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Ecosystem Services Provided by Living Shorelines[1]

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Introduction/Abstract

Coastlines support a large amount of the total human population. When people move in, shorelines are often "hardened" or "armored" with manufactured structures—like jetties or sea walls—that are put in place to protect buildings and other infrastructure. Shoreline development and subsequent hardening usually replace coastal habitats like seagrass, oyster reefs, mangroves, and salt marshes. An alternative to hardening shorelines is to purposefully plan for "living shorelines" that incorporate coastal habitats to provide coastal protection and additional benefits. These benefits nature provides to humans are called ecosystem services. Ecosystem services include but are not limited to fisheries and water quality improvement. Previous EDIS documents have described what ecosystem services are (Blair et al. 2014), some of the benefits of specific types of living shorelines (e.g., oysters; Wallace et al. 2022), and how to monitor living shorelines (Reynolds et al. 2021). The purpose of this document is to explain the types of ecosystem services provided by different types of living shorelines and how to quantify these values. The target audience for this document is local governments and municipalities that make decisions about developing, conserving, and restoring living shorelines; state management agencies that oversee broader scale habitat management; and finally, homeowners who will be immediately affected by any of these decisions.

Overview of Living Shorelines

A living shoreline uses nature to stabilize shorelines. Salt marshes, mangroves, seagrasses, and oyster reefs are adapted to life in the coastal zone. These habitats effectively prevent erosion by creating complex surfaces that dampen wave energy and trap sediments. A living shoreline is a type of nature-based, or "green," infrastructure that incorporates aspects of the natural world in stabilization methods. Oysters and salt marsh plants are common species associated with living shorelines in lower wave-energy settings. Bluffs, dunes, and beaches are shorelines that dissipate wave energy in higher energy settings. Different types of shorelines are shown in Figure 1. These natural features can be used for shoreline protection, alone or with hardened shorelines, while also improving water quality and habitat value. Established living shorelines can be equally as good at providing shoreline stabilization as hardened structures. While living shorelines attenuate waves and prevent erosion, there may be a lag in effectiveness while the shoreline establishes. However, hardened shorelines can have adverse impacts to estuarine ecosystems (e.g., habitat loss, disruption to natural shoreline movement, and sediment scouring) and require additional maintenance overtime. While living shorelines and hardened shorelines both can prevent erosion, living shorelines provide additional ecosystem functions that benefit society. Ecosystem functions are

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processes that occur in nature and can be measured in the laboratory. Ecosystem functions that benefit humans are ecosystem services.

Figure 1. Examples of different types of shoreline stabilization. Credits: A: Seawall photo by A. Smyth; UF/IFAS, B: Living shoreline with stone sill by S. Barry, UF/IFAS; C: Oyster and marsh living shoreline at Cedar Key, FL by UF/IFAS; D: Living shoreline with oyster bags by S. Barry, UF/IFAS

Overview of Ecosystem Services

Ecosystem services are elements of nature that provide value to humans (Costanza et al. 1997). The main categories of ecosystem services living shorelines provide include (1) climate regulation through shoreline protection and carbon sequestration; (2) water quality through nitrogen removal and filtration; (3) food production by providing habitat for shellfish and finfish; and (4) natural habitat that can diversify the landscape (Table 1) (Mcleod et al. 2011; Barbier et al. 2011; Scyphers et al. 2011; Fodrie et al. 2017; Onorevole et al. 2018). Each service connects to an ecological process, which researchers can measure in the field or laboratory. These measurements are often converted to dollar values using metrics like willingness to pay or nutrient trading credits. Ecosystem services can be challenging to quantify and evaluate because they are generally not traded in markets (Blair et al. 2014; Baker et al. 2015). Yet there are ways to determine the monetary value of ecosystem services (Harrison et al. 2018). Table 1 summarizes the different ecosystem functions, services, and evaluation techniques associated with living shorelines.

How Living Shorelines Produce Specific Ecosystem Services and How They Are Valued

Living shorelines can increase specific types of ecosystem services in different ways. The value we think a living shoreline has depends on what services we think the shoreline provides or the value of an alternative stabilization structure (Gittman et al. 2021). The following text summarizes howsome specific ecosystem services are improved by living shorelines and describes how the services are translated into dollar values. We focus only on services that have available data and are relevant for all habitats. We do not discuss water-quality services such as filtration. The presence of seagrass and salt marsh grass can slow the water and creates a depositional environment, which can increase water clarity, but oysters are filter feeders and directly remove material from the water column as they eat. Because active filtration by oysters disproportionally alters the value of this species compared to the passive filtration services of seagrasses and salt marshes, we do not include this service in the discussion. We focus on proxy and stated-preference methods for evaluating ecosystem services. These approaches allow us to determine a dollar value, but values from different methods should not be directly compared and will not account for the value the service has to people, which may vary greatly.

Shoreline Stabilization

Living shorelines include salt marshes, mangroves, oyster reefs, and seagrasses. All these habitats act as a physical structure, slow water flow, and trap sediment. The structure that these habitats provide prevents erosion and stabilizes the shoreline, like a bulkhead or seawall hardened shoreline. One way to assess the ecosystem service value from shoreline stabilization that a living shoreline offers is to calculate what it would cost to get that stabilization from constructing an artificial structure like a bulkhead, sill, or seawall (Table 2) (Grabowski et al. 2012). For example, suppose a homeowner has a 100 m mangrove shoreline. In that case, that shoreline provides $63,000 worth of value because that is the cost ($630/meter × 100 m) of building a bulkhead. This approach assumes the mangrove shoreline protects to the same degree as the bulkhead. Yet mangroves or other living shorelines might provide better or worse protection, depending on the specific threat (i.e., hurricanes, sea-level rise). Because not all shorelines function like bulkheads, this method of valuing might over- or undervalue the ecosystem service. Another challenge is that different hardened structures cost different amounts, and it is not always obvious which type to compare to the living shoreline. A final challenge is that the relative importance of shoreline stabilization can vary from location to location. For example, imagine an especially vulnerable shoreline with a current plan and budget to harden by installing a bulkhead. In this situation, if officials decided they could achieve the same results via a living shoreline, it would be easier to say that the shoreline provides a value comparable to the cost of the bulkhead. It is much harder to assume the value of the living shoreline in a place where it is hard to imagine one spending money to protect that shoreline. Depending on specific design and situation, living shorelines can be less or more expensive to install than hardened structures, but they often have lower costs for installation, maintenance, and replacement (Gittman and Scyphers 2017).

Carbon Sequestration

Living shorelines can also, in a small way, help mitigate the unfolding climate crisis. Some habitat-forming organisms used in living shorelines, like seagrasses, salt marshes and mangroves, are known as “Blue Carbon” habitats. “Blue Carbon” habitats are ocean and coastal habitats that capture and accumulate carbon. This carbon storage is called carbon sequestration. Carbon sequestration is measured by the amount of carbon in living tissues or buried in the sediment below the zone where animals live. Carbon sequestration removes CO_2 from the atmosphere as plants use the CO_2 for growth and can help offset greenhouse gas emissions. To place an economic value on carbon sequestration, carbon content and carbon burial must be measured. The measured carbon can be valued by a carbon offset market or by the proxy approach of comparing what it would have cost to plant trees that would have removed a similar amount of carbon (Baker et al. 2015). Carbon offset markets allow people or companies that emit a lot of carbon to “offset” it by paying other people or companies that use less or remove carbon. A challenge with carbon sequestration is the lack of carbon markets, and uncertainties in carbon burial rates and carbon budgets make it difficult to determine carbon sequestration accurately.

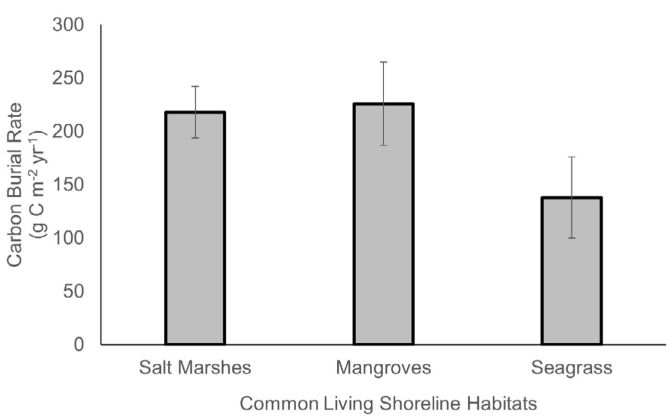

Figure 2. Annual carbon burial of natural habitats commonly created or left in place as living shorelines.
Credits: Data from Mcleod et al. (2011)

Seafood Production

Another benefit of having a living shoreline is that it provides nursery grounds and a habitat for shellfish, invertebrates, and finfish, all of which have important commercial value. This means that a living shoreline may increase fish populations, leading to higher sustainable fisheries catch. To value these increases, scientists estimate how specific fish populations (like blue crabs or red drum) might be affected by hardened shorelines versus living shorelines. If living shorelines increase overall fish populations, this change can be converted to expected changes in fisheries catches and be valued by their market prices. An example of this would be that mangroves provide important habitat for juvenile mangrove snapper, a valuable commercial fish. Assuming that available nursery habitat is the limiting factor for mangrove snapper populations, increasing mangrove shorelines could increase the population of mangrove snapper and lead to some increase in the catch. The greatest challenges here are (1) understanding the net effect that changes in habitat will have on fish populations and (2) if the changes in habitat affect fish production. The impacts of living shorelines on fisheries will probably depend on the specific fish species and the habitat. This requires careful studies to tell the difference between fish *preferring* one habitat over another or a habitat change that increases fish population size.

Nitrogen Removal

Nitrogen, when in excess, is considered a pollutant. Too much nitrogen can cause algal blooms and the eutrophication of coastal ecosystems. Nitrogen removal is an important water-quality service in coastal systems. Living shorelines can remove nitrogen through enhanced sediment denitrification and nitrogen storage into sediments and tissue. Denitrification is nature’s way of converting forms of nitrogen that fuel algal growth into harmless nitrogen gas. Measurements of sediment and tissue nitrogen content or denitrification are needed to evaluate the ecosystem service of nitrogen removal, which relates to water quality. The monetary value of nitrogen removal is quantified using the cost of nitrogen from nutrient trading credit programs or through cost of replacement. In the cost of replacement method, the nitrogen removal value is evaluated based on the cost to remove nitrogen through other means, typically through wastewater treatment (Piehler and Smyth 2011). The challenge with assessing nitrogen removal is that measurements of denitrification are technically complex and require special instrumentation. Additionally, the cost of nitrogen removal via wastewater treatment varies based on location. Willingness to pay is the maximum price a consumer will spend on a product or service and is often used for water quality but is difficult to quantify accurately.

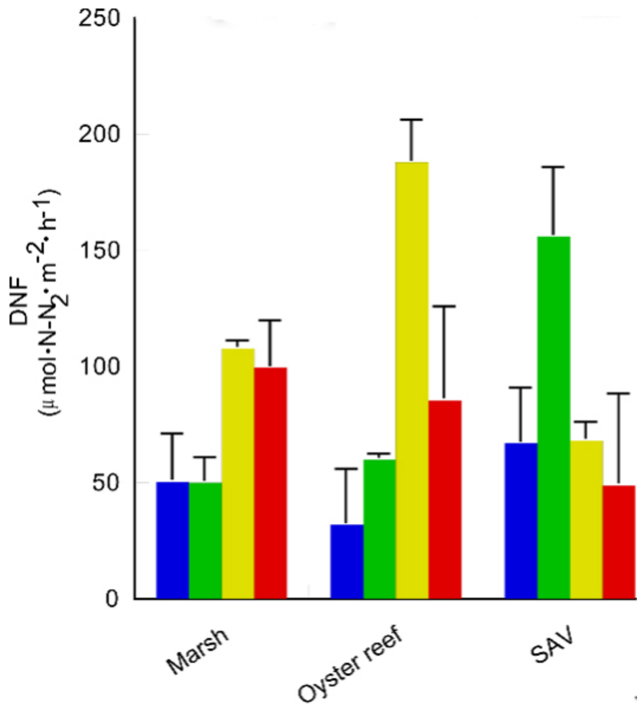

Figure 3. Seasonal denitrification (DNF) rates measure how much harmful nitrogen is transformed to harmless nitrogen from natural habitats (salt marshes, oyster reefs and submerged aquatic vegetation [SAV]) commonly created or left in place as living shorelines.
Credits: Modified from Piehler and Smyth (2011)

Habitat and Biodiversity

The ability of living shorelines to provide habitat to other organisms is an ecosystem service related to habitat. This service is considered a diversification of the landscape and represents the biodiversity ecosystem service. For example, salt marsh grasses and mangroves are thought to be critical juvenile habitats for finfish that anglers like to catch (like common snook and red drum) and may be important nesting or foraging areas for birds that people want to watch. We can evaluate this service in different ways. We can calculate the number of recreational trips people would make to an area based on habitat type and then calculate how much money they spent to make those trips. For example, suppose we learn that recreational fishers make 40% more trips to areas with mangrove shorelines than hardened shorelines. In that case, we could calculate the recreational value as the change in trips multiplied by the average trip cost, but this would be the minimum value and would not account for consumer surplus. Other habitats people may not visit or "use" but may still want them to exist. In those cases, we might survey people to determine their willingness to pay to have specific habitats or restore a particular habitat. The challenges here are trying to figure out what people would do if habitats differed—either how their trips would change or what they would pay to go to a different location. We ask people what they would do or compare what they have done in other cases. The tricky part is that sometimes how people respond is very specific and people do not always do what they say. Still, some rough estimates of recreational value can be calculated from past studies of how recreational trips change and what people spend on them or past studies of roughly how much people value particular habitats.

Ecosystem Services from Living Shorelines

All living shorelines have one thing in common: a reliance on natural elements to control shoreline erosion. Salt marsh grasses, mangroves, oysters, and seagrasses are all habitats that form living shorelines. While each habitat provides shoreline stabilization, mangroves, salt marshes, and seagrass beds are highly valued for carbon sequestration. In contrast, oyster reefs provide more water-quality services because of active filtration and improved water clarity. Quantifying the monetary value of ecosystem services provided by living shorelines should facilitate their use in coastal management by providing an economic justification for such projects. For example, Grabowski et al. (2012) quantifies the ecosystem services of oyster reefs, Jackson et al. (2020) describes how the value of habitats protecting property in northwest Florida was calculated, and Barbier et al. (2011) provides an overview of the economic value of many coastal habitats. Yet ecosystem service evaluations are often conservative because not all living shoreline services can translate to dollar values. This article summarized several important ecosystem services provided by living shorelines and ways to monetarize these benefits. These estimates do not include the full range of services and involve many assumptions. The number of assumptions and how to treat the assumptions is part of the reason ecosystem services values are highly variable. There is no one-size-fits-all approach to conducting an economic evaluation of the ecosystem services provided by living shorelines. Instead, the presentation and evaluation of ecosystem services can help support living shorelines for efficient coastal management.

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Table 1. Summary of ecosystem services, ecosystem functions, and evaluation techniques to consider for living shorelines. Additional details about the ecosystem services and ecosystem service evaluation are discussed in more detail below, following the "Ecosystem Services: What Is Monetized" column.

Type of Service	Type of Living Shoreline	Ecosystem Service: What Is Monetized	Evaluation Technique	Ecosystem Function: What Is Measured
Climate Regulation	Oyster reefs, mangroves, marshes, seagrass	Shoreline stabilization	Replacement cost for shoreline protection by bulkheads or seawalls	Erosion, shoreline stability, flood control
	Mangroves, marshes, seagrass	Carbon sequestration	Carbon credits, cost of replacement with planting forests	Burial of carbon
Food Provision	Oyster reefs, mangroves, marshes, seagrass	Seafood production	Dockside market prices shellfish, crab, and fish	Increased fish production
Water Quality	Oyster reefs, mangroves, marshes, seagrass	Nitrogen removal	Per-unit prices paid for nitrogen reduction in markets or cost of replacement for wastewater treatment	Enhanced denitrification
	Oyster reefs	Water clarity	Willingness to pay	Light availability or turbidity
Habitat	Oyster reefs, mangroves, marshes, seagrass	Habitat & Biodiversity	Tourism and recreation, willingness to pay	Submerged aquatic vegetation enhancement, fish nursery use

Table 2. Costs of installation of different shoreline stabilizers from Gittman and Scyphers (2017). Cost does not include maintenance and upkeep.

Shoreline Structure	Cost (per linear meter)
Bulkhead	\$462–\$6,002
Groin or Jetties	\$1,300–\$49,639
Living Shorelines	\$228–\$6,205