Great Marsh Resiliency Modeling Workshop
Monday, April 11, 2016 9AM-4PM

I. MODELING/DATA NEEDS FOR DECISIONS

How do we start putting the science into decisions of working in the Great Marsh?

Federal Perspective: Andrew Milliken USFWS – a big portion of work of coastal resilience; federal agency perspective.

1) Federal land ownership – understand local impacts on these systems and how each refuge fits into the larger picture. Increase persistence of resilience.
2) Managing ESA. Impact of SLR on existing listed species, how are changes on beach habitat going to affect species like PIPL or saltmarsh sparrow? What are the suite of actions we can take?
3) General responsibility of migratory fish & birds. Which areas along the coast most resilient? Manage for the future.
4) Facilitate regional partnerships.

State Perspective: Marc Carullo, MA CZM – mission to help balance human activity with coastal resources.

- Agency does a lot of technical reviews. Have been working on development tools to monitor and assess salt marsh issues. Marsh characterization, monitoring-
- Ecosystem Services (ES) – important to get a handle on what Ecosystem Services tidal marshes provide within our state. what are carbon sequestration tradeoffs of tidal fresh converting to salt/brackish, adaptation/restoration techniques
- Need further research on nutrient impacts. Many methods being demonstrated regionally. Need to understand life expectancy of different restoration projects. What are the adverse impacts on system and nearby systems? Working towards these answers.
- Climate action tool will be online shortly. Collaboration key in forming multidisciplinary teams; work with site managers; collaboration w. researchers is key, engaging w. managers/practitioners to define research objectives data sharing – it all helps as we plan ahead.

Local perspective: Conservation Community: Peter Phippen Mass Bays – Works a lot with coastal communities. Concerns include increased flooding of marsh platform, changes from high marsh to low marsh vegetation, marsh edge erosion, increased wave action, increased water temperature resulting in increased invasive species, and changes in water quality. Looking to see what type of restoration project should be happening where. Restoration option to consider include thin layer deposition, enhancing drainage, Living shorelines. Hoping the models help to determine where to do these restoration strategies. Are there cumulative impacts with mitigation projects such as dredging, raising roadways.

Local perspective: Municipalities

Julia Godfredsen, Newburyport –

- **COMMUNITY SERVICES!** What do things like TLD mean to a city? Need a direct link between research results and community benefits. How do the results translate to real life decisions.

- Need to explain why write grants for restoration when armoring is easier and could be cheaper. Translate research data into a language a city mayor and city council can understand to gain support for things like green infrastructure or a grant for work to continue. Speak about benefits in terms of public safety, public infrastructure.

Lisa O'Donnell – Essex Make the science relevant and understandable, pertinent to our backyards. Keenly aware climate change is going to affect our town. We need the knowledge to ask the right questions. Need dialogue with researchers. From a town perspective, public town meeting makes decisions on articles and operations on town, including expenditures. Need information to be relayed in a very laypersons terms. Many people are still climate change skeptics. Strong need for towns to work together across the Great Marsh, but local basis for permitting/approval.

Inter-relationship among salt marshes, tidal inlets, barrier islands and tidal delta sand reservoirs – Fitzgerald

- Plum Island system began forming 3,500-4,000 years ago
- Sea level rise is the major stressor for the Great Marsh
- Sea level curve based on dating basal peats (Donnelly, 2006). Marshes built laterally and vertically last 3500 years at a SLR rate that was 5 times slower than the current rate.
- SLR was 0.5 mm/yr 1,000 years ago (Meade diagram 1975). Current sea level rise rate is 2.8 mm/yr (regionally – Boston tide gauge).
- The lack of fine grained sediment esp in the north, related to lack of river discharge (not just due to dams, due to glacial history.
- Sediment Elevation data shows average of 2.5-2.6 mm/yr marsh accretion rates (note: accretion rate slower than rate of SLR at 2.8 mm/yr)
- Difficult for marshes to keep up with SLR due to erosion and lack of fine grain sediment in system today which is needed to build salt marsh. Joppa Flats would be called Joppa Marsh if we had enough fine grain sediment.
- See Wilson (2014) paper for more on marsh morphology
- Marsh dynamics along tidal channels: slumping, calving
- Marsh Edge Erosion Study (PI: Alyssa Novak) – 69 monitoring sites in 7 marshes
- Conceptual model: As sea level increases, the tidal exchange increases (with widened inlets), which leads to increased water in the back barrier (coincident with drowning marsh). There is a direct relation between tidal prism and sand volume of ebb tidal delta (Walton & Adams 1976). Increasing open water areas in back barrier will lead to increased coastal water exchange, leading to inlet widening. Increasing sediment on ebb tidal delta. Tidal prism dictates size of tidal inlets, narrower inlets have less sand volume in ebb tidal delta. Increasing discharge, net sediment transport offshore, at expense of adjacent barrier islands. The consequences of an increased tidal prism: erosion, deposition, deeper tidal inlets, barrier islands are thinning resulting in a grand tear.
- Trying to backstrip the marsh to see how the hydrodynamics have changed. Strong ebb dominant at inlet transport sand, storms bring sand behind the inlet (upstream). Back stripping marsh 1-2 m doubles the tidal prism, vastly enlarging ebb tidal delta. Enlarging size of tidal inlets and depositing sand in delta at expense of barrier islands. This won't happen right away, but it will happen.
- Glaciated relic landscape may prohibit marsh transgression (steep upland slopes compared to coastal plain marsh systems of the mid- and south-Atlantic)

- System currently “ebb dominant”. Ebbing tide leaving system carrying more sediment than flooding tide.

II. SALT MARSH SESSION

Anne Giblin, Overview of salt marsh response to climate change and how models are used to improve understanding and make predictions

- Really great opportunity working in the Great Marsh because of all the partnerships and coordination with refuge staff actually using the best information to make decisions now. Need to understand what activities work and don’t work.
- Long-term SLR is 2.8 mm/yr; 4 mm/yr over last 20 years.
- The past cannot be used as a guide to make decisions in the future. Marshes were not here when sea level was this fast after glaciation. Can salt marshes survive an event that they could not historically grow under?
- Marsh accretion is a function of both inorganic sediment and soil organic matter. 3 mechanisms to survive: 1) migrate backwards to higher ground, 2) accumulate organic and inorganic material from incoming tides, 3) can accrete vertically, both above and below ground, from growing vegetation.
- Marsh gains and losses is a 3D problem. Marsh is constantly re-arranging. Marsh transgression – 3 barriers to moving: biological like *Phragmites*, steep elevation change, and development.
- Models have a lot of great features, but we need to know more about erosion and deposition processes. Many unknowns even in well-developed models. How fast the changes at Plum Island happen will depend on many variables. Model grid size has a big impact on model resolution, need good bathymetry, digital elevation model for erosion/deposition models, waves are a challenge in these models, but otherwise they work well for regular erosion/deposition rates.
- Removal of dams won’t help with sediment issue but are good for other reasons.
- Elements of our conceptual model that are uncertain:
    - Sediment transport: role of biota; changing sources
    - Ecomorphic feedback: nutrients; temperature; species. Don’t know much about effects of temps on decomposition rates, increased nutrients may affect sediment accretion of organic matter.
    - Transgression: biological barriers like *Phragmites*, as well as elevation and armoring
    - Hydrodynamics: waves
    - Bioturbation: burrows; excavation. Biological films, marsh grasses means erosion doesn’t happen as though are unconsolidated particles, decomposition in sediment can change susceptibility to erosion
- Near term (next 100 years)- Plum Island changing to low marsh, more open water.

Sergio Fagherazzi, Marsh bank erosion, wave energy, and implication for marsh stability

- Paradigm: when SLR increases, marshes accrete faster. Increased water can drown marshes if pace/rate is too fast, but marshes can accrete with the (potential) increased input of sediment associated with the hydrodynamics (note: but we are in a sediment poor system).

- Horizontal dynamics – there is a small/narrow buffer to allow for marsh "equilibrium"; in most cases, the marsh is either expanding or eroding (horizontally). At the refuge, some spots are eroding, some are accreting. Boundary is always moving one way or another.
- Goal is to look at entire system for marsh resilience. **Look at net changes, don't try to save the existing boundary positions**
- Marsh formation is dependent (in part) on sediment availability. More importantly, net sediment flux is important. Creating/knowing the sediment budget for the entire system is critical. Marsh survival = sediment input > sediment output
- Has been studying creek bank erosion at Plum Island and other salt marshes along East Coast for 10+ years; 7 years of pre-Sandy data. Erosion is a result of waves and currents
- Biofilms (e.g., algae) stabilize mud by binding the sediment surface
- Developed models (Delf-3D; SWAN nearshore wave modeling + COAWST Modeling System: coupled ocean-atmosphere-wave-sediment transport) based on field research.
- There is a linear relationship between wave power and erosion. Bigger storm cause more erosion; but they are not very frequent, so don't contribute to overall erosion very much.
- Most erosion of a marsh not due to hurricanes; 36% caused by gentle breeze; 1% by hurricanes. Barnegat Bay – little erosion for Hurricane Sandy.
- **Lateral erosion is driven by moderate storms (i.e., Nor'easters), where the magnitude of erosion is low, but constant and predictable**

Marsh Equilibrium Model (MEM) – Morris

- Developed marsh equilibrium model to account for feedback between hydrology and biology. Using these to simulate marsh activity on Plum Island. Marshes will survive between mean sea level to mean high high water.
- There's an optimal growth curve for all plants. James Edwards- classified diff veg types (*S. patens*, SA, upland). *Spartina patens* peaks at 1.5 m above NAVD88 (0.8 to 2.4). *Spartina alterniflora* goes down to MSL (0.0 NAVD88).
- Mean elevation of PIE is 0.47 m, 100 yrs hence it will be left skewed distribution of elevations (much lower hypsometry's)
- SLR can either promote or inhibit plant communities. With SLR, *S. alterniflora* increases, *S. patens* decreases.
- Marshes accrete more if the plants are growing better. MEM models shows PIE marsh converts to all *Spartina alterniflora* by 2100 assuming 1 m of SLR, but further out in time, the crash of PIE marsh is DRAMATIC.
- Marshes are not keeping up with SLR due to limited sediment input. Most marsh loss is the low zone *S. alterniflora*, would be a good place for thin-layer deposition; may decrease the fetch and slow the erosion. In many marshes accretion nutrient limited. With fertilization, accretion rates increased. Biomass gained w. plants fertilized- leads to elevation gain.
- Experiments fertilizing plants to generate biomass. Currently, *S. alterniflora* is not at optimal growth, can tolerate more SLR. *S. patens* is past optimal growth. SLR will start to drown these marshes.
- Nitrogen has accelerated accretion in marshes in South Carolina; but not in Plum Island. This indicates that in Plum Island, nitrogen is not the limiting factor. {LTER research also shows that many beaver dams and extensive wetland complexes along the rivers remove most nitrogen before it reaches the estuary}

Hydrodynamic model of Plum Island using MEM – Hagen

- Coupling of hydrodynamic model for long waves (ADCIRC) w/MEM. NOAA funding originally. 6 years collaboration. Outputs: tidal harmonics
- 15 m resolution in Plum Island; no wave coupling at this time
- Calculating mean high and mean low water in marsh systems. These are spatially variable thru the system, can't just use inlet values.
- Used model data for applications in MS, FL & AL.
- Timucuan, FL looking at dredging study implications with climate change, channel deepening & widening. Looking specifically at intertidal marshes from Chesapeake Bay to Delaware Bay, Forsythe & Chaffee Refuges, and Plum Island.
- For PIE- calculating MHW and MLW over the entire marsh surface critical for proper function of MEM. Needs to know elevation of the marsh surface. LIDAR data is a huge step forward for marshes. NED has uncertainity of 3 m. LIDAR is 6 in-1ft (it is better than NED but still needs better resolution).
- The model can show low, medium, high biomass distribution. Even with 120 cm SLR, there will be a functioning marsh, but there's an increase in vulnerability and decrease in viability.
- Trying to tie back to carbon emissions scenarios. CE scenarios incorporate temperature, rainfall, SLR, incorporating changes in decomposition, shoreline & dune morphology changes, Landuse/Landcover changes, and population growth)
- Climate change is a generational problem. " A society is resilient when it provides future generations with more choices." We won't see a solution, but we need to help address it. Numerical modeling technology is awe inspiring, but still very limited. Need to recognize it's a diagnostic tool, but the future is unknown.

Q/A: Duncan has tidal data (3-4 weeks) in upper reaches of estuary. LTER has some. NEW NOAA permanent tide gauges at PI bridge and Rt 1A bridge in Salisbury.

Salt Marsh Group Discussion

A question from the audience: Did Duncan and others say that PIE is the weakest marsh?

- Duncan- we are sediment limited. not lots of fine grained seds so makes our marshes weaker
- Anne- hi tidal range makes it easier for the marsh to evolve- better off than micro-tidal marshes, less development up to marsh edge gives time for transgression. Stability for another century? Duncan agrees.
- Jim- doesn't agree that this is the weakest marsh. All over the east coast we are in limited sediment supply. Have 1-1.5 m of elevation to play with here before the marsh drowns.
- Duncan- high marsh transformation to low marsh is important.
- Duncan- stymied on 100+ time scale b/c little sediment input. Anne/Jim saying over shorter timeframe- high tide range confers some persistence
- Does relative elevation matter? Yes. As SLR there will be greater tidal prism so there will be greater erosion rates.
- Geoff Walker- rivers are moving lots of sediment. Traps get buried when left out >several days. Grain size is too big to get up on the marsh platform.

Fertilization and impact of Nutrients

- Jim Tureck- N loading may benefit above ground biomass at the expense of belowground biomass.?
- Plots fertilized for 37 years are higher, have *Iva* on them. When nitrate added- creeks eroded faster?
- Anne-Inconclusive re: Deegan's work. AG/BG ratio changed a bit. Jim Morris fertilizes with ammonia sulfate, ammonia nitrate- not sure if the source of fertilization matters. In South Carolina, belowground biomass increases a lot w. fertilization. Root:shoot ratio increases. Great Marsh does not have a N problem, eutrophication is not a problem yet. Somehow this watershed is nitrogen retentive (Anne), only 15-20% of septic reaches coast, usually is 25%
- When sewage treatment plant on Ipswich R- should discharge at high vs low tide as SLR- where will discharge go? Anne- so much dilution at high tide, nutrients from discharge is not as much as an issue.
- *Phrag* stands are due to FW inputs, this may be the bigger concern with sewage and other discharge (on the other hand, *Phrag* accretes at faster rate than either *Spartina* species)
- Sue A. – *Phrag* in Chesapeake Bay – if it is the only vegetation holding up in marsh, should we consider leaving it there if the alternative is open water? Saltmarsh sparrow SHARP program an example of doing things differently.

Andrew – we should manage salt marshes as best to our ability for the short term regardless of the unknowns of the long term.

CZM person- thin layer deposition as a Great Marsh mgmt. technique? When to start? And where?

- Sergio- TLD has had mixed results in Venice. Area that is low marsh has been so for 300 years. Doesn't think we should raise this. We should only supplement where high marsh has for sure turned to low marsh. How much (elevation wise) and sediment size is a big question. Sometimes the marsh has shrunk.
- Duncan- beneficial re-use of dredge material,
- Jim Morris – plants have a "sweet spot" for growth in salt marshes. Plants grow best at particular elevations. Here MHW is 145 cm. marsh elevation is 130 right now, for SP. When doing thin-layer deposition, you want to be aware of this to create the right conditions for plant growth with new elevations you are creating.
- Hennok- make SA more resilient to decomposition (GMO)?
- Jim- hybrid *Spartina* in SF Bay – more vigorous than its parents, think about utilizing some hybrids to select for building/trapping more sediment.
- Recommendation: only apply thin layer deposition (TLD) on marsh where we know high marsh has already turned into low marsh
    - Elevation is critical
    - Drainage, sediment composition
    - Proactive vs. reactive – timing is important parameter to consider

Ed- plants are responding to duration of inundation too. Creek hydrology affects inundation

- Liz Duff- ? re: tidal restrictions
- Long-term legacy of ditches – drainage, organic soil particles
    - Need to balance inundation with drainage
- Dave Burdick- long term impacts of ditches is that sediments are degrading quicker. Sweet spot for drainage about 10 cm below soil surface. When surface subsides- the plants get wetter and wetter. Runnels dug to 15 cm to partially drain the pools and allow the plants to recover. RI Save the Bay have used this technique- runnel.

Need to consider human impacts:

- Shellfishing – is there a correlation to marsh vulnerability? Digs up sediment, more susceptible to erosion. Also breaks bio-film that holds sediment together. Sergio thinks that in some instances, it may actually by re-suspending sediment, making it available to marsh accretion.
- Boat wakes? Are these having significant impact to creek bank erosion (Sergio's work)?

Community outreach: why this all matters? "So what"?

- People are concerned about the present, not 100 years from now. A lot easier to sell the idea when there are impacts to local infrastructure or economics. Newburyport- starting to see increased damage from storms so helping to sell this issue.
- Community leaders need to help to know what to do with all of this data and what options are best to choose. Communities need the guidance on what to do with all this great research. Catalog of management responses (Sue A suggestion) needed? Vague responses of Yes.
- Rick B. – DOI Hurricane Sandy story map. Spoke about socio-economic metrics and how communities can help answer the "so what." Linking ecological performance to community resilience as part of Sandy projects
- Sue A. – related to talking to climate skeptics, sometimes we need to put aside the "why" of water level changes and discuss where the water is and how it is changing.
- Vulnerability analysis is the first step a community can take to know where to put resources.

Other data needs

- Sue A-- Neil Ganju's work- areas within salt marshes that are stable/unstable, Identify areas where mgmt. could have an effect within the marsh for thin-layer (refuges are interested in this)
- Ed Reiner- crabs clipping SA, clammers turnover the area and roots are exposed, *Carcinus* may be slowing veg colonization into the mudflats
- Sue Adamowicz suggestion-NA LCC to facilitate the RTK data to NOAA VDatum to improve its applicability to estuaries? Talk to Jamie Carter about who in NOAA NCII might want this?

<u>III. BARRIER ISLAND</u>

Overview of barrier island response to climate change and how models are used to improve understanding and make predictions – Fitzgerald

- Frequency of storms will likely not change, but warmer water may lead to larger magnitude storms

- *Geomorphic changes primarily responding to SLR
- SLR yields loss of sand offshore (sediment leaving the barrier system)
- **Hurricanes don't affect us as much as nor'easters. Changes will occur slowly to the barrier island system at first. Overwash not going to happen on the barrier island here until the foredune ridges are lost or broken down.**
- Mouth of jetty: ebb and flood oriented bedforms
- Sand sourced from offshore has likely ceased
- Riverine source and regressive delta deposits
- Sediment transport is dominantly N to S; finer-grained material is found down by Wingersheak Beach
- Some sand movement along the beach S to N (indicated by accumulations trapped by groins)
- Loss of sand after storms increases with SLR; wave orbitals cease interacting with seafloor to push sediment back onto beach
- Sand will be lost to ebb-tidal delta and the sand will move into the Sound.
- GEOMBEST (Geomorphic Model of Barrier, Estuarine, and Shoreface Translations) – improved initial models (governed by SLR scenarios, geometric cross-shore model, conservation of mass, equilibrium profile) by incorporating the composition of the seafloor
- **Marshes are critical for the equilibrium of the island. If we lose marshes in the back barrier, the barrier will move westward (transgress) faster.**

Vulnerability of infrastructure to coastal flooding under SLR scenarios: Preparing for SLR and climate change at a community and individual asset scale – Bosma

- Qs: What is the probability of flooding? What is vulnerable and how do we prioritize?
- Existing data: FEMA maps are only backward looking. Bathtub doesn't work with high tidal ranges, depends on when the storm hits about how much is flooded. Winds, fetch- affect flooding which isn't captured in bathtub modeling.
    - These are not good enough to answering the desired questions
- Spatial variability can be assessed better with dynamic modeling
- MassDOT/FHWA pilot study
    - WHG Boston Harbor (Main Artery) model: dams and pumps are accounted for; most of the grid is at 5 m resolution, while some areas are refined to a 2 m resolution grid
    - MassDOT selected 2030, 2070, 2100 time horizons on the high SLR projection curve (2.0 m)
    - Model validation of historic storms
    - Exceedence probability maps
    - Depth and inundation maps
    - MA DOT changed the location of their maintenance facility based on their results. Can plan where and when to move pumping stations to increase resiliency of city infrastructure.
- CZM SLAMM project – Great Marsh focus
    - doing 18 panels across the state. How NWI classes are changing as a function of SLR (tidal attenuation). Using MEM to provide veg based accretion rate to SLAMM. Tidal attenuation thru the system using their Boston bathtub model.
    - Model provides <u>Exceedance probability maps –</u> probability of "getting wet." If your property is in a certain location, you can now start to answer the "so what" if you are in

an area likely to flood. You can't just add SLR to your results, need to consider other variables.
  - Hard infrastructure in Boston makes it easier to model b/c there is no geomorphology change as opposed to non-armored coasts. Increase in open water in PIE. Using SLAMM results to work w. Chris Hein and Duncan to figure out how the inlet formations are changing. MassDOT pilot project on adaptation options for the Central Artery of Boston. Can put in adaptation options (seawalls, economic changes, etc.) and see how it affects the model .
  - 2070 high SLR scenario w/MEM → dominantly low marsh in Great Marsh

<u>Porter </u>Conceptual framework: connecting those studying nature with social scientists. "Coupled nature – human dimensions." Cycle of erosion and accretion going back over 100 years. 1930's-40's we saw the house building boom in coastal areas.

Historic and modern sediment budget and sand movement on Plum Island – Hoagland

- Part of Chris Hein's larger Plum Island study
- Addressing the socio-economic component of coastal protection/planning
- Study composed of a multi-disciplinary team, "Coupled nature – human dimensions."
- Project is in its second year (of five)
- Different temporal and spatial scales concerning coastal sediment dynamics (supply and transport)
- Cyclical changes – cycle of erosion/accretion over the course of ~100 years
- Chart of houses built in Newburyport over time (1850-2010) – explosion of house building beginning around 1920; similar trend seen on Humarock Beach, Scituate
- Hedonic price method (HPM) – uses data from housing market; used to estimate implicit price of:
  - Waterfront; waterviews; beach width; beach quality; distance to beach; elevation; risk of erosion/inundation; hard or soft structural protection; building or zoning restrictions
  - Bigger markup for public vs private shoreline protection
- Models exist for Plum Island and Sandwich (Scituate in progress)
- Value-Capture Tax: one-time tax; mechanism to finance (e.g., beach nourishment) – "fair", "efficient". Proposals for taxes for beach nourishment that decrease in amount as a property gets further from the coast. But there should be some accounting for a beach nourishment project for non-adjacent properties b/c it does contribute to the value of a house.
- "geotime" – time until inundation (based on understanding of erosion history/hazard in front of property. People actually rent bulldozers and rebuild dunes prior to a storm to buffer/protect their properties

Q: How much do flood insurance rates reflect risk of flooding- There is no insurance for coastal erosion (not covered) sometimes flood insurance covers flooding due to erosion though.

Barrier Island Discussion – Group

- Data gaps:
  - Is the tidal prism actually changing? Or only translating?

- Full accounting of what's available today; what is already being covered?
    - Timeframe for decision making?
    - What's the best delivery mechanism?
        - *face-to-face
        - Maps for towns—Built-out maps really mobilized town action.
- To what extent do we allow beaches to be dynamic?
    - Pros/Cons to beaches/beach systems vs. marshes behind
        - Should we consider Inlet closures such as at Fire Island, NY; Plum Island is a robust barrier – compare to Fire Island in NY
        - USACE mandated to close inlet breaches
- Hunt-culture on a static environment is dead. Can't look back to figure out what is to come. Bracketing our risk is needed to understand the future scenarios for flooding, SLR, etc. How do we bring these model outputs to local communities to let them know what is coming.
- Anne- suggests taking away the barrier beach in the models to show what happens to the marsh.
- Kirk-flooding risk model for Great Marsh using landform response is coming in 2 years. Current model for Essex uses bathtub model.
- Kirk-- Sandwich MA gets it re: protecting their barrier beach, b/c they will lose their marsh without it. Green infrastructure attenuating the waves- is always way cheaper than the damage that will be incurred from storms to infrastructure.
- Geoff W.- they rebuilt the jetty and are putting water & sewer on Plum Island houses- even if only 25 yrs of time left- worth it to some landowners.

III. CLOSE OUT DISCUSSION/NEXT STEPS

- List ecosystem services to Great Marsh barrier island-
    - Carbon sequestration
    - Nitrogen assimilation
    - Robust salt marsh protects houses on barrier island as well as wave attenuation against erosion to uplands
    - Ecotourism
    - Is this being used in decision making?
- Jim Morris: Marshes built land; so as important as beach nourishment.

- Erik Hutchins-how much are we just buying a little time w. our restoration actions but overall are we just kidding ourselves that we are making the coast more resilient from an infrastructure perspective?
    - Most ongoing projects aren't putting much of a dent in increasing resilience – scale issue
- *Need for cultural shift/education for truly understanding upcoming changes (i.e., SLR) → use best available info to bracket risk
- How to utilize models to address next steps – intermediate info/results as placeholders while refining higher resolution datasets
- *"So what" :
    - What do you need to spend to maintain a house in these coastal areas?
    - How to quantify?

- "What if" scenarios
  - E.g., What would models show in the absence of protected features (e.g., barrier, marsh)
  - What happens to risk? Should $$ be spent elsewhere?
  - Compare to "build out scenarios" that MAPC/EEA did recently to show what would happen in the absence of zoning
- Capital expenditures at a town meeting – what resonates at local level for that "so what" question
  - Quality of life – recreational opportunities; dining/commercial waterfront
  - Shellfish
  - Flood protection – roads, houses, infrastructure; conversion of marsh to open water allows for storms to have further reach upstream
- Perspective of capacity to address risk vs. vulnerability
- How can we expand the short-term lens of communities, how do we integrate these longer-term natural resource resilience or restoration efforts?
  - Rating scale
  - Prioritize, including natural infrastructure (e.g., dunes)
- *Must be a system approach – recognize the inter-connected relationships in the natural system; can't "fix" or restore one component in isolation
- Need to bring marsh process into design considerations for restoration and mitigation projects.
- Need to get longer, wider perspective into immediate decision making process (e.g. culvert replacement).
- Kirk—models can be used to prioritize actions.
- Take advantage of towns planning schedule… Community Development Plans – bringing in SLR to plan updates
  - Ipswich is currently updating their 2003 plan which currently doesn't include SLR
- What do we have to work with now?
- CZM coastal resiliency grant (Julia Knisel): for vulnerability assessments, education, design, all working with communities.
- Where are we with getting maps out to towns? (Relates to a larger discussion on translating results from models and research studies to applicable "tools" for local officials.)

Scott Hagen cautioned us on taking this information and thinking we have the answers. These are all predictive models; can we truly know what the weather is going to do? No. It's great information and useful tools, but he urged to use it cautiously when generating data to make decisions.

<u>Highlights and Major Discussion Points from Workshop:</u>

RESILIENCY SCIENCE

- Great Marsh will persist in next 100 years, but it will be dominated by low marsh. Beyond 100-200 years, the system will change dramatically with catastrophic changes to both marsh and barrier.
- We need to plan for both long and short-term changes:
  - In the long term, Great Marsh is a low sediment system, and increasing tidal prism will lead to rapid change in (loss of) salt marsh and barrier system.
  - In the short term, we will see increased inundation from daily and monthly flooding tides. We're seeing an increase in low marsh and decrease in high marsh.

- Thin layer deposition: only apply where we know high marsh has already turned into low marsh
    - Elevation is critical
    - Drainage, sediment composition
    - Proactive vs. reactive – timing is important parameter to consider
- Experiment with TLD in low marsh turning to mudflats to slow down conversion to open water? More open water = more fetch/tidal prism, which can rapidly destabilize both marsh and barrier system.
- Inundation is a function of Flooding (SLR, wind) and Drainage (waves, barriers).
    - Look at legacy land practices such as roads, culvert, ditches, plugs to see how they affect inundation. Can we address any of these?
    - Refuge and UNH is experimenting with some techniques to enhance drainage (plug removal, runnels, ditch remediation, etc.)
- Should we investigate innovative methods to accrete marsh fasters? Need further exploration due to negative impacts.
    - Hybrid *Spartina* in SFO accretes marsh faster than other *Spartina* species.
    - *Phragmites* accretes sediments faster than native salt marsh species.
- Given Sergio's findings, what is the impact of boat wakes on creek bank erosion?
- Shellfishing probably causes creek bottom erosion; but that may be helpful to marsh by suspending sediment.
- Conservation community needs to make sure restoration strategies do not harm resiliency.
- A lot of detailed modeling/research data for Great Marsh coming in the next two years.

COMMUNICATIONS

- In order to garner community support for the system-based mitigation strategy, we need to answer the "SO WHAT" question.
    - For city/town, this is needed to support capital investment, as it's easier to sell infrastructure protection than funding to protect the marsh itself.
    - Newburyport is seeing the possible benefits of marsh to protect against storm damage.
    - A few "So What"
        - Healthy salt marsh and barrier island protects quality of life for local communities.
        - Healthy salt marsh stabilizes barrier island to prevent west-ward migration
        - Salt marsh peat absorbs storm impacts
        - Healthy marsh builds elevation (land).

- Messages to communicate:
    - Salt marsh system still resilient
    - Barrier Island is wide compared to others; still have some time.
    - Great Marsh is shifting from a relatively static environment (last 4,000 years) to a dynamic environment (within 100 years). What works in the pass will not work for future. Need to clearly communicate what changes are coming.
    - Salt Marsh protect inland protections from storm damage; but also keeps the barrier island from migrating westwards (protect beach front properties).
- Next steps:
    - Produce flood risk models with and without the barrier island/salt marsh to show the protective importance of natural system. {data for WHG model for Essex coming within next 2 years}

- Need to do face-to-face conversation/ science delivery to the towns.
- Present science in terms of risk brackets. Community needs to feel like they can address risk.
- Goal: bring resiliency into all design considerations. With every project, ask "What can marsh do for us?" How do we broaden lens of decision to bring in details of science and models.

- Challenges for Towns working on long term solutions for resiliency.
  - Different neighborhoods don't see entire system of salt marsh and barrier island… only what's most important to their neighborhood.
  - Town departments are silo'ed.
  - Major time constraints on staff.