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The intent of the Baylor Survey of 1892 was to define the naturally-producing oyster grounds in Virginia waters and to set them aside for public use. Actually, some natural ground was omitted and some barren ground was included within the bounds of the Survey; however, it stands as a definition of public grounds from which any citizen of the State may, for a small fee, obtain a license to take oysters. Only hand tongs are permitted in this public fishery.

These oyster bars within the Baylor Survey are about twice as extensive as the ground outside leased to private planters but they yield only about one-third as many oysters of market size (Marshall, 1951). On the other hand, certain of these public grounds provide the seed or small oysters that are transplanted to private grounds and are essential to the success of leased bottoms which are seldom self-sustaining. Based on this relationship an extensive area in the lower James River (Figure I) noted for its capacity to produce great numbers of small oysters, has been established by law as a seed area. This area is not subject to the usual regulation that oysters must remain on public grounds till they grow to marketable size. Tongers harvest and sell to private planters from one to two million bushels of seed oysters from this James River area annually. Actually each such bushel is a mixture of small seed oysters, the old shell to which the seed have attached, and a small quantity of oysters of marketable size.

The removal of this mixture of live oysters and shell might reduce critically the amount of cultch available for the setting of larvae. This might also cause decline and other changes in the surface of the bars, thus modifying the hydrodynamics of the region and otherwise disturbing ecological conditions. The widely varied speculations concerning such effects make it especialy imperative to search for data on this subject. A step that can be taken toward this end is to compare soundings on early hydrographic surveys with those taken more recently and thus to observe some of the physiographic changes that have actually occurred. The first complete depth surveys of the portion of the lower James River in question are those made by the U. S. Coast and Geodetic Survey in 1854-55. Additional comprehensive surveys were conducted by the Survey in 1871-73 and 1943-48. All such soundings are plotted on what are known as hydrographic surveys which, of course, provide the primary reference data for drafting navigation charts, *etc.*

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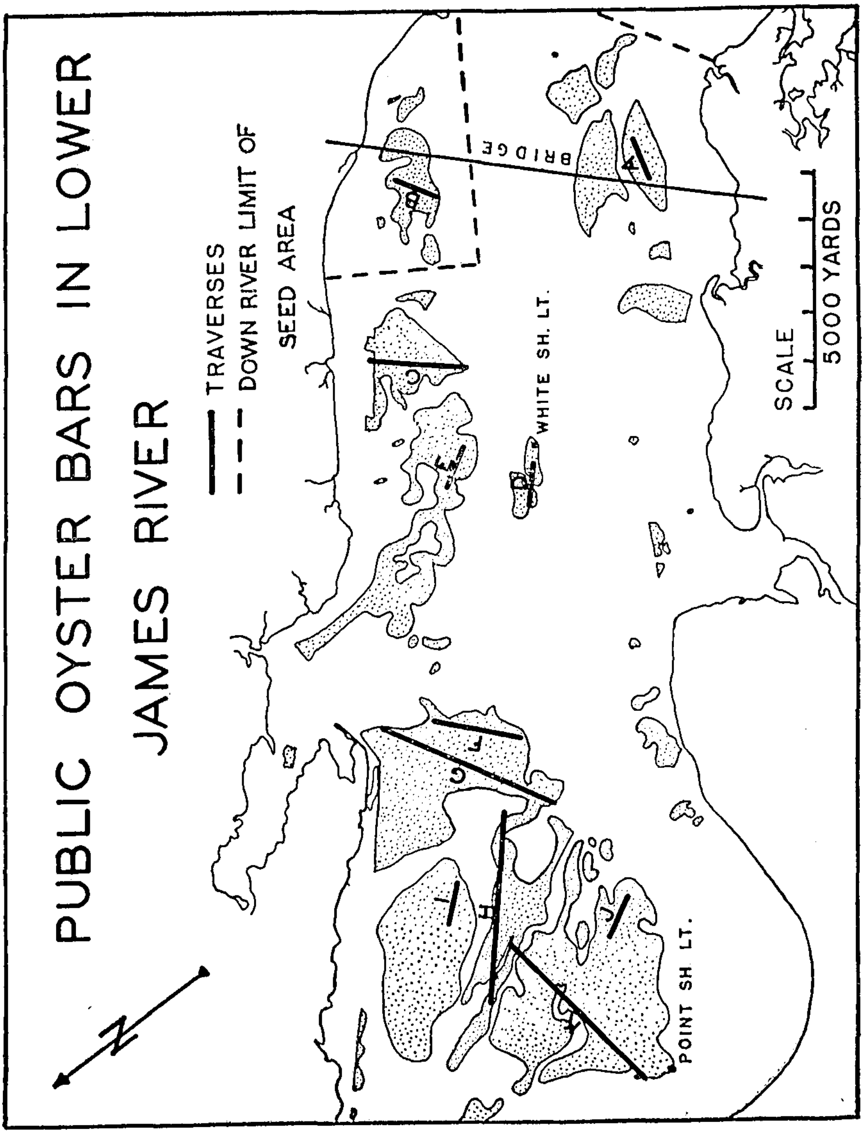

FIGURE I. Public Oyster Bars in Lower James River. The location and length of these traverses, also the names of the bars covered, are indicated in Table I.

METHODS

From Moore's (1910) maps of the oyster grounds in the area, as his party observed them shortly before his publication, traverses were selected across representative bars. Each such traverse (Figure I and Table I[2]) is a straight line, crossing, for at least 75 per cent of its length, grounds which Moore designated as supporting a dense growth of oysters. An exception is the straight line across Brown Shoal which, though not covering such a high percentage of dense growth, was studied to represent bars that were formerly exposed at low water.

These traverses were plotted on the hydrographic survey of each period mentioned above, and using the shortest interval practical on the less intensive older survey, the depths were read every 100 yards. Thus at every hundred yards a point was established at which depths could be compared on successive surveys. As reported by the U. S. Coast and Geodetic Survey (correspondence from the Acting Director, 1949 and 1952) there has been a 0.6 foot rise in sea level in the region between 1855 and the late 1940s. To allow for this in the present study concerned with bottom changes, a one-half foot correction factor was used when comparing soundings of the 1940s with those of earlier years.

The points on these traverses that lie over slopes and channels are not well suited for this study. Oystering is not limited to the crests of the bars, yet points over the slopes often miss oyster bottom; depths at such points are likely to be altered primarily by hydrographic conditions, perhaps with little relation to oystering and oyster growth; and errors in surveying and draftsmanship are exaggerated in contrasts over sloping surfaces. For these reasons, only those points over relatively level stretches of the bottom, well up on the bars, were compared.

RESULTS AND DISCUSSIONS[3]

At 121 of the points compared the bottom was more elevated in the 1850s than it was in the 1940s, whereas the reverse was true at 38 points. An analysis of the depth differences at these points for the entire ninety-year period is as follows:

Number of points compared	= 173
Mean of depth differences	= —1.1 ft .
Standard deviation of differences	= 1.9 ft.
Standard error of differences	= 0.14 ft.
t value	= 7.9
95% fiducial limits of differences	= —0.82 to —1.38 ft.

[2] Point of Shoals Light and White Shoals Light, used as reference points in defining the traverses, are not operating but still stand. In some cases it was obvious that a traverse drafted on Moore's maps of the area crossed slightly different grounds than when plotted on the hydrographic surveys of the U. S. Coast and Geodetic Survey. It was assumed that this was due chiefly to errors in Moore's maps. This does not, of course, affect the accuracy of comparisons between hydrographic surveys.

[3] Table II presents a summary of the data giving means of depths and means of differences at comparison points. The complete data are on file at the Virginia Fisheries Laboratory and are scheduled to appear in the **Proceedings of the National Shellfisheries Association for 1953** (near print).

An analysis of the depth differences for the first 17-18 years is as follows:

Number of points compared	= 173
Mean of depth differences	= −0.3 ft.
Standard deviation of differences	= 2.2 ft.
Standard error of differences	= 0.17 ft.
t value	= 1.8
95% fiducial limits of differences	= +0.04 to −0.64 ft.

As another check, all the depths at the comparison points were lumped for each of the three periods. These three samples were subjected to an analysis to see if they might have been drawn from a single population. This analysis of variance gives an F value of 5.90, indicating a greater than 99% probability that there is a real difference between the groups.

These analyses support certain generalizations, applicable to the extent these data represent the history of the oyster bars. Over the ninety-year span there has been a mean lowering of about one foot from the crests of the bars, this being in addition to the depth change due to a rise in sea level. This figure is statistically significant, far better than the 1% probability level, and lies within relatively narrow fiducial limits. The analysis for the first eighteen years leaves greater doubts as to the validity of the calculated depth change of 0.3 feet. The low t value indicates that the mean difference is not highly significant, and the fiducial limits indicate the change could have been a slight increase rather than a loss from the surface of the bars.

Quite noticeable in survey comparisons is the almost complete disappearance of emergent or intertidal oyster shoals since the 1870s Though the surveys do not always indicate it, it is probable that the typically elongate, exposed areas in the middle of the oyster grounds are intertidal oyster reefs. Ignoring the shoals adjacent to and thus essentially a part of the shore, approximately 12,000 yards of intertidal reefs were noted from the 1854-55 surveys, 17,000 yards in the 1871-73 surveys, and less than 100 yards in recent surveys. On the original surveys there are so many indications of more thorough work in the 1870s than in the 1850s that the added reef measurements of the second period seem to result from more critical surveying. On the other hand, the difference indicated between the 1870s and the 1940s seems real, as would be expected with a one-foot mean loss from the surfaces of the oyster bars plus the half-foot rise in sea level.

DISCUSSION

The depth comparisons may be discussed under two interdependent headings — the net loss of surface over the ninety-year period, and the variation from point to point. The variation indicates that changes in the bars may be quite different even within relatively short distances. This is also apparent from depth contours, as illustrated in Figure II of the White Shoals area. That the changes should be so varied seems to

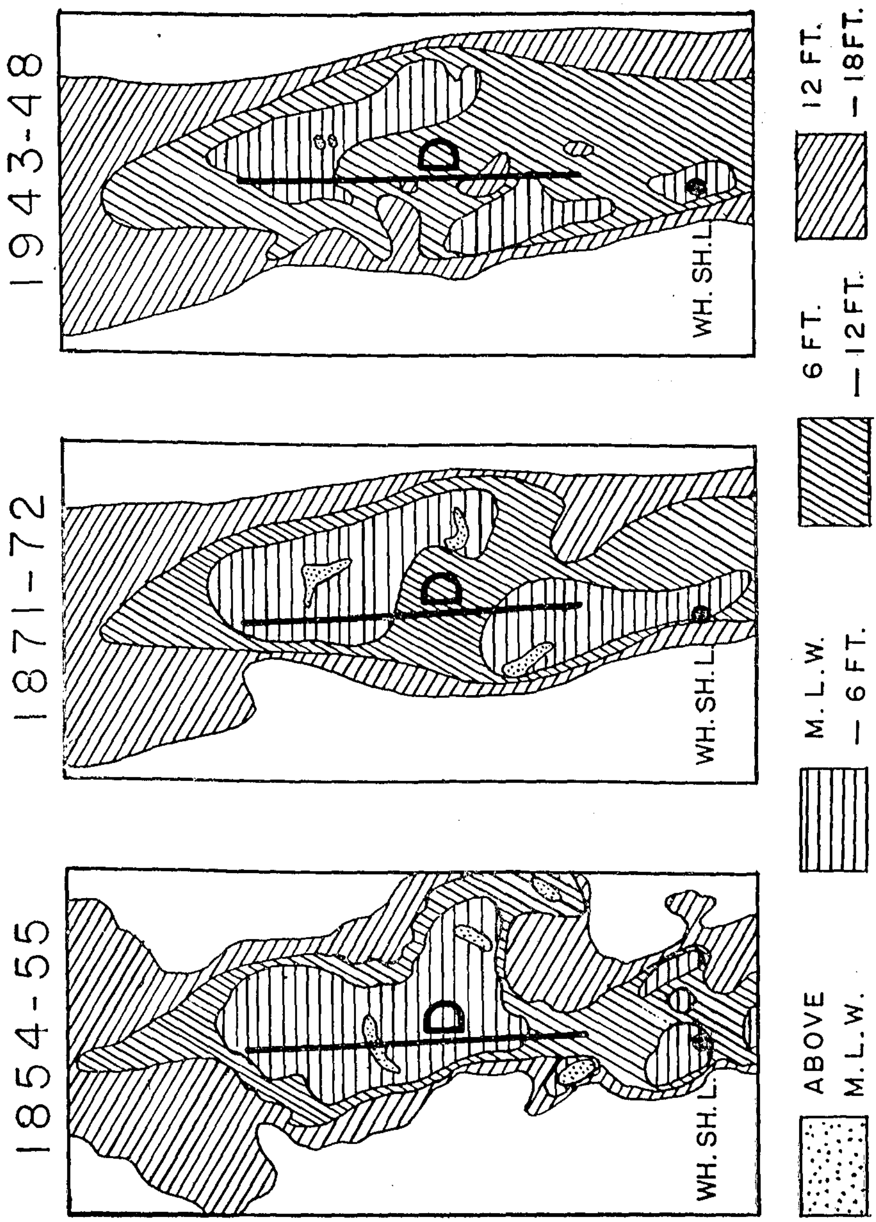

FIGURE II. Depth Contours in the Vicinity of White Shoals Light. Traverse D, 1000 yards, is drawn in to show location and scale.

stress the importance of natural environmental factors, cutting, building, and depositing sediments to mold the shape of the grounds. Thus the bars are quite dynamic, everchanging in form. Though the physical and biological forces involved must be set aside in this discussion as a complex not thoroughly analyzed, it is important to recognize that final effects involve an interaction between such natural forces and the fishery influences. Such interactions are similar to those encountered in dealing with the many fishery populations that obviously vary in response to environmental forces.

Before considering the possible role of the fishery in the net decline of the bars, two forces should be mentioned that constantly tend to lessen the depth. (1) Whatever oysters are on the bars continuously add to their shells and thus to the bottom development. (2) This is an area of salting out of matter in suspension, associated with a marked downstream increase in the salinity and clarity of the water (see Chesapeake Bay Institute Data Report, No. 7, 1952, for tabulations of salinity and light transmission). Brown, Seavy, and Rittenhouse (1939) reported large scale filling due to sedimentation in the York River and Gottschalk (1945) reported the same for the upper Chesapeake Bay and its tributaries. If the James is at all comparable, it must be assumed that there has been a great deal of filling in the seed area. It may be, however, that the scouring and cleansing action of live oysters has kept sedimentation at a minimum over the bars.

To consider the effect of oystering in the over-all decline in the surfaces of the bars it is necessary to estimate the magnitude of shell removal by the fishery. Catch statistics applicable to the seed area, which coincides with the region of these depth comparisons except that the latter included Brown Shoal (Traverse B B[1]), are the only records from which we might estimate shell removal rates. The harvest of seed oysters in Virginia is given in various U. S. Fish and Wildlife Service (formerly U. S. Bureau of Fisheries) reports and is presented in what appear to be comparable summaries for the 1920-21 and the 1924-25 seasons and the years 1929 through 1944. The average annual seed harvest in these years in terms of U. S. standard bushels was 1,675,000. Since only seed oysters are harvested from the James River seed area and since the recorded Virginia seed harvest is almost entirely that of the James, it seems reasonable to use a rounded figure of 1,500,000 bushels to represent the annual removal during the period covered by the data.

The use of the bars in the lower James River has changed through the years, but as Wharton's (1948) historical review suggests, oystering in the state was probably as intensive in the 1850s as it is today and the James River has always been the center of this fishery. Thus the estimate of 1,500,000 bushels a year, taken from the region now defined as a seed area, may be used for the entire period since 1854. Of this harvest the actual volume in seed is small for the small oysters are generally attached to empty shells which may comprise about two-thirds of the total or 1,000,000 bushels annually. On the other hand, removal of empty shell from the surface of bars was undoubtedly less extreme in former years when the region was used more for market oysters. For an approximation of the average annual removal of empty shell incidental to the removal of live oysters from this area since the 1850s, a figure of 700,000 bushels will be used.

Moore (1910) found about 3200 acres of dense growth on the bars of the present seed area. If we assume that two-thirds of the estimated shell removal comes from such areas this would amount to a layer 0.05 inches deep taken from this area annually. At such a rate a little less than 5 inches of shell would have been removed in the ninety-year period, whereas the net decline at the points compared was about 1 foot.

These removal estimates, being extremely crude, cannot be used as a basis for critical interpretations. On the other hand, if one were to make allowance for factors tending to build the bars and then were to estimate the removal of shell involved in the net loss of a foot, the figure would greatly exceed the above estimates from catch records. This raises many questions. The catch records may fall far short of the actual harvest, or the actual lowering of the bars may be less than indicated by the data presented here. The removal of shell may initiate depletion processes which exceed the amounts tonged from the bars. Possibly there has been some settling of the river bottom in general, producing a lowering of oyster bars.

SUMMARY

This study compares original U. S. Coast and Geodetic Survey depth observations over the productive oyster bars of the lower James River for the period 1854-55 through 1943-48. There was considerable variation in the physiographic changes in the surface of the oyster grounds during that period; however, at most points depth comparisons indicated decline, and the net effect was a mean loss of about a foot in the elevation of the bars.

The variations in depth comparisons and changes in the courses of depth contours suggest that oyster bars are quite dynamic, changing form in response to environmental factors. The physiographic history of these bars is probably the result of both natural and fishery influences just as fishery populations have complex histories of interwoven fishing and environmental effects.

ACKNOWLEDGMENTS

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TABLE I. Location of Traverses of Oyster Bars in the Lower James River, Virginia

GALLEY SIXTEEN (16)

	Distance	*Direction*	*Reference*	*Traverse Description*
A	5985 yds.	30.2° EofS	of Wh. Shoal Lt.	1000 yds. across
A¹	6795 yds.	35.6° EofS	of Wh. Shoal Lt.	Fishing Pt. Rks.
B	6350 yds.	81.9° EofS	of Wh. Shoal Lt.	1000 yds. across
B¹	5539 yds.	76.0° EofS	of Wh. Shoal Lt.	Brown Shoal
C	2168 yds.	87.9° EofN	of Wh. Shoal Lt.	2000 yds. across
C¹	3818 yds.	65.3° EofN	of Wh. Shoal Lt.	Kettle Hole Rk.
D	1328 yds.	45.6° WofN	of Wh. Shoal Lt.	1000 yds. across
D¹	315 yds.	42.5° WofN	of Wh. Shoal Lt.	White Shoal
E	2025 yds.	12.3° EofN	of Wh. Shoal Lt.	1000 yds. across
E¹	1455 yds.	40.2° EofN	of Wh. Shoal Lt.	Thomas Pt. Rk.
F	9030 yds.	86.4° EofS	of Pt. Shoal Lt.	2000 yds. across
F¹	7680 yds.	75.9° EofS	of Pt. Shoal Lt.	Wreck Shoal
G	6210 yds.	75.7° EofS	of Pt. Shoal Lt.	4000 yds. across
G¹	7585 yds.	87.8° EofN	of Pt. Shoal Lt.	Wreck Shoal
H	4058 yds.	58.9° EofN	of Pt. Shoal Lt.	4000 yds. across
H¹	6488 yds.	84.3° EofS	of Pt. Shoal Lt.	Mulberry Swash Rk.
I	5640 yds.	70.8° EofN	of Pt. Shoal Lt.	1000 yds. across
I¹	6010 yds.	80.2° EofN	of Pt. Shoal Lt.	Marshy Rock
J	3188 yds.	78.7° EofS	of Pt. Shoal Lt.	1000 yds. across
J¹	3855 yds.	66.4° EofS	of Pt. Shoal Lt.	Pt. of Shoals Rk.
K	615 yds.	25.8° EofN	of Pt. Shoal Lt.	4000 yds. across
K¹	4380 yds.	77.2° EofN	of Pt. Shoal Lt.	Long Shoal and Swash Rock

TABLE II. Summary of depth comparisons at 100-yard intervals over oyster bars in the James River, Virginia. Depths from U. S. Coast and Geodetic Survey hydrographic surveys.

		Means of depths in ft. from readings at comparison pts.			Means of differences at comp. pts.	
Trav.	N	1854-55	1871-73	1943-48	1854-55 minus 1871-73	1854-55 minus 1943-48+½*
AA[1]	11	5.0	5.7	6.0	—0.59	—0.41
BB[1]	9	0.7	3.6	5.5	—3.00	—4.39
CC[1]	17	7.7	7.2	7.9	+0.46	+0.29
DD[1]	8	4.6	3.9	6.6	+0.75	—1.44
EE[1]	9	9.6	9.6	10.7	0.00	—0.61
FF[1]	18	5.6	7.9	8.5	—2.25	—2.54
GG[1]	36	6.1	6.4	7.6	—0.31	—1.02
HH[1]	19	9.8	9.6	10.4	+0.29	0.00
II[1]	11	9.8	10.5	10.8	—0.73	—0.48
JJ[1]	9	4.7	5.6	6.8	—0.94	—1.72
KK[1]	26	5.0	4.0	6.1	+1.03	—0.62

* Added to offset differences resulting from a half-foot rise in sea level.