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Investigations of the effects on oyster culture of the dredging for the Hampton Roads bridge-tunnel : an investigation conducted by the Virginia Fisheries Laboratory for the Virginia State Department of Highways

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INVESTIGATIONS OF THE EFFECTS ON OYSTER CULTURE OF THE DREDGING FOR THE HAMPTON ROADS BRIDGE-TUNNEL

An investigation conducted by the Virginia Fisheries Laboratory for the Virginia State Department of Highways

Special Scientific Report No. 12

Virginia Fisheries Laboratory
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Addendum to Special Scientific Report No. 12

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Since Special Scientific Report No. 12 was issued, additional recoveries of marked oysters have been made in Hampton Roads. Tables 3 and 4 have been revised to include new data collected since the final report was completed, some old data omitted previously, and to correct an error in Table 4. It is requested that these revised tables be substituted for the old ones.

Because the recovery of marked oysters at some stations had been poor, another attempt was made on June 14 and 17, 1957, by diving. At Station 3, near Darling's watchhouse, a good recovery was made. More than one-third of the marked oysters had died, but some of these were small and obviously had been dead for more than a year. Eliminating these, a death rate of 30 per cent for the past year was derived.

The surviving oysters at Station 3 were large market oysters which have shown excellent growth since they were planted over two years ago. Most live oysters and boxes were settled firmly in the bottom.

We dived at other stations including Station 2 (Ballard's Plot 7), Station 4 (Miles' Plot 2), and a station offshore from Darling's watchhouse. At each of these places paint-marked oysters had been planted but the original stakes and buoys were gone and none of the marked oysters could be found.

It was called to our attention that lack of authors' names on Special Scientific Report No. 12 may prove an inconvenience to our colleagues and others referring to the report. We request, therefore, that the names of the authors be placed on the covers as follows: Jay D. Andrews, Dexter S. Haven, and J. L. McHugh.

Investigations of the Effects on Oyster Culture of the Dredging for the Hampton Roads Bridge-Tunnel

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INTRODUCTION

The possible effects of the Hampton Roads bridge-tunnel project upon adjacent oyster grounds can be divided conveniently into three categories: (1) losses of oysters by deaths, (2) reduction of growth and decrease of condition or fatness, and (3) damage to the oyster beds which result in losses in the first two categories over a period of years. These effects are listed in the order of increasing difficulty of biological analysis and most of our efforts have been given to the first item.

There is no easy way of determining the mortality on a bed of oysters for a fixed period of time unless the losses are sudden and catastrophic in magnitude. If a sudden mortality occurs, counts of fresh boxes (hinged valves with the meats gone) and live oysters will give a fairly reliable estimate of the death rate. The validity of box counts will be discussed later, but realizing the deficiencies of this method, we have attempted to estimate the death rates by the use of trays and marked oysters on natural beds.

To study the causes of oyster deaths, it is essential to separate or isolate each factor insofar as possible. We have found that in lower Chesapeake Bay about one-fourth to one-fifth of oysters placed in trays suspended above the bottom die each year. Since these oysters are protected from predators and removed from factors associated with the bottom, it is apparent that a good many oysters die from diseases and parasites carried by the water itself. It is our purpose to determine the normal level of: 1. water-associated mortality, 2. bottom-associated losses. For each of these groups of death agents, it is important to know seasonal patterns and annual variations of losses. Any obvious deviations from these patterns can be analyzed with respect to the bridge-tunnel construction activities.

Most of these studies are concerned with oysters over two years of age and over two inches in length. Seed from the James River contains many spat and small oysters, of which many are lost to drills and smothering soon after planting. We have not attempted to determine the death rates of these small young oysters since it would be extremely difficult, and most oystermen believe these are not very important in producing a crop. Furthermore, most oysters which survive the drills reach two inches the first summer after transplanting and thereafter are relatively immune to predation.

MORTALITY OF OYSTERS IN TRAYS

Since 1950 we have been holding various groups of oysters in trays suspended in the York River at Gloucester Point. About 75 different groups have been studied and most of the results are given in two published papers by Hewatt and Andrews (1954) and Andrews and Hewatt (1957). Since the oysters are examined and counted frequently, the death rates are accurate and the major causes of death well-established. The seasonal patterns and annual variations in death rates of oysters in the trays at Gloucester Point are important as background for we intend to show that these are similar in Hampton Roads. We will then attempt to relate the deaths in trays to those on natural bottoms and much of this work has been pursued on private grounds, commercially operated by the Tillages, near Gloucester Point.

The agents causing deaths of oysters in trays are: 1. the fungus Dermocystidium, 2. the mud-worm Polydora, 3. unknown agents which cause a few deaths in late winter (Feb. and Mar.) and again in late spring (May and June) each year, 4. boring sponge Cliona, 5. miscellaneous minor causes. We have shown (Andrews & Hewatt, 1957) that 85 to 90 per cent of all deaths in trays are caused by the fungus, hence the fluctuations by seasons and years reflect the activities of this organism and for practical purposes the other agents can be disregarded. One feature of the epidemiology of this fungus essential to this discussion is that uninfected oysters from low-salinity waters where the fungus is absent, such as the James River seed area, have fewer losses the first warm season after transplanting than in later years. By the second summer the full mortality-producing effect of the fungus is brought to bear and we must distinguish between these "acclimated" oysters and those recently transplanted.

Seasonal Pattern of Mortalities

Nearly seven years of records reveal a consistent pattern of high death rates during the "warm season" and low rates during the "cold season". Each year approximately 90 per cent of all deaths occur from June to October with peak losses in August and September. Usually well over half the annual losses occur in these two months and as high as 25 per cent of a group has died in one month. During the seven "cold season" months, November to May, losses in acclimated oysters seldom exceed five per cent, less than one per cent per month. The amount of losses varies each year but the time pattern is quite consistent with slight shifts in the occurrence of the peaks. Since most of these losses in trays are caused by the fungus, which is dependent upon weather conditions primarily, this pattern will persist as long as Dermocystidium is the chief death-agent.

In Figure 1, the patterns and rates of death are compared in two representative trays at Gloucester Point (Trays 11 & 12) and two groups of trays suspended at Darling's Watchhouse in Hampton Roads. The patterns and levels of death rates are similar at the two stations. The oysters in

Trays 49 and 50 were not "acclimated" in 1955, hence had a lower death rate. The high death rate at Gloucester Point in 1954 was typical of all trays; presumably the lower death rate at Darling's Watchhouse can be attributed to lower temperatures in the relatively deep waters there.

As further evidence that the causes and numbers of deaths are comparable at Gloucester Point and in Hampton Roads, we have taken from the two areas, since July 1953, samples of commercially-planted oysters for fungus tests. These data are presented in the paper by Andrews and Hewatt (1957) and reveal close similarities in the incidence and intensity of fungus infections in the two areas. While the occurrence in live oysters cannot be translated into numbers of deaths, experience with oysters in trays has shown us that similarity in timing and intensity of infections in groups of oysters usually results in similar death rates. In Figure 2 the occurrence of fungus infections in bottom oysters and the pattern of deaths in trays are compared in respect to intensity and timing.

Annual Variations in Death Rates

From 1951 to 1955 summer temperatures were higher than long-term averages of the Weather Bureau and winters were warmer than normal until 1954-55. The destructiveness of Dermocystidium is directly related to the duration of high temperatures. We believe that the first half of the present decade has brought unusually heavy losses of oysters from Dermocystidium. Losses in acclimated oysters in trays were between 20 and 25 per cent in 1951 and 1952, over 30 per cent in 1953, reached a peak loss of over 50 per cent in 1954, declined to 25 to 30 per cent in 1955 and returned to about 20 per cent in 1956 (Fig. 1). These warm summers were followed by an exceptional number of hurricanes which traversed the Virginia-Carolina region, as a result of the same weather forces that brought high temperatures. The hydraulic dredging for the bridge-tunnel began the winter following the season of the worst oyster losses both from Dermocystidium and hurricanes. The annual death rates shown in Figure 1 are quite characteristic for groups of acclimated oysters grown in trays at Gloucester Point. It appears that losses were somewhat less in the trays at Darling's Watchhouse and this probably reflects the lower temperatures in 15 feet of water as compared to 3 or 4 feet at Gloucester Point.

MORTALITY OF PAINT-MARKED OYSTERS ON NATURAL BOTTOM

Since not all the conditions found on natural bottoms can be duplicated in trays, it is important to establish the ratio of death rates in the two habitats. It is difficult to estimate the death rate for a given period by sampling commercial plantings because boxes of indeterminate ages are present. The purpose of planting marked oysters is to give close control over the number, size and history of the group. If at the end of each period of testing all oysters can be recovered, an accurate record of mortality is obtained. Although full recovery has never been attained, experience has led us to believe that there is little difference in the distribution of boxes

and live oysters from their original location and, therefore, fairly reliable estimates of the death rate can be obtained by samples. If samples are taken, however, it is important not to return any of the live oysters to the population and to remember that future samples give estimates of mortality from the time of first planting. The alternative method is to make intensive efforts at each examination to recover as nearly the original count of oysters as possible. If this recovery is high, the chances for errors in subsequent periods is low; therefore, the live oysters are returned to the bottom and each period of testing is considered as a separate unit. We have used both methods for estimating death rates, and recoveries have been attempted by diving (SCUBA) and tonging.

Experiments on Tillage's Ground at Gloucester Point, Virginia

In June 1955, market oysters from Hoghouse Bar in the Rappahannock River were placed in trays and on natural bottom on Tillage's ground for a direct comparison of mortalities. The trays were heavy iron baskets with legs, which lifted the oysters about one foot off the bottom and closely duplicated conditions in the suspended trays at our pier and at Darling's Watchhouse. The paint-marked oysters were planted around a stake (Station B) within a few feet of the trays. At a second station (C), about a quarter of a mile away, a group of the same oysters was placed on the bottom but no trays were installed. Station B, with five feet of water at mean low water, had a sandy bottom not too suitable for oyster culture although oysters have been grown there commercially for many years; Station C, with a depth of eight feet had a good typical muddy-sand bottom with considerable cindery shell. The Hoghouse oysters may be considered only partially acclimated to the Gloucester Point area since they originated in an area with relatively moderate incidence of the fungus.

Table 1 shows the number of oysters planted, the number recovered and the percentage mortality for one winter and two summer periods. On Tillage's Ground losses of oysters in trays and on the bottom during the warm season of 1955, never exceeded 22 per cent which is somewhat low for fully acclimated oysters in that season. It was difficult to maintain rigid timing on the diving work; the periods of testing are somewhat irregular and summer periods were cut short by cold waters which prevented diving without special suits.

Recoveries of paint-marked oysters were good at both stations and we believe that mortality estimates are fairly reliable (Table 1). The live oysters were returned to the bottom each time. All losses in the trays were accounted for. There was little difference between the death rates in suspended trays at the Laboratory pier, the summer rates were lower in 1955 and 1956 but the winter mortalities were somewhat higher; however, after the last examination on October 5, 1955, about 6 per cent of the oysters in trays at the Virginia Fisheries Laboratory pier died before the end of the "warm season" on November 1. This is partly compensated by the inclusion of most of June in the "cold period". We conclude, therefore, that on natural grounds winter mortalities exceeded somewhat the one per cent per month expected in trays, whereas summer losses were lower than in trays at the Virginia Fisheries Laboratory pier. In two of the three periods oysters on natural bottoms had

slightly higher losses than tray oysters. These experiments suggest that tray culture gives fairly reliable indices of annual death rates of large oysters on natural grounds if smothering, dredge damage and hurricane losses are excluded.

In Table 2, data are given on fungus-free oysters planted in trays and on natural bottoms at Station A on Tillage's ground in 1956. The period covered includes the full "warm-season" plus part of the cold season. This table shows: 1. that recently-transplanted oysters have much lower death rates than fully-acclimated oysters (c.f. Table 1 for the same year), 2. that again death rates are similar in trays and on natural bottoms.

At Station A an earlier experiment with 585 marked oysters on natural bottom was carried out between August 18, 1953 and February 5, 1955. These oysters were obtained in August 1953 from a fungus-free area, therefore, few deaths were expected in 1953. A sample of 127 oysters taken by tongs on September 3, 1954, a year after planting, had 45 per cent boxes. The live oysters were not returned. On February 5, 1955, a sample of 199 oysters obtained by divers contained 61 per cent boxes after 18 months of exposure. The death rates obtained by the two samples represent essentially the losses for the warm season of 1954 and compare favorably with the rates obtained for that year in trays at the Virginia Fisheries Laboratory pier.

EXPERIMENTS IN THE HAMPTON ROADS

Plan of Experiments

To determine the effects of the bridge-tunnel project on adjacent oysters, three stations were established on Hampton Bar at varying distances from the spoil dredging and another five on Miles' ground off Willoughby Spit. At each station three or four groups, each of 500 oysters, marked with paint of different colors, were placed on the bottom in different directions from stakes or buoys. The intention was to recover the oysters of one color at the beginning and another color at the end of each warm season for an estimate of mortality. No live oysters were returned to the bottom once collected. In addition, approximately 600 oysters handled in the same way were placed in trays at Darling's Watchhouse and Fort Wool. Hence, one tray station was very close to the dredging and the other quite distant. The oysters were obtained from buy-boats in the James River seed area during the unusually cold month of January 1955. It is possible that a little damage occurred to oysters from freezing on the decks of the boats or during subsequent handling. Oysters from the James River were chosen because they are known to be free from fungus infections, hence would be expected to have a low death rate the first year after transplanting. It was believed this would simplify the detection of mortalities, if any, caused by spoil deposition or silting. We do not have good records of the dates when spoil dredging occurred but it is our impression that most of the north island was completed before our oysters were planted on Hampton Bar on the 10th and 26th of January whereas, our oysters were planted on Miles' ground before the dredging began in that area.

Experiments on Natural Bottoms in Hampton Roads

On June 8, 1955, five months after the paint-marked oysters were planted and well after the initial dredging for the north island had been completed, Chesapeake Bay Institute divers picked up oysters of one color at Stations 1 (lower edge of Plot 15 of Ballard's) and 2 (lower edge of Plot 7). It became apparent from tonging and diving in the summer of 1955 that Station 1 had unsuitable bottom for oyster culture. Plot 15 was heavily planted with James River seed oysters in the fall of 1954 and to avoid placing our marked oysters in these dense beds we located our station along the border of the plot. Here the bottom changed rather abruptly from good planting ground to soft mud bottom, partly perhaps as a result of the new channel dredged almost immediately adjacent to this border.

The divers reported that the oysters at both stations were in fairly dense piles, mostly above the mud, and plainly visible. In view of subsequent examinations of the bottom, however, we were surprised that the mortality was no greater at Station 1 (Table 3). Station 2 can be considered satisfactory oyster bottom, therefore, the death rate of 15 per cent appears to be high if the death rates of 7 per cent in the trays at Darling's Watchhouse are representative of normal losses on the bottom. Since the oysters in trays and those on natural bottom had the same history, the differences between the death rates must be attributed to causes associated with the bottom. In all the groups summarized in Table 3, recoveries of oysters were quite good and we believe the estimated death rates are fairly reliable.

Additional information on the effects that the bridge-tunnel dredging may have had on oyster mortality is given in Table 4, which summarizes subsequent examinations of paint-marked oysters at Stations 1 and 3. Of 338 oysters tonged at Station 1 in November 1955, 40 per cent were boxes, which is quite excessive for recently-transplanted oysters in their first summer in fungus-infested areas. At Station 3, however, which was presumably outside the area most likely to be affected by spoil dredging, the mortality after 17 months on Hampton Bar also appeared high (38 per cent) and during this same period oysters with the same history but suspended in trays at Darling's Watchhouse lost 34 per cent. Of these losses in trays about nine per cent were in November 1955, probably from Dermocystidium, and nearly eight per cent died the following June from unknown causes. Thus, in the warm season of 1955 losses were much greater at Station 1 than at Station 3. It must be concluded that the losses on natural bottom near Darling's Watchhouse were normal or at least water-associated losses.

All these test oysters were planted in mid-winter, which is a normal operation in Chesapeake Bay. However, it is possible that some losses are incurred through oysters being dropped during the near-dormant period into positions which prevent normal water pumpage. On August 11, 1954, market-size oysters were collected from a dredge boat on Hampton Bar; 384 were planted around a stake near the watchhouse, and 150 were placed in Tray 44 at the watchhouse. Eight months later, and a few months after dredging for the north island had been completed, 24 per cent of those planted

on the bottom were dead in samples acquired by tonging and diving. The oysters in Tray 44 had 17 per cent mortality during this period.

In summary, it appears that perhaps four-fifths of the losses on natural bottoms are caused by water-associated factors, therefore, the death rates in trays provide a rough estimate of minimal losses on oyster beds. This applies only to bottoms which are firm enough to prevent oysters from becoming buried; most of the grounds in Hampton Roads are suitable in this respect. The data suggest that most bottom losses in excess of those experienced in trays probably occur during the "cold season" from smothering and storm damage.

Our experiments give no evidence of unusual losses of oysters planted on the bottom at Darling's Watchhouse from August 1954 to June 1956. There did appear to be more deaths at Station 2 (Plot 7) between January and June 1955 than would be expected under the circumstances. The data from Station 1 is not very useful because the experimental plot was placed on unsuitable bottom.

The experiments with marked oysters below Fort Wool were almost completely unsatisfactory. Two trays suspended from a dock at Fort Wool could not be retained due to a combination of factors including swift currents, interference by unknown persons, and damage to the dock by heavy construction equipment. The trays containing James River seed oysters of the same collection used in other experiments were placed at Fort Wool on January 26, 1955. One tray was last seen on May 31, at which time 12 per cent of the oysters had died. In the other tray, last seen on July 26, 16 per cent of the oysters had died. By July 26, 1955, trays of the same oysters at Darling's Watchhouse had about 9 and 10 per cent dead oysters respectively. Although the death rates were slightly higher at Fort Wool, the experiment is not considered accurate enough to conclude that damage from water-associated factors was indicated. These oysters, although suspended, were exposed to heavy silt loads in the water during much of the dredging for the south island.

The efforts to recover marked oysters from the bottom below Ft. Wool were even more fruitless. The depths and the turbidities from strong currents resulted in such poor visibility that oysters could not be found even though planted close to buoys.

SUMMARY OF DATA ON BOXES

In our early reports on methods and plans for detecting damage to oyster grounds from the bridge-tunnel activities, we expressed our dissatisfaction with the box-count method for estimating seasonal or annual mortalities. Only in the event that sudden extensive mortality occurs can box counts be relied upon as an absolute measure of losses sustained. The appearance of mud over quite extensive areas of Hampton Bar in early 1955 led us to gather background data on the incidence of boxes on various grounds

in the bridge-tunnel area in the event that a severe loss did occur. Fortunately, this did not happen and we consider the box counts of limited value. In tables 5 and 6 we have summarized the data on box counts.

Our analysis must be very general for it is obvious that on a given bed of oysters the percentage of boxes may vary widely in successive samples. We have examined the data for evidence of abnormal occurrences of boxes and found none. Our major premises are: 1. counts of boxes present on a ground give a minimal estimate of the number of deaths for about the previous year; 2. seed oysters will have low box counts the first year after transplanting, but thereafter until harvested the incidence will be considerably higher; 3. dredged and vacant grounds will have higher counts of boxes than undredged grounds with mature oysters; 4. in typical years a box count of about 15 to 20 per cent is to be expected in Hampton Roads (see Report G6).

Hampton Bar

The five plots on Hampton Bar which have been sampled most frequently vary in distance from the bridge-tunnel, in presence or absence of planted oysters and in age of oysters since planting (Table 5). Analysis of each bar with the previously-stated premises in mind indicates that Plots 1 and 15, both of which were newly-planted shortly before or after the hydraulic dredging, always had box counts of less than 20 per cent even as long as two years after planting. The survey of March 8, 1955 revealed some dying oysters on the down-river edge of Plot 15 and also on Ballard's Plot 16 and the adjacent grounds of Quinn. Plots 7, 9, and 11 were vacant or intermittently dredged during the period in question and typically had rather high box counts. When Plot 9 was replanted in October 1955, the box count immediately dropped to a low level. Some of the counts on Plots 7 and 11 are quite high and cannot be adequately explained; plot 11 was barren throughout the period of construction and presumably was not dredged.

Willoughby Spit Area

On Miles' Plot 1, which was vacant throughout the bridge-tunnel operations, the box count seems high even for untended grounds. The percentage of boxes on Plot 3 is, on the other hand, less than would be expected. On Plots 5 and 8 the time of replanting can be detected from box counts. Our records are incomplete on the time of planting, harvesting and replanting for each plot but there is little evidence of unusual mortalities in these counts.

Conclusions

Although on several plots rather wide fluctuations in the percentage of boxes were noted in successive samples, no persistent major changes in the incidence of boxes can be found except those caused by harvesting or replanting oysters. The box counts do not indicate an increase in the death rate of oysters from the construction operations. In late spring of 1955

the occurrence of gapers and blackened shell in the areas immediately adjacent to the north island indicates some mortality over and above normal winter losses. These losses, although too small to be measured by box counts, were quite clearly caused by silting from the dredging of the north island.

CONDITION INDEX OF OYSTERS

During construction of the Hampton Roads Bridge-Tunnel a series of monthly tests on the condition or "fatness" of oysters was carried out at a station four and one-half miles up river from the north Portal Island. This location was selected because records of oyster mortality and fungus infections were available from the region.

The condition of oysters is often judged visually by commercial oyster growers, but this method is not particularly reliable. However, both biologists and oystermen agree that oysters with firm, creamy white meats which seem to fill the shell cavity completely are in good condition. Oysters which are watery, flabby, translucent, and do not completely fill the shell cavity are poor in condition.

A more exact method for determining condition exists, and this can be used to compare oysters from different places or over periods of time. This measure, known as the "Condition Index", is defined as:

$$\text{Condition Index} = \frac{\text{Dry Weight of oyster meat in grams} \times 100}{\text{Volume of the oyster shell cavity in cc.}}$$

It is generally agreed that this condition index is a good measure of the quality of the oysters. Oysters with an index of over 10.0 are exceptional while those below 5.0 are considered to be poor. Tests at the Virginia Fisheries Laboratory show that the condition index of most oysters in the James, York, and Rappahannock Rivers ranges from 5.5 to 8.5.

Figure 3 compares the seasonal changes in condition index at the station in Hampton Roads, and at a station in the lower York River. Oysters store food as glycogen for spawning purposes, therefore, the highest indices are usually found in late May or June just prior to spawning. At the end of spawning in August and September oysters are at their poorest but stored food is quickly replenished in the fall and early winter. The most noticeable feature of Figure 3 is that the Hampton Roads oysters were almost consistently higher in condition than oysters from the York River.

In addition to the regular monthly samples at established stations a few additional areas were tested, as shown in table 7. The data are fragmentary and serve only to show that oysters all over the area were about average in condition.

In conclusion, no apparent abnormality in the condition index of oysters in the Hampton Roads area was observed from April 1955 through March 1957.

SUMMARY AND CONCLUSIONS

During this project we have tried to call attention to the pitfalls of the various survey methods used and above all to provide background information on the causes and seasons of oyster mortalities. The experimental results have been given and discussed in previous sections but with this background our conclusions are based to a large extent upon observations which cannot be given difinite numerical values. In both the Hampton Bar and Fort Wool areas we had the opportunity to see typical dredge hauls from many plots prior to dredging for construction purposes. Subsequent surveys have been reported individually. All remarks refer to areas outside the right-of-way of the bridge-tunnel. The terms mud, silt and spoil have been used interchangeably without any connotation of particle size.

Hampton Bar

In late 1954 the beds on Hampton Bar showed oysters of good color with little mud in the dredge hauls. Boxes were abundant from deaths that occurred the previous summer and fall. By early spring a layer of silt had settled over the oysters as far up as Plot 7 and as the water warmed the black color of silt-buried shell and oysters became fairly conspicuous. At this time it was feared that organic matter and smothered organisms had accumulated to such an extent that anaerobic conditions might prevail and cause an oyster kill. Box counts were begun to provide a base line in the event of catastrophic mortalities. As the spring progressed a few gapers (dead or dying oysters) were found on Plot 16, and the lower edge of Plot 15 of Ballard's grounds, and Plot 2 of Quinn's. These were also the areas of most intense blackened shells and dead fouling organisms. At low temperatures, meats may persist in gapers for a month, therefore the death rate can be quite low and yet gapers can be found. There is no way of estimating the death rate but it was probably no greater than 10 per cent above normal (about 1 per cent per month) for the first five months of 1955. There was no evidence of unusual losses on the other plots farther removed from the area of construction.

Surveys in the springs of 1956 and 1957 indicated that all plots with the exception of the lower edge of 15 and Plot 16 appeared normal so far as color of oysters and presence of mud were concerned. Plot 16 has been seriously damaged by deposition of silt. On December 1, 1954, we spent most of one day repeatedly dredging oysters over one strip of this ground, and our notes and impressions of the hard shelly nature of this bottom are clear. The most recent survey of this bottom on February 27, 1957, revealed considerable amounts of mud in each dredge haul.

It is possible that oysters can be grown with limited success on Plot 16 now but probably the yield and quality of the crop will be reduced until the mud is dissipated. We do not feel, however, that we are as competent to judge this matter as are the buy-boat captains and oystermen who work the grounds regularly.

In the course of these surveys, we found no evidence that oyster growth or condition were appreciably altered during the period of construction.

It is our conclusion that a mortality of perhaps 10 per cent above normal occurred on Ballard's Plot 16 and the lower edge of his Plot 15 and on Quinn's Plot 2. The oysters had been removed from Plot 16 and only a sparse population remained. Also, appreciable damage was done to the bottom on Plot 16 and possibly parts of Plot 15 by the deposition of silt which has not yet been removed or consolidated. Mortalities and damage to the bottom, if any, on the remaining plots could not be detected by our survey methods. It is our opinion that the silt which caused the damage on the grounds of Ballard and Quinn came from the construction activities on the Hampton Roads bridge-tunnel. The reports of Chesapeake Bay Institute give detailed accounts of the distribution of this material and also indicate the origin. It should be understood that for the most part our surveys were concerned with plots as a whole. Usually only one or two samples were taken in a plot and no attempt was made to measure variations in a plot. Damage, of which we are unaware, may have been done to corners, edges or small areas of a plot.

Willoughby Spit Area

At no time did we find evidence of damage to the grounds east of Fort Wool. These bottoms were for the most part extremely hard, clean and sandy, and depositions of silt would have been conspicuous in the dredge hauls. There were no indications of black shells or dying oysters in excess of normal conditions. We are aware that with stronger tides, deeper waters and hard sandy bottoms, conditions east of Fort Wool were markedly different from those on Hampton Bar. For example, dredge loads of oysters would be more thoroughly washed before they reached the deck in the Willoughby Spit area. Probably localized damage was done to Plot 1 by heavy equipment and spreading sand but these were impossible to detect by our survey methods. We must conclude that so far as our knowledge goes the grounds below Fort Wool were left unimpaired by the construction activities.

Fig. 1. The death rates of oysters grown in trays at Gloucester Point (Trays 11 & 12, acclimated oysters) and Darling's Watchhouse. The oysters in Trays 30, 44, and 45 had been acclimated in the Hampton Bar area for at least one year prior to the beginning of mortality records; those in trays 49 and 50 were transplanted in January 1955 from the James River seed area to the Watchhouse and were not acclimated.

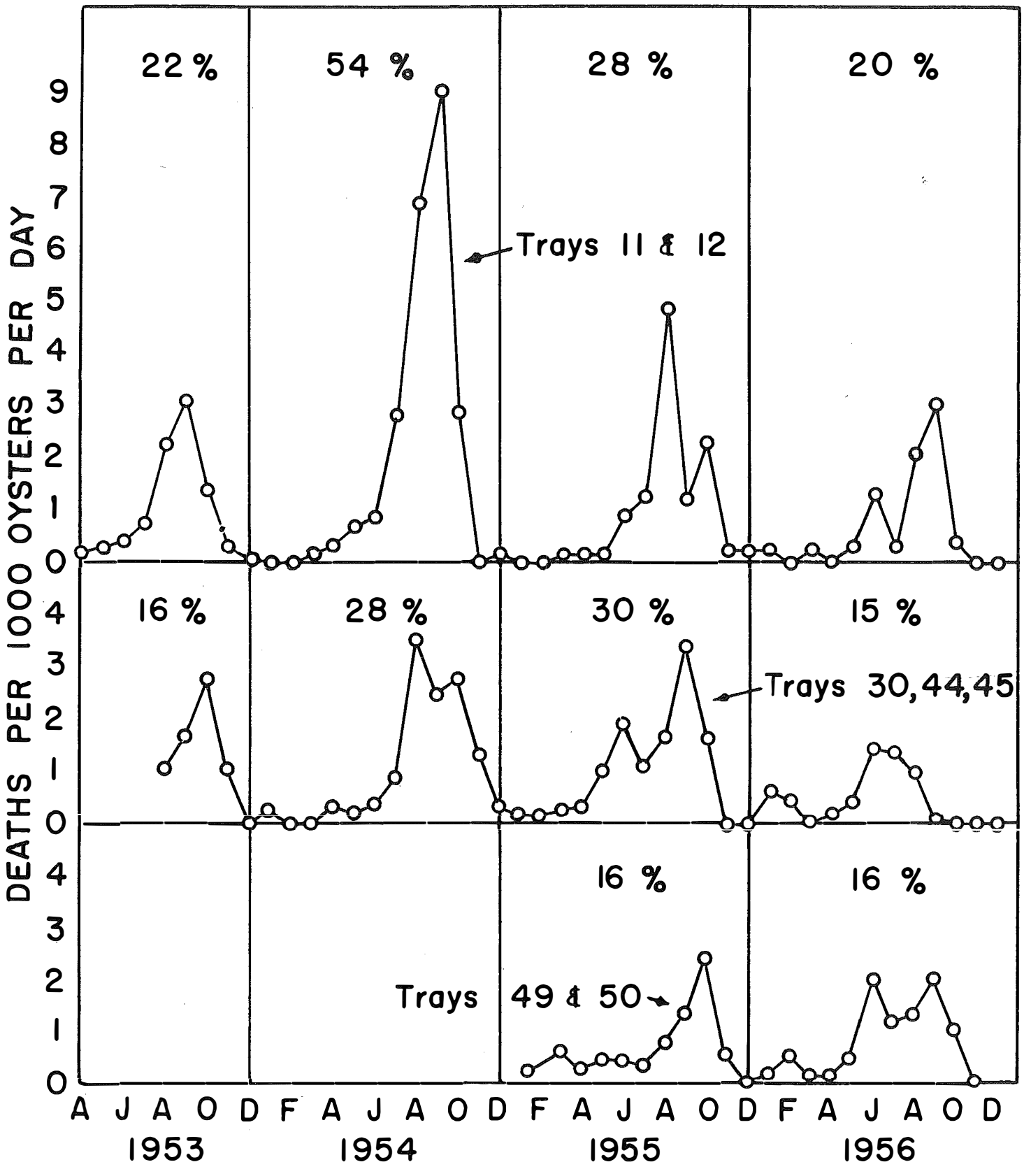
22 %
54 %
28 %
20 %
Trays 11 & 12
16 %
28 %
30 %
15 %
Trays 30,44,45
16 %
16 %
Trays 49 & 50
DEATHS PER 1000 OYSTERS PER DAY
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4
0 1 2 3 4
A J A O D F A J A O D F A J A O D F A J A O D
1953
1954
1955
1956

Fig. 2. The death rates of oysters in Trays 30, 44, and 45 at Darling's Watchhouse and the incidences of the fungus Dermocystidium in oysters from planted grounds of Hampton Bar during the years 1953 to 1956.

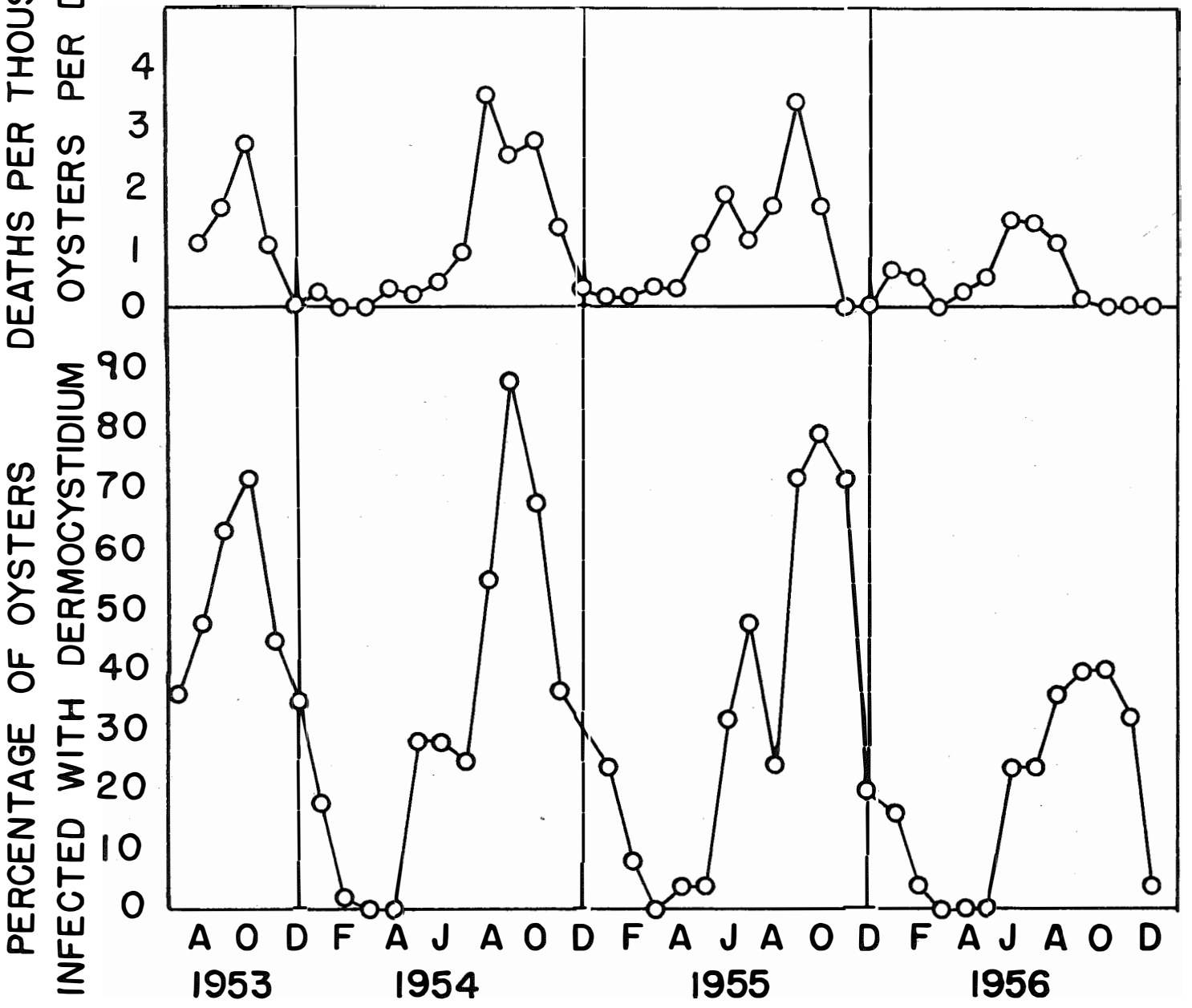
PERCENTAGE OF OYSTERS INFECTED WITH DERMOCYSTIDIUM
DEATHS PER THOUSAND OYSTERS PER DAY
0
1
2
3
4
90
80
70
60
50
40
30
20
10
0
A O D F A J A O D F A J A O D F A J A O D
1953
1954
1955
1956

Fig 3. The condition index, a measure of "fatness" of oysters from Hampton Bar and York River from May 1955 to March 1957.

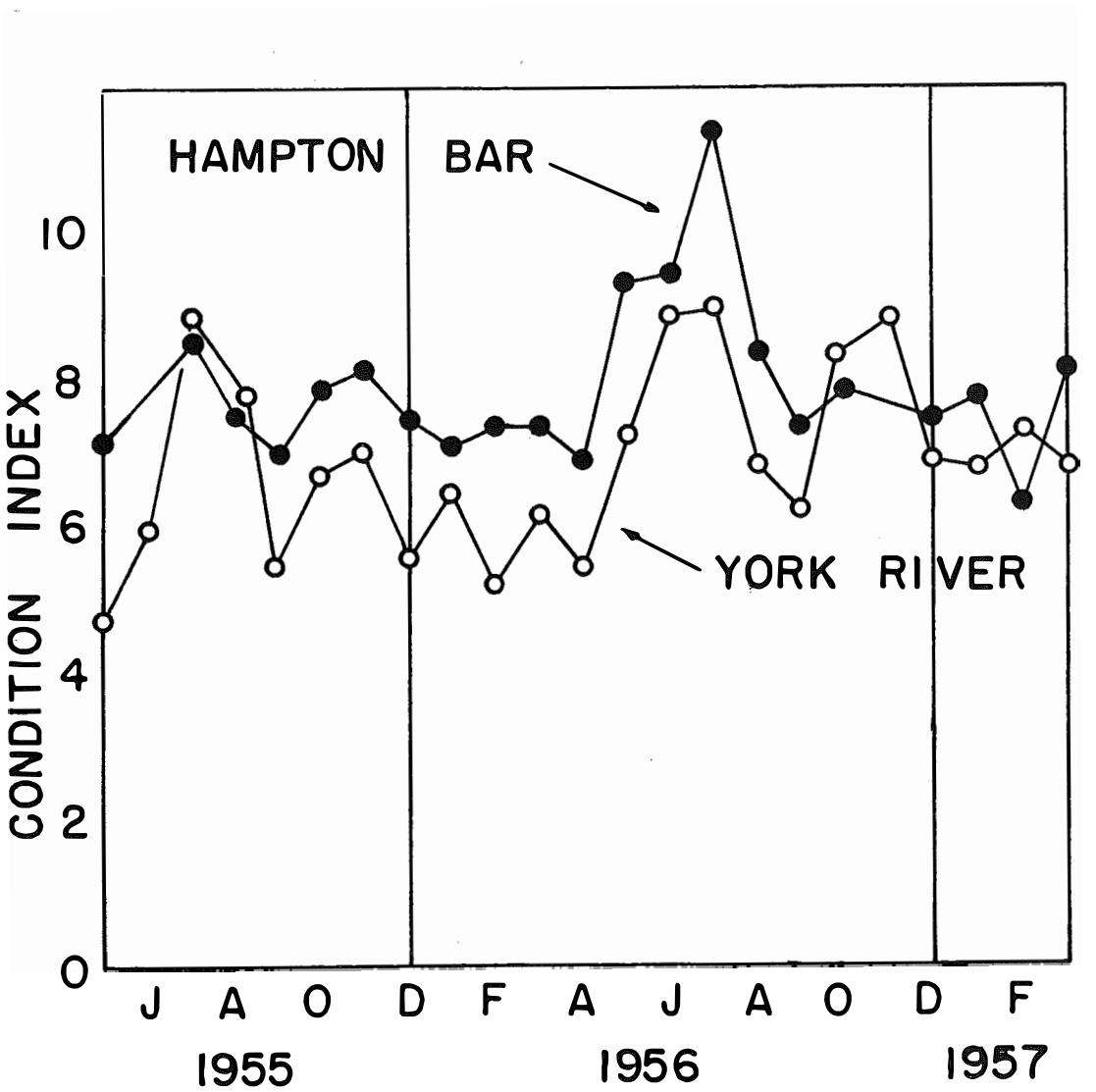
HAMPTON BAR
YORK RIVER
CONDITION INDEX
0
2
4
6
8
10
J A O D F A J A O D F
1955
1956
1957

Table 1. Mortality of acclimated oysters from Hoghouse Bar grown in trays and on natural bottoms on Tillage's ground Gloucester Point, York River, Virginia

Location	Period	Habitat	No. planted[1]	No. recovered	No. dead	Percentage[2] dead
Station B	11 June to 5 Oct. 1955	Trays 63 & 65	473	472	70	14.8
		Natural bottom	500	428	88	22.1
	5 Oct. 1955 to 25 June 1956	Trays 63 & 65[3]	402	402[4]	37	9.2
		Natural bottom	398	295	41	13.9
	25 June to 7 Sept. 1956	Trays 63 & 65	292	292	53	18.3
		Natural bottom	357	253	28	11.1
Station C	14 June to 5 Oct. 1955	Natural bottom	500	335	66	19.7
	5 Oct. 1955 to 15 June 1956	Natural bottom	434	352	56	15.9
	15 June 1956 to 10 Sept. 1956	Natural bottom	378	259	37	12.2

[1] Includes those lost or not recovered in previous pickups

[2] Where more than one examination occurred the precentages for each period were converted to instantaneous mortality to calculate annual mortality

[3] To 5 July for calculations

[4] Lost about 100 oysters when boat hit tray but this loss adjusted in calculations.

Table 2. Mortality of James River seed in trays and on natural bottoms on Tillage's Ground, Gloucester Point, Va., Station A, 8 June 1956 to 8 January 1957.

Habitat	No. planted	No. recovered	Percentage dead
Tray	523	518	5.4
Natural bottom	519	467	4.2

Table 3. Mortality of oysters on Hampton Bar from January 10 to June 8, 1955

Habitat	Group designation	History	No. planted	No. recovered	No. dead	Total percentage dead	Percentage killed by drills
Trays	Trays 49 & 50	Transplanted from James R. (not acclimated)	641	622	46	7.4	0
	Trays 30, 44 & 45	Acclimated on Hampton Bar	333	333	23	6.9	0
Natural bottom	Station 1 Plot 15 (Ballard's)	James R. seed	500	463	105	22.7	0.4
	Station 2 Plot 7 (Ballard's)	James R. seed	500	343	52	15.2	0.9
	Station 3* (Darling's watch-house)	James R. seed (10 Jan to 20 Jun)	500 (whites)	234	50	21.4	0.0
		(26 Apr to 20 Jun)	1500	174	15	8.2	0.0

* On 20 Jun 1955 all boxes and live oysters were returned to the bottom.

Table 4. Mortality of paint-marked oysters on natural beds of Hampton Bar

Location	Group designation	Period	No. planted	No. recovered	No. Dead	Percentage dead
Station 1 (Plot 15)	James River transplants	10 Jan 55 to 1 Nov 55	500	338	135	40.0
Station 3 (Darling's watchhouse)	James River transplants	10 Jan and 26 April to 3 Jul 56	2000	565	233	41.2
Darling's Watchhouse	Market oysters-acclimated	11 Aug 54 to 15 Apr 55	384	268	63	23.5
Station 3 (Darling's watch-house)	James River transplants (acclimated)	3 Jul 56 to 14 Jun 57	332*	343	120	35.0

*This was the number of live oysters recovered and replanted on 3 Jul 56 but some additional oysters from the original planting were recovered on 14 Jun 57.

Table 5. The percentages of boxes counted on Ballards Plots on Hampton Bar[1]

Plot Number	1	7	9	11	15
History - Planted	Jan 55	Jun 50	Nov 52	Jun 50	Jan 54
- Harvested	Fall 56	Fall 53,54 55.	Fall 54	Fall 53	Fall 56
- Replanted	Jan 57	Oct 56	Oct 55	Not replanted	
Dates					
29 Dec 1954					
10 Jan 1955	4	22	21		6
8 Mar 1955		21		29	16
18 Mar 1955		6	22		6-10
31 Mar 1955			21	30	7-17
15 Apr 1955	9	36			
27-29 Apr 55	7	12	21	52	11
16 May 1955	9	30	37	54	8
8 Jun 1955		35	21		
23 Jun 1955	7	39	28	65	15
8 Aug 1955	2	41	27	53	13
1 Sep 1955			17		
21 Sep 1955	3	41	19	67	15
21 Nov 1955	11	45	2	56	20
5 Apr 1956	8	16	4	54	19
14 Sep 1956	21	45	3	34	8
27 Feb 1957	2	1	4	6	1

[1]Samples from other plots were taken occasionally but have been omitted from this table.

Table 6. The percentages of boxes on Miles' Plots in Hampton Roads below Fort Wool

Plot Number	1	3	4	5 & 6	7	8	12	16
History - Planted		Fall '54	vacant	Fall '54	Fall '54	Fall '54	Fall '55	1954 & 5
History - Harvested							Fall '56	
History - Replanted							Fall '56	
Date								
16 Feb 1955		7	20	12	8		20	21
6 Jun 1955		7	22	22		32	31	40
20 Jun 1955[1]		12	20	26		31	23	43
		6	18	21		33	32	31
20 Jul 1955	58	8	23	27		42	32	32
22 Sept 1955		11	23	22		37	24	26
13 Dec 1955		15	42		16		40	
6 & 10 Apr '56	54	20	25	5	14	10	16	23
14 Sep 1956	48	20	25	5	24	3	35	
26 Apr 1957	38	16	14	4	12	5	3	

[1]First line of percentages represents samples taken with a heavy dredge on vessel "Ocean View"; second line gives percentage boxes as shown by light dredge from "Anomia".

Table 7. Condition Index of oysters taken from the Hampton Roads area during 1955.

Date	Location of Station	Condition Index
May 31, 1955	Ballard's square No. 9 Hampton Bar	9.0
Jun 6, 1955	Miles' square No. 4 off Willoughby Spit	7.0
Jun 20, 1955	" " No. 16 " "	8.1
Jun 20, 1955	" " No. 4 " "	7.4
Jul 20, 1955	" " No. 4 " "	7.2