Alternative Material Options:

Erosion Control and Living Shorelines in South Carolina

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Overview

Between South Carolina's oyster shell shortage in recent years and the introduction of a DHEC living shoreline permit for private property owners, the demand for oyster shells in the state has increased dramatically. While oyster shells make one of the best substrates for attracting spat, there are alternatives being explored in other states that South Carolina has yet to test and utilize. This document is a catalog of living shoreline/erosion control materials that would either minimize or replace the use of shell.

While designed with the goal of assisting local agencies and other environmental organizations, this document can also serve as a resource to contractors and homeowners looking to build living shorelines and protect local salt marshes.

What is being used currently?

1. Oyster shell bags
2. Manufactured wire reefs (MWRs)
3. Coir logs
4. Salt marsh grass plantings
5. Oyster castles
6. Recycled crab traps

For more details on how and where these methods are being deployed in SC, please refer to *Summary of Living Shoreline Research to Inform Regulatory Decision-Making in South Carolina,* published by SCDNR in 2019.

Review Considerations

Here are some of the standards used to evaluate the materials and products described in this document.

How effective is oyster recruitment and/or sediment accretion?

Since these are the primary functions for these installations, this metric is of utmost importance when considering erosion and marsh health solutions.

Does it attenuate wave energy, and can it hold up in tropical storms?

Wave and wind energy are the most common reasons for shoreline erosion. Any erosion control structures must be able to attenuate that energy. South Carolina is subject to regular flooding events combined with king tides and storm surges, not to mention its vulnerability to hurricanes. While they might not prevent the impacts from these events, erosion control structures must be able to withstand these conditions.

What is the cost?

Costs of the material / product itself is extremely important for homeowners as well as state or nonprofit agencies looking to construct erosion control structures.

If a cost estimate was provided by a company or agency, it is bolded within that section. A relative cost estimate indicated by the symbols $-$$$$ is listed next to the name of each product.

Where has it been used and in what environmental conditions?

It is important to know where a product has been successful and in what environmental conditions (sediment type, escarpments, etc.) to determine its potential success in South Carolina Waterways.

How has it been monitored for success and what is success?

Similarly to above, how a material is monitored and what success looks like is important to understand when determining potential success in South Carolina.

Does it contain plastics or other potentially harmful substances?

Many products marketed for erosion control contain polypropylene / polyethylene plastics or concrete that could leach chemicals into the surrounding environment. It is important to minimize environmental harm with these implementations.

Can it be built/installed by property owners, or are contractors and heavy equipment needed?

If construction equipment, barges, contractors, etc. are needed to install an erosion control structure, it increases the overall price.

Can it be manufactured locally?

If a product is manufactured in SC, it supports our economy, and it also minimizes transportation costs.

Does it have a natural aesthetic?

Aesthetic value is an important factor– especially for some private property owners. Lower profile, less “gray” methods that enhance the natural features and blend into the environment are ideal.

Recruits Oysters + Accretes Sediment	Only Accretes Sediment
Atlantic Reefmaker Articulated Concrete Blocks BESE Products ECOncrete GROW Oyster Reefs Oyster Catcher Marine Mattress Quick Reef Gabion baskets Natrx	Filtrexx Wave Attenuation Devices Geotubes Envirolok Growth Bags SOX Erosion

Erosion Control Materials | oyster-recruiting

Atlantic Reefmaker | $$$

Atlantic Reefmaker is a product that is made of fiberglass rebar and can attenuate wave energy while acting as a substrate for oyster settlement and accreting sediments. It consists of a piling with concrete disks stacked on it. The disks can be 18 inches or 5 feet in diameter depending on the energy requirements of the site , and have the option of coming pre-seeded. The company has licensing rights in North Carolina, SouthCarolina, Georgia, and Florida.

The product can work in softer sediments with a longer piling, and can accommodate for sea level rise by extending the piling and stacking additional disks. It also leaves space for marine animals to move freely, since there is space between the structures.

The Reefmaker system is significantly more expensive and requires professionals and heavy equipment to install. They are also bulkier and have a lower natural-looking aesthetic value compared to other more low-profile products.

Source: Atlantic Reefmaker

BESE Products | $$

There are several BESE products designed for use in shoreline restoration. Designed to be an alternative to plastic mesh bags, BESE produces biodegradable mesh bags. It retains a similar look as plastic mesh bagged shell and is still light enough to self-install or with volunteer labor.

These mesh bag products have a short lifespan, biodegrading quickly. According to the data sheets provided on the BESE website, there are two versions of the product. One is a cellulose mesh that biodegrades in ~1-3 months in an intertidal zone, faster in warmer waters (anecdotally it can dissolve in a matter of weeks if not stored carefully; keeping the product out of the elements until deployment is vital). This provided estimate was corroborated in a 2022 study where all the deployed cellulose bags were fully disintegrated within two months in the Gulf. BESE does offer an option to include an oak resin coating to increase the lifetime of the product but does not state what that new lifespan is. The other mesh bag product is made of a newer biopolymer material with a 1 cm sized mesh that is said to biodegrade in 5-15 years. However, the lifespan of this new material is still being studied in different environmental conditions.

In a study comparing different biodegradable living shoreline materials, BESE's short lifespan is shown to negatively affect the density of oyster recruitment after several months. This is thought to be due to the mesh disintegrating at the 2-month mark, breaking apart the complex structure and resulting in less oyster recruitment. There are also anecdotal concerns about microplastics still leaching from these products.

BESE cellulose mesh bag; Source: BESE website

BESE biopolymer mesh bag; Source: BESE website

While BESE products are beneficial in that they are biodegradable, i.e., not exposing the environment to microplastics, they still use similar shell quantities as their mesh bag counterparts. Cellulose bags are shown to be 55-78% more expensive than plastic mesh bags. However, it should be considered that these prices do not account for the environmental cost of using plastic mesh.

Another product that BESE offers is BESE Elements, which is a thicker, latticed mat that has been studied in comparison to Vexar plastic oyster mats. Vexar mats have a record of being successful in Florida.

The BESE Elements mats function very similarly to Vexar in terms of recruitment and shell height where they were studied. The mats were found to have degraded 50%

within 4.4 - 6.7 years in the experiment. The Elements product uses recycled oyster shells more efficiently (they are zip-tied to the mat); however, BESE Elements were 377.8% more expensive than the Vexar mats. This price would only increase more if BESE brand biodegradable zip-ties were used in the process as well to mitigate plastic use further.

While BESE products remain a promising direction for material sourcing in the future, the lifespan will need to be lengthened and the cost lowered to make it a more accessible option in South Carolina.

BESE Elements mesh (L) with growth (R) ; Source: BESE website

ECOncrete | n/a

ECOncrete produces a concrete admixture that when added at a 10% ratio to regular concrete, makes a “chemically balanced” material that is beneficial for restoration projects. The admix prevents chemical leaching from the concrete and creates a rougher surface for invertebrates, such as oysters, to attach to. The company also sells texture agents and mold liners which further increases the surface complexity. The products are made in Israel, or at their other manufacturing partners in the UK or US; therefore local manufacturing in SC would not be an option for this material. However, any molding and casting needed for the project

can all take place on site.

ECOncrete could be useful for methods such as making PROs/POSH modules, as mentioned later in the document, and recycled crab traps. However, it has been

difficult to find documentation of what “chemically balanced” means to ECOncrete and how the admixture accomplishes that.

ECOncrete packaging; Source: ECOncrete website

Articulated concrete blocks | $$

Examples of brand names for these are Shoreflex and Flexamat. They are a promising option that could stabilize and accrete sediments while also recruiting oysters along the “toes”. It’s a series of concrete blocks connected by a plastic grid that is sold in rolls. The plastic material is a disadvantage, but the concrete can recruit oysters, while the spaces between the blocks leave room for plant growth to anchor sediments and the mat in place.

Source: ReadyReef

GADNR is testing Flexamat , but they have not been installed long enough to know the time it takes for oyster recruitment to take place. However, sediment has accreted since its deployment. From the company Ready Reef, the cost of installation can range from **$100-$400 per linear foot.**

This product works well in softer sediments due to its wide surface area, but is less suited for steep slopes or escarpments. It is not manufactured in South Carolina, nor can it be installed by volunteers or property owners. It is extremely low-profile and will blend into the environment quickly as plants grow in and sediment accretes.

Gabion Baskets | $$

Gabion baskets are galvanized wire cages filled with oyster shells, rocks, or a combination of the two. They do not contain plastic, and keep oyster shells from losing their structure. GADNR and the NC Coastal Federation tested gabion baskets and found them to be heavy and expensive to install. In addition, they observed many baskets popping open on the corners after installation. There are concerns about wildlife entrapment and impediments to horseshoe crab spawning as well. Some fish were observed by GADNR that became trapped in the mesh. Diamondback terrapins are of particular concern of becoming entrapped.

In lower-energy environments, some of these concerns will not be an issue, but it seems that the MWRs and recycled crab traps currently used in SC are a better, cheaper option compared to gabion baskets.

Source: Gabion Barriers website

GROW Oyster Reefs

The Grow Oyster Reefs company uses a proprietary 85% calcium carbonate concrete mix to create their oyster restoration products. This mixture does not leech harmful substances and provides a calcium carbonate source for the oyster shells to access as they grow. The concrete can be used for casting, spraying or for 3D printing, although as of now, it is not sold by itself. The company sells “reef tile” products made from their concrete which have a flat bottom, are designed to have interstitial space for both oyster settlement and a hole for marsh grass plantings and can be designed to suit a variety of sediment types. These units are about 28 pounds each, making it a viable option for self-install or for volunteer installation.

The oyster tiles have been tested in Maine; Harris Creek, Maryland; Elizabeth River, Virginia and Florida. There is currently a project deployed near Conway, South Carolina. All of the products are manufactured in Charlottesville, Virginia. A single crate of approximately 50 units costs **$50/unit**, but ordering in bulk can bring the price down to approximately $35/unit.

Source: GROW Oyster Reefs website

Natrx | $$$

Based out of Raleigh, North Carolina, Natrx uses 3D printing to create their concrete products. Natrx worked with the University of Kentucky ensuring their products do not leach harmful chemicals. The ExoForm units are *typically* 3 x 3 feet and weigh 500 pounds, though this can vary considerably. Their satellite monitoring system measures metrics such as fetch, water speed, etc. at the desired site and uses that information, in addition to the sediment type, to adjust the dimensions and concrete properties of their product for that site.

Oyster Rings are an alternative by Natrx that has been installed in Louisiana, Gloucester, Virginia as well as further north along the East Coast.

Volunteer and self-installation are not possible for these products. The price of Natrx is higher compared to other options with the average cost being approximately $200 per linear foot - not including the price of contractors to install

the products.

Natrx installation; Source: Natrx website

Oyster Catcher | $

Oyster Catcher units are made of jute plant fiber coated in cement and molded to dry into a desired structure. Typically, they are molded into tables, pretzels, and pillows, as shown below. The rough structures help to accrete sediment and recruit new oysters. The units are versatile; tables can be stacked and tiered to increase settlement surface area and can even be pushed down or installed at an angle in the sediment to accommodate for softer sediments or escarpments. The pretzel and pillow units can be combined with tables and “hammocked” underneath to further increase surface area for settlement.

Units can be installed in hybrid with bulkheads, accreting sediment landward and strengthening the shoreline until the bulkhead is no longer necessary. Some studies suggest the Oyster Catcher materials slow shoreline retreat and fare better in severe storms compared to bagged shells.

The versatility in function and structure is a key advantage of Oyster Catcher. They are successfully deployed in Virginia, North Carolina, South Carolina, and Florida

(and are being studied in Georgia by GADNR), in both low and high energy settings including the intercoastal waterway of North Carolina. The NC Coastal Federation successfully installed a 185-foot Oyster Catcher reef. They cost less than $100 per linear foot and are lightweight, making them feasible for volunteer and self-install.

Pillow, table, pretzel, pillow cross section; Source: Abby Stephens

Oyster Catcher products are found to recruit oysters in less than one year and have significantly higher density and length of oysters grown compared to the bagged shell and natural reefs surveyed. Full spat cover was seen within just one season.

When comparing the Oyster Catcher to shell bags and a natural reef, Oyster Catcher reef had a more than 800% higher density of oysters compared to the shell bag treatment after three years. The Oyster Catcher reef also had longer adult oysters for the first and final years of the study.

Marine Mattresses | $$$

Marine mattresses are similar in concept to gabion baskets, except the "basket" is a low-profile, plastic geotextile filled with stone and typically topped with granite

riprap. They can also be installed on top of a geotextile fabric to prevent scouring. It works well in areas with higher wave energy and is effective at recruiting oysters and

accreting sediments. It was locally installed by Olsen Associates in Hilton Head, SC, and cost approximately $180 per square yard. This is a product that definitely requires professional installation.

Source: Tensar Corps website

Quick Reef | $

Quick Reef is a product of the North Carolina-based Native Shorelines company. They are 90 pound blocks consisting of 10% Portland cement and limestone, sand, and pieces of oyster shell making up the rest. They measure 1 ft x 2.5ft x 5in and are stacked in a pyramidal fashion. For higher energy environments, there is an option to connect the blocks with cables.

Source: QuickReef

There is evidence of wave attenuation behind the structures, and it accretes some sediment. It withstood Hurricane Ian, so has a good track record of standing up to storms.

The blocks are mainly deployed throughout North Carolina (Bogue Banks, New Bern, New Hanover County, New Brunswick). The NC Coastal Federation has a QuickReef test site, and during their 1.5-year deployment they have performed well.

Quick Reef is still undergoing monitoring projects, none of which have been published yet. One experimental site has a 67-mile fetch which will show its effectiveness in a higher energy environment. The rough surface of the blocks seems to be an effective substrate with thorough spat coverage within a year.

In most cases, a barge is not needed for installation - pallets can be sent in on trucks, with each pallet holding 16 units. It is difficult to self-install or to use volunteers for installation since the blocks are 90 pounds each, but with contractors, it can be installed at a rate of about 100 feet per day.

Erosion Control Materials | non-oyster recruiting

Wave Attenuation Devices (WADs) | $$$$

WADs are large structures made of concrete and fiber meshing that resemble pyramids with tapered openings on all sides. They dissipate wave energy, causing sediments to fall out of suspension as the water slows, resulting in rapid sediment accretion. They are currently deployed in tropical regions such as Mexico and Jamaica, as well as in Delaware and Virginia. The units are large and weigh about

8,100 pounds each. They are an outlier for cost in this document. A 2018 project in LA estimated the cost of material to be $1400 per linear foot.

A steel mold is manufactured by Living Shoreline Solutions, then sent to a local manufacturer for concrete pouring. This makes it possible to employ local SC

businesses with this method. WADs are not as effective at oyster recruitment as other products, but are very effective in high energy environments for both sediment accretion and wave attenuation.

Source: Living Shoreline Solutions

SiltSoxx Natural Plus | $$

The brand Filtrexx makes a sock-like structure out of cotton or wood fiber. They are filled with compost media and are staked into the ground. They could be a potential alternative to using coir logs for erosion control as they seem to have similar properties such as biodegradability and a similar lifetime of ~18 months, although they will likely degrade quicker in an intertidal setting.

According to the NC Coastal Federation, the cotton socks broke open and were less successful at their sites. They were tested by GADNR at a newer tidal creek living shoreline site in 2021, but it has yet to be evaluated.

Filtrexx brand Siltsoxx Natural Plus+; Source: Filtrexx website

Geotubes | $$

Geotubes are long geotextile tubes filled with sediment and seeded to grow marsh grasses. The root structures help anchor the geotube in place and accrete sediment behind the structure. While they have been used in sandy environments, this report only analyzes their potential use for estuary habitats.

Equipment is needed to both install the bags and fill them with local sediment. The product is not manufactured in SC. Aprons are available to underlie the installation site to help prevent scouring along the edges of the bags. A downside of this product is they are made of plastic fibers.

Envirolok Growth Bags | $$

Envirolok growth bags are similar in concept to geotubes, the main difference being that Envirolok is a series of smaller bags, whereas a Geotube is one large bag. It can accrete sediment in approximately one year and creates a great habitat for native plants. It consists of smaller, stacked bags which allows for more flexibility in placement along steep or irregular shorelines. These bags are made of plastic, similar to Geotubes and have been installed locally on Kiawah Island.

Source: Envirolok website

While the product isn't volunteer or self-installation friendly, it does not need extensive equipment nor engineered backfill. The product itself is not locally manufactured but can be filled with local sediment or a mix of sand and topsoil.

SOX Erosion Solutions | $$

SOX Erosion Solutions is a company based out of Boca Raton, Florida that produces ShoreSOX and DredgeSOX. These products are described as being like geotubes, although more "taco-shaped" than tube-shaped. The material is made of plastic, double layered and knitted, making it more tear resistant, and filled with dredged or local sediment and topped with sod. It can be dry seeded after filling it, or holes can be cut into the mesh to plant marsh grasses. While the product is used mainly on golf courses and in city parks, it has a good record of sediment accretion and works well on escarpments since it can act as "soil lift" and has been used to replace failing bulkheads and seawalls.

Source: SOX Shoreline Solutions

In a higher energy environment where scouring is a concern, riprap can be placed in the bottom of the SOX product before filling. They can also dissipate wave energy if installed with a more gradual slope along a shoreline.

While the product itself is manufactured elsewhere, training is offered to local contractors.

The product can be cut and shaped around trees, posts, pipes, etc., and can cost **approximately $90-$160 per linear foot.**

Additional Methods (not proprietary)

POSH modules (Pervious Oyster Shell Habitat) | $

POSH modules are a living shoreline material developed by the University of North Florida as an alternative to bagged shells. Construction instructions are published for free online. This is a huge advantage since they can be made locally. The design uses shell as a substitute for aggregate in the concrete mixture. The materials are able to be sourced at most larger stores, and admixtures can be added if more strength is needed for a particular site.

Source: Uddin et al. 2021

Once the units are built, they weigh between 30-50 pounds and cost approximately **$20 each** to make. With this price and weight, they have great potential for self-install and volunteer programs.[10] In Florida, they have even been constructed using the help of middle and high schoolers.

While the POSH modules are not as effective at sediment accretion and wave attenuation as other materials mentioned, they are a great substrate for oyster recruitment. They work in soft sediment areas but are not recommended at sites with steep escarpments. The modules are mainly being tested around Jacksonville, Florida and will soon be tested in Georgia.

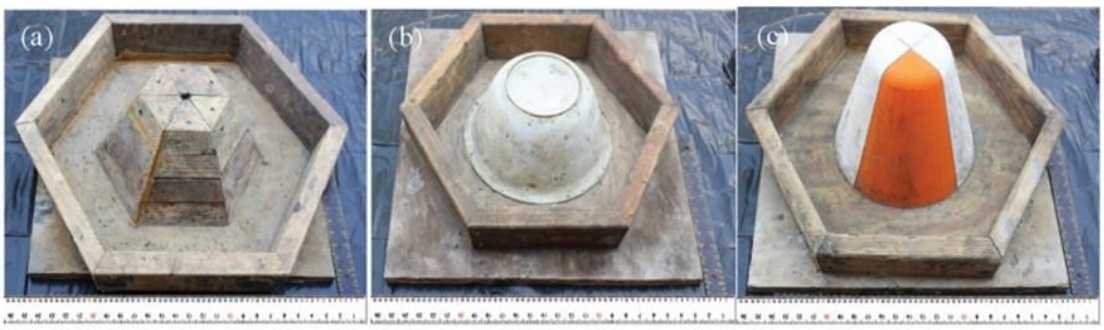

Fig. 8. POSH concrete molds (a) Hexagonal pyramid mold made from scrap lumber, (b) Plastic bowl mold, and (c) 3D printed mold.

Source: Uddin et al. 2021

PROS (Plastic-free Restoration of Oyster Shorelines) | $

These reef prisms are produced in an effort by the University of Florida to serve as a plastic-free, more sustainable alternative to oyster shell bags. They consist of jute-fiber erosion control mats coated in grout (both of which are available at most large hardware stores). The grout has a lower carbon footprint, a higher break strength, and a more neutral pH at 8.5 compared to Portland cement. The units resemble triangular logs, and can be stacked. They have a fairly low profile once installed.

Source: University of Florida

These units can be made locally rather than having to be manufactured elsewhere and shipped. The construction methods and information about materials are all open source. This is an affordable and volunteer friendly option for SC living shoreline construction.

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Appendix

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