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Living Shoreline Ecosystem Service Valuation Tool[1]

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Abstract

Living shorelines are an increasingly popular way for coastal property owners to protect and stabilize waterfronts. Living shorelines provide valuable benefits to humans, including water quality improvement, habitat, fisheries, and carbon sequestration. Estimating the economic value of the ecosystem services living shorelines offer is an integral part of management decisions. The living shoreline valuation tool can help quantify the costs and benefits of living shoreline projects. This publication briefly describes the ecosystem services associated with living shorelines. The purpose of this publication is to introduce the ecosystem service valuation tool. Our target audience for the living shoreline evaluation tool includes natural resource Extension agents, community organizations, and coastal homeowners who want to calculate the value of ecosystem services provided by coastal restoration projects, including living shorelines.

Living Shoreline Ecosystem Services

Research on the habitats that make up living shoreline projects is increasing (Smith et al. 2020). With new measurements, our knowledge of the ecosystem functions and services provided by living shorelines has improved. Ecosystem functions are natural processes that occur in the environment and are measurable by scientists in the field or laboratory. Ecosystem services directly benefit humans and can be valued monetarily. You can find additional details on the ecosystem services of living shorelines in other EDIS publications such as #SL494, "Ecosystem Services Provided by Living Shorelines," and #FA252, "How Ecosystem Services Are Measured and Why It Matters for Florida." This publication describes how to use a new spreadsheet calculator tool to calculate the monetary value of ecosystem services provided by living shorelines. Since ecosystem services like those that living shorelines provide are not bought or sold in a market, calculating their monetary value is challenging. Most ecosystem service values are assigned via "proxy markets." Proxy markets estimate the value for something (often not sold) by seeing what similar items cost. For example, one could estimate the value of oysters for shoreline stabilization by looking at the expenses of engineered shoreline stabilization options, like shoreline armoring with bulkheads and seawalls. Proxy markets and corresponding values of ecosystem services have been compiled for many coastal habitats. We utilized a framework for oyster reef ecosystem services (Grabowski et al. 2012) to quantify the ecosystem services generated by other living shoreline habitats such as seagrasses, mangroves, and marshes. Using published data on ecosystem functions of coastal habitats used in living shoreline projects (Table 1),

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we can calculate the ecosystem services provided by living shoreline projects.

Evaluating and Quantifying Ecosystem Services of Living Shoreline Habitats

We developed the living shoreline calculator to address the need to quantify the economic value of living shorelines. This tool provides the minimum, maximum, and average ecosystem service monetary value from a living shoreline project after the shoreline has matured. The spreadsheet tool focuses on five ecosystem services: carbon sequestration, water quality, shoreline stabilization, fisheries, and landscape (Table 1). To quantify the monetary value of services relevant to Floridians, we used measurements reported in the literature for Florida habitats, when available, and regional or global values when Florida-specific data were not available. Each service requires a unique approach to quantify and evaluate the ecosystem services. These are summarized in Table 2 and described in more detail in EDIS publication #SL494, "Ecosystem Services Provided by Living Shorelines" (Smyth et al. 2022*)*. Below we briefly describe how to measure and evaluate the five services (Table 2).

- **Carbon sequestration**, associated with climate regulation, was obtained from carbon burial rates and evaluated based on the cost to plant trees that would store the equivalent amount of carbon.
- **Improved water quality** was calculated based on enhanced denitrification. This natural process removes harmful nitrogen from the ecosystem, that can cause algal blooms and fish kills when in excess, and then converts it into nitrogen gas, a form of nitrogen that is relatively inert and harmless. We calculated the monetary value of the nitrogen removal services based on the cost to remove the same amount of nitrogen via wastewater treatment.
- To evaluate **shoreline stabilization**, we used different approaches based on the available data. The different approaches were to use data either on maintenance and construction of gray infrastructure (where available) or on the market price for erosion protection.
- We used **fisheries** landings and ecosystem productivity data for the fisheries ecosystem services, which was converted to dollar values by using commercial dockside landings values or recreational fisher willingness to pay for improved fishing.
- We determined the value of the living shoreline for **diversification of the landscape** from tourism and recreation values or willingness to pay. Because measurements varied widely, we included a minimum, maximum, and average value.

We obtained the dollar value of nitrogen removal and carbon sequestration for Florida counties (Table 3) using wastewater treatment costs for nitrogen removal and the creation of tree plantations for carbon storage (Baker et al. 2015). For other services, we followed the evaluation procedure from Grabowski et al. (2012).

Calculating Living Shoreline Ecosystem Services

The total ecosystem services, or monetary value of environmental benefits, can be calculated using the area of the living shoreline project and county. Users can apply the spreadsheet-based calculator to discover the economic value of the ecological benefits created by the living shorelines of interest. The tool can answer questions like these: How do ecosystem services compare between an oyster reef living shoreline and a seagrass living shoreline project in Levy County? What is the annual value of a living shoreline project in Brevard County? What are the ecosystem and economic tradeoffs from investing $1 million in an oyster reef living shoreline project?

There are many different tables in the calculator worksheet. However, the only one that is editable is the Value Calculator. Using the Value Calculator tab, users can input the area of their living shoreline project and select the habitat type and county from the dropdown menu. Once the users input these variables, the values from the appropriate habitat sheet are called and printed on the value calculator tab. The calculator will report the minimum value obtained using the lowest cost for the ecosystem function, the maximum obtained from the maximum measurements, and the average. For example, Table 4 shows the value of each ecosystem service associated with restoring 12 ha of mangrove habitat in Miami-Dade County. In this example, "Average" was used for "County" since county-specific C and N monetarized values did not exist.

These calculated values are synthesized from results in published literature. References for these values can be found in the Eval Val and Refs by Service tab (Table 1). When the user reports results from the calculator, we recommend using the average, minimum, and maximum values to capture the full range and variability associated with the evaluation of ecosystem services. Given the limited number of studies used for each service and given how the results were reported in the literature, we included the average value. Consequently, the average could be skewed high, being based on only one study. With more data, it would be appropriate to use the median instead.

Ecosystem Services of Living Shorelines Calculator
Change input variables and services will automatically calculate

Inputs	**Habitat**	Mangrove	
	Area Restored (ha)	12	
	County	Average	Can also use average or median

Ecosystem Service	Ecosystem Function	Avg Value ($ ha^{-1} yr^{-1})	Min Value ($ ha-1 yr-1)	Max Value ($ ha-1 yr-1)
Shoreline Stabilization	Shoreline stabilization & flood control	$310,746.00	$47,952.00	$573,540.00
Fisheries	Increased fish production	$1,455.00	$900.00	$2,010.00
Water Quality	Nitrogen removal via denitrification	$317.01	$5.35	$628.67
Landscape	Increase in biomass or species	$12,288.00	$0.00	$79,524.00
Carbon Sequestration	Carbon storage in Sediment	$602.82	$289.11	$996.49
Total Value		$325,408.83	$49,146.46	$656,699.16

Figure 1. Screenshot example of using the living shoreline value calculator tab to calculate the average, minimum, and maximum values of ecosystem services for restoring 12 ha of mangrove habitat. "Habitat" and "County" have preset options, which can be selected from the dropdown menu or typed. Options for habitat are in the Habitat tab, while "County" options are from Table 3 and in the N and C Cost per County tab.
Credits: Ashley R. Smyth, Laura K. Reynolds, Savanna C. Barry, Joshua T. Patterson, and Edward V. Camp; UF/IFAS

Considerations & Conclusions

The ecosystem services of a living shoreline are variable based on factors such as habitat type and location. For example, seagrasses and oyster reefs are typically found at greater water depths and stay submerged for a longer portion of the day. Differences in air and sun exposure will impact the animals that use these structures as habitats. Larger fish will spend less time in shallower, intertidal marshes than deeper subtidal seagrass meadows and oyster reefs. Similarly, mangroves and salt marshes occupy the same physical zone. However, the woody structure and increased height of mangroves may impact animal use, like how roosting birds are more likely to be found in mangrove trees than in salt marshes. These differences can impact the landscape and fisheries ecosystem services.

There is also some variation in ecosystem functions and services provided by individual living shoreline species. More closely planted mangroves or seagrasses will reduce wave energy more effectively than those spaced apart (Massel 1999; Chen et al. 2007). Additionally, location within the shoreline can impact functions. For example, different organisms live on the edge of seagrass patches than in the center of seagrass patches (Bologna and Heck 2002). The environment can also impact ecosystem functions and, thus, the services. Water quality in the region can affect the animals that live there. If there are large, healthy ecosystems nearby, there will be a larger animal community. The actual benefit of living shorelines to fisheries may vary dramatically from location to location and will often depend on which species are using which habitats as well as which species have access to alternative habitats. The functions and services of an oyster living shoreline, for example, will vary across regions and over latitudes. Living shorelines in south Florida experience higher temperatures than those in the northern portion of the state—impacting the animal species (e.g., temperate versus tropical species) found there and driving increases in microbial rates, which increase the rates of decomposition and denitrification. The variety of conditions, locations, and orientations of living shorelines are why the ecosystem services span an extensive range of values. This variability is why it is vital to use the minimum and maximum values in addition to the average. In the ecosystem services provided by the living shoreline, there is not only variation in measurements, but also variation in the estimated monetary value of the services. Given the variety of factors that affect the total value of ecosystem services, it is important to consider this full range. Also, not all living shorelines provide sufficient ecosystem services, so the value of services can vary.

Whenever ecosystem services are valued using dollars, a big challenge is understanding how "real" the values are. The dollar values from the ecosystem service evaluation are not true dollar values because there is no market value. Ecosystem services are almost by definition not bought and sold (with some exceptions). The proxy market methods help give a number. Still, they can be misleading in that they usually do not represent actual dollar amounts paid. For that reason, it is not appropriate to compare ecosystem service value to other types of economic numbers, like expenditures, market values, or even many non-market values. Despite the lack of market data, ecosystem service values allow for comparisons of costs associated with providing the same service in different ways. It is also vital to understand that value estimates are just that—estimates. Tools that estimate ecosystem services use the best available data. Still, often the "best available" data might be from studies conducted far away or a long time ago. Until current, local estimates are available, ecosystem service valuation tools cannot produce exact values for a specific location. Suppose one can measure these functions directly (see Reynolds et al. 2021 for methods). In that case, they can calculate a specific value for their location. However, this tool provides a logical range in value based on the anticipated variability in function.

Despite the challenges, there is utility to quantifying the monetary value of services provided by living shoreline projects. Even though ecosystem service values are not a perfect measure, they are often the best measure available. These evaluations may be the only thing decision-makers can rely on when making good economic and environmental decisions. Probably the best use of ecosystem service values of living shorelines is for comparing across options. For example, coastal homeowners could use this calculator to help describe how specific living shorelines might be more or less valuable than others.

Follow this link to download "The Living Shoreline Ecosystem Service Calculator" spreadsheet tool: https://uflorida-my.sharepoint.com/:x:/g/personal/ashley_smyth_ufl_edu/Edsec2ed2IFBuZezGwhAbhQBUXgt4clP39s5guoaf3SxAA?e=b8ow0F.

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Table 1. References and ecosystem functions used for assigning a valuation to living shoreline habitats.

Ecosystem Service	Ecosystem Function	Habitat	Reference	Reference Location
Carbon Sequestration	Carbon burial	Mangrove	Marchio et al. 2016	Naples Bay, FL
		Marsh	Rainville, Davis, and Currin 2016	Florida
		Oyster	Fodrie et al. 2017	North Carolina
		Seagrass	Mcleod et al. 2011	Global
Water Quality	Enhanced denitrification	Mangrove	Monroy and Twilley 1996	Terminos Lagoon, MX
		Marsh	Piehler and Smyth 2011	North Carolina
		Oyster		
		Seagrass		
Shoreline Stabilization	Erosion protection	Mangrove	Himes-Cornell, Grose, and Pendleton 2018	Global
	Hurricane protection	Marsh	Costanza et al. 2008	
	Bulkhead comparison	Oyster	Grabowski et al. 2012	North Carolina
	Disturbance regulation	Seagrass	Barbier et al. 2011; Blair et al. 2018	Global
Fisheries	Estimates of fish production	Mangrove	Rönnbäck 1999	Global
	1979 fisheries data	Marsh	Bell 1997	Florida
	Non-oyster fisheries landings	Oyster	Grabowski et al. 2012	North Carolina
	Productivity method	Seagrass	Dewsbury, Bhat, and Fourqurean 2016	Global
Landscape	Tourism and recreation	Mangrove	Himes-Cornell, Grose, and Pendleton 2018	Global
	Willingness to pay	Marsh	Costanza et al. 1997	
	SAV enhancement	Oyster	Grabowski et al. 2012	North Carolina
	Nursery value	Seagrass	Dewsbury, Bhat, and Fourqurean 2016	Global

Table 2. Overview of ecosystem services considered in the evaluation tool and methods used to obtain the measurement and monetary values.

Ecosystem Service	Monetary Evaluation Technique
Carbon Sequestration	Equivalent amount of carbon storage from trees, evaluated based on cost of planting trees
Water Quality	Enhanced denitrification Cost to remove same amount of nitrogen through wastewater treatment
Shoreline Stabilization	Comparison with maintenance and construction costs of gray infrastructure The market price for erosion protection
Fisheries	Augmented fish production based on fisheries landing data and market value of the fishery
Landscape	Tourism and recreation value and willingness to pay for aesthetics or views

Table 3. Value of N removal and C storage for Florida Counties based on Baker et al. 2015.

County	$N/lb	$N/kg	$C/ton	$C/kg
Brevard	$3.44	$7.64	$40.64	$0.04
Charlotte	$3.44	$7.64	$30.94	$0.03
Collier	$5.22	$11.60	$119.01	$0.12
Dixie	$3.44	$7.64	$21.95	$0.02
Franklin	$3.44	$7.64	$0.71	$0.00
Indian River	$5.22	$11.60	$113.39	$0.11
Lee	$5.22	$11.60	$97.56	$0.10
Levy	$3.44	$7.64	$16.88	$0.02
Manatee	$3.44	$7.64	$32.60	$0.03
St. Johns	$3.44	$7.64	$24.38	$0.02
Volusia	$5.22	$11.60	$65.80	$0.07
Average	**$4.09**	**$9.09**	**$51.26**	**$0.05**
Median	**$3.44**	**$7.64**	**$32.60**	**$0.03**