November 2008

Focal Point

Woods Hole Sea Grant

Woods Hole Sea Grant Program • Cape Cod Cooperative Extension

County of Barnstable Massachusetts

Introduction to Tidal Flow Restoration

Over the last several centuries, much of the world's salt marsh habitats have been lost to filling, draining, and diking. New England has lost an estimated one third of its salt marshes since 1777 (Bromberg and Bertness, 2005), with much of this loss concentrated in urban areas. For example, roughly 80 percent of Boston's salt marshes were filled as the city grew. Though filling coastal wetlands created more area for development, it also eliminated the many benefits and ecological services salt marsh habitats provide.

While many converted salt marshes would not be considered for restoration for practical purposes, there are a number of areas where restoration of tidal flow may be feasible and desirable. In fact, efforts to restore tidal flow to historically tidally restricted salt marsh estuaries and coastal wetlands have become increasingly common and have occurred, or are occurring, in coastal states throughout the United States.

Of course, removal of such barriers can be expensive, cause a major change in the appearance of the wetland, and alters the environment, raising public concern. In this document, we attempt to address some of the common questions and concerns about tidal flow restoration.

Tidal restriction has led to dramatic changes in the vegetation along the shores of Herring River, Wellfleet, MA (Photo Credit: Stephen Smith, NPS).

Why were coastal wetlands drained and diked?

Coastal wetlands were commonly drained and diked for a number of reasons through the 19th century, as salt hay (*Spartina patens*) farming fell out of favor with the westward migration of agriculture. Farmers began wide-scale conversion of salt marshes to arable land for freshwater crops by draining or ditching marshland or installing tidal gates. Interestingly, many New England salt marshes were diked to enhance salt hay production by limiting tide heights and increasing the high marsh area that salt hay prefers.

The immigration boom in the late 19th and early 20th centuries also increased demand for buildable land in urban areas of the Northeast. A glance at historic maps of Boston or New York reveals that what is now considered prime real estate was historically wetland.

Additionally, in 1897 it was discovered that mosquitoes could carry human disease, which prompted efforts to eliminate floodwater mosquito-breeding habitat by diking salt marshes and/or draining ditches. Large expanses of salt marshes were ditched particularly during the Depression as Civilian Conservation Corps sponsored projects.

Many wetlands were also diked as a consequence of railroad and road construction across coastal wetlands or filled with dredge spoils.

What are the effects of tidal flow restrictions?

Reduction in the flow of seawater has also had a wide range of unintended consequences.

In many cases, freshwater wetland replaces what had previously been a brackish or estuarine ecosystem. Importantly, these ecosystems support a variety of plants and animals often valued by the local community.

Often, however, these ecosystems are dominated by invasive and exotic species of common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), narrow-leafed cattail (*Typha angustifolia*), as well as weedy native plants. These plants are often excluded from salt marshes by the high salinity and waterlogged soil. In particular, *Phragmites* often grow in dense stands that exclude other plant spe-

Many communities have opted to restore tidal flow by opening tide gates in dikes such as this one in the Herring River, Wellfleet, Massachusetts.

cies, inhibit water flow and fish access, and can increase the risk of wildfires.

Tidal restrictions reduce flow, which in turn leads to increased sedimentation in channels and decreased sediment transport on the wetland surface. Consequently, creeks and channels upstream of a tidal restriction often fill in with fine-grained sediment, while the coastal wetland sinks — a serious problem in the face of rising sea level.

Both surface waters and soils become acidified after a tidal restriction. This is because the naturally occurring sulfur in the peat, when exposed to oxygen, becomes sulfuric acid. This acid can leach toxic metals (e.g. aluminum) from otherwise harmless native soils, leach into surface waters and poison aquatic animals.

Tidal restrictions reduce tidal flushing, often leading to low oxygen events upstream. The slow moving water heats up, and bacteria that consume the abundant organic matter deplete the water's dissolved oxygen. Resulting oxygen depletions kill fish and other aquatic animals.

The environmental effects listed above cause fish kills and decrease the diversity and abundance of many aquatic animals. Significantly, these also pose a hurdle to fish migrations as certain species (e.g., river herring) swim back upstream to freshwater to spawn, and their young must also return downstream to the sea.

The drainage of salt marsh peat by diking and ditching causes the wetland to shrink like a drying sponge, due to pore-space collapse and increased decomposition. Consequently, the wetland sinks and it, together with adjacent upland, becomes more vulnerable to storm surges and rising sea level.

Ironically, tidal restrictions can increase the mosquito nuisance problem. The diminished drainage and tidal exchange can lead to stagnant, isolated pools of water up in the marsh. Poor water quality and limited tidal range make it difficult for predatory fish to reach mosquito breeding pools on the wetland surface, and the mosquito populations are often very large.

What is tidal restoration, and why is it done?

Tidal restoration is the practice of removing human-made barriers and fill from coastal wetlands to return tidal flow to the area. Though a transitional period of disturbance is expected, with the mortality of salt-sensitive plants that have invaded the original salt marsh, tidal restoration over the long-term (years to decades) reversed the environmental damage of tidal restriction and restored the ecosystem services expected of a coastal salt marsh.

The objectives for tidal flow restoration are to displace *Phragmites* and other invasive plants, eliminate soil and water acidity, increase water-column flushing and oxygenation, increase sedimentation to counter sea-level rise, facilitate natural mosquito control, and, most basically, restore originally productive and ecologically diverse coastal wetlands, including native finfish and shellfish populations.

Restoration of tidal flow kills off *Phragmites* in East Harbor, Truro, Massachusetts.

What are the effects of tidal flow restoration?

Restoration should allow a habitat to once again act as a productive salt marsh. Some effects can be observed in relatively short time frames (a year or two), while other effects may take more than a decade to realize.

Increased flushing associated with greater tidal exchange often leads to improved water quality. Additionally, this can also dilute fecal coliform bacteria, which otherwise accumulate to degrade shellfish water quality.

Increases in salinity may challenge salt-sensitive vegetation, including woody vegetation, over time. To address local concern about this, tides and salinity may be restored incrementally, e.g. over years, allowing a gradual transition to re-established salt marsh cover.

Tidal flow restoration is often advocated as a means of increasing fish and shellfish habitat. Salt marshes and coastal wetlands are particularly important nursery grounds for many fish species. The improvements in the habitat of commercially important and/or recreationally fished species may, therefore, increase these valuable resources for the local community. Opening and widening culverts also improves the habitat for marine fish.

Restoration of tidal flow can lead to relatively quick recolonization by estuarine and marine species, such as these various bivalve species, found in East Harbor (Truro, Massachusetts) within 24 months of increased tidal flow.

Expansion of salt marsh vegetation (green area on either side of the tidal creek) after restoration of tidal flow at Hatches Harbor, Provincetown, MA. (Photo Credit: Stephen Smith, NPS).

Restrictions like this culvert dramatically reduce tidal flow upstream.

Furthermore, restored tides should flush stagnant pools of water, which are prime mosquito breeding sites. Predatory fish should also have greater access to the marsh surface, preying on mosquito larvae and other nuisance insects. Tidal flow may increase the number of tide pools in the salt marsh.

Changes in sediment transport and deposition can be expected. In undisturbed Cape Cod salt marshes, most sediment is carried upstream by flood tides, to be deposited on our coastal marshes and helping to keep them above the rising sea. Tidal restoration should re-establish this relationship, but some downstream flow of sediment is expected near the original tidal restriction and especially after large rain events. Therefore, restoration managers often advocate incremental openings of tidal restriction to prevent large-scale and sudden sediment transport.

Salt marshes stand between the sea and developed uplands, and thereby buffer the effects of storm surges. This function depends on the regular accumulation of sediment, a process that can only occur with unrestricted tidal exchange.

While there is concern that restoration of a salt marsh might lead to intrusion of salt water into groundwater and shoreline wells, tidal restoration should, counter intuitively, thicken the freshwater lens adjacent to diked flood plains. This is because diking and drainage lower the wetland's average surface water level, reducing resistance to groundwater discharge, and consequently decreasing the thickness of the fresh groundwater aquifer. In contrast, tidal restoration increases the wetland's average water level. This increases resistance to groundwater discharge and thickens the fresh groundwater aquifer. The one notable exception would be wells installed in the flood plain proper, subject to direct flooding by high-salinity surface water.

The rapid restoration of the wetland's salinity will have profound chemical effects. Although most will benefit water quality, there may be a short-term increase in ammonium-nitrogen, a nutrient that could stimulate algae blooms. For this and other reasons mentioned previously, a slow, incremental and carefully monitored program of tidal restoration is often recommended for large and complicated salt marsh systems.

Conclusion

Salt marshes face a diversity of challenges, beyond tidal restrictions and filling. Increased nutrient run-off, 'hardening' of edges with rip rap and seawalls, more and more neighboring impervious surfaces (and increased run off and pollutants), invasive species, and climate change will have dramatic effects on salt marsh habitats. Despite these challenges, restoration of salt marshes by removal of fill or tidal restrictions can dramatically improve salt marsh habitat. The decision to proceed with restoration should be done with awareness of the costs, risks and, of course, benefits.

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This document, a collaboration of the Woods Hole Sea Grant Program and Barnstable County's Cape Cod Cooperative Extension, should be cited as follows: Introduction to Tidal Flow Restoration, by W. Walton, J. Portnoy & D. Murphy.

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