Appendix 1

NC National Estuarine Research Reserve
Shoreline Stabilization Needs Assessment Results
(Property Owners)

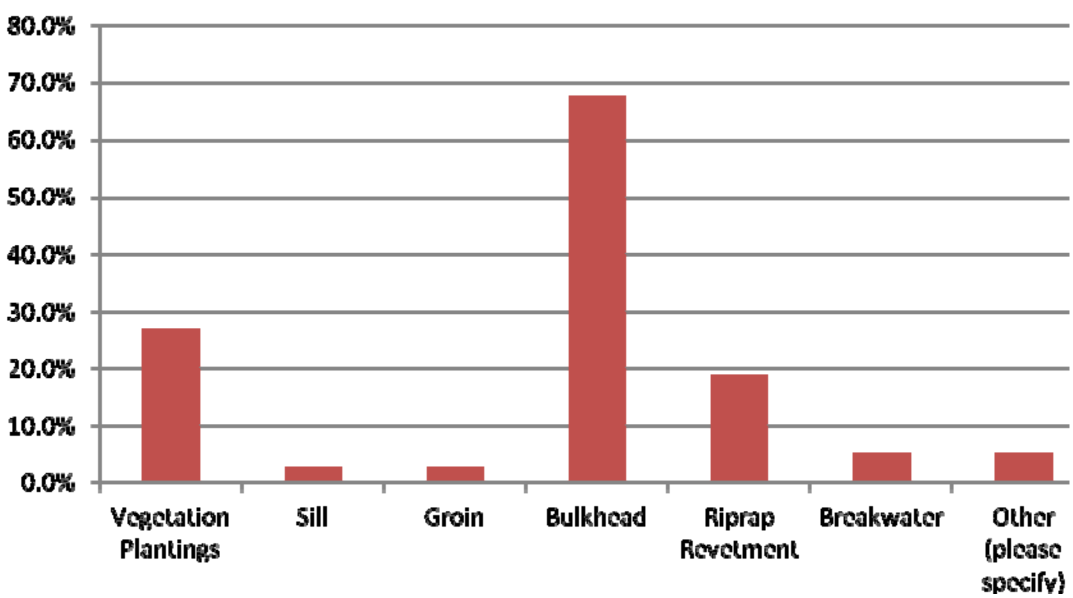
The North Carolina Coastal Reserve/National Estuarine Research Reserve conducted a needs assessment survey to help determine landowners' knowledge and perceptions of various shoreline stabilization structures and practices. The survey results will help guide educational and training programs.

866 postcards were sent to estuarine coastal property owners. We initially received only 30 responses, so we additionally put out a press release inviting coastal property owners to take the survey, which was featured on our website. We had a total of 75 responses.

RESULTS:

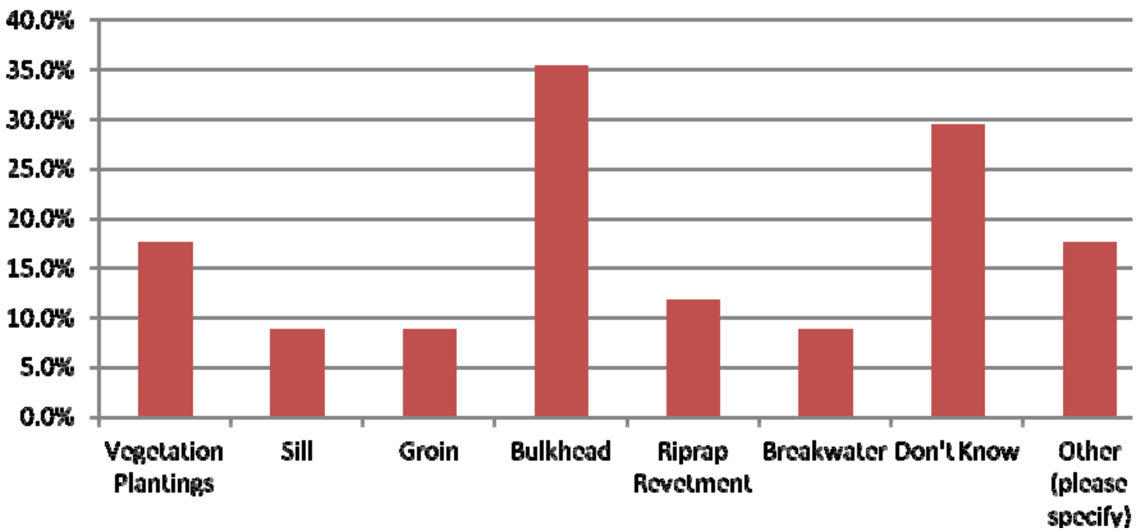
65 of the respondents currently own coastal property, and just over half (54%) of those individuals have an existing stabilization structure on the property.
The most common type of structure is by far a bulkhead. 68% of individuals with an existing structure have a bulkhead. 27% used vegetation plantings to stabilize their property.

Figure 1: What type of structure do you have?



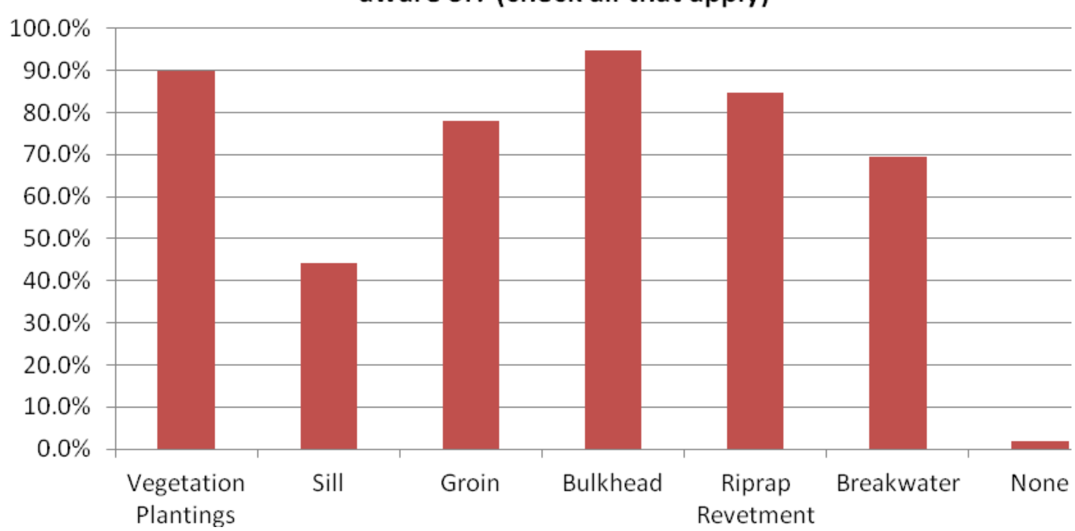
65% of coastal property owners are not currently experiencing erosion. And not surprisingly, 60% of individuals have not considered installing a shoreline stabilization structure. For those who have considered installing a structure, bulkheads were the most frequently considered (Figure 2). 29% remain undecided and 17% have considered employing vegetation plantings. Other alternatives included removal of a neighbor's structure, and a combination of the various structure types.

Figure 2: What type of structure(s) have you considered?

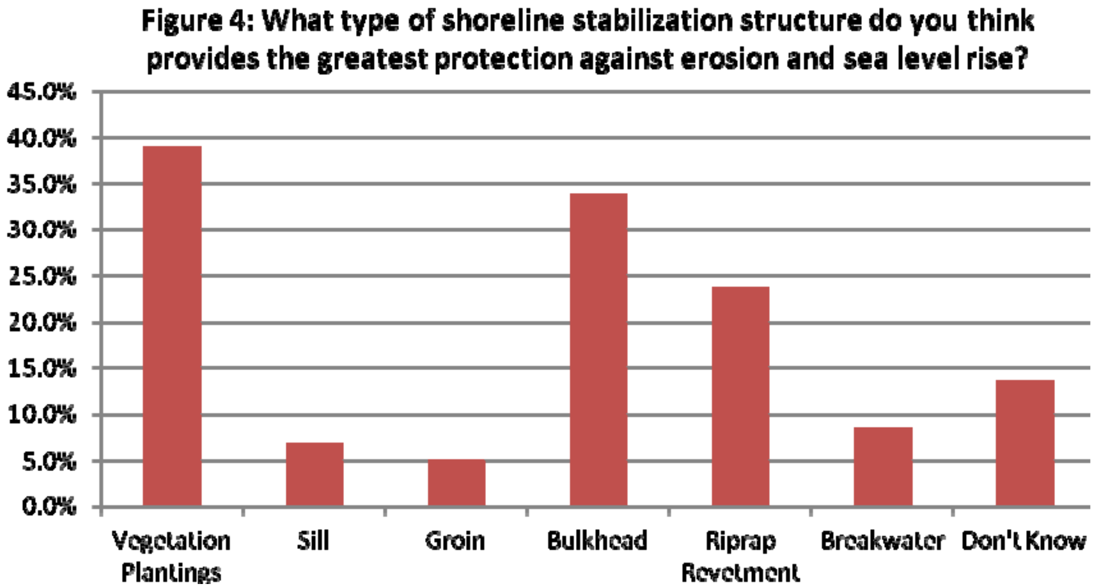


In order to gauge peoples' existing knowledge of shoreline stabilization structures, we asked a series of questions about them. Respondents were most familiar with Bulkheads (95%) and Vegetation plantings (90%), but 70-85% were also familiar with Groins, Riprap Revetments and Breakwaters. The least familiar structure type was the sill. (Figure 3)

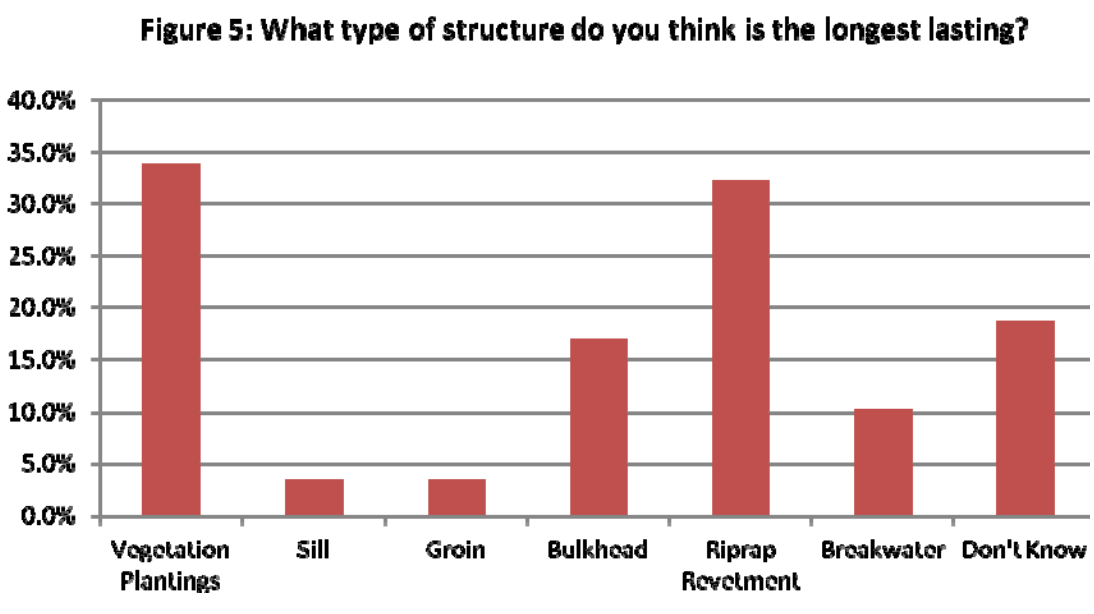
Figure 3: What type of shoreline stabilization structures are you aware of? (check all that apply)



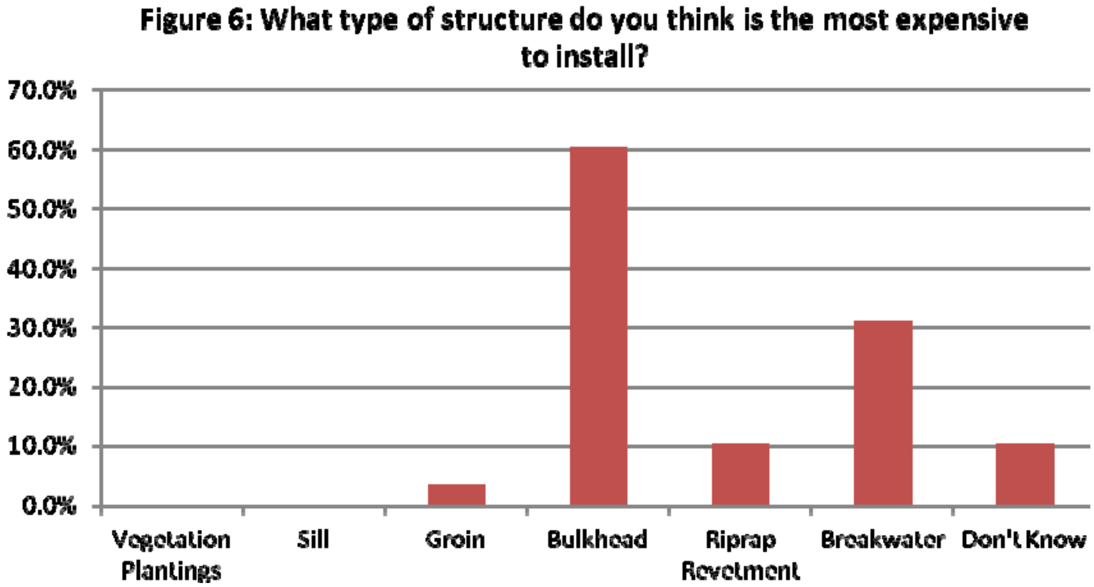
When asked what type of structure would provide the greatest protection against erosion and sea level rise the most common response was vegetation plantings. 39% of those surveyed feel that vegetation plantings provide the most protection. The second most common response was bulkhead (34%). (Figure 4)



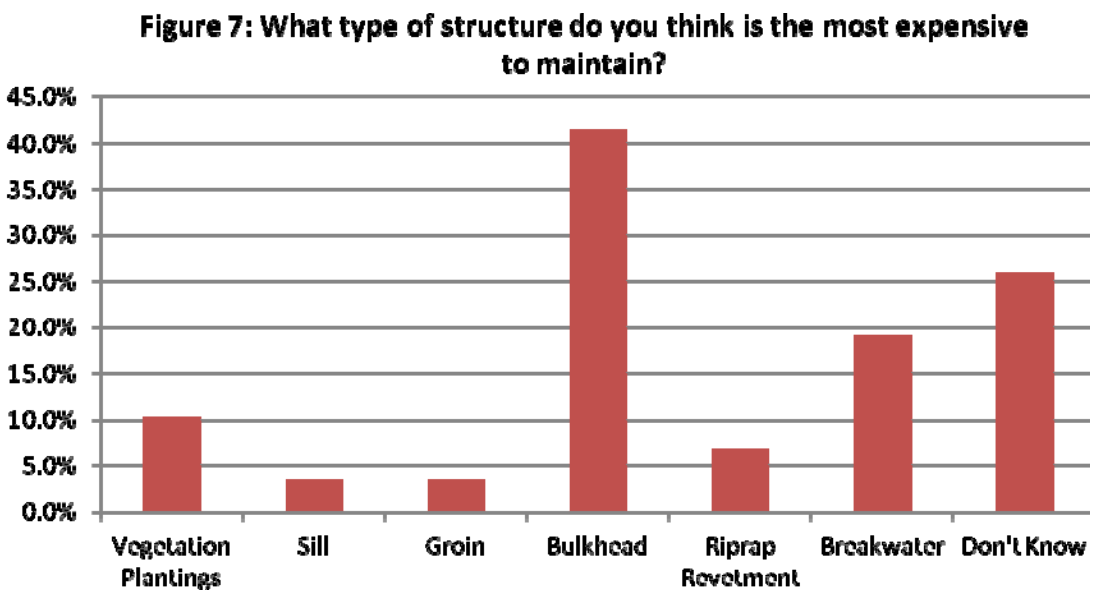
The greatest percentage of respondents felt that vegetation plantings (34%) and riprap revetments (32%) would be the longest lasting. 19% did not know.



60% of respondents felt that Bulkheads are the most expensive to install, followed by breakwaters and riprap revetments. (Figure 6)

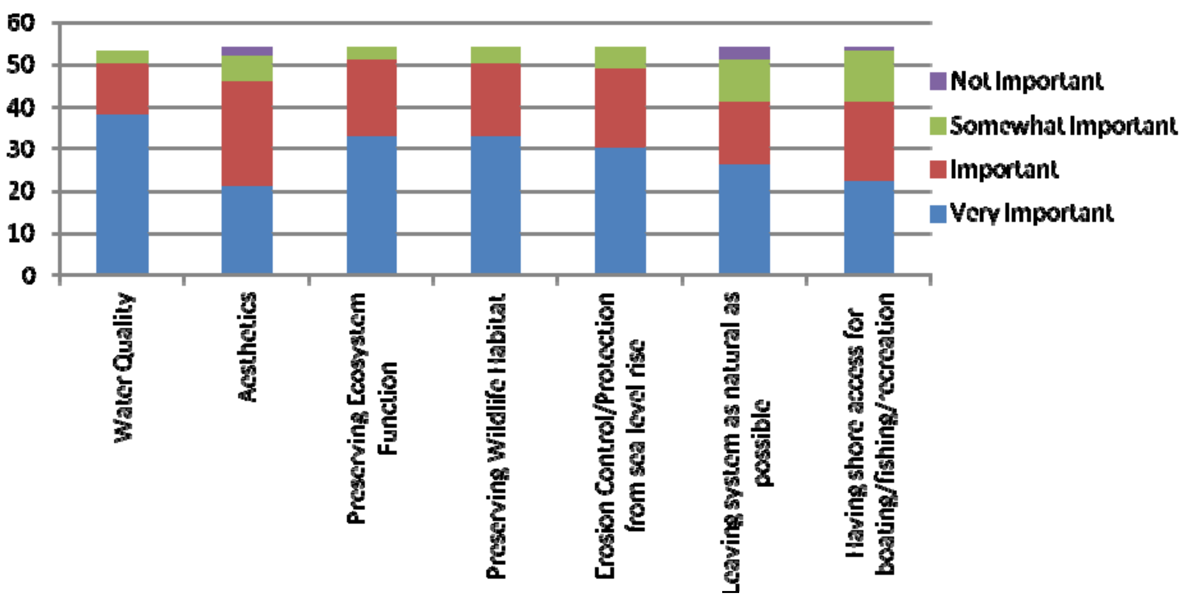


41% of respondents, similarly, felt that bulkheads would be the most expensive to maintain. However, 26% did not know which type of structure would be the priciest to maintain. (Figure 7)



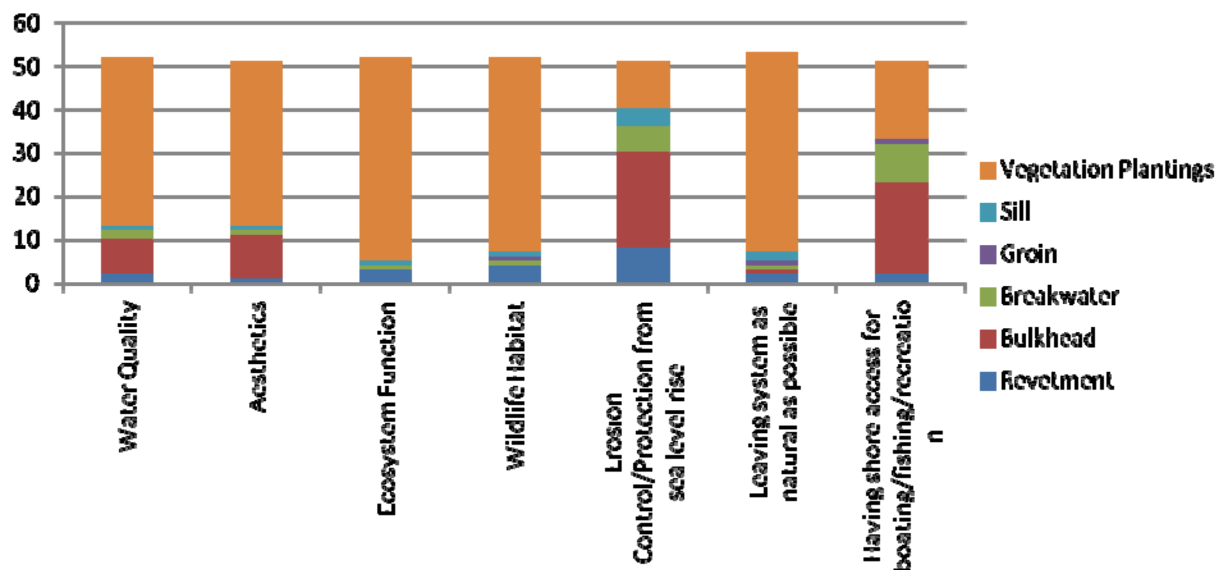
Respondents were asked several questions to elucidate their values and motivations as they pertain to shoreline stabilization structures. Figure 8 shows the relative importance of several values that could influence an individual's decision on what type of structure to construct. Water quality was very important to the greatest number of respondents and was at least somewhat important to all respondents. Similarly, preserving ecosystem function, wildlife habitat, and erosion control were at least somewhat important to all surveyed. The values that appeared to be somewhat less important overall were aesthetics, leaving a system as natural as possible, and having shore access for recreational activities.

Figure 8: Rate the following in terms of the importance to you:



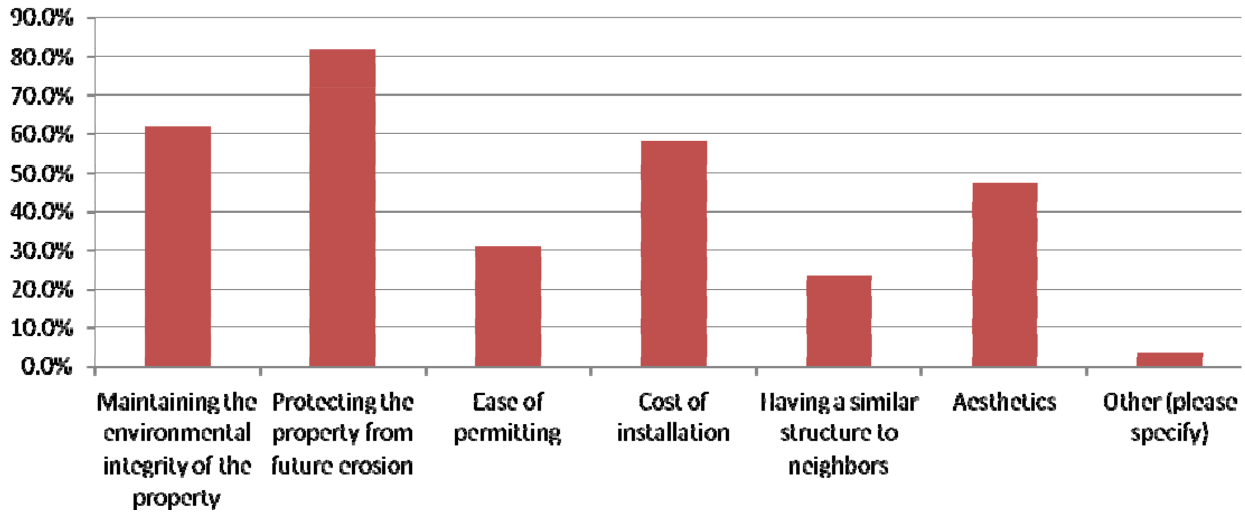
We then asked landowners to select which structure types they felt would best preserve those same values (Figure 9). Vegetation plantings were overwhelmingly thought to best preserve water quality, aesthetics, ecosystem function, wildlife habitat and for leaving the system as natural as possible. Bulkheads (and to a lesser extent breakwaters) were selected for erosion prevention and for having shore access for recreation.

Figure 9: Which structure(s) do you feel best preserves the following values?



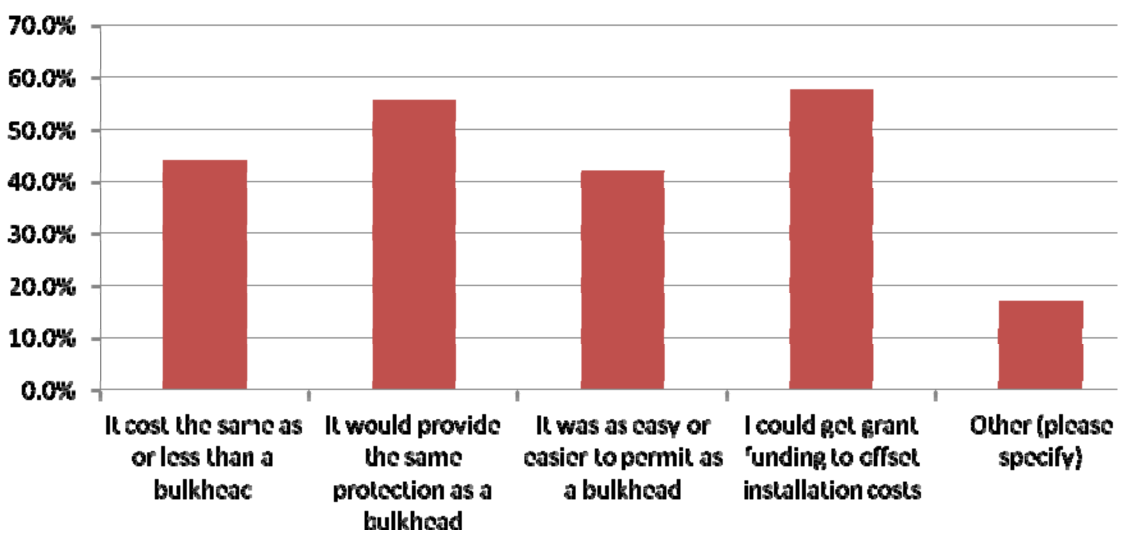
Landowners were asked what factors would be most influential in determining what type of structure they would choose to construct (Figure 10). 82% would be most influenced by the ability of the structure to protect against future erosion. Other important factors were maintaining the environmental integrity of the property and cost of installation. Ease of permitting and aesthetics were only important for <30% of respondents.

Figure 10: What would most influence your choice of structure to stabilize your shoreline?

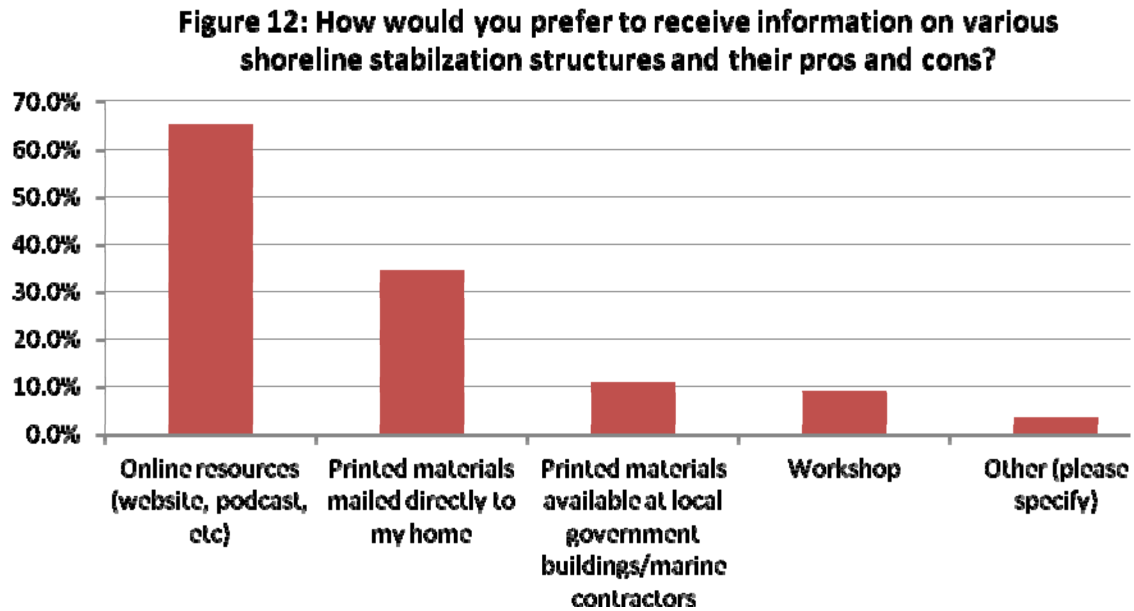


We asked whether landowners would consider a living shoreline stabilization method in a variety of circumstances. 58% would consider a living shoreline if they could get grant funding to offset installation costs. 56% would consider it if they would provide the same protection as a bulkhead (Figure 11).

Figure 11: Would you consider using a living shoreline stabilization method (vegetation plantings or vegetation plantings in combination with a sill, etc) on your property if...



65% of respondents were interested in receiving additional information on alternative shoreline stabilization methods. Figure 12 illustrates how they would prefer to receive information.



NC National Estuarine Research Reserve
Shoreline Stabilization Needs Assessment Results
(Marine Contractors)

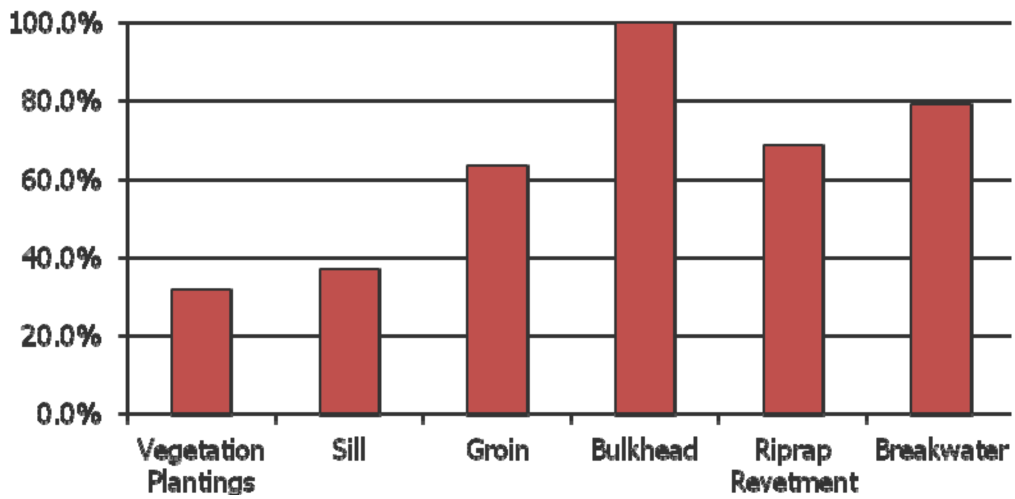
The North Carolina Coastal Reserve/National Estuarine Research Reserve conducted a needs assessment survey to help determine marine contractors' knowledge and perceptions of various shoreline stabilization structures and practices. The survey results will help guide educational and training programs.

41 Marine contractors were contacted by email. We had a total of 19 responses, for a response rate of 46%.

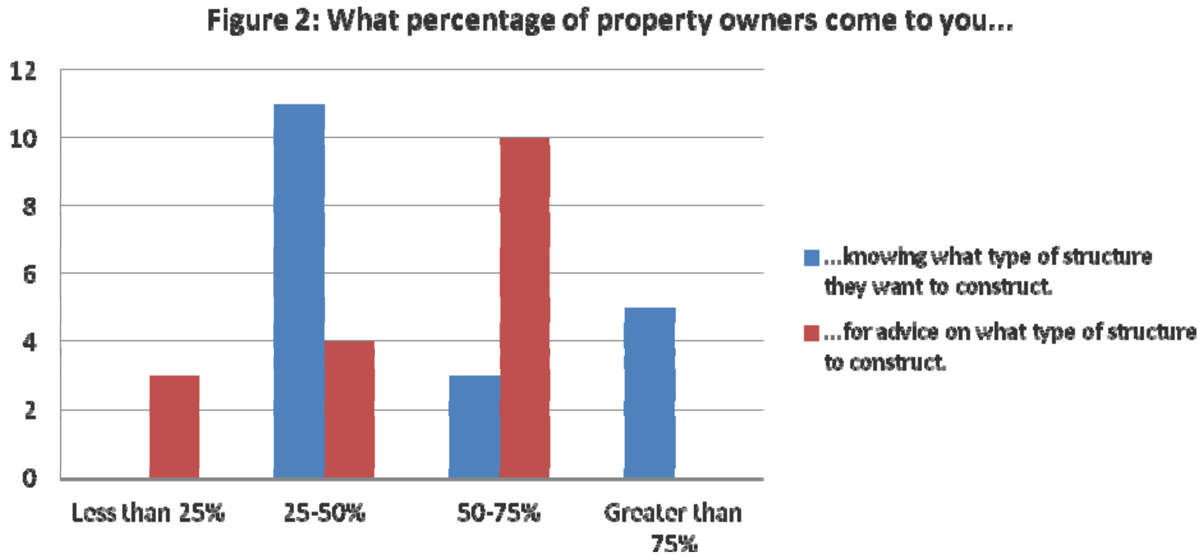
RESULTS:

Contractors were asked what type of shoreline stabilization structures they install. All contractors install bulkheads while only 30% use vegetation plantings. Bulkheads and breakwaters are the most commonly installed structures (Figure 1).

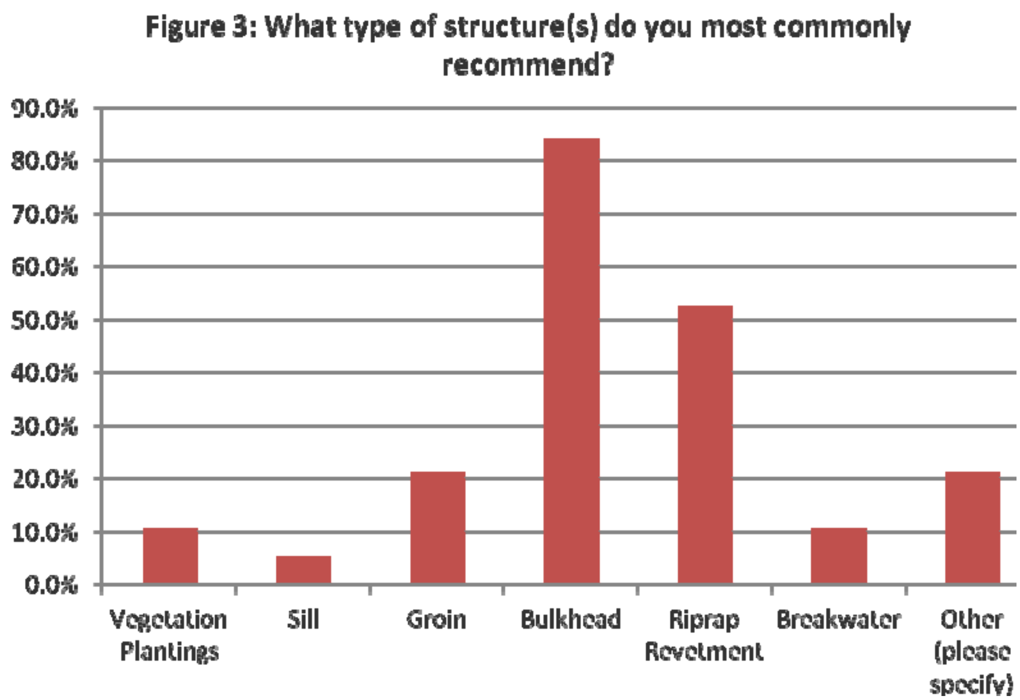
Figure 1: What type of shoreline stabilization structures do you install? (Check all that apply)



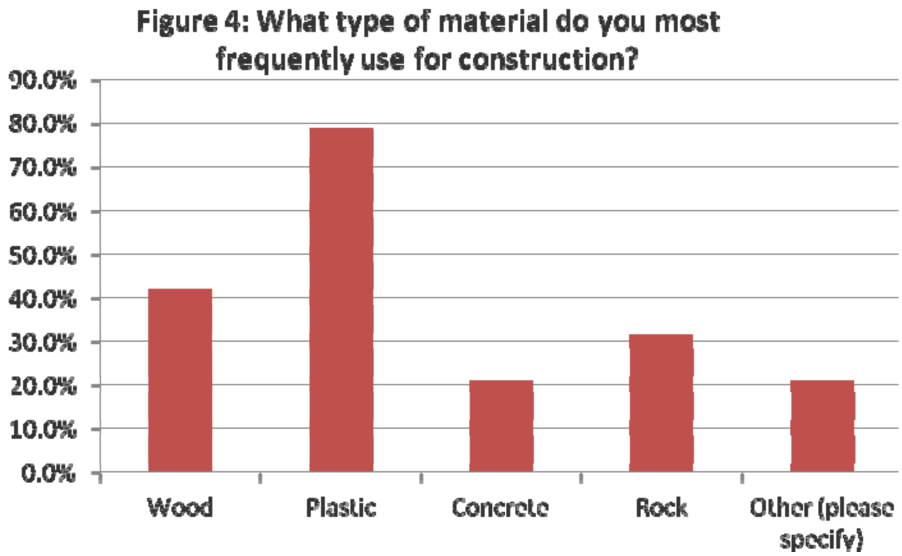
We were interested in what percentage of contractors' clients come to them a) knowing what type of structure they'd like to construct or b) for advice on what type of structure to use. 58% of respondents reported that between 25-50% of clients know what type of structure they want. 26% of respondents found that greater than 75% of clients know what type of structure they're interested in. 53% of contractors reported that between 50-75% of clients come to them for advice. (Figure 2)



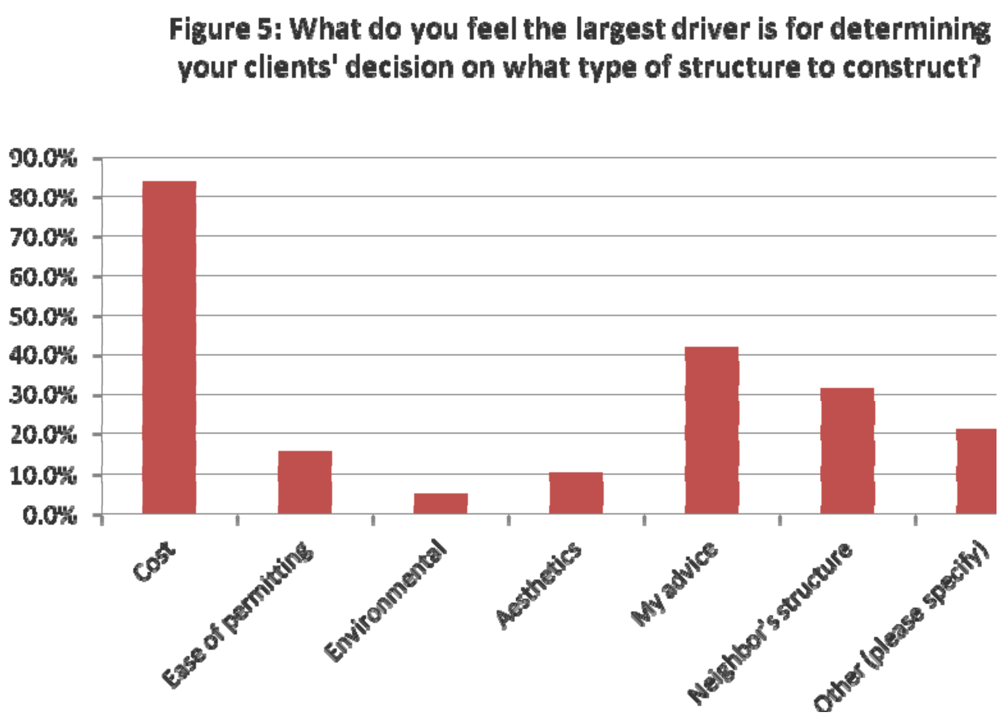
The most commonly recommended structure is the bulkead, which is recommended by 84% of contractors. The second most commonly recommended type of structure is a riprap revetment. All other shoreline stabilization structure types are recommended ~20% of the time or less. (Figure 3)



Plastic is the most commonly used material for the construction of shoreline stabilization structures. 79% of contractors report that it is the most frequently used material in structure construction (Figure 4).

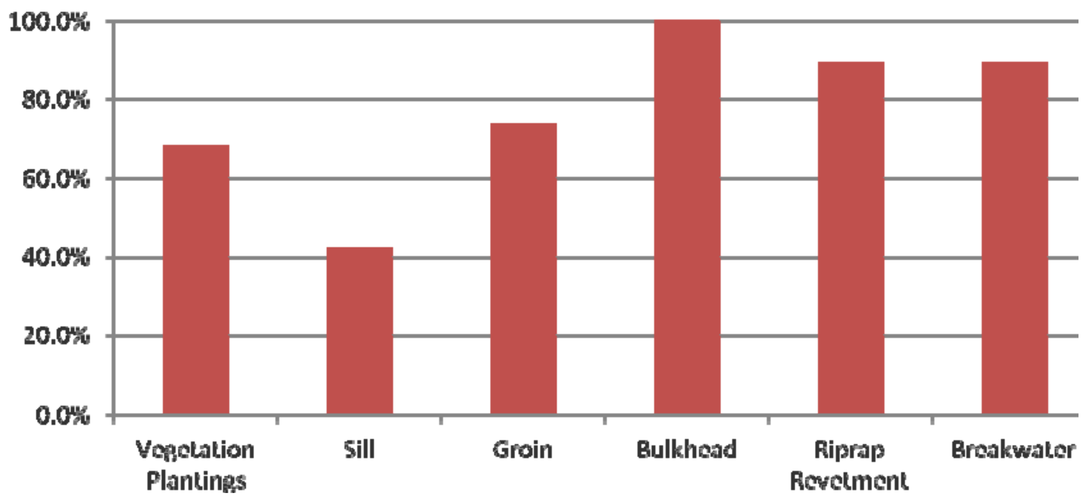


We were interested in what drives clients' decisions on what type of structure to construct. Over 80% of contractors feel that the largest driver is cost. Other important drivers included the advice of the contractor and the type of structure on neighboring properties. Contractors did not feel that environmental reasons played much of a role in determining what type of structure to construct. (Figure 5)



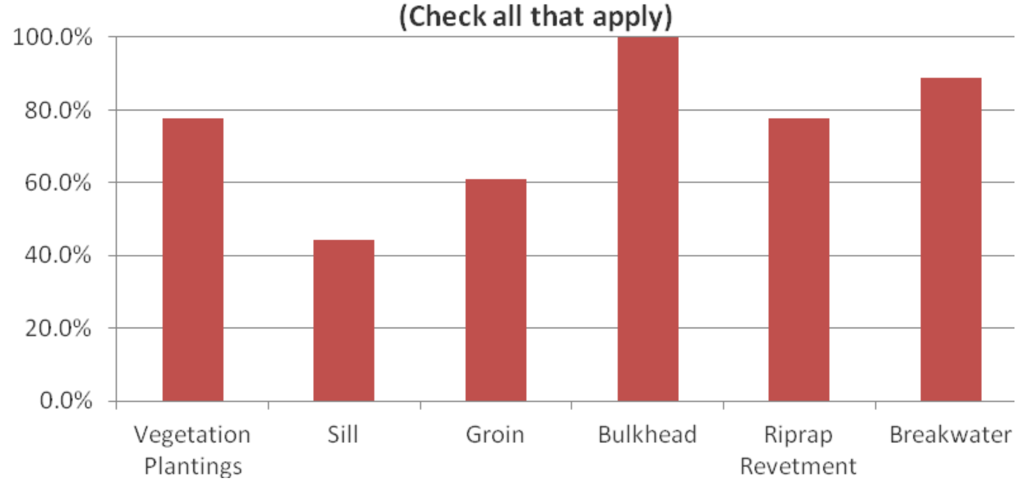
Contractors were asked whether they were familiar with the pros and cons as they pertain to performance of the various structures. All responded that they were familiar with the pros and cons of bulkheads. 90% of respondents claimed to have knowledge of the pros/cons of riprap revetments and breakwaters. Fewer than half of the respondents had any familiarity with the pros/cons of sills. (Figure 6)

Figure 6: Are you familiar with the pros and cons of the following structures as they pertain to performance? (Check all that apply)

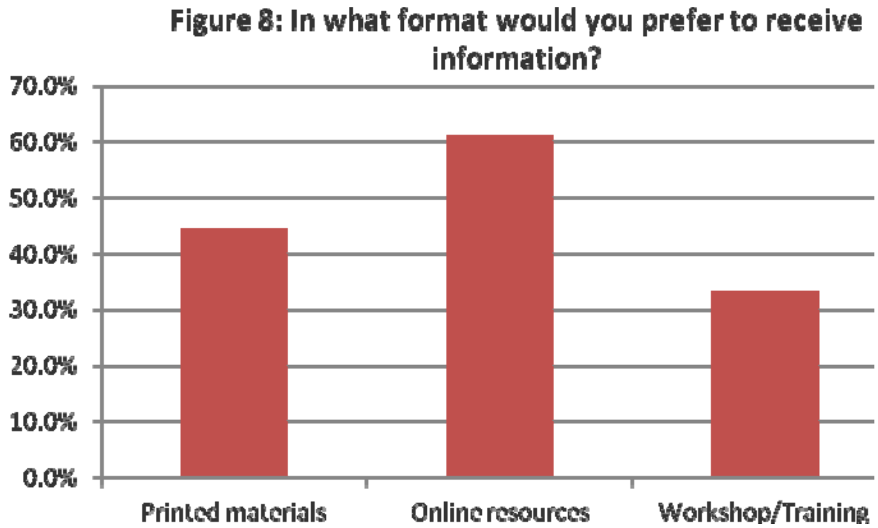


We were also interested in contractors' knowledge of the pros and cons of structures as they pertain to environmental impacts. 100% and 90% claim to have familiarity with the environmental pros/cons of bulkheads and breakwaters respectively. Sills appear to be the least well understood structure with just over 40% of contractors familiar with the environmental pros and cons. (Figure 7)

Figure 7: Are you familiar with the pros and cons of the following structures as they pertain to environmental impacts? (Check all that apply)



When asked whether they would be interested in receiving information on living shoreline stabilization structures 84% of respondents said yes. We asked in what format they would prefer to receive information and the most popular response was online resources (Figure 8).



Contractors were asked under what circumstances they would consider recommending a living shoreline. 2 respondents reported that they would recommend a living shoreline at their clients' request. 8 responded that they would recommend them if site conditions were appropriate (low erosion, space permitting, if surrounding area allowed). 4 contractors report that they currently recommend living shorelines frequently and lament the fact that they are difficult to permit and expensive. Only 2 individuals responded that they were unlikely to ever recommend a living shoreline.

We asked whether the contractors would be interested in attending a training session on how to install living shorelines and 89% said that they would be interested.

We also wanted to know whether the contractors would be interested in an environmentally-friendly coastal contractor program that identifies marine contractors and coastal developers that use best managemetn practices and promote ecologically-sound construction techniques and structures. 89% of respondents responded that they would be interested in such a program.

Appendix 2

Weighing Your Options

How to Protect Your Property from Shoreline Erosion:

A handbook for estuarine property owners in North Carolina

CICEET

Nicholas Institute for Environmental Policy Solutions

SEACHANGE CONSULTING

Written by Seachange Consulting
for the
N.C. Division of Coastal Management -
North Carolina National Estuarine Research Reserve in association with the
National Oceanic and Atmospheric Administration, Center for Coastal Fisheries Habitat Research,
and
The Nicholas Institute for Environmental Policy Solutions.

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INTRODUCTION

Welcome to *Weighing Your Options: How to Protect Your Property from Shoreline Erosion*. If you own property on one of North Carolina's estuaries, you can use this guide as a tool to learn about the choices you have to control your shoreline erosion and help decide which approach may be right for you. In North Carolina, we make a distinction between waterfront property that is located on the estuary, referred to as *estuarine, shoreline, soundfront* or *riverside* property, and waterfront property located directly on the ocean, referred to as *oceanfront*. Why? State laws and regulations addressing estuarine and oceanfront property, and the available erosion control methods, are quite different.

Exploring the estuary, Bogue Sound

This guide focuses on estuarine property. We'll introduce you to the six main erosion control options in use in North Carolina and give you information about the out-of-pocket costs and tangible benefits of each option. We'll also give you information about "hidden" costs and benefits that you may want to factor into your decision-making.

Kite-boarding, Cape Hatteras

You are fortunate to have a piece of estuarine shoreline to call your own, whether it's your year-round residence or a weekend getaway. And if you've noticed some shoreline erosion lately, you're probably a little concerned. But there are ready solutions. Let's start with some preliminary steps to get a "big picture" overview before we get to the details.

STEP 1: LOOK AT ALL THE OPTIONS

Main Erosion Control Methods Used for Shorelines in North Carolina Estuaries

- **Vegetation**
- **Oyster Reefs**
- **Marsh Sills**
- **Riprap**
- **Breakwaters**
- **Bulkheads**

Some of the methods used to protect against shoreline erosion may be familiar to you, and some less so. Each method has its advantages and disadvantages, depending upon location and exposure – that is, which direction your property faces, the amount and power of the wind and waves it withstands, geography, and shore type. We'll discuss each alternative, using photos and drawings to explain each approach and how it works to control erosion. We'll also list property characteristics favorable to each option, note installation costs, and talk about other costs and benefits associated with each option that affect the beauty and ecological health of the estuaries and sounds that make coastal North Carolina so special.

Nesting egret

STEP 2: CONSIDER WHAT YOUR ESTUARY DOES FOR YOU

North Carolina has one of the longest estuarine coastlines in the nation – close to 9,000 miles in fact, and we're proud of that. Besides being beautiful, our estuaries provide jobs, offer food and habitat for aquatic and land-loving creatures, purify our water, help temper the effects of hurricanes, and provide recreation for fishermen, sailors, kite-boarders, hunters, swimmers and bird watchers, among many other attributes.

Bird watching in winter, Pamlico Sound

Estuaries also provide a source of transportation and beautiful real estate. And in addition to protecting us from storms and wave surge, a healthy estuary provides a nursery for juvenile fish, offers a home and feeding ground to birds, and feeds and houses innumerable shellfish, dolphins, otters and turtles – making it possible for us to enjoy the aforementioned opportunities.

Together, these characteristics make up the "estuarine ecosystem." The functioning of estuarine ecosystems is largely dependent on how people use the adjacent coastal land, and while you may not think your individual shoreline stabilization protection project will have much effect on the surrounding ecosystem, the cumulative effect of all the shoreline alterations in your area can alter the balance of ecosystems in the near-shore environment.

Boating in Back Sound

STEP 3: NARROW YOUR OPTIONS

Six may seem like an over-whelming number of choices, and that's before we count the combinations. Oyster reefs and vegetation can be combined with all the other options. But chances are good that you can narrow the number down pretty quickly. You'll find a list of questions in the back of the guide on a worksheet. Answer the questions as best you can before reading the guide, and then compare your answers with the information presented as you read through the text.

The Importance of Shoreline Type

The first question asks, "What is your type of shoreline?" In North Carolina, the shoreline bordering an estuary can be, broadly, a swamp forest, a marsh, an oyster reef, or a sediment bank (photo examples are on the right).

Certain protection methods are better suited to certain types of shoreline. For example, a low sediment bank, which has a continuous gentle slope below and above the water line, can be protected well by a marsh sill, whereas a high sediment bank, with a steep slope, can't. A swamp forest works well with certain vegetation (i.e., cypress trees), but since there is no bank to stabilize, a bulkhead would not be a good match. We'll point out the good matches throughout the document.

Right column: Shoreline Types (top-bottom): swamp forest, marsh, oyster reef, low sediment bank, high sediment bank.

You'll notice that two shoreline types, marshes and oyster reefs, are also included in our list of erosion control methods. That's because they have the ability to stabilize the shoreline on their own. If your property includes a marsh, it's partly under water at high tide or during a wind tide. The marsh vegetation traps the sediment washed in by the tides, and the dense root system holds it in place. Marsh vegetation dies back and roots become incorporated into the sediment, further building the foundation for sustaining marsh growth. Together, these self-perpetuating processes counter erosion by dissipating waves and adding sediment. If you have an oyster reef, it accumulates shell material and traps sediment landward of the reef, adding fill and maintaining the shoreline.

Step 4: Understand the Permit Process

Your State Representative

Permitting is often viewed as a bureaucratic quagmire. Actually, the process can be streamlined and efficient, and over and done within two weeks. The representatives from the North Carolina Division of Coastal Management (DCM) who come to look at your property can be very helpful. They are a part of DENR – the Department of Environment and Natural Resources, and have permitting responsibilities under CAMA – the Coastal Area Management Act. The permit reps have the same goals you have: to keep you and your property safe and the estuary healthy.

Surveying near Wilmington, N.C.

Types of Permits and Costs

Marsh sills, riprap revetment, and *bulkheads* can require a general or a major permit; *oyster reefs* and *breakwaters* require a major permit; and *vegetation* can require a major, minor, or general permit, or none at all. A **general permit** is used for projects that have relatively small impacts on the environment, and the process usually involves contact with only DCM. A **major permit** is used for large projects and those requiring other state or federal permits.

You may need a major permit if, for example, your project will cover vegetation that's in the water, alter fish habitat, or interfere with water quality. If your project requires a major permit DCM reps can provide help with the process. Depending on the scope of your project, your location, and the permit required, you (or your contractor, engineer, or landscaper) may need to interact with as few as one or as many as 14 federal and state agencies, such as USACE (United States Army Corps of Engineers), North Carolina DMF (Division of Marine Fisheries), or North Carolina DWQ (Division of Water Quality). A list of all 14 agencies, including their acronyms and full names, appears at the end of this guide, with a brief explanation of what they do and why they would be concerned with your project.

DCM permit costs run between $100 and $400, and additional charges may be encumbered depending on the permit requirements of the agencies involved.

Doing It Yourself vs. Bringing in the Professionals – or Both

Two erosion control alternatives; vegetation and oyster reefs, lend themselves to being Do It Yourself (DIY) projects. Consider your personal situation: do you have more time than money? If so, then pay particular attention to the vegetation and oyster reefs descriptions and see if they fit your project goals. The other options – riprap revetments, marsh sills, bulkheads, and breakwaters – will probably require the services of a contractor or coastal engineer.

Bulkhead under construction

These options can be supplemented by planting vegetation or adding hard material that supports oyster growth, such as oyster cultch (shell material), limestone or granite, so you can include some DIY involvement if you choose.

Bulkhead with planted marsh, Beaufort, NC

If you think you'll need a contractor but haven't hired one yet, read through this guide, note the kinds of experience and skills you're looking for, and then call DCM. Ask for a preliminary visit, and ask your rep for a list of local contractors – and ask your neighbors, friends, and real estate agent for their recommendations.

Contractors tend to specialize in one stabilization type based on their experience and the equipment they own or can readily access. Not surprisingly, that will be the method they recommend, and they may not take into account all the specifics regarding your property and the impact you choose to have on your estuary. Reading through this book will help ensure you get the best stabilization method possible for your property and make you a more informed client, as well as add to your appreciation of your local ecosystem.

If you're already working with a contractor, keep in mind that experts agree that to preserve the existing shoreline type and ecosystem, the location of the erosion control method on your property is more important than the actual method. So if you're installing a bulkhead or riprap revetment, the more landward it can be placed, the better. Again, your DCM rep can size up your property and make site recommendations to support your preferences.

Neighboring properties with different erosion protection approaches

Being a Good Neighbor

Under CAMA **general permitting guidelines**, you must demonstrate to DCM that you have contacted all adjacent property owners and notified them about your plans. This can be done in two ways: submit 1) signed letters of no objection; or 2) a certified mail return receipt form. Your neighbor will have 10 days upon receipt of your letter to submit comments to DCM on your planned work; if they fail to submit a response, this is interpreted as "no objection."

Major permitting requirements are similar but have a more stringent notification requirement.

Where to Find a DCM Rep

Whatever your situation, you'll be doing yourself a favor to get DCM involved from the start. Local offices and phone numbers are listed below.

Contact Information for DCM

- Elizabeth City: 252-264-3901
- Morehead City: 252-808-2808
- Washington: 252-946-6481
- Wilmington: 910-796-7215

For More Information

Complete DCM contact information and in-depth information about the permitting process can be found at: http://dcm2.enr.state.nc.us

STEP 5: KNOW YOUR TIDES

Estuarine water levels are extremely variable, a result of storm and wind events, seasonal changes, and astronomical cycles. For example, in North Carolina's estuaries, the average water level is 7 inches higher in September than in January. And the "mean" or "normal" high tide line indicates where the high tides reach about half the time – which means the other half of the time, tides are higher than the mean high tide line. Add this variability to the current trend of rising sea level, and it's a good idea to install shoreline stabilization structures such as bulkheads and riprap as high on the shoreline as possible. This will add to their longevity and help protect the natural resources seaward of your property.

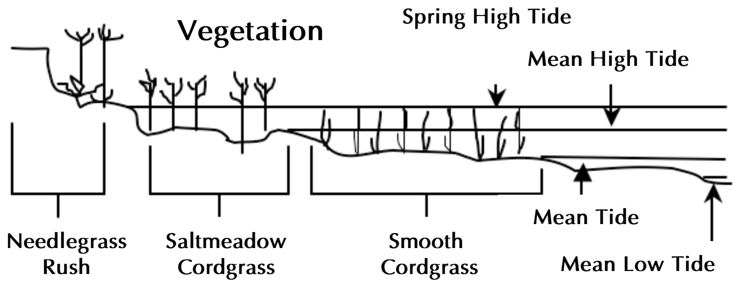
Now, let's get started finding an erosion control option that works for you.

Boat wake from a passing vessel

VEGETATION

What is it and how does it work?

Salt tolerant plants, such as smooth cordgrass, saltmeadow cordgrass, and needlegrass rush, are planted along the shoreline in 10–40 foot wide patches, forming a marsh fringe. Once the marsh is established, it is very effective at blocking wave energy—a 15-foot wide marsh can reduce the incoming wave energy by over 50 percent. Plant roots extend a foot or more below the surface, and further stabilize the shoreline.



Best for property that…

- has low-energy shoreline
- has little boat wake traffic
- has a gentle, wide slope (low sediment bank)
- faces a "fetch" (the distance over water that the wind blows) of less than 3 miles or, if fetch is more than 3 miles, is protected from waves by sandbars or shallow mudflats
- if fetch exceeds 1 mile, an oyster reef, coir log, riprap toe, or sill may help stabilize the plants (see photos below)

Vegetation with stone sill

Vegetation with coir log

Vegetation with riprap toe

Vegetation with oyster toe

Out-of-pocket costs& considerations

At-a-glance:

Vegetation Planting

- Range: $7.50 (DIY) –$100 (full-service landscaper) per linear foot / 20 ft wide
- Average: $22

Factors in determining cost:

- cost of labor
- number of plants
- fill and grading
- shipping
- landscaping fees
- cost of coir logs, toe or sill (if recommended)
- need for replanting

Consider: Vegetation planting lends itself to a DIY project. Plants are sold by the “plug,” measuring either about 4" x ½" and averaging $1.10 each, or 2" x ½" and averaging $0.50 each. Depending on the size of the plug, you’ll need at least one or two cordgrass plants for every 4 square feet of property you want to plant, and one to three saltmeadow plants for every 2 square feet. One motivated person can plant 1,000 plugs in a day; another tactic is to enlist a few semi-motivated friends and encourage them to plant 3,000 plants in about five hours; yet another approach is to hire local labor at the rate of $1–$3 a plug. Planting between March and June will give the plugs time to stabilize before winter storms and increase the likelihood of success.

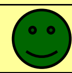
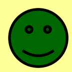
However, if you require coir logs, a landscaper must install those and a major permit is required. A coir log is interwoven fibers bound together with biodegradable netting. The log stabilizes a site while vegetation becomes established. They cost about $100–$150 each for a 12" x 10' log, and cost approximately $50 for installation. If you need a riprap toe or stone sill, you’ll need a contractor to install that structure.

Maintenance: Vegetation planting may require weed control in low salinity areas, replacement of dead and missing plants, and post-storm inspection.

Longevity: Planted salt marshes can last for decades, although storm events or changes in site water movement and wave energy may shorten their lifespan. However, if plants are lost as a result of a storm event, as long as the sediment bank remains relatively unchanged, a replant can be done at fairly low cost. And, vegetation can often recover on its own. Results will vary depending on a variety of site-specific factors, including storm events, local rates of relative sea level rise and sediment availability. Coir logs have a 6-12 year lifespan.

Permits: No permit is necessary for vegetation planting unless you need to fill or grade your property before planting. Larger projects or projects that will require fill or grading will require a permit, and installing a riprap toe or sill will require a general or major permit. Coir logs require a major permit as well.

Ecosystem costs & considerations

Ecosystem Service	Effect of Vegetation Planting on Ecosystem Value	
Wave erosion and sea level rise protection		marshes dissipate wave energy, provide stability, and trap sediments
Water quality		marsh systems filter runoff and improve water quality
Animal habitat		salt marshes provide food and protection for finfish and shellfish, mammals and shorebirds
Carbon storage		both marsh plants and the soil beneath them store significant amounts of carbon
Fish production		marshes provide protection and habitat for juvenile fish
		adult fish prowl the edges of salt marshes seeking prey
Ecosystem diversity		plants and animals thrive, increasing species diversity
Recreation		planting a salt marsh will replace beach area (depends if you like beaches)
		if you want a pier, it may need to be higher in the areas where it crosses the marsh

Sample project costs

Specifications	Project #1 –Full Service Landscaper	Project #2 – DIY
Region	Pamlico Sound	Swansboro
Shoreline exposure	long fetch (5 miles)	short fetch (1/2 mile)
Length of property	500 feet	100 feet
Width of proposed marsh fringe	40 feet	20 feet
Cordgrass/saltmeadow/ needlegrass	20/10/10 feet	13/7/0 feet
Fill required	1 ton	none
Permit	general	none
In-water stabilization	coir logs	none
Estimated cost	$25,000	$750

Possible Combinations

- Vegetation landward of oyster reefs and breakwaters
- Vegetation seaward of bulkheads and riprap
- Marsh sills (see section below)

Did You Know?

There is a direct link between the quantity of cordgrass found in our estuaries and the health of our fisheries. Adult fishes, such as sea trout, red drum and flounder, prowl the edges of marshes feeding on shrimp, killifish and other prey hiding among the vegetation.

Low salinity marsh, Kitty Hawk Bay

The coastal marsh is one of the most productive areas on earth, producing up to 70,000 pounds of plant material per acre per year.

Red drum fishing, Newport River

In 2007, N.C. commercial fishermen landed more than 30 million pounds of finfish, and over 32 million pounds of shellfish, resulting in an industry valued at $82 million per year.

OYSTER REEFS

(also called oyster rock, sills, beds, patches and toes)

What are they and how do they work?

Oyster reefs form natural breakwaters and protect shoreline property from erosion and storm damage. They are often used in conjunction with one of the other shoreline control types discussed in this guide, and may be added to a pre-existing shoreline erosion project. Reefs are built by adding material to the water, such as small bags of oyster shells, loose oyster or clam shells, riprap, marl, or other suitable substances. The material attracts live oyster spat, which settles and creates a live reef. Permitting representatives will assess your site and determine if a sill, rock, patch, bed or toe is more appropriate, and guide you to the best material and design specifications to use.

Generally, if you live in the northern part of the state, a subtidal oyster reef is the way to go; if you live in the central or southern region, an intertidal reef will probably work best.

Oyster reef

Barge dispersing "cultch"

Best for property that...

- is on water with known oyster productivity

Out-of-pocket costs & considerations

At-a-glance:

DIY near-shore reef, 10-ft. wide

- Range per linear foot: $0.50 – $5.50
- Average: $5.00

Contractor, offshore reef

- Range per linear foot: $100 – $150
- Average: $100

Factors in determining cost:

- access to water
- whether location of reef is subtidal or intertidal
- cost of reef material: concrete, marl and granite
- availability and cost of oyster culture
- cost of transporting material to site
- rental of barge and dispersal of loose cultch or bags
- labor to carry bags or other structures into water
- labor to fill bags

Consider: The design of your oyster reef and the material used need to be appropriate for your property type. For example, light material in a high-energy area will be scattered, and heavy material on a site with deep, soft mud will sink until enough material is deployed to stabilize the site – which could be very expensive.

Rock and marl can be used for lower layers and capped with cultch to help minimize costs. Remember, the cost of transporting them must be factored into your costs. Also, in some situations it will make sense to hire a barge and dispersal unit and approach the project area from the water. In others, if there is easy access to the site from your property for large equipment, a trailer would be the better choice.

Maintenance: Assuming your site and environmental conditions are suitable, oysters may take up to a year to cement into a living reef.

Before they do, shells may be lost or shift following a storm, and they can be buried with normal wave action; in either event they will need to be replaced. Once the reef is established, it is self-sustaining.

Longevity: Once established, oyster reefs are extremely durable and may last for 50 years or longer.

Permits: Contact DCM when planning your oyster structure. You will need DCM, USACE, DMF, and DWQ guidance and approval for any oyster project that involves deployment of material into North Carolina coastal waters.

Possible Combinations

- Oyster reef with landward marsh
- Oyster "toe" on bulkheads
- Oyster cultch added to intertidal riprap and breakwaters

Oyster reef with landward marsh and spot fishing "fleet," Gallants Channel, Beaufort, NC

Ecosystem costs & considerations

Ecosystem Service	**Effect of Oyster Reefs on Ecosystem Value**	
Wave erosion and sea level rise protection		oyster reefs dissipate wave action, trap sediment and add shell material to living reef
Water quality		oysters filter runoff and improve water quality
Animal habitat		reefs provide habitat for shrimp, crabs, clams, snails and worms, as well as many finfish
Carbon storage		oysters remove carbon from the water column in forming their calcium carbonate shells
Fish production		if you live in an "approved" harvest area, as specified by DENR based on input from the FDA, oysters, fish, and crab can be harvested from the reefs or areas nearby during the open season, usually Oct. 5 – May 15
		growing areas can be permanently or temporarily closed to harvest due to poor water quality and public health concerns
		certain state waters are approved for shellfish harvest, and this harvest is part of the public trust. If you deploy oyster cultch and oysters successfully grow on your reef, the general public is entitled to harvest those oysters. (*Continued*)

Ecosystem costs & considerations (cont.)

Ecosystem Service	Effect of Oyster Reefs on Ecosystem Value	
Fish production (cont.)	☺	animal habitat attracts larger fish, enhancing hook-and-line fishing
Ecosystem diversity	☺	by filtering water, more light reaches vegetation on bottom
Recreation	☹	oyster shells are sharp under foot, reducing beach access
	☺	cleaner water results in increased recreational use

Oyster reef with marsh

Sample project costs

Specifications	Project #1	Project #2
Region	Albemarle Sound	Bogue Sound
Shoreline exposure	long fetch	low wave energy
Length of property	208 feet	150 feet
Number of mounds	20 mounds, 20 ft. each, set in checker-board pattern	n/a
Distance from shoreline	50 feet	20 feet
Construction material	concrete, marl and loose shells	bags of "cultch"
Professional help	marine contractor and barge operator	labor to fill bags; barge operator to disperse bags
Estimated Costs	$25,000 + permits	$3,700 + permits

Did you know?

A single adult oyster is capable of filtering 15-35 gallons of water each day.

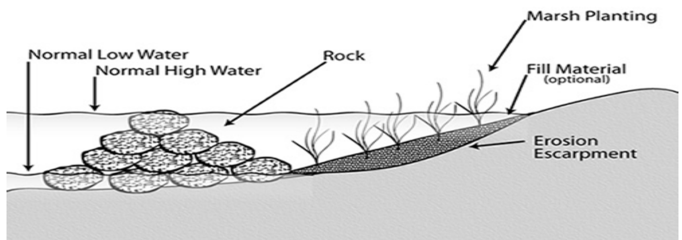
Flounder, menhaden, herring, anchovies, spadefish, striped bass, cobia, croaker, silver perch, spot, speckled trout, Spanish mackerel, pinfish, butter fish, harvest fish, blue crab, stone crab, penaeid shrimp, black drum, and several species of mullet all spend a part of their life on Atlantic Coast oyster reefs.

MARSH SILLS

What are they and how do they work?

A marsh sill is a combination of a protective barrier placed in the water parallel to the shoreline and a 10–30 foot wide strip of vegetation planted (or pre-existing) on shore. Constructed of sloping stone, oyster rock or wood, the barrier – the sill – breaks wave energy and allows the marsh to grow, and the marsh further absorbs wave energy and prevents erosion. Most sills have a low profile, usually rising only 6 inches above the water at high tide; this allows waves to pass over and through it, providing nutrient-rich sediment to the marsh. The sill's intermittent openings allow fish to swim into the marsh and feed.

Marsh Sill
VIEW FROM SIDE



Best for property that...

- has shoreline facing a fetch of 1 to 10+ miles
- has relatively shallow water
- has a low sediment bank or existing marsh
- is in an area experiencing moderate to heavy boat traffic and boat wake effects

Out-of-pocket costs & considerations

At-a-glance:

Stone work & site work

- Price range: $75–$150 per linear foot
- Average: $130

Planting (labor & plants)

- $7.50–$100 per linear foot / 20 ft wide
- Average: $22

Factors in determining cost:

- equipment access
- stone work
- site work (bottom preparation, land fill)
- access to water
- material (wood, stone, concrete riprap, marl)
- labor for planting
- cost of transporting materials to site
- cost and type of plants

Consider: In North Carolina, the Community Conservation Assistance Program (CCAP) may provide assistance for marsh sill projects, reimbursing landowners up to 75% of their costs up to a maximum of $5,000. Applications are submitted through local soil and conservation districts. For more information, visit http://www.enr.state.nc.us/DSWC/pages/ccap_program.html.

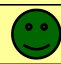
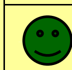
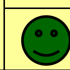
Maintenance: Depending on construction material, a marsh sill may require repair following a storm. Plants may have to be replanted until the marsh is well established, even if no storms occur.

Longevity: The planted marsh associated with a sill can last for decades, and can be replanted if needed. Granite structures are extremely durable and may persist for 50 years or longer. Results will vary depending on a variety of site-specific factors, including storm events, local rates of relative sea level rise and sediment availability.

Permits: A marsh sill can require either a major or a general permit.

Stone sill with marsh

Ecosystem costs & considerations

Ecosystem Service	Effect of Marsh Sill on Ecosystem Value	
Wave erosion and sea level rise protection		marsh sills protect existing shoreline from wave energy
		marsh sills absorb and dissipate wave energy; marsh vegetation traps sediments, which counters sea level rise
		sills can sometimes reflect wave energy, causing erosion issues in other locations
Water quality		marsh systems filter runoff and improve water quality
Animal habitat		a sill is an immediate “condominium” for aquatic species, often colonized by oysters
		installing a sill may cover habitat of existing species
Carbon storage		marsh is an excellent storage facility for carbon
Fish production		marsh provides a nursery for juvenile fish
Ecosystem diversity		the addition of marsh and marsh habitat attracts new species, e.g., migrating birds
		a marsh maintains animal access to the water
Recreation		may increase length of dock required to reach open water
		dry beach habitat is replaced by a marsh sill system
		marshes attract migrating birds, increasing bird-watching opportunities

Sample project costs

Specifications	Project #1	Project #2
Region	Pamlico Sound	Grapevine Bay
Shoreline exposure	long fetch	low wave energy
Length of property	150 feet	500 feet
Base width of sill	9 feet	15 feet
Distance from shoreline	20 feet	75 feet
Construction material	wood	limestone
Width of marsh	20 feet	40 feet
Area of planned marsh	3,000 sq feet	48,000 sq feet
Permit	general	major
Estimated cost	$3700 + permits	$25,000 + permits

Possible Combinations

- Marsh sill & oyster reef

Marsh sill with offshore oyster reefs

Did you know?

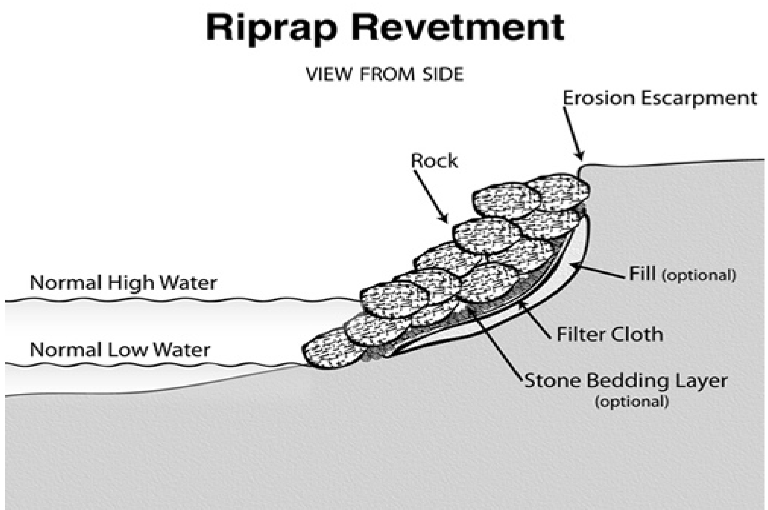
Studies valuing shorefront real estate show that the cleaner the body of water, the higher the value of the property – and there's a ripple effect on adjacent non-shorefront property, positively affecting neighborhood property values up to 500 feet from the water's edge.

RIPRAP Revetment

(also called a revetment, sloping revetment and shoreline hardening)

What is it and how does it work?

Riprap forms a protective, sloping barrier between the water and land. Usually constructed of heavy stone and lined with a permeable sheet, riprap breaks wave energy and prevents soil from eroding. The angle of the riprap is determined by expected wave height, but is commonly 3:1 to 1.5:1 (horizontal : vertical). The larger the expected waves, the flatter the riprap and the heavier the stones need to be.



Best for property that...

- faces moderate to high wave energy

Out-of-pocket costs & considerations

At-a-glance:

- Price range: $90–$150 per linear foot
- Average: $120

Factors in determining cost:

- access to shoreline
- material: broken concrete; marl, granite
- depth of water
- source of stone and delivery distance
- size of stone
- fill
- bedding layer
- height
- distance riprap extends

Consider: Broken concrete, free of rebar, can be used as a low-cost option as a base, then "dressed up" with granite. Granite weighs four times as much as concrete, but the same tonnage can cost twice as much. If you are in a high wave energy location, granite may be necessary due to its increased weight.

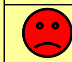
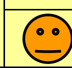
Maintenance: Stones or rocks will settle and readjust with storms or waves, and occasionally will need replacing. Limestone will be displaced much more easily than granite.

Longevity: Riprap is durable and installations can last for several decades, although storm events may shorten the lifespan of riprap installations. Granite is more durable than marl.

Permits: Riprap can require either a general or a major permit

Riprap revetment with grasses and lawn

Ecosystem costs & considerations

Ecosystem Service	Effect of Riprap on Ecosystem Value	
Wave erosion and sea level rise protection		if properly built, riprap can withstand waves in extreme conditions
		reflected waves may cause scour or erosion of adjacent property
Water quality		material chosen for riprap should be clean and not introduce any pollutants into the water
		if vegetation is removed or lost, there is a loss of water-filtering function
Animal habitat		can add to habitat complexity by introducing new surface material, e.g., barnacles and oysters
		a sloping surface causes a wider footprint that extends further waterward, covering more bottom habitats
Carbon storage		no significant effect
Fish production		reduction in habitat causes reduction in fish population
Ecosystem diversity		riprap alters the bottom habitat, replacing soft bottom with hard, affecting plant and animal diversity and abundance
		reduces diversity and abundance of birds and shellfish, among other species
Recreation		can be used adjacent to deep water for easy boat access
		may reduce beach area

Sample project costs

Specifications	Project #1	Project #2
Region	Pamlico Sound	Wilmington area
Shoreline exposure	5 mile fetch	low wave energy
Length of riprap	150 feet	500 feet
Depth of water at high tide	4 feet	10 feet
Height of riprap	2 feet	5 feet
Construction material	broken concrete; marl	granite
Permit	general	major
Estimated cost	$13,500	$75,000

Possible Combinations

- Riprap & marsh
- Riprap & oyster reef
- Riprap & bulkhead

Did you know?

Worldwide, estuaries store 7,200 teragrams of carbon a year – that's between 3% and 7% of all human-produced emissions.

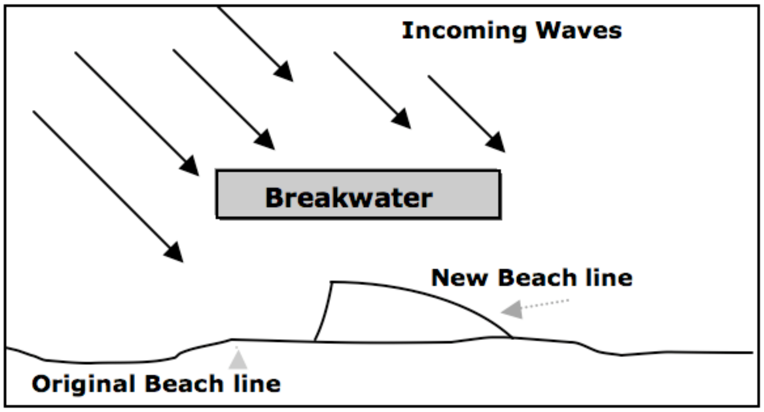
Canoeing on Albemarle Sound

BREAKWATERS

(also called a wave break, wave fence, or hardened structure)

What are they and how do they work?

A breakwater is a stone structure placed in the water parallel to the shoreline. As the name implies, it "breaks" the strength of the incoming waves, resulting in a weaker wave reaching land, lessening erosion. For a longer stretch of shoreline, a series of breakwaters can be set up side by side at regular intervals, with the gap between them equal to the length of one breakwater. Sand often fills that gap, creating a small beach between the breakwater and the land.



Best for property that...

- experiences moderate to high wave action
- experiences boat wake traffic and sand moving down the shore

Out of packet costs & considerations

At-a-glance:

- Price range: $90–$150 per linear foot
- Average: $120

Factors in determining cost:

- access to the water
- equipment necessary
- depth of water
- length and number of structures
- material: granite, wood, or vinyl

Consider: Breakwaters require a major permit, and costs will include environmental consultants and an engineer to design the structure. They are generally more expensive than other hardened structures such as a bulkhead or riprap because of the volume of stone and the cost of installing the breakwater in open water.

Maintenance: Water can move rock, especially on Albemarle Sound. Inspection after a storm is recommended.

Longevity: If appropriately weighted rock is used, a breakwater can last for over 40 years.

Permits: A breakwater requires a major permit.

Series of breakwaters showing "tombolo" effect

Ecosystem costs & considerations

Ecosystem Service		Effect of Breakwater on Ecosystem Value
Wave erosion and sea level rise protection		the sand that accumulates and forms a beach landward of a breakwater is often "stolen" from shorelines down drift of the property
		effectively dissipates wave energy
		waves reflected from breakwaters may cause scour or erosion of adjacent shorelines, "tombolos" (see photo on previous page) are formed as a result of reflected rather than absorbed wave energy
Water quality		no significant effect
Animal habitat		barnacles and oysters often settle on breakwaters, increasing foraging areas for fish
		the "beach" that is formed from accumulating sediment reduces fish habitat
Carbon storage		no significant effect
Fish production		reduction in habitat causes reduction in fish population
Ecosystem diversity		no significant effect
Recreation		a new beach is formed (depends if you like beaches)

Sample project costs

Specifications	Project #1	Project #2
Region	Albemarle Sound	Cedar Island
Shoreline exposure	long fetch	low wave energy
Length of breakwater	150 feet	Two x 10 feet
Depth of water at high tide	4 feet	4 feet
Height of breakwater above high tide level	2 feet	1 foot
Construction material	stone	stone
Permit	major	major
Estimated cost	$25,000	$5,000

Did you know?

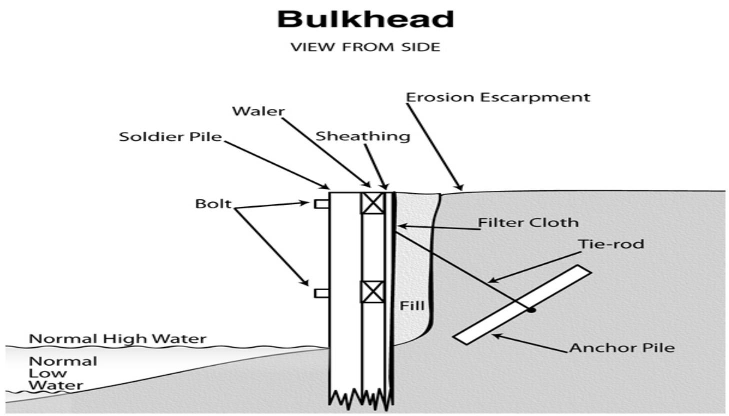
Estuarine wetlands can remove 20 to 60% of metals in the water, trap and retain 80 to 90% of sediment from runoff and eliminate 70 to 90% of entering nitrogen.

BULKHEADS

(also called shoreline hardening, armoring, and seawall)

What are they and how do they work?

A bulkhead is a vertical structure, much like a solid fence, built on the water-side of an eroding shoreline and anchored into the eroding bank. Once erected, the gap between the bulkhead and a nearby highpoint on the property is filled in with soil. The bulkhead holds the soil in place, acting as a barrier between the waves and the property. It can be built of wood, vinyl, steel, concrete or fiberglass.



Best for property that…

- is exposed to high wave energy
- has significant existing erosion

Out of pocket costs & considerations

At-a-glance:

- Price range: $80–$1,200 per linear foot
- Average: $135

Factors in determining cost:

- access to the water
- equipment necessary
- shoreline conditions – cleanup, roots
- length of bulkhead
- contractor workload
- minimizing impacts on existing seagrass, oysters, or marsh
- amount of backfill required
- material: wood, concrete, steel, fiberglass or vinyl
- number and complexity of tiebacks necessary
- height of wall (above "mud line")
- if required, adding riprap in front of bulkhead

Consider: As expected from the number of factors to consider in building a bulkhead, the range in price is huge: $100–$1,200 per linear foot, with residential prices about $135 / ft. As a rule, the taller the bulkhead needs to be, the more expensive it will be.

Maintenance: Backfill must be retained for the bulkhead to function. Cracks and holes in the bulkhead will allow soil to escape, weakening the bulkhead's support and leading to possible collapse. Periodic inspections are recommended. Wood is the most difficult material to repair.

Longevity: Longevity depends on type of construction and local site conditions, particularly storm events. The usual lifespan for bulkheads varies between 10 and 40 years, with wood falling at the lower end of the range, concrete in the middle, and vinyl/fiberglass at the upper end. With proper construction and maintenance, an average lifespan of 30 years can be expected.

Permits: A bulkhead can require a general or major permit. There are restrictions on the distance from your shoreline you can build a bulkhead and the amount of fill allowed, as well as limits on placement, especially if your site has existing seagrass, oysters or marsh.

Ecosystem costs & considerations

Ecosystem Service		Effect of Bulkhead on Ecosystem Value
Wave erosion and sea level rise protection		if properly built bulkheads provide protection from waves in extreme conditions
		wave energy is reflected rather than absorbed, reflected waves may cause bottom scour and loss of vegetation
		*if vegetation is removed*: natural buffer to ease waves and stabilize sediments eliminated
Water quality		if bulkhead base is in the intertidal zone, there is an opportunity to plant vegetation that can provide effective filtering and improve water quality
		*if vegetation is removed*: loss of marsh filtering capacity and reflected wave energy may increase re-suspension of sediments into water column
Animal habitat		interruption of corridor between terrestrial and aquatic habitat
		loss of shallow water habitat
Carbon storage		no significant effect
Fish production		barnacles and oysters often settle on bulkheads, increasing fish foraging areas

Ecosystem costs & considerations (cont.)

Ecosystem diversity		stops the natural creation of wetlands
		bulkheads reflect incoming wave energy, and depending on the setting may cause scouring of the bottom of the bulkhead; as a result, vegetation and many aquatic organisms cannot become established in front of a bulkhead, reducing diversity.
Recreation		easy access to deep water

Vinyl bulkhead

Sample project costs

Specifications	Project #1	Project #2
Region	Wrightsville	Ocracoke
Shoreline exposure	high wave energy	long fetch
Length of bulkhead	150 feet	50 feet
Depth of water at high tide	6 feet	4 feet
Height of bulkhead above high tide level	5 feet	2 feet
Construction material	fiberglass	wood
Permit	Major	General
Estimated cost	$90,000	$7,000

Bulkhead Combinations

- Bulkhead & waterward marsh
- Bulkhead & riprap
- Bulkhead & oyster toe

Vinyl bulkhead with waterward marsh

Did you know?

"We think of fish as living throughout the oceans, but most of the action happens close to shore where the food is." More than 90 percent of North Carolina's commercial and recreational seafood species, such as shrimp, flounder and crabs, depend on estuarine waters to provide protective habitat and food. Recreational fishing in North Carolina produced revenues totaling $1.2 billion in 2006

PUTTING IT ALL TOGETHER

Choosing the best shoreline erosion control option for your property is an important decision. This booklet has been designed to provide you with an overview of your alternatives so that you can make informed decisions about your choices. In addition to reducing property loss, erosion control methods also have ecological consequences, cost factors and aesthetic implications.

Now that you've read the handbook, you have a solid foundation of information. You can speak with representatives from the North Carolina Division of Coastal Management and/or your contractor about issues of concern, and work with them to select the most appropriate erosion control method for your property.

By taking an interest in your shoreline, you are helping to protect the exceptional beauty of North Carolina's estuaries and preserve it for generations to come.

STATE AND FEDERAL AGENCIES POTENTIALLY INVOLVED WITH YOUR EROSION CONTROL CONSTRUCTION, AND AREA OF OVERSIGHT

North Carolina

- Department of Administration, State Property Office **(NCDOA – SPO)**: manages the state's submerged lands
- Department of Cultural Resources, Division of Archives and History (**NCDCR – Archives & History**): protects historic properties and archaeological sites
- Department of Commerce, Division of Community Assistance (**NC Commerce – DCA**): assists local governments with growth management
- Department of Transportation, Division of Highways (**NCDOT**): protects state wetlands and waterways through the Highway Stormwater Program and the Ecosystem Enhancement Program
- Department of Environment and Natural Resources (**DENR**): serves as the lead stewardship agency for the preservation and protection of North Carolina's natural resources. Through its natural resource divisions, DENR works to protect fish, wildlife and wilderness areas. Divisions within DENR include:
  - Division of Coastal Management (**DCM**): responsible for the environmental health of 20 coastal counties, DCM regulates development, helps plan for future growth, and manages the state's coastal reserves
  - Division of Environmental Health (**DEH**): oversees shellfish harvests and recreational water quality
  - Division of Water Quality (**DWQ**): regulates and manages water quality throughout the state, including aquatic habitat

- Division of Land Resources (**DLR**): oversees development within North Carolina while preventing pollution by sedimentation
- Division of Marine Fisheries (**DMF**): promotes health of marine fish by regulating habitat, bottom, wetlands, water column, and submerged aquatic vegetation, and regulates oyster production
- Division of Water Resources (**DWR**): examines hydrology and promotes ecological integrity of streams
- Wildlife Resources Commission (**WRC**): manages hunting, boating, fishing and wildlife conservation

United States

- Environmental Protection Agency (**EPA**): oversees protection of public water supplies and the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife, and allows recreational activities
- Fish and Wildlife Service (**USFWS**): manages habitat and resource conservation
- National Marine Fisheries Service (**NMFS**): promotes habitat conservation and sustaining marine fisheries
- Army Corps of Engineers (**USACE; ACE; the Corps**): helps preserve and restore wetlands and estuaries, reduce shore erosion and restore beach habitat and oyster beds

WORKSHEET

Answer these questions as best you can. You'll learn a lot about your property and you'll identify the characteristics that make it better suited to certain erosion control options. Then, as you're reading through the handbook, you can compare the information about your property with the suitability of each alternative.

1. WHAT IS YOUR SHORELINE TYPE? (SEE PHOTOS ON PAGE 4)

Swamp Forest (are there cypress gum trees?) ___________________

Marsh (are there salt water-tolerant plants?) ____________________

Oysters (do you have oyster reefs?) ____________________________

Sediment Banks (is there no vegetation?) _______________________

- Low sediment bank (is there a gentle slope above the water line, less than 3 feet over 5 yards?) _________________________
- High sediment bank (is there a steep slope above the water line, more than 3 feet over 5 yards?) ________________________

Combination (e.g., swamp is upland from a marsh; marsh is landward of an oyster reef) _________________________________

2. DO YOU KNOW WHAT IS CAUSING THE EROSION?

Yes____ No _____

If yes:
Boat wake_____ storms ______ wind tides _____
gradual effects _____ other cause (describe) __________________

3A. WHAT DIRECTION(S) DOES YOUR SHORELINE FACE?

N__ NE__ E__ SE__ S__ SW__ W__ NW__

3b. In eastern North Carolina, the direction of strong winds is fairly predictable. **If you marked N, SW, NE, W, or S as your answer to 3a**, put a big circle around it and pay attention to question 4. The combination of exposure to strong wind and "high fetch" can direct you to certain erosion control alternatives.

4. How much "fetch" does the property face?

(i.e., how much water does the wind blow over before it reaches your property?)

a) less than ½ mile (low fetch) ____

b) more than ½ mile but less than 2 miles (medium fetch) ____

c) more than 2 miles (high fetch) ____

5. How much wave energy is hitting the shoreline?

(i.e., how high do the waves come up the shoreline above the usual high tide mark?)

a) from boat traffic ____________ feet

occasionally? __________

frequently? ____________

b) during a storm _______________ feet

occasionally? __________

frequently? ____________

Note: Properties with long fetch plus deep water will usually experience high wave energy; properties with a long fetch but shallow water, vegetation or sandbars directly in front of the shoreline usually experience moderate wave energy.

6. What is the length of the shoreline that needs protecting?_______ feet

7. WHAT ARE YOUR NEIGHBORS DOING?

a) to the left ____
b) to the right ____

8. WHAT BODY OF WATER DOES YOUR PROPERTY TOUCH?

____

9. WHAT IS THE SLOPE OF YOUR PROPERTY?

a) gentle _____

b) steep ______

10. Which of the following activities are important to you?

Fishing_____
Hunting_____
Bird watching_____
Swimming____
Boating____
Nature____

11. WHICH OF THE FOLLOWING ESTUARY SERVICES ARE MOST IMPORTANT TO YOU?

Pollution control____
Fish production and habitat____
Wildlife habitat____
Migratory bird habitat____
Water quality____
Surge and flood protection____

12. HOW LONG DO YOU PLAN TO BE AT THIS PROPERTY?

____

NOTES

For more information, visit the following organizations online:

NC DCM: http//:dcm2.enr.state.nc.us/
NOAA / National Estuary Research Reserve System (NERRS): http://www.nerrs.noaa.gov/
NOAA Center for Coastal Fisheries and Habitat Research: www.ccfhr.noaa.gov
North Carolina Coastal Federation (NCCF): http://www.nccoast.org/
CICEET: http://ciceet.unh.edu/

Credits:
P. 11, coir log: Photo used courtesy of the Partnership for the Delaware Estuary.
P. 42. Rowan Jacobsen and Michael Beck, “Where Oysters Grew on Trees.” *New York Times*, July 24, 2010.
Pp. 2, 4c, 5, 7, 9, 16, 20, 32, 41 and 42: Photos courtesy of National Oceanic and Atmospheric Administration/Department of Commerce.
Pp. 4-5, 7-8, 10, 11a, 15a, 18, 22, 26-28, 30, 36, 37 and 40: Photos courtesy of DENR.

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SEACHANGE
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Appendix 3

Table 1. Mean species abundance and standard error (SE) for various marsh thickness levels within the SoCo (Southern) Region (2009). Marsh numbers denote specific sites.

Year	Region	Marsh Thickness	Species	Mean	SE
2009	South	4 No Marsh	*Acteocina canaliculata*	0.33	0.33
2009	South	4 No Marsh	*Capitella capitata*	8.00	2.52
2009	South	4 No Marsh	*Caulleriella killariensis*	0.33	0.33
2009	South	4 No Marsh	*Laeonereis culveri*	22.00	1.00
2009	South	4 No Marsh	*Leitoscoloplos* sp.	2.67	0.88
2009	South	4 No Marsh	*Neanthes succinea*	1.00	0.58
2009	South	4 No Marsh	*Oxyurostylis smithi*	0.33	0.33
2009	South	4 No Marsh	*Streblospio benedicti*	1.33	0.67
2009	South	4 No Marsh	*Tagelus plebeius*	0.33	0.33
2009	South	4 No Marsh	Tubificidae spp.	0.33	0.33
2009	South	4 No Marsh	*Upogebia affinis*	0.33	0.33
2009	South	3 Narrow Marsh	*Aricidea suecica*	1.00	0.58
2009	South	3 Narrow Marsh	*Armandia maculata*	0.33	0.33
2009	South	3 Narrow Marsh	*Capitella capitata*	0.33	0.33
2009	South	3 Narrow Marsh	*Caulleriella killariensis*	0.67	0.67
2009	South	3 Narrow Marsh	*Cirrophorus* cf. *forticirratus*	3.33	1.45
2009	South	3 Narrow Marsh	*Drilonereis longa*	0.33	0.33
2009	South	3 Narrow Marsh	*Heteromastus filiformis*	8.33	2.40
2009	South	3 Narrow Marsh	*Ilyanassa obsoleta*	34.00	2.65
2009	South	3 Narrow Marsh	*Laeonereis culveri*	19.00	3.21
2009	South	3 Narrow Marsh	*Mediomastus ambiseta*	0.33	0.33
2009	South	3 Narrow Marsh	*Mediomastus* sp.	1.67	0.88
2009	South	3 Narrow Marsh	*Neanthes succinea*	0.33	0.33
2009	South	3 Narrow Marsh	Paraonidae sp.	0.33	0.33
2009	South	3 Narrow Marsh	*Paraonis fulgens*	2.67	0.88
2009	South	3 Narrow Marsh	*Streblospio benedicti*	4.33	1.86
2009	South	1 Medium Marsh	*Aricidea suecica*	0.33	0.33
2009	South	1 Medium Marsh	*Cirrophorus* cf. *forticirratus*	1.00	1.00
2009	South	1 Medium Marsh	Gastropoda sp.	0.33	0.33
2009	South	1 Medium Marsh	*Heteromastus filiformis*	7.67	0.88
2009	South	1 Medium Marsh	*Ilyanassa obsoleta*	29.00	11.02
2009	South	1 Medium Marsh	juv. Gastropod	0.33	0.33
2009	South	1 Medium Marsh	*Laeonereis culveri*	7.33	1.45
2009	South	1 Medium Marsh	*Leitoscoloplos fragilis*	0.33	0.33
2009	South	1 Medium Marsh	*Leitoscoloplos* sp.	0.33	0.33
2009	South	1 Medium Marsh	*Mediomastus* sp.	0.33	0.33
2009	South	1 Medium Marsh	*Neanthes succinea*	1.67	0.88
2009	South	1 Medium Marsh	Paraonidae sp.	0.67	0.67

Year	Region	Marsh Thickness	Species	Mean	SE
2009	South	1 Medium Marsh	Serpulidae sp.	0.33	0.33
2009	South	1 Medium Marsh	*Streblospio benedicti*	22.67	10.17
2009	South	1 Medium Marsh	*Streptosyllis pettiboneae*	0.33	0.33
2009	South	2 Medium Marsh	*Ampelisca* sp.	0.33	0.33
2009	South	2 Medium Marsh	*Aricidea suecica*	0.33	0.33
2009	South	2 Medium Marsh	Bivalvia sp.	0.33	0.33
2009	South	2 Medium Marsh	*Boccardiella* (sp. A)	0.33	0.33
2009	South	2 Medium Marsh	*Capitella capitata*	3.00	3.00
2009	South	2 Medium Marsh	*Caulleriella killariensis*	8.00	2.65
2009	South	2 Medium Marsh	*Cyathura* (*madelinae*)	0.33	0.33
2009	South	2 Medium Marsh	Dolichopodidae sp.	0.33	0.33
2009	South	2 Medium Marsh	*Heteromastus filiformis*	11.67	5.04
2009	South	2 Medium Marsh	*Ilyanassa obsoleta*	14.67	6.49
2009	South	2 Medium Marsh	juv. Bivalve	7.67	7.67
2009	South	2 Medium Marsh	juv. Gastropod	1.33	1.33
2009	South	2 Medium Marsh	*Laeonereis culveri*	26.67	5.78
2009	South	2 Medium Marsh	*Leitoscoloplos* (*robustus*)	0.67	0.67
2009	South	2 Medium Marsh	*Leitoscoloplos* sp.	0.67	0.33
2009	South	2 Medium Marsh	*Neanthes succinea*	0.33	0.33
2009	South	2 Medium Marsh	Nemertea sp.	0.67	0.33
2009	South	2 Medium Marsh	*Polydora cornuta*	0.33	0.33
2009	South	2 Medium Marsh	*Streblospio benedicti*	20.00	2.08
2009	South	2 Medium Marsh	*Streptosyllis pettiboneae*	1.00	1.00
2009	South	2 Medium Marsh	Tubificidae spp.	0.67	0.67
2009	South	6 Wide Marsh	*Eteone heteropoda*	0.33	0.33
2009	South	6 Wide Marsh	*Ilyanassa obsoleta*	4.33	2.33
2009	South	6 Wide Marsh	juv. Gastropod	0.33	0.33
2009	South	6 Wide Marsh	*Laeonereis culveri*	1.00	0.58
2009	South	6 Wide Marsh	*Streblospio benedicti*	35.67	11.17
2009	South	6 Wide Marsh	Tubificidae spp.	63.33	2.96
2009	South	5 Natural Marsh	*Aricidea suecica*	0.67	0.33
2009	South	5 Natural Marsh	*Bezzia/Palpomyia* sp.	1.33	0.88
2009	South	5 Natural Marsh	Brachyura sp.	0.33	0.33
2009	South	5 Natural Marsh	*Capitella capitata*	122.67	21.28
2009	South	5 Natural Marsh	Dolichopodidae sp.	0.67	0.67
2009	South	5 Natural Marsh	Dolichopodinae sp.	0.67	0.67
2009	South	5 Natural Marsh	*Eteone heteropoda*	0.33	0.33
2009	South	5 Natural Marsh	*Fabriciola trilobata*	116.33	42.45
2009	South	5 Natural Marsh	*Heteromastus filiformis*	1.67	1.20
2009	South	5 Natural Marsh	Hydracarina sp.	0.67	0.33
2009	South	5 Natural Marsh	*Ilyanassa obsoleta*	1.67	0.33

Year	Region	Marsh Thickness	Species	Mean	SE
2009	South	5 Natural Marsh	juv. Bivalve	0.33	0.33
2009	South	5 Natural Marsh	juv. Gastropod	0.33	0.33
2009	South	5 Natural Marsh	*Laeonereis culveri*	1.67	0.88
2009	South	5 Natural Marsh	*Leitoscoloplos* sp.	0.67	0.67
2009	South	5 Natural Marsh	Leptocheliidae sp.	0.67	0.67
2009	South	5 Natural Marsh	Nemertea sp.	2.00	0.58
2009	South	5 Natural Marsh	*Orchestia uhleri*	1.00	0.00
2009	South	5 Natural Marsh	*Polydora cornuta*	0.33	0.33
2009	South	5 Natural Marsh	*Rhithropanopeus harisii*	0.33	0.33
2009	South	5 Natural Marsh	*Streblospio benedicti*	72.33	9.17
2009	South	5 Natural Marsh	*Streptosyllis pettiboneae*	0.67	0.33
2009	South	5 Natural Marsh	Tubificidae spp.	128.33	38.11
2009	South	5 Natural Marsh	*Uca* sp.	1.00	1.00

Table 2. Mean species abundance and standard error (SE) for various marsh thickness levels within the CeCo (Central) Region (2009). Marsh numbers denote specific sites.

Year	Region	Marsh Thickness	Species	Mean	SE
2009	Central	1 No Marsh	*Ampithoe longimana*	0.33	0.33
2009	Central	1 No Marsh	*Ampithoe* sp.	0.67	0.67
2009	Central	1 No Marsh	*Capitella capitata*	44.00	10.00
2009	Central	1 No Marsh	Caprellidae sp.	0.33	0.33
2009	Central	1 No Marsh	*Cyclaspis varians*	0.33	0.33
2009	Central	1 No Marsh	*Eteone heteropoda*	1.67	0.33
2009	Central	1 No Marsh	*Gammarus mucronatus*	0.33	0.33
2009	Central	1 No Marsh	*Geukensia demissa*	0.33	0.33
2009	Central	1 No Marsh	juv. Bivalve	0.33	0.33
2009	Central	1 No Marsh	juv. Gastropod	0.33	0.33
2009	Central	1 No Marsh	*Laeonereis culveri*	40.33	9.60
2009	Central	1 No Marsh	*Melita nitida*	0.33	0.33
2009	Central	1 No Marsh	*Microprotopus raneyi*	0.33	0.33
2009	Central	1 No Marsh	*Nassarius vibex*	0.33	0.33
2009	Central	1 No Marsh	*Neanthes succinea*	1.00	1.00
2009	Central	1 No Marsh	*Onuphis eremita oculata*	0.33	0.33
2009	Central	1 No Marsh	*Pagarus longicarpus*	0.33	0.33
2009	Central	1 No Marsh	*Pilargis berkeleyae*	0.33	0.33
2009	Central	1 No Marsh	Platyhelminthes sp.	0.33	0.33
2009	Central	1 No Marsh	*Pseudonototanais* sp. B	0.33	0.33
2009	Central	1 No Marsh	Serpulidae sp.	10.33	2.33
2009	Central	1 No Marsh	*Spiochaetopterus costarum*	0.33	0.33
2009	Central	1 No Marsh	*Streblospio benedicti*	2.67	1.20
2009	Central	1 No Marsh	Tubificidae spp.	1.00	0.58
2009	Central	1 No Marsh	*Upogebia affinis*	0.33	0.33
2009	Central	3 Narrow Marsh	*Capitella capitata*	8.00	4.73
2009	Central	3 Narrow Marsh	Cirratulidae sp.	0.33	0.33
2009	Central	3 Narrow Marsh	*Crassostrea virginica*	0.33	0.33
2009	Central	3 Narrow Marsh	*Edotea* sp.	0.33	0.33
2009	Central	3 Narrow Marsh	*Eteone heteropoda*	1.67	0.88
2009	Central	3 Narrow Marsh	*Gemma gemma*	1.33	0.88
2009	Central	3 Narrow Marsh	*Hargeria rapax*	0.67	0.67
2009	Central	3 Narrow Marsh	*Heteromastus filiformis*	0.67	0.67
2009	Central	3 Narrow Marsh	*Hydroides dianthus*	0.33	0.33
2009	Central	3 Narrow Marsh	*Ilyanassa obsoleta*	1.00	0.58
2009	Central	3 Narrow Marsh	juv. Gastropod	0.33	0.33
2009	Central	3 Narrow Marsh	*Laeonereis culveri*	39.67	5.81
2009	Central	3 Narrow Marsh	*Neanthes succinea*	1.33	0.88

Year	Region	Marsh Thickness	Species	Mean	SE
2009	Central	3 Narrow Marsh	Phyllodocidae sp.	0.33	0.33
2009	Central	3 Narrow Marsh	*Prionospio heterobranchia*	0.33	0.33
2009	Central	3 Narrow Marsh	*Prionospio heteropoda*	0.33	0.33
2009	Central	3 Narrow Marsh	*Saccoglossus kowalevskii*	0.33	0.33
2009	Central	3 Narrow Marsh	*Streblospio benedicti*	38.33	18.91
2009	Central	3 Narrow Marsh	*Tagelus plebeius*	0.33	0.33
2009	Central	3 Narrow Marsh	Tubificidae spp.	9.33	4.06
2009	Central	2 Medium Marsh	*Acteocina canaliculata*	0.33	0.33
2009	Central	2 Medium Marsh	*Americamysis bigelowi*	0.67	0.33
2009	Central	2 Medium Marsh	*Axiothella* sp.	0.33	0.33
2009	Central	2 Medium Marsh	*Bezzia/Palpomyia* sp.	3.67	2.03
2009	Central	2 Medium Marsh	*Capitella capitata*	2.67	0.67
2009	Central	2 Medium Marsh	*Crepidula maculosa*	0.67	0.67
2009	Central	2 Medium Marsh	*Crepidula plana*	0.67	0.67
2009	Central	2 Medium Marsh	*Dasyhelea* sp.	0.67	0.67
2009	Central	2 Medium Marsh	*Edotea* sp.	0.33	0.33
2009	Central	2 Medium Marsh	*Eteone heteropoda*	1.67	1.20
2009	Central	2 Medium Marsh	*Eupolymnia nebulosa*	0.33	0.33
2009	Central	2 Medium Marsh	*Gammarus* (*palustris*)	9.33	1.67
2009	Central	2 Medium Marsh	*Gammarus mucronatus*	0.33	0.33
2009	Central	2 Medium Marsh	*Geukensia demissa*	0.67	0.33
2009	Central	2 Medium Marsh	*Glycera* sp.	0.33	0.33
2009	Central	2 Medium Marsh	*Gyptis brevipalpa*	0.33	0.33
2009	Central	2 Medium Marsh	*Hargeria rapax*	2.33	1.33
2009	Central	2 Medium Marsh	Hydracarina sp.	0.67	0.33
2009	Central	2 Medium Marsh	*Hydroides dianthus*	2.67	1.76
2009	Central	2 Medium Marsh	*Ilyanassa obsoleta*	1.00	0.58
2009	Central	2 Medium Marsh	juv. Bivalve	0.33	0.33
2009	Central	2 Medium Marsh	juv. Gastropod	1.67	1.67
2009	Central	2 Medium Marsh	*Laeonereis culveri*	3.00	1.73
2009	Central	2 Medium Marsh	Leptocheliidae sp.	2.33	2.33
2009	Central	2 Medium Marsh	*Lucina* sp.	0.33	0.33
2009	Central	2 Medium Marsh	*Mediomastus ambiseta*	0.33	0.33
2009	Central	2 Medium Marsh	*Neanthes succinea*	1.33	0.88
2009	Central	2 Medium Marsh	*Orchestia uhleri*	4.00	2.65
2009	Central	2 Medium Marsh	Paraonidae sp.	0.33	0.33
2009	Central	2 Medium Marsh	*Polydora cornuta*	0.33	0.33
2009	Central	2 Medium Marsh	*Prionospio heterobranchia*	1.33	0.67
2009	Central	2 Medium Marsh	*Pseudonototanais* sp.	1.33	0.33
2009	Central	2 Medium Marsh	*Pseudonototanais* sp. B	0.33	0.33
2009	Central	2 Medium Marsh	*Sabella* sp.	0.67	0.67

Year	Region	Marsh Thickness	Species	Mean	SE
2009	Central	2 Medium Marsh	Sabellidae sp.	0.33	0.33
2009	Central	2 Medium Marsh	*Sphaeroma* sp.	0.33	0.33
2009	Central	2 Medium Marsh	*Streblospio benedicti*	45.67	11.33
2009	Central	2 Medium Marsh	Tubificidae spp.	10.67	2.85
2009	Central	2 Medium Marsh	*Upogebia affinis*	0.33	0.33
2009	Central	4 Medium Marsh	*Americamysis bigelowi*	1.00	1.00
2009	Central	4 Medium Marsh	*Ampelisca holmesi*	0.33	0.33
2009	Central	4 Medium Marsh	*Aricidea suecica*	0.33	0.33
2009	Central	4 Medium Marsh	*Bezzia/Palpomyia* sp.	2.33	0.88
2009	Central	4 Medium Marsh	Bivalvia sp.	0.33	0.33
2009	Central	4 Medium Marsh	*Capitella capitata*	2.00	1.00
2009	Central	4 Medium Marsh	*Caulleriella killariensis*	0.67	0.67
2009	Central	4 Medium Marsh	Diptera sp.	0.33	0.33
2009	Central	4 Medium Marsh	*Eteone heteropoda*	2.67	0.67
2009	Central	4 Medium Marsh	Gastropoda sp.	0.33	0.33
2009	Central	4 Medium Marsh	*Gemma gemma*	1.33	0.88
2009	Central	4 Medium Marsh	*Geukensia demissa*	0.67	0.67
2009	Central	4 Medium Marsh	*Glycera* sp.	0.67	0.67
2009	Central	4 Medium Marsh	*Gyptis brevipalpa*	0.33	0.33
2009	Central	4 Medium Marsh	*Hargeria rapax*	1.00	0.58
2009	Central	4 Medium Marsh	*Ilyanassa obsoleta*	12.33	5.24
2009	Central	4 Medium Marsh	juv. Bivalve	0.33	0.33
2009	Central	4 Medium Marsh	*Laeonereis culveri*	19.00	2.00
2009	Central	4 Medium Marsh	Leptocheliidae sp. (juvenile)	0.33	0.33
2009	Central	4 Medium Marsh	*Marenzelleria viridis*	0.33	0.33
2009	Central	4 Medium Marsh	*Melita nitida*	0.67	0.67
2009	Central	4 Medium Marsh	*Pagarus longicarpus*	0.33	0.33
2009	Central	4 Medium Marsh	Paraonidae sp.	0.33	0.33
2009	Central	4 Medium Marsh	Phyllodocidae sp.	0.33	0.33
2009	Central	4 Medium Marsh	*Prionospio heterobranchia*	0.33	0.33
2009	Central	4 Medium Marsh	*Spio pettiboneae*	0.67	0.67
2009	Central	4 Medium Marsh	*Spiochaetopterus costarum*	0.33	0.33
2009	Central	4 Medium Marsh	*Streblospio benedicti*	33.00	12.12
2009	Central	4 Medium Marsh	*Streptosyllis pettiboneae*	1.33	0.33
2009	Central	4 Medium Marsh	Tubificidae spp.	18.00	8.19
2009	Central	6 Wide Marsh	*Ampelisca verrilli*	0.33	0.33
2009	Central	6 Wide Marsh	*Aricidea suecica*	2.67	1.33
2009	Central	6 Wide Marsh	*Bezzia/Palpomyia* sp.	38.33	27.64
2009	Central	6 Wide Marsh	*Capitella capitata*	46.33	43.35
2009	Central	6 Wide Marsh	Caprellidae sp.	0.33	0.33
2009	Central	6 Wide Marsh	Cirratulidae sp.	0.33	0.33

Year	Region	Marsh Thickness	Species	Mean	SE
2009	Central	6 Wide Marsh	*Dasyhelea* sp.	0.33	0.33
2009	Central	6 Wide Marsh	*Drilonereis longa*	0.33	0.33
2009	Central	6 Wide Marsh	*Eteone heteropoda*	1.67	1.20
2009	Central	6 Wide Marsh	*Fabriciola trilobata*	0.67	0.67
2009	Central	6 Wide Marsh	*Gammarus* (*palustris*)	0.33	0.33
2009	Central	6 Wide Marsh	*Gemma gemma*	1.67	0.33
2009	Central	6 Wide Marsh	*Heteromastus filiformis*	1.00	0.58
2009	Central	6 Wide Marsh	*Ilyanassa obsoleta*	24.67	11.22
2009	Central	6 Wide Marsh	juv. Gastropod	1.67	1.20
2009	Central	6 Wide Marsh	*Laeonereis culveri*	8.00	3.21
2009	Central	6 Wide Marsh	Leptocheliidae sp.	0.67	0.67
2009	Central	6 Wide Marsh	Nemertea sp.	0.33	0.33
2009	Central	6 Wide Marsh	*Polydora cornuta*	0.33	0.33
2009	Central	6 Wide Marsh	*Prionospio heterobranchia*	0.33	0.33
2009	Central	6 Wide Marsh	*Streblospio benedicti*	15.67	7.86
2009	Central	6 Wide Marsh	Tubificidae spp.	32.00	24.44
2009	Central	6 Wide Marsh	*Uca* sp.	0.33	0.33
2009	Central	5 Natural Marsh	*Campylaspis* sp.	0.33	0.33
2009	Central	5 Natural Marsh	*Capitella capitata*	10.33	8.88
2009	Central	5 Natural Marsh	*Caulleriella killariensis*	0.67	0.33
2009	Central	5 Natural Marsh	*Gammarus tigrinus*	1.00	1.00
2009	Central	5 Natural Marsh	*Gemma gemma*	4.00	1.00
2009	Central	5 Natural Marsh	*Glycera* sp.	0.33	0.33
2009	Central	5 Natural Marsh	*Hargeria rapax*	8.67	4.91
2009	Central	5 Natural Marsh	*Heteromastus filiformis*	0.33	0.33
2009	Central	5 Natural Marsh	*Ilyanassa obsoleta*	8.67	4.70
2009	Central	5 Natural Marsh	*Laeonereis culveri*	16.67	7.26
2009	Central	5 Natural Marsh	*Mediomastus ambiseta*	0.33	0.33
2009	Central	5 Natural Marsh	*Neanthes succinea*	0.33	0.33
2009	Central	5 Natural Marsh	Nemertea sp.	0.33	0.33
2009	Central	5 Natural Marsh	Orthocladiinae sp.	0.33	0.33
2009	Central	5 Natural Marsh	*Polydora cornuta*	1.00	1.00
2009	Central	5 Natural Marsh	*Pseudonototanais* sp.	2.33	2.33
2009	Central	5 Natural Marsh	*Streblospio benedicti*	50.33	15.96
2009	Central	5 Natural Marsh	Tubificidae spp.	51.67	25.50

Table 3. Mean species abundance and standard error (SE) for various marsh thickness levels within the SoCo (Southern) Region (2010). Marsh numbers denote specific sites.

Year	Region	Marsh Thickness	Species	Mean	SE
2010	South	4 No Marsh	(*Pseudonototanais* sp.)	1.33	1.33
2010	South	4 No Marsh	*Acteocina canaliculata*	0.33	0.33
2010	South	4 No Marsh	*Ampithoe longimana*	0.33	0.33
2010	South	4 No Marsh	Ascidiacea sp.	0.33	0.33
2010	South	4 No Marsh	*Brachidontes exustus*	0.33	0.33
2010	South	4 No Marsh	*Capitella capitata*	21.33	14.33
2010	South	4 No Marsh	Caprellidae sp.	0.33	0.33
2010	South	4 No Marsh	*Caulleriella killariensis*	1.00	0.58
2010	South	4 No Marsh	Cirratulidae sp.	0.67	0.67
2010	South	4 No Marsh	*Gammarus mucronatus*	0.33	0.33
2010	South	4 No Marsh	*Heteromastus filiformis*	1.67	0.88
2010	South	4 No Marsh	juv. Bivalve	1.00	0.58
2010	South	4 No Marsh	*Laeonereis culveri*	20.67	9.53
2010	South	4 No Marsh	*Leitoscoloplos* (*fragilis*)	1.00	1.00
2010	South	4 No Marsh	*Leitoscoloplos fragilis*	0.67	0.67
2010	South	4 No Marsh	*Leitoscoloplos* sp.	4.33	0.88
2010	South	4 No Marsh	*Neanthes succinea*	2.67	2.19
2010	South	4 No Marsh	Nemertea sp.	0.33	0.33
2010	South	4 No Marsh	*Oxyurostylis smithi*	0.33	0.33
2010	South	4 No Marsh	*Streblospio benedicti*	1.33	0.88
2010	South	4 No Marsh	*Streptosyllis pettiboneae*	0.33	0.33
2010	South	4 No Marsh	*Tagelus plebeius*	0.33	0.33
2010	South	4 No Marsh	Tubificidae spp.	6.33	5.36
2010	South	4 No Marsh	*Tubificoides heterochaetus*	0.67	0.67
2010	South	3 Narrow Marsh	*Apocorophium* sp.	0.33	0.33
2010	South	3 Narrow Marsh	Balanidae sp. (juvenile)	12.33	9.06
2010	South	3 Narrow Marsh	*Bezzia/Palpomyia* sp.	0.33	0.33
2010	South	3 Narrow Marsh	*Brachidontes exustus*	0.67	0.67
2010	South	3 Narrow Marsh	*Cassidinidea lunifrons*	0.33	0.33
2010	South	3 Narrow Marsh	*Caulleriella killariensis*	6.67	3.71
2010	South	3 Narrow Marsh	Cirratulidae sp.	3.33	1.20
2010	South	3 Narrow Marsh	*Cirrophorus* cf. *forticirratus*	2.67	0.88
2010	South	3 Narrow Marsh	Dolichopodidae sp.	1.33	0.88
2010	South	3 Narrow Marsh	*Eteone heteropoda*	5.67	1.20
2010	South	3 Narrow Marsh	*Gemma gemma*	1.67	1.67
2010	South	3 Narrow Marsh	*Geukensia demissa*	0.67	0.67

Year	Region	Marsh Thickness	Species	Mean	SE
2010	South	3 Narrow Marsh	*Heteromastus filiformis*	6.33	0.67
2010	South	3 Narrow Marsh	*Ilyanassa obsoleta*	3.00	0.58
2010	South	3 Narrow Marsh	juv. Bivalve	1.67	0.67
2010	South	3 Narrow Marsh	juv. Gastropod	0.33	0.33
2010	South	3 Narrow Marsh	*Laeonereis culveri*	10.33	4.06
2010	South	3 Narrow Marsh	*Leitoscoloplos* (*fragilis*)	0.67	0.67
2010	South	3 Narrow Marsh	*Leitoscoloplos fragilis*	6.33	6.33
2010	South	3 Narrow Marsh	*Leitoscoloplos* sp.	1.67	1.20
2010	South	3 Narrow Marsh	Megalops sp.	0.33	0.33
2010	South	3 Narrow Marsh	*Neanthes succinea*	8.33	3.18
2010	South	3 Narrow Marsh	Nemertea sp.	1.00	0.58
2010	South	3 Narrow Marsh	*Paraonis fulgens*	1.33	0.67
2010	South	3 Narrow Marsh	*Streblospio benedicti*	3.00	1.15
2010	South	3 Narrow Marsh	*Streptosyllis pettiboneae*	9.00	0.58
2010	South	3 Narrow Marsh	*Tagelus plebeius*	0.67	0.33
2010	South	3 Narrow Marsh	*Tharyx* sp.	3.33	1.76
2010	South	3 Narrow Marsh	Tubificidae spp.	2.33	1.45
2010	South	3 Narrow Marsh	*Uca* sp.	2.33	1.20
2010	South	1 Medium Marsh	(Enchytraeidae sp.)	45.00	23.03
2010	South	1 Medium Marsh	*Anurida maritima*	0.33	0.33
2010	South	1 Medium Marsh	*Aricidea suecica*	0.33	0.33
2010	South	1 Medium Marsh	*Capitella capitata*	9.00	8.02
2010	South	1 Medium Marsh	*Caulleriella killariensis*	1.67	1.20
2010	South	1 Medium Marsh	Cirratulidae sp.	1.33	0.88
2010	South	1 Medium Marsh	Collembola sp	0.33	0.33
2010	South	1 Medium Marsh	Dolichopodidae sp.	4.33	2.33
2010	South	1 Medium Marsh	*Drilonereis longa*	0.33	0.33
2010	South	1 Medium Marsh	Enchytraeidae sp.	48.00	48.00
2010	South	1 Medium Marsh	*Eteone heteropoda*	1.33	0.88
2010	South	1 Medium Marsh	*Gammarus tigrinus*	0.33	0.33
2010	South	1 Medium Marsh	*Glycinde* sp.	0.33	0.33
2010	South	1 Medium Marsh	*Hargeria rapax*	0.33	0.33
2010	South	1 Medium Marsh	*Heteromastus filiformis*	1.33	0.67
2010	South	1 Medium Marsh	Hydracarina sp.	0.67	0.67
2010	South	1 Medium Marsh	*Ilyanassa obsoleta*	2.00	1.15
2010	South	1 Medium Marsh	Insect sp. (grub)	0.33	0.33
2010	South	1 Medium Marsh	juv. Gastropod	1.67	1.20
2010	South	1 Medium Marsh	*Laeonereis culveri*	5.00	4.04
2010	South	1 Medium Marsh	*Leitoscoloplos* sp. (juvenile)	0.33	0.33

Year	Region	Marsh Thickness	Species	Mean	SE
2010	South	1 Medium Marsh	*Littorina irrorata*	0.67	0.33
2010	South	1 Medium Marsh	Lumbriculidae sp.	7.00	7.00
2010	South	1 Medium Marsh	*Melampus bidentatus*	4.33	3.84
2010	South	1 Medium Marsh	*Mercenaria mercenaria*	0.33	0.33
2010	South	1 Medium Marsh	*Orchestia uhleri*	16.33	8.21
2010	South	1 Medium Marsh	*Streblospio benedicti*	2.00	1.15
2010	South	1 Medium Marsh	*Streptosyllis pettiboneae*	2.67	2.19
2010	South	1 Medium Marsh	*Tharyx* (*acutus*)	0.33	0.33
2010	South	1 Medium Marsh	Tubificidae spp.	4.67	2.73
2010	South	1 Medium Marsh	*Uca* sp.	0.67	0.67
2010	South	2 Medium Marsh	*Balanus* sp.	0.33	0.33
2010	South	2 Medium Marsh	*Capitella capitata*	1.33	0.67
2010	South	2 Medium Marsh	*Cirrophorus* cf. *forticirratus*	0.33	0.33
2010	South	2 Medium Marsh	Dolichopodidae sp.	2.67	0.88
2010	South	2 Medium Marsh	*Edotea* sp.	0.33	0.33
2010	South	2 Medium Marsh	Enchytraeidae sp.	51.67	46.28
2010	South	2 Medium Marsh	Ephydridae sp.	0.33	0.33
2010	South	2 Medium Marsh	*Eteone heteropoda*	3.67	2.73
2010	South	2 Medium Marsh	Gammaridae sp.	0.33	0.33
2010	South	2 Medium Marsh	*Glycinde solitaria*	1.00	0.58
2010	South	2 Medium Marsh	*Heteromastus filiformis*	9.00	4.93
2010	South	2 Medium Marsh	Hydracarina sp.	14.00	4.73
2010	South	2 Medium Marsh	*Ilyanassa obsoleta*	23.67	9.82
2010	South	2 Medium Marsh	juv. Bivalve	0.33	0.33
2010	South	2 Medium Marsh	juv. Gastropod	1.33	0.33
2010	South	2 Medium Marsh	*Laeonereis culveri*	9.00	3.61
2010	South	2 Medium Marsh	*Leitoscoloplos* sp. (juvenile)	0.67	0.67
2010	South	2 Medium Marsh	Lumbriculidae sp.	2.00	2.00
2010	South	2 Medium Marsh	*Melampus bidentatus*	0.33	0.33
2010	South	2 Medium Marsh	*Neanthes succinea*	2.67	1.20
2010	South	2 Medium Marsh	*Orchestia grillus*	19.00	8.19
2010	South	2 Medium Marsh	*Orchestia uhleri*	0.33	0.33
2010	South	2 Medium Marsh	*Paraonis fulgens*	0.33	0.33
2010	South	2 Medium Marsh	*Sphaerosyllis* (*glandulata*)	0.33	0.33
2010	South	2 Medium Marsh	*Streblospio benedicti*	8.33	3.84
2010	South	2 Medium Marsh	*Streptosyllis pettiboneae*	0.67	0.67
2010	South	2 Medium Marsh	*Tagelus divisus*	0.33	0.33
2010	South	2 Medium Marsh	Tubificidae spp.	170.00	67.12
2010	South	2 Medium Marsh	*Uca* sp.	0.33	0.33

Year	Region	Marsh Thickness	Species	Mean	SE
2010	South	6 Wide Marsh	*Capitella capitata*	0.67	0.33
2010	South	6 Wide Marsh	*Edotea* sp.	0.33	0.33
2010	South	6 Wide Marsh	*Gammarus mucronatus*	0.33	0.33
2010	South	6 Wide Marsh	*Ilyanassa obsoleta*	13.67	4.33
2010	South	6 Wide Marsh	juv. Bivalve	0.33	0.33
2010	South	6 Wide Marsh	*Streblospio benedicti*	45.33	10.35
2010	South	6 Wide Marsh	Tubificidae spp.	37.00	6.66
2010	South	5 Natural Marsh	*Astarte* sp.	0.33	0.33
2010	South	5 Natural Marsh	*Bezzia/Palpomyia* sp.	0.33	0.33
2010	South	5 Natural Marsh	*Capitella capitata*	3.67	1.86
2010	South	5 Natural Marsh	*Caulleriella killariensis*	0.33	0.33
2010	South	5 Natural Marsh	*Cyclaspis varians*	0.33	0.33
2010	South	5 Natural Marsh	*Fabriciola trilobata*	2.00	2.00
2010	South	5 Natural Marsh	*Gemma gemma*	0.33	0.33
2010	South	5 Natural Marsh	*Heteromastus filiformis*	1.00	0.58
2010	South	5 Natural Marsh	Hydracarina sp.	3.00	1.73
2010	South	5 Natural Marsh	*Ilyanassa obsoleta*	0.33	0.33
2010	South	5 Natural Marsh	juv. Bivalve	0.33	0.33
2010	South	5 Natural Marsh	juv. Gastropod	1.00	0.00
2010	South	5 Natural Marsh	*Laeonereis culveri*	0.67	0.33
2010	South	5 Natural Marsh	*Leitoscoloplos* sp.	0.67	0.33
2010	South	5 Natural Marsh	*Mediomastus* sp.	0.67	0.67
2010	South	5 Natural Marsh	Megalops sp.	0.33	0.33
2010	South	5 Natural Marsh	*Neanthes succinea*	2.33	0.88
2010	South	5 Natural Marsh	Nemertea sp.	0.67	0.67
2010	South	5 Natural Marsh	*Orchestia grillus*	0.67	0.67
2010	South	5 Natural Marsh	*Streblospio benedicti*	97.67	21.65
2010	South	5 Natural Marsh	Tubificidae spp.	126.67	36.43
2010	South	5 Natural Marsh	*Uca* sp.	0.33	0.33

Table 4. Mean species abundance and standard error (SE) for various marsh thickness levels within the NoCo (Northern) Region (2010). Marsh numbers denote specific sites.

Year	Region	Marsh Thickness	Species	Mean	SE
2010	North	2 No Marsh	*Chironomus* sp.	5.00	1.15
2010	North	2 No Marsh	Curculionoidea sp.	0.33	0.33
2010	North	2 No Marsh	*Dasyhelea* sp.	0.33	0.33
2010	North	2 No Marsh	*Enallagma* sp.	1.67	1.67
2010	North	2 No Marsh	*Gammarus* sp.	0.33	0.33
2010	North	2 No Marsh	*Gammarus tigrinus*	1.00	0.58
2010	North	2 No Marsh	*Hargeria rapax*	0.67	0.33
2010	North	2 No Marsh	Hydracarina sp.	1.00	1.00
2010	North	2 No Marsh	juv. Gastropod	0.33	0.33
2010	North	2 No Marsh	*Laeonereis culveri*	2.33	0.88
2010	North	2 No Marsh	Leptocheliidae sp. (juvenile)	0.33	0.33
2010	North	2 No Marsh	Naididae sp.	0.33	0.33
2010	North	2 No Marsh	*Polydora cornuta*	0.33	0.33
2010	North	2 No Marsh	*Polydora* sp.	0.33	0.33
2010	North	2 No Marsh	*Streblospio benedicti*	0.33	0.33
2010	North	2 No Marsh	Tanaidacea sp.	0.33	0.33
2010	North	2 No Marsh	Tipulidae sp.	0.33	0.33
2010	North	2 No Marsh	Tubificidae spp.	33.00	11.50
2010	North	1 Narrow Marsh	*Apedilum* sp.	0.33	0.33
2010	North	1 Narrow Marsh	*Bezzia/Palpomyia* sp.	0.33	0.33
2010	North	1 Narrow Marsh	*Chironomus* sp.	48.67	14.31
2010	North	1 Narrow Marsh	Corixidae sp. (juvenile)	1.00	1.00
2010	North	1 Narrow Marsh	*Dero* sp.	90.33	90.33
2010	North	1 Narrow Marsh	*Elasmopus levis*	0.33	0.33
2010	North	1 Narrow Marsh	*Enallagma* sp.	1.67	0.88
2010	North	1 Narrow Marsh	Ephydridae sp.	0.33	0.33
2010	North	1 Narrow Marsh	*Eristalis* sp.	0.33	0.33
2010	North	1 Narrow Marsh	*Gammarus tigrinus*	2.00	1.00
2010	North	1 Narrow Marsh	*Goeldichironomus devineyae*	0.67	0.67
2010	North	1 Narrow Marsh	*Hargeria rapax*	1.33	0.88
2010	North	1 Narrow Marsh	*Hobsonia florida*	0.67	0.67
2010	North	1 Narrow Marsh	Hydracarina sp.	0.67	0.67
2010	North	1 Narrow Marsh	juv. Gastropod	1.00	0.00
2010	North	1 Narrow Marsh	*Laeonereis culveri*	10.67	1.20
2010	North	1 Narrow Marsh	*Limnodrilus hoffmeisteri*	0.33	0.33
2010	North	1 Narrow Marsh	Naididae sp.	17.33	16.34

Year	Region	Marsh Thickness	Species	Mean	SE
2010	North	1 Narrow Marsh	*Parachironomus* sp.	1.00	0.58
2010	North	1 Narrow Marsh	*Paranais* sp.	0.33	0.33
2010	North	1 Narrow Marsh	*Polydora cornuta*	1.33	0.33
2010	North	1 Narrow Marsh	*Polypedilum* sp.	1.00	0.58
2010	North	1 Narrow Marsh	Tubificidae spp.	334.67	241.31
2010	North	4 Medium Marsh	*Americamysis* (*bahia*)	0.33	0.33
2010	North	4 Medium Marsh	*Anurida maritima*	0.33	0.33
2010	North	4 Medium Marsh	*Bezzia/Palpomyia* sp.	1.00	1.00
2010	North	4 Medium Marsh	*Capitella capitata*	7.00	3.79
2010	North	4 Medium Marsh	*Caulleriella killariensis*	0.33	0.33
2010	North	4 Medium Marsh	*Chironomus* sp.	15.00	4.36
2010	North	4 Medium Marsh	Cirratulidae sp.	0.33	0.33
2010	North	4 Medium Marsh	Collembola sp.	3.00	1.53
2010	North	4 Medium Marsh	*Dasyhelea* sp.	0.33	0.33
2010	North	4 Medium Marsh	Dolichopodidae sp.	2.00	2.00
2010	North	4 Medium Marsh	*Eteone heteropoda*	3.33	1.76
2010	North	4 Medium Marsh	*Fabriciola trilobata*	0.67	0.67
2010	North	4 Medium Marsh	*Gammarus* (*tigrinus*)	0.67	0.67
2010	North	4 Medium Marsh	*Geukensia demissa*	0.33	0.33
2010	North	4 Medium Marsh	*Hargeria rapax*	0.67	0.67
2010	North	4 Medium Marsh	*Hobsonia florida*	5.00	1.53
2010	North	4 Medium Marsh	Hydracarina sp.	0.67	0.67
2010	North	4 Medium Marsh	juv. Bivalve	0.33	0.33
2010	North	4 Medium Marsh	*Laeonereis culveri*	8.33	2.33
2010	North	4 Medium Marsh	*Leitoscoloplos* sp.	6.33	4.10
2010	North	4 Medium Marsh	Lumbriculidae sp.	0.33	0.33
2010	North	4 Medium Marsh	*Mediomastus* sp.	1.33	0.67
2010	North	4 Medium Marsh	Naididae sp.	0.67	0.67
2010	North	4 Medium Marsh	*Neanthes succinea*	0.33	0.33
2010	North	4 Medium Marsh	Nereididae sp.	2.33	2.33
2010	North	4 Medium Marsh	*Paraonis fulgens*	0.33	0.33
2010	North	4 Medium Marsh	*Polydora cornuta*	1.33	0.88
2010	North	4 Medium Marsh	*Pristina* sp.	0.33	0.33
2010	North	4 Medium Marsh	Serpulidae sp.	0.33	0.33
2010	North	4 Medium Marsh	*Streblospio benedicti*	0.33	0.33
2010	North	4 Medium Marsh	*Streptosyllis pettiboneae*	0.33	0.33
2010	North	4 Medium Marsh	*Tharyx* sp.	0.67	0.67
2010	North	4 Medium Marsh	*Tipula* sp.	0.33	0.33
2010	North	4 Medium Marsh	Tipulidae sp.	1.33	1.33

Year	Region	Marsh Thickness	Species	Mean	SE
2010	North	4 Medium Marsh	Tubificidae spp.	62.67	21.05
2010	North	5 Medium Marsh	*Aricidea suecica*	0.33	0.33
2010	North	5 Medium Marsh	Diptera sp. (pupae)	0.33	0.33
2010	North	5 Medium Marsh	juv. Gastropod	0.67	0.33
2010	North	5 Medium Marsh	*Laeonereis culveri*	0.33	0.33
2010	North	5 Medium Marsh	*Orchestia uhleri*	0.33	0.33
2010	North	5 Medium Marsh	*Streblospio benedicti*	25.67	25.67
2010	North	5 Medium Marsh	Tubificidae spp.	7.33	2.67
2010	North	3 Wide Marsh	*Anurida maritima*	1.00	0.58
2010	North	3 Wide Marsh	*Bezzia/Palpomyia* sp.	0.33	0.33
2010	North	3 Wide Marsh	*Capitella capitata*	0.33	0.33
2010	North	3 Wide Marsh	*Cassidinidea lunifrons*	0.33	0.33
2010	North	3 Wide Marsh	*Chironomus* sp.	1.33	0.67
2010	North	3 Wide Marsh	Collembola sp.	0.33	0.33
2010	North	3 Wide Marsh	*Dasyhelea* sp.	3.33	1.20
2010	North	3 Wide Marsh	*Dero* sp.	1.00	0.58
2010	North	3 Wide Marsh	*Enallagma* sp.	4.00	2.31
2010	North	3 Wide Marsh	*Gammarus tigrinus*	0.33	0.33
2010	North	3 Wide Marsh	Gastropoda sp.	0.33	0.33
2010	North	3 Wide Marsh	*Heteromastus filiformis*	0.33	0.33
2010	North	3 Wide Marsh	*Hobsonia florida*	1.00	0.58
2010	North	3 Wide Marsh	Hydracarina sp.	0.67	0.67
2010	North	3 Wide Marsh	*Ilyanassa obsoleta*	7.33	7.33
2010	North	3 Wide Marsh	juv. Gastropod	2.67	1.45
2010	North	3 Wide Marsh	*Laeonereis culveri*	18.33	1.45
2010	North	3 Wide Marsh	*Limnodrilus hoffmeisteri*	16.67	16.67
2010	North	3 Wide Marsh	*Limnophila* sp.	0.33	0.33
2010	North	3 Wide Marsh	Lumbriculidae sp.	0.33	0.33
2010	North	3 Wide Marsh	*Merragata* sp.	1.00	0.58
2010	North	3 Wide Marsh	*Monopylephorus irroratus*	49.67	49.67
2010	North	3 Wide Marsh	Naididae sp.	2.67	2.19
2010	North	3 Wide Marsh	*Polydora cornuta*	0.33	0.33
2010	North	3 Wide Marsh	*Pristina* sp.	2.33	1.86
2010	North	3 Wide Marsh	*Streblospio benedicti*	0.67	0.67
2010	North	3 Wide Marsh	Tubificidae spp.	268.67	155.40
2010	North	6 Natural Marsh	*Anomalagrion/Ischnura* sp.	0.33	0.33
2010	North	6 Natural Marsh	*Chironomus* sp.	91.00	2.65
2010	North	6 Natural Marsh	Ephydridae sp.	0.33	0.33
2010	North	6 Natural Marsh	*Eteone heteropoda*	3.00	0.58

Year	Region	Marsh Thickness	Species	Mean	SE
2010	North	6 Natural Marsh	*Goeldichironomus devineyae*	1.33	1.33
2010	North	6 Natural Marsh	*Hobsonia florida*	8.67	0.67
2010	North	6 Natural Marsh	juv. Bivalve	0.33	0.33
2010	North	6 Natural Marsh	juv. Gastropod	0.33	0.33
2010	North	6 Natural Marsh	*Laeonereis culveri*	0.67	0.67
2010	North	6 Natural Marsh	*Parachironomus* sp.	0.33	0.33
2010	North	6 Natural Marsh	*Polydora cornuta*	0.33	0.33
2010	North	6 Natural Marsh	*Polypedilum* sp.	3.00	0.58
2010	North	6 Natural Marsh	*Streblospio benedicti*	8.00	1.15