The Effects of Four Sediment Types on Shell Growth in Recently Settled Hard Clam (*Mercenaria mercenaria*) Juveniles

Heather Rain, Gettysburg College
(rainhe01@gettysburg.edu)
RIOS Program, Summer 2004, IMCS Rutgers University

ABSTRACT

In a single seven-day experiment in an annular flume, post-settlement *Mercenaria mercenaria* juveniles (352.8±44.5 μm) had higher growth rates in tape mud (both with and without the resident amphipod *Ampescila abdita*) than in sand or mud. Both tape mud treatments also had higher bottom roughness than sand or mud, as indicated by a higher free stream velocity (U*) at a flow rate of 10 cm s^{-1}. The data support the hypothesis that tape mud habitats have enhanced particle fluxes. These results suggest that *M. mercenaria* living in tape mud may have better food access and consequently higher growth rates, which may help to relieve predation pressures.

INTRODUCTION

The waters of Raritan Bay, New Jersey, are highly productive for the hard clam, *Mercenaria mercenaria* (McHugh 2001). Although *M. mercenaria* inhabit a variety of sediment types, they are more abundant in the southeastern area of Raritan Bay where the sediment is matted by tubes and fecal pellets, or "tape mud", of the amphipod *Ampelisca abdita* (MacKenzie et al., submitted, abstract).

This adult distribution pattern may be established during larval settlement, or it may result from post-settlement processes such as food availability, predation, and migration (Snelgrove and Butman 1994). The first hypothesis would require that *M. mercenaria* larvae actively select sediments based on a particular characteristic. Some research indicates that higher bottom roughness may promote larval settlement (Kraeuter et al. 2003; Ahn et al. 1993a). The fact that tape mud increases bottom roughness suggests that the hypothesis of larval selection may be worth investigating (Maxemchuk 1991). However, Snelgrove and Butman (1994) suggest that bottom roughness does not trigger settlement, but rather increases post-settlement survival. Greater bottom roughness generates higher particle flux, which is beneficial to suspension-feeders. Consequently, high bottom roughness may provide the *M. mercenaria* inhabiting tape mud with a competitive advantage: enhanced food availability, resulting in faster growth and consequently decreased predation pressures for post-settlement juveniles.

The original goal of this project was to investigate settlement of *M. mercenaria* larvae in different sediments. However, a series of survival tests in the small flume revealed that increased pressure from the diaphragm pump caused gas bubble disease and high mortality in the larvae (Bisker and Castagna 1985). Therefore, I focused on the rates of shell growth of recently settled juveniles in tape mud and other sediments. The sediment treatments included sand, mud, and tape mud with and without resident amphipods. The null hypothesis was that shell length would not differ between the four treatments after one week. Alternately, I hypothesized that shell growth rates would be related to bottom roughness, with higher rates in the tape mud treatments than in sand or mud.

METHODS

Tape Mud Samples

Tape mud was collected at two sites along the New Jersey coast (Figure 1). The first sample came from the waters near the Rutgers University Marine Field Station (RUMFS) in Tuckerton, New Jersey, on June 3, 2004. The second sample was taken from southeastern Raritan Bay on June 24, 2004, because the first sample had very low densities of amphipods and their tubes (Figure 2). The Raritan Bay tape mud had a density of about 20,000 tubes/m^2 (Clyde MacKenzie, personal communication) and appeared much more "mat"-like than the tape mud from the RUMFS site. Samples were kept in flowing seawater tables in the IMCS facility.

Rearing Clams

Batches of *Mercenaria mercenaria* larvae were obtained on June 3 (~200 um) and June 8 (~175 um), though only recently settled juveniles (>210 um) were used in flume experiments (Figure 3). Larvae were cultured at 20°C and a density of 1-2 individuals ml^{-1}; they were fed 10^5 cells ml^{-1} of algae (*Isochrysis* or *Tetraselmis*) daily.

Flume Experiments

Three growth experiments were run in an annular flume, filled to a depth of 15 cm with seawater (Figure 4). Each experiment tested the growth rate of recently settled *M. mercenaria* juveniles in tape mud with amphipods present (hereafter TM+), tape mud without amphipods present (hereafter TM-), mud, and sand treatments. In all three experiments, the rate of flow was 10 cm s^{-1}, and there was no evidence of bedload resuspension. Water temperature was about 20°C. Each experiment lasted seven days, and the clams were fed 10^5 cells ml^{-1} algae daily.

In the first two experiments, eight 9-cm Petri dishes were filled with the sediment treatments (two replicates per treatment). Experiment #1 used tape mud from RUMFS, and experiment #2 used tape mud from Raritan Bay. The Petri dishes were placed in the flume, flush with the sand bottom. Fifty *M. mercenaria* each of two size classes (mean shell length: 200.4±13.1 μm and 338.6±40.8 μm for experiment #1, 248.0±38.4 μm and 344.4±45.4 μm for experiment #2) were placed in each replicate.

Due to low recovery rates in the first two experiments (18% and 21%, respectively), the third experiment employed a modified design. The same eight replicates (including Raritan Bay tape mud) were placed in 5-cm Petri dishes, which were then placed flush within 9-cm dishes filled with sand. Fifty *M. mercenaria* of a single size class (mean shell length: 352.8±44.5 μm) were placed directly into the small dish. The clams were allowed 25 minutes to burrow before the flow started. At the end of this experiment, small samples of sand immediately upstream and downstream of the large dishes were taken, to determine which way the clams might be traveling. This design was meant to determine whether the clams were selecting sand over other sediments.

The flow regime above each sediment type at 10 cm s^{-1} was measured, using a Laser Doppler Velocimeter (LDV). The free sheer velocity (U*) was used to compare the flow over the four sediment types, as an indication of bottom roughness.

A nested ANOVA analysis was used to compare the differences in mean shell length.

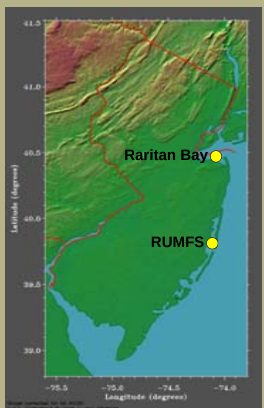
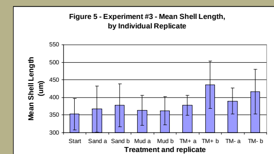


Figure 1 – Tape mud collection sites (map from http://fermi.jhuapi.edu/states/maps1/nj.gif, edited to include site labels)

Figure 2 (top) – *Ampelisca abdita* (from http://www.calacademy.org/research/izg/SFBay2K/SPRP/Ampelisca%20abdita.htm)
Figure 2 (bottom) – Tape mud, made by *A. abdita* (from http://www.csc.noaa.gov/lcr/nyharbor/html/gallery/sgampeli.html)

Figure 3 – Clams in A) larval stage, with velum, and B) settled stage, with foot (from http://www.marine.org/Philippines/Clam_Cycle_Big.html)

Figure 4 – Annular flume in the IMCS Seawater and Flume Facility (from http://marine.rutgers.edu/flume/annular.html)



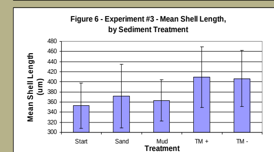


Figure 5 (top) – Experiment #e, mean shell lengths and standard errors, by individual replicate.
Figure 6 (bottom) – Experiment #3, mean shell lengths and standard errors, grouped by treatment type.

Replicate	Mean	N	SNK Grouping
TM+ B	436.3	16	A
TM- B	416.9	29	A B
TM – A	390.0	18	B C
Sand B	377.9	29	B C
TM + A	377.9	14	B C
Sand A	366.9	32	B C
Mud A	363.3	15	C
Mud B	362.7	15	C

Treatment	Mean	N	SNK Grouping
TM+	409.0	30	A
TM-	406.6	47	A
Sand	372.1	61	B
Mud	363.0	30	B

Table 1 (top) – Individual replicates, with means, N (number of individuals recovered), and SNK grouping*.
Table 2 (bottom) – Treatment types, with means, N, (number of individuals recovered), and SNK grouping*.
Means with a letter in common are not significantly different.

RESULTS

Experiments #1 and #2

The overall recovery rates of clams from experiments #1 and #2 were quite low, 18% and 21% respectively; these numbers were too low to get any reliable data or statistics. The sand treatments in these experiments generally had higher recovery rates than the other three sediment types.

Experiment #3

The overall recovery rate from the large and small dishes was 61.5%. Among the four sediment types, the highest recovery rate came from the sand treatment (61% for both replicates combined). The mean starting shell length was 352.8± 44.5 μm (Figures 5 and 6).

The mean shell lengths, number of individuals recovered, and SNK groupings of the individual replicates are shown in Figure 5 and Table 1. The SNK groupings indicate significance; replicates with at least one letter in common are not significantly different. The TM+ B replicate had the highest mean (436.3±67.4 μm) and was the only replicate grouped as A. The TM- B replicate was the next highest (416.9±63.2 μm) and was the only replicate grouped as AB. The two mud replicates had the lowest means (363.3±42.9 μm and 362.7±40.1 μm) and were grouped as C. The other four replicates were grouped as BC.

The mean shell lengths, N values, and SNK groupings of the sediment treatments (replicates grouped) after one week are shown in Figure 6 and Table 2. Again, treatments with the same SNK grouping are not significantly different. The two tape mud treatments grouped as A had the highest means (409.0±59.8 μm for TM+, and 406.6±55.8 μm for TM-). The sand and mud treatments grouped as B and had lower means (372.1±63.0 μm and 363.0±40.8 μm, respectively).

A nested ANOVA analysis of the means of each treatment type, when considering only variation within each replicate, revealed a significant difference among treatments (F=6.78, p=0.0002). However, comparing the variation between the two replicates within each treatment group revealed a significant difference between replicates (F=2.84, p=0.0261). Therefore, when considering variation between replicates of the same treatment type, there was no significant difference between the four sediment types (F=2.03, p=0.2524).

Flow Profiles

Flow over the TM+ treatment had the highest sheer velocity, U*=0.962 (Figure 7). Flow over the TM- treatment had the next lowest value (U*=0.704), followed by sand (U*=0.672) and mud (U*=0.536).

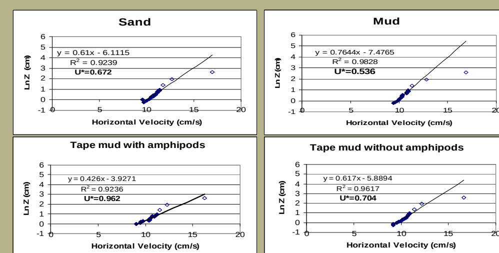


Figure 7 – Flow profiles over the four sediment treatments, measured with an LDV.

DISCUSSION

The results of the first two experiments revealed that many of the juvenile *M. mercenaria* did not stay contained in their starting sediments, which led to the modified design of experiment #3. Furthermore, the highest recovery rates came from the sand treatments in all three experiments. The possibility the clams were dislodged from the non-sand treatments by the current is largely refuted by the apparent lack of bedload resuspension at 10 cm s^{-1}. A more probable explanation is that clams specifically selected to move into the surrounding sand. While there is no evidence yet to support this hypothesis, the observation is worth further investigation.

Because of the high variances within the individual replicates, there was no significant difference in the mean shell lengths of clams growing in the four sediments. However, there was a trend toward higher growth rates in the tape mud treatments (with and without amphipods) than in the sand and mud treatments. For example, the SNK groupings show that the TM+ and TM- treatments were significantly different from the sand and mud treatments (Table 2). The SNK groupings for individual replicates were less clear-cut, but the TM+ B and TM- B replicates were significantly different from both mud replicates (Table 1). However, because these data are based on a single trial, the experiment must be repeated.

Both tape mud treatments had higher final shell lengths, as well as higher sheer velocities (U*), relative to the sand and mud treatments. These results suggest, as I hypothesized, that higher bottom roughness caused by tape mud may have enhanced the particle flux to the sediment bed. This flux would have increased the food availability to *M. mercenaria* living in the tape mud and enabled them to grow more quickly than clams living in sediments with lower bottom roughness.

Another possibility is that smaller clams had a higher tendency to leave the Petri dishes (by independent movement or by the flow), thus skewing the means. Size analysis of the clams in the sand boundaries revealed no striking differences in mean shell length, but the possibility remains. None of the replicates had 100% recovery, and the mean shell length of the missing clams is not known. The upstream and downstream scoops near each replicate have yet to be searched for the missing clams; data from these samples may help to confirm or refute this hypothesis.

Although the evidence is incomplete and the experiment has not been repeated, my original hypothesis is not entirely refuted. The results of this investigation do suggest that tape mud habitats provide a competitive advantage for juvenile *M. mercenaria*. If true, the higher growth rates would enable these clams escape pressures from certain predators at an earlier age, thus increasing their chances of survival. But again, the experiment must be repeated to determine if these results hold true and apply to the observations from Raritan Bay.

ACKNOWLEDGEMENTS

An NSF/REU grant and the IMCS at Rutgers University sponsored this project. The following individuals provided assistance: Dr. Judy Grassle served as my mentor; Charlotte Fuller did the LDV profiling; Hongguang Ma performed all statistics calculations; Jeanine Rosario, Piotr Nawrot, Shannon Newby, and John Quinlan assisted with setting up the flume; Clyde MacKenzie (NMFS, Sandy Hook) assisted with tape mud collection from Raritan Bay. Many thanks to the RIOS Committee for my acceptance into the RIOS program.

REFERENCES

Ahn, I.-Y., Malouf, R., Lopez, G. (1993a). Enhanced larval settlement of the hard clam *Mercenaria mercenaria* by the gem clam *Gemma gemma*. Mar. Ecol. Prog. Ser. 99: 51-59.

Bisker, R., and Castagna, M. (1985). The effect of various levels of air-supersaturated seawater on *Mercenaria mercenaria* Linné, *Mulinia lateralis* Say, and *Mya arenaria* Linné with reference to gas-bubble disease. J. Shellfish Res. 5: 97-102.

Kraeuter, J. N., Kennish, M. J., Dobarro, J., Fegley, S. R., Flimlin, G. E. (2003). Rehabilitation of the northern quahog (hard clam) (*Mercenaria mercenaria*) habitats by shelling – 11 years in Barnegat Bay, New Jersey. J. Shellfish. Res. 22: 61-67.

MacKenzie, C. L. Jr., Pikanowski, R., McMillan, D. G. (submitted, abstract). Characteristics of mud and sand habitat as related to abundances of northern quahogs, *Mercenaria mercenaria*, in Raritan Bay, New Jersey. Fishery Bull.

Maxemchuk, A. (1991). Rates of colonization of the subtidal amphipod *Ampelisca abdita* with respect to environmental disturbance, temperature, stage of the animal's life cycle, and bottom roughness. Unpubl. George H. Cook Honors Thesis, Cook College, Rutgers University, 38 pp.

McHugh, J. L. (2001). Management of hard clam stocks, *Mercenaria mercenaria*. In Kraeuter, J. N. and Castagna, M. Biology of the Hard Clam, Elsevier, New York, pp. 631-649.

Snelgrove, P. V. R., Butman, C. A. (1994). Animal-sediment relationships revisited: cause versus effect. Oceanogr. Mar. Biol. Ann. Rev. 32: 111-177.