

# The Effect of Shell Morphology on Sediment Retention in Turritelline Gastropods

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#### Abstract

Turritelline gastropods are typically semi-infaunal, spending the majority of their lives in sediment with only their apertures exposed at the sediment-water interface. Species vary in both whorl profile and shell sculpture, which consists of varying numbers of fine to pronounced spiral chords, but the effect of these variations on sediment retention has not previously been analyzed.

In order to consistently compare a variety of morphologies we micro-CT scanned six extant and fossil species representing a variety of shell forms, Mesalia brevialis (Recent), Turritella abrupta (Miocene), T. acuticarinata, T. banksii (Recent), T. duplicata (Recent), and T. montanitensis (Miocene). These species range from straight-sided (T. banksii) to strongly convex (M. brevialis) in profile and from nearly smooth (T. banksii) to strongly bicarinate (acuticarinata). These digital models were cropped to 50 mm in length and 3D printed the models using an ObJetPro 3D printer using the polymer acrylic DurusWhite RGD525.

The printed models were placed in a flume with a small amount of the apertural end of the model exposed and the rest of the model buried 1 cm below the sediment water interface at the apical end. All models were tested in 2 natural sands, a fine sand (average particle diameter 0.25 mm), and a coarse sand (average diameter 1.5 mm). Photos were taken before and after 15 minutes of exposure to current and the additional area exposed was calculated. Each species-sediment size pair was tested multiple times. While all results appeared normally distributed, they were also highly variable for each species. Further, superior performance in a particular sediment type was not necessarily consistent with the habitat of that species. Additionally, sculpture complexity, measured as the trace of one side of a whorl divided by the height of that whorl, did not exhibit a strong relationship with sediment retention.

#### Introduction

Turritelline gastropods are semi-infaunal suspension feeders are common components of Cretaceous-Recent macrofaunal assemblages worldwide (Allmon, 2011). As an infaunal suspension-feeder, most turritellines spend a large portion of their time buried shallowly under sediment, with only the aperture of their shell on the surface to allow for feeding (Fig. 1). Burrowing is time consuming, energetically expensive, and leaves the animal exposed on the sediment surface. Therefore, the ability to stay buried under sediment is central to the organism's mode of life, as well as to remain hidden from predators while feeding (Allmon, 2011). Sculpture has been considered as potentially important as a direct defesne against predation (inhibiting predator handling) in several studies of turritellines but does not appear to provide protection against drilling or peeling predators (Allmon et al., 1990). The effect of shell sculpture on sediment retention has never been examined in this group in any context. Therefore we chose 6 taxa representing a variety of whorl profiles and sculptures. Th objective of this experiment is to test if whorl profiles or sculpture are related to sediment retention under both unidirectional and oscillatory flow regimes.

### Materials and Methods

In order to assess the relationship between external shell morphology and sediment retention in turritellines we surveyed a variety of morphologies and chose 6 disparate taxa representing straight-sided to rounded whorl profiles and smooth to highly sculptured ornamentation. Taxa chosen include *Mesalia brevialis* (PRI 68714), *Turritella abrupta* (PRI 68713), *T. acuticarinata* (PRI 68718), *T. banksii* (PRI 68715), *T. duplicata* (PRI 68712), and *T. montanitensis* (PRI 68717). Taxa were from the recent collection of the Paleontological Research Institution except for *Turritella abrupta and Turritella montanitensis* (Miocene). Nano-CT scans were performed with a ZEISS-Xradia Versa 520 housed at the Cornell University Institute of Biotechnology. These were cropped to 50 mm in length (so all models would be directly comparable) using a Avizo 3D data visualization software by FEI Viualization Scineces group and then sent to the Cornell NanoScale Science and Technology Facility and printed on a ObJetPro 3D printer by Sratasys using a polymer acrylic material, DurusWhite RGD525, by the same company with a specific gravity of 1.17 (in comparison aragonitic shell material has a specific gravity of 2.95, however most of the volume of a turritelline shell is either empty or filled with biological material with a specific gravity only slightly higher than 1). These models were then cleaned for use by removing 3D printed matrix by hand and washed. Models were examined under both unidirectional flow and oscillating flow.

Unidirectional flow experiments were conducted in an experimental flume (Fig. 3a) housed at the JosephH. DeFrees Hydraulics Laboratory was set to a speed of ~0.15 m/s as determined by placing a floating object in an area of constant current in the flume, and recording the time spent traveling from one point to another, then averaging 20 trials (Ersdal, 2011). Models were placed in the flume parallel to flow direction with the apex directed into the current- the stable orientation for a turritelline shell (Toots, 1965; Nagle, 1967). Models were placed in a natural fine sand with the apertural end exposed and the apex 1 cm below the sediment water interface. Models were photographed after emplacement and again after 15 minutes (Fig. 4a). The area exposed in the original photo was then subtracted from the final photo. These trials were repeated 6 times. In order to assess the effect of sediment type 3 5-minute trials were performed in both fine sand and a coarse sand.

Oscillatory flow was examined in a wave tank housed in the SUNY Geneseo department of Geological Sciences (Fig. 3b). Sediment within the wave tank was a combination of fine quartz sand and a small fraction of coarse (0.5 mm) garnet sand. Trials were conducted simultaneously for all models. Models were randomly distributed across the shoreface equidistant from the wave source and oriented perpendicular to wave direction- the stable orientation for turritelline shells (Nagle, 1967), and buried with the apex 1 cm beneath the sediment. Five trials were performed. After each trial the wave influenced portion of the shoreface was restored and models were again randomly ordered. Photographs were taken when emplaced and every 5 minutes until 20 minutes (Fig. 4b). Again original areas exposed were subtracted from final areas exposed for comparison. Five additional trials were performed with models oriented parallel to wave direction to separate the effect of oscillatory currents from the orientation of the models.

Tukey's q was used to determine whether any of the differences in sediment retention were significant among models and Student's t was used to experiments. compare highly sculptured specimens collectively to less sculptured species.

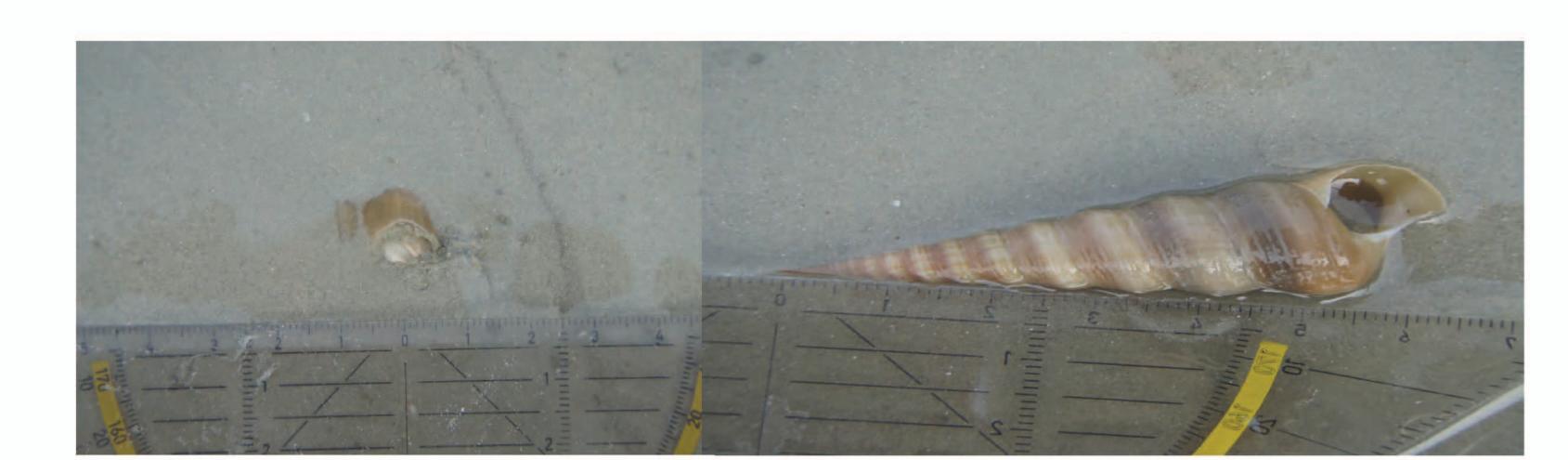


Figure 1. *Turritella duplicata* from Thailand showing the organism in place with only the aperture exposed and extracted from its burrow. Photos courtesy of Richard Waite.



Turritella abrupta Mesalia brevialis Turritella duplicata Turritella banksii Turritella acuticarinata Turritella montanitensis

Figure 2. Turritella species chosen to represent a variety of whorl profiles and sculptures.

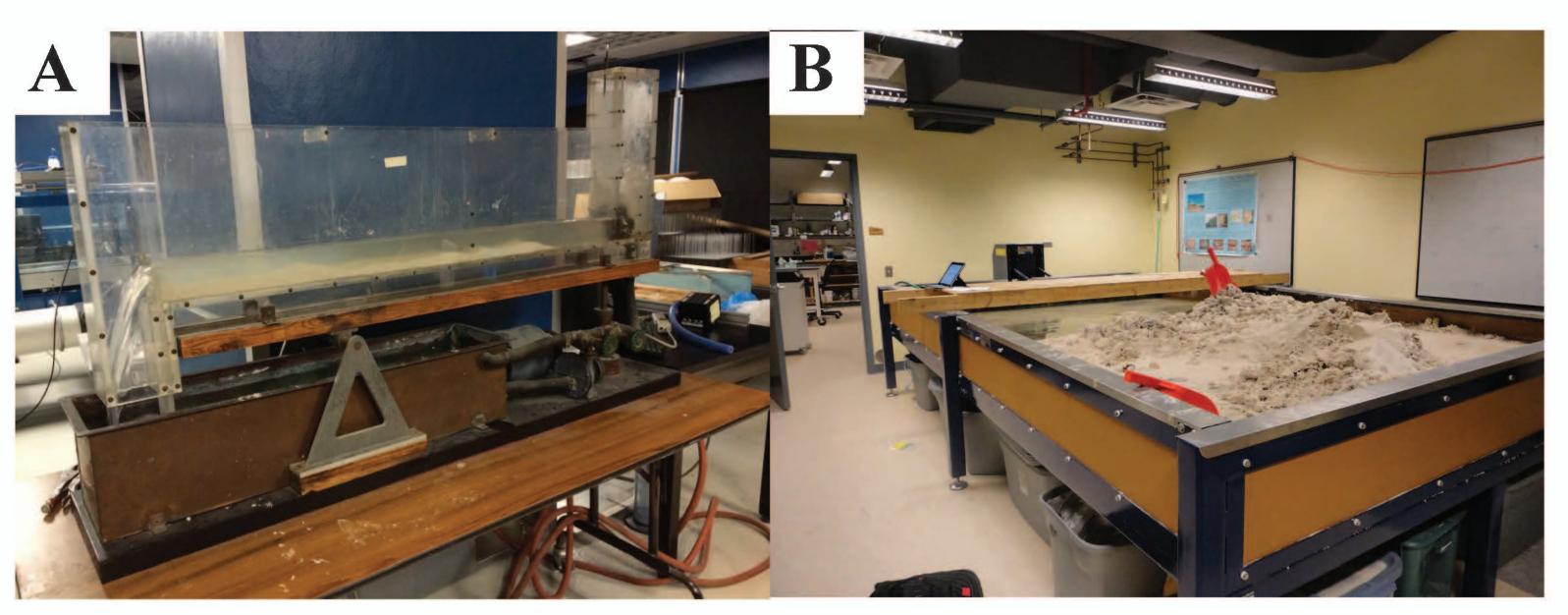


Figure 3. A. The demonstration flume (DeFrees Hydraulics Lab, Cornell University) and Wave tank (SUNY Geneseo) used in this study.

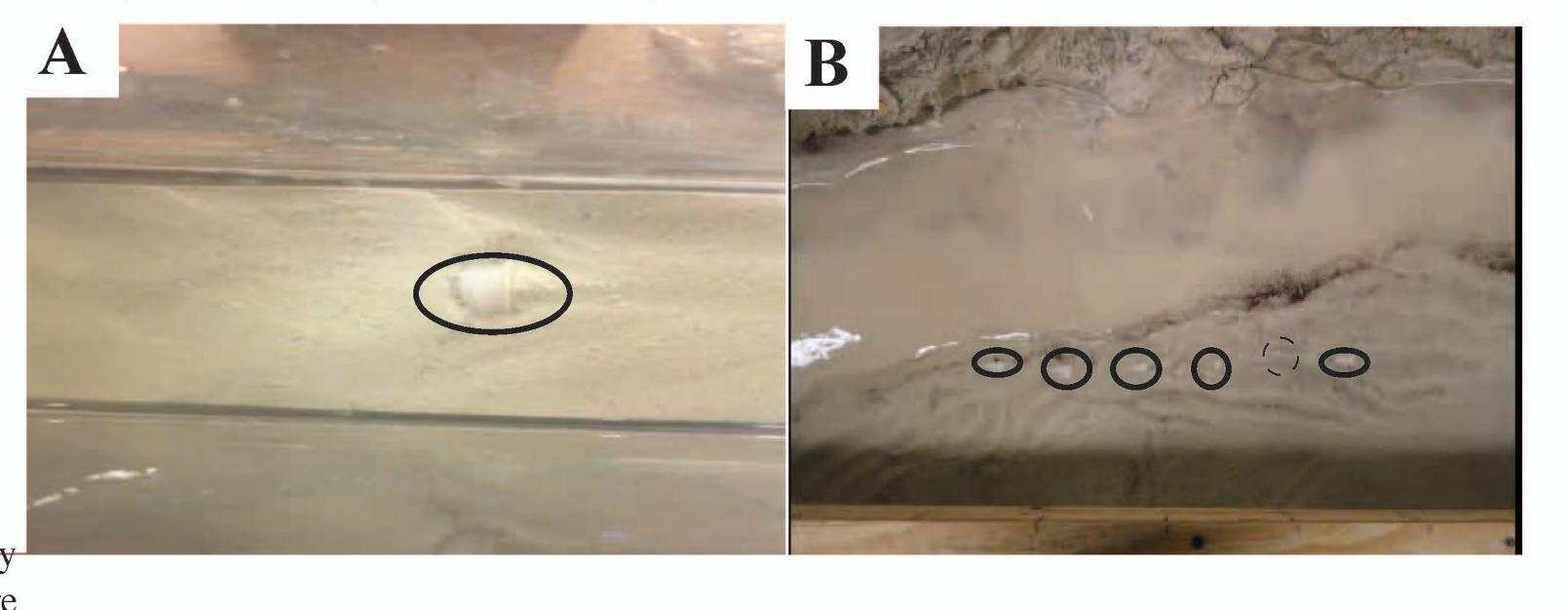


Figure 4. Example photos of models being exposed during flume (A) and wave tank (B) experiments.

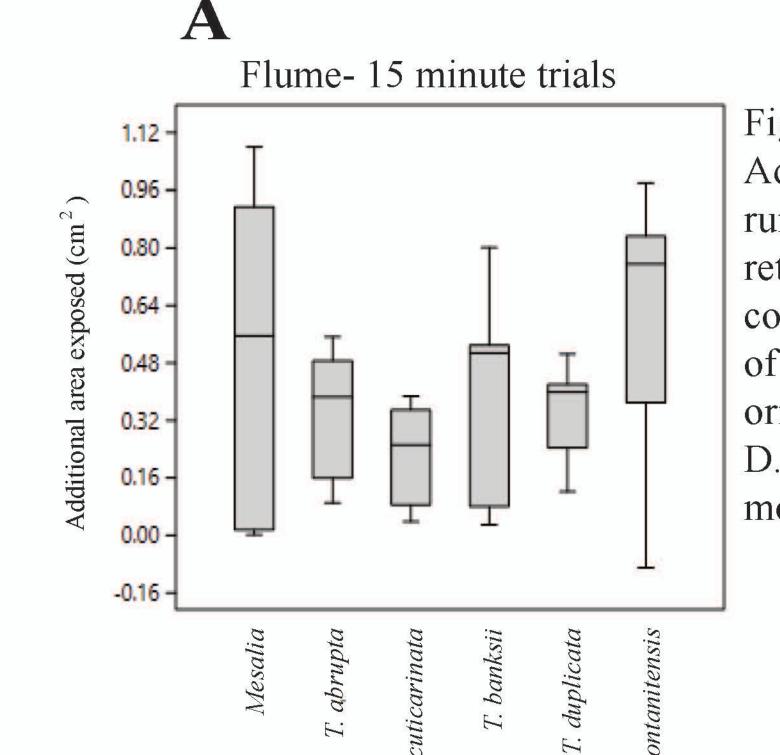
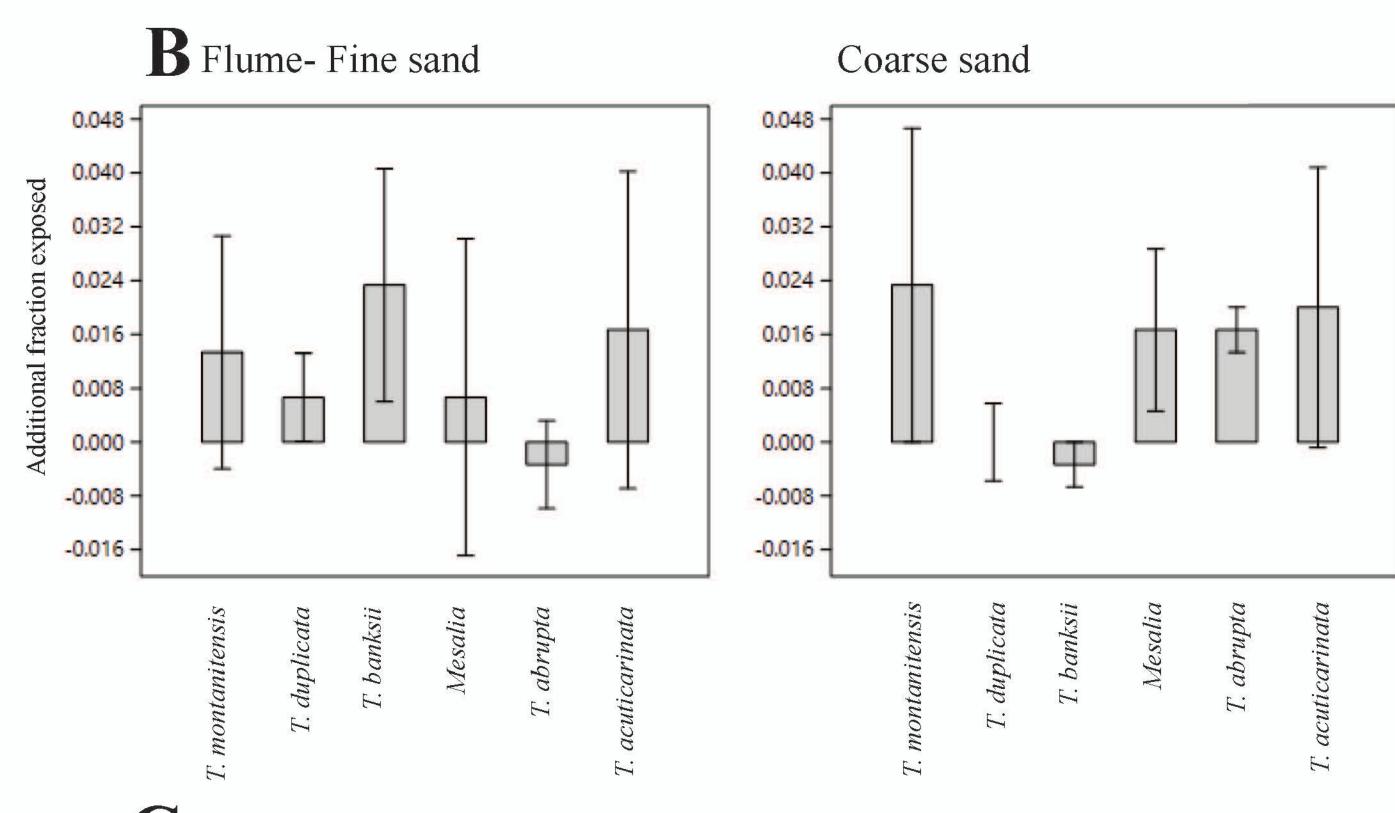
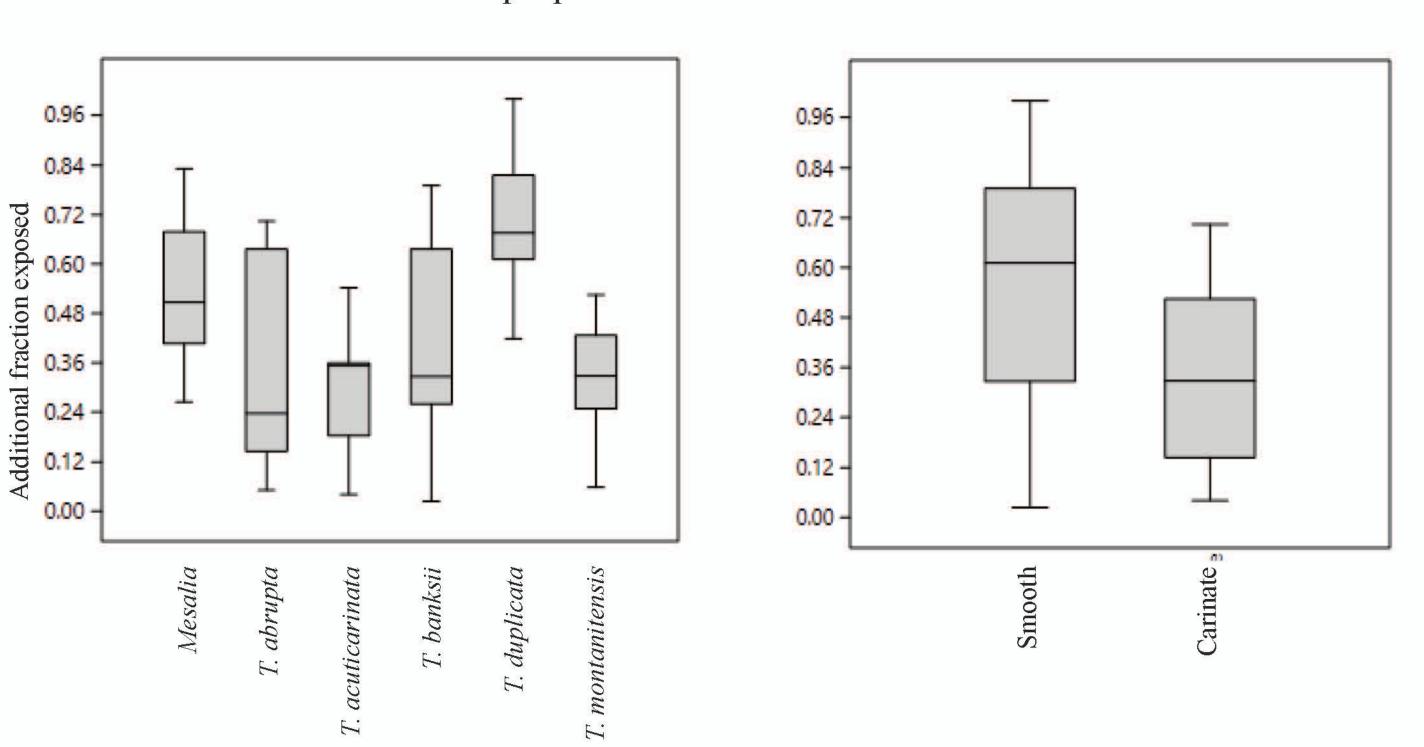


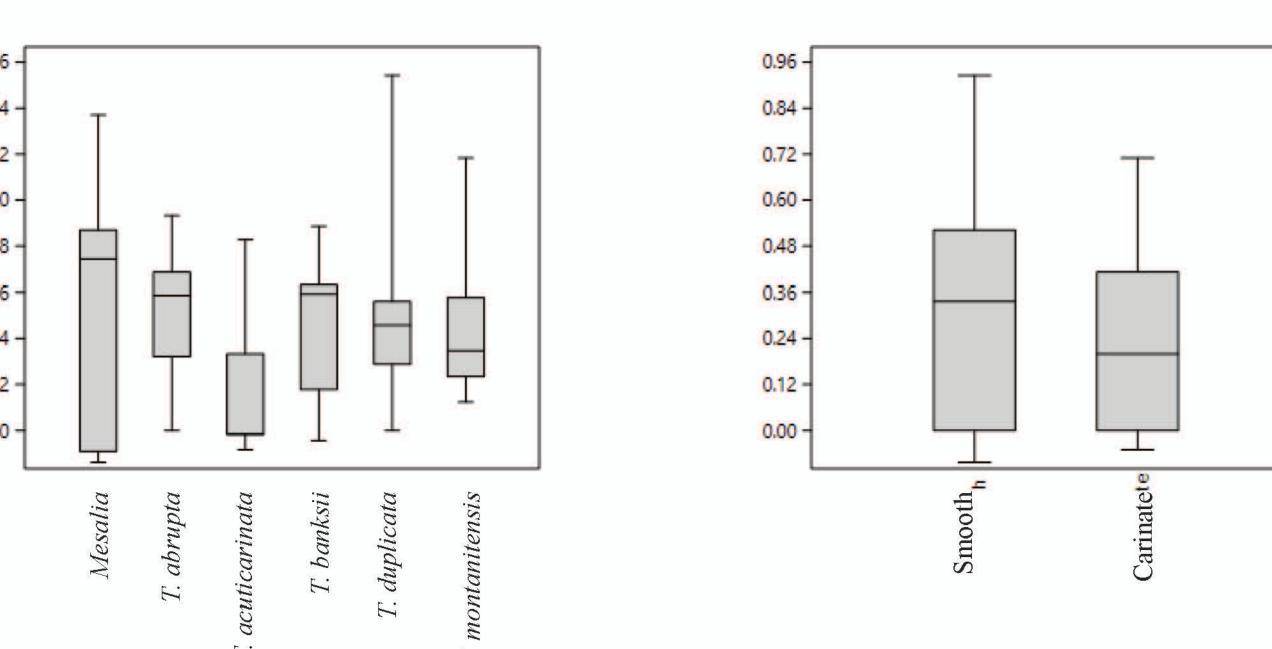
Figure 5. Results of flume experiments. A. Additional area exposed during 6 15 minute runs in fine sand. B. Comparison of sediment retention during 5 minute flume experiments conducted in fine and coarse sand. C. Results of wave tank experiments when models were oriented perpendicular to wave direction. D. Results of wave tank experiments when models were oriented parallel to wave direction.



C Wave tank- models perpendicular to wave direction



Mave tank- models parallel to wave direction





#### Results

Flume experiments revealed no significant differences among taxa (Tukey's pairwise comparison) (Figure 5a). No difference was detected comparing carinate (*T. abrupta*, *T. acuticarinata*, *T. montanitensis*) vs. non carinate spcies (p=0.81). Varying sediment type (coarse and fine sands) also resulted in no dfferences among species (Figure 5b). While some differences were observed these were not significant and did not appear at all related to the preferred habitats of these organisms.

Wave tank experiments with models oriented perpendicular to wave direction showed no statistically significant differences among all taxa, but **did show a significant difference between carinate and non-carinate species** (mean additional fraction exposed 0.55 for smooth and 0. 32 for carinate species, p= 0.015; Fig 5c). When models were oriented parallel to wave direction no significant differences were observed among taxa or between carinate and non-carinate species.

Spearman's rho was used to compare sculptural complexity to sediment retention for each of these comparisons. No significant relationship was found.

#### Conclusions

- If turritellines naturally burrow perpendicular to wave direction (the natural orientation of unoccupied turritelline shells in such environments) sculpture may enhance sediment retention. This is the first evidence of a potential adaptive function of turritelline shell sculpture unrelated to predation.
- Sculpture does not appear to provide benefits when shells are exposed to strong unidirectional currents.

#### Future Work

- Their may be a relationship between sculpture and resistance when burrowing; we will examine the force required to emplace these models in a variety of sediments.
- We will use a larger flume to determine whether orienting shells perpendicular to current direction produces significant results, or if sculpture is only adaptive in oscillatory regimes.

#### References

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