994 shell plant	16.6	9.7	0.0	26.3	1.7	4.0	5.7	13.1
South Hummock 1993 shell plant	2.9	219.4	2.3	224.6	5.1	4.6	9.7	12.6
South Hummock 1993 turnover	14.3	353.1	10.3	377.7	20.0	34.3	54.3	24.6
(3) Quinby, 1995								
Barge Point 1993 high shellplant	8.0	406.3	2.9	417.1	16.6	4.6	21.1	4.3
Barge Point 1993 low shell plant	0.6	46.9	0.0	47.4	6.3	1.1	7.4	4.0
Cockle Creek 1992 shell plant & 1993 turnover	1.1	358.3	55.4	414.9	20.0	14.9	34.9	8.0
Major Midhole 1993 shell plant	24.0	176.6	2.9	203.4	9.1	12.0	21.1	14.9
Middle Gap South 1993 turnover	24.0	276.6	1.7	302.3	21.7	50.9	72.6	27.4
Middle Gap North 1993 shell plant	19.4	66.3	2.3	88.0	27.4	30.9	58.3	14.0
Middle Gap North 1993 turnover	3.4	95.4	8.0	106.9	12.0	4.6	16.6	8.6
(3) Quinby, 1996								
Barge Rock, 1993 shell plant	529.1	54.9	10.9	594.9	3.0	15.9	18.9	1.4
Barge Rock, 1994 shell plant	88.6	24.6	4.0	117.1	1.0	2.1	3.1	1.7
Bordenstake 1994 shell plant	682.9	57.1	8.0	748.0	2.3	17.7	20.0	1.2
Cockle Creek 1993 turnover	246.9	36.6	21.7	305.1	2.9	23.9	26.7	2.1
Little Gap 1993 turnover	336.0	21.1	2.9	360.0	2.0	3.4	5.4	4.2
Major Mud Hole 1993 turnover	303.4	81.7	0.0	385.1	4.6	5.3	9.9	1.9
Middle Gap East 1993 shell plant	303.4	53.1	4.6	361.1	2.1	9.4	11.6	2.3
Middle Gap West 1993 turnover	410.9	73.7	4.0	488.6	3.1	16.6	19.7	2.6
Middle Gap West 1993 turnover, 1995 shell plant	183.4	14.9	1.7	200.0	0.9	3.6	4.4	3.1
Sloop Channel 1995 turnover	609.7	128.0	1.1	738.9	4.9	10.0	14.9	2.3
Uphur Bay Channel 1995 shell plant	440.6	14.3	2.3	457.1	2.7	0.6	3.3	2.3
(4) Hog Island, 1995								
Upper Draft 1993 shell plant high	145.1	393.1	0.0	538.3	37.7	16.6	54.3	24.6
Upper Draft 1993 turnover	115.4	72.0	0.0	187.4	17.7	17.1	34.9	21.7
Upper Draft 1993 shell plant low	23.4	81.1	0.0	104.6	17.1	2.9	20.0	20.0
Upper Draft bagless dredge	30.9	54.9	0.0	85.7	9.1	16.0	25.1	32.3
(5) Oyster, 1995								
Brockenberry 1992 shell plant	82.3	117.7	2.3	202.3	13.7	84.6	98.3	14.3
Brockenberry 1993 shell plant	27.4	506.3	8.6	542.3	60.0	45.7	105.7	2.1
Narrow Channel S.W. 1992 shell plant	31.4	243.4	4.0	278.9	26.3	44.6	70.9	10.9
Narrow Channel S.W. 1993 shell plant	30.3	77.7	1.1	109.1	13.7	7.4	21.1	15.7
Narrow Channel East 1993 turnover	11.4	6.3	0.0	17.7	1.7	6.3	8.0	20.0
Narrow Channel turnover west	5.1	0.0	0.0	5.1	0.0	4.0	4.0	29.1
Pointer Rock 1993 shell plant high	26.9	128.6	0.6	156.0	11.4	11.4	22.9	11.6
Pointer Rock 1993 shell plant low	26.9	125.7	3.4	156.0	22.3	25.7	48.0	4.6
Pointer Rock 1993 turnover	24.6	197.1	0.0	221.7	39.4	23.4	62.9	18.6
Rams Horn shell plant	34.3	125.1	1.1	160.6	14.9	52.0	66.9	9.1
Rams Horn 1993 turnover	41.1	31.4	0.6	73.1	14.9	42.9	57.7	12.9
(5) Oyster, 1996								
Narrow Channel West 1993 turnover	268.7	0.0	0.0	268.7	1.0	0.5	1.5	3.7
Narrow Channel 1993 shell plant	205.1	63.4	14.3	282.9	2.7	1.7	4.4	2.9
Narrow Channel 1992 shell plant	465.7	41.1	0.0	506.9	2.9	16.7	19.6	3.0
Narrow Channel 1993 turnover	825.1	31.4	1.1	857.7	2.0	1.0	3.0	2.4
Pointer Rock 1993 shell plant	211.4	56.6	1.7	269.7	5.3	11.9	17.1	1.6
Pointer Rock 1993 (old rock)	994.3	57.1	10.9	1062.3	9.7	30.6	40.3	0.7
Pointer Rock East 1993 turnover	701.7	30.3	3.4	735.4	2.9	14.4	17.3	1.6
Pointer Rock West 1993 turnover	632.6	52.6	1.7	686.9	4.9	15.6	20.4	1.1
Running Channel 1994 turnover	406.9	58.9	1.1	466.9	4.6	14.4	19.0	2.4
South Bay 1994 shell plant	303.4	32.6	0.0	336.0	2.7	16.7	19.4	2.7

in the public market season during the Fall of 1995. Market oyster abundance's were generally low at Quinby stations in 1996, but spat abundance's were very high, consistently higher than any stations in the James River. This promises to be good for future harvests in this limited area of the Eastern Shore as these spat grow to market size. A similar pattern to the Quinby stations was observed at the Oyster stations with consistently exceptional spat settlement, good small oyster abundance's (better than all but a few reefs in the James River), but a very limited number of market oysters. Again, the decrease in small oyster abundance's may well have been related to growth and harvest activity in 1995.

High spat densities are a indicator of the value of careful replenishment activity; however, the variability between spatially adjacent stations offer the opportunity to examine variation related to the type of replenishment activity (e.g., shell turnover versus shell plant). Until recently the majority of replenishment activity on the Seaside has consisted of shell planting and bagless dredging; however, this has more recently been supplemented with "turnover"; effective exhumations of deeper buried shell than would typically be exposed by bagless dredging. "Turnover" is effected with a device similar to a garden tiller, and is cost comparable with shell planting in areas where buried shell resource is abundant, a description which applies to numerous sites on the Seaside that have recently been inundated with finer sediments. The use of a "turnover" approach minimizes the cost associated with logistics of large shell volumes, small barge movement and tides that dominate activity in the Seaside reef and marsh systems. 1995 observations of small and market oyster abundance at Cockle Creek suggested that, when used in combination with shell planting, this approach produced the highest oyster densities observed at any stations in the entire surveys. When used as the single replenishment activity at Middle Gap, Upper Draft, and Pointer Rock (Area 3, 4 and 5 respectively) oyster densities were still very high (100-300 oysters per sq. m range), at the last location exceeding that of adjacent shell plants. Only at Narrow Channel (Area 5) was the turnover approach both unsuccessful and notably poorer than adjacent shell plant stations. 1996 observations at the Quinby stations of Cockle Creek, Major Mud Hole, Middle Gap West, Sloop Channel, and Uphur Bay Channel all suggested the value of "turnover" procedures by the presence of high oyster densities. Similar comments are appropriate to Oyster stations at Narrow Channel West, Narrow Channel, Pointer Rock and Running Channel.

The estimates of mortality in these populations from articulated shells (boxes) are lower in 1996 data that in 1995; however, the residual shell values have also decreased suggesting some loss associated with harvesting or burial of shell since the 1995 surveys. Residual shell in samples for 1996 is comparable or lower than James River data for the same period.

Conclusions and recommendations

The current survey represents the third year of fishery independent surveys in the James and Rappahannock Rivers, and essentially the first such surveys for other parts of the Virginia portion of the Chesapeake Bay. The concordance of total standing stock for 1994 and 1995 Fall surveys and small oyster estimates for all survey years in the James and Rappahannock rivers lends support to the soundness of the survey design (see Table 3). The notable decrease in market oyster estimates for Fall 1995 in the James River (see Table 3) has been addressed earlier. The disparity in estimates of small and market oysters between 1994 and 1995 Fall surveys is very much accounted for the by the change in the dividing size limit from 2.5 to 3 inches (63 to 76 mm) and further supported by the extensive size distribution data. Within the Bay the only the James River remains as an oyster resource of any substance. The alarming decline of market oysters in the James between the Fall 1994 and Fall 1995 surveys was not related to commercial harvest but to atypical environmental conditions which exacerbated disease associated losses, and added the insult of a major summer freshet resulting in further mortalities associated with low salinity stress at high temperature. These atypical events serve to underscore the fragility of the James River oyster resource. If this is to be considered as the remaining vestige of native oyster in the Virginia portion of the Bay, and if there is to be serious adoption of a commitment in resource management to "No Net Loss" as recommended by the Haskell - Pruitt Blue Ribbon Panel, then there must be appreciation of fishery independent data by management agencies. We cannot assume that when, **in any one year**, market harvest is equal to recruitment that we have the basis for a **multi year** plan to stabilize or rebuild the resource. Losses such as those observed in the 1994-1995 period may be atypical, but without a commitment to build equity in the resource on a annual basis such unpredictable losses will result in continuing erosion of the resource to unacceptably low levels. There is clear need to consider "No Net Loss" **as a minimal acceptable standard within any one year**, but with a long term commitment to build equity in the resource in order to buffer against atypical years where natural events cause extensive mortality. Management based on assessment data, especially management by region, is prudent and urgently required. In spite of our best efforts, and the approval of our studies by peers in the scientific community, we have yet to attain an acceptable equilibrium situation with active fishery managers. The most recent debate over options for use of the very depauperate resource in Tangier Sound illustrates this situation.

Size distribution data for the James River further illustrate losses over the 1994-1996 period, but also serve to indicate the value of recent initiatives to apply shell at maintenance levels to facilitate spat settlement on productive reefs, and to make certain areas of the river "market only" harvesting regions requiring the return of all spat and small oysters caught during harvest. These activities have resulted in increases in small oyster numbers on "market only" reefs as illustrated in the series of Figures in section 2. With typical river flow years such small oysters should recruit to the fishery in a two-three year time period.

The general lack of shell resource throughout the Virginia portion of the Bay remains a great concern. Again, education must prevail. In a previous annual report we commented that replenishment activity must focus on low density shell supplementation of extant reef, not on misguided attempts to extend reefs into areas where they have not developed over recent geological time. Some progress is being made in this arena but it is painfully slow. Oyster shells, an already valuable and increasingly costly resource, will rapidly bury and require further shell application unless applied in an optimum region and at optimum thickness. The long employed methods of large scale shell planting which allowed only minimal control of the thickness of application have been subject to recent attention, and while they are not perfect, they are improved with respect to controlled shell application at lower density.

The Seaside of the Eastern Shore of Virginia has generally received secondary attention in terms of replenishment activity. A recent (past five years) increase in the status of this area has been driven by the conviction that there exists untapped potential for an oyster fishery on the Seaside. Certainly, the results of limited surveys in early 1995 and 1996 are very encouraging, with a number of site showing large numbers of small oysters and an exceptional spat settlement in 1995. Continued development of the Seaside reefs would appear prudent, although it must be realized that these are of limited area, they are spatially disparate (providing law enforcement nightmares) and in regions where sustained shell planting can be logistically difficulty and/or expensive. Fortunately, the cultivation or "turnover" of buried shell appears a promising technique for use in marginal regions of fresh shell availability and is clearly worthy of further application in a wider area.

Literature cited

Bros, W. E. and B. C. Cowell. 1987. A technique for optimizing sample size (replication). J. Exp. Mar. Biol. Ecol. 114: 63-71.

Chai, A-L, M. Homer, C-F. Tsai and P. Goulletquer. 1992. Evaluation of oyster sampling efficiency of patent tongs and an oyster dredge. North American Journal of Fisheries Management 12: 825-832.

Hargis, W. J. Jr. and D. S. Haven. 1988. The imperilled oyster industry of Virginia. VIMS Special Report NUmber 290 in Applied Marine Science and Ocean Engineering. 130p.

Haven, D. S., W. J. Hargis, Jr. and P Kendall. 1981. The present and potential productivity of the Baylor Grounds in Virginia. Va. Inst. Mar. Sci., Spec. Rep. Appl. Mar. Sci. Ocean. Eng. No. 243: 1-154.

Haven, D. S. and J. P. Whitcomb. 1983. The Origin and Extent of Oyster Reefs in the James River, Virginia. J. Shellfish Res. 3(2):141-151

Haven, D. S. and J. P. Whitcomb. 1989. The Location and Topography of oyster reefs in the Rappahannock River Estuary, Virginia. J. Shellfish Res. 8:105-116