Preliminary Investigations into the Use of Dredge Material as a Substrate for the Growth of Benthic Organisms

A. Whitlock[1]; M.L. Ballentine[2]; K. Beauchesne[3]; C.J. Freeman[1]; A.J. Kennedy[2]; E.M. McDonald[4]; C. Miller[5]; Z. Moffitt[4]; C.M. Woodley[5]; P.A. Lee[1]

[1]Biology Dept., College of Charleston, Charleston, SC; [2]ERDC, U.S. Army Corps of Engineers, Vicksburg, MS; [3]American Marine University Research Institute, Seminole, FL; [4]Consolidated Safety Services, (*under contract to NOAA Charleston*), [5]Hollings Marine Lab, NOAA National Ocean Service, Charleston, SC

Introduction

Annually, in excess of 200 million cubic yards of sediment is dredged in federally-administered navigation channels to provide safe passage for vessels. Of that amount, ~85% is available for beneficial use but only 30-35% is currently used for beneficial purposes. Beneficial Uses, as defined by the U.S. Army Corps of Engineers (USACE Beneficial Uses of Dredged Material, Engineer Manual 1110-2-5026), is the "*productive and positive uses of dredged material, which cover broad use categories ranging from fish and wildlife habitats, to human recreation, to industrial/commercial uses*".

The objective of this study was to determine if dredged sediment could be used beneficially to create artificial substrate for the growth of sessile organisms that subsequently could be used in ecosystem restoration efforts. These efforts could include the building of larger artificial reef structures or smaller structures for lab-based culturing and rearing of organisms for the eventual seeding of new reef structures or replenishment of existing reefs. Two types of substrate designs were developed for this preliminary ongoing investigation. First, small flat plates were deployed in the New Cut branch of the Wadmalaw River (Johns Island, SC) to assess the suitability of the dredge sediment as substrate for invertebrate and algal communities. Second, small pyramids were made to assess the suitability of the dredge sediment for the settlement of coral larvae during laboratory experiments.

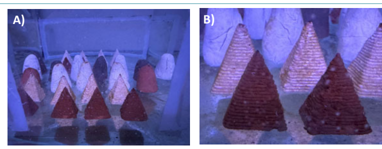

Fig 1. A) Larvae settlement structures in the glass kreisel. The pyramids in the two rows closest to the camera were used in this study. **B)** Close-up of the pyramids used in this study (Dredge sediment pyramids are in the front row, clay material in the second row). During the conditioning process, Crustose Coralline Algae (CCA) colonize the surface and create a biofilm (the light brown coloring most noticable on the second row of pyramids). The CCA produce chemical cues that promote larval settlement and are thought to enhance larval metamorphosis.

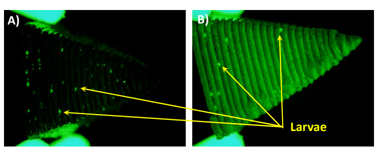

Fig 2. Exemplar images of the pyramids in the fluorescence imaging system showing the settled larvae. **A)** Dredge Sediment. **B)** Ceramic Material.

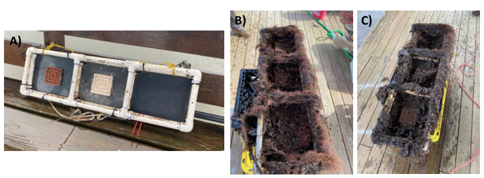

Fig 3. A) Example of an invertebrate plate stretcher prior to deployment. **B)** and **C)** Examples of the stretchers after 42 days in the water.

Methods and Materials

Material for 3D extrusion printing was prepared from a control stoneware clay and a Confined Disposal Facility (CDF) dredge sediment. Both were evenly spread out on a drying tray to air dry. Once dry, the sediment was ground using a soil grinder and large debris collected and removed. The ground sediment or clay was then sieved and any material that passed through a 1.6 µm sieve was kept for 3D printing. The material was then stored for later use.

In preparation for printing, the material was mixed with ~30% RO water by mass and loaded into the clay 3D printer. For these prints, a direct-drive clay 3d printer (3D Potter Micro10) with a 3mm nozzle was used. The designs were printed at a 1.5mm layer height. After printing, the designs were air dried for 24 hours then placed into a kiln for firing. The prints were fired at 1000°C for 12 hours with a ramp speed of 100°C/hour. The designs were created using Autodesk Inventor software.

For the coral larvae settlement tests, 4 ceramic and 4 CDF 3D-printed pyramids (~25mm base, ~35mm high) were placed in adult coral culture systems to condition for 14 days and then transferred to a glass kreisel containing ~10k *Pseudodiploria clivosa* (PCLI) larvae (Fig 1). The PLCI larvae were spawned at the Florida Aquarium, transported to the HML and placed in the kreisel 4 days after spawning and 6 days prior to the introduction of the pyramids. Images of the vertical (triangular) sides of each of the pyramids were taken 8 days after the introduction of the pyramids to the kreisel using an Olympus MVX10 Macroscope (0.63X objective) under a Wide Blue light filter with a 5.5 sec exposure time (Cellsens software; Fig 2).

For the invertebrate settlement tests, square plates (~90mm x ~90mm) were designed and produced to replicate low and high "roughness" surfaces (referred to as "Smooth" or "Rough", respectively). A sediment and ceramic plate of each surface type were attached to a PVC plate using titanium wire and assembled into a "stretcher" containing a sediment plate, a ceramic plate and a blank PVC mounting plate (Fig 3). The plates have been photographed every 2 weeks for determining area coverage, species abundance and richness since July 12^{th}, 2024.

Results – Coral Larvae

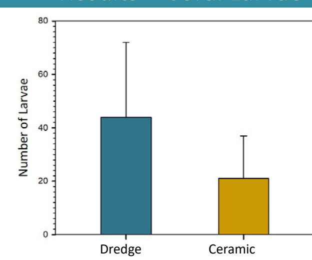

Fig 4. Counts of total larvae from all 4 triangular sides of the pyramids (bottoms of the pyramids were not counted). Error bars, where present, represent the 90% confidence interval.

Results – Sponge Settlement

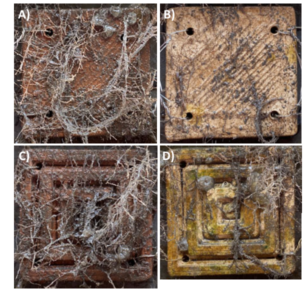

Fig 5. Exemplar images of the invertebrate settlement plates taken on 6^{th} September 2024. **A)** Low Surface Area "Smooth" Dredge Sediment, **B)** High Surface Area "Rough" Dredge Sediment, **C)** Low Surface Area "Smooth" Ceramic, **D)** High Surface Area "Rough" Ceramic.

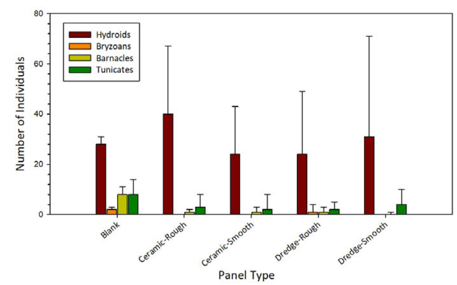

Fig 6. Estimated community composition on the invertebrate plates on September 6^{th}, 2024 (56 days after deployment). Algae were also noted, but are not included in the composition estimates due to sporadic occurrence. Error bars, where present, represent the 90% confidence interval.

Discussions and Conclusions

- With an appropriate amount of conditioning (data not shown), initial efforts show that dredge sediment is not detrimental to settlement of coral larvae in a laboratory setting (Figs 2, 4). Efforts are continuing to determine the impact of CDF sediment on larval development.
- The invertebrate plates have been deployed for 70 days as of September 20^{th}, 2024, and have shown no sign of degradation thus far.
- Considerable variability was observed between the community composition of the invertebrate plates but the results to date have shown that dredge sediment is not detrimental to the growth of benthic organisms in a natural setting (Figs 3, 5-7). Efforts are continuing to assess the longevity of the invertebrate plates and the impact of dredge sediment on benthic community succession.

Contact

Dr. Peter Lee
Hollings Marine Lab,
College of Charleston,
331 Fort Johnson Rd, Charleston, SC 20412
Email: leep@cofc.edu

Acknowledgements

The authors wish to thank Captain Tom Garrick for the use of his dock for the deployment of the sponge panels. AJK and MLB acknowledge funding from Engineering With Nature Project ERT-23-10.

Fig 7. Snapshots of 3D models of a Rough Ceramic invertebrate plate (left) and a Smooth Dredge invertebrate plate (right) taken using the PolyCam 3D Scanner (Photogrammetry) App.