The Superior Substrate: The Effects of Shell Type on Oyster Restoration

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Background

- *Crassostrea virginica*, the eastern oyster is a critical ecologic and economic component of the Galveston Bay estuary. Oysters prevent shoreline erosion, filter the surrounding water, and create three-dimensional structures that serve as habitats for hundreds of marine organisms.
- Oyster larvae recruit to hard substrate and grow. The permanently attached oyster larvae are called spat (Fig. 1).
- In the last century, multiple stressors have led to a 50-89% decline in oyster populations in the Gulf of Mexico (Beck et al., 2011). Cataclysmic storm events like hurricanes or floods cause massive oyster mortality by depositing sediment, and freshwater on reefs and essentially burying the oysters alive (Haby et al., 2009). When oyster shells remain buried under sediment in an anoxic environment, they turn black (Comeau et al., 2016). This decreases available substrate for larval recruitment.
- Texas Parks and Wildlife has spent over $4.6 million (Rodney, 2014) rebuilding oyster reefs. Restoration efforts are centered on utilizing recycled sun-cured oyster shell as substrate for larval recruitment. However, with limited restoration shell after large scale storm events, TPWD is using black shell as settlement substrate, but the effects of black shell on larval recruitment are limited.
- The primary purpose of this experiment was to determine the effect of different shell types: white cured shell, fresh black shell, and cured black shell on larval recruitment.

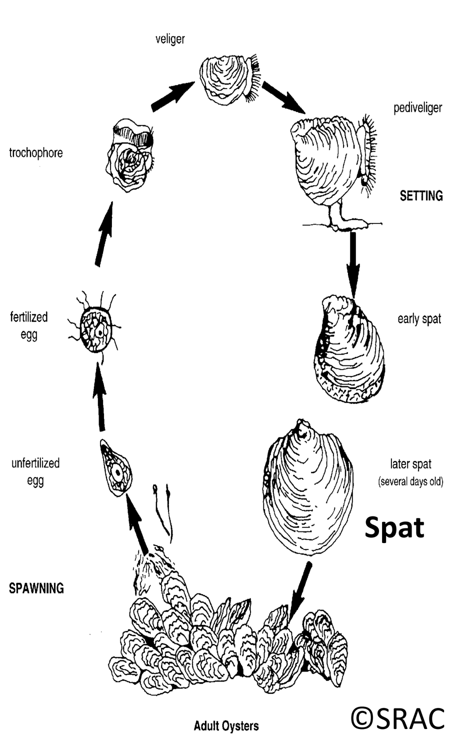

Figure 1. Oyster life cycle

Figure 2. Location of reefs in Galveston Bay

Methodology

- Intertidal oyster reefs created by Galveston Bay Foundation (GBF) in 2014-2015 with recycled and bagged shell were utilized for this study. These five reefs are located in Sweetwater Lake (Fig. 2) semi-enclosed embayment off West Galveston Bay.
- Reef background density was measured by collecting five bags of oysters from each reef, with each bag being removed from a different part of the reef. The first 20 live oysters in each bag were measured and the remaining enumerated.
- White cured shell was acquired GBF's Shell Recycling program, cured black shell was provided by TPWD, and fresh black shell was collected from buried bags on the reef. A total of 10 shells for each treatment type were placed in a single 20 x 20 cm hardware cloth cage and then a lid was added to reduce predation (Fig. 6).
- 8 replicates of the treatment types were zip-tied to the reefs in July 2019 (Fig. 7) and retrieved in mid-October of 2019. After retrieval, all of the oyster spat (Fig. 1) were measured and the mussels in each cage tray were enumerated.

Background Density

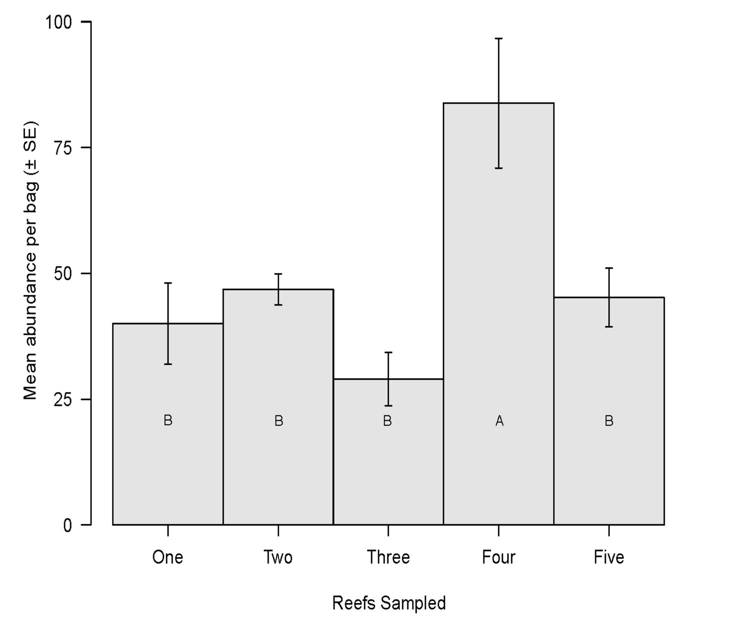

Figure 3A. Mean (± SE) oyster abundance significantly varied ($F_{4,20}$=7.05, P = 0.001) between reefs sampled, with significantly greater abundance on Reef 4. Different letters show significantly different (P < 0.05) results from SNK post-hoc test.

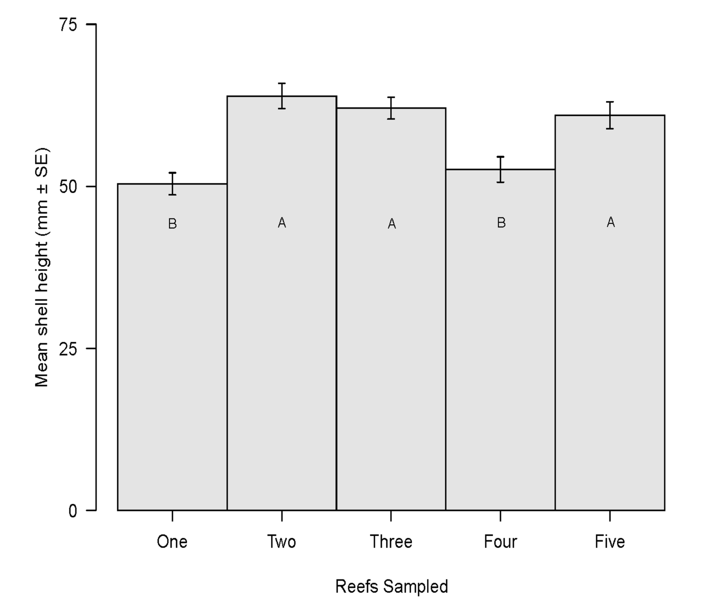

Figure 3B. There was a significant difference ($F_{4,492}$=10.37, P < 0.001) for oyster mean shell height (mm ± SE) among the reefs sampled. Different letters show significantly different (P < 0.05) results from SNK post-hoc test.

Recruitment Rates

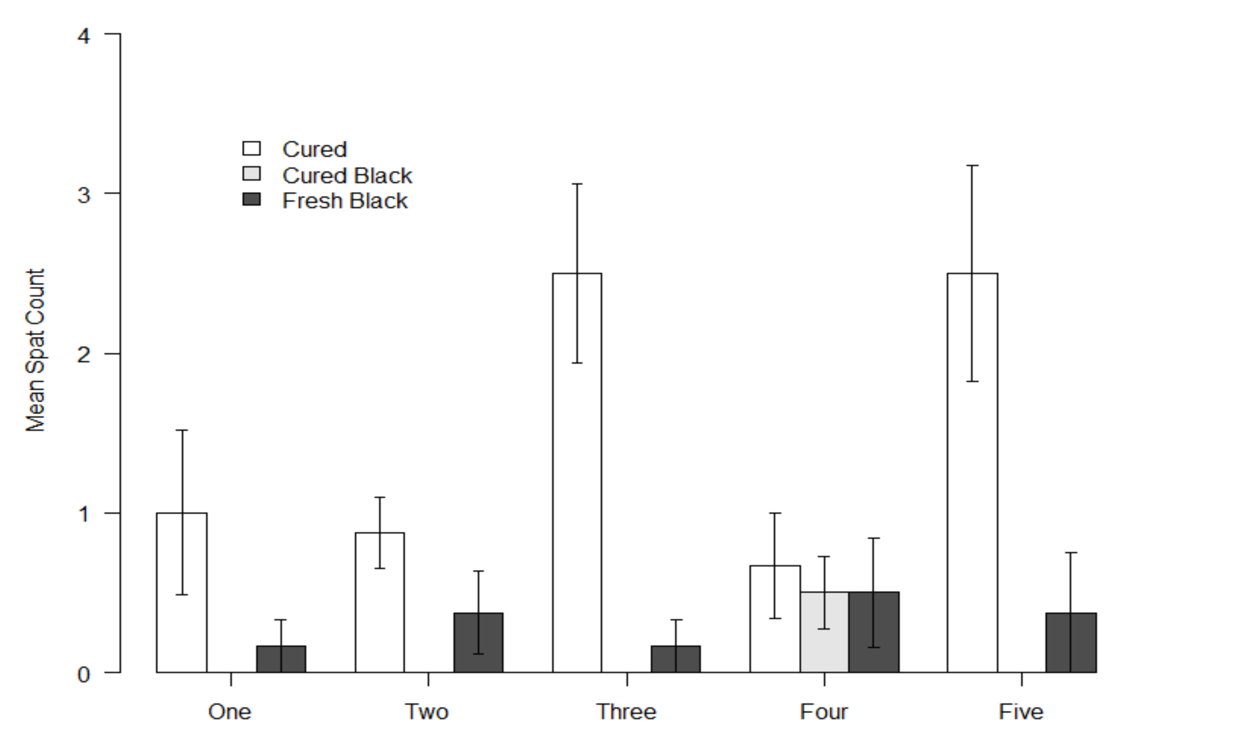

Figure 4. Mean oyster spat recruitment varied significantly for reef number and treatment type ($F_{8,87}$=2.96, P = 0.005).

Mussel Count

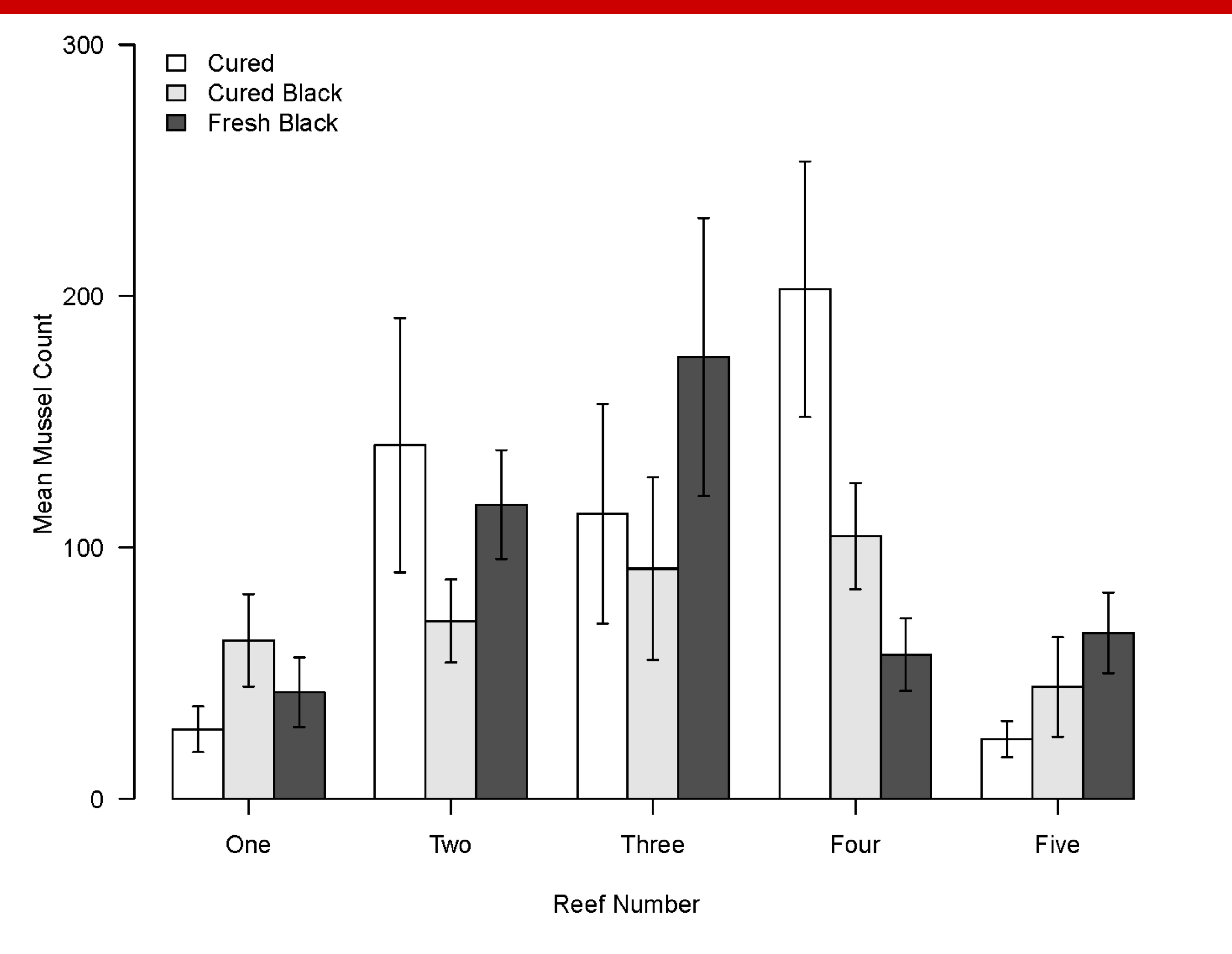

Figure 5. Mussel recruitment varied significantly by reef number and treatment ($F_{8,87}$=2.21, P = 0.03).

Results

- The background reef densities were significantly higher on reef four compared to the other reefs (Fig. 3A). Mean oyster shell height was significantly lower (P < 0.001) for reefs one and four (Fig. 3B).
- Cured white shell had significantly higher spat recruitment compared to either black shell treatment types ($F_{2,87}$=24.48, P < 0.0001). Further, there was a significant interaction between the treatment type and reef number (P= 0.005, Fig. 4). This significant interaction may be driven by unique recruitment patterns observed reef four (Fig. 4).
- There were no significant differences in spat size among the different treatment types ($F_{2,55}$= 1.83, P = 0.17), suggesting that different shell types influence recruitment but not growth.
- There was no significant correlation between mean oyster abundance and total recruitment per reef (Pearson Correlation, r(3)=-0.26, P=0.66). This suggests that variance in recruitment between the reefs may not be driven by established oyster populations on individual reefs.
- Mussel recruitment varied significantly by reef number and treatment (P = 0.03, Fig. 6). However, there was no correlation between different treatment types and mussel recruitment. Furthermore, there was no relationship between different reefs and mussel recruitment. This suggests that oyster spat are more selective than other organisms when recruiting to oyster reefs.

Figure 6. From Top: Fresh Black, Cured Black, & Cured Shell

Figure 7. 8 Replicates per Reef

Figure 8. A single replicate

Conclusion

- Reef background densities were measured to see if oyster larvae would preferentially recruit to reefs with higher adult densities. Reef four had higher oyster abundance than the other reefs, however, there was no relationship between mean oyster abundance and total recruitment to different reefs.
- Reefs (1 & 4) with lower mean shell height had more space available for larval recruitment.
- White cured shell had higher larval recruitment than the black treatment types among all reefs, but there was no significant difference in mean spat size among the different treatment types. This suggests that oyster larvae prefer to recruit to white cured shell over black shell and that shell type has little influence on the spat growth rate. In addition, reef four had elevated recruitment rates for black shell due to interactive effects between the reef and treatment type.
- There was no correlation between mussel recruitment and reef number or treatment type indicating that unlike mussels, oyster spat rely on a different unknown factor when recruiting to oyster reefs.
- For oyster reef restoration purposes, this experiment offers an initial insight into utilizing cured shell for restoration purposes. Given management organizations have spent approximately $4.6 million uncovering shell, these results may suggest that utilizing buried shell may not be as effective as oyster larvae prefer to recruit to white cured shell over black cured shell. While more research is needed for a holistic understanding, restoration efforts should focus on utilizing white cured shell, or other established methods, for restoration efforts.
- Oyster spat growth rates were not influenced by the differences in shell type, so future research should be conducted to determine the feasibility of using black cured shell on subtidal reefs and feasibility in aquaculture where larval recruitment rates are less of a constraint.

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