Anthropogenic Influences upon Coastal Marsh Landscapes

We have substantially modified the coastal zone, which is no surprise; it provides us with privacy, exclusivity, leisure, and historically, an easy mode of transport. Our actions, as a group, have caused imbalance, and we are starting to figure out how to put some puzzle pieces back together. Coastal marsh losses from climate change and SLR have been staggering. Marshes provide a variety of ecosystem services, but are often expensive and complicated undertakings. Further study is needed to optimize these investments, and ensure that ecosystem services remain the priority for rehabilitation action decisions.

Rehabilitation of coastal marshes is a direct response to climate change and sea level rise (SLR) and needs to consider a myriad of influences: social, ecological - environmental, wind, water wave interaction, sediment transport, land use and housing density, etc. It is, to say the least, difficult to consider all these factors for effectual change, say nothing of an optimized solution. Landscape ecology has a major role to play in this process, and provides us tools consider these inputs. The landscapes at heart of this review, are those that comprise the coastal zone, typically those at water’s edge, and often semi-submerged. These include barrier beaches, sand dunes, intertidal marsh (salt and fresh), and increasingly armored shorelines. These natural features provide a variety of services, such as the attenuator of flood waters, separation from storm surges and high velocity flows, to groundwater filtration and viable habitat. The economic and environmental values of these services are astounding. Additionally, marsh restoration alone has become a billion dollar industry, these are not easy or cheap features to replicate. Major storms like Hurricane Katrina and Sandy have brought issues of SLR and climate change to the forefront, and at a regional scale water quality and pollutant treatment are becoming priorities. While some trial and error can be expected in any developing procedure (especially those with an ecological tone, nature is full of variables.) I would argue that we have billions to trillions of dollars at stake over the next decades in the coastal zone, and we need to be able to refine our science so we can accurately and efficiently tackle these issues.

Coastal marsh and dunes are at the front lines of SLR. Many local and regional studies have been conducted which accurately index and predict the losses (and gains) in response. In many cases,
there are gains, fresh and saltwater marshes will retreat upward with the tide, and local elevation changes will allow for larger areas of natural growth, potentially. Single use designs, such as terraced marshes may work well for their intended purpose, (Feagin, 2006) yet miss the larger picture of ecosystem services made available by more traditional restoration. The science is nuanced, certain marshes may be more productive for a variety of ecosystem services (e.g. freshwater vs. saltwater) and location near or away from urban areas plays a role. Property valuation and marsh derived ecosystem services valuation are two sides of the same coin (Feagin, 2010) such that both often rely on each other (property values marsh for ecosystem services, and marshes value property for the effort allocated to their preservation). Curiously, urban areas may be those where marshes persist, due to the symbiotic needs of each. These are not simply viewed at a 1:1 ratio across the board.

Advances in GPS, GIS and on ground measurements using Surface Elevation Tables has evolved to an advanced state. (Morris, 2002) We have collected good data of the existing conditions and the change in conditions, at least for the past couple decades. As marshes abut residences and infrastructure, the potential areas of expansions will be competing on these front lines, overall losses can be expected. At the heart of the issue of marshes retreating is rate. While local fauna type, sediment, erosion and avulsion play a role, marshes, in general can only cope with SLR so fast, it is possible in many area that the rate of change of the tide will exceed the marshes natural capability to adapt. This may lead to a vegetative void, subject to avulsion and storm tides (compounding our problems) or replanting of native species. In many areas, ecologists and planners are heading the issue off at the pass and restoring depleting marshes that have begun to, or been lost already.

Exotic vegetation and replanting schemes, though well meaning can often miss the point, and often decades long practices may be detrimental when studied in detail. (Harpinder, Sandhu, 2014) We need to be able to understand, measure, and quantity the ecosystem services we wish to receive from these replanted areas and determine an optimal overall solution. There are many tools available, including planning incentives, retreat, coastal fortification (regional), and well as stabilization and reintroduction of native species. Within this decision tree, we need to analyze our practices in detail. Some commonly perceived benefits, such as wave attenuation may not be a byproduct of marsh vegetation, but underlying soils.(Feagin, et al. 2009). Other ecosystems services should be studied in a similar manner, perhaps in situ. If we are expending vast resources in the name of ecology alone, these processes will not be sustainable in the long term. A comprehensive approach is a must.
Another aspect, which is often overlooked is maintenance. Any man made feature, even a replanted / rehabilitated marsh, is, a man made feature. Any coastal system, natural, and especially man made will need effort to sustain them in the face of SLR and climate change. Such effort needs to be considered in the design phase, both for practical upkeep but just as importantly for cost benefit analysis, again so that an potentially optimum solution can be reached. Marsh restoration is too important and costly to remain a niche or regional activity, furthermore it is an expensive activity, though inaction is more costly. These practices are, en masse are becoming large scale geo-ecological engineering, and need to be viewed locally and at scale under many lenses to be property optimized and remain viable.
Annotated Bibliography


Utilizing a seemingly controversial thesis, Feagin et al. seek to determine the effects of salt marsh on wave erosion. While perhaps not a strict ecological study, this outlines the main perceived benefits of salt marshes, that of wave force attenuation. The study notes that marsh restoration has become a major "industry" and challenges one of the primary incentives for installation or rehabilitation of costal marshes. Both lab tests (wave flumes) and field testing was conducted. Essentially, the study concludes that soil type, not vegetation is the primary factor in preventing lateral erosion. While in no way is this broad enough to challenge the entire practice of marsh restoration, nor does it seek to review other ecological benefits; it does recommend that the correct soil type be used for restoration and that vegetation be used, or considered to replenish suitable soil types.


This study seeks to determine long term stability of coastal marsh in response to sea level rise. The area of interest was primarily marsh habitat around Charleston SC. Morris et al. conducted field surveys of the marsh surface elevation using Surface Elevation Tables (SET) attached to survey benchmarks to measure vertical accretion. The study product, is essentially marsh response data in reference to Relative Sea Level Rise (RSR); in other words, what is the maximum amount of accretion from sea level rise marshes can withstand before they are essentially overrun. It's an important study, though limited in area the concept is sound. While sea level rise is obviously increasing, it may be difficult to use these studies to accurately predict future marsh conditions as the exact level and rate if increase is variable and changing. There is a determination of an optimal marsh elevation, which is useful, though the study fails to discuss many potential solutions or management techniques (excepting fertilization) which would be viable in these instances. Further review would be needed, perhaps even on a case by case,( or marsh by marsh) basis for management solutions.


An area wide study of Cape May County, New Jersey, what is a more or less standard fare vulnerability assessment, in light of Hurricane Sandy was unfortunately prescient. The assessment covers the normal range of inputs, Land use / land cover, storm exposure, elevation, subsidence, erosion and loss of buffer zones. Utilizing these factors, Wu et al proceed to prepare a distribution of present flood risks map, based on the National Hurricane Center's SLOSH (Sea, Lake and Overland Surges from Hurricanes) Model, which produces a calculated storm surge height for hurricane intensities from 1-4
Coupled with expected rivervine flooding the map displays land area broken down into four risk zones (low to very high). From there, it updates the map to its potential year 2100 configuration, based on IPCC estimates. The results, quite frankly are drastic. The first 3+ miles of the coastline, jumps from a mix of risk categories to a completely shaded Very High Risk zone. Furthermore, taking into account land use and cover, social vulnerability zone maps are produced. Finally, it neatly displays future population scenarios for the county, with populations shown as low, medium and high risk, all increasing, which high risk at a much sharper slope. What may seem obvious to those in the environmental community, is neatly and efficiently displayed such that laypersons could clearly understand. With a few small tweaks, this would be a Time Magazine or Economist info graphic, it’s quite stark. Papers like this should be requisite for any locale on the coast, especially those within hurricane prone areas. While this may not be an ecologically focused report, it is necessary to bring in this type of data to balance the ecological perspective.


This is a very general paper, starting with the most basic of topics (SLR, GHG’s, species and habitat change, etc.) It also attempts to define landscapes, both historically and culturally, while referencing additional more specific studies. Some focus is given to sustainable design through landscape architecture, building re-use, and site selection. It’s a bit too vague to be truly useful, but perhaps at best outline some generalized landscape design concepts and questions for consideration.


Das and Sandhu seek to determine the effect of ecosystem services from Casuarinas (Australian Trees) on Indian Coastline. The planting was proposed as a bio-shield, to protect from Cyclones, tsunamis and storm surges and was intensely practices along India’s east coast. The practice of planting these trees dates back to the 1920’s, primarily for coastal protection. The study areas (Odisha - Kendrapara and Puri) are well accustomed to cyclones. Past studies found these provided little protection against the 2004 Indian Ocean tsunami. In my opinion, this is a solid paper, considering all aspects of the practice, from it’s intended function versus natural conditions, to the range of potential ecosystem services provided. These include soil retention, nutrient cycling, nitrogen fixation, bird and vertebrate / invertebrate habitat and soil borne disease suppression. Casuarinas provides fuel wood which is an important factor to the developing nation, all in all, a range of economic benefit. The papers premise, that Casuarinas fails to provide adequate costal protection is made obvious, a facet of the species inherently (wave attenuation potential is easily measured by tree size and spacing, to which Casuraina are not well suited, due to high spacing and potential breakage) and unfortunately native
vegetation such as mangroves has a higher protective value. Where the paper is lacking, is specificity in attempting to measure the unintended though beneficial aspects provided by the practice to conclusively distain the practice. Either way, this paper reinforces the point that anthropogenic coastal changes have impact, in this case, it was directly responsalbe for a higher number of deaths in the subject areas.


An older paper, though it's nice to check in on for reference. General is scope, it considers reactions to coastal dunes in response to SLR and climate change, most importantly increased erosion potential in response to SLR; though it speculates that higher CO2 may positively impact dune vegetation (and thus enhance stability.) What's most interesting is, it references a 1990's IPCC report, with predictions for 2030. While these are easy enough to research, it's interesting to see it in context. The prediction was for 0.09- 0.29m rise. Well over halfway there, we've already surpassed the 0.1m lower bound. Dune stability is influenced by vegetation, by near shore current transport, and windblown deposits. While the paper acknowledges it's speculation, it's obvious that higher seas and larger storm would, on average lead to an overall degradation of dunes in general though structure plays a key role. Dunes provide a degree of function, protection of succession landscapes, groundwater regulation and preventing saltwater intrusion.


This report, using GPS, lab and GIS modeled SLR effects on tidal marshes along the Georgia coast. The model simulations use standard Intergovernmental Panel on Climate Change (IPCC) SLR estimates to 2100, and focuses on ecosystem services changes. Modeling indicates a 20% + 45% decline, under respective mean and maximum SLR, while tidal freshwater marshes may increase by 2% (mean) and decrease 39% under the maximum scenario (by area). What this study, specifically does not account for is gradual accretion / reliction and sediment transport. While these are likely to have some effect, the general methodology is sound. Aside from coastal protection and some wave attenuation, waste treatment (particularly Nitrogen removal) is a key ecosystem service provided by marshlands. This study is not significantly different than other studies of the same ilk; this is not a criticism, area specific studies are necessary, but not unique.

This is primarily a technical paper, in the sense that it enables highly accurate measurements of coastal marshland. Using a rod surface elevation table (RSET), researchers are able to record long term GPS based measurements to a very high degree of accuracy (1.3 - 4.3 mm), using pipes set to refusal (or sufficient resistance). This is all critical for the long term accurate monitoring of sea level rise in specific study areas, and more importantly marsh and mangrove elevation changes from reliction and avulsion, which are often SLR influence. In and of itself, the paper is not quite earth shattering, it’s an evolutionary upgrade to leveling devices and is probably not at all interesting to those outside the field. However, to myself, and others interested in the subject matter, it’s a very necessary precursor data to understand the challenges, and success in allowing accurate measurements.


Another Feagin piece, more potential controversy here. The main assertion, or contention is regarding the ability of vegetation to resist wave heights of more than a few meters in significant storm events. This, obviously has ramifications for the calculus of wetland and coastal preservation values. Again, at the heart of the debate is the question the attenuating sources, e.g. what does the vegetation provide, versus what the underlying conditions (vertical / horizontal distances, soil type, landscape geography, etc) across a range of events, from tsunami waves to tropical storms and hurricanes. This is incredibly valuable stuff, as we, as a society determine the best allocation of resources to stem the detrimental effects of climate change. If we’re over estimating benefits on one side of the coin, we obviously need to know - so we can factor it out.


Climate change and sea level rise are forcing competition for the coastal zone. As the tides migrate upward, they are taking coastal marshes with them, and decreasing the distance and elevation to developed land and infrastructure. Though it may not be intuitive, changes in this case do not always equal loss, as sediment, accretion and zonal patterns are highly complex and varied, and more importantly the reserve area for potential growth may be larger than the currently existing. It’s always interesting to note how complex these problems are, it’s often a case of the devil in the details. Coastal wetlands and marshes are a field ripe for GIS and ecological studies, spatial and elevation data is becoming incredibly detailed, and the studies regarding these are able to yield a higher value of data. The study area of Galveston TX is near ideal, a highly developed coastal city with a major history of significant storms. Personally, this is a textbook example area study for me, integrating survey and LiDAR data, ecological and SLR effects, along with an economically themed output range (as the premise is -wetlands survival is dependant on the rate of return of property value). The determination that, the most efficient outcome is the maintenance of urban areas (housing) and coastal barriers, at the expense of wetlands is seemingly obvious. While changes in valuations may alter this, its not likely that any situation would come ot pass (except in areas of total potential loss, e.g. complete devaluation) where, from a societal and economic perspective, wetlands would be the valued priority. Perhaps the most
interest piece, though mostly speculation, is that housing prices in Galveston actually increased after Hurricane Ike, due to reduced supply. To economists, this is obviously no suprise, but when viewed through an ecological lens it shows that even after major storm events, there could be an indirect link that actually recedes the 'value' of wetlands after a devastating storm, when it would appear most likey they would most highly valued.


Feagain and Wu study terraced salt marsh restoration project, versus standard reference marshes in Galveston Island State Park. Terraced marsh, with *Spartina alterniflora* were designed to maximize the edge between habitat types. Two study areas were chosen, there restored plots, and three reference plots While terracing works to create and aquatic edge for fisheries production, but does not match reference marshes for spatial configuration or habitat composition. Marsh restoration study is an important topic, both for current restorative efforts but as future SLR occurs, more and more projects will be proposed. The spatial arrangement of these features is important, and as more and more are created we want to maximize the value of the features, both economically and for ecosystems services (though I would argue these are one in the same, all things considered). Personally, I'm all for maximally efficient solutions, but in this case we need studies like this to figure out what they are (and what they are not). It is difficult however, not to fall down the rabbit hole of highest practical use, these are complicated features and need deep analysis. Occasionally, even a sub-optimal idea (terraced plots), is required to further the development of the science, it is often a case of trial and error.