Survey of Potential Marsh Dieback Sites in Coastal Massachusetts

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Summary

During the summer of 2006, staff from the Massachusetts Bays National Estuary Program (MBNEP) and the Massachusetts Office of Coastal Zone Management (CZM) surveyed 25 sites in coastal Massachusetts where previous anecdotal reports had indicated the occurrence of marsh dieback. A survey form was developed to qualitatively assess conditions. Most sites were on Cape Cod, with a small scattering of sites on the South Shore and one north of Boston. Sites in Wellfleet Bay exhibited signs of recently dead and dying plants with no immediately evident source of stressors. A number of sites exhibited unvegetated areas where salt marsh vegetation may have occurred in past years, but in 2006, existing vegetation appeared healthy and no recently dead or dying vegetation was observed. Some sites appeared to exhibit minor effects from identifiable stressors from a combination of anthropogenic sources and physical conditions. This report includes 14 recommendations for future efforts for continued investigations and observations.

Introduction

Marsh dieback is a condition that has been described as the loss or death of emergent vegetation in salt marsh systems. Dieback, also called brown marsh in other states, has been noted and studied in Louisiana and Georgia since 2000 and 2001, respectively (McKee et al. 2004 and Ogden and Alber 2006). Marsh dieback was first described in the Northeast in Connecticut in 1999 (Rozsa unpublished data 1), where it was called "sudden" marsh dieback to denote that the disappearance had occurred within one year. Starting in 2002, reports of dieback locations in the Northeast increased in number to include sites in all of the coastal states in New England, plus Long Island in New York.

While scientific investigations in Louisiana and Georgia are ongoing—with no consensus among the investigating scientists—evidence suggests that the causes of dieback in those locations may be linked to physical, chemical, and biological stressors contributing to increased plant susceptibility to pathogens. These stressors include drought, pH changes in the soil, soil heavy metal mobilization, and pathogens on the marsh vegetation. *Fusarium* fungus, in particular, has been linked to plant death in Louisiana following drought, although *Fusarium* has been not been completely accepted as the ultimate cause of plant death (Rozsa unpublished data 2). *Fusarium* is widely distributed in marine systems, including apparently healthy ones that exhibit no sign of impairment.

In the Northeast, increased concern over the reports of salt marsh dieback led the US Fish and Wildlife Service (USFWS) to organize a workshop in 2005 to examine the subject in New England. Topics discussed included potential causes of dieback conditions and possible directions for future research. An outcome of the workshop was a list-serve and web site maintained by the New England Estuarine Research Society (NEERS); content includes a basic map of sites where marsh dieback has been reported. A follow up workshop was held in May 2006 to continue discussions on causes, but few new data were presented (meeting summaries at http://wetland.neers.org/reports.html).

MBNEP and CZM conducted a dieback survey during the summer of 2006 in response to a lack of systematic information on the reported sites in Massachusetts. We attempted to visit and qualitatively evaluate all of the sites identified on the NEERS map, as well as additional sites that had anecdotal reports of dieback occurrence. MBNEP and CZM used a survey form that was developed in cooperation with staff at the USFWS, the Cape Cod National Seashore, the Connecticut Department of Environmental Protection, and the Massachusetts Wetlands Restoration Program.

Methods

A survey form (Appendix A) was developed in cooperation with Dr. Susan Adamowicz at the USFWS Rachel Carson Reserve in Maine, Dr. Stephen Smith at the Cape Cod National Seashore, Ron Rozsa at the Connecticut Department of Environmental Protection, and Tim Smith at the Massachusetts Wetlands Restoration Program. The purpose of the survey was to systematically evaluate wetland sites for any signs of marsh dieback in its various forms largely through the use of qualitative observations close to key access points. Attempts were made to identify any potential natural and anthropogenic stressors and photographs were taken to document conditions. In several cases, short hikes into the marsh systems were made for closer investigations. Attempts were made to view complete marsh systems with the use of binoculars, but some of the larger marshes were not easily visible, especially the high marsh portions.

MBNEP and CZM planned to use the survey to identify the distribution of any dieback occurring in 2006, identify which plant species are affected, and to provide a record of baseline condition for future assessments based on 2006 conditions.

The survey contains a series of questions that target: whether diseased vegetation was observed; which species were affected; where in the marsh the effects were seen; whether there were signs of herbivory; what signs of plant disease were observed; whether peat disintegration and erosion were observed; and whether there were signs of winter ice damage, wrack, or marsh subsidence. To assess potential anthropogenic stressors, the survey identified potential pollution sources such as storm water, septic systems, debris or chemical spills, as well as possible physical effects from boat activity, pedestrian trampling, and restrictions of tidal flow from causes such as fill, undersized or damaged culverts, or marsh compaction. Representative photos were taken to document observed conditions.

Over the course of five field days between late July and mid-September 2006, 25 sites were evaluated using the survey form. Evaluations were timed to coincide with low tide conditions, to the maximum extent possible, and to optimize observations of the marsh vegetation, the creek banks, and tidal flats. Evaluations were also conducted at the time of year with the maximum vegetation growth in the salt marshes. The sites were chosen to include all of the sites identified on the NEERS web site, as well as additional sites identified by other agency staff as potentially having marsh dieback conditions, based partially on signatures of marsh condition noted from MassGIS (Massachusetts Office of Geographic and Environmental Information) aerial photography. Additional sites that were encountered while investigating the primary sites were also briefly viewed for potential dieback conditions, primarily on Cape Cod, but no survey form was completed because there was no indication of any disturbance that appeared to resemble dieback. A few additional sites were examined in the office using only aerial photography (MassGIS http://mass.gov/mgis/colororthos2005.htm and Pictometry http://local.live.com/), but observed conditions were determined to likely be the result of apparent tidal restrictions, so no visit was made to the sites and no survey forms were completed.

Most of the sites investigated were on Cape Cod, primarily on the Nantucket Sound side, while there were a few sites on the South Shore in Hull, Marshfield, and Plymouth, and one north of Boston in Newbury (Figure 1). The time required to conduct the survey varied with the size of the system and required from 15 minutes to three hours per site.

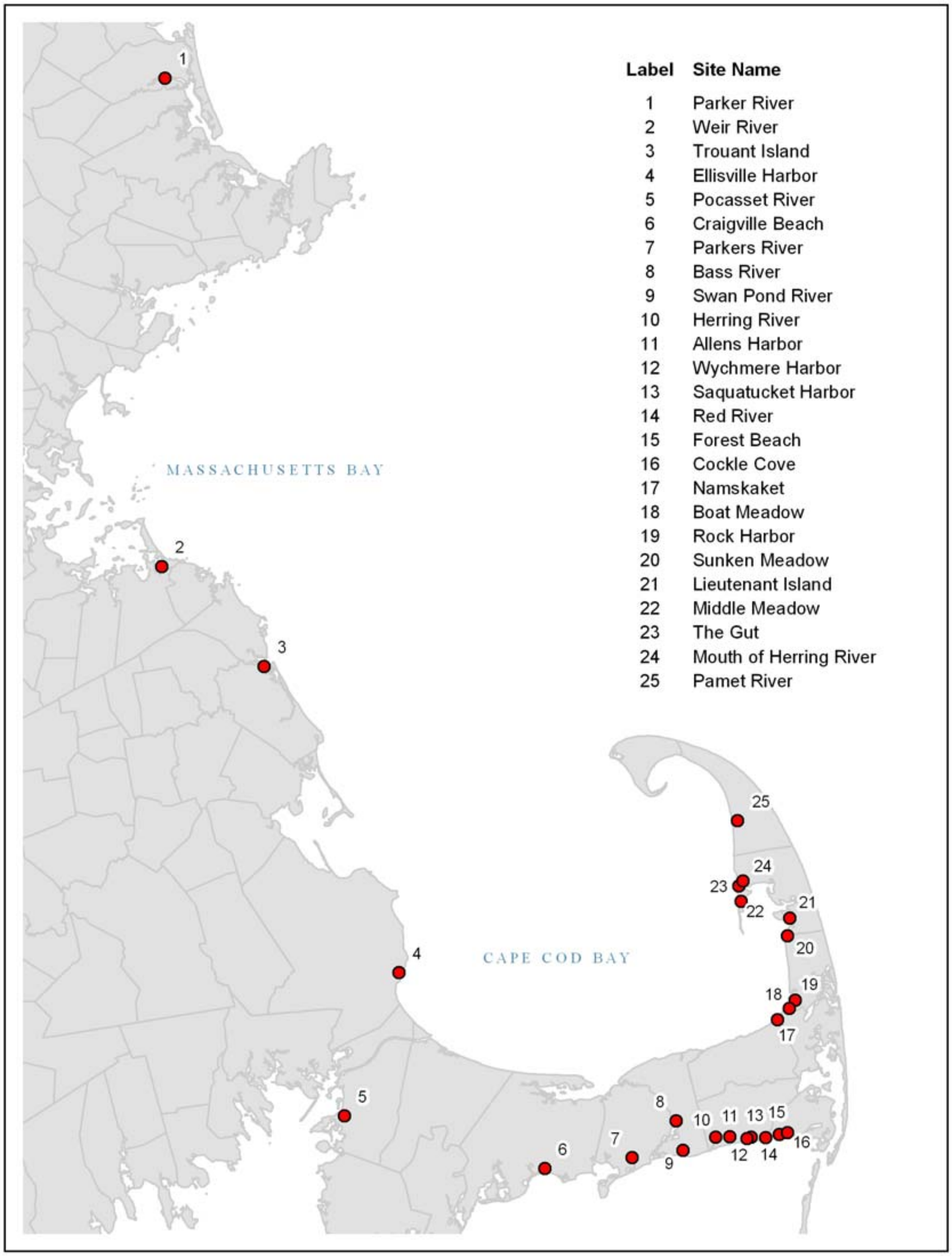

Figure 1. Distribution of marsh dieback sites surveyed in summer 2006.

Results

The table in Appendix B summarizes the survey results.

The Wellfleet sites exhibited the only widespread dying vegetation, particularly at the Great Island sites on the west side of Wellfleet Harbor, originally identified by the Cape Cod National Seashore (S. Smith, draft report). There appeared to be bare patches and dead stubble from previous year's growth intermingled with patches of apparently healthy plants at all of the Wellfleet sites (Figures 2 – 4). The Great Island sites appear nearly completely isolated from anthropogenic stressors and most likely show effects from several types of natural events (e.g., sea level rise, ice rafting, wrack deposition), while the Lieutenant Island site appears also subject to potential anthropogenic stressors (e.g., nutrient loadings from septic systems). A section of the marsh at Lieutenant Island appears to have subsided for unknown causes (Figure 5), and in a few locations peat appeared to have been pockmarked with past ribbed mussel colonies, now occupied by fiddler crabs (Figures 6).

Figure 2. *Spartina alterniflora* at Middle Meadow. GREAT ISLAND, WELLFLEET

Figure 3. A patch of *Spartina alterniflora* stubble at Middle Meadow. GREAT ISLAND, WELLFLEET

Figure 4. A narrow, unvegetated patch separates *Spartina patens* and tall form *Spartina alterniflora* near the mouth of the Herring River. This narrow band stretches for approximately 0.25 miles. THE GUT, WELLFLEET

Figure 5. Large area of apparent subsidence with dead and dying *Spartina patens* in foreground. LIEUTENANT ISLAND, WELLFLEET

Figure 6. *Spartina alterniflora* stubble and pockmarked peat along creek bank. LIEUTENANT ISLAND, WELLFLEET

Three other sites on Cape Cod Bay exhibited what appeared to be natural erosion processes with sediment transport, which included some bank slumping at the creek edge (Namskaket in Orleans, Rock Harbor in Orleans, and the Pamet River in Truro). Extensive coastal erosion at the Namskaket site was causing the burial of the salt marsh and appeared to be due to a disintegrating dune restoration project (Figure 7). The observed erosion at Rock Harbor and Pamet River, originally identified as potential dieback sites based on aerial maps rather than observed conditions, seemed quite possibly due to a combination of natural erosion processes and possibly in response to extensive recreational boat use, since both sites housed large marinas and boat launching ramps. Sunken Meadow in Eastham exhibited the potential for wrack deposits and winter ice accumulation due to poor tidal flushing based on natural coastal sedimentation across the creek mouth. This site was also surrounded by extensive low-density development with septic systems, where nutrients could be contributing to eutrophication. Dieback at the Boat Meadow site at Bridge Street in Eastham was complicated by a bridge and culvert replacement project completed in 1999. The project crosses the marsh, and as a result, construction activities appear to have affected tidal flow to several localized spots (i.e., compression of the marsh surface and new fill in the marsh adjacent to the new road). As shown in Figure 8, the construction impacts appear to have resulted in dying vegetation due to waterlogging in several small locations adjacent to the road. While the overall tidal flow is now improved at this site, the localized construction impacts, as well as the potential for wrack deposits and winter ice-shear impacts, remain. Creek bank erosion and some dead vegetation from previous years were noted.

Figure 7. Coastal erosion causing the burial of a salt marsh at a dune restoration site. NAMSKAKET, ORLEANS

Figure 8. Bridge and culvert replacement project resulting in marsh ponding and dying vegetation. BOAT MEADOW, EASTHAM

Eleven sites on the Nantucket Sound side of Cape Cod were surveyed, since this was the area with many reports of marsh dieback from earlier years. None of these sites exhibited extensive dead or dying vegetation in 2006. A number of bare patches on creek bank edges and marsh surfaces were observed at several sites where salt marsh vegetation would have been expected to be present. *Spartina alterniflora* populations adjacent to these bare patches appeared healthy and tall, as shown in Figure 9. Evidence of peat erosion, disintegration, and pockmarking was observed at a number of sites, particularly at creek edges (8 out of 11 sites). Many of these sites also had abundant ribbed mussels (*Geukensia demissa*) on creek banks (7 of 11 sites). Numerous ribbed mussel shells and creek bank pockmarking suggest extensive mussel mortality. Fiddler crabs (*Uca pugnax*) (7 of 11 sites) (Figure 10) and snails were also numerous at several locations. Geese were present at several sites, but only one individual was observed actively digging and eating *Spartina alterniflora* from a bank while swimming in a creek. A minor amount of waterlogging on the marsh surface was observed at several locations, but the effects on vegetation were unclear. Some wrack deposits and macroalgae occurred at nearly all of these sites. The possible effects of winter ice movement to contribute to bare patches should be considered. The potential for erosion and winter ice-shear damage to contribute to the observed bare patches seemed possible at all of the sites due to exposure to ice movement from wind and wave action. Extensive recreational boat activity was observed at most of these sites (8 of 11). Possible pollution sources, including storm water and adjacent septic systems, were present at all sites. While none of the sites exhibited significant tidal restriction, existing bridges and creek crossings appear to have some minor impact on tidal flow in most locations.

Figure 9. Unvegetated creek bank with adjacent, apparently healthy *Spartina alterniflora*. SAQUATUCKET HARBOR, HARWICH

Figure 10. Ribbed mussels in low marsh and creek bank. SWAN POND RIVER, DENNIS

One site in Bourne on Buzzards Bay exhibited localized effects to vegetation that may be linked to an existing tidal restriction, collapsed mosquito ditches, and associated waterlogging in the salt marsh.

Three sites on the South Shore were evaluated. Ellisville Harbor in Plymouth has been subject to periodic openings and closings of the tidal inlet due to natural coastal sediment transport and human intervention, which has caused the marsh system to oscillate between being a freshwater and a saltwater system. The most recent change occurred in 2003 when the barrier spit was dredged to restore tidal flow (Ramsey et al., in press). Extensive unvegetated flats and apparently healthy salt marsh were observed (Figure 11).

Figure 11. Salt marsh at Ellisville Harbor State Park. PLYMOUTH

Trouant Island in Marshfield was identified as a potential site based on a signature observed in an aerial photograph. We observed a large number of potholes on the marsh surface, possibly due to the extreme exposure to wind and waves. A site visit showed no evidence of any effect on the marsh vegetation. The Hull site exhibited unvegetated creek banks, but unlike those on Nantucket Sound, no pockmarking was observed. Extensive wrack deposits were also noted.

Figure 12. Salt marsh at Route 1A crossing on the Parker River. NEWBURY

On the North Shore, the only site with reported dieback was at the Route 1A crossing at the Parker River in Newbury adjacent to a marina. In 2006, there was no sign of any dead vegetation and the *Spartina alterniflora* appeared tall and healthy. The original photograph of this site showing possible dieback was taken in 2002, about a year after a very large fire at the marina burned many large boats in storage on the marsh edge (Pelczarski, personal comm.). A significant volume of chemicals also burned in this fire. Marsh vegetation at the site appeared healthy in 2006 (Figure 12).

Discussion

MBNEP and CZM observations suggest that the marshes surveyed in the summer 2006, except for the ones in Wellfleet, exhibited generally healthy salt marsh vegetation. Portions of the Wellfleet sites exhibited dying vegetation in both the low and high marsh. In addition, several unvegetated areas were observed at a number of sites, where salt marsh vegetation would have been expected to occur. We observed possible evidence for sources of stress to marsh vegetation related to both natural physical changes in the systems (sea level rise, erosion, burial by wrack, and winter ice damage) and those resulting from human-related activities (nutrients from storm water and groundwater via septic systems, as well as direct physical effects from past alterations to tidal flow and current recreational boat activities). Our observations suggest no widespread damage to marsh vegetation due to pathogens in 2006, except for the dying vegetation found at the Wellfleet sites.

The Wellfleet sites at Great Island exhibited dying vegetation, including both *Spartina alterniflora* and *Spartina patens*. In addition, no explanation was evident for the bare patches on the tidal flat surface at both Great Island (the Gut) and Middle Meadow (Figure 4). It was interesting to note that *Suaeda maritima* adjacent to the bare patches appeared very healthy. The Herring River and Gut sites seemed to have little peat in the marsh system, suggesting that the salt marsh systems at these sites are fairly young. Some peat was observed along the creek edge in Middle Marsh, although much of the Middle Marsh system resembled the adjacent previous two sites with extensive, unvegetated sandy areas. There was evidence of dying marsh vegetation at these three sites, in most cases adjacent to apparently healthy marsh. Ribbed mussels seemed few while fiddler crabs were abundant. There appears to be no immediate explanation for the dying vegetation and unvegetated marsh at Great Island, but a case has been made that the cause may relate to changing sea and marsh elevations, in response to sea level rise (S Smith, draft report). Sources of anthropogenic stressors here appeared minimal. To determine the cause of plant death, the age of the marsh system and potential impacts from sea level rise, and the existence of possible plant pathogens should be explored.

The Lieutenant Island site appeared more complex. Most of the system seemed fairly healthy, but there were signs of stress to the marsh at several locations. Subsidence and plant death (primarily *Spartina patens*) appear to have occurred at one location recently. There was significant evidence for peat erosion and pockmarking at the creek bank, but a minor amount of recently dead vegetation. Vegetation alterations appear to have occurred within the recent past of unidentified stresses and little re-vegetation of these bare areas seems to have occurred in 2006. Living and dead ribbed mussels were observed along the creek bank and in the creek, along with abundant live fiddler crabs. The possibility of ribbed mussel death in creek banks due to cold winter temperatures should be considered. Pockmarks in the creek banks seem as if they could very possibly be a result of mussel death and now seem to be favored by fiddler crabs. Both of these species are near the northern limits of their range in salt marshes. There was suggestion of winter ice impacts, where large chunks (up to several cubic meters) of peat appeared to have been lifted, carried, and deposited on the marsh surface. The northwest exposure of the system suggests that winter ice and wave effects could be driven by the energy from northwest winds, common in winter. Some wrack was observed and the potential for considerable wrack deposits seemed possible with winter wind conditions. While adjacent development was low density, the houses are probably mostly summer residences and on septic systems. Consequently, the potential for nutrient loading to the system should be evaluated, which could contribute to significant observed macroalgae growth, as has been noted in Waquoit Bay in Falmouth (Lyons et al. 1995). In particular, high nutrient levels have also been linked to increased biomass in ribbed mussels (M. Chintala et al. 2005). Localized infections from plant pathogens also seem to be a possibility, perhaps in conjunction with other stressors, to explain dying marsh vegetation. With many potential stressors, the dynamics of this site are complex.

The sites exposed to Cape Cod Bay showed little or no evidence of dying vegetation. All of these sites have similar northwest exposures to that of Lieutenant Island, so consideration of physical factors seems appropriate. Bank erosion was observed, as described for the Pamet River, Rock Harbor, and Namskaket sites, but the conditions may be explained by normal exposure to tides and wind. Both Rock Harbor and Pamet River had extensive large recreational boat traffic, which may contribute to the erosion problem, despite wake control requirements. Namskaket exhibited extensive movement of coastal sediments that buried the salt marsh system in several locations, likely contributing to vegetation impairment. The source of much of this sediment appears to be a drifting dune created for restoration purposes. Sunken Meadow in Eastham was surrounded by a nearly complete ring of low-density development—mostly summer cottages on septic systems. Potential nutrient (and probably pathogen) loadings may be significant. The narrow entrance to Sunken Meadow suggests that it may periodically restrict tidal flushing. However, overall, the marsh showed few impacts, with a few wrack deposits, perhaps related to the constriction of the creek mouth. Boat Meadow at Bridge Street in Eastham underwent a major reconstruction of the bridge crossing from 1999-2001. There was extensive reconstruction of the road and a culvert replacement, which included adding fill to support the road bank. It appeared that heavy equipment may have compressed the marsh surface in several places, causing relatively recent ponding of water, which appeared to be contributing to salt marsh plant death. The curvature of the road also appears to trap large mats of wrack. Creek bank erosion was present, along with dead ribbed mussels and live fiddler crabs, consistent with the concerns raised for the Lieutenant Island site.

A common feature for nearly all of the sites facing Nantucket Sound was evidence of creek bank and peat erosion and often extensive pockmarks in the peat. Dead and living ribbed mussels were abundant, as were live fiddler crabs in the holes in the peat. Studies of ribbed mussel reproduction have found that their populations respond well to nutrient-laden systems, which could explain what appear to be extremely high mussel densities at many locations (Chintala et al. 2005). Massachusetts Department of Environmental Protection has focused its initial efforts to develop Total Maximum Daily Loads (TMDLs) for nutrients and institute nutrient management in communities facing Nantucket Sound due to the extensive development and high nutrient loadings in these systems, which is consistent with the observation of large ribbed mussel populations. However, cold winter temperatures have been found to limit mussel populations, especially those in creek banks on Long Island (Franz 2001). Consequently, a winter dieback of mussels might explain the observed pockmarks, as mussels die and leave holes in the peat structure. Research has also suggested that an inadequately investigated mutualism involving nitrogen between ribbed mussels and *Spartina alterniflora* exists and should be studied further (Bertness 1984). Many of these systems show possible effects from wave action and winter ice shear, especially near the mouths of small rivers. Effects from boat wakes seem possible for most of these small embayments and river systems. Observed macroalgae growth and deposits at several locations also suggests effects from nutrient loadings.

The one site in Buzzards Bay seemed to be primarily impacted by a human-induced tidal restriction, as well as minor hydrological impacts from collapsing ditches that were impairing tidal flow to small sections of the marsh. Ponding on the marsh surface due to the collapsing ditches seems to be a potential source of long-term marsh impacts in a localized area of this system.

The effects on the Ellisville Harbor site on the South Shore are likely linked to the periodic shift in salinity due to natural coastal sedimentation and periodic opening and closing of the mouth to tidal flow. The dramatic changes in salinity may have significantly altered marsh vegetation on a periodic basis. Otherwise, the impacts to this system appear low, and much of the adjacent upland buffer areas are in state and local protection. The Trouant Island site, while unusual in its appearance based on the aerial photographs, also appears quite healthy, other than effects that may occur because of wave and wind energy due to its direct northeast exposure. The river flow and coastal currents are quite dynamic at this location, and, in combination with northeaster storm events, the physical conditions could be subject to radical short-term changes. Observations at the Hull site suggest that effects from ice shear may occur, given its location at the end of relatively small tidal creek.

The Parker River site on the North Shore appeared healthy in 2006. Any possible effects from the fire in 2000 were not evident.

A number of the sites that we surveyed were identified from MassGIS aerial photography. Our site surveys suggest that this was not a useful tool for identifying dying marsh vegetation. In part, the available photographs were not taken at a time of year (April) when there would be extensive vegetative growth in the marshes, or at an identifiable tidal stage when the marsh and the flats would be exposed. Photography used by the Cape Cod National Seashore was more useful in showing a time series of changes in Wellfleet for the peak growing season.

Conclusion

Despite anecdotal reports of marsh dieback in Massachusetts, for the 25 sites investigated in this study, 21 showed no sign of dying vegetation in 2006. Fourteen of the 25 sites did exhibit bare (unvegetated) patches in areas where salt marsh vegetation would typically be predicted to occur. At the sites where recent plant death was noted, the species involved were *Spartina patens* and *Spartina alterniflora*. A variety of potential stressors were noted for each of the sites surveyed and further recommendations for future research have been identified.

Recommendations

Based on these observations and a partial review of the literature, MBNEP and CZM offer the following recommendations, not prioritized.

1. A common terminology should be developed to describe dieback conditions to ensure consistency in discussions among wetland scientists.

2. Additional surveys should be conducted in future years to track salt marsh condition over time for any potential dieback. These surveys should include dated photo-documentation. A time series of aerial photography during peak plant growth conditions would be informative. In addition, specific long-term plot surveys at suspected dieback sites and in transition zones adjacent to suspected dieback sites could be valuable in delineating year-to-year changes.

3. Careful assessments of impacts from hydromodifications, including tidal restrictions, tidal impoundments on marsh surfaces, compression of marsh surfaces, and collapsing ditches and other past marsh alterations should be conducted to track impacts and to develop corrections for past problems with human-induced physical alterations.

4. Impacts from wrack need to be carefully studied at selected locations where it is known or likely to accumulate, especially for impacts to high marsh, where wrack could sit for extended time periods after a flood tide.

5. Impacts from winter ice and erosion on physical conditions need attention. Winter temperatures are not consistently cold, since the winters of 2004 and 2005 featured exceptionally cold stretches, while the winter of 2006 was fairly mild. The episodic nature of these impacts requires careful investigation since it appears that these factors may be underestimated.

6. Impacts due to excessive nutrient loadings and from winter ice and low temperatures on ribbed mussel (*Geukensia demissa*) populations are important to investigate. Ribbed mussels, which are key components in creek and peat formations, respond to a high level of nutrient loading with population growth, but are also sensitive to low winter temperatures. High densities of mussels on Cape Cod, especially in south-facing tidal areas with high levels of development and associated high nutrient loading, may result in damage to salt marsh creek banks and contribute to subsequent peat erosion following cold winter temperature events (such as occurred in 2004 and 2005), when mussels experience high mortality and leave extensive gaps in the peat structure. The mutualism between ribbed mussels and *Spartina alterniflora* also deserves further research. Research has also suggested that high nutrient loadings to salt marsh systems can affect species competition among low, high, and fringing marsh plant species, so that research is also needed to further investigate the role that nutrients may contribute to structuring these communities and affecting plant survival.

7. Linkages to drought events and soil types should be examined, since it has been linked to a chain of events resulting in marsh dieback in Louisiana. Sulphate soils may be releasing heavy metals and stressing plants, making them more susceptible to pathogens. The age of the marsh system could play a role in susceptibility of plants to salt marsh community alterations.

8. The role of sea level rise, marsh elevation, and climate change should be considered, especially in relation to nutrient loadings. Some work has suggested that New England marshes are less susceptible to effects from sea level rise since much of the landscape is still rebounding from the last ice age (Morris 2006), but localized impacts still merit additional investigation. Elevation data for salt marsh systems would be valuable for long-term investigations.

9. The role that nutrient loading may have on the system should be investigated, in terms of how plant communities (macroalgae, as well as salt marsh vegetation), invertebrate communities, water quality, and pathogens are affected.

10. Grazing impacts by various herbivores (crabs, snails, geese, muskrats, and deer) should be investigated. A minor amount of grazing by geese was observed in this study, and one local watershed on Cape Cod has seen its marsh vegetation rebound after goose control efforts. Grazing seems unlikely to occur at a scale that would cause the observed effects in Wellfleet and elsewhere in the US, but should still be considered for localized impacts.

11. The investigation and characterization of any pathogens that might be causing the dieback that has been observed seems important. While some suggestions are that pathogens act only after plants are already stressed, it seems important to determine if pathogens are the proximate cause for any observed plant disease.

12. The possible role that water withdrawals for human use might have, even if localized, should be investigated for its potential to cause surface subsidence in salt marshes. This phenomenon has caused substantial problems for coastal wetlands systems in California.

13. Potential interactions among any of these factors may also occur and should be considered.

14. The locations in Wellfleet are well suited for further research since these sites have demonstrated salt marsh vegetation impacts most clearly and also present complicated systems where many of the identified potential factors that may contribute to potential dieback exist.

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Appendix A

<u>Salt Marsh Evaluation Sheet for Dieback Conditions</u> v. 1.1 26 July 2006]

Local Name (marsh or area) and description:

Town: Evaluator(s):

Date: Time:

1. **Evaluate salt marsh for any signs of dieback, in its various forms.**
   Please use the space provided below each item to record COMMENTS while in the field. Include information about past events and local knowledge that might shed light on impacts.

   Observations of Natural Impacts:

   a. Is there a presence of recently dead or dying vegetation (i.e., not last year's thatch)? y / n

   b. What species are affected?

   c. Where in the marsh is dieback occurring (low, mid, high, creek bank)?

   d. Are there any signs of herbivory (i.e., are there leaves that look shredded or chewed in any way? y / n / unknown

   e. Are there any signs of snails, crabs, geese, deer, or other herbivores? y / n
   If so, please describe.

   f. Observe for the following signs of plant disease:
   - Yellowing/discolored stems or leaves y / n
   - Dark/black spots on stems or leaves y / n
   - Discoloration of the vascular tissue in stem cross-sections y / n

   g. Signs of sediment erosion from around remnant peat or disintegration of peat itself? y / n

   h. Signs of rhizome mortality (i.e., a significant portion of roots/rhizomes that have been washed of mud are brown rather than white)? y / n

   i. Ice scraping or damming (i.e., ice can lift and move the marsh surface or dam tidal flow and waterlog the marsh surface and peat)? y / n

j. Wrack (i.e., could temporarily smother the marsh until a spring tide carries it away)? y / n

k. Other (i.e., that might contribute to water logging or smothering of the marsh)? y / n

Observations of Anthropogenic Impacts:

l. Observe for impacts caused by the following:
- Boat activity or marina operations y / n
- Trampling by pedestrian traffic y / n
- Tidal restriction (past or present) y / n
- Pollution sources (e.g., stormwater or other discharges) y / n
- Fill, floating debris, or chemical spills y / n
- Sources from adjacent properties (e.g., septic systems) y / n
- Other:

2. Map distribution of potential dieback area(s) if observed.

Delineate the dieback area(s) using a sub-meter GPS receiver. If the dieback area is inaccessible, collect a pair of coordinates by offsetting (input distance and compass bearing if this feature is available) the center of the area. At the very least, describe its location below for delineation from aerial photos.

3. Photograph dieback area(s) if observed (if not observed, photograph representative areas of marsh to keep on record).

Using a digital camera, photograph the dieback area(s) and any potential sources of impacts or symptoms (e.g., storm water discharges, dark spots on plant shoots, boat activity, etc.). Use the date/time stamp feature of your camera, if available, and capture images at medium to high resolution.

Number of photos taken = ____

Appendix B

	Site Details																
	This Year's Dead and Dying Vegetation	Attributable to Evident Stressors? (Y/N)	Low Marsh or High Marsh?	Unusual Bare Patches (Y/N)*	Herbivory (# = Observed snails and Crabs)	Plant Disease	Dead Ribbed Mussels	Erosion / Peat Disintegration	Estimated Signs of Ice Scraping or Damming	Wrack	Sources Contributing to Waterlogging	Boat Activity / Marina Operation	Other Recreational Use	Pollution Sources**	Septic Systems	Fill, Floating Debris, Hazardous Waste	Tidal Restriction Past or Present
Wellfleet																	
Lieutenant Island	++	Y	Both	Y	+#	0	++	+++	++	+	+	0	+	0	++	0	0
Middle Meadow	++	?	Both	Y	0#	++	0	+	+	+	++	0	+	0	0	0	+
The Gut	++	?	High	Y	0#	0	0	0	0?	++	+?	+	+	0	0	0	0
Mouth of the Herring River	++	?	High	Y	0#	0	0	+	+?	++	+	0	+	0	0	+	0
Cape Cod Bay																	
Mouth of Pamet River in Truro	0			N	0	0	0	+	++	0	0	+++	+	++	+	0	0
Namskaket in Orleans	+	Y	Both	N	0	0	0	+	0	0	+++	0	+	+	+	0	0
Rock Harbor in Orleans	0			N	+	0	0	0	0	0	0	+++	+	+	+	0	0
Sunken Meadow in Eastham	+	Y	High	Y	0	0	0	0	0	++	+	0	0	+	++	0	+
Boat Meadow at Bridge St. in Eastham	+	Y	Both	Y	+	0	0	++	++	+++	++	0	0	+	+	+	++
Nantucket Sound																	
Craigville Marshes in Barnstable	0			Y	0#	0	++	++	+?	+	++	++	++	++	++	0	+
Parker River Estuary in Yarmouth	0			Y	+	0	+	+++	0?	+	0	++	++	++	+++	0	++
Bass River in Yarmouth (Highland Road)	0			N	0	0	0	+	0?	0	+	++	0	++	+	0	+
Swan Pond River in Dennis	+	Y	Low	Y	++	0	++	++	+?	+?	0	++	++	+++	++	0	+
Allen Harbor in Harwich	0			Y	0	0	0	+	0?	0	0	+++	+	+++	++	+	0
Saquatucket Harbor in Harwich	0			Y	0#	0	+	+++	+?	+	0	+++	0	+++	++	++	+
Wychmere Harbor in Harwich	0			Y	0	0	0	0	0	++	0	+++	+	++	+	++	+
Herring River in Harwich	0			Y	0#	0	++	++	++?	+	+	+++	0	++	++	++	+
Red River in Harwich/Chatham	0			N	0#	0	++	++	+?	+	++	0	0	+	++	+	++
Cockle Cove in Chatham	0			N	0	0	0	0	0	++	0	+	++	++	++	+	0
Forest Beach in Chatham	0			N	0#	0	++	++	0?	+	0	+	+	+	+	0	0
Buzzards Bay																	
Pocasset River (Barlow's Landing) in Bourne	+	Y	Both	N	0	0	0	+	+	+	++	+	0	+	+	0	++
South Shore																	
Ellisville Harbor in Plymouth	0			Y	0	0	0	0	?	++	+++	0	+	+	+	0	+++
Trouant Island in Marshfield	0			N	0	0	0	0	+++	+	0	++	0	0	+	0	+
Weir River in Hull	0			Y	?	0	0	+	++?	+	0	+	0	++	+	+	0
North Shore																	
Parker River at Route 1A in Newbury	0			N	0	0		+	0	0	0	+++	0	++	+	+++	0

* Bare (unvegetated) patches where salt marsh vegetation would typically be predicted to occur

** Pollution sources include stormwater and point discharges

Key:	0 = None	+ = Minor	++ = Some	+++ = Major	? = Unsure