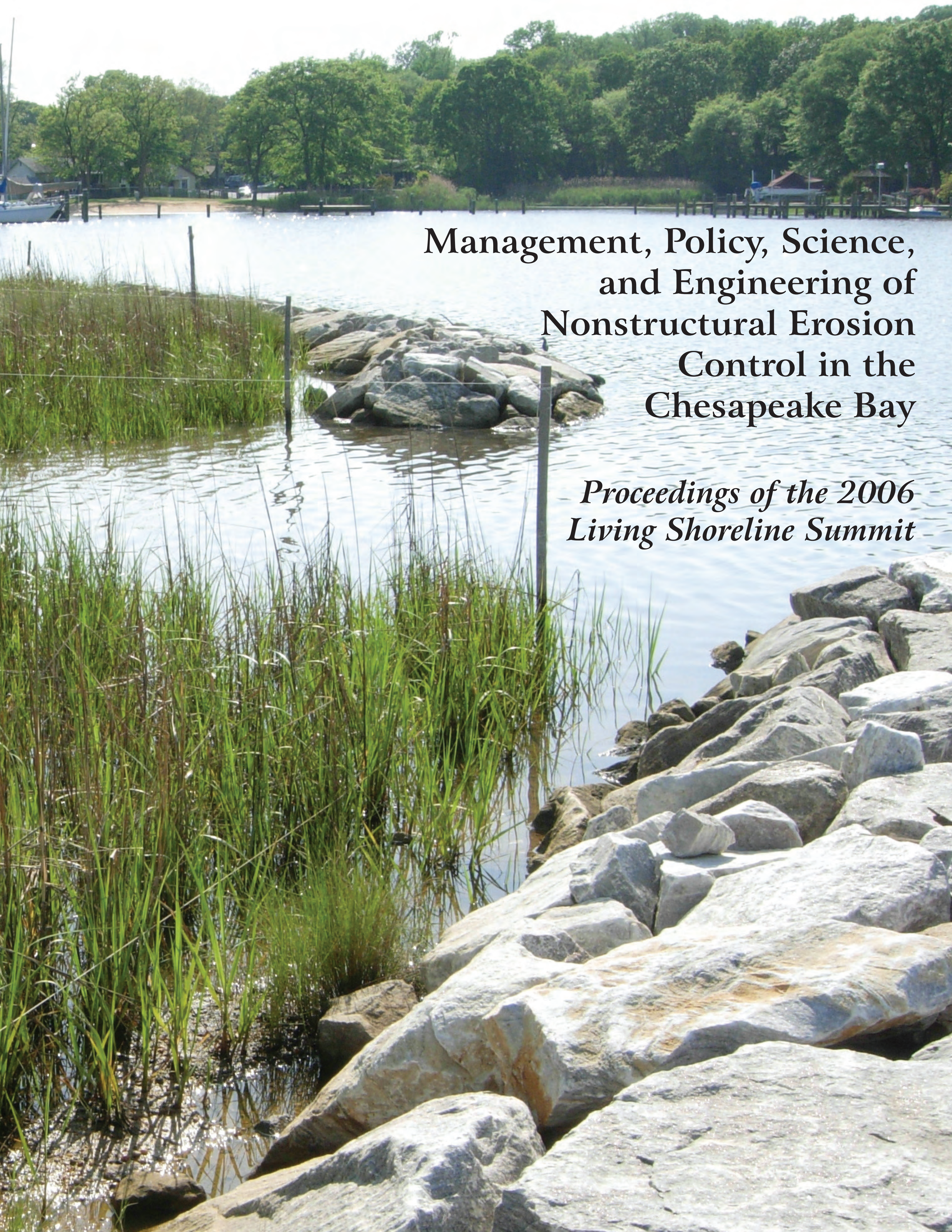
Management, Policy, Science, and Engineering of Nonstructural Erosion Control in the Chesapeake Bay

Proceedings of the 2006 Living Shoreline Summit



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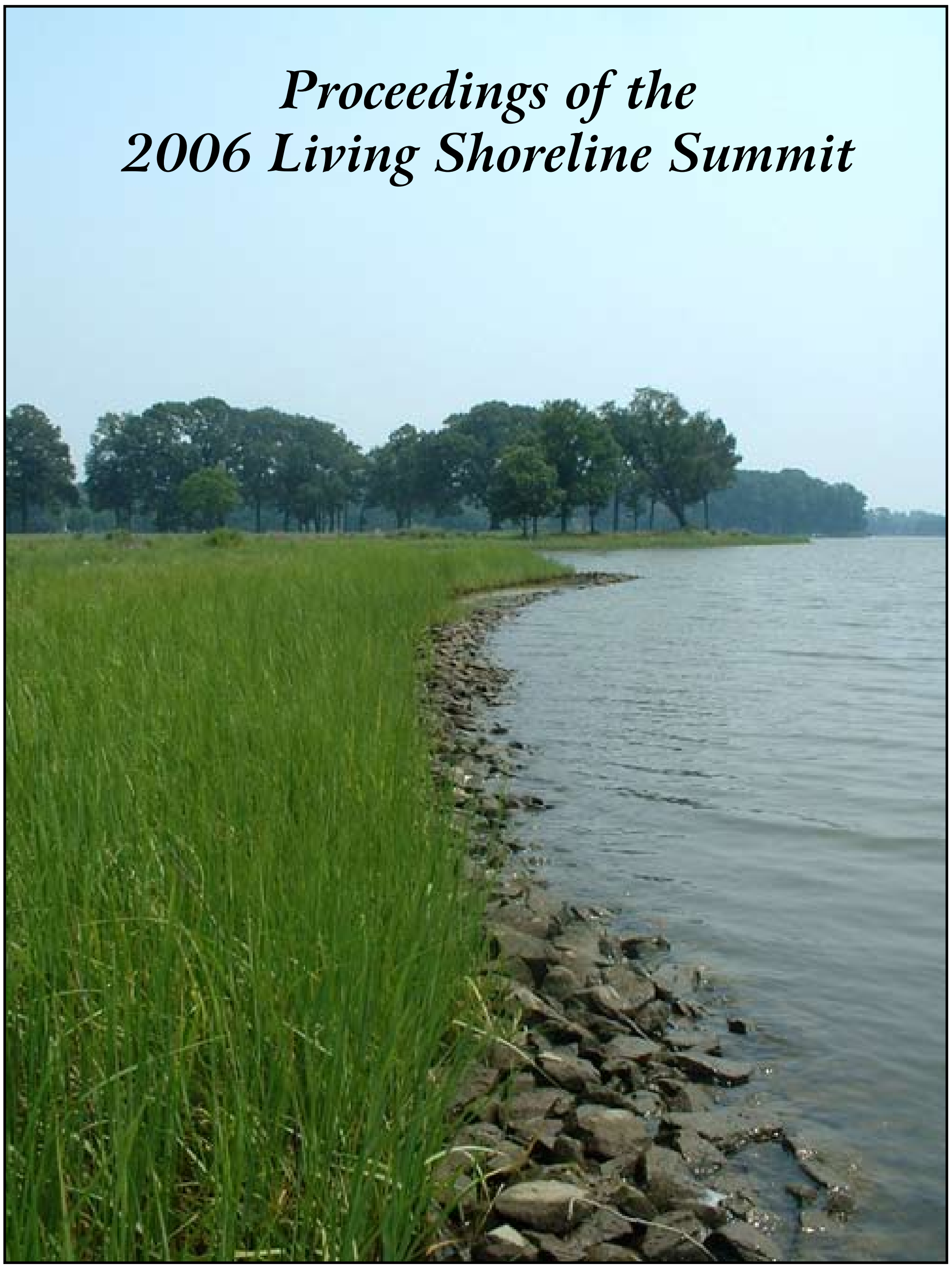

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Management, Policy, Science, and Engineering of Nonstructural Erosion Control in the Chespeake Bay

Proceedings of the 2006 Living Shoreline Summit

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Funding for the Living Shoreline Summit and proceedings was provided through grants from a number of organizations, and the editors and Steering Committee are extremely grateful to: Chesapeake Bay National Estuarine Research Reserve in Maryland, Chesapeake Bay National Estuarine Research Reserve in Virginia, Chesapeake Bay Trust, Chesapeake Research Consortium, Keith Campbell Foundation for the Environment, NOAA Chesapeake Bay Office, NOAA Chesapeake Bay Restoration Center, Virginia Coastal Zone Management Program, Virginia Department of Conservation and Recreation, and Virginia Institute of Marine Science.

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Table of Contents

Preface

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Shorelines of all estuaries erode over time, in part a natural process and in part a process exacerbated by human activity. In the Chesapeake Bay, for example, one third of all shorelines are classified as eroding, some areas losing as much as 20-40 cm of shoreline per year (1). At the same time, estuarine areas support a disproportionately large human population that relies on the resources of these sheltered coasts for shipping, fisheries, recreation, transportation, and other uses. For example, 60% of Virginia's population lives in the 22% of the state that falls within its Coastal Zone. Nationwide, 51% of the U.S. population lives in coastal counties, which account for only 13% of the nation's continental area and income per square kilometer in coastal counties is more than eight times that of inland counties (2). As a result of this human reliance on and use of estuarine systems, estuarine erosion has become a problem that requires solutions.

Residents and users of estuarine and open coastal shorelines have, over the past several centuries, worked hard to protect their shorelines from erosion. The methods traditionally employed have focused on structural shoreline armor, such as riprap revetments, bulkheads, and seawalls. In some areas, more than half of the shoreline has been armored. For example, the shoreline of Barnegat Bay in New Jersey is 71% developed, with 45% in bulkhead alone (3). San Diego Bay is 74% armored, providing habitat for open-coast hard substrate species in a traditionally soft-substrate estuary (4). Some sub-watersheds of the Chesapeake Bay are also more than 50% armored (5). Hundreds of miles of Chesapeake Bay shoreline have been armored in Virginia and Maryland since the 1970s (6, 7).

Armor replaces shoreline vegetation, reducing water filtration and habitat functions. These structures, especially bulkheads and seawalls, also steepen shorelines, reducing or removing altogether valuable shallow-water nursery and refuge habitat for many estuarine species. According to the 2006 National Academies report, *Mitigating Shore Erosion along Sheltered Coasts*, the cumulative ecological, water quality, and erosion-control impacts of such armoring have only recently begun to be documented (8). However, impacts of these structures on flora and fauna are beginning to emerge (e.g., 9, 10).

As a result of differences between hard armor and natural shoreline qualitatively observed as early as several decades ago, techniques for incorporating natural habitat elements into shoreline stabilization techniques have been developed as an alternative to hard armor. Restoration scientists in the Chesapeake Bay region have served as initiators of these efforts, coining the phrase "Living Shoreline." This phrase has been defined as shoreline stabilization methods that employ as many natural habitat elements as appropriate for site conditions to protect shorelines from erosion. These natural habitat elements can include emergent marsh grasses, submerged aquatic vegetation, riparian vegetation, coarse woody debris, and oyster reef and shell, and they are hypothesized to provide better habitat and water quality functions, while serving similar, if not better, shoreline protection functions.

The purpose of the Living Shoreline Summit was to investigate the state of the science of living shorelines, identify areas in which additional information is necessary, and investigate paths to increasing implementation of living shorelines as an alternative to hard shoreline armor, where appropriate. The Summit was intended for many audiences, including marine contractors, regulators, policy-makers, scientists, homeowners, marine engineers, consultants, and members of nonprofit groups.

As populations continue to grow along shorelines nationwide and in the Chesapeake Bay, and as sea level continues to rise worldwide, the need for shoreline stabilization will only increase. By 2015, coastal population in the U.S. is expected to increase to 165 million, up 21 million people from 1990 and up 58 million from 1970. An average of 3,600 people move to coastal counties each day (11). The Chesapeake Bay region will experience an even faster rate of growth, with the 16-million person watershed becoming the home to several million additional residents by 2020 (12).

In addition, as we learn more about the Chesapeake Bay and sources of nutrient and sediment pollution, shoreline stabilization will likely become an important area in which sediment reductions can be achieved; currently, it is estimated that 57% of the sediment in the Bay comes from eroding shorelines (13). Though this sediment source may be more 'natural' than other sources (such as sediment input from development or agricultural activities), shoreline stabilization may contribute at least in part to the overall solution for reducing coastal sediments to the tidal Bay.

The goal of the information contained in these Proceedings is to encourage use of shoreline stabilization methods that serve habitat, water quality, and erosion control functions. Papers focus on the design of living shorelines and criteria to consider, evaluation of the functions of living shorelines, regulatory processes and suggested ways to improve them, landowner decision-making processes and ways to incentivize living shorelines, and finally next steps in promoting living shoreline implementation in areas that are conducive to the techniques.

This information is intended for a wide range of audiences. The shoreline community will rely on its scientists and engineers to take the next steps to fill in information gaps on design and function, on its contractors to use this new information to market living shorelines to their clients, on its policy-makers and managers to use the information in decision-making, and on its property-owners to make informed choices for their land as 85% of the Chesapeake Bay shoreline is privately owned (14). It is the goal of Living Shoreline Summit participants that the recommendations on next steps serve to accelerate progress on investigation and implementation of nonstructural shoreline protection techniques.

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Changes in Maryland Living Shorelines Policy

Just prior to final publication of the Proceedings of the Living Shoreline Summit, the Maryland General Assembly passed, and Governor Martin O'Malley signed, the Living Shoreline Protection Act of 2008 (House Bill 973, introduced by Delegate M. McIntosh for the Maryland Department of Environment). This new law defines living shorelines as the "preferred method of shore protection," and finds that shoreline protection practices should consist of nonstructural methods wherever technologically and ecologically appropriate.

Specifically, the new law amends the Annotated Code of Maryland's Environmental Article (Section 16-201) to require property owners to use nonstructural shoreline stabilization measures that "preserve the natural environment, such as marsh creation," where feasible. Areas deemed not feasible for living shorelines include those subjected to excessive erosion (greater than two feet per year, which characterizes about 10% of the Chesapeake Bay shoreline), are subjected to heavy tides, and areas too narrow for living shorelines. Property owners who believe that living shorelines are not appropriate must demonstrate to the Maryland Department of Natural Resources lack of feasibility of this approach through a waiver process. The Living Shoreline Protection Act of 2008 goes into effect October 1, 2008.

Prior to the enactment of this new law, tidal wetland regulations outlined an order of preference for shore erosion control measures as follows:

1) no action and relocation of structure,
2) nonstructural shoreline stabilization, including beach nourishment and marsh creation,
3) revetments, groins, and breakwaters designed to promote viability of nonstructural stabilization projects,
4) revetments,
5) breakwaters,
6) groins, and
7) bulkheads.

The new living shoreline law was driven in part by a recommendation by the Maryland Commission on Climate Change in January 2008 and in part by the advances in living shoreline science. This new law is similar to policy in Kent County, Maryland (see Luscher et al., this volume), and in North Carolina (see the North Carolina Living Shorelines Law, House Bill 1028, passed in 2003).

Text of the new Maryland law can be found at:
http://mlis.state.md.us/2008rs/chapters_noln/Ch_304_hb0973E.pdf

Introduction

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The National Academies Report On *Mitigating Shore Erosion Along Sheltered Coasts*

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ABSTRACT

Property owners often install structures that harden the shoreline as a way to prevent land loss from erosion or sea level rise. These structures cause changes in the coastal environment that alter landscapes, reduce public access and recreational opportunities, diminish natural habitats, and harm species that depend on these habitats for shelter and food. On sheltered, lower energy coastal areas, erosion often can be managed using nonstructural alternatives such as vegetated, graded bluffs and planted fringing marshes. The National Research Council Committee on *Mitigating Shore Erosion along Sheltered Coasts* concluded that a regional management approach is needed to assess the costs, benefits, and cumulative impacts of structural approaches and to encourage erosion control alternatives that help retain the natural features of coastal shorelines.

INTRODUCTION

Throughout the coastal regions of the world there are a significant number of areas that are partially or fully protected from the high-energy regimes associated with open coastlines, such as ocean-facing beaches. These sheltered coastlines include environments such as estuaries, bays, lagoons, mud flats, and deltaic coasts that may be generally characterized as lower energy systems. Many of the processes that govern erosion and deposition on the open coast also apply to sheltered coasts, but generally at significantly reduced scales. Also, unlike the typically long linear features associated with open coasts, sheltered coasts exhibit characteristics that are distinctively more compartmentalized with discrete areas of the coast encompassing a variety of geomorphic types and biological resources. Typical physical conditions associated with sheltered coasts include relatively low velocity tidal currents and mid-to-low energy wave climates associated with a limited fetch (distance from shore to shore). These conditions promote the formation of ecological complexes (i.e., mangroves, marshes, and mudflats) that are generally not found along open coasts.

Landowners frequently respond to the threat of erosion by armoring the shoreline with bulkheads, revetments, or other structures. Although the armoring of a few properties has little impact, the proliferation of structures along a shoreline can inadvertently change coastal environments and ecosystems. Managers and decision makers have been challenged to balance the trade-offs between protection of property and potential loss of landscapes, public access, recreational opportunities, natural habitats, and reduced populations of fish and other marine species that depend on these habitats.

At the request of the U.S. Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACE), and the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), the National Research Council (NRC) of The National Academies conducted a study examining the impacts of shoreline management on sheltered coastal environments and evaluating strategies to minimize potential negative impacts to adjacent or nearby coastal resources. The report (1), released in October 2006, is summarized in this paper.

Study Design

The NRC committee met three times during the course of the study. The first meeting, held in Washington, DC, in June 2005, provided the committee with an opportunity to discuss the background and study expectations with the sponsors. In addition, the committee developed plans for a workshop that was subsequently held in Seattle, WA, in October 2005. The purpose of the workshop was to provide the committee with additional background information, largely focused on an analysis of options available to mitigate erosion of sheltered coasts. In planning this activity, the committee decided not to limit the discussion to marine or estuarine areas, but to include experts from the Great Lakes. The workshop explored the geomorphic settings of sheltered coasts and the strategies used to address land loss from erosion and sea level rise. The workshop brought together approximately 32 professionals with diverse expertise in state and federal regulatory matters, science, engineering, land use planning, and legal issues. The participants came from around the continental U.S. and provided expertise on the range of erosion problems and strategies for managing erosion in a variety of coastal regions.

The committee's report identifies four broad categories of options to address erosion on sheltered coasts:

1. Land use regulation and management;
2. Vegetative stabilization;
3. Hardened structures (armoring the shoreline); and
4. Trapping or adding sediment.

These options are described in the context of the physical environment, ecosystem services and values, and the various regulatory, engineering, esthetic, and financial considerations that contribute to the decision-making process for mitigating erosion.

DISCUSSION AND CONCLUSIONS

Sheltered Coasts and Erosion

Sheltered coasts typically face smaller, shallower water bodies and have more varied shore morphologies than open coasts. In part, this is due to lower ambient wave energy. Lower energy conditions foster habitats and ecological communities, such as marshes and mud flats, typically not found on open coasts. The unique characteristics of sheltered coasts affect the potential technological approaches and the consequences of actions taken to stem erosion and land loss from sea level rise.

Erosion is caused by various natural processes including winds, waves, currents, and tides that transport shoreline sediment; and weathering processes that destabilize landforms such as bluffs and cliffs. The erosion rate may be accelerated by human activities such as construction of dams upstream of estuaries or installation of groins and seawalls that alter the magnitude and direction of sediment transport. Other human activities that increase erosion include dredge and fill operations, wetland drainage, boat traffic, and channel dredging. Sea level rise will exacerbate the loss of waterfront property and increase vulnerability to inundation hazards. It changes the location of the coastline, moving it landward and exposing new areas and landforms to erosion. Additionally, sea level rise is chronic and progressive, requiring a response that is correspondingly progressive.

Current Approaches to Protecting Against Erosion

The pressure to develop and stabilize shorelines in sheltered coastal areas is increasing because coastal populations are growing. More people desire waterfront homes and coastal property values have risen. There are several types of strategies taken to stabilize shorelines. The most common response is a "hold the line" approach that hardens the shoreline with structures such as bulkheads and revetments. Mobile Bay, Alabama, experienced a dramatic increase in the amount of shoreline armoring, from 8 percent in 1955 to 30 percent in 1997, corresponding to the rate of population growth in the area (2). Of greater concern than the amount or rate of armoring was the associated loss of intertidal habitat, roughly estimated at 4 to 8 hectares (approx. 10 to 20 acres), corresponding to about 10 km of intertidal beach shoreline.

There are alternatives to bulkheads, such as constructed marsh fringes, that are designed to preserve more natural shorelines while still reducing erosion. The selection of the type of response to prevent or offset land loss depends on understanding local causes of erosion or inundation. The NRC report discusses four categories of commonly used techniques to address erosion: (a) manage land use, (b) vegetate, (c) trap or add sand, and (d) harden. These are briefly summarized below.

Manage Land Use

Land use control and land management techniques transfer much of the responsibility for shoreline management from the individual to the community. Interest in and success of this option will depend on local customs which may range from support for individual property rights to enforcement of community standards through strict building codes. The long-term and cumulative benefits of managing land use include: maintenance of ecological integrity (less habitat loss and habitat fragmentation); reduced coastal infrastructure and development; higher water quality; retention of recreational access to the waterfront; higher overall property values; and reduced loss of private property.

Vegetate

Vegetation can be used to stabilize the shore zone and upland banks or bluffs. This strategy is often referred to as a “living shoreline” and is offered as an alternative to hardening techniques. On shorelines fronted by beaches and mudflats, native grasses can be planted into the tidal and supratidal substrate. These techniques work best in areas with a low fetch, where marshes and grasses may have been found in the past. Where the fetch is greater, sand fill, with or without a sill, may be required to attenuate wave energy. In Chesapeake Bay, over 300 marsh fringes have been constructed with an impressive record of performance over 15-30 years for erosion control and wetland habitat creation (3).

Trap or Add Sand

Creating, restoring, or maintaining a beach is often an attractive option for landowners. Trapping or adding sand or gravel provides effective shore protection. To trap sand, structures are installed either parallel (breakwaters) or perpendicular (groins) to the shoreline. Groins reduce the volume of sand that would otherwise be deposited to areas downstream, in some cases leading to erosion of the neighboring beaches. Beach nourishment replenishes sand lost to erosion and protects the adjacent upland from storm wave impacts. Periodic maintenance is usually required and quality sand may be difficult and expensive to obtain. Also, addition of sand displaces the existing intertidal community, changing the habitat to beach and dune.

Harden

The most widely applied shoreline technique is to harden the shoreface by installing a bulkhead, seawall, or revetment. The primary goal of hardening is to protect the coast from wave attack by creating a barrier. On an eroding shoreline, hard structures such as bulkheads increase wave reflection and scour, often causing a decrease in the width of the nearshore environment and an increase in water depth. These processes can contribute to erosion on flanking shores, often causing a domino effect of hardening down the shoreline. As more and more of the shore becomes hardened, the impacts become greater. The cumulative impacts of hardening include permanent removal of sand from the littoral system, loss of intertidal zones, and loss of intertidal and beach habitats.

A shift away from hardening has been slow, in part because there is a greater familiarity with these methods than with alternative approaches such as constructing a marsh fringe or using vegetation to stabilize a bluff. Contractors are more likely to recommend structures such as bulkheads because they have experience with the technology and know the design specifications and expected performance. Landowners often assume that a hard, barrier-type structure will be required to prevent loss of property and protect buildings. In many regions, government regulations may unintentionally encourage shoreline armoring because it is simpler and faster to obtain the required permit(s). However, there are indirect costs associated with mitigation options that armor the shoreline. Many of these costs are borne by the public rather than the landowner.

For example, installation of a groin to trap sand can affect neighboring beaches, while a bulkhead built on an eroding beach will eventually become the shore edge, replacing the beach that provided public access and scenic amenities. Construction on a marshy shoreline can lead to the loss of this highly diverse and productive habitat and the attendant loss of ecosystem services—nursery areas for important fish stocks, removal of excess nutrients from land runoff, feeding areas for migratory birds, and sediment stabilization.

A New Shoreline Management Framework

Changing the current practice of armoring sheltered coasts will require a change in the shoreline management framework. Decision makers should appreciate the costs and benefits of the spectrum of potential solutions to shoreline erosion problems, including potential cumulative impacts on shoreline features, habitats, and other amenities. The management framework should encourage approaches that minimize habitat loss and enhance natural habitats in environments where such methods offer effective stabilization. Overcoming the obstacles associated with the current regulatory environment will require a number of societal and institutional changes in the following areas:

- Improving knowledge of sheltered shoreline processes and ecological services;
- Improving awareness of the choices available for erosion mitigation;
- Considering cumulative consequences of erosion mitigation approaches;
- Revising the permitting system; and
- Improving shoreline management planning.

Conclusions

Until the government regulatory framework addresses sediment transport processes at a regional scale, stabilization of individual sites will often include structures that damage adjacent areas and create a domino effect of coastal armoring. Currently there is no national mandate to document erosion processes on sheltered coasts or develop regional scale plans. Hence, implementation of a regional plan will require a new commitment for coordination among local, state, and federal programs. This might include a regional general permit for projects consistent with the applicable regional plan. The report recommends development of a new shoreline management framework to help decision makers evaluate the spectrum of available approaches to shoreline erosion problems in the context of the environmental setting. The new framework would include assessment of the physical and ecological properties of the shoreline and the potential cumulative impacts.

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Living Shoreline Design

Photo credit: Karen Duhring, VIMS

Integrating Habitat and Shoreline Dynamics Into Living Shoreline Applications

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ABSTRACT

The installation of successful living shoreline projects will consider the ecological importance of the biological and physical processes in maintaining healthy ecosystems along the shoreline. The enhancement of habitat along the shoreline and in the nearshore area in mid to high energy environments often requires the incorporation of structural (generally rock) components. The level of habitat improvement is typically dependent on the maintenance of biologic and physical processes and the appropriate integration of structural components.

INTRODUCTION

Protecting shorelines from erosion is a well-studied science and societies have been employing different methods of shore erosion protection for centuries. In the United States, the Army Corps of Engineers and other organizations have been actively studying different shoreline protection methods for decades. There is substantial information available on the effectiveness of bulkheads and revetments and other highly structural methods in controlling erosion collected by groups such as the U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory in Vicksburg, the Virginia Institute of Marine Science, and the Surfrider Foundation. When it comes to protecting shorelines from the erosive forces of wind, wave, and tide, there is sufficient knowledge to assure fairly consistent success in limiting impacts.

There are other options now, with considerable interest in Living Shorelines. The use of "Living Shoreline" techniques is an evolving science. There has not been as much study of the different techniques involved in the living shoreline approach in contrast to armored shoreline techniques. Nor has there been much development of guidance to the types of approaches that work best within different ecological settings. Therefore, as we move forward to determine what techniques most effectively reduce erosion and provide habitat, we need to also consider how these techniques fit into and work with the natural environment where they will be constructed.

It is important to emphasize that most shoreline property owners are primarily concerned about shore erosion. Contractors and others who provide consultation on shoreline matters are typically only asked to visit a shoreline when there is an erosion "problem." In many cases, there is no "problem" at all. For the most part, erosion is a natural process and one that is critical to the ecological health of estuarine areas, providing sediment for new habitat, creating new habitat in eroded shores, and if not accelerated through anthropogenic activity, useful in transporting accumulated nutrients and organisms downstream. However, erosion is certainly considered a problem by shoreline property owners who may be losing large areas of property to wave and tidal energies.

Hence, the erosion issue is a critical part in developing a living shoreline project. As a relatively new approach, living shorelines need property owner acceptance and even a few failures can severely impede adoption by other owners for a fledgling erosion strategy. Many owners are skeptical of living shoreline practices and may only be interested if they see that these methods work elsewhere; only then will the methods be employed.

There are many different concepts that define a living shorelines approach. The definition used in this presentation is the following: Living shorelines is a concept based on an understanding and appreciation of the dynamic and inherent ecological value that our natural shorelines provide. Living shoreline projects apply these natural principles in the design and construction of shorelines in order to enhance habitat and maintain shoreline processes.

The important aspects of this definition are: dynamic, function, habitat, and processes. Dynamic implies variable and changing; function is aggregated in inherent ecological value, that includes wave-sediment-flora-fauna interactions at the shore and offshore and downstream of the eroding area; habitat includes the water-land interface (sediment size, water exchange, flora and faunal interactions) that permit use of the shore by a suite of bay plants and animals; and processes refers to the hydrology, chemistry, and biotic activities that typify this fluid water-land interface. These are the principles that need to be integrated into the development of living shoreline projects if they are to control erosion and function as sustainable living shorelines.

SITE-SPECIFIC APPROACHES

Integrating these concepts into shoreline protection projects in low energy wave environments can normally be accomplished without much difficulty. However, developing living shoreline solutions for eroding shorelines in medium and high energy wave environments can be a much more difficult task.

Certain shore erosion strategies will require a higher level of protection than others. Using large rocks can provide a very high level of protection against certain wave climates and specific storm events. Very reliable design structures that are practical in some instances to withstand explicit storm occurrences have been developed; the engineering principles for these are well known and well-tested. However, integrating other variables such as habitat enhancement into these applications may lead to less effective erosion control for these established engineered systems, with the net effect that the established engineering principles become less reliable. Therefore, developing living shoreline approaches in medium and high energy wave environments can be a balancing act of maintaining a certain level of protection while, at the same time, providing for viable habitat and continuation of natural land-water exchange and processes.

LIVING SHORELINE SUBSTRATES

Rock, other natural materials, and fibers are often used in living shoreline projects. Rock can be placed in specific locations and oriented to the winds and waves to dampen wave energies and allow for the maintenance or development of marsh and beach features. In many living shoreline projects, rock is often placed offshore as breakwaters or sills to create marsh or beach between the existing shore and the added rock. This combination of rock and marsh in higher energy wave environments (or other biotic considerations) is often referred to as a "hybrid" design. Sills of rock placed parallel to the shore to dampen wave energy can be an effective hybrid approach. Marsh or beach is typically created landward of the sill structure, creating habitat for Bay flora and fauna. However, if not designed and installed correctly, shoreward marsh (and its habitat value) may not develop and the beach may still erode.

The use of gaps, also called windows or tidal gates, in sills have been hypothesized to be effective in providing for habitat and maintenance of shoreline processes if designed and installed correctly. The sill breaks enhance tidal flushing and connectivity and should be maximized, though to date no quantify gate effectiveness studies have been done. If exchange is not facilitated, the areas landward of the sill may become 'dead' zones for aquatic species that cannot exit as the tide ebbs. Appropriate window locations and sizes should be governed by the suite of aquatic organisms likely to utilize the area as well as wind, wave, and tidal conditions specific to each site. More work to establish specific guidance based on ecological and engineering needs is needed in window design.

The skill in designing and building functional living shorelines often has to do with determining the fine line between adequate structural placements (e.g., rock, reefs, sills) balanced with desired habitat area.

Living shorelines may not provide the same level of erosion protection as other more structural practices. However, living shoreline techniques should provide for mobility of shoreline and nearshore sediments which may cause seasonal changes to shoreline configuration. As a result, there may be more of a marsh area or beach in one time of the year than another. The systems are dynamic by nature and appropriate living shoreline applications will act as part of the natural system, not against it. Stability in these living shorelines should be viewed much like the ebb and flood of tides or as a seasonal progression of sedimentary processes and accompanying habitat forms.

LIVING SHORELINES AND PROPERTY OWNER OBJECTIVES

Those opting for Living Shoreline approaches to reducing erosion and enhancing habitat must consider several factors such as:

1. What does the owner hope to achieve; and
2. What is the owner willing to do to get it? Or, phrased another way, how much effort is the owner willing to put into the shoreline?

Effort typically equates to time or money. Highly structural applications can be very successful in stopping immediate, non-event erosion but can also have a similarly high cost. On the other hand, living shoreline approaches may not stop erosion altogether, but, if successful, will reduce erosion to an acceptable degree, enhance habitat, and may be substantially less expensive that high armored endeavors.

As living shoreline methods continue to evolve, guidance needs to be developed that defines when and where specific applications are most effective and applicable and how they can best be constructed to provide environmental benefits.

Overview of Living Shoreline Design Options for Erosion Protection on Tidal Shorelines

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ABSTRACT

The term "living shoreline" was recently associated with particular types of shoreline stabilization methods that emphasize the use of natural habitat features such as deeply rooted riparian vegetation, vegetated wetlands, and sand beaches. This overview of living shoreline design options for tidal tributaries describes six nonstructural and four "hybrid" or structural methods for erosion protection. Structures are included with living shoreline design options to make habitat restoration or creation possible without substantial impacts to tidal exchange or habitat functions. The use and effectiveness of other methods not included in this summary are still under investigation, such as oyster shell reefs and pre-cast concrete structures.

INTRODUCTION

Erosion Protection Methods

There are a variety of erosion control methods for tidal shorelines of the Chesapeake Bay depending on the expected wave climate of a particular shoreline location. The term "shoreline armoring" refers to the practice of installing protective structures such as bulkheads and rock revetments. Erosion protection is the primary purpose for these structures and the permanent loss of natural shoreline habitats tends to be unavoidable where they are installed (1).

Nonstructural methods will stabilize bank erosion and restore wetland habitat in protected, low energy settings. Natural erosion buffers are integral, such as riparian buffers with deeply rooted vegetation, wide tidal marshes, and sand beaches. Successfully using planted tidal marshes and other nonstructural techniques depends on the shoreline location and wave climate (2,3). The fetch or distance across open water should be short, the erosion trend moderate, and the water depth near the shoreline should be shallow (4). Plenty of sunlight and existing marshes in the general vicinity also indicate suitable growing conditions for vegetative treatments.

"Hybrid" designs combine advantages of both nonstructural and structural methods. The strategic placement of structures makes restoration or creation of natural erosion buffers possible. In addition to erosion protection, this provides water quality and habitat benefits usually displaced by extensive shoreline armoring (1,5).

What is a "Living Shoreline" Method?

The term "living shoreline" is associated with options in the nonstructural and hybrid categories of stabilization methods. This approach advocates the restoration and enhancement of natural habitat features that are increasingly needed in developed watersheds (1,6). If functioning riparian buffer and tidal wetland habitats can be sustained instead of replaced by stabilization projects, they will reduce non-point source pollution by filtering ground and surface water runoff and trapping sediment.

Various agencies and organizations have their own working definitions of living shoreline methods to advocate their use (6-8). This concept was previously referred to as the "natural," "soft," or "nonstructural" approach. Common themes in these definitions include strategies for managing shoreline erosion while also preserving and improving valuable ecosystem services, such as providing habitat for terrestrial and aquatic species and maintaining water quality.

Another shared concept is integrating three distinct yet ecologically connected shoreline habitats - the riparian buffer, tidal wetland, and subtidal area. There is also a consistent reference to gradual slopes to provide optimal growing conditions for vegetation. The strategic placement of structures and other materials such as sand fill and wetland plants should only minimally disrupt normal coastal processes, such as tidal exchange and sediment transport.

Guidelines are available for non-tidal stream bank stabilization using similar methods, but these design options are not readily transferred to estuarine settings (9). The same principles for enhancing natural erosion buffers still apply, but different applications and design specifications are needed to include estuarine habitats. Living shoreline treatments for tidal tributaries must also be able to withstand tidal currents, wind, and wave climates not present in non-tidal settings.

METHODS

The following description of living shoreline design options for tidal shorelines includes six nonstructural and four "hybrid" methods commonly used in the Chesapeake Bay region (Table 1). Each description includes the primary design features and the most suitable site characteristics where it can be applied effectively. This information was compiled from existing descriptions and findings from recent studies.

Nonstructural	Hybrid
Riparian vegetation management	Marsh toe revetment
Beach nourishment & dune restoration	Marsh sill
Tidal marsh enhancement	Marsh with groins
Tidal marsh creation	Offshore breakwater system
Bank grading	
Fiber logs	

Table 1. *Living shoreline design options are divided into nonstructural and "hybrid" methods that include structures to support habitat restoration or creation.*

RESULTS

Nonstructural Design Options

Riparian Vegetation Management

Activities to enhance the density or species diversity of stabilizing bank vegetation are referred to collectively as riparian vegetation management. These actions include trimming tree branches overhanging a marsh to increase sunlight, selectively choosing desirable plants for natural regeneration, or planting additional landscape material to increase cover or diversity. Using vegetation buffers to intercept stormwater runoff from developed areas and controlling invasive species that degrade habitat quality and stabilization effectiveness are also included. Most tidal shorelines are suitable for some type of riparian vegetation management and enhancement activities.

Beach Nourishment and Dune Restoration

Beach nourishment is the addition of sand to a beach to raise its elevation and increase its width to enhance its ability to buffer the upland from wave action. Dune restoration is the process of reshaping and stabilizing a dune with appropriate plants usually after a beach nourishment event. Common plant species for Chesapeake Bay beaches and dunes include *Ammophila breviligulata*, *Panicum amarum,* and *Spartina patens*.

These actions are best suited for gently sloping, sandy beach shorelines with low erosion. Beach and bank erosion may still occur during storms. Periodic replenishment is usually needed to maintain the desired beach profile. This method may not provide sufficient protection where no beach currently exists or where tidal currents and wave action remove sand rapidly.

Tidal Marsh Enhancement

Tidal marsh enhancement includes adding new marsh plants to barren or sparsely vegetated marsh areas. Sand fill can be added to a marsh surface to maintain its position in the tide range or to increase its width for more protection. Replacing marsh plants washed out during storms also fits into this category. Less mowing of wetland vegetation can also enhance the stabilizing and habitat features of a tidal marsh.

Shorelines with existing marshes or where marshes are known to have occurred in the recent past may be suitable for this treatment. Water depth and the amount of sunlight available are key factors to consider. A wide, gently sloping intertidal area with minimal wave action also indicates suitability.

Tidal Marsh Creation

Tidal marsh creation can be applied where a natural marsh does not exist. Non-vegetated intertidal areas can be converted to a tidal marsh by planting on the existing substrate. Because a wide marsh is needed for effective stabilization, this method normally requires either grading the riparian area landward or filling channelward into the subtidal area for a wider intertidal zone. The plant species will depend on the local salinity range plus the depth and duration of tidal flooding. Two common tidal marsh grasses used for this purpose are *Spartina alterniflora* and *S. patens*.

The most suitable shorelines for tidal marsh creation have wide, gradual slopes from the upland bank to the subtidal waters, a sandy substrate without anaerobic conditions, and plenty of sunlight. Extensive tree removal in the riparian buffer just to create suitable growing conditions for a tidal marsh should be avoided, especially if the forested bank is relatively stable. Salt marsh plants have a limited tolerance for wave action (10). The wave climate and the frequency and size of boat wakes must also be considered (2,10).

Bank Grading

Bank grading is a land disturbance activity that physically alters the slope of a shoreline segment, particularly shorelines with near vertical slopes. A dense cover of deeply rooted vegetation on the graded bank acts as a buffer for upland runoff and groundwater seepage. Stabilization in the wave strike zone can be provided with dense vegetation on the lower portion of the graded bank. Bank grading can also be combined with planted tidal marshes and beach nourishment.

Low eroding banks with only partial or no vegetative cover are particularly suited for bank grading. Confining layers in the bank material and the transition to adjacent shorelines may dictate the extent of possible grading. Surface and groundwater management measures may be needed.

Fiber Logs

Fiber logs are also known as coir logs or biologs. These biodegradable logs come in a variety of sizes and grades for different applications. They must be aggressively staked into place to prevent them from being lifted and moved by tidal currents and wave action. Fiber logs are particularly useful to temporarily contain sand fill and reduce wave action at planted marsh sites (Fig. 1).

Fiber logs decay in five years or less. They may need to be replaced if the planted marsh does not stabilize before the logs break down. They have also been placed along undercut banks where excessive shading prevents the growth of marsh vegetation. The effectiveness of using fiber logs to reduce the undercutting effect of tidal currents and boat wakes is still under investigation, but it is assumed that they must be inspected regularly and replaced periodically.

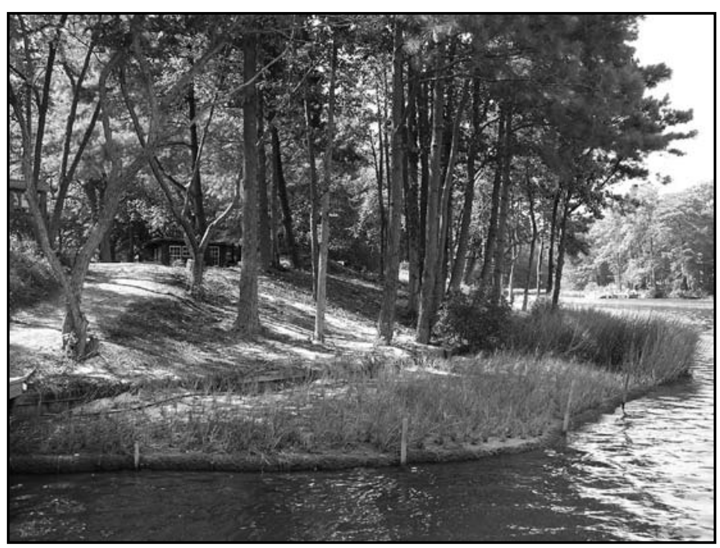

Figure 1. *Fiber logs provide temporary soil containment and protection for planted marshes until the root system becomes established.*

Hybrid Design Options

Marsh Toe Revetment

Marsh toe revetments are low profile structures placed at the eroding edge of an existing tidal marsh. This approach is also known as marsh edge stabilization. They are typically constructed with quarry stone. If the structure height will exceed the mean high water elevation due to the expected wave height or the target shoreline requires a long continuous structure, then gaps may be needed to facilitate tidal exchange. The most suitable sites for this treatment have existing tidal marshes wide enough to provide upland erosion protection but with an eroding edge and a trend for landward retreat.

Marsh Sill

Marsh sills are a similar type of low stone structure, but they are used where no existing marsh is present. Sills are usually located near the low tide line, then backfilled with clean sand to create a suitable elevation and slope for planted tidal marsh vegetation (Fig. 2). Like marsh toe revetments, the height of the sill should be near the mean high water elevation to minimize interruption of tidal exchange.

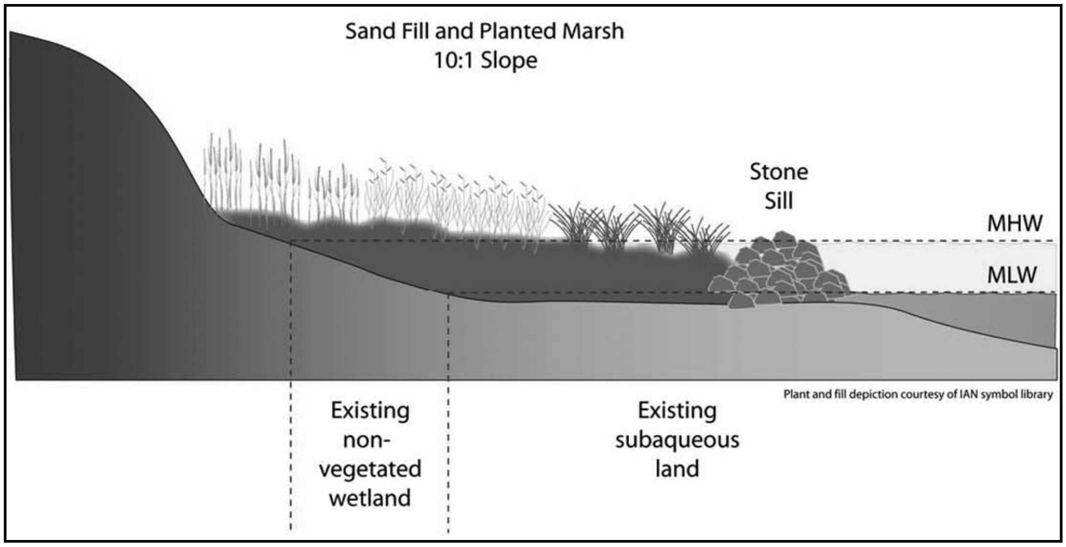

Figure 2. *A typical cross-section for a marsh sill with sand fill and planted tidal marsh vegetation. Marsh toe revetments are similar structures adjacent to natural tidal marshes.*

Eroding banks without a tidal marsh present are candidate sites for marsh sills, particularly if marshes exist in the general vicinity. However, the physical alterations needed to create suitable planting elevations and growing conditions should not require major disturbance to desirable shoreline habitats, such as mature forested riparian buffers or valuable shallow water habitats (e.g., shellfish beds, submerged aquatic vegetation). If bank grading is appropriate to create target slopes, then the bank material can possibly be used to backfill a marsh sill if it is mostly coarse-grained sand. Sand fill can also be imported from an upland source.

Marsh with Groins

Using short stone groins to support a planted marsh is a similar approach to a marsh sill, except these structures are placed perpendicular rather than parallel to the shoreline. The groins can be used to contain sand fill within the project site. This method is suitable for lower energy shorelines where erosion of the unprotected marsh edge is expected to be minimal, while sills can be used where direct wave action and boat wakes need to be reduced. However, the potential effects on sediment transport and downdrift shorelines need to be considered.

Offshore Breakwater System

An offshore breakwater system is a series of freestanding trapezoidal structures strategically positioned offshore to create a stable beach profile with embayments. Even though they tend to be large and costly projects, offshore breakwater systems are commonly included as a living shoreline approach because they include a dynamic, natural beach feature in the design. Non-vegetated beach areas within breakwater systems also provide habitat for terrestrial and aquatic wildlife, including shorebirds, turtles, terrapins, and the northeastern beach tiger beetle. Oysters, mussels, algae, and other reef-dwelling organisms may colonize the shallow water structures.

Suitable sites for offshore breakwater systems are medium and high-energy sand beaches, banks, and bluffs without adequate sand for erosion protection and an historic trend for landward retreat. Like groins, offshore breakwater systems can interrupt longshore sediment transport and adversely affect downdrift shorelines. Beach nourishment and stabilizing beach and tidal marsh vegetation are usually included rather than allowing for natural accretion of sand.

DISCUSSION

This brief summary includes methods for erosion protection and habitat restoration collectively referred to as the "living shoreline" approach for tidal shorelines. If shoreline erosion must be stabilized, then choosing the least intrusive yet effective method is the main objective. Nonstructural methods that emphasize the use of dense riparian and wetland vegetation can be applied to many low energy shorelines with minimal wave action or boat wakes. They can also be combined with hybrid methods, such as a marsh sill combined with bank grading and a planted marsh.

The hybrid types of living shoreline design options have several characteristics in common. The structures should be necessary to support habitat enhancement, restoration, or creation. Important coastal processes are also minimally disrupted by properly designed hybrid projects, particularly tidal exchange and sediment transport. Effective hybrid projects provide enough protection without the need for erosion control structures at the riparian-wetland habitat interface if possible. This allows for the landward retreat of tidal marshes and sand beaches in response to rising sea levels. Connections between riparian and wetland habitats can enhance bank stability in the wave strike zone while also providing wildlife habitat value with food, cover, and vegetated corridors.

Some methods were not included in this summary of living shoreline design options because they are not widely practiced and their effectiveness is still under investigation. Oyster shell reefs can be designed to mimic marsh toe revetments or marsh sills, but it is not clear if uncontained oyster shell is sufficiently resistant to wave action and tidal currents. The placement of oyster shell adjacent to existing or planted marshes to support native oyster restoration efforts is most likely suitable even with limited erosion protection benefits.

Pre-cast concrete structures in various shapes have also been deployed in intertidal and subtidal areas to provide wave dissipation as well as habitat for shellfish and other reef dwellers. "Living walls" for steep bank stabilization is another method commonly applied to upland slopes, but only recently installed on tidal shorelines in Virginia. This engineered system of support structures with planted vegetation is intended to provide stabilization without extensive land disturbance and bank grading.

Selecting the most appropriate erosion protection method depends on the level of protection that is desired. Nonstructural and hybrid methods may not provide enough protection in some circumstances. Rock revetments and other defensive structures may be more suitable than a living shoreline approach where upland improvements are at significant risk (e.g., buildings, roads, utilities, septic drain fields, etc.), or where it is necessary to protect public health and safety. Limited construction access for installation and maintenance may also limit possible alternatives.

Depending on the level of protection that is needed, nonstructural and hybrid methods may not always be easier, less costly, or require less maintenance than rock revetments and bulkheads. While this may be the case with tidal marsh enhancement and creation projects, professional design and engineering assistance is usually required. Local knowledge or predictions of tide range, predominant wind direction, and wave height are required for effective designs. The amount of sand fill needed for sills, groins, and breakwater systems has to be accurately calculated to prevent adverse downdrift effects. Predicting how banks should be graded to achieve stable slopes and determining if the bank material is suitable for backfill also requires professional expertise.

Wider acceptance of the living shoreline approach with its inherent limitations could shift the current trend for shoreline armoring, particularly in very low energy settings. The guiding principles presented here can assist with the selection of possible alternatives, but site-specific design considerations are also required. Contacting local, state, and federal regulatory agencies for permit requirements is also advisable before any shoreline work is performed.

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Recommending Appropriate Shoreline Stabilization Methods for Different Estuarine Shoreline Types in North Carolina

Bonnie Bendell and The North Carolina Biological and Physical Processes Work Group

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ABSTRACT

Estuarine shorelines are dynamic features that experience continued erosion by short and long term processes. As coastal populations encroach on estuarine shorelines, coastal states have begun to formulate new management strategies for estuarine shoreline erosion. These strategies try to strike a balance between the need to provide property owners with options to protect their investments from coastal hazards and the need to maintain the integrity of the natural system. The North Carolina Division of Coastal Management (NCDCM) concluded that more research and discussion was needed between managers and researchers to effectively address and understand the impact of shoreline stabilization methods on the habitats and productivity of estuarine systems. The NCDCM formed the Estuarine Biological and Physical Processes Work Group to develop recommendations for appropriate shoreline stabilization methods for different shoreline types. The Work Group relied on prior research and best scientific judgment in developing recommendations. The Work Group evaluated the ecological functions and values of the different North Carolina shoreline types and the habitat changes due to the physical impacts associated with each shoreline stabilization method. The recommendations of shoreline stabilization methods are based upon the Work Group's goal of maintaining the current shoreline type and continuation of the current ecological functions and values. The final report has been submitted to the NC Coastal Resources Commission Estuarine Shoreline Stabilization Subcommittee to help guide the development of new estuarine shoreline stabilization rules.

INTRODUCTION

Estuarine shorelines are dynamic features that experience continued erosion. Land is lost by short-term processes, such as erosion by storms, boat wakes, and tidal currents occurring within the long-term process of rising sea level. Rising sea level by itself does not cause loss of land; rather it changes the relationship between sea level and land elevation, and is effective in moving the shoreline only where land elevations are quite low. As coastal populations encroach on estuarine shorelines, coastal states have begun to formulate new policies and management strategies to address estuarine shoreline erosion. These strategies try to strike a balance between the need to provide property owners with options to protect their investments from coastal hazards and the need to maintain the integrity of the natural system. Various estuarine shoreline-armoring strategies have been examined by coastal states, culminating in the revision of new estuarine shoreline stabilization permitting guidelines.

To protect coastal property, North Carolina has permitted homeowners to armor the waterward boundary of their property with vertical and sloped structures such as bulkheads and revetments. These methods are effective, but due to the shoreline-type-specific habitats and structure impacts, it is becoming apparent that some stabilization methods are not necessarily appropriate for all shoreline types. The North Carolina Division of Coastal Management (NCDCM) concluded that more research and discussion was needed to more fully address and understand the impact of shoreline stabilization methods on the habitats and productivity of estuarine systems. This conclusion was the main motivation for the formation of the Estuarine Biological and Physical Processes Work Group.

The Work Group is a science-based panel specifically charged with the task of developing recommendations for an existing array of shoreline stabilization methods for different shoreline types. The members were selected based on research experience and knowledge of the estuarine system. The Work Group relied on prior research and best scientific judgment in developing recommendations. Beyond classification and measurement of shoreline recession rates, there has been little research that applies directly to shoreline stabilization methods in North Carolina. The final report includes recommendations that take into account the dynamic nature of the estuarine system and consider the benefits and impacts of shoreline stabilization methods on the biological communities and physical processes. The Estuarine Biological and Physical Processes Work Group Members consisted of:

- Dr. Mark Brinson, East Carolina University, Wetland Ecology/Sea Level Rise
- Dr. Martin Posey, University of North Carolina at Wilmington, Benthic Ecology
- Tracy Skrabal, North Carolina Coastal Federation, Coastal Erosion
- Spencer Rogers, North Carolina Sea Grant, Erosion Control
- Dr. Stanley Riggs, East Carolina University, Geology and Estuarine Physical Processes
- Anne Deaton, North Carolina Division of Marine Fisheries, Fisheries Biology
- David Moye, North Carolina Division of Coastal Management, Rules and Permitting Practices
- Bonnie Divito, North Carolina Division of Coastal Management, Coastal Engineer and Work Group Coordinator

MATERIALS AND METHODS

North Carolina Estuarine Shoreline Types

Shorelines are highly variable in the estuarine system and range from gently sloping land colonized by hydrophytic vegetation to steeply incised cliffs composed of older sedimentary and rock material (1). The waterline (line of intersection on the land) is not constant and changes due to astronomical and wind tides, creating a shore zone.

The Work Group found that the estuarine shoreline is composed of a diverse array of shoreline types, ranging from organic and sediment bank shorelines to combination shorelines. Combination shorelines, which are a composite of two or more shoreline types, are representative of most of the estuarine shorelines in North Carolina. This diversity in shoreline types led the Work Group to conclude that a “one rule fits all” strategy is not appropriate. The Work Group decided to approach discussions of impacts/benefits through a list of representative shoreline types according to the classification scheme developed by Riggs (1,2). Using Riggs’ shoreline classification as a guide, eleven shorelines were determined to exist in North Carolina:

- Swamp Forest
- Marsh
- Marsh with Oysters
- Marsh with Mud Flats
- Low Sediment Bank with Marsh
- Low Sediment Bank with Swamp Forest
- Low Sediment Bank with Oysters/SAV (submerged aquatic vegetation)
- Low Sediment Bank with Woody Debris
- Low Sediment Bank with Sand
- High Sediment Bank
- Overwash Barrier/Inlet Areas

Shoreline Stabilization Methods

Below is a list of the shoreline stabilization methods (3) and their main purposes considered by the Work Group. Each of the methods can be constructed using an array of possible materials. Each structure's main purpose and specific design varies slightly for different geographic regions.

- Land Planning – development projects that incorporate existing or future erosion without the use of any stabilization structure in the development plans.
- Vegetation Control – the use of wetland vegetation plantings to control erosion and dissipate wave energy.
- Beach Fill – placing sand on the shoreline to act as a sacrificial erosive barrier.
- Sill – a coast-parallel rock or sheet pile structure that is designed to protect existing or newly planted wetland vegetation.
- Groin – a coast-perpendicular structure designed to trap sand carried by long shore transport either built singly or in a series.
- Breakwater – a coast-parallel structure that is designed to trap sand and to attenuate wave energy.
- Sloped Structure – a shore-parallel, watertight, or porous structure constructed against a bank to protect the bank from erosion. A sloped structure may also be placed at the toe of wetland vegetation, waterward of the vegetation, for protection against erosion.
- Vertical Structure – a seawall or bulkhead designed to prevent overtopping, flooding, or sliding of the land.

Ecological Assessment

Each unique shoreline type differs somewhat in the beneficial ecological functions that it provides. To assist in the evaluation of the impacts/benefits of the implementation of shoreline management options to the shoreline's ecological functions, a functional assessment of each shoreline type was completed. This exercise provided a baseline for understanding the importance of individual shoreline types to the estuarine system. Given that a list of functions was not available specifically for estuarine shorelines, the Work Group drew on the functions of riverine wetlands (4) as a starting point for the list. The definitions were modified to apply to estuarine shorelines and shore zones of North Carolina.

The resulting matrix (Table 1) was scored using three discrete values. The three values were minimal (0), moderate (1), or exceptional (2) functional importance to the estuarine ecosystems. It should be recognized that scores only reflect natural functions and do not imply ecologically superior or inferior conditions. Conditions altered by human activities are treated as physical impacts and were evaluated in the physical assessment. To create the matrix, the Work Group applied best scientific judgment and research experience without specific reference to the published research literature.

Physical Assessment

The physical impact assessment is intended to demonstrate likely results of modifying and altering natural shorelines and shore zones. The Work Group constructed a table (Table 2) based on scientific judgment and research experience, consisting of the impacts of the different shoreline stabilization structures. This process helped lead to a ranking of the severity of impacts relative to the condition of maintaining the natural shoreline types.

RESULTS AND DISCUSSION

The following rankings (Table 3) are based upon the Work Group's stated goals of 1) maintaining the current shoreline type and 2) continuation of current ecological functions and values. Based on these

Shoreline Types	Hydrologic Functions				Biogeochemical Functions			Plant and Animal Community Functions					
	Surface Water Storage	Storm Buffer/ Energy Dissipation	Filtration of Particulates/ Baffling	Groundwater Storage	Nutrient Retention/ Cycling	Biotic Productivity (in situ)	Detrital Export/ Retention	Biodiversity/ Community Structure	Habitat Structure/ Refuge	Filtering (active)	Foraging/ Nursery	Habitat Diversity/ Connectivity	Unique Habitat
High Sediment Bank	0	2	0	2	1	0	0	0	0	0	1	1	2
Swamp Forest	2	2	2	0	2	2	2	2	2	1	2	2	0
Marsh	2	2	2	0	2	2	2	2	2	2	2	2	0
Marsh with Oysters	2	2	2	0	2	2	2	2	2	2	2	2	0
Low Sediment Bank with Swamp	2	2	2	0	2	2	2	2	2	1	2	2	0
Low Sediment Bank with Marsh	2	2	2	0	2	2	2	2	2	1	2	2	0
Low Sediment Bank with Oyster/SAV	0	1	1/2	0	2	2	2	2	2	2	2	2	0
Low Sediment Bank with Woody Debris	0	1	1	0	1	1	1	2	2	0	2	2	0
Low Sediment Bank with Sand	0	1	0	0	1	1	0	1	0	0	1	1	0
Marsh with Mudflats	0	1	1	0	2	2	1	2	1	1	2	1	0
Overwash Barrier/Inlet Areas	0	1	0	0	1	1	0	1	0	0	1	1	2

Table 1. *Functions of natural shoreline types: (0)=minimal, (1)=moderate, and (2)=exceptional functional importance to estuarine ecosystems.*

criteria, the lists of stabilization measures for each shoreline type represent a ranking of options, from the option with the least potential adverse impact to the existing system (ranking of 1), to the option with the greatest potential adverse impact. Since rankings could vary for specific sites or were equal in adverse impacts, some stabilization methods are listed on the same ranking level.

CONCLUSIONS

The recommendations for each of the shoreline types are different with a few consistent similarities. The number one recommendation for all estuarine shoreline types is land planning (i.e., planning or developing the property around current or possible future erosion of the shoreline). The second recommendation is typically vegetation control as a natural and environmentally beneficial stabilization method. Beach fill is usually the third recommended action because of its nonstructural, non-hardening features, but only when it maintains the current shoreline type. Generally speaking, when shoreline-hardening stabilization methods are proposed, the Work Group ranks sills as the most preferred option. In North Carolina, sills are small structures that are always constructed to support wetland plantings, or the conservation of existing wetland vegetation. Groins, breakwaters, sloped structures, and vertical structures vary in ranking and were determined to be shoreline-type and site specific. On some shoreline types, groins,

Land Planning	Vegetation Control	Beachfill	Sill	Groin	Breakwater	Sloped Structure	Vertical Structure
Continued erosion with loss of upland	Reduces sediment and nutrient input	Changes from sandy bottom to upland	Reduces sediment and nutri-ent input	Reduces sediment and nutrient input	Reduces sediment and nutrient input	Reduces sediment and nutrient input	Reduces sediment and nutrient input
	Reduces erosion landward	Reduces erosion landward	Reduces erosion landward	Reduces local erosion landward	Reduces erosion landward	Reduces erosion landward	Reduces erosion landward
		Possible change in sediment size distri-bution	Creates hard struc-ture for non-mobile marine life	Creates hard struc-ture for non-mobile marine life	Creates hard structure for non-mobile marine life	Creates hard struc-ture for non-mobile marine life	Creates hard structure for non-mobile marine life
		Buries local shoreline type with sand	Fill result-ing in wetland or upland	Sand trap or fill results in wetland or upland	Sand trap or fill results in wetland or upland	Possible loss of inter-tidal habitat or environ-ment	Possible loss of intertidal habitat or environment
			Creates a new, lower energy environment	Increased erosion downdrift	Creates a new, lower energy environment	Reduces sediment to depositional areas downdrift	Reduces sediment to depositional areas downdrift
			Fragments habitat	Starves sediment depositional areas	Fragments habitat	Deepens water	Deepens water
			Increases habitat complexity	Increases habitat complexity	Increases habitat complexity	Increases habitat com-plexity	Concentrates turbulence
						Concen-trates turbulence	

Table 2. *Possible habitat changes resulting from specific shoreline stabilization methods*

breakwaters, sloped structures, and vertical structures are not recommended at all because their adverse impacts are too great.

The full report (5) was distributed to the Coastal Resources Commission at their September 2006 meeting. The Estuarine Shoreline Stabilization Subcommittee will use the report's findings and conclusions to draft new estuarine shoreline stabilization rules.

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	Swamp Forest or Marsh	Marsh with Oysters or Mudflats	Low Sediment Bank with Marsh or Swamp Forest	Low Sediment Bank with Woody Debris, Oysters or SAV	Overwash Barrier/Inlet Areas	Low Sediment Bank with Sand or High Sediment Bank
1	Land Planning	Land Planning	Land Planning	Land Planning	Land Planning	Land Planning
2	Vegetation Control	Vegetation Control	Vegetation Control	Vegetation Control	Vegetation Control, Beach Fill	Beach Fill
3	Beach Fill	Sill, Toe Protection, Sloped Structure	Sill, Toe Protection, Sloped Structure	Sill	Groin	Vegetation Control
4	Sill, Toe Protection, Sloped Structure	Groin	Groin, Break-water, Sloped Structure, Vertical Structure	Sloped Structure	Sill	Groin
5	Groin			Vertical Structure	Breakwater	Sill
6	Breakwater				Sloped Structure	Breakwater
7					Vertical Structure	Sloped Structure
8						Vertical Structure

Table 3. *Summary of ranking of stabilization methods*

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Design Criteria for Tidal Wetlands

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ABSTRACT

The design and construction of tidal wetlands can often be a perplexing, mystifying process. Many of the techniques are solely the domain of practicing professionals which leaves many individuals and organizations at a loss when contemplating a project. This paper attempts to present practical guidelines that can be used by the lay person as well as restoration practitioners for the successful construction of tidal wetlands. These include screening criteria for site selection that will help avoid inherent problems with a particular site and design criteria to guide the development of wetland hydrology and the successful establishment of wetland vegetation.

INTRODUCTION

During the course of a number of wetland construction projects over the years, a number of guiding principles have emerged. Incorporation of these guiding principles or design criteria into a project can have a profound/major impact on the success of a particular project. These principles are applicable to Living Shorelines as well as other wetland restoration situations.

Development of general guidelines for Living Shorelines has been a joint effort of numerous practitioners such as Edward Garbisch with Environmental Concern in Maryland (1,2), Stephen Broome at North Carolina State University (3), and others who have pioneered the science of wetlands restoration. They have shared their successes and failures in numerous publications that have benefited many others in the field. James Perry (4) and C. Scott Hardaway (5) at the Virginia Institute of Marine Science (VIMS) have freely shared their experiences as well.

When embarking on a wetland construction project, it is critically important to focus on the objective of the project whether it is shoreline protection, habitat development, restoration, mitigation, or stormwater treatment. Each of these objectives involves slightly different features or approaches that can drive the design. For example, if one's goal is stormwater treatment, emphasis might be on stormwater residence time while a habitat restoration project might emphasize community diversity and fish access. These characteristics would likely result in different wetland configurations and landscape positions. Living Shorelines designed predominantly to provide erosion protection while also providing desirable ecological functions and values might have increased width and height of the fringing marsh for erosion protection and also habitat for fish and crabs.

I have organized these criteria into a number of categories that should be considered when planning any type of wetland including screening (considered prior to design) and design (addressed during design and construction) criteria. This paper is not intended to be an exhaustive treatise, but rather a detailed checklist of the most important considerations necessary when designing a tidal wetland. Furthermore, it has been my intent to present the information in terms that will be useful to the experienced practitioner as well as the novice.

SCREENING CRITERIA

The first step in the design is a general evaluation to ensure that a project is possible at the site in general, and no undue impacts will occur as a result of the project.

- Are there contamination issues at the site?
- Are endangered species an issue?
- Are cultural resources an issue?
- In urban areas, are underground or aerial utilities an issue?
- Is there adequate construction access to the site?
- Will valuable existing habitat, such as a mature hardwood forest, have to be destroyed to construct the wetland?

All of these questions need to addressed and resolved prior to proceeding with any detailed design.

DESIGN CRITERIA

Landscape Position

The most important aspect of this criterion is fetch, a measure of the exposure of the site to wave action. Generally when the fetch exceeds one mile, the chances of success without some type of structural protection are limited. Between one and 0.5 miles, chances improve but some minimal structure, such as biologs, is advisable to help the marsh become established. When the fetch is <0.5 mile, chances of success without structural toe protection, such as a rock sill, are good. If water quality improvement is part of the restoration objective, it is important that the runoff from the adjacent watershed be directed into or through the wetland as opposed to a simple excavated basin with a limited watershed.

Elevation

The critical elevations for tidal wetlands establishment are mean low water (MLW), the average low water at the site, mean high water (MHW), the average high water level at the site, mean tide level (MTL), roughly halfway between MLW and MHW, and the upper limit of wetlands (ULW), approximately 1.5 times the mean tide range at the site. These are the important elevations that will dictate the various planting zones within the new marsh.

Design elevations need to be based on a tidal datum such as the National Ocean Service (NOS) MLW and not strictly on a geodetic datum like the North American Vertical Datum of 1988 (NAVD 88). Tidal datums are based on water level observations over a 19 year period (a tidal epoch) where all of the high tides and low tides are averaged to determine MHW and MLW. NAVD 88 is based on the elevation of a fixed point in Canada and is not directly related to tidal elevations. Relationships between tidal and geodetic datums have been established for many locations but can vary widely. The NOS MLW datum used should also be based on the 1983-2001 tidal epoch to help ensure recent sea level rise has been taken into account. More information on tidal elevations and datums can be found at http://tidesandcurrents.noaa.gov/.

Biological benchmarks (BBM) are elevations established by surveying the elevations of representative plant communities in an adjacent reference marsh. These elevations can then be corroborated with the tidal datum to cross reference the design elevations for the wetland. The advantage of incorporating biological benchmarks into the design is that these elevations integrate any vagaries in the local hydrology that might influence the distribution of plant zonation. For example, if there is a hydrologic constriction that prevents the area from draining completely, it can result in a perched mean low water and a concomitant compression of the tide range that will affect the success of the plantings.

Slope

Flat slopes in the new marsh are important because they help maximize the plantable area within the intertidal zone and, where applicable, help dissipate wave energy and reduce erosion potential. Very often the slopes will be dictated by the size of the site, but, where possible they should at least 10:1 (H:V), preferably flatter if possible. In some situations, the intertidal area can be maximized by creating a bench between the creek and the upland that is very flat from MTL to MHW followed by a steeper slope from

MHW to the adjacent upland. The slope of this transition zone should also be kept as flat as site conditions will allow. In higher wave energy sites where there is steep upland transition, some type of structure may be necessary to stabilize this slope. It is also important for the slopes to provide positive drainage for the site at low tide. If the site does not drain completely and there are large areas of standing water within the area to be planted, plant survival can be compromised. I generally recommend that areas of standing water greater than 100 square feet be avoided unless they are an intentional feature of the design to increase habitat diversity.

Hydrology

Hydrology is the most important factor in successfully establishing a wetland. Several of the other important factors, e.g., elevation and slope, can have a direct influence on hydrology as well. To put it simply, to effect wetland hydrology in a tidal wetland, the area must be under water at high tide and dry at low tide. This may sound overly simplistic but it is the essence of tidal wetland hydrology. It is also the easiest way to explain the grading plan to an equipment operator.

Being dry at low tide is just as important as being wet at high tide. The reason that vegetation only grows down to MTL instead of MLW is that the roots need to breathe at low tide in order to survive. The dominant salt marsh plants do not grow well in permanently standing water. If the elevations and drainage, i.e. hydrology, in your planted marsh mimic the hydrology in the connecting waterway, the plants will adjust accordingly.

If the tidal connection to your site is highly convoluted or culverted, it can produce a phase lag in the hydrology. A phase lag usually results from having too much friction in the discharge channel which does not allow the site to drain effectively. Imagine a typical tidal cycle. At high tide because of the force of the incoming tide, the water levels within your site and those of the connecting waterway are equal. As the tide ebbs, it ebbs more slowly within the site because friction slows down the flow of water to the creek. Consequently, when it is low tide in the creek, there might still be a considerable amount of water waiting to drain from the site. As the tide begins to flood in the creek, it will rise to the level of the still ebbing water from the marsh. This level effectively determines the low water elevation because, from this point, the water begins to rise again within the marsh. The ultimate result of this situation is a higher MLW and a compressed tide range in the new marsh. This can have a dramatic impact on the survivability of the plants if the tidal levels from the adjacent creek, and not the site itself, are the main determinants for the planting elevations. In this regard, projects that involve pipes, tide gates, or other plumbing devices should be carefully evaluated.

Substrate

When constructing a new marsh you need to think of the substrate, first and foremost, as the medium for growing plants. There are other factors such as the amount of organic carbon in the soil that govern functions, like denitrification. However, in the beginning, it is more important to establish the vegetation as rapidly as possible. To do this, the best medium is sand. It provides a good anchor for the plants, allows for rapid root growth and effective drainage. In exposed conditions, coarser sand should be used to minimize transport by wave action. Silt-clay and peat can work but they make planting more difficult and are not as effective at anchoring the plants. Heavy plastic clays should be avoided because of planting difficulties and the impediments to root growth. Likewise, organic amendments, topsoil, and mulch should be avoided in brackish tidal marshes. Once they become wet, they are difficult to plant because they often do not effectively anchor the plants which naturally float and tend to be dislodged by tidal and wave action.

When excavating a new marsh from upland, it is critical that borings be made to the proposed planting elevation to identify the type of substrate that will be exposed for planting. If the substrate at grade is not suitable because of plastic clay, rubble, or *Phragmites* roots, it will be necessary to over-excavate the site and bring in at least a foot of good clean sand to bring the site back up to the desired elevation.

Shade

Most wetland plants require a minimum of six hours of direct sun during the growing season. They require large amounts of energy to cope with the stress of salinity and inundation twice a day. When planting fringing areas, this may require the judicious pruning of the lower branches of adjacent trees to allow for additional sunlight. Trees should only be removed when absolutely necessary. The design should also take into consideration shading from nearby structures and north facing shorelines which can induce unwanted shade. North facing shorelines, particularly forested, tend to receive less sunlight because of the low angle of the sun during the winter, spring, and fall.

Salinity Considerations

Site selection should also include an analysis of the local salinity regime. Consideration needs to be given to annual variation from lower spring to higher summer salinities. Do not depend on a single salinity measurement to be indicative of a site unless you are intimately familiar with the area. Also, be mindful of flashiness in the system, particularly in head water areas that are susceptible to freshwater pulses following major rain events. Plant selection must be reflective of this salinity regime. Natural vegetation in adjacent similarly situated marshes should be used as a guide to recommend species most likely to be successful. It is also important that the nursery stock to be planted is conditioned to site salinity levels. Plants grown in freshwater at the nursery and planted in high salinity areas can have a difficult time adjusting, delaying effective establishment of the stand. It can also lead to failure of the planting.

Zonation and Salinity Regimes

A general overview of planting zones and salinity tolerances for some of the more commonly planted species is provided in Table 1. This is neither exhaustive nor definitive and should be only used as a guide to be tempered by local conditions. Almost anyone will be able to find exceptions to these recommendations, but they will work in a vast majority of situations. It is critical to the success of a project to effectively match plant material, planting zones, and salinity regimes.

Species	Inundation Zone	Salinity Range
Spartina alterniflora	MTL – MHW	5 – 30 ppt
Spartina patens	MHW – ULW	5 – 30 ppt
Spartina cynosuroides	MHW – ULW	0 – 5 ppt
Distichlis spicata	MHW – ULW	10 – 30 ppt
Scirpus americanus	MHW – ULW	0 – 15 ppt
Juncus roemarianus	above MHW	10 – 25 ppt
Iva frutescens	near ULW	5 – 30 ppt
Baccharis halimifolia	near ULW	0 – 30 ppt
Panicum virgatum	above ULW	0 – 25 ppt
Myrica cerifera	above ULW	0 – 30 ppt

Table 1. *Zonation and salinity levels for common wetland plants (see text for zone abbreviations).*

Planting Materials and Methods

The preferred method of planting is nursery grown plants. These plants are readily available and have an excellent success record. The plants are typically grown in plastic cell packs with 72 plants per flat. The leaves should be a uniform green color with roots that are white and appear to be actively growing. Depending on the age of the plant, it may appear pot bound which is acceptable. Sometimes when the plants are received, the leaves have all been clipped to a uniform height. This is usually done on older plants to facilitate transport. It can also help with plant establishment by reducing initial demands on the root system. When planting, it is important to get the bottom of the plant at least 4 inches deep to effectively anchor the plant. The plants should also be firmly compacted into the soil to eliminate any air pockets. When explaining the planting process to volunteers, it is important to emphasize that the plants are not delicate and cannot be planted too deep or packed down too hard.

Transplants from an existing marsh can be used but are not generally recommended except for small projects with a viable donor marsh. Transplant excavation is a very labor intensive operation because of the dense root system of most plants. When excavating transplants, care must be taken to spread out the plugs removed so as to not unduly impact the donor marsh.

Seeding of brackish marshes can be a viable option under the right circumstances. It requires a knowledgeable contractor, a very protected site, and a substrate firm enough to support planting vehicles and implements. In tidal freshwater systems, the seed bank of the existing marsh substrate can be a highly effective seed source. In this case, marsh sediments are salvaged during construction, for example from an entrance channel. Once grading is complete, these sediments and seed bank can be incorporated into the new substrate as a means of revegetation.

Volunteers can often be used to do the planting. This works best when working in firm sand and is less successful in soft mucky conditions. The key is the demonstration of the proper planting technique and adequate supervision.

Fertilizer

It is very important to get the planted vegetation established as quickly as possible. The faster it becomes established, the sooner it can begin functioning within the system. Consequently, the limited use of high nitrogen, slow release fertilizer is typically recommended, e.g., Osmocote 18-6-12. These fertilizers are placed in the planting hole at the time of planting. Normally, an application of one-half ounce (one tablespoon) per plant is sufficient to establish the plant. Time release is temperature and moisture dependent and different release periods are available. Timing should be based on the amount of growing season remaining, e.g., nine month release for spring planting, six for summer, and three for fall.

Planting Times

The best time for planting is spring because the plants have the entire growing season to get established. But as with any planting, there is always a measure of risk. When planting in the early spring (March), the plants tend to be smaller unless they have been carried over from the previous year. Also, there is a greater chance a spring storm could dislodge the plants. April, May, and June typically are the lowest risk times. Planting in the summer, July, August and much of September, can be risky for high marsh plants with irregular inundation, if there is insufficient rainfall to sustain the plantings and irrigation is not available. Low marsh plants should do well except for a slightly shorter growing season. Fall plantings, September and October, are typically successful in protected settings but take longer to achieve complete cover. Plantings in late fall and winter, November, December, January, and February, can also be successful in protected settings, but the risk of damage from storms and winter ice can be significant. The planting of large shrubs and trees should be done in the fall and winter to minimize transpiration stress. Smaller size shrubs typically do better in spring than summer. In short, tidal wetlands can be established during most of the year, but the degree of risk varies substantially. If using optimum planting, fertilizing (see above), spacing, and maintenance (see below) techniques, plants can become established quickly (e.g., Fig. 1a,b).

<u>Spacing</u>

1. 1 foot centers – very rapid cover
2. 1.5 foot centers - rapid cover
3. 2 foot centers – average conditions
4. 3 foot centers – large areas
5. Alternate species in transition areas
6. Plant above and below predicted elevations

Typical plant spacing for restoration projects is 2’ on center. This will usually give complete cover in two full growing seasons. Mitigation projects or those requiring faster cover are normally planted on 1.5’ centers. Closer spacing is seldom necessary and rarely recommended. When planting large areas where rapid cover is not necessary or when cost is a significant issue, a 3’ on center spacing can be effectively used with a resulting delay in reaching full cover.

When planting in transitional areas, like in the vicinity of MHW or ULW, it is advisable to alternate species along the rows both above and below the juncture. This allows the right plants to be available to help accommodate minor variations in topography at critical breaks in slope and community transitions.

Maintenance

Many maintenance issues and problems can be very complex and require the services of wetland professionals. These are beyond the scope of this paper. The use of water control structures, pipes, weirs, tide gates, etc. should be avoided unless absolutely necessary. Wetlands should be designed as self-sustaining natural systems. This simplicity is compromised anytime a structure is required that needs maintenance to function properly. Notable exceptions are forebays which are small settling basins typically located where high volume discharges from adjacent watersheds enter a constructed wetland. These structures can help contain large sediment loads and help modulate flows. However, they do need to be maintained to function effectively.

It is very important to maintain effective erosion control in newly established wetlands due to wave action or upland erosion. The effects of a storm event on a newly planted marsh can easily be mitigated with additional plantings. Significant upland erosion that deposits large amount of sediments into a new established wetland can smother plantings. It can also cause hydrological modifications and alter elevations within the wetland that would alter vegetative communities and, perhaps facilitate the invasion of *Phragmites*.

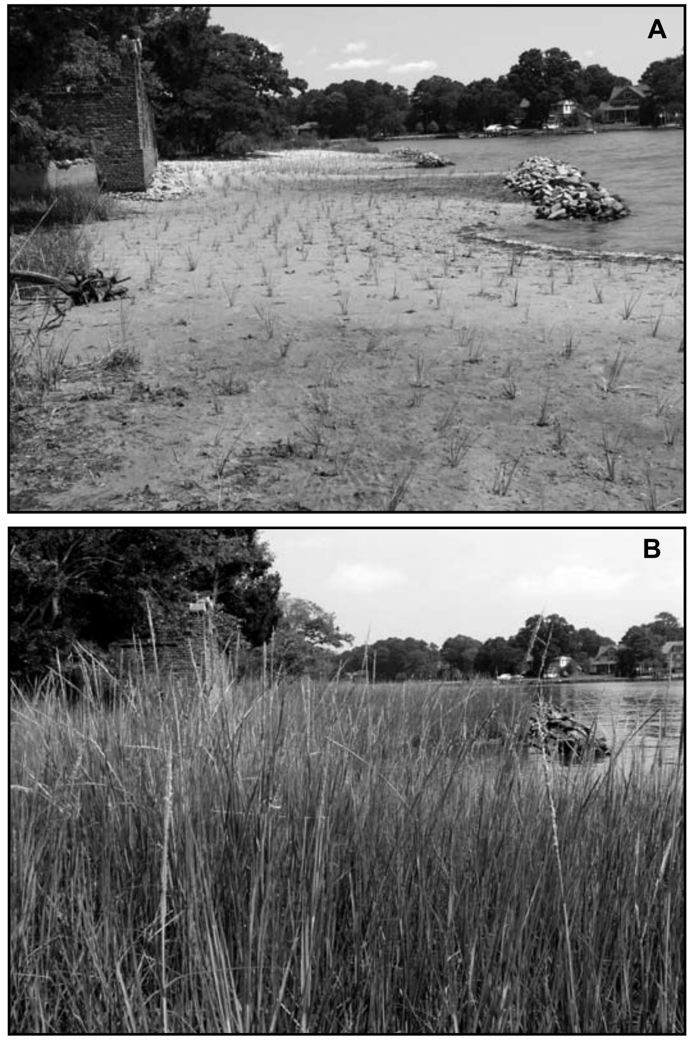

Figure 1. *Living shoreline using a segmented sill design at the Hermitage site in Virginia (a) immediately after planting (May 2006) and (b) the following summer (August 2007).*

In areas with populations of the common reed *Phragmites australis*, extraordinary measures are often necessary to eliminate existing stands and prevent recolonization. While there are no guarantees, there are a number of techniques which can help limit the risk. Whenever possible, existing stands should be sprayed with an appropriate herbicide prior to construction. During construction, every effort should be made to excavate and remove from the site as much of the *Phragmites* as possible. This should include over-excavation of at least a foot of material and backfill with clean sand. It is also important to design the majority of the site below MHW. In areas of moderate to high salinity, this can be a very effective deterrent. The creation of a subtidal ditch around the perimeter of the site can also help deter recolonization by rhizomes from adjacent stands. *Phragmites* control is an issue that requires continuing vigilance including at least semi-annual inspections and a comprehensive plan to treat future infestations. This is a very complex issue and consultation with a wetland professional is highly recommended.

Herbivory or the unwanted consumption of newly planted marshes is an emerging problem due to the burgeoning populations of resident Canada geese. These animals relish new stands of *Spartina alterniflora* and can quickly devastate plantings. They can, however, be effectively excluded by intensive fencing practices. They are not a threat to be underestimated, and again, a wetland professional should be consulted if geese are perceived as a threat.

The accumulation of debris, flotsam and jetsam, as well as wrack material, *Spartina* stems, and eelgrass leaves, can smother and devastate newly planted marshes. Care needs to be taken on any windward shore, particularly in coves facing the dominant wind direction. The only remedy is constant surveillance and judicious removal.

CONCLUSION

The purpose of this paper has been to outline some of the critical elements in the design of tidal wetlands. Due to the nature of this paper, the treatment of some elements has been necessarily cursory. Hopefully, though, it will precipitate intelligent questions during the design process and lead to better designed marshes that can effectively function as productive components of the estuarine system.

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Evaluation of Living Shoreline Techniques

Photo credit: Jana Davis, Chesapeake Bay Trust

Current Understanding of the Effectiveness of Nonstructural and Marsh Sill Approaches

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ABSTRACT

A panel session at the Living Shorelines Summit in Williamsburg, Virginia was dedicated to the current understanding of the effectiveness of nonstructural erosion protection methods and marsh sills. Four panelists described their professional experience with either design and construction or monitoring of projects in tidal waters of Maryland and Virginia, including marsh edge stabilization (marsh toe revetments), marsh sills with sand fill, and planted marshes. Their collective experience revealed that planted tidal marshes and supporting structures can be effective alternatives to revetments and bulkheads. Site-specific engineering is required to ensure they provide functional ecological benefits, particularly in medium and high energy settings. Another important factor for effective projects is landowner acceptance of dynamic shoreline conditions and the level of protection provided. Additional project tracking and research is needed to further investigate positive and adverse effects of created tidal marshes and supporting structures.

INTRODUCTION

The principle of living shorelines can be defined as "a shoreline restoration and protection concept that emphasizes the use of natural materials including marsh plantings, shrubs and trees, low profile breakwaters/sills, strategically placed organic material, and other techniques that recreate the natural functions of a shoreline ecosystem" (1). The current paper is a summary of the presentations that were a part of the Living Shorelines Summit held in Williamsburg, VA from December 6 to 7, 2006, with Dr. Kevin Sellner as the facilitator. The most important goals for the panel were to be provocative, to challenge and inspire people about living shorelines projects, and to provide the most current information to increase understanding of the effectiveness of nonstructural and marsh sill approaches. This paper is not a conventional manuscript; rather, it summarizes the collective experience of four shoreline professionals who were directly involved with the design, construction, and monitoring of living shoreline projects. Their work and presentations are summarized below.

THE LIVING SHORELINE: MORE THAN SHORELINE STABILIZATION (Gene Slear)

Approximately 4.7 million cubic yards of sediment cloud the waters of the Chesapeake Bay every year. More than 57% of this sediment load is from tidal erosion, both shoreline and nearshore (2).

Historically, shoreline erosion was managed by installing a wood bulkhead or placing stone against the bank. In the early 1970's, Environmental Concern (EC) constructed a salt marsh channelward of an eroding shoreline at a low-energy cove in Talbot County, Maryland. The marsh thrived, and shoreline erosion was reversed. Over the next two decades, scientists and engineers at EC refined and expanded the initial design, creating sustainable salt marshes in highly erosive environments.

The advantages of the Living Shoreline over the traditional riprap or bulkhead are well-documented. In the interest of clarity, we have presented the advantages in four general categories:

Productivity

The net primary productivity of the salt marsh exceeds that of most ecosystems (3). Tidal marshes provide the primary food sources for the Bay's living aquatic resources (4). Above-ground biomass in created *Spartina alterniflora* marshes on the Atlantic Coast or in Chesapeake Bay quickly reaches parity with natural marshes if basic conditions for marsh establishment and survival are employed (5).

Habitat Enhancement

- 80% of America's breeding bird population relies on coastal wetlands (4).
- 50% of the 800 species of protected migratory birds rely on coastal wetlands (4).
- Nearly all of the 190 species of amphibians in North America depend on coastal wetlands for breeding (6).
- The cost benefit for a living shoreline is significant. For every dollar spent to construct vegetative shoreline stabilization, as much as $1.75 is returned to the economy in the form of improvements to resources, including submerged aquatic vegetation (SAV), fish, benthic organisms, shellfish, waterfowl, and wetland habitat (7).

Water Quality

The salt marsh traps silt and pollutants, including nitrogen and phosphorus contained in stormwater runoff and receiving waters (8, 9). However, only 30% of the nitrogen load is from surface runoff; the balance moves unimpeded to the Bay's waters via sub-surface flow and groundwater. When this flow encounters a salt marsh, denitrification will likely occur. Denitrification is an important but little known marsh process. Simply stated, high productivity plants such as salt marsh vegetation move large amounts of biomass (carbon) below ground to provide electrons necessary to drive a process which converts elemental nitrogen to N_2 (an inert gas), thereby dampening coastal eutrophication (10).

Shoreline Stabilization

Reduction of wave height (wave attenuation) and thus the severity of the impact at the upland bank is a function of wave interaction with the bottom, wave interaction with the sill structure, and wave interaction with marsh vegetation. Knutson *et al.* (8) report that *Spartina alterniflora* (SA) marshes significantly reduced wave height and erosional energy. Wave height was reduced by 50% within the first 5 m of marsh and 95% after crossing 30 m of marsh.

A properly engineered living shoreline will provide as much or more protection than riprap or a bulkhead and will improve water quality and enhance habitat as well. Engineering is site specific. Additionally, SA living shoreline design does not always fit neatly into the regulatory guidelines. This can be frustrating for the landowner who wants to protect the shoreline as quickly and as inexpensively as possible. In Maryland, the shoreline stabilization guidelines state that marsh creation is the preferred methodology and must be used wherever practicable (see new Maryland guideline details on page *xiii*).

INTEGRATING HABITAT AND SHORELINE DYNAMICS INTO LIVING SHORELINE APPLICATIONS (Kevin Smith)

It is common knowledge that shorelines are not stable, but dynamic (11). With the growing number of people moving to coastal communities (12), it can be safely assumed that there will be an increasing demand for the stabilization of shorelines. Traditional methods of shoreline stabilization typically lack a habitat component. Therefore, if we are to preserve and maintain the important role that natural shorelines provide, it is imperative that we develop solutions to address the need for erosion control, and to a greater extent, to address the historic and current loss of shoreline habitat. Living shoreline applications are a method to address this issue. The author defines living shorelines as "a concept based on an understanding and appreciation of the dynamic and inherent values that our natural shoreline would provide and applying those natural principles to shoreline enhancement and restoration projects."

The real challenge exists when we try to construct living shorelines in medium- and high-energy wave environments. Typically, this requires the use of some structural components. These structural components are often necessary to provide vegetation with an adequate growth environment. Further, we often overlook the fact that shorelines have been eroding naturally over time and this betrays a fundamental flaw with structured stabilizers (bulkheads and ripraps): What we see as a problem is actually a very important natural process and something critical to the bay's ecology. In some areas, the author notes that the Bay is sediment starved (in the case of sand), and erosion provides material to replenish shorelines and offshore bottoms. These sediments are critical to maintain existing beaches and near-shore sandy bottoms. Living shorelines offer the right balance between shoreline protection and the natural process of erosion. The concept of living shorelines is not a trouble-free strategy, particularly in medium and higher-energy environments (5). Determining adequate design for structures such as sills and breakwaters, while maintaining habitat function, can be very challenging and hence, is of great importance.

Structural components can be used successfully but must be constructed in a way that provides for habitat. Sills, for example, can do more harm to wildlife than good. Fish and crabs can get trapped behind sills and cannot escape when the tide ebbs. Hence, as above, project design must provide functional ecological benefits.

As with any project, it is imperative that landowners are involved in project goals and fully understand the project and performance they can expect. It is important to provide landowners with a reality check that, contrary to general beliefs, living shoreline projects may provide less protection than other more traditional approaches. They need to understand that shorelines are dynamic, requiring maintenance, such as the replacement of plants and/or sand, more commitment than traditional methods. Shoreline property owners need reasonable expectations within such a complex and dynamic system where success requires site-specific assessment prior to modifications and appropriate design for site characteristics. The key is to continue to develop, design, and place structures that are suitable for the environment, wildlife, and landowner goals.

NONSTRUCTURAL METHODS & MARSH SILLS: HOW EFFECTIVE ARE THEY IN VIRGINIA? (Karen Duhring)

Qualitative field evaluations of 36 tidal marsh protection structures were conducted in 2004 and 2005 in six localities on the Northern Neck and Middle Peninsula of Virginia. Twenty-eight structures were placed adjacent to natural tidal marshes for marsh edge stabilization (marsh toe revetments). Eight were marsh sill projects with sand fill and planted tidal marshes. All of the structures were made with quarry stone and two structures included gabions (wire mesh cages) to contain the stone. Most of these projects were constructed after 2000.

The created marshes were up to forty feet wide with a target slope of 10 to 1. A majority of the projects were in low energy settings and most were in areas where the fetch was less than 0.5 mile. Some of these project sites also had considerable boat wake influence. Nine projects were in high energy settings, and 4 of these sites were in major tributaries with a fetch more than 5 miles. Baseline conditions before installation were not studied, but available information was obtained from permitting records (application drawings, photographs, environmental assessments).

Defining whether each project was effective or not was difficult because there were no standard parameters. The actual need for the structure was determined based on the apparent level of erosion protection needed. Structural integrity was considered sound if there were no visible changes in rock placement, no evidence of eroded marsh edges or upland banks, and no significant changes in wetland slope. Other parameters used to determine project effectiveness were the apparent health of natural and planted marsh vegetation, physical evidence and observations of tidal exchange in and out of the marsh (e.g., wrack lines, dry and wet substrate), the crest height of the stone in relation to the mean high water elevation, and the vegetative transition between wetland and upland habitats.

The upland bank height was low (less than 5 feet) and baseline information indicated real or perceived erosion before installation in almost all of these projects. No active marsh or upland bank erosion was reported in only two cases where there was no apparent need to install any type of structure. Most of the stone structures remained in place with only minor structural damage or movement of rock. Sand placement remained stable with no visual signs of significant changes in marsh slope. Both the marsh edge stabilization structures and marsh sills were generally effective for reducing both marsh edge and upland bank erosion. Tidal exchange appeared to be adversely restricted at some of the large structures at medium energy settings. The marsh vegetation seemed to be healthy, but there were few physical indicators of tidal inundation and access for the movement of aquatic organisms was restricted along the entire length.

These projects were found to be most effective for fringing and embayed tidal marshes and less effective for spit marsh features with open water on two sides. The baseline erosion condition of the spit marshes continued in spite of structures at the marsh edge and planted marsh vegetation also failed. It is not clear why these projects were not as effective for this marsh type.

In addition to the survey of marsh structures, two nonstructural methods were monitored between 2000 and 2006 during routine site inspections and shoreline advisory evaluations. Planted tidal marshes without structures were generally not as effective for reducing upland bank erosion as planted marshes with sills. Although tidal marsh vegetation was successfully established in the intertidal area in some cases, the planted marshes were apparently not wide enough for wave and erosion reduction. The planted vegetation failed at sites where regular high tides reached the upland bank and where overhanging trees cast too much shade. The time of year for planting also mattered. Planted marshes completed in early spring were more successful than those planted later in the summer, probably due to heat stress. Anecdotal reports of grazing by mute swans were also received, similar to Canada geese.

Bank grading is another nonstructural practice in Virginia with and without erosion control structures at the toe of the graded banks. Presently, there are no guidelines for how to incorporate the intertidal area for a wide, planted marsh adjacent to graded upland banks. Boat wake and storm erosion continued at graded banks without a wide intertidal area. Functional riparian buffer habitats were not commonly restored on graded banks, although a dense cover of upland vegetation is recommended for additional bank stabilization and erosion protection particularly where storm waves may strike the bank.

The main finding from the study and observations mentioned was that low stone structures were the most effective for erosion protection where they were placed along the edge of wide, natural fringe marshes adjacent to low banks. Several practices were found to be less effective for reducing erosion or they adversely impacted habitat functions of the tidal marshes. For the marsh protection structures, tidal exchange within the marsh was sometimes restricted by tightly packed stone or the structure height. Structures placed adjacent to spit marsh features were also found to be less effective.

For the nonstructural methods, planted marshes were most successful where regular high tides do not reach the upland bank and when the vegetation was planted in early spring. Graded banks without a marsh terrace or a dense cover of riparian vegetation remained vulnerable to erosion and storm waves. Due diligence by property owners and contractors for routine inspections and repairs was another common factor in effective projects, both structural and nonstructural.

EVALUATION OF MARSH SILLS, GROINS AND EDGING PROJECTS ON MARYLAND'S EASTERN SHORE: A PILOT STUDY OF TALBOT COUNTY (Bhaskaran Subramanian)

Maryland Eastern Shore RC&D Council, Inc. has been working on living shoreline projects for over 20 years (1987-2006) and has completed 258 projects. RC&D wanted to document the success of these projects so as to expand the knowledge base for the concept of living shorelines techniques as a viable erosion control alternative to conventional bulkheads and ripraps. A pilot study of 35 projects (marsh sills, groins, and edging) in Talbot County was conducted as a part of the effort. Parameters included slope of the bank (steep or flat as compared to as-build), bank condition (undercut/slumping), marsh erosion, structure type (sills/groins/edging), structure condition (displacement, sinking, or no change), and the presence/absence of plant species (other than the ones that were planted initially) were studied to assess the success of all projects. The study also involved the development of a Geographical Information System (GIS) database that could aid in decision-making for future projects.

A Global Positioning System (GPS) unit was used in the field to collect and input data related to location and other parameters. A laser level was used to calculate the change in slope along the marsh fringes, and a camera was used to record the current status of the projects for comparative analysis.

After careful analysis of the data, it was found that 83% of banks inspected were stable (no undercut or slumping), and 74% of the marshes exhibited minimal erosion or no erosion. The stone structures in 71% of the projects were in excellent condition. Overall, 32 out of the 35 projects studied were ranked good or improved from initial conditions. Therefore, the pilot study results indicate that living shorelines have been used successfully for erosion control purposes. Further studies are needed to confirm the findings with additional data and analysis needed to determine impacts of fetch, energy of the system, and the role of design type to expand knowledge of living shoreline project success. Plans are in place to inspect the remaining projects in other counties.

PANEL CONCLUSION

It can be concluded that design guidance for living shorelines projects is necessary for successful use of this technology. If designed properly, living shorelines have shown to be an appropriate tool for addressing erosion control issues in many cases. Project design is site specific and a combination of structural approaches (stone sills or breakwaters) with marsh plantings has been shown to be synergistically effective for both erosion protection and providing habitat for aquatic organisms. Though there is skepticism about using rock, it is imperative to understand that in most cases, rock acts as the first line of defense for marsh vegetation. A more robust database and further monitoring of existing projects are critical to understanding project design and possible site-specific success. Maintenance of living shorelines projects is critical. Overall, living shoreline technology can successfully be used for shoreline protection while providing essential habitat in many erosional areas.

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A Comparison of Structural and Nonstructural Methods for Erosion Control and Providing Habitat in Virginia Salt Marshes

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ABSTRACT

Shoreline stabilization methods that emphasize the use of tidal marshes and riparian vegetation are encouraged as a baseline defense for tidal shoreline erosion in Virginia. The effectiveness of three of these methods in preventing erosion and providing habitat was evaluated, including marsh stabilization structures (marsh toe revetments and sills), planted tidal marshes, and bank grading. This evaluation includes results from a recent field survey of 36 tidal marsh stabilization structures, permitting records, and other monitoring data. Marsh structures effectively reduced erosion of fringing and embayed marshes but were not as effective for gradually disappearing spit marshes. Adverse impacts of restricted tidal exchange were observed where the revetment height was more than one foot above the mean high water elevation. The two nonstructural methods provided both habitat and erosion protection, but were generally not as effective as marsh structures. Planted marshes were most effective where regular high tides do not reach the upland bank. Graded banks that included a flat area for marsh vegetation at the toe were more effective than banks graded steeply landward from the toe. Graded banks maintained as lawns were not as effective for preventing storm erosion as densely vegetated slopes. Additional research is needed to investigate how sand fill and fiber materials can be used beneficially to enhance tidal salt marshes and beaches for erosion protection.

INTRODUCTION

Erosion control structures are widely used on Virginia's tidal shorelines to protect private and public property. Flood reduction, improving riparian access and landscape aesthetics, improving navigation, and creating recreational beaches are other motivating factors for shoreline modifications. Shoreline armoring, or hardening, refers to the cumulative impact of fixed structures, such as vertical bulkheads, stone revetments, offshore breakwaters, groins, and jetties. These structures are effective for protecting the upland from wave attack and erosion, yet it is now apparent that they may not be appropriate for all shoreline types. Multiple structures installed in a piecemeal fashion degrade estuarine ecosystem conditions due to increased wave reflection and water depth, decreased sediment supply, tidal wetland and beach loss, and forest fragmentation (1-3).

Coastal erosion management programs generally discourage shoreline modifications unless they are absolutely necessary to protect property from coastal hazards. Where erosion must be stabilized, the "living shorelines" approach suggests using environmentally sensitive protection. Methods that enhance tidal shoreline habitats are encouraged where such methods offer effective stabilization (4,5).

Nonstructural methods such as planting tidal marshes, bank grading, and beach nourishment are feasible for shorelines experiencing mild erosion. These low energy shorelines tend to occur where the widest fetch is less than 1 mile (5-7). Planted marshes and other nonstructural methods are not as effective if the wave climate is excessive, the intertidal area is narrow, if there is no sand entrapment by the marsh, or there is regular boat wake influence (4,6).

Some techniques include structures but also incorporate wetland and upland vegetation that acts as an erosion buffer and provides other ecological functions (8). These "hybrid" type projects, such as marsh toe revetments and marsh sills, incorporate both nonstructural and structural elements for successful stabilization. The strategically placed structure forces waves to break channelward from the upland bank with only minimal alteration to the wave climate. A dense vegetation cover or wide sand beach provides additional wave dissipation (6,8).

According to a database maintained by the Center for Coastal Resources Management at the Virginia Institute of Marine Science, 8.2 miles of tidal marsh stabilization structures were permitted in Virginia from 2001-2006. It is presumed that marsh structures are beneficial because they preserve eroding tidal marshes and make it possible to create new ones where they do not naturally exist (3). In order for these projects to effectively provide habitat functions, tidal exchange and the movement of aquatic animals into and out of the marsh cannot be severely restricted. Healthy tidal marsh vegetation requires adequate tidal inundation with complete drainage at low tide. Numerous aquatic organisms utilize fringing marshes along the channelward edge where these structures tend to be placed (9). The indirect effects of marsh stabilization structures on sediment transport, temperature regulation, and access to the marsh for habitat use are still not completely understood (8). The purpose of this study was to compare available information about two nonstructural methods (planted tidal marshes, bank grading) with the hybrid method of using marsh toe revetments and marsh sills. The relative need for the structures and the effectiveness of each method for reducing visible erosion scarps and providing habitat were evaluated.

Figure 1. "Marsh toe revetments" are placed next to the edge of an eroding tidal marsh.

MATERIALS AND METHODS

Marsh Revetment Survey

A recent field survey of existing tidal marsh stabilization structures focused on two types of rock structures. "Marsh toe revetments" are used to stabilize the eroding edge of a natural tidal marsh (Fig. 1). "Marsh sills" are freestanding structures used to contain sand fill needed to create a tidal marsh at a non-vegetated site (Fig. 2).

Thirty-six structures were evaluated from June 2004 to August 2005 in six counties on the Middle Peninsula and Northern Neck of Virginia. General dimensions for each marsh structure were recorded and observations made of erosion evidence, the need for the structure, structural integrity, construction access impacts, and adjacent landscape settings. Baseline information about shoreline erosion conditions at each site and design specifications were obtained from permit records. The widest fetch distance was used to categorize wave climate settings from low to high energy.

Figure 2. "Marsh sills" are used to contain sand fill that is planted with tidal marsh vegetation.

The marsh structures were considered effective if evidence of marsh or upland bank erosion was reported before construction, but then there was no evidence of erosion observed during the field evaluation. Indicators of effective habitat functions included a healthy and diverse stand of tidal marsh vegetation with only minor disruption of tidal exchange. Other positive indicators include a connected cover of vegetation between upland and wetland habitats plus evidence of wildlife utilization.

Planted Tidal Marshes and Bank Grading

Information about planted tidal marshes and bank grading was obtained from permitting records and shoreline evaluations performed as an advisory service to regulatory agencies and the general public. The planted tidal marshes in this study were relatively small, voluntary habitat restoration projects sponsored by grassroots organizations and individuals (Fig. 3). The presence or absence of visible erosion scarps after planting, the local wave climate, water depth at the bank toe, and frequency of boat wakes were considered.

Numerous bank grading projects were tracked between 2000 and 2006 to monitor how effective this nonstructural method is over time (Fig. 4). Graded banks are effective if active erosion does not continue even with periodic wave action and run up. The presence or absence of dense herbaceous or woody vegetation was noted, particularly at the toe of the graded slope where storm waves are likely to strike.

Figure 3. *A planted tidal marsh with* Spartina alterniflora *on the existing grade using natural marsh vegetation as a benchmark (foreground).*

Figure 4. *A previously vertical, eroding bluff was graded and planted with native and ornamental grasses.*

RESULTS

Marsh Revetment Survey

Ten planted tidal marsh projects that did not include stone structures were evaluated. All but 4 were constructed in the past 5 years. They were all constructed with quarry stone on filter cloth, including 2 projects that used gabions to contain the stone. A small stone size was used in most cases, permitting hand placement at marsh sites with limited access for heavy equipment.

The average revetment length was 271 feet and there were 17 structures that exceeded a 200-foot length. Ten of these long, continuous structures had tidal openings. The base width varied from 3-14 feet, with an average of 6.5 feet at low-energy settings. Four projects at high-energy locations had base widths ranging from 6 to 14 feet where the widest fetch was greater than 5 miles. The height of all the structures above the substrate was less than 4 feet and usually less than 3 feet. The top elevation was more than 1 foot above the mean high water elevation in 21 cases.

Planting tidal marsh vegetation on sand fill was included with 8 project designs. The created marsh width varied from a narrow fringe less than 5 feet wide to a 40-foot wide high marsh and low marsh combination at one of the high-energy sites. The plant species used were primarily *Spartina alterniflora* and *S. patens*. Only one of these planted marshes failed to establish.

Where existing natural marshes were present, marsh erosion was almost always present before installation. Three different types of eroding tidal marshes were targeted, including fringing marshes (n=18), spit marshes (n=12), and embayed marshes with tidal ponds (n=4). The natural marsh width was between 20-50 feet in 25 of these cases and greater than 50 feet wide at 3 sites. The upland banks adjacent to these structures were usually less than 5 feet high. Upland bank erosion was not always reported before construction.

Most of these marsh revetments were located in low energy settings where the widest fetch was less than 0.5 mile (n=20), although nonstructural methods should be sufficient if boat wakes are not frequent (6). There were 9 projects located on minor rivers and major tributaries where the widest fetch is between 1-5 miles. Four projects were located on major tributaries with Bay influence in high-energy settings with a fetch greater than 5 miles.

All 36 structures were structurally sound with a few exceptions, even though most of them were subjected to a coastal storm in 2003 just after construction (Tropical Storm Isabel). In a few older cases, the stone had settled into a wider and flatter profile than designed. Small stone was also scattered over the marsh surface in a few cases. Property owners reported only minor work was performed after storm events, such as replacing the scattered stone and removing tidal debris from the marshes.

The marsh toe revetments and marsh sills effectively reduced both upland and marsh erosion, particularly for fringing and embayed marshes. Both upland bank and marsh edge erosion were visibly reduced because of the structures and the wide tidal marshes they support. The pre-existing erosion trend was reversed in 4 cases where there was evidence of channelward marsh expansion. There was no obvious evidence of sediment accretion or sand entrapment because of these structures.

Erosion of spit marsh features continued even though marsh toe revetments were installed, especially for narrow spit features. Isolated areas of continuing marsh erosion were also observed at 8 sites where marsh toe revetments were placed more than 10 feet channelward from the marsh edge. "End-effect" erosion was observed in two cases where erosion of the untreated marsh edge at the end of the revetments appeared to have accelerated. Upland bank erosion was still evident where the revetment height was less than 1 foot above the mean high water elevation at medium and high-energy settings and also where the marsh width was less than 15 feet.

While the marsh vegetation usually appeared healthy, there was evidence that some structures were adversely interfering with other habitat conditions and functions. This was particularly true where the revetment height was more than one foot above the mean high water elevation. One marsh was perched well above the mean high water elevation due to the height of the stone, isolating it from tidal exchange. Macroalgae growth and dieback of planted *S. alterniflora* was observed where tidal exchange was restricted by tightly packed stone inside a long continuous gabion sill. There was no apparent loss of sand fill.

Planted Tidal Marshes

Ten planted tidal marsh projects were evaluated. These particular marshes were planted on the existing substrate in narrow intertidal areas without the addition of sand fill. Existing marsh vegetation was used for biological benchmarks where possible. Pruning or removal of riparian vegetation was required in three cases to provide enough sunlight during the growing season. Slow-release fertilizer was used below ground at the initial planting and a few property owners continued to fertilize their planted marshes annually in early spring.

Some habitat is provided by these planted tidal marshes, but they were usually too narrow for sufficient erosion protection. None of them was greater than 10 feet wide. The marsh plants did not successfully become established where regular high tides reached the upland bank. At least one planted marsh failed where excessive pruning of trees overhanging a mudflat was required. The pruning activity alone apparently did not improve growing conditions well enough, probably due to sediment chemistry and other limiting factors. Another planted marsh became patchy when pruned vegetation was not maintained.

The time of year for planting also affected the success of these planted marshes. Early summer planting was not as successful as spring planting. The new plants were not established before stressful and prolonged heat spells in June and July. There is also an increasing need for grazing exclusion devices in Virginia: resident Canadian geese and an expanding population of mute swans were attracted to the newly planted marsh vegetation.

Bank Grading

The most common bank grading plan extended landward from the bank toe without cut and fill channelward from the bank. Bulkheads and revetments were installed at the toe of some of these graded banks. Boat wake influence and continued erosion at the toe were cited as reasons for adding these structures.

Landscape restoration on graded banks typically does not include the recommended dense cover of deeply rooted vegetation that is not mowed frequently. In one case where a marsh flat was included with a graded bank, substantial erosion occurred above the marsh vegetation during a storm. This particular slope was routinely mowed and maintained as a lawn down to the planted marsh vegetation. The property owner decided to stop mowing so close to the water in order to extend the stabilizing vegetation buffer further up the graded bank instead of installing a rock revetment between the bank toe and the planted marsh. Other graded banks with a wide dense buffer of naturalized riparian vegetation experienced only minor storm damage.

DISCUSSION

Marsh toe revetments placed along the eroding edge of natural marshes were more common than marsh sills with backfill and planted marshes. Most of the marsh structures were located where the widest fetch was less than 0.5 mile. The presence and effect of boat wakes was not included with this study, yet only one of these projects was determined to be excessive and unnecessary for erosion control purposes. Continued erosion and loss of valuable tidal marshes was expected if a structural, "hybrid" approach was not used. Sand fill was also not expected to remain on site without containment structures.

The wave breaking function of the structures depends on the crest height above the mean high water elevation, yet excessive height also restricts tidal exchange. The target height should be the mean high water elevation and up to 1 foot above mean high water where the fetch distance or boat wakes indicate that additional height is necessary. If additional height is needed, then tidal openings or a variable height should be provided without creating erosion hot spots or shoaling problems. Additional research on the effects of restricted tidal exchange should include temperature regulation and sediment transport.

Formerly vegetated marsh spits continued to disappear after marsh revetments were installed. Planted vegetation on marsh spits also failed, consistent with a previous conclusion that points of land reaching into a body of water are not suitable planting sites (10). It is not clear why these structures failed to protect spits from continued erosion. Sand fill may be a necessary component for marsh spit restoration with strategically placed containment structures that enhance rather than restrict sand entrapment.

Marsh revetment projects that were determined to be effective for both reduced erosion and for supporting living resources had several characteristics in common, including:

- The marsh structure was necessary, i.e., a nonstructural approach would likely not be effective.
- A tidal marsh greater than 15 feet wide was the primary erosion buffer.
- No or only minor erosion of the upland bank and marsh edge was evident after the structure was installed.
- The structure was appropriately designed, with a revetment base width generally less than 8 feet at low energy settings, less than 14 feet at medium energy settings.
- Tidal exchange was provided either with a height <1 foot above the mean high water elevation and/or strategically placed tidal connections.
- Tidal wetland and riparian habitats were connected with a vegetation cover in a natural condition.
- There was evidence of habitat use by typical salt marsh species.

The two nonstructural methods included with this evaluation were not as effective overall as the structural "hybrid" approach, but each method has advantages and disadvantages (Table 1). Planted tidal marshes would be more effective for both erosion protection and habitat enhancement if the marsh width can be expanded either landward with bank grading or channelward with sand fill and containment. This study suggests that the target width for the created marsh should be at least 15 feet, with even more effectiveness expected if the planted marsh is 25 feet wide (4,5). Fertilizing newly planted tidal marshes did enhance plant density that is beneficial for erosion protection, but annual fertilizer treatments do not necessarily improve established marshes (10).

Method	Advantages	Disadvantages
Marsh toe revetments and sills	Wave reduction Longevity	Fish / wildlife movement interrupted Wave diffraction
Planted tidal marshes (at grade)	Fish / wildlife habitat Buffers nutrient and sediment inputs	Limited erosion protection Diligent maintenance, storm repairs
Bank grading	Easily combined with other methods Improves access for maintenance	Sediment runoff during land disturbance Toe protection needed in wave strike zone

Table 1. *Advantages and disadvantages of the three erosion control methods surveyed.*

It appears more emphasis should be placed on including sand fill with both sill projects and planted marshes, assuming only suitable material will be used. The target slope for created or enhanced tidal marshes is 10:1 (6). If the existing slope is steeper than this target grade, then backfill or bank grading with cut and fill should be encouraged to create a stable planting area wide enough for both erosion protection and habitat values. The effectiveness of temporary containment methods, such as coir mats and coir logs instead of marsh structures, should be investigated further particularly in fetch-limited settings. Determining if wave climate anomalies occur where boat wakes are frequent would clarify where structural methods may be necessary.

Renewed emphasis should also be placed on the effective use of bank grading and riparian buffer vegetation for stabilization. Sediment grain size analysis of bank material should be encouraged to determine its suitability for sand fill. The current practice of retaining all bank grading material landward from the mean high water elevation could be reconsidered, to identify those circumstances where channelward fill would be appropriate to create or enhance a tidal marsh or beach feature. If professional landscape designs were available that utilize salt-tolerant, native plants arranged for both stabilization and aesthetic appearance, then perhaps more property owners would be willing to restore a functioning riparian habitat on the graded bank.

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Living Shorelines Projects in Maryland in the Past 20 Years

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ABSTRACT

Maryland Eastern Shore RC&D Council, Inc. has been involved in living shorelines projects in the coastal counties of Maryland for the past 20 years. Many of the projects are on private properties, while some projects have been completed on public lands including boat ramps, marina, and parks. This paper focuses on compiling information from these projects and creating baseline information of the benefits in these counties of Maryland. Nearly 258 projects at a total cost of $8.9 million were completed from 1987 to 2006. All the nonstructural projects have exhibited many benefits, such as reducing nitrogen and phosphorus inputs to the Bay, creating/preserving wetlands, and shoreline erosion control.

INTRODUCTION

According to the Maryland Geological Survey (2007), Maryland has a shoreline of approximately 7,532 miles (1). One of the most significant problems facing landowners along Maryland's long coastal environment is shoreline erosion, a natural process (2), but also affected by human activities. With the current focus on hurricanes, floods, and other natural disasters, the need to protect people, land, and natural resources is of great importance. This paper deals with the use of "living shorelines" as a method of shoreline erosion control. The primary goal of this paper is to compile information from projects completed on eroding shorelines, while creating baseline information of the benefits of these living shoreline projects in the coastal counties of Maryland, in comparison with other conventional practices.

There are many different types of waterfront property, some on small creeks, while others face open water. Some of these properties (public and private) are suffering the effects of steady erosion. Through the years, landowners and mangers have tried many different techniques to protect their properties. Some less than traditional techniques commonly used have been recycled concrete materials and old tires (2). Traditional erosion control techniques include groins, bulkheads, and riprap (2). For many years, in spite of the differences in shoreline types, there has mostly been a "one-size-fits-all" approach to shoreline protection (2). Bulkheads and riprap are called "structural methods" of shoreline erosion control techniques, good solutions in certain situations. However, even when carefully designed, these methods cause unintended consequences for people and wildlife and a number of problems such as aesthetic issues and elimination of valuable fringing wetlands and sand beaches that help improve water quality and support wildlife (2).

Nonstructural Approach

In cases of creeks or coves that receive low energy waves, the shoreline can be protected by using methods other than structural techniques. Examples include (re)planting wetland vegetation and beach replenishment (3). These methods are appropriate if the property has had a vegetated wetland or beach, or if neighboring shorelines currently have vegetated wetland shorelines or beaches. For these marsh restoration projects, where no sand or sediment is added or removed, no regulatory permit may be needed, reducing both cost and time (3).

Hybrid Approaches

In locations with greater exposure to waves, it may still be possible to maintain a mostly natural shoreline with structural additions like near and offshore breakwaters, sills, and low profile rock groins (3). While the purpose of bulkheads and revetments is to reflect or absorb wave energy, sills, breakwaters, and low rock groins are placed within the intertidal zone, or beyond the low tide mark, to enhance sand buildup along the shoreline.

Living Shorelines Approach

During the mid-1980s, “soft” shoreline stabilization alternatives were referred to as “nonstructural shore erosion control” which incorporated many elements of today’s “living shoreline” techniques (2). Hence, living shoreline approaches could be any kind of shoreline erosion control technique (nonstructural and hybrid) as long as there was a “biological” component to the erosion control methods.

“Living shorelines” are an increasingly popular approach to erosion control that uses strategically placed plants, stone, and sand to reduce wave action, conserve soil, and provide critical shoreline habitat. Living shorelines often stand up to wave energy better than solid bulkheads or revetments. Living shoreline treatments are designed with the intention of maintaining or minimally disrupting normal coastal processes, such as sediment movement along the shore and protection and restoration of wetlands (2).

The Jefferson Patterson Park Museum (2) summarizes many benefits of living shorelines. For example, a variety of living shoreline treatments is possible in different situations. In subtidal waters, researchers are experimenting with stone or oyster shell breakwaters which are installed and then seeded with oyster spat to create living oyster reefs. In another study, scientists are introducing submerged aquatic vegetation (SAV) that can enhance water quality, further dampen wave energy, and provide food and cover for a variety of wildlife. Although a spectrum of living shoreline treatments is possible, the most inexpensive technique is to plant marsh grass on eroding shorelines. This can be done along unvegetated, but protected shorelines with limited wave action or boating activity. The marsh vegetation reduces erosion in several ways. They form a dense, flexible mass of stems that help dissipate wave energy as water moves through the marsh. As the wave energy decreases, sediment transported from shallow waters is deposited in the marsh causing build-up or “accretion” of the shoreline. The root matter from the plants forms dense root-rhizome mats building marsh elevation. This is especially important during the winter when plant stems provide much less resistance to waves. While marsh grass alone can control erosion along very low wave energy shorelines, structural support is needed to maintain a marsh in areas where fetch exposure exceeds 0.5 mile.

Effects of Living Shoreline Approach - Benefits and Drawbacks

Even though the primary aim of hardened shorelines is to provide protection from storms, the concern of the authors is that more homeowners in coastal areas are choosing to harden their shorelines even when they are in medium or low-energy areas (fewer problems compared to homeowners in high-energy regions). It is imperative that these homeowners realize that there are many benefits in choosing living shoreline approaches in these areas rather than bulkheads or ripraps.

Benefits

Recent studies have shown that hardened shorelines (bulkheads, rock revetments) have a lower abundance of bottom-dwelling organisms offshore and lower numbers of juvenile fish and crabs when compared to shorelines with vegetated marsh (3). Seitz et al. (4) concluded that benthic abundance and diversity were higher in habitats adjacent to natural marsh than those adjacent to bulkheaded shorelines, and abundance and diversity were intermediate in riprapped shorelines. Predator density and diversity tended to be highest adjacent to natural marsh shorelines, and density of crabs was significantly higher in natural marshes than in bulkheaded habitats, suggesting a crucial link between marshes, infaunal prey in subtidal habitats, and predator abundance (4). This is of great importance as miles of Maryland and Virginia shorelines are hardened each year, thereby increasing the vulnerability of shorelines to storm damage and loss of valuable habitat for fish, crabs, and waterfowl (5).

Other major benefits of living shorelines include lower construction costs, maintaining a link between aquatic and upland habitats, restoring or maintaining critical spawning and nursery areas for fish and crabs, maintaining natural shoreline dynamics and sand movement, reducing wave energy, absorbing storm surge and flood waters, and filtering nutrients and other pollutants from the water (6).

Drawbacks

While there are many benefits associated with living shorelines, they are not effective in all conditions, especially in high energy environments (6). Other drawbacks include low numbers of knowledgeable marine contractors and the lack of information on the science behind the effectiveness of living shorelines for different types of shores and under different energy regimes and storm conditions (6).

RESULTS AND DISCUSSION

Over the past 20 years, RC&D along with the Maryland Department of Natural Resources (DNR) Office of Shoreline Erosion Control Program, were involved in 258 shoreline erosion control projects (Table 1), worth approximately $8.9 million, in 10 counties of Maryland (Table 2). Projects were constructed on both public and private properties, implemented mostly in areas with limited fetch and low-to-medium exposure.

Research carried out by RC&D indicates that these shoreline protection control projects have benefited the waters of our rivers and streams, and have helped the coastal environments of Maryland. These shoreline erosion control projects have helped protect 117,208 linear feet of shoreline, with the highest in Talbot County (Table 2). Using the linear footage of shorelines saved, we can determine the amount of sediment not eroded and lost (Table 2) using an estimate of the long-term rate of linear retreat of the

Type of Project	Number of Projects
Breakwater	22
Edging	21
Groins	131
Sills	55
Combination Projects*	27
Others (Planting and Stream bank restoration:	2

*Combination projects include the following:
a) Groins + Sills
b) Groins + Edging
c) Sills + Breakwaters
d) Sill + Edging

Table 1. *Summary of living shoreline projects based on project type*

Counties of Maryland	Number of Projects	Total Project Length (ft)	Sediment saved (tons y-1)	N Saved (lbs y-1)	P Saved (lbs y-1)
Calvert	22	8,694	5,826	4,634	3,047
Caroline	14	7,005	2,645	1,983	1,304
Cecil	5	1,369	421	307	202
Charles	6	3,600	2,320	2,149	1,413
Dorchester	28	10,581	2,737	2,124	1,396
Kent	28	11,714	3,863	2,931	1,927
Queen Anne’s	58	34,791	17,941	16,030	10,540
Talbot	91	37,605	13,695	11,316	7,441
Wicomico	4	1,514	267	233	153
Worcester	2	335	162	129	85
Total	**258**	**117,208**	**49,877**	**41,836**	**27,508**

Table 2. *Merits of living shoreline projects in coastal counties of Maryland in the past 20 years*

shoreline due to shore erosion and the present bank height. Multiplying these factors together yields an estimate of volumes of sediment that are prevented from entering a waterway due to the completion of the vegetative shoreline stabilization project at the property; the range is from 162 tons annually in Worcester County to >16 thousand tons y^{-1} in Queen Anne's County. Previous studies of historic shore erosion rates on the Chesapeake Bay in Maryland (7,8) have shown that the shore is eroding at an average rate of 1-2 ft y^{-1}.

Nitrogen and Phosphorus Saved

With the knowledge gained from the amount of sediments saved and quantitative relationships in Ibison et al. (9), we calculated the amount of nitrogen (0.73 pounds per ton of soil) and phosphorus (0.48 pounds per ton of soil) prevented from entering the waterways (Table 2) via shoreline (bank) erosion. Ibison et al. concluded that the nutrient loading rates from shoreline erosion were much higher than agricultural nutrient loading due to the large volumes of soil (sediments and their associated nutrients) lost in shoreline erosion and added directly into the Bay. The nutrient concentrations arising from loading, on the other hand, are lower for shorelines than agricultural runoff because in the case of agricultural land, the underlying soil horizons remain relatively undisturbed and do not contribute to downstream nutrient loading (9).

One of the other major benefits of the living shoreline technique of shoreline erosion control projects completed by RC&D is the creation/preservation of wetlands (Table 3). Total acreage exceeds 2.3M ft^2 in created wetlands and over 200,000 ft^2 of protected wetland.

County	Wetland created (ft^2)	Wetlands protected (ft^2)
Calvert	209,048	0
Caroline	108,128	72,500
Cecil	37,043	0
Charles	127,610	0
Dorchester	173,838	9,585
Kent	224,566	15,043
Queen Anne	711,981	0
Talbot	748,204	103,181
Wicomico	34,232	0
Worcester	1,920	0
Total	**2,376,570**	**200,309**

Table 3. *Area of wetland created/preserved by the living shorelines projects in the past 20 years in Maryland.*

CONCLUSION

In conclusion, the living shoreline projects that RC&D completed in the past 20 years have yielded the following benefits:

1. Stabilization of 117,208 linear feet of shorelines.
2. Reduction of sediment inputs (49,877 tons y^{-1}), presumably due to decreased wave action, delivered to waterways.
3. Creation of 2,376,570 ft^2 and preservation of 200,309 ft^2 of tidal wetland habitat.
4. Loading reductions of approximately 41,835 pounds of nitrogen and 27,508 pounds of phosphorus per year, respectively.

Thus, living shorelines approach is an effective shoreline erosion control strategy that has additional environmental benefits in its routine use.

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Evaluating Ecological Impacts of Living Shorelines and Shoreline Habitat Elements: An Example From the Upper Western Chesapeake Bay

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ABSTRACT

Living shorelines, or use of natural habitat elements in shoreline protection rather than hard shoreline armor, have been used in the Chesapeake Bay for decades due to anticipated habitat and water quality benefits. The goal of this work is to begin to quantify how quickly living shorelines assume "natural" ecological function. On the upper Western Shore of the Chesapeake Bay, macrofauna at control marsh sites and bulkhead sites slated for living shoreline installation were sampled before and after construction (before-after control-impact design). Species with higher densities at marsh than bulkhead sites prior to bulkhead removal (e.g., mummichog *(Fundulus heteroclitus)*, grass shrimp *(Palaemonetes pugio)*, and spot *(Leiostomus xanthurus)*) were expected to increase after living shoreline installation, and those with higher densities at bulkheads (e.g., white perch *(Morone americana)*) were expected to decrease. Two months after restoration, densities of mummichog, grass shrimp, and pumpkinseed *(Lepomis gibbosus)* had increased at the experimental site relative to the control marsh, though densities of some marsh species had not. Results suggest that certain species can respond almost immediately to installation of living shorelines. Results also suggest that incorporation of multiple structural habitat elements may expand the functional value of living shorelines. In a second study element comparing assemblage structure in several structural habitat types (riprap, oyster shell, vegetation, woody debris), vegetation served the greatest nursery function, oyster reef provided the greatest refuge for species like blue crabs, riprap hosted the greatest proportion of older life-history stages, and all four hosted different suites of species. Work to optimize living shoreline design relative to erosion control function is on-going in the management and engineering arenas. Similar efforts to correlate design elements to ecological function by the scientific and restoration communities will serve to maximize the benefits of living shorelines to estuarine biota.

INTRODUCTION

Hard shoreline armor, such as riprap revetments, bulkheads, and seawalls, has been used to protect soft estuarine shorelines for centuries. In some areas, more than half of the shoreline has been armored. For example, in San Diego Bay, armor makes up almost three-quarters of the shoreline, providing habitat for open-coast rocky intertidal species in the bay (1). Some of the sub-watersheds of the Chesapeake Bay are similarly armored (2).

Despite the widespread use of hard shoreline armor, only recently have questions begun to be addressed about its ecological impacts and roles (e.g., 1,3). As a result of this concern, the technique of "living shorelines," or the incorporation of natural habitat elements such as fringe marshes into shoreline stabilization, has been developed. This new technique is based on growing understanding of the value of marsh habitats (e.g., 4) and advances in the wetland restoration field that have refined restoration practices (e.g., 5, 6).

Though the benefits of natural and created marsh habitats have been quantified, and therefore the benefits of living shorelines relative to artificial armor expected, ecological impacts of installing living shorelines have not yet been quantified. Such quantification will help to justify use of living shorelines in place of armor, both in new shoreline protection and in replacement of existing armor with greener techniques. In addition, more information about ecological impacts will aid in the refinement of living shoreline techniques and designs, a field that is currently rapidly advancing.

The objectives of this study were threefold. First, we add to the discussion about ecological impacts of armor by comparing macrofaunal assemblages and habitat characteristics at armored sites relative to natural marsh sites. Second, we begin to quantify impacts of living shoreline techniques by conducting a before-after control-impact assessment of a living shoreline installation on a macrofaunal assemblage. In this case, a natural fringe marsh that remained unchanged over the course of the study served as the control, and a bulkhead transformed into a living shoreline served as the impacted experimental site. Third, we provide information useful to living shoreline design by comparing macrofaunal assemblage characteristics (species densities, species diversity, and organism size) of four types of structural habitat (riprap, oyster shell, woody debris, and vegetation) that are often incorporated in the lower intertidal and subtidal elements of living shoreline restoration projects. We test the hypothesis that certain structural habitat types provide refuge, nursery, and other habitat for different types of species during different life-history stages. This information will help designers determine what types of structural habitat to include in living shoreline projects.

METHODS

Bulkhead Versus Natural Marsh

Macrofaunal assemblages, sediment grain size, and bottom slope were quantified at two Maryland sites slated for bulkhead removal and installation of living shoreline. The first, a 250-m section of bulkhead on College Creek, a tributary of the Severn River, was sampled in June 2006. The second, consisting of two 40-m sections of bulkhead on Norman's Creek, a tributary of the West River, was sampled in May 2006. At each site, a natural fringe marsh within 500 m was sampled as well. We acknowledge that the fringe marshes used for comparison were in highly fragmented systems, and therefore likely have different characteristics than marshes in pristine areas. However, these fragmented marshes are similar in scale to living shorelines, and were the closest marsh habitat to use for comparison.

At College Creek, three 20-m sections along the bulkhead and along a natural fringe marsh on the opposite side of the creek were sampled for a total of six collections. Beach seines (10 m long, 2 m high, 0.6-cm mesh) were used to collect fishes, crabs, and shrimp, which were identified to species, counted, and measured. Sediment cores (30 cm high, 3.8 cm^2 diameter) were collected at distances of 0, 4, and 8 m from shore along two cross-shore transects in each habitat type. Sediments were sieved into six size classes: gravel (#18 sieve), sands (#35, #60, #120, and #230 sieves), and silt/clay $<63\ \mu m$. Water depths were measured every 2 m along six cross-shore transects per habitat type from 0-24 m from shore or until water depth exceeded 120 cm. At Norman's Creek, sampling was the same except that two seine replicates were taken in each of two bulkhead sections and one marsh section for a total of six seines.

Densities of macrofaunal species were log-transformed to achieve normality and compared between bulkhead and fringe marsh using a two-way fixed effects ANOVA with habitat type and site as factors. Percent of sediment in three grain size categories ($>500\ \mu m$, sand ($63\text{-}500\ \mu m$), and silt/clay ($<63\ \mu m$)) were arc-sin square root transformed and compared between marsh and bulkhead sites with two-way ANCOVAs (habitat type and site as factors) with depth as a covariate. Bottom slopes and intercepts at the shoreline were compared using t-tests following Zar (7).

Before-After Comparison

Removal of bulkhead and installation of the living shoreline at College Creek took place in June-July 2006. Unfortunately, construction at the Norman's Creek site was delayed until spring 2007, after submission of this work. Post-construction macrofauna were sampled at College Creek in September 2006, two months after installation following the same procedures as above. The same sections used in June at the natural marsh were sampled again and serve as the controls in the before-after-control-impact study design. Sections of the living shoreline as close to the original bulkhead sites as possible were sampled. Before-after changes in species densities were compared for the two habitat types (control marsh vs. bulkhead/living shoreline) with t-tests (8).

Structural Habitat Element Comparisons

Macrofauna were compared in blocks of habitat of five types: riprap, oyster shell, woody debris, vegetation, and bare sediment deployed at two locations in the Rhode River, located between the Severn and West Rivers on the Western Shore of the Bay. Eight blocks of each habitat type, 4 small (0.25 m^2) and 4 large (0.75 m^2), were placed at a mean 30 cm depth with tops exposed at mean low water. Riprap blocks of the small size category were created by stacking 10 granite rocks to mimic a low-intertidal sill. Small oyster shell blocks were created with about 200 shells. Small woody debris blocks consisted of three 50-cm long branches staked together. Vegetation blocks were artificial mimics of seagrass, created according to methods described elsewhere (9) with polypropylene ribbon (30 cm long, 5 cm wide) tied to mesh in a density of 2000 "shoots" per m^2. Large blocks of each habitat type were created by placing three small blocks together.

Entire habitat blocks were sampled using 1.5 m x 0.5 m metal drop traps (with a metal dividing sheet inserted in the trap for small patches) deployed by two people, and all fishes, crabs, and shrimp present were collected by sweeping out the drop trap area, counted and measured. Molt stage of blue crabs was also identified. Blocks were deployed in March 2001 and sampled once per month from April to September 2001. To test whether certain habitat types had species diversity (Simpson's index) or higher densities of each species than others, log-transformed densities in the different habitat types, block sizes, and months were compared using a three-factor (fixed effects) repeated measures ANOVA. For species with significant habitat type effect, Tukey post-hoc tests were used to test for differences among specific habitat types. To compare nursery function of each habitat type, organism size within species were also compared among habitat type. Organism size, because all species were not present during all months, could not be analyzed with repeated measures ANOVA which requires full replication. As a result, mean individuals sizes were compared, depending on occurrence of the species, with one-, two-, three-, or four-way ANOVAs with habitat type, size, month, and site as factors.

RESULTS

Bulkhead vs. Natural Fringe Marsh

Depth and Slope

The shallowest depths available to macrofauna at College Creek and Norman's Creek bulkheads were much deeper than those available at marshes. At College Creek, when measured at mean low water, shallowest depths at the base of the bulkhead were 60 cm. At Norman's Creek, shallowest depths were 30 cm (Fig. 1). Though shoreward (most points were deeper at bulkheads), slopes did not differ between bulkheads and marshes (p>>0.05).

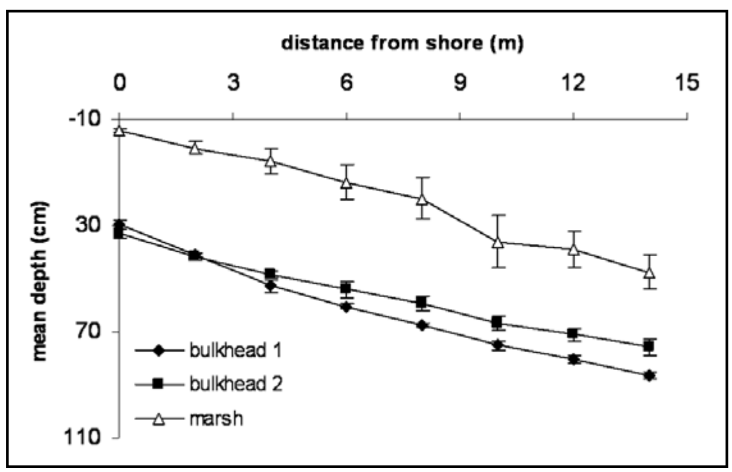

Figure 1. *Water depth profiles at one fringe marsh and two bulkhead (BH) sites at Norman's Creek. Means ± SE are plotted (n=6 for all data points). The College Creek site had a similar pattern, though depth at the bulkhead was deeper (60 cm).*

Sediment Grain Size

Sediment grain size was larger at marshes than at bulkheads due to differences in the largest and smallest grain sizes. The proportion of the sample composed of large particles was greater at marsh than bulkhead sites, (ANOVA: effect of habitat type: $F_{1,25} = 3.9$, $p = 0.05$). Proportion of sand did not differ between habitat types (ANOVA: $F_{1,25} = 1.6$, $p = 0.22$). Proportion of silts and clays was greater in bulkhead than marsh habitats at both sites (ANOVA: $F_{1,25} = 6.4$, $p = 0.02$); Fig. 2). Patterns were the same at both sites (effect of site: $p>0.1$, and no significant interaction terms). Depth did not affect proportion of any sediment size class ($p>0.1$ for all analyses).

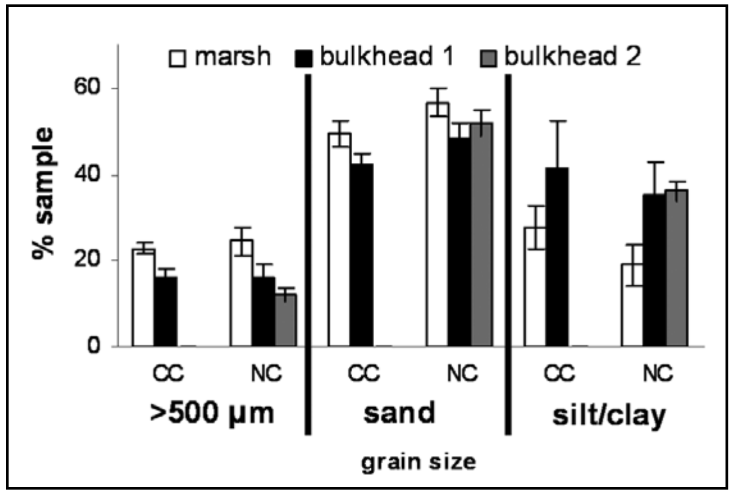

Figure 2. *Sediment grain size distributions at one marsh and two bulkhead sites at College Creek (CC) and Norman's Creek (NC). Mean (± SE) proportions are plotted (n=6 for all data points). Sand (medium and fine) is defined as 63-500 µm. Silt/clay particles were <63 µm.*

Macrofauna

In "before" samples, 18 macrofauna species were collected in marsh seine samples and 14 species at bulkheads. Marsh species never collected at bulkheads included pipefish (*Syngnathus fuscus*), sticklebacks *(Speltes quadracus)*, sheepshead minnow *(Cyprinodon variegates)*, and naked goby *(Gobiosoma bosci)*. No species were present only at bulkhead sites. Mean number of species was not significantly higher at natural marsh than bulkhead sites; however, more species had higher densities at marsh sites (Table 1). Three species had significantly or marginally significantly higher densities at marsh sites, spot *(Leiostomus xanthurus)*, mummichog *(Fundulus heteroclitus)*, and grass shrimp *(Palaemonetes pugio)*). Two species, white perch *(Morone americana)* and anchovy *(Anchoa mitcheli)*, were more abundant at bulkheads.

Species	Bulkhead mean density (# m^{-2})	Marsh mean density (# m^{-2})	Effect of habitat $F_{(1,8)}$	Effect of habitat p-value	Site* hab F	Site* hab p-value
* Grass shrimp, *Palaemonetes pugio*	0.001	0.158	3.42	0.092	2.40	0.16
** Mummichog, *Fundulus heteroclitus*	0.009	0.128	8.46	0.020	0.15	0.71
Pumpkinseed, *Lepomis gibbosus*	0.087	0.173	1.99	0.196	4.79	0.060
Stickleback, *Apeltes quadracus*	0	0.060	1.20	0.197	at CC site only	
** Spot, *Leiostomus xanthurus*	0.011	0.040	9.29	0.016	5.60	0.045
Chain pickerel, *Esox niger*	0.002	0.015	1.6	0.185	at CC site only	
Total # spp.	0.043	0.054	1.03	0.339	1.05	0.34
Striped killifish, *Fundulus majalis*	0.002	0.005	1.56	0.247	1.55	0.25
** Anchovy, *Anchoa mitchelli*	0.015	0.003	7.54	0.025	11.06	0.010
Silverside, *Menidia menidia*	0.030	0.012	1.72	0.226	0.93	0.36
** White perch, *Morone americana*	0.088	0.003	12.09	0.008	10.90	0.011
Menhaden, *Brevoortia tyrannus*	0.642	0.001	1.01	0.344	1.01	0.34

Table 1. *Differences between habitat types in densities of the most abundant macrofauna. Species are organized in order of difference between marsh and bulkhead sites. ANOVA statistics are presented for the effect of habitat (hab) type and site*habitat interaction in two-way ANOVAs. ** and * = statistically (p<0.05) and marginally (p<0.10) significant differences between habitat types, respectively. BH = bulkhead; CC=College Creek. Density values have not been corrected for seine gear efficiency.*

Before vs. After Sampling: Impact Of The Living Shoreline At College Creek On Macrofauna

Because "after" sampling occurred late in the summer, after peak abundance of organisms which typically occurs in July in this system, an overall decline in species richness and densities occurred, leading to negative after-before changes (Fig. 3). Many of the species collected in "before" sampling, such as white perch, chain pickerel, and stickleback, were not present at either habitat type after construction. As a result, analysis of the impact of restoration on these species will have to wait until summer 2007.

For species present in both "before" and "after" samples, those that were initially more abundant at natural fringe marshes than bulkheads were expected to increase at living shorelines relative to marshes, as was overall species richness. Though this expectation was not met for overall richness (t = 0.7, p = 0.51, Fig. 3), it was met for three species more abundant initially at marshes and present in high enough densities in "after" samples to measure (Fig. 4). Two of these species, the grass shrimp and mummichog, increased in density over time at the living shoreline while decreasing at the marsh. One species, pumpkinseed, decreased less at the living shoreline than at the marsh (indicating a relative increase). A fourth species, silverside, did not change more at the living shoreline than the marsh (Fig. 4).

***Figure 3**. Mean (with SE) number of species per m² at each habitat type (living shoreline and marsh) "before" vs. "after" transformation of bulkhead to living shoreline in College Creek.*

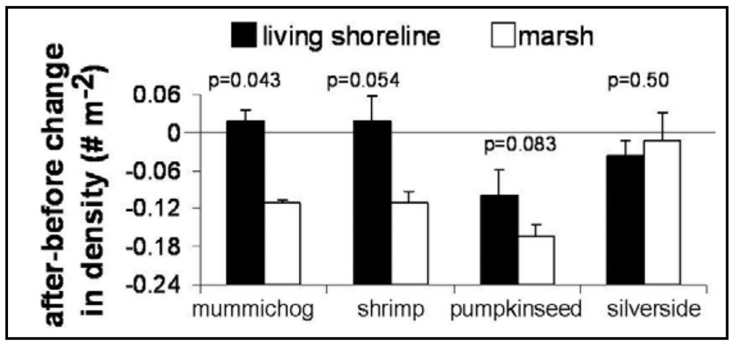

***Figure 4.** For the four most abundant species, "before" vs. "after" change in mean density at the living shoreline and marsh in College Creek. Positive values (above the zero line) indicate increase in density over time at a particular site; negative values, a decline over time.*

Impact of Habitat Type on Species Assemblage

Nineteen fishes and three invertebrates were sampled in the five habitat types deployed in the Rhode River. Oyster reef had highest total densities (mean = 52 individuals m^{-2}) and highest densities of the relatively cryptic and benthic skilletfish, blennies, gobies, and mud crabs (Table 2). Vegetation mimics (total density 13 individuals m^{-2}) had the highest densities of the relatively mobile mummichog, pipefish, sticklebacks, and grass shrimp. Only one species, the non-native green sunfish, had highest densities in riprap, a habitat with total mean densities of 13 individuals m^{-2}. No species had highest densities in woody debris, which had the lowest overall mean density (9 individuals m^{-2}), only above bare sediment (7 individuals m^{-2}).

Blue crabs occupied structural habitat in higher densities than bare sediment, but there was no difference among the structural habitat types in density, suggesting this species is a structural generalist. However, blue crabs in late pre-molt, molting, and post-molt (soft) stages differed in use of habitat types, with highest values in oyster reef (51% of crabs molting) and riprap (40%), and lower values in vegetation (34%), woody debris (29%), and bare sediment (12%) (chi-square test: $p<0.001$) Overall, total proportion of molting crabs collected the study was high (35.4%), suggesting that shallow-water structural habitats serve as a refuge for molting blue crabs.

Six species had significantly smallest body sizes in vegetation, including all three invertebrates and three of six fishes abundant enough for comparisons. Two additional fishes, pipefish and stickleback, were found almost exclusively in vegetation. Three species had largest sizes in riprap (Table 3).

DISCUSSION

While study of additional living shoreline projects is needed to improve sample size, this initial before-after control-impact (BACI) study suggests that some species' responses to shoreline restoration can be almost immediate. Some species responded within two months, increasing in abundance at the living shoreline site after installation relative to the marsh. The initial colonizing individuals in this study were mostly adults due to timing of construction, which was post-recruitment season for most species. Analysis of use of the living shoreline by juveniles during the next recruitment season will provide additional information about the role of this habitat for the assemblage.

Species	Veg	Rip-rap	Oyster	Wood	Bare sed.	$F_{4,30}$
Sp diversity	**1.1**[a]	**1.1** [a]	0.4 [b]	0.8 [c]	0.1 [c]	6.6
Goby	3.4 [a]	4.1 [a]	**41.0** [b]	2.2 [a]	0.1 [c]	187
Mud crab	387 [a]	121 [b]	**599** [c]	110 [b]	11 [d]	60
Blenny	0.2 [a]	0.6 [a]	**2.6** [b]	0.1 [a]	0 [c]	63
Skilletfish	0.4 [a]	1.1 [b]	**3.9** [c]	1.7 [b]	0.1 [a]	8.7
Mummichog	**2.5** [a]	0.9 [b]	1.3 [b]	1.4 [b]	0.2 [c]	8.6
Stickleback	**1.6** [a]	0.01 [b]	0 [c]	0.3 [d]	0 [c]	16
Gr. shrimp	**247** [a]	87[ba]	98 [b]	98 [b]	4 [c]	31
Pipefish	**1.9** [a]	0.05 [b]	0.9 [c]	0.1 [b]	0.1 [b]	12
Gr. sunfish	1.0 [a]	**3.0** [b]	2.3 [c]	0.4 [d]	0 [e]	21
Blue crab	**0.8** [a]	**0.5** [a]	**0.4** [a]	**0.7** [a]	0.1 [b]	4.8
Silverside	2.1	3.5	1.6	3.1	5.0	1.2

Table 2. *Densities (# m^{-2}) of major assemblage members in the five habitat types, and effect of habitat type (riprap, vegetation, oyster, woody debris), a between-subjects fixed effect factor, in three-factor repeated measures ANOVAs run for each species. F-statistics and degrees of freedom are presented. All p-values were <0.001 except silverside, for which p=0.333. Species diversity = Simpson's species diversity index. Superscripted letters indicate statistically similar values determined by Tukey* post-hoc *tests. Habitats with highest densities are in bold.*

The reasons for the relative increase in certain species' densities at the transformed site (bulkhead to living shoreline) can be linked to aspects of the bulkhead habitat. In this study, bulkhead offered different habitat characteristics than fringe marshes and were used by different species. The amount of shallow area available to fauna was reduced at bulkhead sites. At one site, College Creek, the shallowest areas available were 60 cm deep before the restoration, which is deeper than what is considered a refuge from subtidal predators (10). Bulkheads also unexpectedly had more small sediments. Because bulkheads reflect energy, they were hypothesized to lose more fine sediments than marshes, which slow wave energy and result in deposition. At both sites in this study, however, bulkhead sites were characterized by a hard-packed clay layer only a few cm below the sediment-water interface. Though infauna were not measured in this study, hard clay layers are generally impenetrable by infauna (e.g., 11).

Species	Veg	Rip-rap	Oyster	Wood	F-statistic	p-value
Mummich.	52 [a]	68 [b]	60 [c]	62 [c]	$F_{3,139}$ =3.4	0.03
Mud crab	7.7 [a]	9.1 [b]	8.9 [b]	8.0 [c]	$F_{3,219}$ =6.5	0.001
Gr. shrimp	29 [a]	35 [b]	30 [c]	31 [c]	$F_{3,239}$ =2.6	0.05
Goby	33 [a]	37 [b]	42 [c]	36 [b]	$F_{3,136}$ =16	0.001
Skilletfish	29 [a]	36 [b]	40 [c]	36 [b]	$F_{3,39}$ =4.8	0.01
Blue crab	47 [a]	55 [b]	64 [c]	70 [d]	$F_{3,31}$ =3.4	0.03
Blenny	51 [a]	50 [a]	50 [a]	51 [a]	$F_{3,46}$ =0.01	0.99
Gr. sunfish	49 [a]	51 [a]	48 [a]	45 [a]	$F_{3,27}$ =2.0	0.13
Silverside	50 [a]	46 [a]	42 [a]	47 [a]	$F_{3,44}$ =0.9	0.46

Table 3. *Mean size (mm) of major assemblage members in the five habitat types, and effect of habitat type (riprap, vegetation, oyster, woody debris), a fixed effect factor in multi-way ANOVAs run for each species. F-statistics, degrees of freedom (df), and p-values are given. Error df differs among species due to presence in different numbers of habitat blocks. Superscripted letters indicate statistically similar values determined by Tukey* post-hoc *tests.*

Results from this study also suggest that living shoreline designs should include multiple habitat elements to maximize diversity and expand their functional value. In this study, oyster reef served as the greatest refuge for molting blue crabs. Vegetation served more of a nursery function than the other habitat types, more often occupied by the smallest size classes, a result noted in other studies (12). Riprap had the largest individuals of several species, perhaps playing a refuge role for mating individuals. Future study to compare living shorelines with diverse habitat elements (such as the living shoreline at College Creek, which includes oyster shell, seagrass, emergent vegetation, and riprap) to those with just emergent vegetation will help to further address this question.

Many additional questions pertaining to impacts of living shoreline design on ecological function remain. For example, some designers advocate installing as many windows (also called tidal gates) as possible in sill living shoreline projects to allow maximum access to mobile fauna, without compromising erosion control function. Research is needed to identify how large and how numerous these windows should (from an ecological viewpoint) and can be (from an engineering and erosion control viewpoint). These improvements in design will benefit not just the Chesapeake Bay, but other estuaries to which living shoreline technology continues to expand.

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Landscape-Level Impacts of Shoreline Development on Chesapeake Bay Benthos and Their Predators

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ABSTRACT

Within the coastal zone, waterfront development has caused severe loss of shallow-water habitats such as salt marshes and seagrass beds. Little is known about the impact of habitat degradation and ecological value of subtidal shallow-water habitats, despite their prevalence. In coastal habitats, bivalves are dominant benthic organisms that can comprise over 50% of benthic prey biomass and are indicative of benthic production. We examined the effects of shoreline alteration in shallow habitats by contrasting the benthos of the subtidal areas adjacent to natural marsh, riprap, and bulkhead shorelines in three Chesapeake Bay subestuaries that differ in the level of shoreline development. In all cases, benthic abundance and diversity were higher in subtidal habitats near natural marsh than those near bulkhead shorelines; however, abundance and diversity were intermediate near riprap shorelines, and appeared to depend on landscape features. In heavily impacted systems such as the Elizabeth-Lafayette system, benthos adjacent to riprap was depauperate, whereas in less-developed tributaries (York River and Broad Bay), benthos near riprap was abundant and was similar to that near natural marsh shorelines. Furthermore, predator density and diversity were highest adjacent to natural marsh, intermediate near riprap, and low near bulkhead shorelines. There is thus a crucial link between natural marshes, benthic infaunal prey in subtidal habitats, and predator abundance. Restoration of living shoreline habitats is likely to have benefits for adjacent benthos and their predators. Protection and restoration of marsh habitats may be essential to the maintenance of high benthic production and consumer biomass in Chesapeake Bay. Moreover, the collective impacts of the system-wide, landscape-level features are felt from the benthos through higher trophic levels.

INTRODUCTION

Marine systems are suffering losses to biodiversity from overexploitation, introduction of invasive species, global climate change, and most importantly habitat degradation and loss. Habitat degradation is the largest threat to biodiversity in terrestrial systems and one of the largest threats in marine systems (1). The disturbing effects of biodiversity loss on other ecosystem services have been noted: "…rates of resource collapse increased and recovery potential, stability, and water quality decreased with declining diversity" (2). Causes of marine habitat degradation are many, but here we focus on effects of shoreline development and the relationships with local landscape features. With increases in population abundance and the tendency for people to live near the water (approximately 60% of the U.S. population resides within 100 km of the coast; 1), shoreline development has been increasing at an alarming rate. For example, within the Chesapeake Bay region, the population within the watershed has tripled in the last century (3). Along with this elevation in population, the need for homeowners and businesses to protect against erosion has also increased, which comes at the detriment of marshes and other natural habitats. Estuaries are the most modified and threatened of aquatic environments (4), thus changes in associated marine systems due to habitat modifications can be great in estuaries.

Natural marshes serve important ecosystem functions including protecting uplands from wave action, filtering runoff, cycling nutrients, and housing multiple species of macrofauna. A diverse benthic community resides within and adjacent to marshes, and these species provide essential habitat services (5).

Nutrient cycling, filtering of water-column plankton, and serving as prey for predators are among the most important functions of benthic communities. Increased abundance within these communities may increase secondary and tertiary productivity of the system (6).

The Chesapeake Bay is a drowned river valley with 50% of the bay at <6.5 m in depth (7). Consequently, the shallow-water habitats, particularly the polyhaline regions, are prominent and important (8) and have been designated with better "benthic condition" than deeper areas that may go hypoxic (9). Moreover, the shallow (<1.5 m), subtidal habitats near natural marshes often support high biomass and diversity (8). Within the shallow-water zone, shoreline type further influences the abundance and diversity of organisms that reside in adjacent subtidal habitats.

Shoreline alteration and benthic community resources have been studied at large spatial scales to examine regional patterns of land use and consequent impacts on benthos and predators. In a system with extensive bulkheading (Linkhorn Bay), there was low benthic diversity and abundance (10). At a regional scale, shoreline marshes were deemed important for bivalves (11). These benthic patterns likely translate to higher trophic levels, as predators of the benthos were negatively affected by altered shorelines (12, 13, 14).

We would expect higher-trophic-level predators (e.g., blue crabs) to be affected by benthos because their diet may include up to 50% bivalves (15). Moreover, crab densities are increased where prey densities are elevated (i.e., bottom-up control of predators occurs) (16). We therefore examined the effects of shoreline development upon the benthic community and epibenthic predators in shallow subtidal areas of the Elizabeth-Lafayette River system, the York River, and Broad Bay (in the Lynnhaven River system).

The tributaries within Chesapeake Bay vary in degree of shoreline development, which may influence the relative abundance of benthos and predators within each system. In the York River, which is about 50 km long, ~86% of the distance along the shoreline is natural marsh, whereas ~6% is developed (riprap, bulkhead, groin, or miscellaneous) and ~8% is upland (17). The Lynnhaven system, including Broad Bay (about 2.5 km long), has a large percentage of shoreline with natural marsh (~78.4%), 11.2% developed with bulkhead only, and 5.2% developed with only riprap (P.G. Ross, pers. comm.). In contrast, the Elizabeth-Lafayette system (about 8 km long) is highly impacted, with over 50% of its shoreline developed, and it has been described as "an urban, highly developed region… [where] few shoreline miles remain unaltered" (18). Thus, these three systems vary in shoreline development (Fig. 1) and provide an interesting contrast for examining impacts of shoreline development on benthos and predators. Our unique contribution is a synthesis of the importance of landscape features and variations in the degree of shoreline development among the three different systems that contribute to changes in benthos and predators.

METHODS

Using a random points program for ArcMap software, for each river we chose 6-15 independent, subtidal sites in marsh creeks adjacent to (<5 m from shore) natural *Spartina* marshes, 6-8 sites adjacent to bulkhead (vertical seawall) structures, and 5-8 sites adjacent to riprap (rocks placed on a slope for erosion control) shoreline structures. For each site, we chose areas with >50 continuous m of the shoreline type. We had replicates of each shoreline type in each river system and a different number of total sampling sites for the Elizabeth-Lafayette system (18 sites), the York River (16 sites), and Broad Bay (31 sites). Trawling was conducted to collect predators at all sites in the York River and Elizabeth-Lafayette and 10 of the 31 sites in Broad Bay.

Bivalves were quantified using suction sampling gear, which samples 0.17 m^2 surface area and penetrates 40-60 cm into the sediment. This is essential for accurate estimation of densities of large bivalves that dwell 30-40 cm deep and are sparse (19). On the suction apparatus, we used a 1-mm-mesh

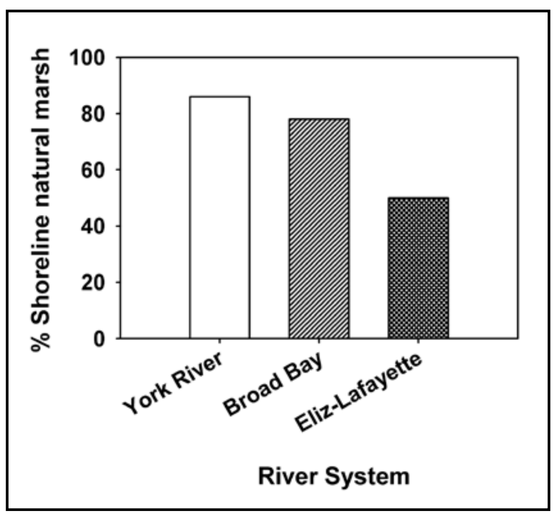

Figure 1. *Approximate percentage of shoreline comprised of natural marsh during surveys from 1999-2006.*

bag and sieved contents on a 1 mm-mesh screen. All bivalves retained on the screen were identified to species, measured, and frozen for biomass estimates. At each site, we measured physical variables including water temperature, salinity, dissolved oxygen (DO), turbidity, water depth, and sediment grain size. Since systems were generally evaluated separately, one-way ANOVAs using shoreline treatment as the factor for each separate river system were performed. The exception to this rule was one instance when we pooled predator data for the York and Lafayette systems for a 2-way ANOVA with river and shoreline as factors.

RESULTS

Physical Variables

All three systems were generally similar in salinity, DO, and sediment type. In the York River, salinity was 18-19, in the Elizabeth-Lafayette it was 16-19, and in Broad Bay it was 19-22. All of these shallow-water systems were normoxic, and sediments were muddy sand or sand in general.

The Benthic Community – York, Elizabeth-Lafayette, and Broad Bay

The benthic community included bivalves such as *Macoma balthica*, *M. mitchelli*, and *M. tenta*, the stout razor clam *(Tagelus plebeius)*, the hard clam *(Mercenaria mercenaria)*, as well as *Mulinia lateralis*, *Aligena elevata*, *Anadara* sp., *Gemma gemma*, and the angel wing clam *(Cyrtopleura costata)*. The most numerous clams were *M. balthica* and *T. plebeius*, which comprised 40% and 36% of all clams, respectively, in the Elizabeth-Lafayette system (8). We also collected several species of polychaetes, some phoronids, and small crustaceans.

In the York River, infaunal species density and diversity were significantly higher near natural marsh and riprap habitats than near bulkhead habitats, though near riprap, diversity and density were intermediate and not significantly different than natural marsh habitats (Fig. 2a,b). In the Elizabeth-Lafayette, total bivalve densities were greater near natural marsh than riprap or bulkhead (Fig. 3a). Bivalve diversity did not change appreciably with shoreline type (Fig. 3b). Densities of the deposit-feeding bivalve *M. balthica* were significantly different among shoreline types in the Elizabeth-Lafayette (Fig. 4a): densities were highest near natural marsh whereas densities near riprap were low and similar to those near bulkhead. For the suspension-feeding bivalve *T. plebeius*, there was no significant difference in densities among shoreline types (Fig. 4b).

In Broad Bay, bivalve abundance was higher near natural marsh and riprap than bulkhead, and this difference was marginally significant (Fig. 5a; ANOVA on log-transformed data). Bivalve species richness was higher near natural marsh and riprap compared to bulkhead shorelines, but this difference was not significant (ANOVA: df = 2, 31, F = 2.02, p = 0.150). Shannon-Wiener bivalve diversity was significantly greater adjacent to natural marsh and riprap than bulkhead shorelines (Fig. 5b; ANOVA on log-transformed data, Tukey test). In Broad Bay, densities of the facultative deposit-feeding bivalve *M. balthica* (Fig. 6a) and the suspension-feeding bivalve *T. plebeius* (Fig. 6b) did not differ significantly among shoreline types, though the highest densities occurred near riprap and natural marsh, while lowest densities occurred near bulkhead.

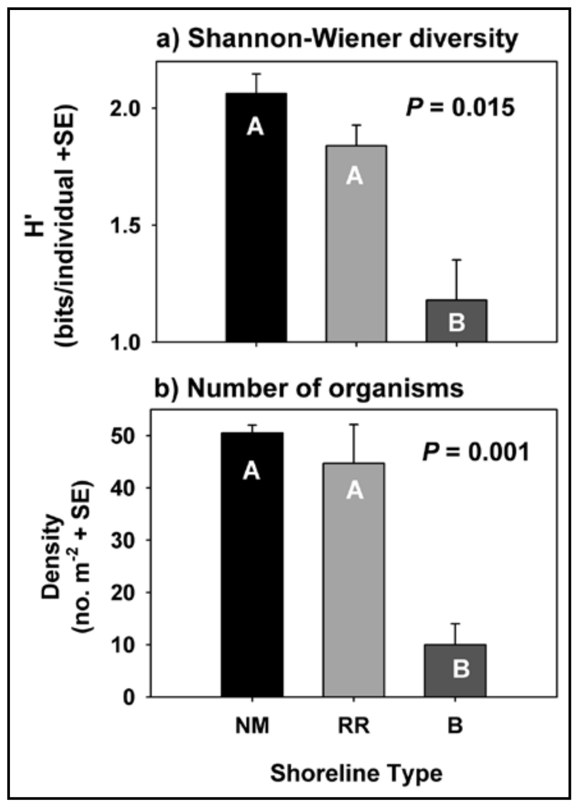

Figure 2. *(a) Mean number of organisms m^{-2} (+SE) and (b) mean Shannon-Wiener diversity (+ SE) of all benthic infauna in a subset (2-3 per habitat) of shallow subtidal sites adjacent to natural marsh (NM), riprap (RR), or bulkhead (B) shorelines in the York River. P-value from ANOVA listed. Different capital letters indicate significant differences (Tukey test, modified from 8).*

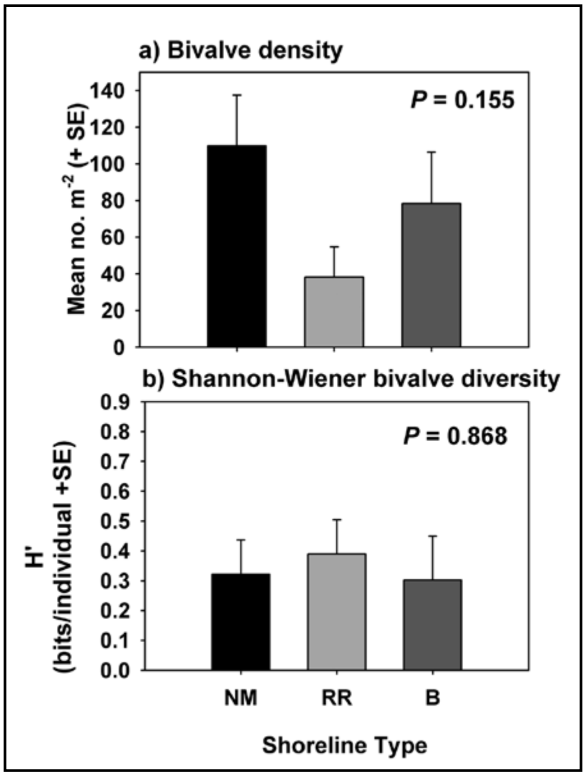

Figure 3. (a) Mean number of bivalves m^{-2} (+SE) and (b) mean Shannon-Wiener bivalve diversity per sample in habitats adjacent to natural marsh (NM), riprap (RR), or bulkhead (B) shorelines in the Elizabeth-Lafayette system (modified from 8).

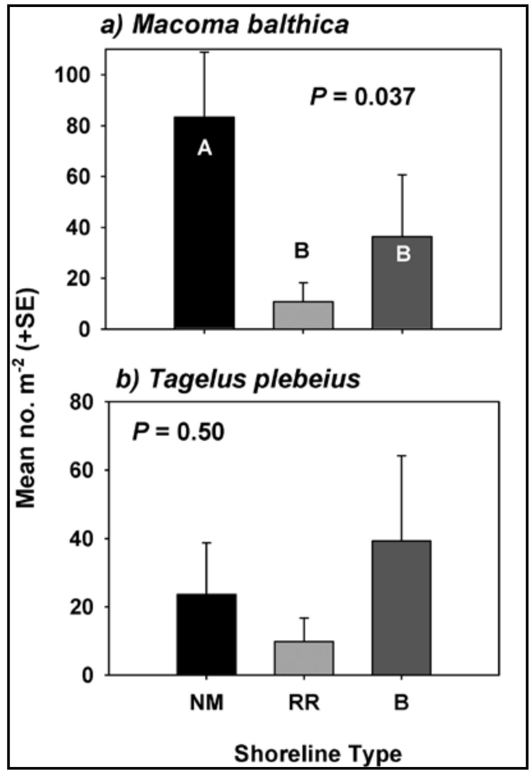

Figure 4. Mean number of clams m^{-2} (+SE) in habitats adjacent to natural marsh (NM), riprap (RR), or bulkhead (B) shorelines in the Elizabeth-Lafayette system for the bivalves (a) Macoma balthica and (b) Tagelus plebeius. Note that scales are different (modified from 8).

Predators – York, Elizabeth-Lafayette, and Broad Bay

In the York and Elizabeth-Lafayette systems, we collected many predators including spot *(Leiostomus xanthurus)*, croaker *(Micropogonias undulates)*, oyster toadfish *(Opsanus tau)*, silver perch *(Bairdiella chrysoura)*, summer flounder *(Paralychthys dentatus)* (predators did not include fish such as anchovies and silversides), as well as blue crabs *(Callinectes sapidus)*, spider crabs, and mud crabs. In the York River, the abundance of predators near natural marsh was slightly higher than that near riprap or bulkhead shorelines. This pattern held for both fish (Fig. 7a) and for total crabs (Fig. 7b), though these differences were not significant (Fish ANOVA: p = 0.592; Crab ANOVA: p = 0.628). In the Elizabeth-Lafayette, fish abundance did not change with shoreline type (Fig. 7a; ANOVA: p = 0.973). However, crab abundance was higher adjacent to natural marsh than riprap or bulkhead shorelines (Fig. 7b), though this difference was not significant (ANOVA: p = 0.359). In pooled data from both the York and Elizabeth-Lafayette river systems, crab densities were significantly higher near natural marsh than riprap or bulkhead shorelines (Fig. 7b; 2-way ANOVA with River and Shoreline as factors; Shoreline p = 0.033, Tukey test). However, fish did not show this significance with pooled data (Fig. 7a; ANOVA: Shoreline p = 0.876).

In our trawl samples in Broad Bay, we collected 12 species of fish as well as blue crabs *(C. sapidus)* at the ten sites. Similar to patterns in the York and Elizabeth-Lafayette rivers, abundance of predatory fish (i.e., not including anchovies and silversides) and crabs was greatest near natural marsh, intermediate near riprap, and lowest near bulkhead. Pooled data with fish and crabs were nearly significant (Fig. 7; ANOVA: P = 0.097) (Fig. 7).

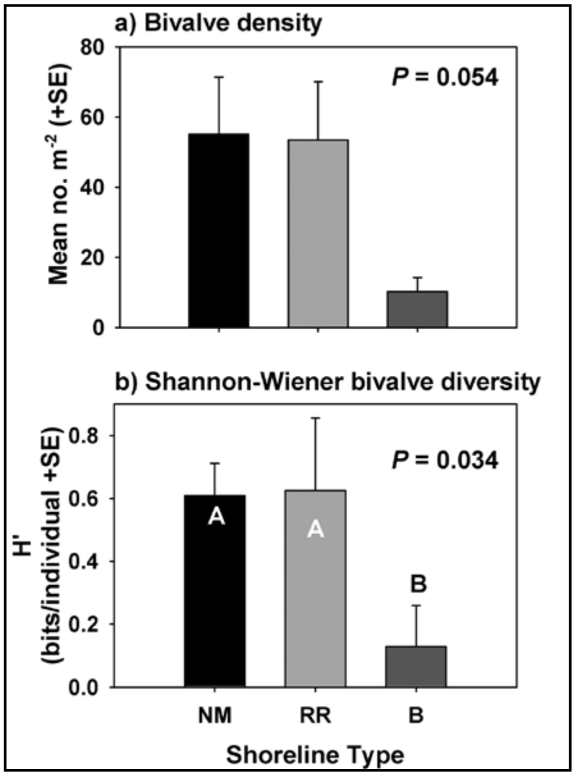

Figure 5. *(a) Mean number of bivalves m^{-2} (+SE) and (b) mean Shannon-Wiener bivalve diversity per sample in habitats adjacent to natural marsh (NM), riprap (RR), or bulkhead (B) shorelines in Broad Bay (modified from Lawless, in prep.)*

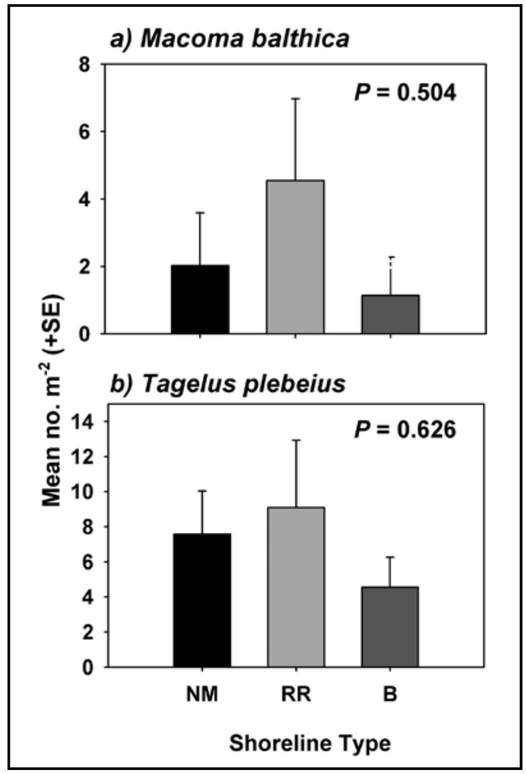

Figure 6. *Mean mean number of clams m^{-2} (+SE) in habitats adjacent to natural marsh (NM), riprap (RR), or bulkhead (B) shorelines in Broad Bay for the bivalves (a) Macoma balthica and (b) Tagelus plebeius. Note that scales are different (modified from Lawless, in prep.).*

DISCUSSION

Density and diversity of benthic bivalves were greatest adjacent to natural marsh habitats compared to riprap or bulkhead shorelines in all three systems studied, the York River, Elizabeth-Lafayette, and Broad Bay. The York River was the most natural of the three systems (86% natural marsh; 17). This system is less developed and larger (at 50 km long) than the Elizabeth-Lafayette (8 km long) or Broad Bay (2.5 km long) systems, and bivalve abundance and benthic community diversity were greater in *both* natural marsh *and* riprap than in bulkhead habitats. The communities adjacent to riprap were intermediate in abundance and diversity. We hypothesize that the York River system has much larger expanses of unaltered marsh habitat available to subsidize adjacent developed shorelines, and therefore riprap habitats are not as negatively influenced by development as those in more heavily developed systems. The Lynnhaven system is also relatively natural (78% marsh), and in Broad Bay the benthos adjacent to riprap was similarly intermediate in abundance and diversity. These data suggest that there may be some small level of development (i.e., <10%) that has no discernible negative impact. Again, the landscape features of the system allow deficient habitats to be re-populated by nearby communities. Populations next to bulkheads may also be re-populated by nearby natural marsh but may remain at low density and diversity because these habitats lack other essential features that occur in both natural marsh and riprap systems (e.g., delivery of nutrients or carbon from upland). In contrast, the Elizabeth-Lafayette system is highly developed (over 50% of shoreline developed; 18), and the overall density and diversity of benthic invertebrates was significantly lower in both riprap and bulkhead shorelines compared to natural marsh. The overall system is apparently so degraded that intermediate habitats (i.e., those near riprap) are not effectively re-populated by other habitats in the system.

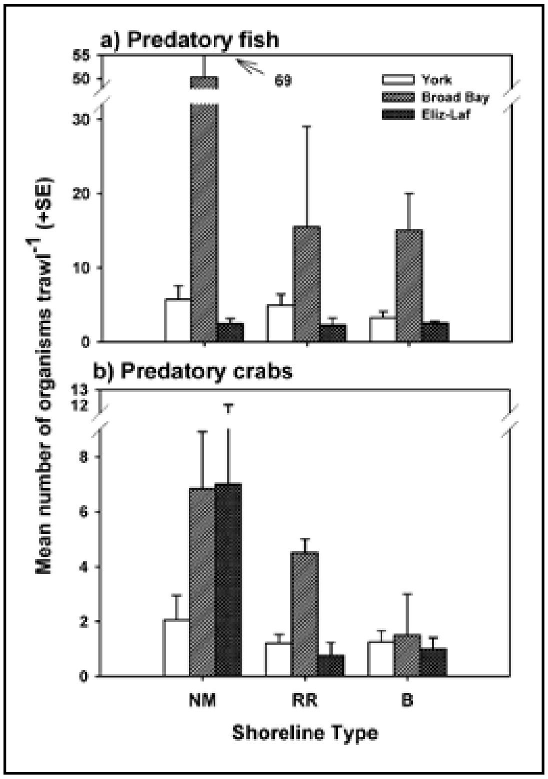

Figure 7. Mean number of predators (+ SE) per 20 m^2 area trawled in habitats adjacent to natural marsh (NM), riprap (RR), or bulkhead (B) shorelines in the Elizabeth-Lafayette, York River, and Broad Bay systems for (a) Predatory fish (i.e., not including anchovies and silversides that would not feed on benthos) and (b) Predatory crabs. Note that +SE for Broad Bay ends off of the visible scale at 68 fish trawl^{-1} (modified from 8 and Lawless, in prep.).

We suggest that the beneficial effects of the marsh may arise because the allochthonous input of carbon from marsh materials may be an important food source for benthos (20), particularly for deposit-feeding infauna (e.g., *M. balthica*). However, the important input of carbon from the marsh is reduced where shorelines are covered with riprap or bulkhead. This may also explain why organisms that are not deposit feeders (e.g., *T. plebeius*) are not affected by shoreline type, since they may rely on water-column food sources. Another possibility is that the alteration of the shoreline changes the hydrodynamics such that higher current flow impedes settlement of some benthic organisms. The only study of which we are aware that demonstrates negative effects of shoreline development upon the subtidal benthic community was one that examined the impact of toxics in CCA-treated wooden bulkheads (21). In our study, only some of the bulkhead shorelines used treated wood, so a negative impact of chemically treated wood could only partially explain our results.

Most developed shorelines in all three systems we studied not only had negative impacts on benthic infauna in subtidal habitats adjacent to the shoreline, but also had detrimental effects on higher trophic levels. In all cases the abundance of predators was highest near natural marsh. In the York River, predator abundance was intermediate near riprap shorelines. Conversely in the Elizabeth-Lafayette, fish predators were low adjacent to all habitats, whereas crab predators were only high near natural marsh but not near riprap. This suggests that the low predator densities may reflect the overall degradation of this system, or that the low to moderate densities of benthic prey associated with riprap are not high enough for predators to feed in those areas. In Broad Bay, densities of higher trophic levels were low near both riprap and bulkhead, which is more in line with the pattern in the highly degraded Elizabeth-Lafayette. Though the benthos in Broad Bay seemed to be subsidized somewhat by adjacent natural habitats, predators may search and feed in only the most productive benthic habitats, and thus are not found in the riprap habitats with slightly lower densities of infauna. A similar general pattern of predator and prey densities in all three systems suggests there is a functional relationship between predators and prey whereby predators may be concentrating in habitats with elevated prey densities (i.e., bottom-up control). We have previously shown evidence for bottom-up control of the blue crab by its principal prey (i.e., clams) in the York River (16), and the findings of this study also are consistent with bottom-up control. Although elevated densities of prey and predators in marsh habitats may have been caused by an independent factor, we suggest that reduced infaunal densities adjacent to developed shorelines diminished predator densities and likely diminished corresponding production of the system.

We have provided convincing evidence that a key link exists between salt-marsh habitat, food availability for predators, and predator abundance. Consequently, protection and restoration of salt-marsh habitats may be essential to the maintenance of high benthic production and consumer biomass in estuarine systems. The results herein provide strong evidence that restoration of marshes can be extremely important for adjacent benthic and epibenthic higher-trophic-level communities and suggest that "if you build it, they will come." This demonstration of the critical influence of marsh habitats on adjacent subtidal communities should be encouraging for those involved with the establishment of "Living Shorelines" that includes creation of marsh habitat.

ACKNOWLEDGEMENTS

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Shoreline Policy: Regulatory Overview

Photo credit: Karen Duhring, VIMS

Regulatory Process for Living Shoreline Implementation in Maryland

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ABSTRACT

Several pieces of federal and Maryland State legislation have granted federal, state, and local government authority over construction or alteration of the riparian and tidal areas of the shoreline. At the federal and state level, tidal wetland permits, licenses, and certifications in Maryland have been streamlined into a joint federal/state application. However, local grading and building permits may also be required. Therefore, property owners seeking to implement shoreline projects must often apply for multiple permits. The purposes of this paper are to: 1) describe the federal/state permitting processes for living shorelines in Maryland, 2) provide an example of a local jurisdiction permit process (Kent County, MD), and 3) discuss some issues and potential future regulatory enhancement areas identified during the Living Shoreline Summit regulatory panel.

INTRODUCTION: GENERAL PERMIT APPLICATION PROCESSES

Shoreline protections and wetland restoration projects (including placement of rock, fill, and plants) can impact the areas extending from the riparian buffer to sub-aqueous bottoms called Public Trust Lands. These lands are held in trust and protected by the government for the benefit of the public as a whole. Due to impacts in both the riparian buffer and subaqueous bottomlands, shoreline projects may require multiple permits at the federal, state, and local levels.

Several pieces of legislation serve as the basis for shoreline project regulation at the various governmental levels. The Environment Article Title 16, Wetlands and Riparian Rights Act, promulgated in 1970, and the related regulations COMAR 26, 24 Tidal Wetlands revised in 1994, give authority to the State of Maryland to regulate shoreline work. The Maryland's Chesapeake Bay Critical Area Program, Natural Resources Subtitle 8-1803 gives authority to local jurisdictions to accomplish and prioritize shoreline protection. Federal authority is given under both the Rivers and Harbors Act of 1899 and the Clean Water Act of 1972 with permitting oversight provided to the US Army Corps of Engineers (the Corps). In 1989, the state and federal permit applications were combined by the Maryland Department of Environment (MDE) and the Corps to help streamline the review process. The joint permit, called the Maryland State Programmatic General Permit (or MDSPGP; hereafter referred to as "joint permit"), is overseen by the MDE Water Management Administration. Under the joint permit, state and federal resource agencies review and comment on applications and activities that could impact sensitive resources. The Corps retains discretionary authority to require an individual permit for any proposed activity that has significant individual or cumulative impacts, impacts threatened or endangered species, impacts cultural or historical resources, impacts identified during the public interest review, or been identified for further review by a federal resource agency.

A joint permit is required for projects that are less than 500 linear feet and extend up to 35 feet into navigable waters. For projects that exceed either 500 linear feet or extend offshore more than 35 feet, a Maryland State Tidal Wetlands License is required from the Maryland Board of Public Works. Proposed projects that exceed one acre of impacts cannot be authorized under the joint permit and require an Individual Permit (IP) from the Corps.

In addition to the joint federal/state permit, applicants are required to obtain a local grading or building permit. Local jurisdiction permits and processes vary and can be more stringent than state and federal policy. As a result, it is important for applicants to contact county or city planning and zoning office about local permit requirements (Table 1). It is advantageous to contact local offices early in the process before the joint federal/state permit application process is initiated. All permits should be sought at the same time. However it should be noted that some counties will not issue their approvals until federal and state authorizations have been granted for the project.

FEDERAL/STATE TIDAL WETLANDS LICENSE PROCESS

Step One: Application Submission

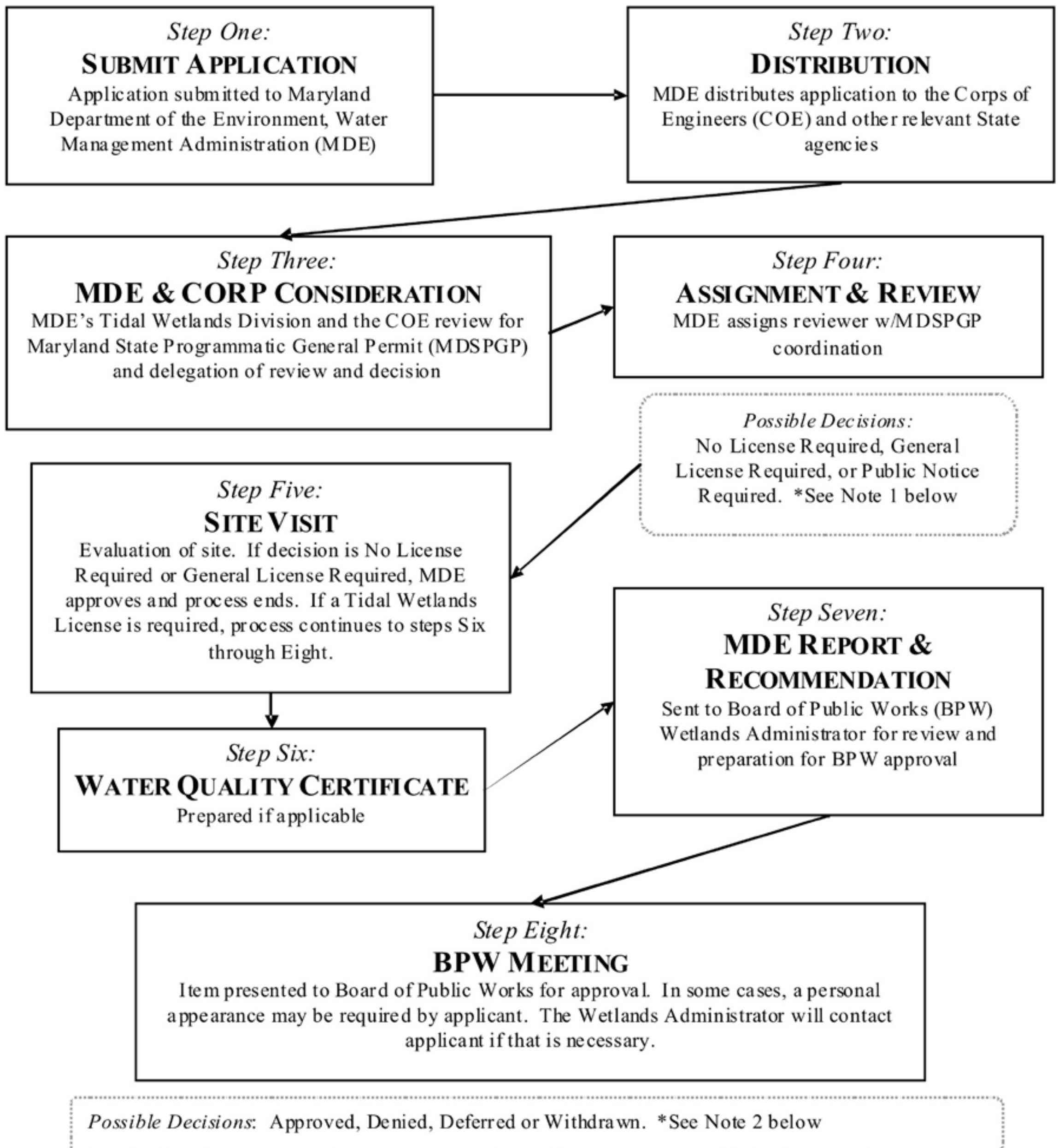
Applicants must apply for the joint permit (MDSPGP) by submitting four copies of the Joint federal/ State Application to the MDE Water Management Administration. Once received by the Regulatory Services Coordination Office of this Administration, the application proceeds through a series of steps (Fig. 1).

County	Office	Contact Information
Anne Arundel	Department of Inspections and Permits	(410) 222-7790 www.aacounty.org/ip
Baltimore City	Department of Permits and Code Enforcement	(410) 396-3540, (410) 396-5915 www.baltimorehousing.org/index/permits.asp
Baltimore	Department of Permits and Developmental Management	(410) 887-3353 www.baltimorecountymd.gov/agencies/permits/index.html
Calvert	Department of Planning and Zoning, Inspections and Permits Division	(410) 535-1600, (410) 535-2348 www.co.cal.md.us/government/departments/planning
Caroline	Department of Planning and Codes Administration	(410) 479-8115 www.carolinemd.org/governmt/planning/plantop.html
Cecil	Department of Permits and Inspections	(410) 996-5235, (410) 996-5220 www.ccgov.org/dept_permits/permitprocessing.cfm
Charles	Permits Administration	(301) 645-0627 www.charlescounty.org/pgm/permits
Dorchester	Inspections & Permits	(410) 228-3234, (410) 228-9636 www.docogonet.com/index.php?page=planning_zoning
Harford	Department of Inspections, Licenses, & Permits	(410) 638-3344 www.harfordcountymd.gov/dilp/
Kent	Inspections & Permits	(410) 778-7423 http://kentcounty.com/gov/planzone/pandz.htm
Queen Anne's	Zoning & Permits	(410) 758-1255, (410) 758-4088 www.qac.org/depts/planzone/planzonehome.htm
St. Mary's	Inspections & Enforcement	(301) 475-4200 www.co.saint-marys.md.us/permits-inspections
Somerset	Division of Planning & Zoning	(410) 651-1424
Talbot	Office of Planning & Zoning	(410) 770-8030 www.talbotcountymd.gov/index.php?page=Planning_and_Zoning
Wicomico	Department of Planning, Zoning, & Community Development	(410) 548-4860 www.wicomicocounty.org/pnz/p&z.htm
Worcester	Department of Development Review & Permitting	(410) 632-1200, ext. 1100 www.co.worcester.md.us/PPI.htm

Table 1. *Contacts for local shoreline project permits in Maryland*

Step Two: Application Distribution

After an initial review, it is forwarded to the appropriate state or federal divisions/agencies. A notice is sent to the applicant notifying him or her of this action and providing tracking information for the application. Additional agencies involved in the review include the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, the Maryland Department of Natural Resources (DNR), the Maryland Historic Trust, and any interested individuals. Initially, shoreline



Note 1 :If decision is: ***No License Required, General License Issued,*** or ***No Notice Required*** – Go to Step Five. If decision is: ***Public Notice Required***, project is placed on 30-day public notice period. If a hearing is requested during the public notice period, it will be scheduled and advertised.

Note 2: If Item is ***Approved***, license will be issued. If Item is ***Denied***, applicant will be notified and given opportunity to appeal. If Item is ***Deferred*** or ***Withdrawn***, Wetlands Administrator and MDE will take corrective action for a re-submission on a later Board agenda.

Figure 1. *State of Maryland Tidal Wetlands Licensing Flow Chart*

projects are distributed to the MDE Tidal Wetlands Division and the Corps. These agencies can contact the applicant individually or jointly if they need to advise the applicant of additional requirements.

Steps Three and Four: Application Review

The MDE Tidal Wetlands Division determines the applicability of review for a proposed project under the joint permit by posing the following questions: 1) Does the proposed work qualify under the joint permit? and 2) If it does qualify, under which category (CAT) should it proceed? (CAT 1 General License Requirements are met, or CAT 3 Public Notice is required because the project exceeds the limits of the State's General Licenses). If the project does not qualify (1 acre of fill or greater), the Corps must conduct an Individual Authorization Review. For CAT 3, the Board of Public Works must issue a Tidal Wetlands License.

The application is also given a public interest review and is considered through four categories (no public notice, public notice, joint public notice, or agency notice only). When determining public interests in a request for 1) a private use structure, 2) activity over/in/under State wetlands, or 3) severance of materials from State wetlands, the State must consider the ultimate project and beneficial purposes to be served. Public interests are considered in the review process and are defined as demonstrable environmental, social, and economic benefits which would accrue to the public-at-large as a result of a proposed action or activity

Agency comments, resource information, and environmental concerns are now taken into account and addressed. As directed by the Wetlands and Riparian Rights Act, related regulations, and the public policy of the State, the review takes into account ecological, economic, development, recreational, and aesthetic values in the process of minimization of impacts to wetlands to prevent despoliation and destruction.

Step Five: Final Permitting Actions

The Department concludes the review of the proposed project by making a determination and/or recommendation to approve, deny, or modify the project. If it meets the requirements of a General License, MDE issues the authorization with the joint permit (MDSPGP) for the Corps, and the process concludes. If the project requires a Tidal Wetlands License, additional steps are required.

Steps Six, Seven, and Eight for Projects Requiring a Tidal Wetlands License

For projects requiring a Tidal Wetlands License, MDE recommends to the Maryland Board of Public Works an action for the Board to consider. The Board of Public Works Wetlands Administrator reviews the application and presents it to the Board of Public Works for approval. In some cases, a personal appearance may be required by the applicant or requested by grieved parties to the MDE recommendation.

Additional Regulatory Requirements

Maryland Coastal Zone Management Program and Water Quality Certification are part of the review process and do not undergo a different review path. The Critical Area Commission requirements are also considered, particularly in cases where the 100 foot Critical Area buffer is being impacted to construct a shoreline project. For example, pruning, limbing, and removal of trees and understory vegetation may be required for the establishment of wetland vegetation, which are above the high water mark and the jurisdiction of local government Critical Areas programs.

PERMITTING FROM A LOCAL JURISDICTION PERSPECTIVE – KENT COUNTY

Under the Erosion and Sediment Control Law, local governments have the authority to manage shoreline erosion protection. The Chesapeake Critical Area Program (Title 27.01.04.02) directs local jurisdictions to (a) encourage the protection of rapidly eroding portions of the shoreline in the Critical Area by public and private landowners and (b) where such measures can effectively and practically reduce or prevent shore erosion, encourage the use of nonstructural shore protection measures in order to conserve and protect plant, fish, and wildlife habitat. This direction has been interpreted differently by various local jurisdictions in Maryland, with some jurisdictions more proactive than others. Some counties rely mainly on the outcome of the joint state and federal permit process, while others have established their own specific living shoreline policies.

Kent County, Maryland, is one local jurisdiction taking an active role in promoting the use of living shorelines for shoreline stabilization. County policy requires property owners to consider a living shoreline option first when proposing to protect shorelines from erosion and to justify use of hardened shoreline armor. This policy has been codified in the County Land Use Ordinance. Two factors have facilitated Kent County's policy on living shoreline. First, Kent County is a Code Home Rule county, meaning that the local government has the option to be more restrictive than the state. Second, Kent County does not have a Critical Area overlay, allowing the same policies to apply in the Critical Area Boundary (the area 1000 ft landward of the shoreline) as they do in non-critical areas. The County has the lead in determining land use activities in both areas. As a result, Kent County has integrated the following language directly into its Land Use Ordinance:

> "The purpose of this section is to encourage the protection of rapidly eroding portions of the shoreline in the County by public and private landowners. When such measures can effectively and practically reduce or prevent shoreline erosion, the use of nonstructural shore protection measures shall be encouraged to conserve and protect plant, fish, and wildlife habitat. The following criteria shall be followed when selecting shore erosion protection practices:
> 1) Nonstructural practices shall be used whenever possible;
> 2) Structural measures shall be used only in areas where nonstructural practices are impractical or ineffective;
> 3) Where structural measures are required, the measure that best provides for the conservation of fish and plant habitat and which is practical and effective shall be used;
> 4) If significant alteration of the characteristics of a shoreline occurs, the measure that best fits the change may be used for sites in that area."

Not only has Kent County pursued an ordinance change to support living shoreline use, the County Department of Planning and Zoning has provided its residents with tools to implement nonstructural approaches. The County has sponsored educational sessions with the commissioners, planning commission, area realtors, watershed associations, and other community groups. The County benefited from initial interest by area contractors to provide the service. In addition, the County was awarded a grant by the Maryland Coastal Program and administered by Eastern Shore Resource, Conservation, and Development Council (RC&D) to promote awareness of living shoreline practices. The RC&D has provided technical assistance and site inspections to county staff to assist them in implementing their policies.

PERMITTING ISSUES TO BE ADDRESSED

Since 1993, permits have been granted for 230 miles of hardened shoreline armor in the Chesapeake Bay. Several impediments have limited the use of living shoreline techniques in place of structural armor. These obstacles are related to questions about design, concerns about effectiveness, aesthetics, lack of property owner awareness and behavior change, and availability of incentives. Incentives to overcoming these impediments are discussed elsewhere in this volume. However, some issues are regulatory in nature and relate to permitting. Addressing these issues may aid in the increased use of living shorelines, rather than hard shoreline armor, under appropriate site conditions.

Reconciling Federal/State and Local Permit Application Processes

As discussed above, some local jurisdictions have additional requirements or policies beyond the state and federal review processes. As a result, applicants who wait to obtain a local permit after the joint federal/state permit is granted could face a substantial revision of their project designs based on local review. Communication related to sequencing of state and county review, similar to the pier permit notification system, would ensure consistency in the application of state and local Critical Area policies. State officials can also promote living shorelines as a preferred method of shoreline stabilization, where appropriate, for applications in jurisdictions with specific living shoreline policies. Therefore, local jurisdictions more involved in the development of shoreline policies and permit review process could facilitate greater implementation of these projects in the future.

Kent County, specifically, is seeking to establish a process related to the sequencing of permits, in which the county review would be concurrent with or prior to state review of a shoreline construction permit. A potential mechanism to implement a sequential process change could be offered by a Memorandum of Understanding (MOU). In addition to an MOU, Kent County is proposing to hold an annual meeting to facilitate and maintain communication between state and federal review staff and local plan reviewers. Increasing open dialogue could improve efficiency and clarify expectations for not only local reviewers, but also for property owners and their contractors.

Duration of Permit Review Process

On an annual basis, MDE receives over 2000 applications for tidal wetland permits to implement both traditional and living shoreline projects. Permit review takes between three and six months but can take longer for projects that (a) are more complex or use non-traditional construction or design elements that require a site visit (a category under which many living shoreline designs fall), (b) require a hearing (20 applications per year), or (c) are sent to the Board of Public Works (about 10% of those received per year). MDE inspectors do not visit all sites, mostly due to the lack of staff resources. Number of staff has been reduced by as much as 60% in recent years. Staffing enhancements would most likely reduce permit review time, increase frequency of site inspections, and potentially allow greater implementation of living shoreline project types.

In many coastal states, permit fees are used to at least partly fund the review and permitting process. In Maryland, however, though a permit fee is required for large-scale projects (greater than 500 linear feet in length or greater than 35 feet offshore), projects below these limits do not require permit fees.

Several bills have been proposed in the Maryland State Legislature requiring a modest fee for general permits to support MDE Water Management Administration activities, thereby reducing the length of permit review time. Such bills have been hotly debated, but no resolution on the issue of general permit fees has been reached. Currently, the fees from the Tidal Wetlands License permits (for the large-scale projects) are deposited in the Tidal Wetlands Compensation Fund, which funds wetlands or living shorelines projects on private lands in the counties from which the fees were collected. These fees cannot be used for personnel within the permitting and inspection offices.

While other coastal states can be used as a model in establishing reasonable license fees, it should be noted that not all fee structures in other states are conducive to living shorelines. For example, North Carolina requires a $100 fee for general permits involving structures abutting the shoreline (such as hard armor revetments) and $400 for projects involving offshore structures (such as living shoreline sills). In this situation, a regulatory and financial disincentive is placed on projects with wetland creation objectives such as offshore sills and breakwaters.

Communication Among Jurisdictions

Watershed issues, including nonstructural shoreline protection, are currently shared and discussed at various meetings and projects such as quarterly Critical Area Commission Maryland Association of Counties, quarterly regional planners' meetings, the Coastal & Watershed Resources Advisory Committee, Tributary Strategy Teams, and collaborative watershed projects such as the Watershed Restoration Action Strategies. Forums such as these will continue to serve as excellent opportunities for local jurisdictions to share information about the effectiveness of living shorelines, design and implementation issues, regulatory and permit processes, and property owners' concerns. Additional coastal counties have indicated an interest in updating or strengthening nonstructural erosion control policies and learning by example from others that have initiated the process. As more information about design and effectiveness of living shoreline techniques continues to be produced, all sectors, including contractors, property owners, and regulators, will benefit from continued education. Over time, success rates and proven practices can be effective regulatory tools as well.

SUMMARY

Recommendations for Property-Owners

1) Property owners should pursue permits from local agencies at the same time they apply for the joint federal-state permit.

Recommendations for Regulators/Managers

2) State and local permitting jurisdictions should communicate frequently about their permitting processes and policies. An annual meeting of state and local regulators should be held.
3) Local jurisdictions should share information on living shoreline codes and policies more frequently, at forums such as Critical Area Commission Maryland Association of Counties, quarterly regional planners' meetings, the Coastal & Watershed Resources Advisory Committee, Tributary Strategy Teams.
4) State and local permit review should occur concurrently, with state and local reviewers communicating information about permit review.
5) State permitters should be kept informed about changes to local policies and codes, such that state officials are aware of regions requiring use of living shorelines where appropriate.

Recommendations for Policy Change

6) The number of MDE permit inspectors should be increased to reduce permit review time and allow for greater inspector input.
7) Lawmakers should consider positive and negative ramifications of instituting a general permit fee that does not inhibit or create a disincentive for living shorelines projects.

Note: See page *xiii* for changes in Maryland Living Shoreline Policy, 2008.

Regulatory Program Overview for Virginia's Submerged Lands and Tidal Wetlands and Options for Promoting Living Shorelines

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ABSTRACT

In Virginia, a number of federal, state, and local regulations, ordinances and policies may affect shoreline management projects, including living shoreline designs. Management of submerged lands and tidal wetlands, however, provides the core of this regulatory framework. The purpose of this paper is to: 1) describe the state and local regulatory process for submerged lands and tidal wetlands as it relates to shoreline erosion control projects in Virginia, 2) discuss initiatives currently underway or planned by the Virginia Coastal Zone Management Program to improve shoreline management and promote the use of living shorelines, and 3) review the options for promoting living shorelines identified during the Living Shoreline Summit panel discussion.

INTRODUCTION

The Commonwealth of Virginia is endowed with over 5,200 miles of tidal shoreline encompassing 2,300 square miles of water surface covering 1,472,000 acres of state-owned bottomlands. These submerged lands, greater in area than the state of Delaware, are a public resource and a valuable habitat for shellfish, crabs, and finfish. In addition, along the fringes of the many coves, creeks, rivers, and bays of the Chesapeake estuary and along the Atlantic Ocean coast grow some 225,000 acres of vegetated tidal wetlands. These vegetated areas, particularly the salt marshes, constitute a vital spawning and nursery area and are an important element of the marine food webs for many economically valuable marine resources of the Commonwealth.

Much of the charge for ensuring that these resources are responsibly used rests with the Habitat Management Division of the Virginia Marine Resources Commission, operating under the mandates of Virginia's tidal wetlands and subaqueous laws. This responsibility is managed through the review of permit applications submitted for encroachments over state-owned submerged lands and for the use or development of tidal wetlands.

In addition to its regulatory responsibilities, the Division also functions as the central clearinghouse for receipt and distribution of the Joint Permit Application (JPA) booklet that is used throughout the Commonwealth. Upon receipt, an application processing number is assigned which is then used by all of the local/state/federal regulatory and advisory agencies. Copies of the application are distributed to the Local Wetland Boards, the Department of Environmental Quality (DEQ), various State agencies, and the Virginia Institute of Marine Science (VIMS) for comment, as well as the U.S. Army Corps of Engineers for concurrent processing. Upon receipt, a JPA is processed independently by each regulatory agency (Fig. 1).

The Code of Virginia (Chapter 12 of Title 28.2) vests ownership of "all the beds of the bays, rivers, creeks, and shores of the sea in the Commonwealth to be used as a common by all the people of Virginia." The Marine Resources Commission Habitat Management Division reviews the permit applications, solicits public comment, applies public interest factors, and then prepares a recommendation to the Commissioner or Commission for a decision.

Habitat Management Division environmental engineers weigh each individual application received to determine that they are in the public interest. This is accomplished to ensure that projects are necessary, there are no reasonable alternatives requiring less environmental disruption, and that adverse effects do not unreasonably interfere with other private and public rights to the use of waterways and bottomlands. Particular emphasis in this regard has been applied to the reduction of unnecessary filling of State bottom, including the proper application of living shoreline treatment options, the reduction of obstructions or hazards to navigation, and the prevention of structures encroaching into adjoining riparian areas. While the Division and the Commission support the concept of living shoreline techniques where appropriate, projects that result in the filling of subaqueous lands must be evaluated on a case-by-case basis to consider any habitat trade-offs involved in each particular decision. Use of these project evaluation criteria at an early stage often suggests project modifications, reduces conflicts between property owners, and, of course, protects intertidal habitats and navigation. Also, each of the Division Engineers is assigned a specific geographic territory. They process all applications received from their assigned areas. This arrangement leads to enhanced area familiarization and increased efficiency. They are required to work closely with the various local governing bodies involved, and invariably develop a network of contacts and generate a level of expertise that itself results in a more efficient application review process. They serve as a single point of contact for the applicant and shepherd the application throughout the entire public interest review process.

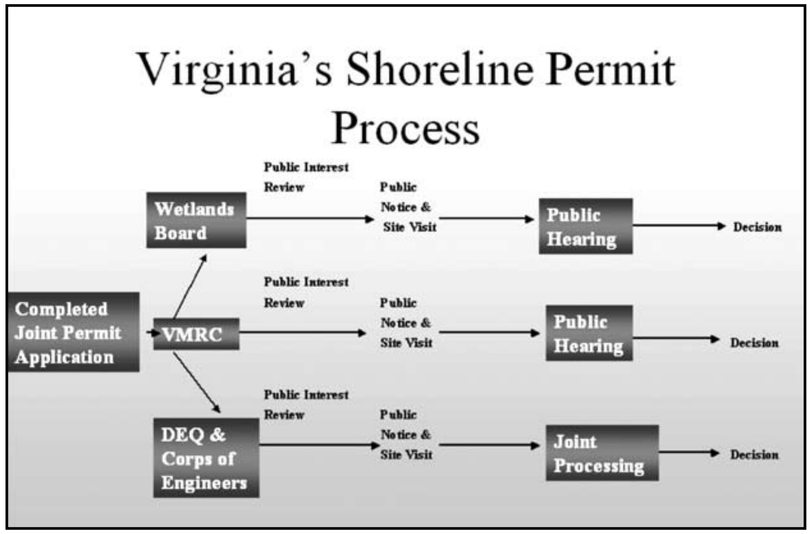

Figure 1. *Virginia's shoreline permitting process.*

Not all conflicts, however, can be settled by Division engineers through consultation with affected parties. Protested projects or those for which commission staff cannot recommend approval must be considered by the nine-member, Governor appointed Commission. As a citizen's body and quasi-judicial board meeting monthly, the Commission does a valuable service by providing not only a forum for public discussion and the airing of disputes, but also as a regulatory body, evaluating the issues and making decisions.

Unlike submerged lands that are the property of the Commonwealth, the tidal wetlands statutes the Division administers are not based on ownership. Rather, they are based on the ability of the State through its police powers to regulate private uses of wetlands because of the anticipated impacts those uses might have on the public's health, safety, and welfare. The enabling legislation provides a model zoning ordinance that is available for local adoption and implementation. Where the locality has chosen not to adopt the ordinance, the State (i.e., the Commission through the Habitat Management Division) assumes that management role. See Figure 2 for a depiction of jurisdictional boundaries for state-owned submerged lands and tidal wetlands.

As required by the tidal wetlands ordinance, every wetlands project is the subject of a public hearing by the local board or the Commission. This process requires the notification of adjacent property owners and various agencies. In addition, wetlands boards as well as the Commission rely heavily on the project assessments prepared by VIMS for each project.

In conformance with §28.2-1310 of the Code of Virginia, the Commissioner reviews every decision rendered by the individual wetland board to ensure uniformity. He will recommend that the full Commission review any local decision where he believes the local board failed to fulfill its responsibilities under the wetlands zoning ordinance. The Commission would then review that decision at a regularly scheduled meeting.

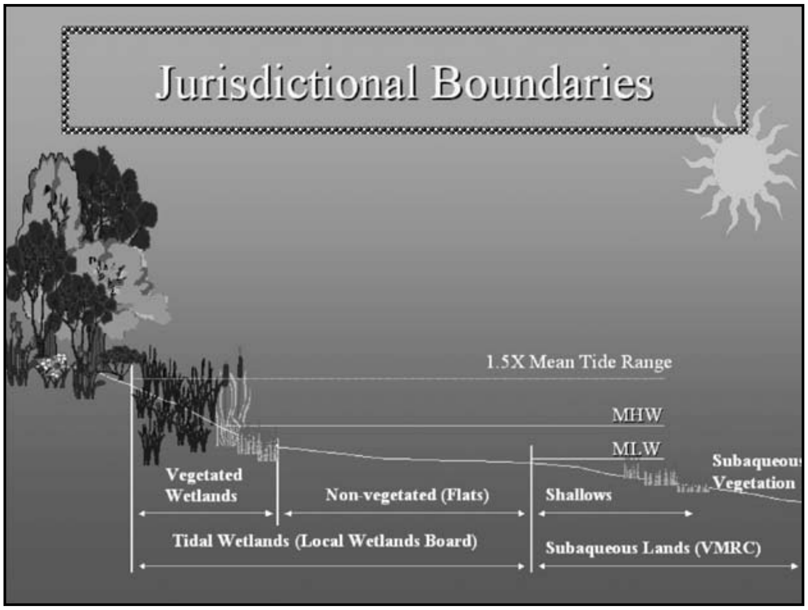

Figure 2. *Jurisdictional boundaries for Virginia-owned submerged lands and tidal wetlands.*

At present, 36 of the 46 Tidewater localities have adopted, and are locally administering under VMRC oversight, the model wetlands ordinances provided in State Code. Many of the localities that have not adopted the model ordinance are located in the western part of the coastal zone, have limited tidal wetlands and as a result see few applications for tidal wetlands permits. Where not locally adopted, the Commission serves as the wetlands board. The Commission also hears and decides all wetland appeals that are filed by either an aggrieved applicant or 25 or more freeholders of property within the locality.

When coupled with the Commission's fisheries management responsibilities, the submerged lands and tidal wetlands laws enable the Commission to regulate not just the fishery, but also the critical habitats upon which those very fisheries depend. This arrangement has served the Commonwealth well for over twenty-five years.

When considering shoreline protection projects involving both wetland and submerged lands, whether they be bulkheads, riprap, breakwaters, or fills for the establishment of a vegetative wetland fringe that one might define as a living shoreline, the existing ecological conditions at the site must be considered along with the impact of any activity on nearby or adjacent properties, fisheries resources, other uses of state-waters and submerged lands, water quality, wetlands, and submerged aquatic vegetation. As such, acceptable projects that may be classified as a living shoreline should improve ecological conditions without any adverse affect when considering these factors.

VIRGINIA'S COASTAL ZONE MANAGEMENT SHORELINE STRATEGY

The Virginia Coastal Zone Management (CZM) Program completed an assessment of coastal resources in 2006 as well as a planning initiative to direct efforts for the next five years under Section 309 of the federal Coastal Zone Management Act. One of the strategies targets shoreline management and focuses on promoting living shorelines. This strategy is slated to provide $750,000 over the five year period for various initiatives and will produce the following outcomes:

- A "Living Shoreline Summit," (held December, 2006) with peer reviewed proceedings, to advance the use of this management technique;
- Revised "Wetlands Guidelines" to be used by the Virginia Marine Resources Commission, the Virginia Institute of Marine Science, local wetlands boards, and others to guide decisions about shoreline and tidal wetlands management;
- Improved data on shoreline conditions to support more informed shoreline management decisions;
- Research to document the habitat value of living shorelines and to improve their design;
- A guidance document for local governments to use in shoreline management planning;
- Outreach materials for land use decision-makers, landowners, and contractors on living shoreline advantages and design principles;

- A training program for contractors and local government staff on living shoreline practices;
- A report on improving management of Virginia's dune and beach resources, including proposed revisions to the Coastal Primary Sand Dunes and Beaches Act;
- Anticipated changes to the Coastal Primary Sand Dunes and Beaches Act by the Virginia General Assembly; and
- Revisions to the Coastal Primary Sand Dunes and Beaches Guidelines.

EXPLORING REGULATORY OPTIONS FOR PROMOTING LIVING SHORELINES

A panel discussion at the Living Shoreline Summit (December 6 - 7, 2006) focused on ways to improve the current regulatory process in order to promote the use of living shorelines where appropriate. There was general agreement among the panel members and the audience that the current system, while it does not discourage the use of living shorelines, also does not actively encourage or provide incentives for living shorelines. Participants felt that structural approaches to shoreline management were the accepted norm and that landowners were comfortable with this approach, in part because structural solutions were more familiar to them, to their neighbors, and to those involved in the permitting process. Participants also agreed that new requirements for mitigation of any tidal wetland impact required by the VMRC Wetlands Mitigation-Compensation Policy and Supplemental Guidelines (Regulation 4 VAC 20-390-10) are likely to increase landowner interest in living shorelines as a way to avoid mitigation requirements. Prior to this regulation, impacts to tidal wetlands under 1000 square feet, such as those commonly associated with construction of bulkheads and revetments, did not require mitigation. Lastly, there was agreement on the importance of influencing waterfront property owners' decisions about shoreline management techniques prior to their submitting a permit application. The group felt that at the point of application, submittal landowners had committed substantial resources toward selecting a specific design and that it was difficult to alter that design.

A short summary of suggestions offered by both panel members and the audience is included below under three general topics. Note that some of the suggestions are already being addressed through the Virginia CZM Program Shoreline Strategy described above. Others will be addressed if deemed to be necessary or as resources become available. Actions taken to address any of these suggestions will be taken by the network of agencies and local governments that comprise the Virginia Coastal Zone Management Program.

Assist Waterfront Property Owners

- Develop outreach materials and an outreach program for property owners. Hold workshops, develop online decision-making tools, and construct local demonstration sites to help property owners with their initial decisions about shoreline management.
- Provide design assistance to homeowners. One option is to expand the reach and scope of the Shoreline Erosion Advisory Service (SEAS) at the Department of Conservation and Recreation.
- Provide opportunities for property owners to consult with representatives from advisory and regulatory agencies prior to submitting permit applications.
- Develop a living shoreline certification process for shoreline contractors so property owners can be assured that the contractor is proficient in this technique. Certification could be obtained by a contractor, agent, or others such as local government officials, by completing a course based on a planned living shoreline design manual. The course and manual are scheduled for development through the Virginia CZM Shoreline Strategy.
- Provide financial incentives to property owners, including grants and low interest loans for construction, tax breaks, and reduced permit fees. Financial disincentives, such as higher permit fees, could also be used in cases were a living shoreline approach was deemed feasible, but not chosen.

Provide Regulatory Guidance on Living Shorelines

- Modify the model ordinance used by localities to manage shoreline development through the Tidal Wetlands Act to encourage the use of living shoreline techniques where appropriate.
- Modify the Tidal Wetlands Guidelines to reflect a preference for living shorelines where appropriate.
- Revise the Joint Permit Application (JPA) to state the preference for living shoreline approaches where appropriate. Provide a sequence of priorities in the JPA and ask project proponents to justify their project. If structural approaches are desired, ask the property owner to demonstrate why a living shoreline approach would not work on their shoreline.
- Review shoreline erosion control projects holistically by evaluating the continuum of coastal resources that may be affected. This would include not only resources along the shoreline, such as wetlands, beaches, and dunes, but also in the riparian and littoral zones. It was noted that in some cases, structures had been moved landward from their original position in order to avoid the jurisdiction of the Tidal Wetlands Act.
- Improve the shoreline management provisions of the Chesapeake Bay Preservation Act's regulations and improve the Water Quality Impact Assessment (WQIA) for shoreline projects.
- Provide additional training for local wetland board members that includes guidance on how the protection of various coastal resources are to be prioritized.

Simplify the Regulatory Process

- Develop a general permit for living shorelines while retaining the oversight authority necessary to protect coastal resources. This should result in reduced review time and lower permitting fees because public hearing advertising fees would be eliminated. It would also require legislative authority from the Virginia General Assembly and living shorelines would have to specifically be defined in the Virginia Code.
- As an alternative to a general permit, provide some other form of expedited permit review for living shoreline projects. Streamline the review process for nonstructural shoreline projects, including administrative approval and a process for exceptions.

Tools and Decision-Making: Facilitating and Encouraging Living Shoreline Implementation

Photo credit: Jana Davis, Chesapeake Bay Trust

NOAA's Shoreline Management Technical Assistance Toolbox

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ABSTRACT

Erosion will claim 25% of all homes within 500 feet of ocean or Great Lakes shorelines over the next 60 years according to a recent Heinz Center study. Therefore, it is not surprising that shoreline stabilization is one of the "hot" coastal management issues many states are trying to address today. A recent survey conducted by the Coastal States Organization found that 68% of coastal managers and staff ranked coastal hazards as either a very important or important topic in their state. The survey also found that 88% of the coastal management community ranked managing areas prone to erosion as the most important coastal hazards issue. Specifically, managers were most interested in additional information on design standards for shoreline management technologies, risk and vulnerability assessments, and alternative shoreline protection technologies.

Therefore, the National Oceanic and Atmospheric Administration's (NOAA) Office of Ocean and Coastal Resource Management, has developed a Shoreline Management Technical Assistance website (http://coastalmanagement.noaa.gov/shoreline.html) to provide coastal resource managers with centralized access to information, resources, and tools to address shoreline erosion and management, focusing on alternatives to traditional shoreline hardening. The website includes information on planning and policy tools, alternative stabilization techniques such as "soft" or hybrid methods (e.g., marsh restoration with breakwater sill), and the economics of shoreline management. For each technique, the website provides links to relevant websites, reports, and management tools, as well as case studies describing how the techniques have been applied.

INTRODUCTION

Shoreline erosion is a natural process. However, coastal storms, sea level rise, and poorly planned shoreline development projects can accelerate natural erosion rates. Additionally, a 2000 Heinz Center report found that within the next 60 years, erosion will claim a quarter of U.S. homes within 500 feet of the shore, costing coastal property owners roughly $530M/year (1).

With over 127 million people living along our coasts and estuaries and 180 million more visiting to recreate each year, the impacts of coastal erosion are a significant problem for coastal managers. In a recent study, 88% of the coastal management community ranked managing areas prone to erosion as the most important coastal hazards issue they face (2).

The Coastal Zone Management Act (CZMA) directs state coastal management programs to minimize loss of life and property caused by erosion and to protect the nation's natural coastal resources. Therefore, the solution to shoreline erosion is not as simple as hardening our shorelines with bulkheads, riprap, or groins to wall off the sea. While traditional hard stabilization techniques (riprap, jetties) may be appropriate and effective solutions under some circumstances, they are not always the best option. These types of hard erosion control structures can be very costly, interrupt natural shoreline processes and sand movement, and lead to increased erosion. In addition, shoreline hardening often destroys valuable shoreline habitats such as wetlands and intertidal areas.

Recently, alternative shoreline management techniques such as soft or nonstructural (vegetative plantings), hybrid (replanting coupled with rock sills), and planning and policy approaches (set-backs, managed retreat) are receiving more attention as potential solutions to shoreline erosion.

To assist coastal managers in addressing these shoreline management issues, NOAA's Office of Ocean and Coastal Resource Management developed a website to provide centralized access to information, resources, and tools to address shoreline erosion and management, focusing on alternatives to traditional shoreline hardening (3). The Shoreline Management Technical Assistance Toolbox (http://coastalmanagement.noaa.gov/shoreline.html) includes four main sections: (1) Planning, Policy, and Regulatory Tools; (2) Alternative Shoreline Stabilization Methods; (3) Economics of Shoreline Management; and (4) Resources. Each section is discussed in more detail below.

PLANNING, POLICY, AND REGULATORY APPROACHES

Planning, policy, and regulatory approaches to shoreline management are intended to influence human use and development near the shoreline. These approaches can be preventative measures to avoid the need for physical shoreline stabilization, or can be implemented in response to shoreline erosion when physical shoreline stabilization would be too costly, ineffective, or undesirable. While each planning, policy, or regulatory approach has merit by itself, coastal managers often find a combination of these methods is the most effective way to manage the shoreline.

Developing strong shoreline management policies, regulations, and planning approaches is very important as they are the only way to effectively reduce, or avoid altogether, the need for costly erosion control measures. They can also help maintain the natural shoreline dynamics and preserve important coastal environments. In addition, shoreline planning is one of the few techniques that allows for a regional, more holistic approach to shoreline management that can be used to address both direct and cumulative impacts.

Therefore planning, policy, and regulatory tools should be employed as the first line of defense against erosion. Despite the numerous benefits these tools offer, implementing these approaches can be technically and politically difficult, especially when good scientific data is lacking or where significant development has already occurred. Table 1 lists the 18 policy, regulatory, and planning techniques included in the Shoreline Technical Assistance Toolbox. More in-depth pages for each technique, which provide a brief overview of the technique, describe its benefits and drawbacks, and provide case studies to illustrate how it is being applied at the state or local level, can be found on the website.

ALTERNATIVE SHORELINE STABILIZATION METHODS

Even with the best planning and regulatory programs, some type of shoreline stabilization is often needed when eroding shorelines threaten waterfront development. To restore, protect, and enhance the natural shoreline environment, "soft" or "nonstructural" stabilization techniques that rely on vegetative plantings and sand

Planning & Policy Tools	Regulatory Tools
High-Risk Erosion Area Disclosure	Construction Setbacks
Insurance Incentives/Disincentives	Erosion Control Easements
Managed Retreat	Erosion Control Structures Regulation
Mitigation *(cross listed)*	High-Risk Erosion Area Disclosure
Shoreline Management Plans	Mitigation *(cross listed)*
Tax Incentives	Shorefront Development Regulation
Transfer of Development Rights Programs	Restrictive Covenants
	Zoning and Erosion Overlay Districts
Other Management Tools	
Cost-Share/Loan Programs	Land Acquisition
Education/Outreach Campaigns	Relocation Assistance/Buy-Back Programs
Research and Monitoring Programs	

Table 1. *List of the 18 policy, regulatory, and planning techniques included in the Shoreline Technical Assistance Toolbox.*

fill, or "hybrid" techniques that combine vegetative planting with low rock sills, can be effective alternatives to hard stabilization structures such as bulkheads, riprap, or groins along low to mid-energy shores. These alternative "soft" and "hybrid" approaches are often collectively referred to as "living shorelines" since they help to preserve the natural, living shoreline.

The Alternative Shoreline Stabilization Methods page describes the difference between "soft" and "hybrid" stabilization approaches as well as benefits and drawbacks of "living shorelines." The page also links to the NOAA Restoration Center's Restoration Clearinghouse. The Clearinghouse includes a section dedicated to living shorelines which provides more in-depth information about living shoreline approaches, including:

- Descriptions of what living shorelines are;
- Outlines the planning and implementation steps needed to install a living shoreline erosion control structure;
- Discussions of the type of living shoreline treatments that would be most appropriate given the type of shoreline;
- Case studies of several NOAA Restoration-funded living shorelines projects;
- Lists of Federal and state statutes, regulations, and permits that living shorelines projects must adhere to; and
- Publications, websites, brochures, news articles, restoration information, and guidance documents related to living shorelines.

Although this section presents many different options for soft-structural stabilization or living shorelines, it is important to note that conducting a thorough site evaluation is still important to identify which approach, if any, would be most effective, given the site conditions.

ECONOMICS OF SHORELINE MANAGEMENT

Economics plays an important role in most decisions we make, including shoreline management. For example, coastal managers may want to use economics to understand what type of shoreline management approach would be most economically feasible to employ, given the social and environmental costs and benefits of a project and its expected lifespan. This section of the web toolbox discusses how economic analyses can help coastal managers make decisions about which shoreline management approaches may be best to use under different circumstances.

The Economics of Shoreline Management section is intended to provide coastal managers and the general public with enough information to:

- Understand basic economic principles and know how they can be applied to shoreline management and erosion control;
- Understand the primary types of economic analyses, what type of questions each can be used to answer, and where to find more in-depth information on certain types of analyses; and
- Know where to go for more information.

RESOURCES

Finally, the last tool in the Shoreline Management Toolbox is the "Resources" section. The Resources section contains an annotated bibliography of papers, reports, websites, and other resources on a variety of shoreline management topics. To facilitate use, resources are grouped by the following categories: (1) General; (2) Shoreline Change, Hazard Assessment, and Other Decision-Support Tools; (3) Policy or

Regulatory Approaches; (4) Model Ordinances/Bylaws; (5) Engineered Shoreline Management Approaches (Hard and Soft Stabilization); and (6) Shoreline Management Economics. When available, links to the website or online documents and reports are also provided. Links are also provided to other state and federal programs for shoreline management.

CONCLUSION

The Shoreline Management Technical Assistance Toolbox is a useful, online resource to help coastal managers address shoreline management issues by highlighting a variety of techniques that can be used to avoid shoreline hardening. The Toolbox is intended to be a dynamic resource, with the capability to add additional approaches, case studies, and resources, as appropriate.

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Maryland Shorelines On-line: A Web Portal and Geospatial Tool for Shoreline Planning and Management in Maryland

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ABSTRACT

Geographic Information Systems are important to natural resource management, but access to data is a challenge for some local governments and the public. A web-based open source tool, Maryland Shorelines Online (MSO), was developed to specifically address access issues. MSO is organized into six major topic areas that include: 1) Introduction, 2) Laws, Regulations, and Permits, 3) Education and Outreach, 4) Assistance, 5) Coastal Hazard Management, and 6) Interactive Mapping. An overview of the MSO portal, and its uses and limitations, is discussed in this paper. The data sets are used in case studies to demonstrate the use of the Maryland Shorelines Changes Online interactive web mapping tool in shoreline management decisions. As the promotion of living shoreline restoration and demonstration projects occur, this website will provide an opportunity for the public and local governments to be more engaged in planning and decision-making. As the potential use of this application is varied, training and outreach on this application will be important for its success in reaching the target audiences.

INTRODUCTION

Web technology and geographic information systems (GIS) are greatly improving the ability of planners and scientists to plan and manage natural resources. The utilization of GIS has provided significant advantages, but the access to utilize GIS-based information is not equal across all levels of government or by the public. The issues associated with accessibility and utility of geospatial products has impeded the incorporation of geospatial information into many of the day-to-day shoreline planning and decision-making activities in Maryland, especially at the local level.

A web-based open source tool, Maryland Shorelines Online (MSO), was developed by the Maryland Department of Natural Resources (MDNR) and Towson Center for Geographic Information Sciences to specifically address some of the access issues. The MSO website was designed as a portal for shoreline and coastal hazard management. The web provides the ideal platform to provide information and data to a desktop. Users are not required to possess or be practiced in the skills of using GIS technology. These tools utilize GIS along with the Internet to serve data right to a personal computer and require no additional software. Target audiences for this website ranges from regulators of tidal wetlands, Critical Areas and local government planners, marine contractors, teachers, and the public. As managers are continued to be asked to do more with less resources, web-based applications and GIS will be important for the future of planning, visualization, and management of shorelines and coastal hazards in Maryland.

An overview of the MSO portal and its uses and limitations will be discussed in this paper. The accuracy of the data should be considered when formulating assumptions from the web-mapping tool as it is intended for general use and educational purposes. Focus will be on using data sets that are available on the website and include the historical shoreline series, shoreline rates of change, and comprehensive shoreline inventory. Case studies will be provided to demonstrate the uses of Maryland Shorelines Changes Online interactive web mapping tool when making shoreline management decisions.

Overview of Maryland Shorelines Online Web Portal

MSO is organized into six major topic areas that include: 1) Introduction, 2) Laws, Regulations, and Permits, 3) Education and Outreach, 4) Assistance, 5) Coastal Hazard Management, and 6) Interactive Mapping (http://shorelines.dnr.state.md.us).

The ***Introduction*** section contains a general overview, discussion, and summary/trend information on coastal hazards affecting Maryland's Coastal Zone. A sub-menu option is a section of definitions that are hyperlinked to the word's position throughout the website.

Laws, Regulations, and Permits has been developed into a series of quick reference matrices that describe federal, state, and local programs/regulations/permitting processes that guide shoreline management activities.

Education and Outreach has been divided into three sub-menus and has general information such as fact sheets, posters, resource links, and studies. The other sub-menus are targeted to training opportunities and educational lessons for middle and high school students. These lessons specifically target coastal hazards and different impacts that shoreline change, natural processes, and human activities have on the natural environment. The lessons are divided into five separate components and address: 1) weather, 2) coastal processes, 3) sea level rise, 4) human activities, and 5) biological communities. All of these subjects are interconnected to affect and contribute to understanding coastal hazards in Maryland (http://shorelines.dnr.state.md.us/k-12.asp).

The ***Assistance*** portion of the website describes opportunities for property owners, communities, and local governments to receive technical and financial assistance with flood and erosion mitigation activities.

The ***Coastal Hazard Management*** section covers multiple topics that address coastal hazard and shoreline management issues. It is divided into the following subjects: 1) technology, data, and research; 2) modeling and monitoring; 3) planning, 4) case studies, and 5) living shorelines.

The ***Interactive Mapping*** section provides hands-on data and tools that can be utilized in decision-making. Links to Maryland Shoreline Changes Online interactive map viewer, Erosion Vulnerability Assessment, Comprehensive Shoreline Inventory, and the Shoreline and Littoral Drift Conditions maps are available in this section.

Maryland Shoreline Changes Online: An Interactive Internet Mapping Application

Maryland Shoreline Changes Online is the interactive GIS mapping application found on the MSO portal (http://shorelines.dnr.state.md.us/sc_online.asp). The tool contains data layers that can be viewed through the web by using ArcIMS 9.2 ® (Internet Mapping System) software, which is produced and published by ESRI (Table 1). The MSO mapping tool represents the gateway to information on shoreline conditions, coastal hazard risk, land use, and infrastructure. It allows users to view site-specific data and information at various scales and to choose any combination of data and characteristics. The flexibility of this tool allows it to work for different audiences and allows for shoreline management to be conducted in a more regional and holistic perspective/approach.

MSO Shoreline Changes Online mapping application contains a set of mapping tools to assist with navigating, analyzing, and displaying data and information (Table 2). This tools gives the user flexibility and functionality and allow him/her to move freely throughout the mapping interface.

RESULTS

Case Studies

Users of this mapping application are varied and can range from federal/state managers, local government regulators/planners, contractors, teachers, and the public. Scenarios are given to illustrate the wide scope of applications for the tools. These scenarios are crafted to address the varied audiences.

Data Layer Category	Data Layers
Shoreline Rates of Change	Shoreline change rates – Summary layer Transects, Baseline, All Historical Shorelines
Historical Shoreline Series	1988-1995, 1946-1977, 1925-1945, 1904-1924, 1883-1903, 1862-1882, 1841-1861 Shoreline photos (move to shoreline inventory below)
Shoreline Inventory	Access structures (docks, piers, marinas, ramps, boathouses) Riparian land use (agriculture, residential, commercial, etc) Stabilization structures (bulkheads, riprap, groins, breakwater, etc), *Phragmites* invasive areas, beach buffer, marsh buffer, bank cover, bank height and condition
Shoreline and Littoral Drift Conditions	Wind rose, sediment transport patterns, shoreline conditions
Storm Surge Areas	Category 1-4 inundation zones
Hydrology	Streams, rivers and lakes, water bodies, rivers and lake labels, stream labels
Transportation	Interstates, major highways, major roads, detailed roads, routes, road names
Topography	LIDAR Digital Elevation Model (DEM) (not currently available in the tool at this time – either indicate that it is coming in the future, or delete it), Bathymetric Contours
Watersheds	8-digit sub-basins, 10-digit watersheds, 12-digit sub-watersheds
Boundaries	Municipalities, counties, states
Imagery	Orthophotography

***Table 1**. Inventory of data layers available on MSO interactive mapping application.*

Scenario 1: A county land use planner is approached by a town manager about annexing several acres for residential development to accommodate the town's growth. The County planner remembers that the area has flooded in the past. Questions and characteristics that might be important to investigate and view in this situation include the following:

- Are there currently any roads or other transportation infrastructure that would be affected by storm surge? How will flooding of these roads impact the evacuation of residents in a new community? Are upgrades to the roads required to accommodate this growth? (Data layers: storm surge areas and transportation).
- Is the shoreline in this area eroding and if so, at what rate? (Data layers: all historical shorelines, transects, baseline, or shoreline rate of change summary layer. Use the ID or select by rectangle analysis tool to allow the online mapping tool to calculate rates of change).
- Are there currently any shoreline structures or buffers in place along the shoreline? (Data layers: stabilization structures, marsh buffers, and beach buffers).
- Are there any alternative locations to implement smart growth principles such as infill or redevelopment? (Data layers: land use/land cover, riparian land use, or use the Add Mapservice display tool to upload remote census data).

Scenario 2: A property owner has just attended a workshop on living shorelines and is interested in determining if the option could work along his or her shoreline.

- Is the shoreline in this area eroding and at what rate? (Data layers: all historical shorelines, transects, baseline, or shoreline rate of change summary layer. Use the ID or select by rectangle analysis tool to calculate rates of change).
- What is the fetch along the shoreline? (Use the measure tool and measure points in multiple directions to the next point of land).

Tools	Mapping Tools Functions
Navigation	
Zoom in	Increases resolution (replace with publication scale) of a map to allow a closer view of a selected area
Zoom out	Moves the view to a wider view perspective
Pan	Drags the view to another position using the mouse
Zoom to coordinate	User can navigate to specific coordinates using either MD State plane NAD83 or Latitude/ Longitude in decimal degrees
Zoom to previous	Allows user to return to the previous map view
Full extent	Map reloads to show a full view of Maryland's Coastal Zone
Locate Address	A point is placed on the map to mark the location of a submitted address
Analysis	
ID	Retrieves and displays information for a feature on a map from an attribute table from the database
Select Rectangle	Allows the selection of multiple features to be displayed together
Find	Locates a specific feature on map
Measure	Allows the distance between two selected points to be measured.
Display	
Print	A map can be printed on an 8.5" by 11" sheet of paper with legend and title
Clear	Removes previous selections and analysis activities
Add Mapservices	Provides connection to information from a remote map services and allows the data layers to be used in the MSO mapviewer
Adjust Mapservices (web page says map services)	Allows adjustment to map display of remote services data layers
Jump to County	Load view to selected county
Jump to Watershed	Load view to selected watershed

Table 2. *Summary of MSO interactive mapping application tools and functionality.*

- What is the bank type and is it stable? (Data layers: height, bank condition, and bank cover).
- Are there currently any shoreline structures up-drift from the shoreline that are contributing to a sediment starvation problem on the property? (Data layers: stabilization structures and littoral drift conditions).
- Could planted vegetation grow along the shoreline? Is there vegetation growing within 100 feet of the shoreline? (Data layers: marsh buffers).
- Will *Phragmites* sp. cause maintenance issues for a living shoreline technique? (Data layer: *Phragmites* invasive areas).

Scenario 3: A teacher working in a coastal county of Maryland would like to educate students about coastal issues. The teacher is required to teach about geography, GIS, and coastal processes. The teacher would also like to plan a field trip that reinforces the course materials.

- Under the "Human Activities" Section, carry out the Information Superhighway lesson and PowerPoint to introduce students to GIS.
- Teach the "Coastal Process" Lesson plan and read the associated Coastal Process fact sheet series.

- Develop a field trip to Assateague Island to conduct a beach profile and view coastal processes in action.
- Go to the Coastal Management section of the MSO website and link to the Living Shoreline section. Find a living shoreline demonstration site in this section and have students visit these as an extra credit assignment.

DISCUSSION

The historical shoreline series and the rates of change derived from the application are intended for general and educational purposes. Data are not intended to determine jurisdictional wetland and Critical Areas boundaries. The information is also not intended to predict future shoreline position, or show short-term changes associated with storm events. These limitations are provided in a disclaimer before a user is allowed to access the mapping tool. The user must first agree that he or she has read over the conditions before launching the tool.

Accuracy of the data should be considered when formulating assumptions from the web mapping tool. In particular, the method used to generate a layer (mapping error) compared to the actual change reflected in the shoreline change database needs to be considered when utilizing this tool. The application is capable of providing shoreline change trends since the mid-1800's. Since shoreline sources earlier than 1940's are less accurate, the application reports shoreline change for the last 50 years. The original sources from which the historical shorelines series were derived are at the scale of 1:10,000 to 24,000. Metadata is available for all layers and can be viewed in the web mapping interface. An error analysis has not been conducted on these data.

As the potential use of this application is varied, training and outreach on this application will be important for its success in reaching the target audiences. To specifically address these concerns, a training manual is being created that will be available online as well as sent out to each local government planner. A series of workshops will be advertised and held at a local library throughout the coastal zone and a workshop especially tailored to citizens and homeowners will be held after hours at MDDNR. The tool has already been promoted through a series of marine contractor workshops and will continue to be a lesson component in any future workshops.

Web-based open source applications and GIS will be important for the future of planning and management of shorelines and coastal hazards. As the promotion of living shoreline restoration and demonstration projects occur, this website provides an opportunity for the public and local governments to be more engaged in planning and decision making. Training and outreach on this application will be important for its success in reaching the target audiences. Improving aerial imagery and the addition of new data layers will be essential for long-term maintenance and usefulness.

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Living Shorelines: A Strategic Approach to Making it Work on the Ground in Virginia

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ABSTRACT

Eighty-five percent of the tidal shoreline in the Chesapeake Bay and its tributaries is privately owned (1). Shoreline management decisions in Virginia thus involve many thousands of individuals and dozens of local government regulatory bodies. The living shoreline initiative seeks to reverse the cumulative impacts of decades of individual decisions to harden the Chesapeake Bay shoreline. This goal can only be implemented "on the ground" with the involvement of those individual landowners, marine contractors, municipal governments, and local conservation organizations. Wetlands Watch, a conservation group in southeastern Virginia, examined ways to influence those landowner/contractor/local government decision points on shoreline alteration. We found little published social science and policy guidance on possible approaches to this task. We did assemble a range of fairly simple policy and programmatic initiatives that could translate Bay-wide living shoreline visions into a more effective strategy for locally based activities.

INTRODUCTION

Despite advances of living shoreline techniques in recent years, many shorelines are still hardened using traditional shoreline armor. The decision to use armor is made by many individuals who play a role throughout the project process, including individual landowners, contractors, and regulators. Therefore, efforts to advance use of living shorelines will need to involve changes to each of these types of decision makers and reach a large number of individuals. The marine contractor plays a key role in landowner selection of shoreline alteration approaches. According to a survey addressing landowner information sources (2), 67% of responding landowners received their information on shoreline erosion strategies primarily from marine contractors and came to the regulatory process with a contractor in hand.

Very few contractors offer a living shoreline approach. In southeastern Virginia, an informal phone survey by Wetlands Watch in 2005 found no marine contractors who offered living or soft shoreline services. At that time, an Internet search turned up only two contractors within the Chesapeake Bay region advertising bioengineered solutions to erosion/shoreline management problems.

The contractor, a developer, or even the landowner presents plans for shoreline alteration as part of the permit application. In Virginia, these tidal wetlands permits are jointly heard by the local wetlands board, the Department of Environmental Quality (DEQ), and the US Army Corps of Engineers. The Virginia Marine Resources Commission cedes its permitting authority for tidal wetlands to local governments that have adopted a model statute and 35 local governments in Tidewater Virginia have this authority. In reality, the local wetlands board dominate the decision-making process on routine, small permit applications that disturb and alter tidal wetlands at the land-water margin.

The Virginia Institute of Marine Sciences (VIMS) reviews the permit application, makes site visits, and provides an advisory report to the local board on the suitability of the proposal. While VIMS advisories have begun moving away from excessive shoreline hardening and encouraging more bioengineered approaches, the local wetlands boards do not routinely follow those advisories, especially if the applicant objects to the recommendations. In the experience of Wetlands Watch, without countermanding opinions present at the wetlands board meetings, the requested shoreline hardening is usually allowed. In addition, with property taxes as the major source of funding for local governments in Virginia, there is some pressure to allow the landowner's requested development to go forward.

Even if landowners and local governments were predisposed to encourage living shoreline approaches, the regulatory process can make approval of these projects difficult. Regulations and regulatory guidelines discourage placement of fill along the shoreline or disturbance of benthic habitat, a necessary component of many living shoreline approaches. Local decision makers are often unprepared to advocate for changes in the *status quo* due to lack of familiarity with the conditions conducive to successful bioengineering of shorelines and incomplete understanding of the ecological benefits of these approaches. In addition, doubts about the long-term viability of these approaches, especially in cases without landowner maintenance in the first years, are other factors contributing to the reluctance of many local governments to press for living shoreline approaches.

Changing this series of decisions by landowners, contractors, and regulators will take a carefully targeted effort. Decision dynamics at each of the key points need to be understood so that outreach and education efforts are property focused and targeted. These efforts need to be undertaken by local partners, "on the ground," willing to provide support for changes in local land use and regulatory decisions in Tidewater Virginia.

Unfortunately, there is insufficient information on key decision dynamics to guide these local partners and no strategic effort was taking place to provide them with the information or expertise needed to enhance efforts directed at living shoreline work.

MATERIALS AND METHODS

In 2006, Wetlands Watch researched ways to promote living shoreline applications along watersheds in Virginia. We believed we could target a watershed in a locality experiencing rapid growth with a program to educate landowners in the watershed about the advantages of living shorelines. Creating that "market demand" from property owners would educate marine contractors and other sources of referral to shoreline hardening approaches about these techniques. Finally, any approach to living shorelines also must include local regulators and wetlands board members to familiarize them with living shoreline work to minimize any regulatory hurdles to adoption.

We identified target localities by examining the statewide data on shoreline alteration and hardening. However, in the course of our research, we discovered a lack of information about landowner decision-making, impeding efforts to properly focus outreach and education work. Similarly, there was a lack of information about decision dynamics and available tools at the local government level, impeding work on local regulatory elements.

These shortcomings provide both a research agenda for the living shoreline effort and a strategic approach that may enhance efforts to promote living shorelines in Virginia.

Research Needs

Only four sources of information on decision dynamics and education and outreach were appropriate to this endeavor. The valuable Department of Environmental Quality (DEQ) report, authored by Krista Trono (2), on regulatory and individual landowner decisions, surveyed local wetlands boards on a range of information related to landowner, contractor, and local regulatory decision dynamics. More practical research of this type needs to be done. Researchers at VIMS looked at the relationship between environmental protection and economic development at the local level in a study conducted for the Environmental Protection Agency (3). This study just begins to examine the economic forces at work at the local government level, a necessary element to effecting change in land use and environmental regulatory decisions. A researcher at Iowa State looked at the reasons why farmers chose to enroll in wetlands restoration programs (4). This paper, while not specifically focused on wetlands decisions made by landowners in the Chesapeake Bay, indicates the strong role that ethics and aesthetics plays in landowner decisions to preserve and restore wetlands, as well as the key role of financial incentives. Finally, a study by the National Academy of Sciences on shoreline erosion control presents many views on the processes involved in applying living shoreline methods (5). Chapter 5 of that publication is especially relevant to discussions on decision-making.

Beyond these few sources of information, there is little to guide those who want to change the decision dynamics of landowners on shoreline alteration. Many of the research needs mentioned at conferences on living shorelines stress the biological or physical aspects of living shoreline work. As critical to the success of these efforts is information on the social and economic aspects of landowner and local government decision processes.

To move beyond single case living shoreline demonstration projects, we will need to know much more about how landowners make shoreline alteration choices, who is involved in helping shape these decisions, what incentives, aesthetic changes, or educational efforts have the most impact, and generally gain a better understanding of the motivations and behavior of landowners and developers. We need to better understand the decision dynamics of local governments on wetlands permits, Chesapeake Bay Protection Act/Critical Areas Act decisions, and zoning and land use decisions, as well as identifying regulatory barriers and any sources of local government reluctance to accepting these practices. We need to examine the local government's role in creating regulatory and financial incentives for living shorelines. The lack of information on these issues presents challenges to those devising a demonstration program with any certainty of success.

A final area of additional research is information about where these efforts will have the most impact. When Wetlands Watch examined the shoreline hardening figures provided by VIMS for the period 1999 – 2004, we discovered that four localities accounted for 50 percent of Virginia's shoreline hardening (Table 1). This clearly demonstrated that we needed to concentrate our work in one of those localities.

Strategic Programmatic Needs

Landowner economic and aesthetic considerations, lack of contractor capability, and lack of engagement with the regulatory process, especially at the local level, will hinder widespread adoption of living shoreline approaches. As government agencies, foundations, and community organizations increase efforts on living shorelines, a more strategic approach will be required, involving some of the following elements.

1) Strategic investment in demonstration projects. With future funding efforts/initiatives, attention needs to be paid to strategically addressing the location and type of projects funded. As shown in Table 1, four localities in Virginia accounted for half of the state's permitted shoreline alteration. Placing demonstration living shoreline projects in those high activity localities would serve to educate landowners and regulators in those high-activity communities on the benefits of these approaches. A contractor capacity would be developed in the communities where those services would be of most ecological benefit. Some of these high activity localities may lack a host organization capable of handling a grant, so early identification of groups and capacity building in targeted areas may be required. In addition, given the length of existing hardened shoreline, funding for retrofit and replacement projects should be a focus.

2) Enhanced attention to the outreach and education elements of funded projects. Demonstration projects serve as places where people can come and "kick the tires" on living shoreline projects. Field days (similar to those used in agricultural extension) should be a part of each project, allowing interested parties like landowners, contractors, local government officials, etc. to see completed projects. Media outreach should also be a component of this phase of the project and a required element of any project located in an area where large numbers of shoreline permits are issued (Table 1). Funding sources should look to multiply the impacts of projects by providing media packages and training, mentoring, or assistance on the conduct of "field days," and other outreach assistance. Funding conditions should include requirements for rigorous

LOCALITY	1999-2004 Hardening (lin. ft.)	% Statewide Total
Northumberland	121,993	20%
Lancaster	78,953	13%
Virginia Beach	66,235	11%
Westmoreland	35,914	6%
State Totals	617,812	

Source: Virginia Institute of Marine Science Wetlands Program (2005) Tidal Wetlands Impacts
Data Home Page: http://ccrm.vims.edu/wetlands/tables.html.

Table 1. *Shoreline hardening of Virginia's top four localities, 1999-2004.*

documentation to allow proof of concepts used, create a pool of information for outreach and education, and develop program guidance to be fed back and inform the awarding of grants in subsequent rounds. Outreach and education for local governments and citizen boards is essential. Wetlands board/Chesapeake Bay Board members in Virginia are not kept abreast of new scientific developments, like living shorelines, because state funding for these functions has been cut over the years and many local governments cannot fill the gap.

3) Better understanding of how the regulatory process impedes or speeds these projects. As some of the currently funded projects move to completion, a set of information is developing on how these approaches fare in the regulatory process. Back casting through these experiences will begin to expose points of conflict between the regulatory *status quo* and the goal of adoption of newer, bioengineered processes. Requirements for adequate documentation (see #2 above) and analysis of final project reports will increase efficiency of the regulatory process. An additional need in this area is the development of detailed guidelines or guidance documents on where these systems are applicable and what constitutes acceptable and best practices for each of the approaches used. These will provide landowner and regulatory reassurance as well as protection against "green scamming" or re-labeling status quo approaches as "living shorelines."

4) Development of a contractor community capable of delivering desired services as demand is built. This is a critical need that has been identified by funders and government agencies alike

At this point it is uncertain what the contractor sector for these services will look like, whether existing contractors will adopt living shoreline services or whether a new contractor sector will emerge. Whatever direction the contractor community takes, if funders are successful in creating demand for these approaches, there is a need to have a contractor community prepared and capable of providing services to landowners. This is especially critical given their central role in shaping the landowner's approach to shoreline projects.

5) Analysis of approaches used to change behavior/adopt new technology in other areas, such as the adoption of no-till farming. There are many parallels between efforts to promote living shorelines today and the work to promote low-till/no-till farming in the 1980's. In both cases, individual landowners were responsible for a broad environmental impact, the minimization of which required the individual landowner to make changes in traditional land management approaches, at the landowner's risk and cost. In both cases, there is a large aesthetic component that needs to be addressed: shoreline homeowners have been conditioned to appreciate "neat" linear shorelines and the farming aesthetic was for fields to be cleaned of all stubble with the soil turned under in the fall. However, in both cases research clearly shows the environmental benefit of minimalist approaches to land management: living shorelines provide numerous environmental benefits just as no-till farming reduces soil erosion.

Achieving adoption of no-till required working with farmers to change their behavior while documenting the cost/profitability of the practices, and making sure that new equipment and materials were ready when the farmers decided to change their ways. Early adopters were given full cost-sharing to adopt the practice and "field days" were held by the Agricultural Cooperative Extension Service/Soil Conservation Service/Agriculture Stabilization and Conservation Service for surrounding farmers to come onto the land and see the benefits. Today in highly erodable areas, no-till farming is practiced with pride in the stewardship ethic it represents. "Messy fields" over the winter are a symbol of good farming

The challenges facing widespread adoption of living shoreline approaches are similar to those facing no-till farming in the 1980's. Changing aesthetic values, proving the economics, developing technology standards and best practices, conducting outreach using successful examples – all need to be part of a strategic approach to adoption of living shorelines. Reviewing the earlier no-till effort (6) and examining the technology adoption practices used then can help guide strategic funding and technology adoption in this area.

6) Work on model zoning and planning tools to create regulatory incentives for living shorelines. Shorelines and adjacent landscape features provide a number of unique environmental services and development in these areas should be avoided or restricted. Local land use decisions are critical to the conservation of these areas and can also be used to provide incentives for living shorelines. Virginia State zoning authority allows the use of zoning to protect water quality and could be of use in living shoreline efforts.

In addition, other zoning and land use tools are options and should be explored, such as special overlay districts, model zoning ordinances, and the like which impose special conditions on construction and development within shoreline zones. Some localities are already using some of these approaches.

7) Creation of financial incentives for living shorelines. In 2005, the Virginia Marine Resources Commission closed a loophole in the regulations that exempted tidal wetlands impacts of less than 1,000 square feet from paying mitigation. These impacts were the exact ones usually associated with shoreline alteration by individual landowners. With this “new” source of funds available to localities, incentives could be provided for living shoreline efforts, should local governments act to sequester the funds. While all shoreline alterations, including living shorelines, are subject to this change, exemptions or lower rates for living shorelines could be an additional incentive option. As shown in the no-till experience, financial incentives can go a long way toward changing behavior.

A comprehensive review of shoreline alteration permits issued in Virginia Beach in 2001 showed 4,265 square feet of uncompensated vegetated wetlands impacts and 19,443 square feet of nonvegetated wetlands impacts. If just the vegetated wetlands were compensated for at the current rate set in Virginia Beach of $25 per square foot, this would yield $106,625 that could be applied toward living shoreline efforts in that city.

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Willingness to Pay for Risk Reduction and Amenities: Applications of the Hedonic Price Method in the Coastal Zone

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ABSTRACT

Expansion of development along U.S. shorelines has put increased pressure on coastal ecosystems. As a result, many shoreline ecosystem services have been degraded or lost. As coastal populations become more vulnerable to natural hazards, policy makers search for methods to evaluate the benefits and costs of different shoreline management alternatives. In this paper, we describe hedonic property models as one method for measuring the benefits and costs of shoreline management alternatives. Hedonic property models are used to investigate homeowner preferences for risk factors and environmental amenities using information on housing market transactions. With appropriate data, these models allow analysts to assess whether such factors affect buyer's bids for property and to estimate the associated private costs or benefits. We begin with a basic description of the model, followed by examples of studies that have applied the method in the coastal zone. Lastly, we speculate on how the model could be relevant to analysis of living shorelines.

INTRODUCTION

Coastal populations have expanded rapidly in the past twenty years, increasing pressure on a multitude of scarce coastal resources. In the U.S., coastal watershed counties, which comprise less than 25 percent of the land area, are home to more than 52 percent of the US population (1). Areas in Florida with shoreline zip codes experienced a 25% increase in population and a 24% increase in housing between 1990 and 2000 (2). The number of building permits in Carolina Beach, North Carolina over a recent 24 month period exceeded the number of permits issued over the previous 20 years (3). As population density rises, open space and natural amenities become scarce resources.

At the same time, coastal property values have increased dramatically. For example, average selling price for residential properties in Wrightsville Beach, North Carolina increased 420 percent since 2001 (3). Numerous factors facilitate growth in the value of coastal real estate. Increases in disposable income have played a role (4). Economists describe coastal recreation as a normal good, meaning that as income increases, demand for coastal recreation also increases. Moreover, with average life spans longer than ever before, many want to spend some portion of their "golden" years on the coast. Coastal areas have experienced a large influx of retirees as the Baby Boomers begin to leave the workforce. Increasing demand with finite land availability leads to escalating prices.

Coastal shorelines constitute dynamic environments where change is often a function of some combination of physical forcing processes (e.g., weather, waves), spatial characteristics (e.g., shore orientation, shore slope), underlying geology (e.g., sediment type, consolidation of material), vegetative communities (e.g., salt marshes, sea grasses), and the physical characteristics of human development (e.g., concrete structures, residential buildings). Expanding populations are not only susceptible to natural coastal hazards—including storms, flooding, sea level rise, and coastal erosion (5,6)—but development patterns can exacerbate the physical and social impact of such hazards. The situation presents a formidable challenge for managers and policymakers—what, if anything, should be done in the public interest? At least two preliminary questions arise in this regard—to what extent do developers and property owners incorporate coastal risk and amenity factors in their decision making process? And, what trade-offs are property owners willing to make? That is, how do they value changes in risk and amenities?

Local governments and property owners must choose a strategy for management of shorelines. Historically, many have chosen hard stabilization techniques such as bulkheads, revetments, breakwaters, sills, and seawalls. These methods often successfully stabilize the shoreline, but have negative impacts on ecosystem services. Many of the hardening strategies have direct impacts on intertidal areas by eliminating nursery habitat and disrupting sediment transport. Shoreline hardening can drastically change the sediment budget of water bodies, affecting sediment inputs from upland areas as well as in stream transport of material. Hardening structures also impact nutrient budgets and wildlife habitat.

Vegetated or living shorelines offer an alternative for addressing erosion. Living shorelines play a crucial role in the transition from terrestrial to aquatic environments, providing important ecosystem services such as wildlife habitat, nutrient uptake, and water purification. Economists argue that the lack of an identifiable market for these services often leads to ecosystem degradation. In many cases, the ecosystem services associated with living shorelines have considerable net social benefits, but property owners often consider only the private benefits and costs when making land use decisions. Under these circumstances, individuals making decisions in their own best interest can engender a situation in which society is made worse off. Economists refer to this phenomenon as market failure, and such a situation may justify—from a strictly normative economic standpoint—government intervention to reconcile private and public interests.

This paper focuses on the application of hedonic property models as they relate to the coastal zone. Hedonic property models are used to investigate homeowner preferences for risk factors and environmental amenities using information on housing market transactions. With appropriate data, these models allow analysts to assess whether environmental and risk factors affect buyer's bids for property and to estimate the private costs or benefits associated with these factors. We begin with a basic description of the model, followed by examples of studies that have applied the method in the coastal zone. Lastly, we speculate on how the model could be relevant to analysis of living shorelines.

HEDONIC PROPERTY MODELS

It is difficult to measure people's preferences for environmental amenities because, in most cases, individuals and firms do not trade environmental amenities in explicit markets[1]. In fact, real estate markets comprise one of the few existing explicit markets on which environmental amenities are implicitly traded. Consumption of property confers an array of associated spatial attributes, such as access to local recreation sites, exposure to local air and water quality, proximity to toxic and hazardous waste sites, and so forth. In a competitive market with many housing bidders and many available properties, market prices reflect the value of the "bundle" of attributes of individual properties. Housing is traded in a single market, but the price adjusts to reflect differences in attributes, and as such, differences in market price reflect individuals' preferences (or "willingness to pay") for housing attributes[2].

The hedonic property model is predicated on the notion that the observable price of a house is a function of structural, neighborhood, and environmental attributes. Homebuyers are assumed to have "well-behaved" preferences (meaning that each individual is able to compare goods and their method of comparison, whatever the motivation, is consistent) for consumption goods and housing attributes. Their choices of housing and consumption goods are constrained by the prices they must pay to consume these

[1]Economists often call goods without explicit markets Non-market Goods. Subsequently, they refer to the process of measuring individual's economic value for these goods using a common metric, non-market valuation.

[2]Housing markets are geographically delineated to include properties which are viewed by buyers as substitutes for one another. This may be influenced by numerous factors, including labor markets. See Palmquist (7) for more information.

goods and their level of income. If they are well-informed about their options and rational in their decision making, they will make choices that maximize their own happiness (or utility). Under this theoretical framework, statistical estimates derived from housing data can be used to estimate the average consumer's "marginal" willingness to pay (WTP) for housing attributes. We refer to marginal WTP because estimates from the hedonic price model only reveal the value of an additional unit of a housing characteristic—for example, an extra bedroom or an extra square foot of living space. Additional assumptions, information, and/or statistical estimation are required to estimate the total value of housing characteristics. Nonetheless, the hedonic property price method can be used to estimate marginal WTP for environmental amenities and risk factors, items not explicitly traded in markets.

A chief advantage of the hedonic property price method is the accessibility of housing data. Local tax assessor offices record information on property transactions, including final price, housing attributes, and date of sale. If there is sufficient variation in housing attributes, an equilibrium hedonic price function can be estimated to recover estimates of homebuyer's marginal valuation of housing attributes. For example, the hedonic price function might take the following form:

$$\ln(price_i) = \alpha + \beta_1 S_{1i} + \cdots + \beta_s S_{si} + \gamma_1 N_{1i} \cdots + \gamma_n N_{ni} + \theta_1 E_{1i} \cdots + \theta_e E_{ei} + \varepsilon_i \qquad (1)$$

where 'ln' represents a natural logarithmic transformation (logarithm to the base e), $price_i$ represents the recorded price of housing unit i, $S_{1i}...S_{si}$ represent s structural attributes of house i, $N_{1i}...N_{ni}$ represent n neighborhood attributes of house i, and $E_{1i}...E_{ei}$ represent e environmental attributes of house i.

In equation (1), α, β, γ, and θ are model "parameters" that are estimated via statistical techniques (e.g., method of least squares, maximum likelihood, or some other method). The model parameters represent the marginal contribution of each attribute to housing price. Some of these attributes, such as structural attributes, are specific to an individual house. Other attributes vary spatially. In coastal environments, housing prices have been shown to reflect beach quality, erosion risk, flood risk, ocean view, proximity to wetlands, proximity to open space, and shoreline armoring. Many of these characteristics are spatial in nature, affecting homes in different locations to varying degrees. For a more complete description of the hedonic property model, see Palmquist (7).

APPLICATIONS OF HEDONIC PRICE MODEL

Housing values capitalize (i.e., adjust to reflect) various aspects of environmental quality based on the nature of the flow of environmental services provided to the property. If environmental quality diminishes (increases), housing value may decrease (increase). In studies of beach quality, researchers have found that homeowners assign a price premium to sections of shoreline with superior beach quality. The dynamic nature of coastal shorelines makes this type of analysis potentially difficult due to variation in beach quality over time. Pompe and Rhinehart (8) examine the impact of beach quality on oceanfront homes in SC, finding that increasing beach width from 79 to 80 feet increases oceanfront home value by \$558. Landry, Keeler, and Kriesel (9) investigate the impact of beach quality on all barrier island homes, since beach quality affords protection not only to oceanfront homes, but also recreational benefits to all landowners. They find a lower overall value for beach quality, when compared to the results of Pompe and Rhinehart. In their study, increasing beach width from 27 to 28 meters increases home value by \$233. This result is not unexpected since adding other, non-oceanfront properties to a sample lowers the average home value.

In addition to valuing beach amenities, hedonic property models have a rich history in valuing other environmental amenities. An amenity relevant to living shorelines is the wetland ecosystem. Wetlands provide a wide array of ecosystem services including provision of flood protection, biogeochemical processing of nutrients, and wildlife habitat. In an urban setting, wetlands also provide open/green space. Mahan, Polasky, and Adams (10) find urban wetlands have a positive impact on Oregon home values. Their results indicate that increasing the size of the nearest wetland by one acre increases property value by \$24. Decreasing distance to the nearest urban wetland by 1,000 feet increases value by \$436. However, empirical evidence suggests that wetlands are not perceived as desirable spatial characteristics in rural settings. Bin and Polasky (11) find that increasing the size of nearest wetland by 25% decreases property value by $217. Similarly, they find that decreasing the distance to wetlands by 25% decreases property value by $945. This finding certainly does not imply that wetlands in a rural setting have no value, but rather that rural landowners are not willing to pay a premium to locate near wetlands or that there is some other disamenity associated with these wetlands.[3] This finding, in fact, makes economic sense, as wetlands and open space are typically not scarce in rural settings. Scarcity, the central tenet of economic theory, is fundamental in economic valuation. Thus, hedonic models may not be useful in estimating economic value of rural wetlands. Some other valuation method must be used if one would like to assess the value of rural wetlands. In this case, property markets are not picking up many of the public benefits provided by rural wetlands, but they are picking up some of the disamenities.

In addition to environmental benefits, housing properties can also capitalize risk. Intuitively, risky properties should sell for less, all else being equal. In their investigation of erosion risk, Landry, Keeler, and Kriesel (9) find a substantial discount for those properties in close proximity to high erosion hazard areas. The market value of homes in high erosion areas were reduced by $9,269. Dorfman, Keeler, and Kriesel (12) examine shoreline protection schemes along the Lake Erie coast, focusing on the impact of hardened structures placed offshore to prevent bluff erosion. They find that housing values capitalize the value of erosion protection; erosion protection structures increase average property value by $16,261 by decreasing probability of erosion loss to a low level (0.05%). In a study of the effects of flood hazards on property values in Carteret County, North Carolina, Bin and Kruse (13) find that average property values are 5% to 10% lower when located in inland flood zones. These results indicate that hedonic models can be used to estimate willingness to pay to avoid erosion and flood risks.

Estimation of willingness to pay from hedonic property price models can be complicated by correlation of housing characteristics. Correlation is found in housing data when two or more characteristics tend to move in the same or opposite directions. For example, houses with large square footage will tend to have more bedrooms and vice-versa, a positive correlation. If too much correlation exists in housing characteristic data, the separate effect of characteristics on housing value cannot be identified. Correlation can be a problem in coastal housing data. Bin and Kruse (13) find that houses in flood zones on the coast tend to sell for more than other houses. However, these homes tend to be oceanfront and/or have superior ocean view (a positive correlation between flood risk and amenities). As such, it can be difficult to separate the effect of flood zone and view amenities in coastal housing markets.

Bin, Crawford, Kruse, and Landry (14) use a novel approach to solve this identification problem. Many previous papers have used ocean frontage as a property attribute (8, 9, 13). These studies argue that ocean frontage primarily conveys benefits in terms of access and amenities. Instead of controlling for ocean-frontage, Bin et al. use distance from the water to account for benefits of access, and use a GIS[4]-derived viewscape measure to account for benefits associated with coastal ocean view. Viewscape is a three-dimensional measure of ocean view that is designed to capture the view amenities associated with a property, taking into account man-made and natural obstructions to view and how these obstructions change over time. Importantly, the viewscape measure varies independently of risk, allowing researchers to disentangle spatially integrated attributes. The authors find that increasing ocean view by one degree increases housing value by $995. For their access measure, they find that a 10 foot decrease in distance to the beach increases housing value by $853. Location in a flood zone decreases housing value, on average, by $36,081.

DISCUSSION

The Committee on Mitigating Shore Erosion along Sheltered Coasts identifies four primary approaches to addressing erosion: 1) manage land use, 2) vegetate, 3) harden, and 4) trap and/or add sand (15). Each of these approaches can be applied individually or in conjunction with one another. In the past,

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[3]The authors control for flood risk, so the negative estimates are not picking up this disamenity.
[4]Geographic Information Systems – a computer-based spatial data processing program

many communities have chosen to harden their shorelines. Hardening techniques form a physical barrier to natural erosive processes. They typically reflect wave energy and bisect coastal habitat, which leads to degradation of nearshore ecosystems (15).

Living shorelines offer an alternative. From an ecological perspective, living shorelines offer a multitude of ecosystem services that are lost with hardening. The societal benefits of these ecosystem services may not coincide with how individuals derive benefits from the use of their private property. Policy makers must determine the extent to which individuals are willing to implement living shorelines as an alternative to hardened structures on their property, and what affects the choice of erosion management techniques. Do property owners value living shorelines as a shoreline management strategy? How do they perceive their effectiveness in controlling erosion and providing for enhanced ecological services and function? Individual choices are rooted in a potentially complex behavioral process influenced by many factors, such as personal experience, knowledge, beliefs, attitudes, and personal constraints.

Analysis of shoreline protection projects and surveys of property owners could be helpful in answering these questions, but the hedonic property price model may also play a role. Any property investment that is commonly viewed as providing protection or enhancing natural amenities may influence housing value. In other words, a home that lacks erosion protection faces higher erosion risk and likely sells at a discount. The discount will likely reflect perceived erosion risk associated with the location, the cost of fortifying the shoreline, and any uncertainty about one's ability to protect the property. Homes that are protected from shoreline erosion should sell for more, all else being equal. A key empirical question is whether homebuyers view hardened structures and living shorelines as equally effective in terms of erosion control and equally desirable aesthetically.

We propose using the hedonic property model to evaluate homeowner's preferences for erosion risk protection and natural amenities. Such a modeling exercise requires data with adequate variation in housing attributes, risk factors, and erosion protection schemes. This type of variation would likely necessitate many data points (i.e., housing sale observations) within a single housing market. In addition to the information recorded in the typical tax assessor's database, one would require various erosion risk factors, such as slope, sediment type, and historical erosion rate. To assess the value of living shorelines *vis-à-vis* hardened structures, one would need to witness a reasonable number (e.g., 10-20%) of properties that had chosen one of these strategies for shoreline erosion management. Ideally, the spatial pattern of these observations would be random, with management strategies allocated in a stochastic manner to different property types and shoreline configurations. One must be careful to ensure that shoreline management strategies are not correlated with other property attributes, such as newer homes tending to utilize living shorelines (this would induce a correlation between age of the house and management strategy).

In order to adequately assess the impact of living shorelines on housing prices, one needs to know shoreline condition that existed at the time of sale. Only properties that had living shorelines installed at the time of sale can be used to infer the value of this type of protection in the hedonic price framework. It may be difficult or impossible to record shoreline conditions for property sales that occurred in the past, though the permitting process could assist in compiling the information as it provides a paper trail on shoreline protection projects. Additional information, such as detailed living shoreline characteristics, could improve the analysis and the quality of inference. The type of shoreline vegetative community should influence the services derived by homeowners. If enough variation exists in available market data, classifying living shorelines by community type may help managers understand the trade-offs that homeowners are willing to make and could assist in designing optimal policies.

If homebuyers find living shorelines more aesthetically pleasing, we would expect a positive effect on home price (all else being equal). A hedonic price analysis would require detailed information on shoreline erosion protection, such as age of the project, whether it is in good shape and performing well at the time of sale, and perhaps other information. Lastly, one might want to consider the array of erosion protection surrounding an individual property. Homebuyers may perceive hardened structures on their neighbor's shorelines as unsightly, or may (perhaps rightly) believe that erosion on their own shore is exacerbated by their neighbor's protection devices. Recording the extent of shoreline armoring and green space on the waterway visible from a property would allow one to explore these potential external effects.

The hedonic property model gives policymakers a method to measure individual values for housing attributes as revealed through market transactions. To the extent that homebuyers value living shorelines as risk mitigants and aesthetic enhancements, one might find that their hedonic price is in fact positive—they tend to increase property value. Such a result would suggest that there exists some purely economic incentive to utilize living shorelines for erosion management. By including data on other erosion management strategies, a hedonic model could provide information on how homeowners view living shorelines *vis-à-vis* other alternatives. To the extent that homebuyers do not value living shorelines, a hedonic property model could identify whether they have no effect on property value or a negative effect. In the case of the latter, results could indicate the magnitude of incentives (i.e., subsidies or reduce property taxes) required to increase the use of living shorelines.

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Incentives to Promote Living Shoreline Techniques in the Chesapeake Bay

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ABSTRACT

Management incentives can be broadly described as financial, technical, and regulatory in nature. A majority of the incentives for living shoreline techniques in the Chesapeake Bay fall under the financial assistance category. Financial assistance includes grant and loan programs for public and private lands. These financial assistance programs have, in turn, begun to indirectly develop an incentive for marine contractors and engineers. These groups have been responding by adding living shoreline techniques to their design toolbox. This paper provides an overview of existing types of grant and loan programs for Chesapeake Bay public and private property owners, and investigates additional types of potential incentives for property owners, contractors, and local governments to promote living shoreline implementation in the future.

INTRODUCTION

Management incentives applicable to living shorelines can be categorized as: (a) financial, such as grants, loans, and tax credits or deductions; (b) technical, such as site review or design assistance; and (c) regulatory, including, for example, permit exemptions, no fees or reduced fees, and streamlined or expedited permits. A majority of the existing incentives for living shoreline protection and restoration techniques in the Chesapeake Bay fall under the financial assistance category, and include grant and loan programs for public lands, local governments, communities associations, and private property owners.

The term "living shorelines" describes the incorporation of natural habitat elements into shoreline protection design, while ensuring effective buffering from erosion. The goal of living shoreline implementers is to use this approach, in place of hard shoreline armor, in as much of the Chesapeake Bay shoreline as possible. Implementing this goal can be achieved by (a) replacement of bulkheads, seawalls, or revetments, where conditions allow, with designs that include habitat elements such as marsh grasses; and (b) installation of living shoreline techniques instead of hard armor approaches in eroding areas that have not yet been stabilized.

Several impediments exist limiting the use of living shorelines instead of structural stabilization. First, as with any shoreline stabilization method, soft or hard, these practices can be expensive. The cost often depends on such factors as energy regime and design, but is generally on the order of hundreds of dollars per linear foot. Many sectors of the public assume that living shoreline options are more expensive than traditional armor, which is generally only true in high energy regimes. In high energy areas, the living shoreline requires large quantities of rock to reduce wave energy enough for vegetation to persist, a factor that can push the living shoreline option above $500 per linear foot (though prices vary greatly depending on conditions). In low energy regimes, living shorelines require less rock than traditional armor, reducing the cost (usually $50-$200 per linear foot, but again, these prices vary depending on conditions).

Second, 95% of Maryland's Bay shoreline is privately owned, which requires major behavior change on the part of waterfront property-owners to achieve wide-scale living shoreline implementation. Some sectors of the public prefer the aesthetics of a neat and trim bulkhead to the natural and wildlife–supporting marsh grasses of a living shoreline. This behavior change requires considerable public education, as well as financial incentives to make the path to living shorelines easier than traditional stabilization.

The third obstacle to implementation is the fact that living shoreline techniques are still considered relatively new and do not have an extensive documented history of performance. Guidelines for living shoreline designs are also still under discussion, and no formal process exists to certify newly trained practitioners. Marine contractors have been resistant to add living shoreline techniques to their suite of solutions due to lack of exposure to the new techniques and/or a perceived greater level of liability for project failure with living shorelines.

The final impediment to implementation of living shorelines is regulatory in nature. In the Bay region of Maryland, both living shoreline projects and shoreline armor projects (bulkhead and revetments) less than 500 linear feet fall under the same general tidal wetlands permit category. Currently, no regulatory preference for the selection of a living shoreline design exists. To the contrary, in some cases, living shorelines may go through a more rigorous review process due to a larger impact on public trust bottoms and encroachment into navigable waters, which may require a public notice and meeting. Since standard designs and specifications for living shorelines are only beginning to emerge, permit applications can include a wide range of designs that may be unfamiliar to both state and local permitting staff. In addition, designs may contain "non-traditional" elements such as woody debris or coir fiber logs, which may slow down the permit approval process.

Identifying these impediments to implementation is the first step towards creating a set of incentives to promote use of living shoreline techniques. Several types of incentives already exist, mostly in the financial realm. However, a broader suite of incentives needs to be crafted to overcome current hurdles. Groups that may be the focus of such targeting include property owners, marine contractors and builders, engineers and designers, and local governments and regulatory staff.

EXISTING INCENTIVES

Incentives for Property Owners

At present, there are several types of grant and loan programs that are designed to encourage public and private property owners to use a living shoreline solution to address erosion. Most of these programs are meant to serve as a cost-share, rather than to finance an entire project. The logic behind the cost-share aspect is that property owners benefit directly from shoreline stabilization, and therefore should play a financial role in the process.

Both public and private landowners, including individuals as well as organizations such as community associations, churches, and schools, are eligible for several grant and loan programs for help with living shoreline implementation (Table 1). Virginia landowners can apply to either the Living Shorelines Initiative administered by the Chesapeake Bay Trust with National Oceanic and Atmospheric Administration Restoration Center, Campbell Foundation, and National Fish and Wildlife (NFWF) partners, or to the Chesapeake Bay Small Watersheds Program administered by the NFWF. For either of these programs, individual private property owners must seek a nonprofit organization such as a regional Resource Conservation and Development Council or county-based Soil Conservation District to serve as the lead applicant on his or her behalf. Technical assistance for applicants is available for both of these programs through the NOAA Restoration Center and the Chesapeake Bay Trust.

Maryland property owners have the same two options described above, in addition to a few others. In terms of grant programs, the Maryland Department of the Environment (MDE) Small Creeks and Estuary Restoration Program serves both private and public lands, and the MDE Tidal Wetland Compensation Fund serves private lands only. For smaller projects, the Chesapeake Bay Trust's Stewardship Program, which funds projects at a lower dollar amount, is also an option for public and private nonprofit projects.

The State of Maryland also offers three loan programs (Table 1). The Department of Natural Resources (DNR) Nonstructural Erosion Control Program offers a no interest loan program for both private and public projects. A DNR Structural Erosion Control Program also exists and can be used for large living shoreline projects such as offshore breakwaters. MDE offers low interest loan programs for projects on either public or private lands sponsored by a local government (Water Quality Revolving Loan Fund) or individually owned public lands (Linked Deposit Program).

Although not direct financial assistance, local government and Natural Resource Conservation Service programs have provided free wetland plants to waterfront homeowners. These programs can provide just enough of a cost savings for a property owner to move from traditional hard stabilization to a greener approach. For example, Anne Arundel County has grown plants and provided up to 2,000 plants to shoreline property owners, who can return each year for a new stock of plant materials.

Incentives for Marine Contractors

Why should a marine contractor or design firm take time to learn about living shorelines techniques? The answer is that the demand will continue to rise. As Bay problems receive increasing attention, more and more waterfront owners are becoming interested in determining an environmentally friendly approach to protecting their shorelines. This demand is developing in part independently of the financial incentives described above. However, those grant and loan programs do often serve as the impetus for a landowner to take action on a failing bulkhead or eroding shoreline. These financial incentives have created a niche addressed by some marine contractors and engineers. Examples of marine contractors taking a lead in an area, becoming known as "living shorelines" contractors, are becoming more common.

State and local government shoreline groups, such as the Maryland and Virginia Coastal Zone Management Programs, have recognized this emerging incentive for contractors and have conducted introductory courses to encourage more contractors to add living shoreline techniques to their project toolbox. More sophisticated regional contractor training sessions that delve into greater design and construction detail are planned. Marine contractors are often the first point of contact a private property owner has when seeking consultation on how to address a shoreline erosion problem. They can also provide feedback to managers about the relative success or failure of projects and policies. It is imperative that managers and marine contractors share more information with each other.

FUTURE INCENTIVES

Investigation into expanding the types of incentives offered to promote living shorelines is ongoing in both Maryland and Virginia. This activity includes both bolstering existing incentives programs and creating new programs to target additional stakeholders.

Incentives for Property Owners

As demand for living shoreline solutions increases, existing grant programs for public and private property owners will likely be expanded by private and government funders. The existing programs listed in Table 1 will most likely continue to fund living shoreline work. As water quality benefits of living shorelines are quantified, other types of grant programs may become open to funding part or all of living shorelines projects. The Conservation Reserve Enhancement Program (CREP) of the United States Department of Agriculture represents a future opportunity for living shorelines on agricultural lands. CREP currently provides financial assistance to farmers for the restoration of buffers to protect water quality. Living shorelines would work well in this program by providing a wider buffer for more effective nutrient absorption, while also protecting the existing riparian buffer from eroding. However, additional studies are needed to quantify the erosion-control benefit of living shorelines in order to overcome perceptions about the lack of long-term success of these designs.

Investigation into a living shoreline tax credit program for waterfront landowners is a viable incentive option requiring further investigation. Tax incentives could be used in a manner that would reward landowners for implementing approved shoreline practices that provide habitat enhancements. Tax incentives can also be offered to property owners for donating land for conservation purposes or for adding a conservation easement along the waterfront of their property to either limit development and/or prevent shoreline hardening (1).

Two other types of tax-related programs may help with implementation of living shoreline projects. In Maryland, the Taxing District Law (Annotated Code Article 25 County Commissioner/Erosion Control)

Organization	Program	Type	Eligible Project Types	State	Amount	Due Date	Contact Information
Chesapeake Bay Trust, NOAA-Restoration Center, Campbell Foundation, National Fish and Wildlife Foundation	Living Shorelines Initiative	grant	public and private	VA, MD	up to $75,000	Sep	(410) 974-2941 cbtrust.org
Chesapeake Bay Trust	Stewardship Program	grant	public and some private	MD	up to $25,000	Jul, Dec	(410) 974-2941 cbtrust.org
National Fish and Wildlife Foundation	Chesapeake Bay Small Watersheds Program	grant	public and private	VA, MD	up to $50,000	Feb	(202) 857-0166 nfwf.org
MD Department of the Environment, Water Management Administration	Small Creeks and Estuary Restoration Program	grant	public and private	MD	75% cost share	Feb	(410) 537-3908 http://www.mde.state.md.us/Programs/WaterPrograms/WQIP/index.asp
MD Department of the Environment, Tidal Wetlands Division	Tidal Wetland Compensation Fund	grant	private	MD	generally up to $50,000	on-going	(410) 537-3835
MD Department of the Environment, Water Quality Financing Administration	Water Quality Revolving Loan Fund	low interest loan	public and private; applicant must be local gov't	MD		Feb	(410) 537-3908 http://www.mde.state.md.us/Programs/WaterPrograms/Water_Quality_Finance/index.asp
MD Department of the Environment, Water Quality Financing Administration	Linked Deposit Program	low interest loan	private	MD		Feb	(410) 537-3908 http://www.mde.state.md.us/Programs/WaterPrograms/WQIP/index.asp
MD Department of Natural Resources Shore Erosion Control Program	Nonstructural Erosion Control	no interest loan	public and private	MD	public: no limit; private: up to $25,000	on-going	(410) 260-8523 http://www.dnr.state.md.us/grantsandloans/shoreerosion-control.asp

Table 1. *Financial assistance programs for Living Shoreline Implementation on public and private lands in Maryland and Virginia.*

permits property owners in a community, with agreement by 75% of the property owners, to become a special tax district, allowing the collection of taxes to pay for community projects. These tax funds provide another erosion control financing option. An example of a community that has used such funds to implement living shoreline projects is Anne Arundel County's London Towne Property Owners Association, which owns almost all of the waterfront property within the community boundaries.

In addition, in 2005, the Maryland State Legislature allowed local governments to develop a Property Tax Credit for shoreline erosion control structures through the authority of Section 9127, Tax-Property Article, Annotated Code of Maryland. Dorchester County was the only local government to take advantage of the opportunity to grant real property tax credit of 30% of the total cost of an erosion control structures over a period of fifteen taxable years. Although intended for larger, more traditional erosion control structures (steel or timber bulkheads, concrete walls, revetments), projects such as stone toe reinforcement, breakwaters, and groins were also included. If properly designed, these projects could be modified to have a greater natural habitat component, qualifying them as living shorelines, and still take advantage of this financial opportunity.

Incentives for Marine Contractors

The growing number of property owners aware of living shoreline techniques serves as the biggest incentive for marine contractors and engineering firms. Additional incentives may include (a) certifying and developing a "green" contractors list to support a broader clientele base, (b) increasing technical assistance opportunities, and (c) establishing regulatory modifications to streamline living shorelines permits that meet certain minimum standards.

In terms of promoting a greater clientele base, managers should continue to hold events, publish literature, and advocate for these projects in order to continue property owner awareness and demand. However, in order to keep pace with demand where high and create demand where low, contractor training programs at which experts discuss and demonstrate design, construction, and maintenance should continue to be developed. By providing more technical assistance opportunities, contractors will become more confident in the designs and more familiar with the biological components, allowing them to add this technique to their repertoires. Trainings should demonstrate to contractors that under some conditions, such as low energy and low fetch areas, the profit margin of living shoreline techniques may be higher, which might be the greatest incentive of all for a contractor, particularly if technical assistance with the various grant and cost sharing programs is also provided.

The Virginia Coastal Zone Management Program has identified living shorelines as a major enhancement area for the next five years under its Section 309 Strategy. The strategy has outlined the development of a living shoreline manual and a marine contractors training program. The Maryland Coastal Zone Management Program has already begun to organize contractor trainings at various locations in Maryland. A formal certification program has also been suggested, such that a contractor or engineer can be awarded a certificate indicating proficiency in living shoreline techniques. These contractors could also be placed on a green contractors list to assist in advertising their special training and services.

Finally, streamlining the regulatory process, such that living shorelines are "green-taped" relative to harder armor options, has been suggested. "Green-taping" or streamlining could potentially increase the profit margin, or at least time efficiency, for a contractor that handles the permit application process. This process may require the adoption of new policies or laws that clearly define what types of projects qualify for the streamlined process and may be aided by the increase in availability of site-specific technical design assistance for contractors. This assistance includes pre-application evaluations for specific projects or assistance with project drawings for the permit process, services already provided to some degree in Virginia by, for example, the Virginia Institute of Marine Science and the Virginia Department of Conservation and Recreation Shoreline Erosion Advisory Service (SEAS)

Incentives for Local Governments

Several incentives have been suggested to facilitate implementation of living shorelines by local governments. As water quality benefits of living shoreline techniques are quantified, these techniques could be established as a best management practice to meet Total Daily Maximum Load (TMDL) requirements or could be counted as wetland mitigation credits. Financial assistance could be made available for local governments to work on and implement zoning and subsequent code changes that promote living shorelines. These changes could require certain types of shoreline protection or land use tools, such as setbacks and no-build areas, to be implemented depending on the sensitivity of a particular watershed, extent of erosion, or benefits to water quality.

Land use laws, such as the Maryland Critical Areas Law and the Virginia Chesapeake Bay Preservation Act, already grant authority to local governments to become more involved in shoreline permitting activities. For example, Kent County, Maryland, Department of Planning and Zoning has developed language in its comprehensive plan that requires landowners seeking to protect their shorelines to first consider a living shoreline technique, and if not appropriate, to demonstrate why it would not work. The County has devoted considerable staff time to implement this policy, with technical help from the Soil Conservation District and the Eastern Shore Resource Conservation and Development Council. Providing such technical assistance can serve, if not quite an incentive, as a mechanism to overcome hurdles in the ability of a county to implement living shoreline policy. In Virginia, local Wetland Boards also require significant technical assistance to adequately function in a capacity to promote living shorelines. The Virginia Institute of Marine Science provides the necessary information tools (permitting database, maps, and studies) to maintain the capacity for these local groups to make these decisions. In order to have more local governments act in a similar capacity, issues with staff time, liability, and lack of data and technical information need to be addressed.

Local governments could use several additional tools or resources to help them with living shorelines policies and planning. The 2006 National Academies of Sciences study on erosion along sheltered coasts promoted regional shoreline management plans that would take into consideration the movement of sediment, hydrology, aesthetics, and recreation opportunities in shoreline management (2). Local government land use authority would provide the optimal mechanism for these plans to be implemented. However, more data on sediment transport and budgets and regional Geographical Information System (GIS) studies are required to build the local government knowledge to make regional land use and shoreline decision making.

SUMMARY

Collectively, the financial and technical assistance and regulatory programs discussed above should provide incentives for various groups to install and maintain living shorelines where hard armor with lower ecological and water quality value might otherwise be used. Incentives for property owners include grants or loans to allow installation to be more affordable, expediting the permit process (assuming change in regulatory programs), improving aesthetics, and increasing awareness of the benefits of selecting an environmentally sensitive approach. Incentives for contractors include a growing clientele base, developing a "name" or a niche in the market, a streamlined permit process (again assuming change in regulatory programs), improved training and potential certification, and potentially a higher profit margin. For local governments, future incentives may include credit for water quality improvements, gaining another tool in the mitigation and management toolbox, and additional financial assistance for comprehensive and land use planning and management. Together, these types of incentives should promote use of living shorelines and increase the rate of adoption in the future.

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Note: See page *xiii* for changes in Maryland Living Shoreline Policy, 2008.

Living Shoreline Case Studies

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INTRODUCTION

Case studies were solicited as a component of the Living Shoreline Summit to provide a sharpened understanding of living shoreline implementation in the Chesapeake Bay. These case studies deliver an in-depth perspective to guide future project implementation, policy activities and enhancements, and research. The following case studies supply a "real-life" context and systematic way of looking at shoreline management alternatives, presented in a manner to offer insight and contemplation on success/performance and habitat benefits/trade-offs. These projects occur throughout the Chesapeake Bay in Maryland and Virginia in variable energy regimes and waterways. Documenting projects in a suite of settings and in more detail, through a more anecdotal account, gives heightened and realistic perspectives on challenges, opportunities, and lessons learned when conducting shoreline restoration activities.

CASE STUDY 1: Longwood University Foundation, Hull Springs Farm's Living Shorelines Research and Habitat Restoration Project: Sharing Living Shoreline Recommendations with Shoreline Property Owners

Project Overview

The project was located on Longwood University Foundation's Hull Springs Farm (HSF) and encompasses the tidal shoreline area of Lower Machodoc Creek, a tributary to the Potomac River, upstream from Coles Neck, near the community of Tidwells in Westmoreland County, Virginia. HSF, a 637-acre property with a mix of agricultural fields and forested tracts, was a bequest to Longwood University by Mary Farley Ames Lee who was committed to preserving the natural state of the farm. The property has approximately 8,400 feet of shoreline along Glebe and Aimes Creeks. The purpose of the project was to establish a framework for potential living shoreline treatments within Lower Machodoc Creek and to implement a living shoreline stewardship program and demonstration project on HSF property. Through three workshops (held in 2005 and 2006) and future access to the demonstration site, landowners, coastal managers, contractors, and others will learn about integrated approaches to shoreline stabilization and habitat enhancement.

The project was designed with the intention of being a catalyst in Virginia's Northern Neck and the Chesapeake Bay region for future living shorelines initiatives. Introducing living shorelines to property owners in Virginia's Northern Neck fit the Foundation's objective to establish Hull Springs Farm as a focal point for area residents, academics, and others interested in conservation and restoration methodologies. The long-range goal is to develop a myriad of "state-of-the-art" stewardship practices, including living shorelines, where people from Northern Virginia, the Northern Neck, and beyond can gain first-hand exposure to Bay-friendly best management practices.

The HSF "Living Shorelines Research and Habitat Restoration Project" was partly funded in 2005-06 by a grant from the National Oceanic and Atmospheric Administration through the National Fish and

Wildlife Foundation. Additional in-kind and financial support came from the project partners. The project was a collaborative effort of several entities that are interested in the advancement of living shorelines in Virginia and Maryland, including: Longwood University Foundation, Inc (LUF), Virginia Institute of Marine Science (VIMS), Burke Environmental Associates LLC (BEA), Northern Neck Soil and Water Conservation District (NNSWCD), Northern Neck Planning District Commission (NNPDC), National Oceanic and Atmospheric Administration, Restoration Center (NOAA), Virginia Commonwealth University (VCU), Clean Virginia Waterways (CVW), and local citizens and students who served as workshop volunteers.

Benefits and/or Trade-offs

The project resulted in two educational workshops about environmentally-friendly shoreline erosion control techniques, as well as a volunteer event where citizens from the Northern Neck assisted in planting 800 plugs of marsh grass (*Spartina alterniflora*) to restore three shoreline areas. More than 110 property owners attended the workshops. Future communication about living shoreline projects will be facilitated by the partnership of government agencies, nongovernmental groups, and academic institutions that was created during this project. In addition, the NNSWCD helped create a database of shoreline property owners' in Lower Machodoc Creek that will assist with future outreach efforts.

Data about the existing shoreline conditions and shore erosion control structures for Lower Machodoc Creek were collected and incorporated into a shoreline conditions database housed at VIMS. Living shoreline treatment suggestions for Lower Machodoc Creek were developed and these recommendations were mapped by NNPDC. The PDF maps are housed on the HSF website (www.longwood.edu/hullspringsfarm/environment/shoreline.htm) for shoreline property owners to review along with extensive information about living shorelines techniques. The web site has received enthusiastic praise from the Virginia Coastal Zone Management Program and several Chesapeake Bay nonprofit organizations.

To acquire biological monitoring data, the VCU Department of Biology collected baseline information on the benthic invertebrates before project construction. Additional surveys will be conducted on vegetation and benthic invertebrates post-construction to determine changes or enhancements to the biological communities from the living shoreline project.

Issues and Lessons Learned

The cumulative effect of Tropical Storm Ernesto (September 1, 2006) and a Nor'easter in October 2006 removed several feet of soil and vegetation from the Hull Springs Farm shoreline near the historic oak tree and "Big House," forcing Longwood and its VIMS advisor to be flexible in plans. The original plan for that highly-exposed bank was to install a low sill of rocks that would reduce wave energy. Between the sill and the bank, a fringe marsh of cordgrass was to be planted to enhance habitat for wildlife, while also preventing further erosion. Due to the extensive loss of shoreline and in order to protect HSF's beloved oak tree, Longwood and VIMS modified the plan to include a riprap revetment at the toe of the bank nearest the oak tree. The revetment will be in place as soon as funding and the permitting process allow, in anticipation of the 2007 hurricane season. The fringe marsh and sill is to be installed as soon as funding is secured, perhaps in 2008. If the sill and fringe marsh had been in place, the bank may have been spared the storms' harshest impacts.

While purchasing plugs of *S. alterniflora*, Longwood found the demand for marsh grasses surpasses the supply in the Chesapeake Bay watershed. The lack of resources have lead to preliminary research on the feasibility of growing marsh grasses at HSF to help meet this demand, especially as living shoreline methods are increasingly used.

CASE STUDY 2: South River, MD – Living Shoreline Demonstration Project Using Volunteer Labor for Construction

Project Overview

The South River Federation was approached to assist the Londontowne Property Owners Association with stabilizing their community owned waterfront property and re-establishing the fringe marsh habitat. The low marsh at this area had completely eroded, jeopardizing the remaining high marsh habitat. The community chose to pursue a living shoreline option that would replace lost low marsh and protect existing shoreline, rather than pursuing a hardened shoreline armor option.

The project was completed over two summers and was installed by volunteers, who moved 220 tons of rock and 250 tons of sand to build the project. The major source of energy along the shoreline is from boat wakes as the fetch to the south is 0.5 miles. The site involved the placement of 33 segmented stone sills across 750 linear feet of shoreline (Fig. 1). The sill structures were built 12 ft in length with 6 foot windows between each sill (Fig. 2). Sand was then backfilled behind the sills and the site was planted in *S. alterniflora* to re-establish low marsh that had eroded.

The community also agreed to create a vegetated buffer that expanded the high marsh and provided a healthy vegetated buffer protecting the waterway from the area with very high impervious coverage. The purpose for these enhancements was to improve water quality.

Figure 1. Placement of 33 segmented stone sills to create a living shoreline along 750 linear feet of shoreline in Glebe Bay, South River, Maryland

Benefits and/or Trade-offs

The project was built during the summer months through the efforts of twelve work parties (Fig. 3). More than 200 volunteers and 800 volunteer hours were needed to complete the project. A marine contractor and board member donated time towards design, permitting, and project management. The use of volunteers decreased the overall cost of the project, while providing a cause for the community to come together and work towards a common goal: creating a restored, protected shoreline with a native buffer.

The site has held up extremely well (3 years post-completion), even under extreme wave events.

Figure 2. *12-foot long sills with 6-foot windows at the living shoreline site in Glebe Bay, South River, Maryland.*

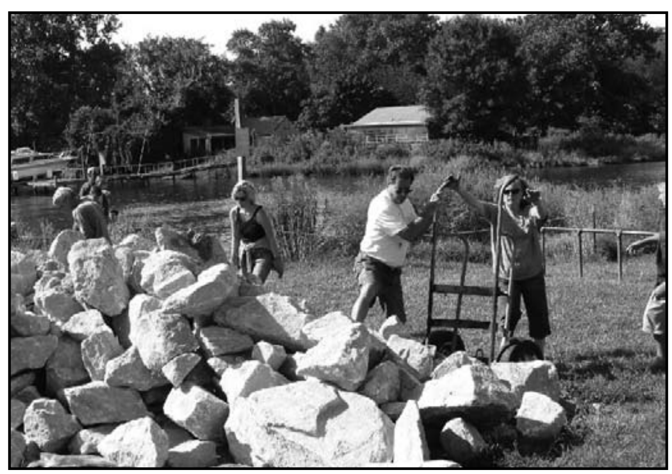

Figure 3. *Contribution of volunteer labor: 200 volunteers contributed 800 hours to construction of the living shoreline in Glebe Bay, South River, Maryland.*

During the 7+ foot storm surge event created during Tropical Storm Isabel, the site captured sand despite the fact that local residents had to borrow significant amounts of sand to fill sand bags. The project also began to gain sand over time once the plants became established, a process highly dependent upon local littoral drift. In this particular project, sand fill was placed in one area and allowed to naturally establish a grade through tidal action and redistribution of sandy material.

Issues and Lessons Learned

One of the biggest challenges working with a community is balancing multiple views and opinions within that community. People are often skeptical of projects that are not standard practices and that are more innovative. Garnering support and backing of community leaders is highly important for project success. Community leaders are vital in the effort of facilitating and moving forward with a project in spite of the comments and objections from (initially) unsupportive community members.

CASE STUDY 3: Hermitage Museum Foundation Living Shoreline and Wetland Restoration

Project Overview

The project was designed to be implemented through a three phase operation. The Living Shoreline segment consisted of approximately 250 linear feet (LF) of stone breakwater and marsh toe protection together with approximately 600 cubic yards of sand beach fill and the planting of 7500 square feet (SF) of marsh grass, primarily smooth cordgrass, *S. alterniflora*. This protected over 300 LF of shoreline including a historic brick wall surrounding the formal garden at the Hermitage. The next phase involved removal of a stand of invasive *Phragmites australis* and replacing it with 5000 SF of tidal marsh. The last phase involved removal of 110 linear feet of riprap and approximately 400 cubic yards of debris to restore approximately 7500 SF of tidal wetlands. These marshes were planted with a combination of smooth cordgrass and saltmeadow hay, *Spartina patens*, depending on the elevation of the sand fill. All totaled, the project restored almost ½ acre of wetlands by removing riprap and debris placed in historic wetlands and providing a "softer" approach to shoreline stabilization, providing intrinsic habitat value as well.

Benefits and/or Trade-offs

One of the purposes of the project was to demonstrate the effectiveness of "Living Shorelines" as an alternative shoreline protection strategy that provides protection as well as habitat value. "Living shorelines" are designed to only use structures where necessary to modulate wave energy sufficient to allow natural structures and processes, like beaches and marshes, to be able to provide effective shoreline protection. This integration of natural shoreline into the erosion protection scenario has the added benefit of providing habitat for many species of fish and wildlife including killifish, blue crabs, spot, croaker, puppy drum, herons, egrets, and ducks. The major trade-off involved the conversion of approximately 3000-4000 SF of shallow subtidal bottom into marsh, beach, and rocky intertidal habitat.

Issues and Lessons Learned

Besides funding, there were two issues that had to be addressed. The first was obtaining regulatory approval for encroachment beyond the previously existing mean low water shoreline. The Living Shoreline design necessitated an encroachment of up to 40 feet for the marsh, beach, and sill construction. It was argued that there was no net loss of aquatic habitat, only the conversion from one type to another.

The other consideration was finding a contractor with the small equipment required for the job that was willing to take a chance on constructing the project for the funding available. Three bids were received. The two high bids were both $100,000 above the $50,000 grant award.

To date, the sills, beach, and marsh constructed by the project have effectively protected the shoreline. The Living Shoreline has also improved habitat at the site by increasing the amount of edge that provides substrate suitable for benthic colonization, rocky intertidal habitat for oysters, and fringe marsh for fishes and crabs. The *Phragmites* sp. and fill removal components have added a substantial area of tidal wetlands that is being used by an array finfish, shellfish, and birds.

SUMMARY

Collectively, these case studies demonstrate the possible successes and challenges faced when constructing living shoreline in the Chesapeake Bay. Volunteerism was a very important component of each of these projects, which minimized costs and assisted in promoting outreach and stewardship for shoreline resources. Monitoring should be incorporated into volunteer activities. This promotes stewardship efforts and generates a baseline of information for long-term reference. As living shorelines are implemented more regularly, more sources of appropriate wetland vegetation will need to be available. There will also be a demand for planners, contractors, and individuals knowledgeable about construction and design of living shoreline projects.

Conclusions and Next Steps

Photo credit: Karen Duhring, VIMS

Living Shorelines in the Chesapeake Bay: Needs and Recommendation for Future Activities

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INTRODUCTION

The Living Shoreline Summit brought together marine contractors, policy-makers, scientists, land owners, marine engineers, regulators, and others to discuss the past, present, and future of nonstructural erosion control methods in the Chesapeake Bay. These disparate groups together identified gaps and ideas for future actions to promote living shoreline activities in the region, focusing on 1) Outreach and education; 2) Incentives; 3) Data and tools; 4) Research; and 5) Planning, policy, and regulation. The recommendations by these groups identify mechanisms to better promote living shoreline practices Bay-wide; improve coordination and streamline activities throughout all levels of government; and identify opportunities to increase funding and incentives for design and construction.

These recommendations emerging from the Living Shoreline Summit will support and help shape additional activities that are ongoing or had already been planned over the next five years throughout the Chesapeake Bay Region. For example, the Coastal Programs in Maryland and Virginia, prior to the Summit, had allocated significant financial and staff support to the issue of living shorelines. Both Programs have included living shoreline activities as a priority in their Coastal Program Enhancement Strategies and available for funding through the National Oceanographic and Atmospheric Administration. Anticipated Bay wide activities and products include waterfront property owner's guidebooks, living shoreline design guidelines, contractor training on living shoreline designs, further research and monitoring, and improved Geographic Information System (GIS) data and decision support tools. Virginia also intends to revise wetland guidelines, while the Maryland Coastal Program will assist counties with building their capacities to be more involved with regulating shoreline development and modifying the sequencing of the state and local permits. These programs will build on information from the Living Shoreline Summit in preparation of their materials and programs.

In addition to Coastal Program activities, NOAA Restoration Center, Chesapeake Bay Trust, Chesapeake Bay Foundation, Eastern Shore RC&D, and River Keepers have become highly engaged in the last five years on this issue by providing funding and/or constructing projects through community and volunteer based efforts. These organizations are providing the much needed on the ground support in order to fill some of the incentive gaps when promoting living shoreline design implementation to property owners. These groups are also making strides towards developing monitoring protocols and conducting assessments on the effectiveness of living shoreline designs for erosion control and their ecological benefits/impacts. Academics are also important in this effort, as the Virginia Institute of Marine Science and University of Maryland are both focusing significant research time and funds towards determining the affects of human alterations to shorelines in natural systems. Recommendations and information from the Summit will help guide these programs as well.

OUTREACH AND EDUCATION

Currently, the majority of waterfront property owners, especially individual private landowners, receive their technical advice directly from marine contractors, who are often their first point of contact on shoreline issues. Since at present most contractors do not know about or use living shorelines techniques, these options are not being readily considered during the interactions between contractors and homeowners. Several suggestions were provided to address this issue and include: increasing awareness of these practices to homeowners through an outreach campaign, providing technical training courses and certifications for contractors on living shoreline designs, and identifying mechanisms to disseminate information through realtors/home sales transactions as well as local commissioning bodies that make local land use decisions.

Developing a clear and simple message on the benefits of living shorelines is an important outreach need. Government and nonprofit organizations should move towards social marketing as a mechanism for changing behaviors and attitudes about shorelines. Concerned citizens can help by emphasizing this issue to elected officials to increase the awareness of living shorelines, their benefits, and the appropriate conditions for their use.

Some additional products requested during the session included: 1) developing a guide on how to conduct maintenance, emphasizing all types of shoreline protection, including bulkheads, revetments, and living shorelines; and 2) creating a living shorelines website to act as a "one-stop shop" for information on this subject.

Recommendations

1. ***Initiate efforts to use social marketing concepts to promote living shorelines in the Chesapeake Bay-*** Social marketing is becoming more common in environmental communications. This social psychology concept shows that attempts to change people's behavior are most successful when they are carried out at the community level and when they involve direct contact. Social marketing could assist the promotion of living shorelines by identifying the barriers that prevent shoreline property owners from specific behaviors such as selecting a more natural erosion protection technique. Use of a marketing technique could further the effort to identify solutions to these barriers and develop a message to promote the new behavior.
2. ***Incorporate Living Shorelines into the (Networked Education for Municipal Officials) NEMO curriculum -*** Networked Education for Municipal Officials (NEMO) was recently established in the Chesapeake Bay to help local officials with natural resource planning. NEMO draws on partnerships with nonprofit organizations and government agencies to offer a slate of workshops on the issues that most concern local officials. NEMO has demonstrated in other areas of the country that local officials respond with interest when regional resources are made accessible in a way that is both organized and responsive to their immediate needs. Living shorelines must be a resource priority in NEMO with curricula created for local government decision makers who become interested in this topic area.

INCENTIVES

A full discussion of the available incentives was covered by a comprehensive panel session during the conference and is discussed in depth as a topic paper in these Proceedings (1). Some additional ideas include: 1) investigate how storm water utility fee can be used for the restoration fund and a source of funds for these restoration projects; and 2) investigate how to link living shoreline activities to water quality in order for local government to use these in zoning tools to meet Total Maximum Daily Load (TMDL) standards and how to get credit for these activities.

Recommendations

3. ***Identify existing or new financial incentives opportunities to promote the implementation of living shorelines over hard stabilization options*** - Many financial incentives already exist for property owners in Maryland, and to a lesser extent, in Virginia (1). These incentives include both grant and loan programs for both public and private property owners, and should be more widely publicized and expanded, where needed. These types of assistance are highly effective at increasing the

interest in these projects, although they should be paired with other incentives such as technical support in design and construction as well as regulatory incentives like lower permit fees or wait times for living shoreline designs.

RESEARCH

As discussed elsewhere in this volume, there are many gaps in knowledge in the field of living shorelines, including large-scale sediment budget issues and more specific questions about design and function of living shoreline practices. Filling these gaps with research is imperative to moving the field of nonstructural erosion control forward. The Cooperative Institute of Coastal and Estuarine Technology (CICEET) has recognized these needs and has initiated a new program to address some of the gaps identified in the National Academies report on mitigating erosion in sheltered coasts (2).

Some of the specific research needs were identified throughout the Living Shoreline Summit. The question of whether the Bay is sand–starved (as opposed to smaller-grained sediment starved) has been raised in the context of dwindling sandy Bay resource areas from the potential combination of sea level inundation and loss of sediment supply from stabilization activities. The 2006 National Academies report on shoreline erosion (3) emphasizes that regional sediment budgets are an important issue that should be addressed before regional shoreline erosion control plans can be formulated (2).

Recommendations

4. ***Promote research on the design of living shorelines, on quantification of habitat and water quality benefits of living shorelines, on impacts of sea level rise on living shorelines, and on impacts of living shorelines on property values.-*** In order to strengthen the case for living shorelines, more information is needed for various types of environments and should include: 1) studying the performance of various design options and identification of optimum conditions (low, medium, high energy) for each; 2) developing more technical engineering specifications to assist contractors without a design background; 3) determining the effects of rising sea level on project longevity and success; 4) identifying how living shorelines affect the value of shoreline property; and 5) elucidating the sediment dynamics in the Bay and how shoreline protection is affecting these processes.
5. ***Determine sediment budgets for the Chesapeake Bay, its tributaries and the coastal bays.-*** Managers and scientists should further investigate and differentiate between clays/silts and sandy sediment processes in the Bay. Techniques to track transport and determine source areas for sediments in the Bay need to be identified or developed. Information on sediment source areas and discrete littoral cells needs to be linked to the regulatory process in an effort to minimize secondary and cumulative impacts on adjacent shorelines. This knowledge will move us towards developing regional sediment and shoreline management approaches. Partnerships also need to be enhanced to achieve this goal and investigate the role the Chesapeake Bay Program has with coordinating multiple state and federal programs to achieve the study goals by leveraging funds and technical support.

DATA AND TOOLS

The Summit showcased the availability of a wide range of GIS data available to assist with planning and determine suitability for living shorelines to address erosion and restore shorelines. Some of the digital products include Shoreline Situation Reports and Comprehensive Inventory, Living Shorelines Suitability Tool, as well as web-based mapping products like Shoreline Managers Assessment Kit (SMAK) for Virginia and the Maryland Shorelines Online (MSO) web portal (4). Although technical tools are becoming available, their promotion needs to be enhanced. More training and promotion of the existing online tools is needed especially for homeowners and local bodies like Wetland Planning Boards or Shoreline Commissions. Concerns expressed in regards to the tools related to the validation of results with groundtruthing, determining limitation of the tools use due to the accuracy and scale of the data, and maintaining the data and tools on a routine basis.

Recommendations

6. ***Use existing monitoring and effectiveness studies to validate GIS-based suitability models and planning tools -*** Comparing projects suggested by suitability models to projects actually implemented for a given waterway would be highly informative and would validate model results. Studies of implemented projects to determine effectiveness are ongoing (see papers in this volume). If these effectiveness studies show that specific project types are working well in a given area, these project types should be part of the suitability model recommendations. If the project types are not working, they should not be recommended in the suitability model, and reasons for failure noted.

DESIGN AND EFFECTIVENESS

Design and effectiveness information will lead to improved project selection and design criteria for specific energy regimes. More specifically, the effectiveness of living shorelines in medium energy areas and threshold designs for protection, while still maintaining/maximizing habitat, is required. Uniform standards/protocols involved in the assessments to determine effectiveness of living shoreline projects are also needed to allow for the comparison of projects implemented throughout the Chesapeake Bay. Specific gaps in technical information included: 1) determining the width of sill windows to effectively flush and provide access for fauna and the implication on submerged aquatic vegetation (SAV) success; 2) determining optimum height of sills and other structures in various energy regimes; 3) measuring the impact of fetch on project success; 4) understanding the use of oysters and oysters shell rubble to protect shorelines; 5) increasing demonstration sites for more innovative habitat designs using offshore sand bars, oyster reefs, and living breakwaters; and 6) determining the effectiveness of coir fiber logs in different energy regimes and develop specifications and installation requirements.

Recommendations

7. ***Improve existing project selection and design criteria to reflect the recent science-based assessments and modeling -*** The criteria and standards for design that currently exist are relatively general, with information collected by practitioners shared in a relatively informal way. Recent monitoring efforts designed to measure project success in variable energy regimes offer a chance to fine-tune these criteria. For example, projects in low fetch areas designed for low fetch systems sometimes fail. In some of these cases, at least, the fetch may indicate low energy area, but boat wakes cause the energy to be much higher than anticipated. Determining reasons for failures will assist in the process to develop more clear design standards or at least understand specific case studies where the selection criteria may not be applicable.

PLANNING, POLICY, AND REGULATION

Increasing opportunities to improve coordination and communication among implementers of living shorelines in Maryland and Virginia was a major theme of the Summit. To start, common definitions and terminology related to living shorelines are needed to improve uniformity between the states and to improve communication on this topic nationwide. Different regions of the country have much to share on this topic, and while other regions may not yet discuss their activities in the context of “living shorelines,” projects in regions such as Pensacola Bay (e.g., the Green Shores project), other areas of the Gulf Coast, the Puget Sound, and North Carolina can provide insights on design, science, and regulatory issues.

In the Chesapeake region, even within states, a lack of coordination on regulatory activities exists between local and state/federal permitting staff and among staff of different counties. Some permit process-based activities such as permit sequencing between agencies may need to be refined in order to allow counties to be more involved in shore erosion control projects and to ease the process for property owners. Currently, the joint state/federal permit in Maryland is often applied for and issued before local building permits are sought. In such cases, it is often difficult for local governments to request or require a living shoreline approach when a state/federal permit for a structural project has already been obtained. However, this situation does sometimes occur, prolonging the process for property-owners who may have felt they already had permission to begin construction.

Staffing limitations appear to play a role in the review process and in lack of ability for state and local government agencies to play a more robust role in offering nonstructural solutions to erosion issues. A more science- and data-intensive regulatory review for secondary and cumulative impact in the permit review process cannot occur at present due to staffing limitations and limited access to data. More specifically, permits continue to be made on a case by case basis and are not reflective of regional processes or impacts. Virginia currently has better capabilities to incorporate a greater suite of data tools in its review activities with the participation of Virginia Institute of Marine Science staff and the generation of automated reports.

With respect to local government land use authorities, comprehensive plans that guide land use decisions need to include a greater suite of natural resources considerations. More specifically, Virginia's Chesapeake Bay Preservation Act needs to improve protection of Resource Protection Areas (RPA) when conducting shore erosion reviews and require living shoreline projects to be considered.

Another way for local and state governments to promote living shorelines, in addition to streamlining or "green-taping" the regulatory process, is to lead by example. It can be difficult to require citizens to implement living shorelines if governments' own lands do not exemplify this practice to the maximum extent possible. Many local, state, and federal lands offer opportunities to implement nonstructural shoreline erosion projects.

Recommendations

8. ***Develop a regulatory framework to allow for regional shoreline management and be more proactive by utilizing shoreline management plans to guide future development activities-*** Few cases exist in which shorelines are managed in the context of regional shoreline management plans and regulation. Those cases in which they do exist are often along ocean coasts where littoral cell boundaries and the regional units can be identified. Regional Sediment Management (RSM) has been successful in the Mobile Bay region (5) and has resulted in cutting costs, allowing the use of natural processes to solve engineering problems, moving away from case-by-case decisions, which allow the environmental integrity of a system to be maintained. As a management method, RSM includes the entire environment, from the watershed to the sea and accounts for the effect of human activities on sediment erosion as well as its transport in streams, lakes, bays, and oceans. To move forward on this issue in the Chesapeake Bay, managers should investigate the role of State Coastal Programs and the use of 309 Enhancement Strategies and funding to advance regional shoreline management activities.
9. ***Encourage government lands to lead by example, and install living shorelines where appropriate.***

SUMMARY

The Living Shoreline Summit was designed to bring together a diverse array of groups including managers, regulators, policy-makers, scientists, contractors, nonprofit organizations, and homeowners to discuss shoreline management issues in the Chesapeake Bay. The sessions were targeted to cover multiple topics such as design case studies, monitoring/assessments, policy/regulatory issues, and incentives that concluded in a final panel discussion. This format allowed the groups to share their work, while also identifying issues and opportunities to continue to promote, study, and implement living shoreline projects.

The recommendations showed that although living shorelines are gaining momentum, some hurdles do exist that prevent broad scale implementation by most property owners in favor of traditional riprap structures. These hurdles often relate to issues of risk and liability, lack of knowledge about alternative options and their benefits, and aesthetic issues - perceptions that natural shorelines are not "tidy." Efforts to train marine contractors are also underway, but need to continue at a greater level and may need to be formal and involve a certification program.

Beyond changing homeowner and marine contractor behaviors and preferences, there exist some policy issues that must also be addressed. These issues center mainly on staff limitation preventing adequate time for site visits and more technical assistance with property owners. Coordination and process-based issues with permit sequencing between state and local are also problems that should be addressed. Working together more cohesively through a bi-state perspective could help the community overcome some of these hurdles listed above. Living shoreline practices are beginning to gain acceptance and offer a compromise for property owners trying to address erosion, while also continuing to assist managers with protection the services that natural shorelines provide to the Chesapeake Bay ecosystem. Instituting the recommendations from the Living Shoreline Summit will accelerate this shift.

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Index

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