The Costs of Shoreline Stabilization

Installation Cost Comparisons

INDUSTRY GENERATED COSTS COMPS
SUPPORTING CALCULATIONS
VERIFIED COST COMPARISONS
SUPPORTING CALCULATIONS

Industry Generated Costs Comparisons

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Section 1.2 Summary of Costs and Construction Time
All Walls

Wall Properties

H := 19·ft Exposed Wall height
L := 100·ft Wall Length

Retaining Wall Type	Construction Duration (Days)	Total Cost for 100 ft. Wall	Cost per Linear Ft.	Cost per Square Ft.	Cost Per Linear Foot 8' Wall
Grouted Anchor Steel Sheet Pile Wall	13	$ 90,607	$ 906.07	$ 47.69	$ 381.52
Cast-In-Place Reinforced Concrete Wall	47	$ 258,572	$ 2,585.72	$ 136.09	$ 1088.72
Concrete Modular Unit Gravity Wall	31	$ 144,741	$ 1,447.41	$ 76.18	$ 609.44
Mechanically Stabilized Earth Wall	35	$ 181,593	$ 1,815.93	$ 95.58	$ 764.64
Soldier Pile and Lagging Wall	26	$ 171,856	$ 1,718.56	$ 90.45	$ 723.6
Slurry Wall*	64	$ 400,145	$ 4,001.45	$ 210.60	$ 1684.8

Industry Generated Costs Comparisons

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Section 1.3 Summary of Costs and Construction Time, Each Wall

Grouted Anchor Steel Sheet Pile Wall

Pay Item No.	Item		Unit	Quantity	Daily Output (unit/day)	Time (day)	Unit Cost	Cost
5	Grouted Anchors - 1" Dia		LF	288.0	120	3	$ 20.30	$ 5,777.20
02	Sheet piling, 19 ft deep excavation	19.3 psf, left in place	TN	29.0	12.95	3	$ 1,950.00	$ 56,550.00
03	Wales, connections & struts	0	TN	1.5	NA	-	$ 300.00	$ 450.00
04	Anchors		TN	0.4	NA	-	$ 2,700.00	$ 958.50
07	Backfill structural	105 H.P., 150 ft haul, sand & gravel	LCY	211.0	670	-	$ 2.02	$ 426.22
08	Borrow loading	Select granular fill	BCY	211.0	NA	-	$ 13.86	$ 2,924.46
09	Compaction, riding vibrating roller	12 in lift, 2 passes	ECY	-	5200	-	$ 0.23	$ -
10	Compaction, walk behind vibrating plate	12 in lift, 2 passes	ECY	211.0	580	1	$ 0.78	$ 164.58
12	Excavation, trench, common earth	14 ft to 20 ft deep, 1.5 cy hydraulic backhoe	BCY	211.0	480	1	$ 3.86	$ 814.46
15	Driven piles, complete pile driving setup	Mobilization, large	EA	1.0	0.27	4	$ 22,000.00	$ 22,000.00
16	Geotextile for subsurface drainage	Fabric, laid in trench, adverse conditions	SY	244.4	1600	1	$ 2.18	$ 532.79
	Totals					13		$ 90,607.21
							Cost per LF	$ 906.07
							Cost per SF	$ 47.69

Verified Cost Comparison - LSSI

Bank Stabilization Cost Estimates
- Little St Simons Island, GA -

Bulkheads: A bulkhead is any shore-parallel vertical structure or wall designed to prevent erosion of the land.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Vinyl bulkhead w/toe protection	Linear Foot	$283	$686

A vinyl bulkhead is a vertical sea wall constructed of rigid, interlocking vinyl sections. Each section is 18" wide on average, has tongue and groove type edges which lock together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

All costs based on heights of 8' of exposed sea wall plus toe protection

Total Length of Embankment = 300 Linear Feet

Installation Costs include the cost to: extend old dock ramp to meet the new top of bank; backfill; and finish grade.

Estimated costs do not include the cost to barge the material to the island or island housing

Verified Cost Comparison - LSSI

Wooden bulkhead w/toe protection	Linear Foot	$241	$652

A wooden bulkhead is a vertical sea wall constructed of pressure-treated wood sections. Each section is 12" wide on average, has tongue and groove type edges which fit together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

Concrete bulkhead w/toe protection	Linear Foot	$476	$1022

A concrete bulkhead is a vertical sea wall constructed of concrete sections. Each section is 18"-36" wide on average, has tongue and groove type edges which fit together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

Verified Cost Comparison - LSSI

Sloped Revetments – sloped revetments are constructed features made of hard materials placed on banks in such a way as to absorb the energy of incoming water. Revetments are usually built to preserve the existing uses of the shoreline and to protect the slope, as defense against erosion.

Type	Unit	Materials Cost ($/Unit)	Installed Cost ($/Unit)
Granite Type 1 Rip Rap w/ Type 1 toe protection	Linear Foot	$164	$469

Granite Type 1 Rip Rap, also known as "surge stone," is comprised of granite stones, each weighing approximately 125 lbs on average and measuring 18" to 24" in diameter. It is used in areas where larger stones are needed for stability or to resist the forces of strong currents or wave action. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss.

Type	Unit	Materials Cost ($/Unit)	Installed Cost ($/Unit)
Granite Type 3 w/ Type 1 toe protection	Linear Foot	$155	$443

Granite Type 3 Rip Rap is comprised of granite stones, each weighing approximately 15 lbs on average and measuring 6" to 8" in diameter. It is used to reduce the velocity and energy of water currents on the upper portions of the bank. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss. Granite Type 1 Rip Rap is used to provide additional stability on the lower portion of the bank.

Type	Unit	Materials Cost ($/Unit)	Installed Cost ($/Unit)
Granite Type 3 w/ Type 3 toe protection	Linear Foot	$152	$440

Granite Type 3 Rip Rap is comprised of granite stones, each weighing approximately 15 lbs on average and measuring 6" to 8" in diameter. It is used to reduce the velocity and energy of water currents on all portions of the bank. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss.

Verified Cost Comparison - LSSI

Living Shoreline **–** A living shoreline is a sloped erosion control technique that mimics natural, native habitat, provides increased opportunities for species diversity and productivity, and can serve to improve water quality and the ecological integrity of the area.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Oyster bags w/ Recycled Concrete Toe Protection	Linear Foot	$120	$361

Oyster bags are plastic mesh bags that are filled with loose oyster shells. Each bag is approximately 10 inches in diameter and weighs 10 lbs on average. Oyster bags are used instead of rip rap to reduce the energy of water currents and also to provide habitat and a growing medium for living oysters. The living oysters in time provide water filtration and natural cementation and structural integrity to the embankment. Native plants are used at the top of the bank to further reduce erosion and provide habitat and water filtration. Granite Type 1 Rip Rap is used on the bottom portion of the bank for additional stability.

Concrete Bulkhead - 200LF

Mobilization	1	LS	7500	7500
Precast Concrete Sheetpile	1	LS	60000	60000
Concrete Pile Cap	15	CY	500	7500
Tie Backs	10	EA	1500	15000
Weephole Drains/Gravel	10	EA	500	5000
Fabric	1	LS	600	600
Type 1 Rip Rap(Toe Protection)	100	TN	70	7000
Labor	300	HR	120	36000
Equipment	1	LS	20000	20000
Fuel	1	LS	5000	5000
Subtotal				163600
Company Overhead				24540
Estimated Company Return				16360
Total				204500
	Cost/LF		$1,023	

Vinyl Bulkhead - 200LF

Mobilization	1	LS	4500	4500
Vinyl Sheetpile	1	LS	26000	26000
Timber Pile Cap	1	LS	3000	3000
Tie Backs	10	EA	1500	15000
Weephole Drains/Gravel	10	EA	500	5000
Fabric	1	LS	600	600
Labor	240	HR	120	28800
Type 1 Rip Rap(Toe Protection)	100	TN	70	7000
Equipment	1	LS	15000	15000
Fuel	1	LS	4500	4500
Misc	1	LS		5000
Subtotal				114400
Company Overhead				11440
Estimated Company Return				11440
Total				137280
	Cost/LF		$686	

Rip Rap Type 3 w/ Type 1 Toe - 200LF w/ 18' slope

Mobilization	1	LS	5000	5000
Rip Rap (embankment)(18")	350	TN	65	22750
Rip Rap (toe)	100	TN	70	7000
Equipment	1	LS	6500	6500
Labor	200	HR	120	24000
Tiebacks		EA	1500	0
Filter Fabric	1	LS	1200	1200
Fuel	1	LS	4500	4500
Subtotal				70950
Company Overhead				10643
Estimated Company Return				7095
Total				88688
	Cost/LF		$443	

Living Shoreline - 200 LF

Mobilization	1	LS	4500	4500
Oyster Shell	350	TN	60	21000
Prep and Grade	1	LS	1500	1500
Anchors	10	EA	150	1500
Geotech	1	LS	1200	1200
Labor	120	HR	120	14400
Recycled Concrete Toe	100	TN	65	6500
Equipment	1	LS	5000	5000
Fuel	1	LS	4500	4500
Subtotal				60100
Company Overhead				6010
Estimated Company Return				6010
Total				72120
	Cost/LF		$361	

Maintain, Repair, Replace Costs

BULKHEADS
ROCK REVETMENTS
HARD DEFENSES GENERAL
LIVING SHORELINES

Bulkheads

Little St Simon's Island Bulkhead Repair

2013 Quoted (with other work): $5134

Length = 37.5'

2016 Estimate (without other work): $7600-$8600

Length = 37.5 LF

LF Price: $202 - $229

Bulkheads

How much does Bulkhead construction cost?

Depending on the local construction market and bulkhead design requirements, repairs may cost $100-$400 per linear foot of wall. Bulkhead replacement may cost $500-$1,000 per linear foot.

Collapsed Bulkheads will drive the Installation Cost of a new bulkhead up 20% or more.

Coastal Systems International

Bulkhead Summary
Coastal Systems International, Inc.

To repair or replace a bulkhead: that is the question

Rock Revetment

2016 Repair Estimate :

LF Price: $100 - $250

Hard Defenses

- Maintenance costs are another significant and ongoing expense when a hard defense is selected. These costs are ongoing for the life of the structure and are therefore likely to result in significant levels of investment through a project's lifetime. Continued investment in maintenance is highly recommended to ensure defenses continue to provide design levels of protection (Linham et al., 2010).
- It has been noted that construction and maintenance costs are likely to increase into the future in response to SLR (Burgess & Townend, 2004; Townend & Burgess, 2004). This is caused by increases in water depth in front of the structure which, in turn cause increased wave heights and wave loadings on the structure.
  - TNA Guidebook Series - Coastal Erosion and Flooding

Living Shorelines

- Hanging Anchors
- Stability
- Foundation
- Ease of Repair
- Holistic Support
- Next presentation

Life-Cycle, External Costs

TRADITIONAL IMPACTS
SHORELINE INTEGRITY
ECOLOGY
SUMMARY OF MARSH VALUE
COST EVALUATION OF MARSH VALUE
LIVING SHORELINE IMPACTS
SHORELINE INTEGRITY
ECOLOGY

Traditional Impacts on Shoreline Integrity

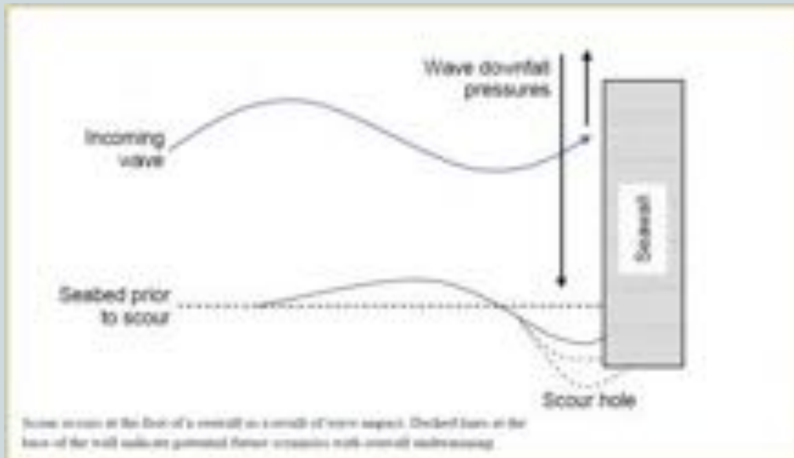


Figure 2: Schematic cross-section illustrating seawall scour (Source: Linham and Nicholls, 2010)

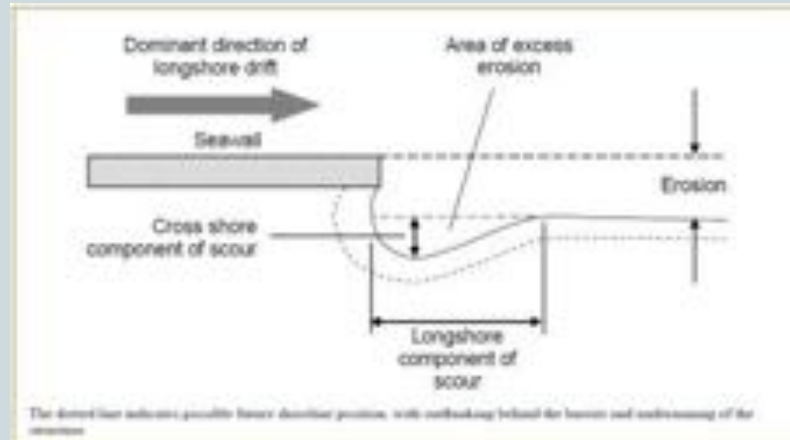


Figure 3: A seawall as viewed from above, showing typical end effects associated with the structure (Source: Adapted from McDougal et al., 1987)

•Smooth, vertical seawalls are the least effective at dissipating wave energy; instead, the structures reflect wave energy seawards. Reflection creates turbulence, capable of suspending sediments (Bush et al., 2004)

•Scour at the foot of a seawall is a particular problem with vertical seawall designs. As a result, seawall maintenance costs can be high (Pilarczyk, 1990a).

•Although seawalls prevent erosion of protected shorelines, where the seawall ends, the coast remains free to respond to natural conditions. This means that undefended areas adjacent to the wall could move inland causing a stepped appearance to the coast (French, 2001). This flanking effect can cause undermining and instability of the wall in extreme cases.

Linham and Nicholls (2010).

Traditional Impacts on Ecology

- Loss of Marsh
- 132 miles of shoreline impacted by shoreline stabilization in GA 2004-2010 (Alexander, 2010)
- 34,000 acres of marsh impacted in four coastal counties in GA

Marsh Benefits

- Provision of nursery habitat for commercially and recreationally important species of shellfish and other wildlife
- Control and dissemination of pollutants
- Detention of surface waters and coastal storm surges
- Maintenance of moderated stream flow
- Transformation of nutrients
- Sequestration of carbon
- Retention of sediment and other particulates
- Provision of essential fisheries and aquatic invertebrate habitat
- Provision of waterfowl and water-bird and other wildlife habitat
  - National Wetlands Inventory and Landscape Level Functional Assessment
- Provision of aesthetic and recreational value

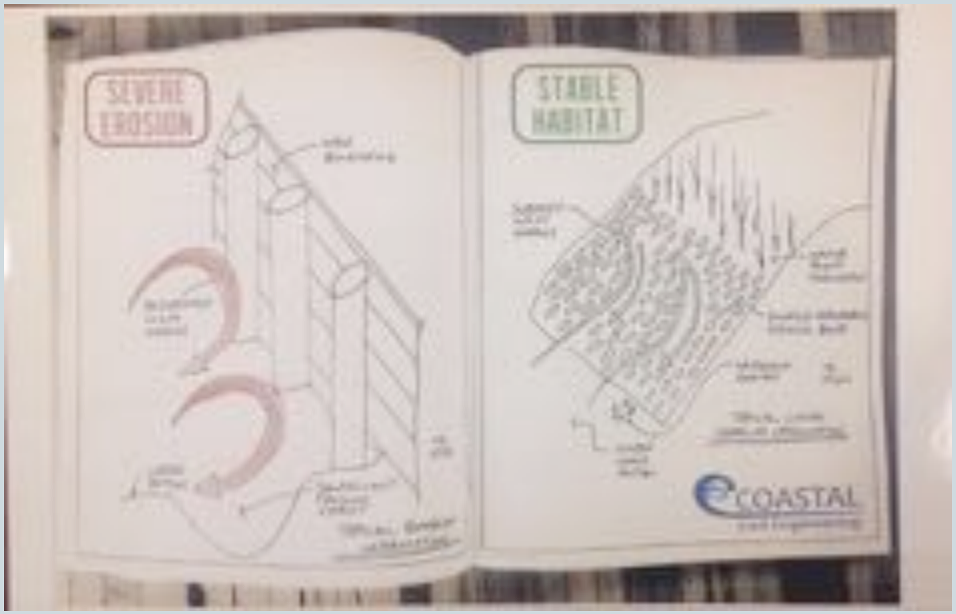
Cost - Benefit

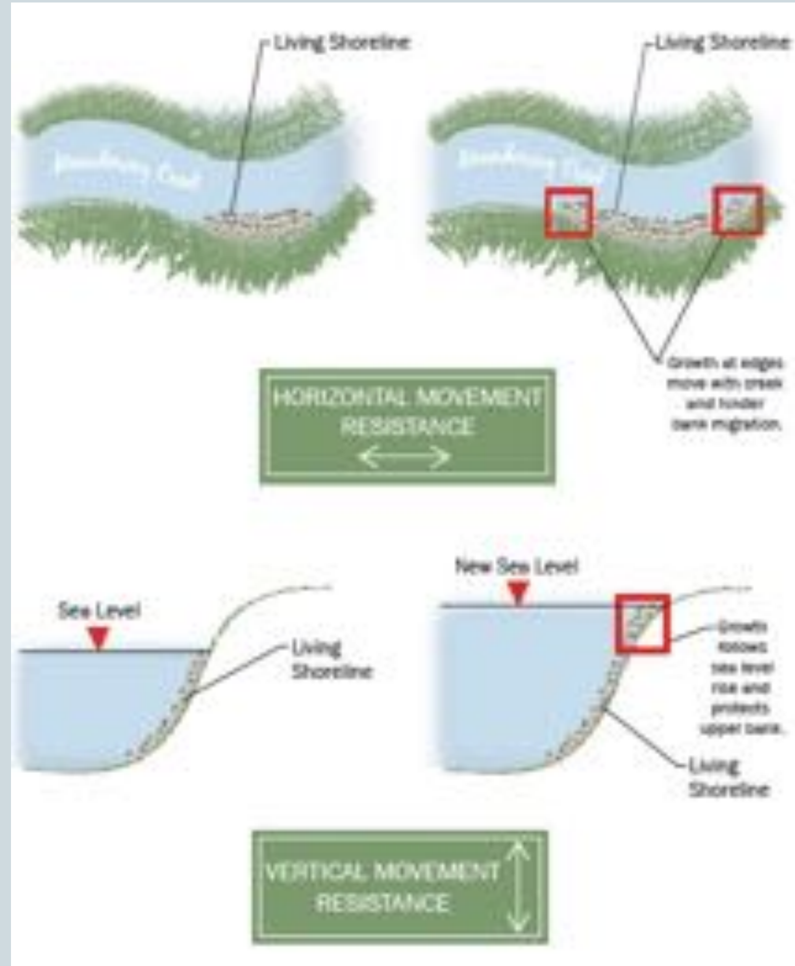
- Provision of nursery habitat for commercially and recreationally important species of shellfish and other wildlife
  - 66% of shrimp and 25% of crab in Gulf of Mexico (Zimmerman et al 2000)
  - $6471 per acre per year of sport fishing in FL (Barbier et al 2011)
- Provision of aesthetic and recreational value
  - $1.9 billion generated in Georgia coastal region by tourism annually (GDITT)
  - 87% of outdoor recreation income comes does not come from hunting or fishing (Landers, 2006, Pg 1)
  - Real Estate
  - $67 million to National Audubon and $521 million to Nature Conservancy
- Control and dissemination of pollutants
  - Heavy metal removal up to 65% (Birch 2004)
  - Each oyster filters up to 30 gallons of water each day and provides up to $10,000 of filtration per acre per year
- Transformation of nutrients
  - $10,000-$15,000 per acre (Grabowski 2012, Barbier et al 2011)
  - N removal from 80%-98% (Zhang 2011)

Cost - Benefit

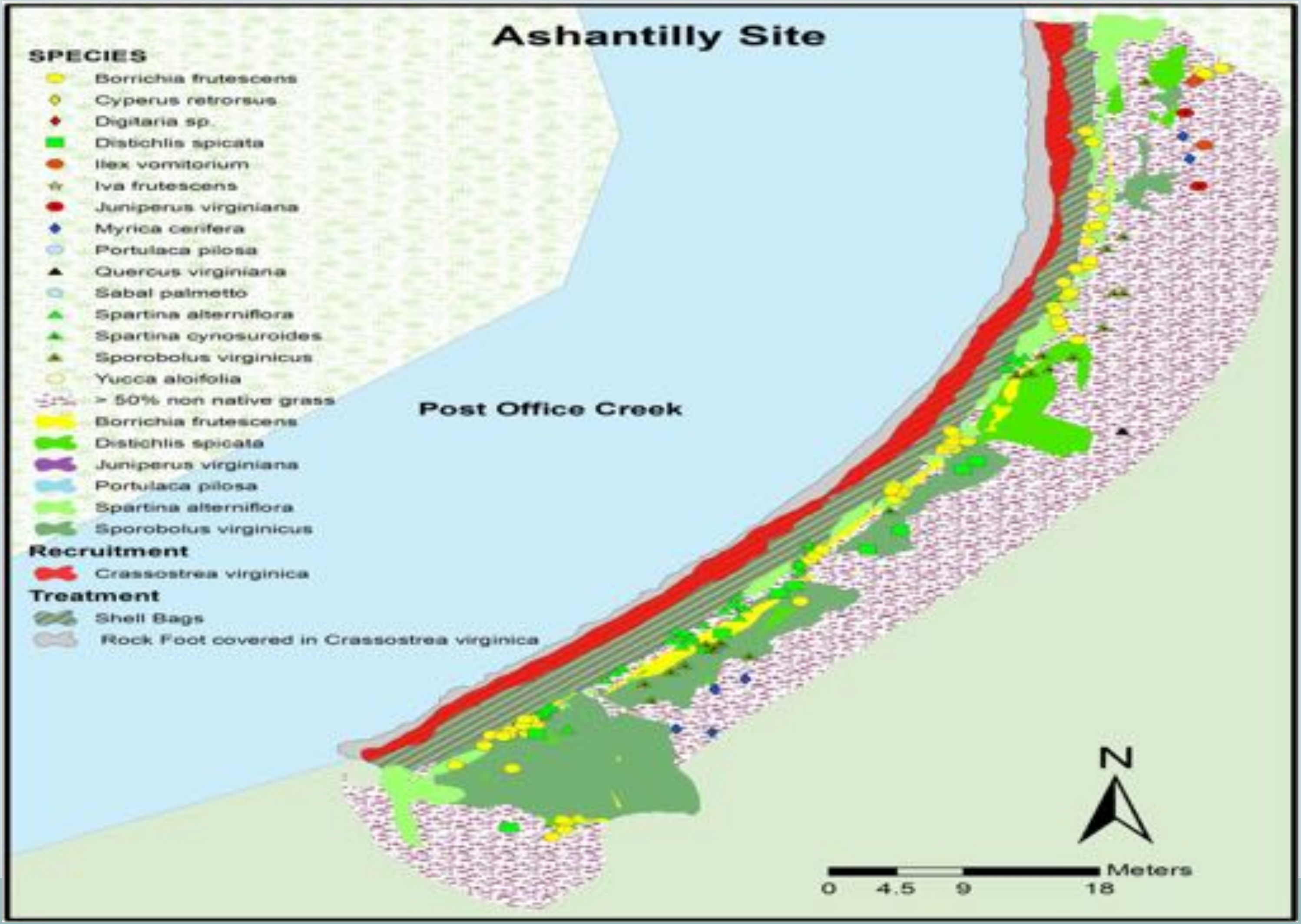
- Maintenance of moderated stream flow
  - Flow velocities reduced in proportion to abundance of wetlands (Wharton 1970)
  - Reduce storm surge duration and height (Barbier at el 2011)
- Detention of surface waters and coastal storm surges
  - Reduce hurricane damages by $8236 per acre (Costanza et al 2008)
- Retention of sediment and other particulates
  - Highest when plants have long stems (koch et al 2006)
  - Friction and baffeling (Morgan et al 2009)
- Sequestration of carbon
  - 50 times more than rainforests (Pidgeon, 2009) and 20 times more than southern Pine per acre per year (Odum, 1961; Gohltz et al 1982)
  - Up to $29 per ton on global market, Up to 707 tons per acre (Patrick and DeLaune 1990) = $20,500/acre/year.

LS Impacts on Shoreline Integrity





LS Impact on Ecology



Results

Preliminary results at LSSI site include a 100% increase in finfish species diversity within the LS area after only 6 months of completion **(Table 1, Figure 7)**. Notably, the capture of two juvenile individuals within the demersal (bottom dwelling) species of concern stocks (Dogtooth Snapper *Lutjanus jocu;* snapper-grouper complex) were within the post-construction fish assemblage. Post-construction survival of planted vegetation approached 95% at six months with losses attributed to deer browsing. Significant increases in both bay anchovies **(Table 1)** and grass shrimp (Bliss et al., 2014) were noted after construction of the Living Shoreline. Oyster recruitment (cementation) onto the shoreline across all tidal zones achieved densities between 44-108/m^2 by the end of the first season of available spat recruitment (April- October, 2013). Slight erosion of upland soils occurred directly following construction due a combination of the instability of soils (large grained sands) and the lack of extensive root development by the newly planted (and volunteer) vegetation.

[illegible]	[illegible]	[illegible]
[illegible]	1119	1714
[illegible]	0	4
[illegible]	8	2
[illegible]	0	1
[illegible]	0	2
[illegible]	0	33
[illegible]	0	3
[illegible]	0	9
[illegible]	0	1
[illegible]	6	8
[illegible]	15	1
[illegible]	0	1
[illegible]	4	1
[illegible]	0	2
[illegible]	3	8
[illegible]	2	8
[illegible]	10	2
[illegible]	1	1
[illegible]	17	8
[illegible]	0	1

Table 1. Metrics for finfish species diversity and abundance pre- and post- construction at the LSSI site.

Figure 7. Pictorial display of the finfish diversity captured through-out the first two sample seasons (pre- and post - construction) at the LSSI site. These photos represent, in all cases the adult phase of each species.

Sapelo Island

Sapelo Island

Little St Simon's Island

Before

After

Canons Point – St Simons

LS Impact on Ecology

“Living shorelines are crucial to habitat development and to the conservation of fish, birds and other wildlife. We must continue to promote these kinds of restoration activities as they are vital to sustaining the delicate ecological system."

-Tom Kelsch, Director of Conservation Programs for the National Fish and Wildlife Foundation.

"Living shorelines provide erosion protection benefits and essential habitat for living resources .”

-Keith Campbell, Foundation for the Environment

Costs Summary

Type	Unit	Installed Cost	Projected Lifespan	Repair Cost	Replace Cost	External Functions	External Cost/Benefit
Vinyl Bulkhead	LF	**$686**	50+	$100-400	120%	Bank Integrity	Loss
						Habitat	
Wooden Bulkhead	LF	**$652**	20+	$100-400	120%	Fisheries	Loss
						Shellfish	
Concrete Bulkhead	LF	**$1,022**	30+	$100-500	120%	Pollution Control	Loss
						Storm Abatement	
Granite Revetment Type 1	LF	**$469**	20+	$100-200	120%	Carbon Sink	Loss
						Nutrient Fix	
						Sediment Retention	
Ganite Revetment Type 3	LF	**$440**	20+	$100-200	120%	Aesthetic	Loss
						Recreation	
						Real Estate	
Living Shoreline	LF	**$361**	Indefinite			Wildlife	Gain

Compounding Costs vs Compounding Gains

vs