Special Symposium at NEERS highlights triumphs and new challenges in restoring and maintaining salt marshes in the northeast.

Over the past 40 years, many salt marsh restoration projects in the Northeast have attempted to reverse centuries of filling, diking, draining and other mismanagement. The New England Estuarine Research Society (NEERS) held a symposium on salt marsh restoration at their spring 2014 meeting in Salem, Massachusetts. The objective was to review progress in the hydrological restoration of salt marshes in New England and Atlantic Canada, and describe what we have learned about marsh management and marsh ecology from these restoration efforts. The symposium also highlighted what we still need to know to better restore and manage marshes, and examined how future restoration efforts will interact with new threats, notably climate change. The symposium, organized by Robert Buchsbaum and Rob Vincent, was inspired by the recent publication, *Tidal Marsh Restoration: a Synthesis of Science and Management (Island Press 2012),* edited by Charles Roman and David Burdick. Speakers included scientists and managers who have worked in marshes throughout the northeast.

The history of marsh restoration in the northeast began in Connecticut. Scott Warren described over 60 years of changes in two Connecticut salt marshes that had originally been diked to create impoundments for waterfowl and for flood control, but were then restored. One of the marshes, Barn Island Marsh, had been the site of classic salt marsh vegetation research by Miller and Eggler in the 1940's and 1950s, and restoration efforts took advantage of a long term data set of vegetation change pre and post restoration. Warren noted that somewhere around 40 years ago, coastal managers began to realize that the best use of a salt marsh is to maintain a functioning natural salt marsh rather than altering the marsh for other purposes. He acknowledged the leadership of William Niering, his former colleague at Connecticut College, who fought for, and finally helped convince managers to restore tidal flooding to the Barn Island impoundments. This hydrological restoration drove the ecological restoration of these systems.

Warren noted how enhancing tidal flow in Connecticut marshes resulted in the decline of invasive *Phragmites australis* (common reed), the expansion of the native salt marsh plants, and the return of typical salt marsh invertebrates, fish, and birds. Where salinities are sufficiently, hydrologic restoration is highly effective in checking the spread of *P. australis* and returning the full suite of salt marsh ecosystem functions and values. Although this has been a general pattern in many northeast marshes, Steve Smith of the Cape Cod National Seashore noted that the actual aerial extents of salt marsh hay (*Spartina patens*) and *P. australis* at Cape Cod restoration sites have not changed much, but their locations throughout the marshes have changed in response to altered hydrologic regimes. Smith noted that the increased tidal flushing extended the amount of salt and brackish (*Phragmites*-dominated) marshes further inland.

The vegetation response of Connecticut, Cape Cod and other marshes depends on how favorable edaphic conditions shift within a marsh in response to hydrologic changes. Gregg Moore of UNH showed how fine scaled salinity mapping of Plum Island Sound salt marshes led to an understanding of why *P. australis* patches show up where they do and what areas are likely to be susceptible to this invasive in the future (i.e., microhabitats of lower salinity). Sue Adamowicz of the US

Fish and Wildlife Service (FWS) observed that ditch plugging, a technique often touted as a restoration method, actually creates sulfide levels that are lethal even to the native *Spartina* spp. As an alternative, FWS has been experimenting with remediating past marsh ditching by putting bales of salt marsh hay (*S. patens*) into ditches to allow sediments to slowly accumulate in the ditches over time, facilitating vegetation growth and marsh peat development.

In addition to hydrology and ground water chemistry, other factors that may influence vegetation recovery in restored marshes were also addressed. Smith discussed the revegetation of bare areas that typically result when fresh water or oligohaline marshes are inundated with sea water. Plants like *Salicornia depressa* that have buoyant seeds are usually the first to colonize such bare areas; however, bioturbation by fiddler crabs or large deposits of wrack may inhibit seed germination of this pioneering species. Based on almost 70 years of vegetation data collected at Connecticut restoration sites, Warren advised against setting specific vegetation patterns as restoration targets, noting the dynamic nature of salt marshes result in constantly changing vegetation communities. Instead, the goal of restoration should be to re-establish the hydrological conditions that allow native salt marsh plants to thrive. With hydrology and plants, other ecosystem functions follow.

One question managers and scientists often ask is how long it takes formerly degraded marsh to reach functional and structural equivalency relative to unaltered reference marshes. Gail Chmura of McGill University, and current President of the Atlantic Canada Coastal and Estuarine Science Society (ACCESS), framed her talk within the context of ecosystem services performed by recovered or restored marshes, such as habitat characteristics, carbon storage, recreational opportunities, food production, and protection from storms. She noted that it can be difficult to find suitable reference sites since so many marshes have been altered. In her studies of Bay of Fundy salt marshes, many of which have been diked for agriculture for hundreds of years, it took about 50 years for vegetation, invertebrate diversity and drainage channel density to become equivalent to that of reference sites when the dikes were breached. Warren noted that marsh vegetation may return relatively quickly (5-10 years) but higher trophic levels may take more than two decades to reach functional equivalency. As an example, he cited Paul Fell's work showing that fish will return almost immediately in large numbers to a hydrologically restored marsh after a new culvert is installed (i.e., if you build it they will come); however, the guts of mummichogs leaving a restored impoundment at Barn Island Marsh were less full than those from a reference marsh even after two decades of restoration, suggesting a delayed response in post-restoration resource availability and trophic function.

Burdick noted several dark clouds on the horizon for marsh restoration including sea level rise, nutrient pollution, and invasive species such as *P. australis* and green crabs. He described the essential ingredients for maintaining a salt marsh under the threat of sea level rise: adequate tidal flooding, a sediment source, and a zone for upland retreat. Expanding on the topic of sea level rise and salt marshes, Jim Morris presented his Marsh Elevation Model. The model is used to predict how tidal range, sediment supply, and marsh elevation affect vegetation growth and sediment trapping, and ultimately whether marsh accretion at a particular site will keep pace with sea level rise. He noted that marshes with a small to moderate tidal range (e.g., southern New England marshes) have a tipping point where they would start to degrade at a lower rate of sea level rise compared to those that are macro tidal. Those macrotidal marshes along the Gulf of Maine and the Bay of Fundy are located higher in the intertidal zone, which buffers them to some extent from the more immediate consequences of sea level rise. His studies at Plum Island Sound in Massachusetts showed that the increased erosion of marsh peat along the edges of tidal creeks due to sea level rise actually supplies sediment to the marsh platform and thereby helps the marsh platform keep up with sea level rise, a process he calls marsh cannibalization.

A microtidal area where marshes are already showing effects of sea level rise is Narragansett Bay. Marci Cole Ekberg of Save the Bay and Kenny Raposa of the Narragansett Bay National Estuarine Research Reserve monitored Narragansett marshes using vegetation transects, sediment erosion tables, elevation surveys, water level monitoring, and habitat surveys. They noted increased areas of ponded water on the marsh surface, many eroded creeks, and the rapid dieback of *Spartina patens*, the high marsh dominant at their sites. *S. patens* has been largely replaced by the low marsh dominant, *Spartina alterniflora*. In one of their study sites, a dramatic decline of *S. patens* occurred over a three year period and, at the current rate of loss, this species was predicted to be completely gone by 2018. Smith also reported large losses of *S. patens* associated with sea level rise at the Cape Cod marshes he has been studying. The Narragansett Bay researchers have been experimenting with runneling and creek excavation to drain waterlogged areas, thin layer soil deposition to raise marsh elevations, and facilitating upland marsh migration as techniques to address sea level rise impacts. Ominously, Raposa mentioned that they have not observed any natural evidence of marshes moving upland into surrounding uplands.

As in the Roman and Burdick publication, the symposium also included agency perspectives on marsh restoration in the Northeast. Federal and state agencies and non-profit organizations have been major supporters and facilitators of marsh restoration projects. However, they now have to grapple with how to address the effects of climate change on marshes and marsh restoration. Hunt Durey of the Massachusetts Division of Ecological Restoration emphasized the need for a more integrated structural framework involving strong collaborations among researchers, managers, and regulators, to guide future restoration directions. Durey and Jon Kachmar of The Nature Conservancy emphasized the need for vulnerability assessments of existing coastal wetlands and resiliency planning, which would include marsh migration potential. Jim Turek of the NOAA Restoration Center described many successful projects in which NOAA has been involved but noted that at least one of them in Connecticut is now under water due to sea level rise.

Panelists in the discussion that followed the formal presentations noted that even if humans were to stop all carbon emissions today, sea level rise impacts on marshes will continue for many decades to come. The message was clear that we need to prepare for these long term impacts while promoting awareness for the effects of carbon emissions on coastal wetlands. A collaborative effort including research, education, outreach, and engagement with public and political forums is necessary to effectively influence the processes that drive climate-induced impacts to costal habitats in the region. Panelists also pointed out the growing importance of landward marsh migration relative to increasing rates of sea level rise, and the immediate need to protect surrounding upland habitat and remove barriers to marsh landward migration. The vulnerability to sea level rise of high marsh fauna and flora was another area of research and conservation focus highlighted by panelists. Burdick noted that future restoration efforts should continue to remove tidal restrictions as a way to insure adequate flooding and as much sediment deposition as possible; however, coastal development, especially flooding potential for abutting land owners complicates the issue. Burdick predicted that the window to carry out successful hydrological restoration is short, no more than 15 years before the effects of sea level rise overwhelms current restoration efforts. In summary, the urgency is mounting to understand and implement measures to alleviate current and future effects of climate and sea level rise on salt marsh ecosystems.

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