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Using Future Benefits to Set Conservation Priorities for Wetlands

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1. INTRODUCTION

With rising sea levels, coastal habitats are changing. Town managers, state resource managers, and others paying attention to health and condition of coastal assets (such as protected species of flora and fauna, beaches for tourism, and wetland capacities such as flood buffering and shorebird stopover habitat) are becoming concerned that as the coastline continues to change, some of these assets will be irrecoverably diminished or even lost completely. In response to this challenge many managers aim to become more proactive (Merrill et al. 2008). Instead of using conventional measures of planning and policy revision, which to date have largely failed to provide a coherent framework by which natural features would migrate inland, these managers aim to combine the best available wetland science with new sea level rise mapping technology. In so doing they can begin to identify where ecosystem service benefits are likely to emerge in evolving coastal landscapes. This would inform prioritization of land protection activities and help coastal land management be more strategic in the face of rising sea levels.

In support of this goal, the Maine Department of Agriculture, Conservation, and Forestry contracted Catalysis Adaptation Partners, LLC in December 2013 to develop and test a software tool that would use the best available scientific input, technical data layers, and spatially-referenced cumulative benefit modeling to help guide the inward migration of marsh lands. By integrating a suite of ecosystem services into the model (such as flood buffering capacity, recreation, and carbon storage), managers should be able to evaluate scenarios more proactively, including prioritizing acquisitions of uplands currently adjacent to wetlands, in ways that preserve or perhaps even enhance ecosystem function to the maximum extent possible.

The chosen approach was to enhance an existing software tool – COAST (COastal Adaptation to Sea level rise Tool) that relies on a Depth Damage Function to calculate lost value under different depths of inundation (Merrill et al. 2010, Merrill et al. 2013), and instead use a Depth Benefit Function to show cumulative benefits (ecosystem services and their associated value) that emerge on parcels expected to become wetlands in the coming century. The functionality created in this project, as a subset of COAST, is called MAST (Marsh Adaptation Strategy Tool).

The specific problem MAST addresses is that even for the ambiguity faced by town planners, land trust representatives, and others at state and local levels (about how much sea level rise might happen when, what type of habitat will emerge in uplands adjacent to the sea, and many other complications of a changing land-water interface), they still must make decisions about the disposition of many parcels. A land trust representative, for example, may have a budget to acquire several upland parcels currently adjacent to wetlands. They may know all the parcels will be underwater in 40 or 60 years, and may choose to not protect the parcels for this reason. Or, they may wish to make the purchase, and have interest in choosing parcels that will provide the best recreational opportunities, flood protection, or fish hatchery habitat, once they become wetlands. However, it is challenging to prioritize based on any of these future possibilities because 1) in any location a suite of ecosystem services specific to that site can be expected to emerge when the parcel becomes marsh and 2) the relative values of these services can be expected to change as water depth increases.

2. MATERIALS AND METHODS

To assist in evaluating options for preserving and enhancing the ecosystem services values in Scarborough Marsh (Scarborough, Maine), a three step process was undertaken: 1) Assessing the values associated with specified wetlands parcels in their current use; 2) Identifying how those values might change over time as sea level changes; and 3) Estimating the extent of inundation from possible sea level rise scenarios on the parcels under examination, and calculating value creation at each location over time (in annual increments that are summed by the software at the end of a programmed period). The first two steps required use of a survey of experts to evaluate current values and probable directions of change in those values with sea level rise. The third step incorporated information from the first two steps into MAST to generate estimates of future values.

2.1 Estimating Values

Over the last several decades the ecological role of wetlands has become more fully understood and the role that wetlands play in serving as a key buffering component of dynamic coastal systems more fully appreciated (Russi et al. 2013).

In the same period economists have become involved in estimating economic values associated with wetlands. The intersection of the ecological and economic assessment of wetlands takes place in estimation of the values of ecosystem services (e.g., Brown and Shi 2014). For this tool-development process, these services were categorized by the assembled group of experts as:

- Attenuation or prevention of flood damages to public or private property
- Effects on land values of property adjacent to or with a view of the wetland
- Effects on water quality through filtration of pollutants
- Drinking water supply
- Recreation (active like boating and hunting or passive like sightseeing and bird watching)
- Aesthetics
- Habitat for any life stage of commercially harvested species such as groundfish or shellfish
- Habitat for any life stage of species significant for the preservation or enhancement of biodiversity, e.g., roosting, breeding, nesting, feeding, or wintering habitat for common and rare species
- Carbon storage
- Export of nutrients utilized by commercially harvested species
- As a research site for hydrologic, wildlife, or ecosystem studies
- Export of nutrients utilized by species critical to biodiversity
- Habitat connectivity
- Other benefits not included in any of the above

Because the MAST software is used to assess values of parcels relative to one another, not relative to an absolute standard, a pseudo-monetary unit was developed (the "wetland benefit unit," or WBU). The WBU permits a valuation process that can reflect basic economic principles of valuation in the assessment of wetlands without having to rely on inherently difficult comparisons with market-based values. That is, it allows people to focus on the relative valuation problem within a constrained choice framework, avoiding the distractions of whether dollar estimates would be “realistic,” either to participants in the process or users of the results. The challenge was to translate the ecological knowledge of the experts into the economic information needed to conduct a valuation process. To accomplish this translation, the group of experts took part in a "Delphi" process that solicited input over multiple rounds, in each of which experts were asked their views based on both their own knowledge and the collected knowledge of other experts (which they could see in subsequent rounds).

The Delphi process was implemented using an online survey. Thirty-eight wetland experts were provided with a map and description of each parcel in Scarborough Marsh and told they had a budget of 1000 WBUs to purchase the above-listed wetlands services for each parcel. The WBU budget required assigned values to reflect scarcity (parcels could not be infinitely valuable) and tradeoffs (higher values for services such as access for recreation may diminish those for items such as habitat). After respondents assigned initial values, results were provided to group members, who were then asked to re-assign values based on their own judgment and what they had learned from how others had valued the same services. The maximum willingness to pay across all respondents for each of the services was then taken as the baseline value of the parcels (Table 1). This is consistent with the relative valuation system effectively being an auction, where the highest value stated by participants is the one that determines an item’s actual value. It also explains why column totals in Table 1 (next page) do not sum to a multiple of 1,000.

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Table 1. Expert Allocations of Wetland Benefit Units at the Three Study Sties

ECOSYSTEM SERVICE	MAINE AUDUBON	PINE POINT	HAMPTON CIRCLE
Flood Damages	100	100	200
Land Values	20	75	100
Water Quality	100	25	100
Drinking Water	10	0	20
Recreation	500	250	100
Aesthetics	100	30	100
Commercial Habitat	50	20	50
Noncommercial Habitat	100	20	200
Carbon Storage	10	20	100
Commercial Species Nutrients	10	10	25
Biodiversity	50	50	100
Research	110	100	0
Habitat Connectivity	10	20	100
Other	10	30	30
TOTAL	1180	750	1225

After identifying site inputs, experts identified the shape of benefit functions at increasing depth for each environmental service (also via Delphi survey), voting among six curve shapes for each service (see Figure 1 on the next page).

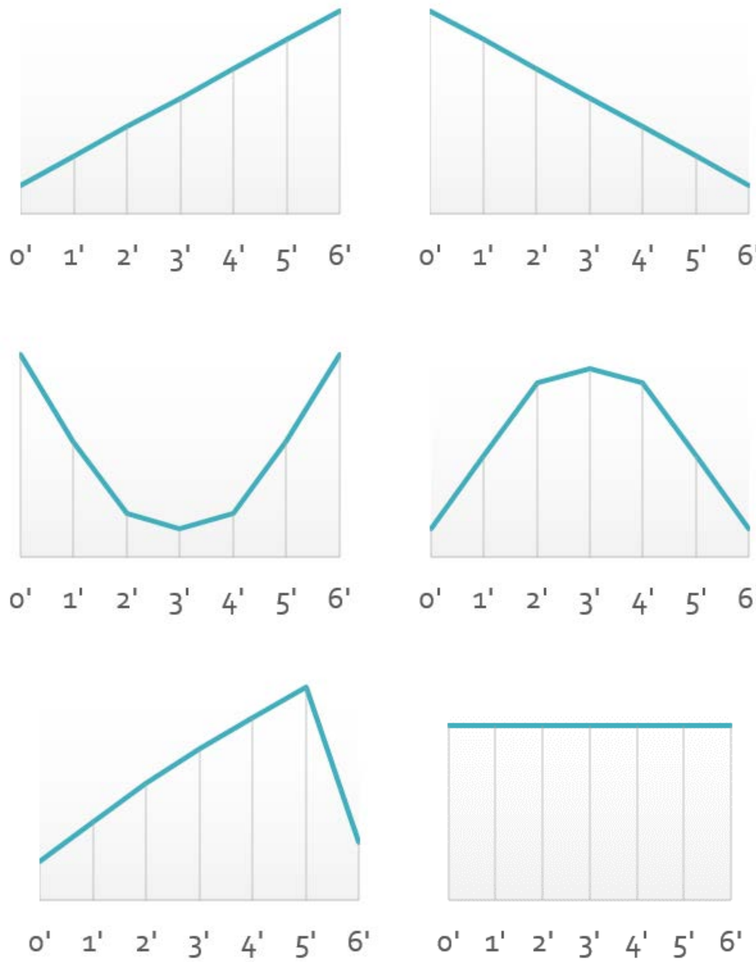

Figure 1. Curves presented to wetland experts for voting via online Delphi survey (curves a-f, reading left to right)

Table 2 (next page) shows experts' responses for each of the curve shapes, across all the ecosystem services.

Table 2. Distribution of Expert Opinion about Benefit Curve Shapes across Ecosystem Service Categories.

Response Curve	Number of Responses	Percent Distribution
a.	14	16%
b.	35	41%
c.	1	1%
d.	12	14%
e.	6	7%
f.	18	21%

The modal view of the experts was that across ecosystem service categories, the initial values would decline over time (curve shape b.), but there was substantial uncertainty among the experts, with nearly as many choosing an increasing response curve for any ecosystem service (shape a.) or a flat curve (shape f.) as chose a declining curve (38% combined flat and upward sloping v. 41% downward sloping). Based on these results, a combined benefit creation function of a decreasing line with slope of -12.5% was determined to be the best representation of all expert opinions about the suite of the 13 identified environmental services. This slope is 1/4 of the negative slope of curve shape b., which was mathematically offset by the positive and flat curve shapes. This integration of the benefits to a single curve served the purposes of the current study, but was recognized as too reductionist. Future applications of MAST will need to calculate the influence of each benefit creation function independently, then sum the WBU results to produce a combined benefit creation estimate.

2.2 Site Selection

Once model inputs had been confirmed, the MAST software model was run for three parcels Maine Audubon (Figure 2), Pine Point (Figure 3), and Hampton Circle (Figure 4).

Figure 2. Maine Audubon site in the Scarborough Marsh, Scarborough, Maine.

Figure 3. Pine Point site in the Scarborough Marsh, Scarborough, Maine.

Figure 4. Hampton Circle site in the Scarborough Marsh, Scarborough, Maine.

These sites were selected to represent a range of possible ecosystem service responses to rising sea levels, including parcels relatively near and far from existing development; having high and low connectivity with adjacent wetlands; and having high and low existing levels of recreational use. Such diversity helped demonstrate the tool's sensitivity to a range of physiographic contexts.

2.3 Calculations

In any scenario year the MAST software overlays flood layers onto a parcel that has an assigned value for the selected suite of ecosystem services, and calculates a new value for the underwater portion of the parcel according to its depth and the benefit creation functions. For example if the sea level rise curve used indicates 13% of the parcel will be under 1' of water in the year 2025, and the starting value of the parcel had been 100 WBUs, 13 WBUs would accrue to the cumulative benefit creation total in that year of the scenario. The software then sums values created on a parcel across all years of a scenario to create a cumulative ecosystem services benefit estimate. Additional software development conducted subsequent to this study now also allows tallies of ecosystem services on the dry portions of each parcel in any scenario year. In the above example this would be 87% of the parcel being counted for ecosystem service values the experts had decided should be counted each year, such as for recreation or aesthetics (at 0' depth from the benefit creation curves).

3. RESULTS

Cumulative expected benefits expressed in WBUs through to the year 2100, in WBUs, indicate that in all sea level rise scenarios the Maine Audubon parcel would produce the largest value, the Pine Point parcel would produce the middle value, and the Hampton Circle parcel would produce the smallest value (Table 3).

Table 3. Cumulative Wetland Benefit Units on Study Parcels through the Year 2100.

Parcel	Sea Level Rise	Cumulative WBUs
Maine Audubon	1'	3,899
Pine Point	1'	3,454
Hampton Circle	1'	276
Maine Audubon	4'	4,640
Pine Point	4'	3,261
Hampton Circle	4'	1,175
Maine Audubon	6.6'	4,803
Pine Point	6.6'	3,154
Hampton Circle	6.6'	1,410

Although the final results could have been sensitive to the slope of the benefit creation function, running the same scenarios with five slopes ranging from -5% to -45% did not change WBU rankings at 1 foot, 4 feet, or 6 feet 6 inches of sea level rise. Nevertheless, the question of how the rate of change in inundation interacts with the rate of change in the benefits derived from wetlands is obviously a central and complex problem. With no real empirical data about how wetlands have increased in value (the vast majority of the research addresses

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declines in economic values), the use of expert opinion filtered through a process such as Delphi is currently the only realistic way of estimating these change functions.

These preliminary results have numerous additional caveats. For example, the benefit curves assume that the ability of ecosystem services to emerge is equal in all parcels. However, some of the Pine Point and Audubon parcels are paved; therefore, this assumption would require pavement to be removed if the parcel were inundated. Furthermore, meeting this assumption may create the need for additional assumptions, such as with Audubon, where the existing parking lot probably explains much of the "recreation" value captured by the benefit creation function. To allow recreation benefits to continue to accrue with depth, alternative parking will need to be created when necessary.

4. DISCUSSION

Because the expert panel assigned high initial WBU values assigned to Hampton Circle by the panel of experts (Audubon = 1,180, Pine Point = 750, and Hampton Circle = 1,225), it was very surprising that the same parcel showed such low cumulative value creation over time. However this is understandable because although the parcel is roughly 60 times larger than the other two, size differences had already been accounted for (i.e., WBUs were acre-adjusted via the budget allocation process). More importantly, the geographic analysis has illustrated that the topography of each site dictates the timing of partial or complete inundation and thus when benefits begin to accrue. After 1 foot of sea level rise, for example, relatively few WBUs accrue on the Hampton Circle parcel, on account of a small ridge along the edge of the parcel. However by the time sea levels rise 6 feet 6 inches, WBUs on this parcel will have become substantially larger, though still smaller than on the other parcels.

5. CONCLUSIONS

If a land acquisition decision were made using these results, the Audubon site, despite being much smaller than the Hampton Circle site, would clearly be the highest priority. This counterintuitive outcome required use of geographic software and careful elaboration of benefit creation curves. Further, it has demonstrated that the cumulative expected benefit approach used by MAST has potential to inform strategic land prioritization decisions both for conservation and development in an era of marsh migration.

Candidate groups that could use the approach include The Nature Conservancy, local land trusts, municipal planning offices, and others that may need to make resource allocation decisions in areas likely to become wetlands when sea levels rise. Lastly, this approach should be especially effective in framing community conversations about relative dollar costs and ecosystem services benefits of potential land management activities.

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