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COMPARATIVE ATTACHMENT, GROWTH AND MORTALITIES OF OYSTER (*CRASSOSTREA VIRGINICA*) SPAT ON SLATE AND OYSTER SHELL IN THE JAMES RIVER, VIRGINIA

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ABSTRACT Slate was investigated as a substitute for oyster shells which are used as a substrate for oyster spat (*Crassostrea virginica*) settlement in James River, Virginia oyster repletion programs. Oyster shells and slate fragments were planted on adjacent plots in two submerged locations about 825 m apart in July 1984. Quantitative .093 m^2 (one ft^2) samples were collected by a diver on seven occasions through July 1985, with additional samples collected from the natural oyster bottoms adjacent to the two areas. Percent mortality, growth and numbers of live spat and spat scars (dead spat) per unit area of bottom were determined. At the end of the study, the number of spat on shell was 4–5 times higher than on slate; however, slate had 5–6 times more spat per unit area of bottom than the shell on the natural bottom. During the July to October setting season mortalities were much higher on slate than on shell; during the remaining period they were high but about equal on both substances.

INTRODUCTION

Experiments have shown that oysters will attach to almost any hard surface, including asbestos plates, frosted glass, wood, cement and marble (Dupuy and Rivkin 1972; Hidu et al. 1975; Kennedy and Breisch 1981). These studies were primarily designed to study setting intensity and patterns of set; none were large scale field studies designed to find a substitute for shell on a commercial scale. We investigated slate as a substitute since it offers a hard surface, low cost, and a plentiful and readily available supply in Virginia. Moreover, it has been used experimentally to study setting patterns of benthic invertebrates such as barnacles (Osman 1977).

METHODS

The study was conducted in the James River, Virginia, in the Wreck Shoals area, a location which receives a moderate to heavy set of oysters each year (Haven and Whitcomb 1983; Haven and Fritz 1985). Two locations about 825 m apart were selected and marked by wooden stakes: 1) Wreck Shoals Inshore and 2) Wreck Shoals Offshore. Water depths (MLW) averaged 2.7 m on each plot. At each location two plots of (37.2 m^2) in size 2.7 m and about 3.0 m apart were selected and marked with stakes (Figure 1). Salinities in the area during the July through October setting season ranged from 8.9 to 19.0‰ ($\bar{x}$ = 13.3) and 11.8 to 20.4‰ ($\bar{x}$ = 15.4) from October to July. The naturally productive bottom on the inshore plot was a mixture of sand, shells, and oysters; on the offshore plot, the bottom was very hard and was comprised largely of oysters, shells, and small shell fragments (Haven and Whitcomb 1983).

From 16–24 July 1984 about 250 bushels (8.8 m^3) of oyster shells obtained from a shucking house and an equal volume of slate were placed on adjacent plots in the inshore and offshore locations. Slate fragments were flat to subangular and ranged from 0.5 to 5.0 cm in length ($\bar{x}$ = 3.0 cm); oyster shells averaged 7–9 cm in length ($\bar{x}$ = 7.5 cm).

Four or five samples of oyster shells and slate were collected at random by a diver on seven occasions from each of the four plots from 10 August 1984 to 15 July 1985 (Table 1). In addition, the natural oyster bottom adjacent to each area was sampled in the same manner on three occasions. Each random sample collected by a diver consisted of material collected inside a .093 m^2 (one ft^2) frame placed on the bottom. The initial sampling depth of the substrate on 10 August 1984 was about 6 cm on shell and about 4.3 cm on slate. However, an examination of these two substrates, and of the bottom by a diver, indicated that sediments had filled most of the voids at and below these two depths. Consequently, subsequent samples were collected to about 3 cm on slate and 5–6 cm on shell. The volume of slate collected in each sample averaged about 1500 cm^3; shell number ranged from 28–60 ($\bar{x}$ = 35).

All samples of shell and slate were examined with a dissecting scope at 15X magnification after washing sediments from the material. Spat were counted and then measured to the nearest mm. Spat scars (the white area left after the top valve of the spat had fallen off) were also counted and measured, but only during and immediately after the setting season (Table 1).

From 10 August to 23 November, 1984 mean data on

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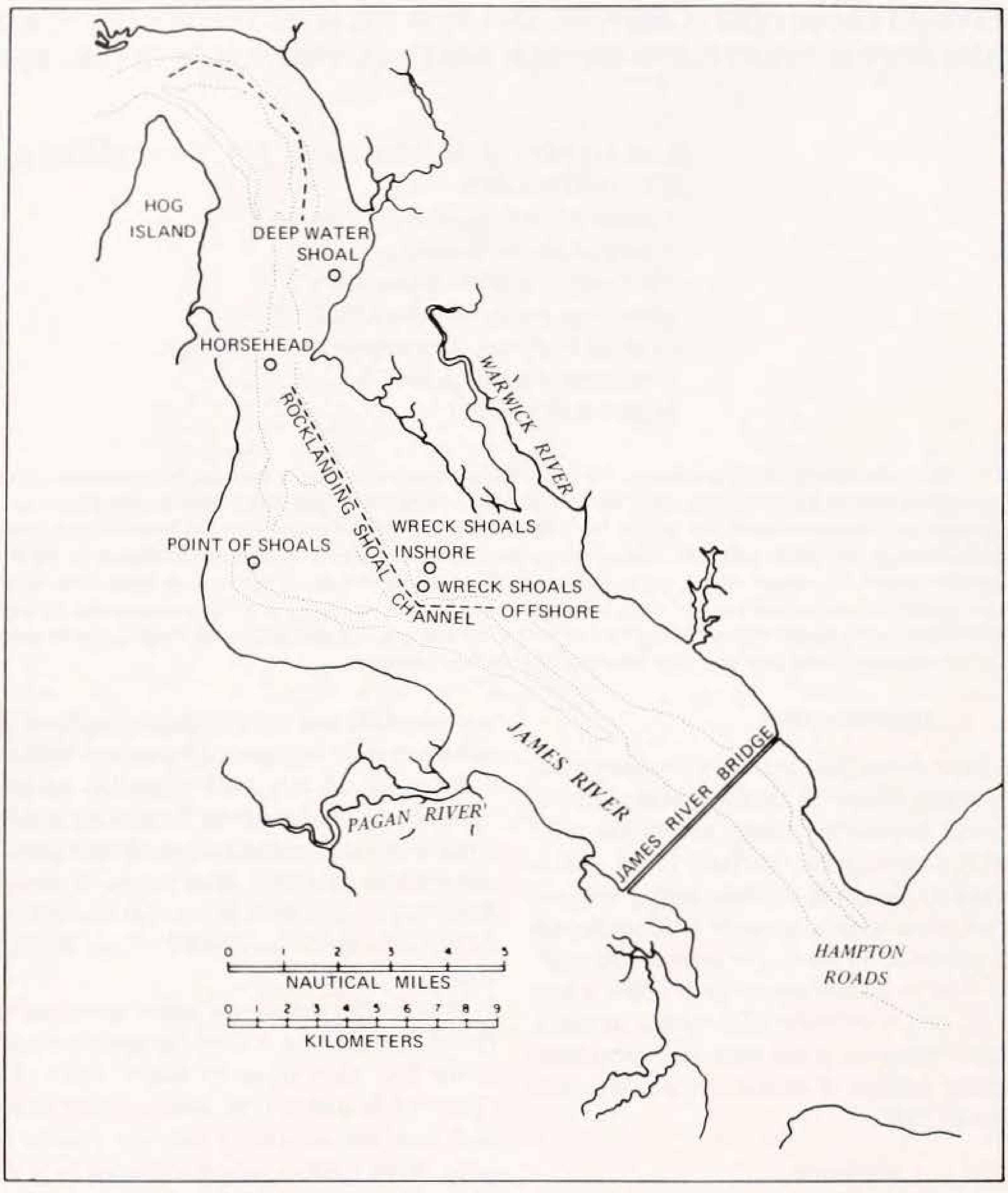

Figure 1. Locations of sampling stations in the James River, Virginia where shell and slate was planted.

spat and spat scar density and their lengths are based on randomly collected subsamples of the slate and shell; 25 to 50% of the total material collected was examined. This was necessitated by the large number of spat and spat scars in the samples. Subsequent counts are based on an examination of all material collected.

The percent mortality of spat during the setting season was not calculated because of the interaction between recruitment and mortality. While spat scar numbers were recorded, they are considered as unreliable indicators of long term mortality due to the difficulty in recognizing them after 2–4 weeks. Mortalities were calculated after setting ceased for the 23 November 1984 to 15 July 1985 period on the basis of changes (percent) in numbers of live oysters between the two dates.

Statistical studies compared numbers of spat m^2 and spat lengths in mm for various locations, dates, and substrate types. Comparisons of spat density were made for the post setting period for October, November, January and March, but not for July (low sample numbers). Lengths were compared for the final two sampling periods in March and July 1985. Data sets being compared were first tested for homogeneity of variance ($p = 0.05$) by a variance ratio (F) test. Later, mean spat lengths and mean number of spat were tested for significant differences between the various variances by a two-sample t-test with Cochrans t approxima-

TABLE 1.

Mean numbers of oyster spat and spat scars per .093 m² (one ft²) and mean lengths of spat and spat scars on oyster shell, slate, at two location on Wreck Shoals in the James River, Virginia, and on adjacent natural bottoms.

	OYSTER SHELL							
	Inshore − x̄				Offshore − x̄			
Date	no. spat	length spat	no. scars	length scars	no. spat	length spat	no. scars	length scars
10 Aug 84	63.2	—	—	—	98.9	—	—	—
30 Aug 84	80.8	5.0	21.0	3.8	27.3	3.8	14.2	2.5
8 Oct 84	228.9	8.2	19.4	7.9	26.1[1]	7.7	3.4	8.3
23 Nov 84	185.2	10.8	33.5	8.7	73.3	7.9	25.8	6.7
8 Jan 85	99.9	10.8	—	—	57.4	10.2	—	—
11 Mar 85	128.4	10.9	—	—	15.0	7.4	—	—
15 Jul 85	35.0	18.7	—	—	11.6	21.9	—	—
	SLATE							
10 Aug 84	5.0	—	—	—	1.6	—	—	—
30 Aug 84	42.1	4.8	16.8	3.0	27.8	3.9	16.9	2.1
8 Oct 84	33.5	7.5	30.2	7.5	22.3	7.9	13.6	7.9
23 Nov 84	45.2	9.6	16.2	6.3	23.6	7.6	12.8	5.8
8 Jan 85	31.6	11.1	—	—	26.0	9.2	—	—
11 Mar 85	17.2	9.1	—	—	11.2	9.9	—	—
15 Jul 85	8.4	16.9	—	—	2.2	16.3	—	—
	NATURAL BOTTOM							
23 Nov 84	2.4	11.0	—	—	—	—	—	—
8 Jan 85	3.4	12.6	—	—	1.2	12.3	—	—
15 Jul 85	1.4	24.0	—	—	0.4	—	—	—

[1] This low value may be anomalous.

tion, which depends on the homogeneity of variance (Guenther 1964). All statistical tests were made at the 95% confidence level or $p = 0.05$.

RESULTS

An inspection of the planted areas by a diver showed that slate and shell had not been evenly distributed at planting. On the Inshore plot, the slate formed an area about 6.1 × 6.1 m in extent, and the adjacent shell plot, about 3 m away, covered an area about 6.1 × 10 m in size. On the offshore plots, the slate had been deposited in the form of an oval about 3.0 × 5.0 m in extent, and the shelled area about 3 m away formed a 4.6 × 4.6 m square.

On the slate plots the diver observed that sedimentation began shortly after planting to form a thin veneer of fine sediment 1–2 mm thick, and it covered an increasing percentage of the clean surfaces with each monitoring period. By 8 October 1984 the slate was about 90–100% covered with fine sediment; the voids between the particles were relatively small or completely filled, and only the upper 2–3 cm were exposed to the water. On areas where shell had been planted there was also the initial fine layer of sediment 1–2 mm thick on 80–90% of the shell, but the remaining surfaces appeared relatively free of silt and biofouling. Moreover, there were still some voids between the shells to a depth of about 4–5 cm. On 11 March 1985 a slight reduction in sediment thickness on both plots was noted and conditions remained relatively similar to the end of the study.

On the inshore plots, there were significantly more spat on shell substrate than on slate for October and November 1984 and March 1985 ($P < 0.05$). No difference was shown for January 1985. A similar comparison for the offshore plots showed no significant difference in mean number of spat on the two substrate types for any month (Table 1).

Spat density on shells on the inshore area was significantly higher than shells offshore for the months of October and November 1984 and for March 1985 ($P < 0.05$). On slate, spat density on the inshore plot was also significantly greater than offshore ($P < 0.05$) during October and November 1985.

During the setting season, which extended to early October 1984, there was an increase in numbers of spat on the shell and slate. This increase was not always linear due to continuing recruitment and heavy but irregular mortalities as evidenced by the occurrance of numerous spat scars in all areas (Table 1). After the setting period, the following percent mortalities were calculated from Table 1 for the 23 November 1984 to 15 July 1985 period: Shell Inshore—81%; Shell Offshore—84%; Slate Inshore—81%; and Slate Offshore—91%.

At the end of the study on the inshore plots for March and July 1985, spat were longer ($P < 0.05$) on shell than on slate. On the offshore area, however, spat on shell were significantly larger ($P < 0.05$) only during July, but the differences cited were not large (Table 1).

While slate was less effective than shell in collecting spat, slate consistantly had more spat per unit area than the oysters and oyster shells on natural bottoms (Table 1). Differences calculated from that source showed that the slate had from 5.5 to 6.0 times more spat per unit areas than the natural bottom on 15 July 1985.

DISCUSSION

The cause(s) of the high mortality observed during the study are unknown, but deaths due to xanthiid mud crabs, blue crabs (*Callinectes sapidus*) and flat worms (*Stylochus ellipticus*) were most certainly involved. These predators often cause excessive oyster mortalities in Chesapeake Bay (Webster and Medford 1961, Krantz and Chamberlin 1978). Siltation was also involved and the fact that its initial coverage was greater on the slate plots may be the cause of much of the observed difference in numbers of spat between slate and shell (Mackenzie 1970).

The reason for the higher setting on shell and slate on the inshore areas in comparison to that observed offshore is not apparent. Depths of the two locations were the same and they were only 825 m apart. Differences in factors such as hydrography, the chemical differences between the two substrates, and available food and predator density were not studied. While our study favors oyster shell over slate as a setting medium, it is emphasized that at the end of the study, slate still had more spat than old shells and oysters growing on adjacent natural bottoms. It is suggested that accumulated biofouling on the latter substrate might have been responsible for the mortalities.

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