White Paper on the Status of Sudden Wetland Dieback in Saltmarshes of the Delaware Inland Bays, Winter 2007

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Sudden Wetland Dieback (SWD) is characterized by the rapid death of at least the above ground parts of saltmarsh vegetation or its failure to grow during a single or multiple growing seasons (Figure 1). SWD may also result in the complete death of saltmarsh vegetation. Saltmarshes normally support lush summer crops of vegetation consisting primarily of saltmarsh cordgrass (*Spartina alterniflora*). Marshes where SWD occurs appear brown or dead because little or no live green vegetation is present and the dead plant material from the previous year remains, or the marsh surface is exposed. The immediate cause of SWD remains unknown. Although, many researchers acknowledge that the cumulative effects of multiple environmental stressors including rising sea levels, increased nutrient levels, and hydrologic alterations may be influential. Sudden marsh diebacks in small patches have been reported in the scientific literature as early as 1968. However, an apparently unprecedented form of the phenomenon has occurred with alarming extent in saltmarshes of the Gulf and East Coasts roughly during the past decade (Table 1). SWD was first reported in Delaware's Inland Bays in 2006 and its appearance may lead to increased loss of valuable tidal wetlands from increased erosion and submergence. The purpose of this paper is to describe the research to date on SWD in the Inland Bays, review the SWD literature, and recommend actions for monitoring and research in light of the overall condition of saltmarshes in the Inland Bays.

Sudden Wetland Dieback in Delaware's Inland Bays

SWD was first documented by the Department of Natural Resources & Environmental Control's (DNREC) Watershed Assessment Section (WAS) staff in early summer of 2006. As part of an assessment of tidal wetland health initiated prior to discovering dieback, DNREC collected extensive data[1] at 10 saltmarshes in Indian River Bay during the 2006 growing season. *Spartina alterniflora* appeared necrotic and decomposing at many sites and had failed to produce a substantial crop at other sites. In response to these observations, the Center for the Inland Bays (CIB) and DNREC conducted aerial photographic reconnaissance of saltmarshes in all three bays on September 22. Photographed marshes were ranked on the intensity of dieback using methods based on those developed in Louisiana [1]. Dieback appeared to be common and tended to occur within the interior of marshes. Creek banks, marsh shorelines, and the ditch edges tended to support healthy grass. Twenty-two percent of marshes were sufficiently observed from the air. Of these, 41% exhibited some level of dieback. Certain areas of dieback appeared so severe that it raised the question whether some marshes had died back in 2005 (Figure 2). Although dieback did not show any pattern among sites, marshes of the Little Assawoman Bay appeared to have less dieback (Figure 3). Following the survey, permanent plots were established and sampled for vegetation, soils, and invertebrates at four marshes with varying levels of dieback. Saltmarsh cordgrass was the only species observed to be affected. The amount of living vegetation ranged widely at dieback sites, with the most severely affected dieback site having only 1% live grass. Soil and plant material samples were analyzed by Robert Mulrooney, (University of Delaware Cooperative Extension Program plant pathologist) for causes of the dieback including fungal pathogens, root nematodes, and soil heavy metal concentrations. DNREC WAS also performed detailed heavy metal analysis. Results showed that no fungal pathogens or root nematodes were present and soil heavy metal concentrations were below toxic levels[2]. Salinities observed in Indian River Bay marshes (n=10) were well within the survival limits for saltmarsh cordgrass.

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[1] Data includes vegetation composition, soil resistance, below ground biomass, above ground macrofauna, soil macroinvertebrates, invasive species, pore water pH, and salinity.

[2] Results based on a limited number of samples and may not be representative of all marshes with dieback.

Indices of drought[3] were assessed from 2004 through 2006 to explore the relation of dieback to precipitation patterns [2, 3]. Southern Delaware experienced a mild drought during January 2004 to May 2005, August to September 2005, and January to March 2006. A moderate drought occurred from April to June 2006 followed by the wettest June on record. August 2006 was the second driest on record. Sea-level during the time of the dieback was also examined. The mean sea level trend for Lewes, Delaware is +3.16 mm/yr from 1919 to 1999 [4]. Tide gauges showed no apparent abnormalities in water levels during the time of the dieback [5].

Review of SWD: Character, Causes, and Recovery

SWD has been reported to affect saltmarsh cordgrass, salt hay (*Spartina patens*), saltgrass (*Distichlis spicata*), and needle rush (*Juncus*) species. Only saltmarsh cordgrass has been observed to dieback in marshes of the Inland Bays, and this may be due to its prevalence relative to other vegetation. Distinctive patterns of SWD have been observed to occur with differing frequency by region of the US. These patterns include dieback in narrow bands along tidal creeks, mid marsh or interior marsh diebacks often of many acres, dieback on the tops and backsides of creek berms as reported from Georgia, and dieback adjacent to uplands as common on Cape Cod [6-9]. Only mid-marsh or interior marsh dieback has been observed in the Inland Bays and may also be present in coastal Maryland's Isle of Wight Bay and certain Prime Hook marshes on Delaware Bay (Figure 4). The different patterns of SWD and their relative presence in marshes of one estuary may be controlled by differences in the hydroperiod of marsh soils and differences in animal communities.

The cause of SWD is still unknown. Suggested causes such as herbivory by saltmarsh snails (*Littorina spp.*) [10] or grasshoppers appear unlikely because these species were not observed during diebacks in multiple regions including sites in the Inland Bays. Any damage by these organisms is likely to follow plant stress originating from a causative agent. This is also likely true for damage by pathogenic species of *Fusarium* fungus as studied by Schneider and Useman [11] and Elmer et al. [12]. Drought has been associated with many SWD events [2, 8, 13], and has been suggested as a likely trigger for SWD in certain [13, 14], but not all regions [7]. McKee et al. [13] provide the most compelling explanation for a drought trigger by partially documenting that a severe drought led to a marsh water deficit followed by soil aeration and chemical oxidation of pyrite that acidified the soil through the production of sulphuric acids. They also documented increases in iron and aluminum concentrations to levels stressful to saltmarsh cordgrass. These elevated concentrations may have interacted with the low pH and water deficits to cause dieback of the vegetation. If the moderate droughts of 2006 produced conditions similar to the severe droughts in Louisiana, they may have interacted with strong seasonal and tidal cycles of sulphur documented in Delaware marshes [15] to create similar conditions stressful to cordgrass. This assumes that affected marshes experienced a water deficit sufficient to create oxidation, which goes against the conventional wisdom that Delaware *Spartina alterniflora* marshes flood twice daily [16 and references therein]. However, oxidation during spring tides of drought years in *Spartina alterniflora* sites of the Great Marsh, DE have been documented and attributed to desiccation [17]. Expert consultation and hypothesis testing is needed to prove or disprove this suggested cause. Further, the pre-existing stresses of marshes prior to dieback and subsequent herbivore and pathogen stressors should be documented during testing.

SWD sites have been shown to recover, though quantitative data is sparse. Ninety-three percent of affected marshes were found to recover in Louisiana [6], with a small portion of these having received restoration efforts. In New England, only 4 of 42 reported dieback sites (10%) have been reported as recovering [18]. Sites on Cape Cod have died back, begun recovery, and then died back again [7]. Marshes may produce new aboveground vegetation where rhizomes have survived, and these sites have been shown to recover rapidly in Georgia (14 mo.)[19]. Where entire plants have died, revegetation may occur by spreading of rhizomes from live plants or seed distribution. Spreading of cordgrass into bare patches was measured at 12 cm/yr in New England [20]. This rate may not be sufficient to fully recolonize large patches before erosion, sediment accretion debt, and changes in soil chemistry make them uninhabitable for cordgrass. Seed distribution in dieback sites may also be insufficient for recolonization because the short form of cordgrass that inhabits these sites seldom produces inflorescence. The tall form of cordgrass produces seed in August. Natural recolonization by seedlings varies by region and can be rare [8]. In Louisiana, a combination of aerial seeding and direct planting were ideal for restoring dieback sites quickly [6].

[3] The Palmer Drought Severity Index and the Palmer Hydrological Drought Index

Recommendations for the Study of SWD in Relation to the Condition of Saltmarshes in the Inland Bays.
SWD may cause the loss or conversion of large areas of saltmarsh to mudflat through erosion or submergence. The potential economic, social, and environmental impacts of rapid loss of saltmarshes in the Inland Bays are a major concern. Saltmarshes protect coastal development and production lands from erosion and storm surges, provide critical habitat for fin and shellfisheries and bird life, regulate Bay ecology by filtering and storing huge banks of nutrients and sediments, regulate climate, and provide invaluable aesthetic appeal. The value of ecological services provided by saltmarshes has been estimated at $24,675 per acre per year, the fourth highest of all the worlds ecosystems [21].

The Inland Bays has lost large areas of saltmarsh to human activity. Daiber et al. [22] estimated that 24% of tidal wetland acreage was lost between 1938 and 1973. Strict regulation has since slowed rates of tidal wetland loss [23]. The most recent estimates of acreage are 13,616 and 10,038 ac of estuarine vegetated wetlands in 1992 from Tiner [24] and the DNREC's SWMP data layer, respectively. It is uncertain which estimate is the most accurate or why the great difference in the acreage exists. The rate of wetland loss to factors such as erosion or submergence is unknown. It is, however, important to note that decadal-scale degradation and catastrophic loss of large areas of wetlands to submergence has been documented throughout the U.S. Particularly relevant examples include mid-Atlantic marshes [25, 26] and the marshes of the Chesapeake and Delaware Bays [27, 28]. The process of submergence occurs when relative sea level rise exceeds the rate at which a salt marsh accumulates sediments and organic material. Submergence may be onset by increases in the rate of sea level rise, land subsidence, groundwater withdrawal, hydrologic modification, excessive herbivory, increased erosion, changes in disturbance regimes, or synergistic interactions of these and other stressors. Rates of sea level rise in the mid-Atlantic are relatively high and Lewes, DE has a 100 year average rate of 0.32 cm/yr [4]. Recent short-term (30 year) rates of saltmarsh accretion from 3 saltmarshes in the Inland Bays averaged 0.26 cm/yr[16]. Another estimate found an average of 0.41 cm/yr for 4 saltmarshes in the Inland Bays [29]. These data suggest that some marshes may not be able to keep pace with sea-level rise. Further, site-level average accretion rates mask high intra-site variability that allows portions of a marsh to subside, which can then lead to mechanical loss of other parts of the marsh. Expert interpretation of aerial photography suggests that certain marshes of the Inland Bays are becoming submerged and starting to break up [30]. The mean projected rate of sea level rise for the mid-Atlantic from 1990 to 2030 is 0.48 cm/yr[31]. This presents a scenario where existing saltmarshes are extremely sensitive to any disturbance that could affect their capacity to naturally maintain their elevation now and especially in the future. Rapid and significant decreases in marsh surface elevation can occur when salt marsh grasses die due to the collapse air spaces within the roots [32]. Dieback events should thus be carefully monitored and managed to prevent rapid loss of wetland resources.

The Delaware Sudden Wetland Dieback Task Group (Table 2) recommends that short term funding be sought to monitor the recovery and distribution of dieback areas using a combination of remote sensing tools and site level data collection. The purpose of this monitoring will be to inform the need for restoration actions and prioritize restoration sites should action be deemed necessary. If areas of dieback do not recover to sufficient levels (to be decided *a priori*), restoration options should be pursued. Investigation of the causative agents should be pursued at low cost at a subset of sites. The dieback workgroup has decided to pursue these three major questions:

1. Will the dieback marshes revegetate in 2007?
2. What is the distribution of dieback?
3. What are the dominant stressors affecting tidal marshes?

Finally, diagnostic studies of past marsh losses should be undertaken to inform potential management of submerging marsh resources. A long term network of sediment elevation tables should be developed to provide more accurate estimates of marsh elevation change. Additional saltmarsh stressors such as excessive snow geese populations and the prevention of inland marsh migration by development should be immediately addressed.

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Tables and Figures

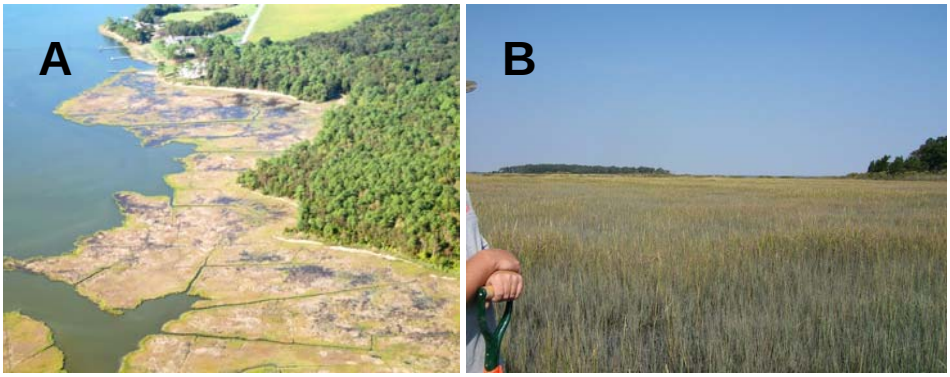

Figure 1. Aerial (A) and ground level (B) view of sudden wetland dieback on Piney Neck saltmarsh, Indian River Bay. The marsh produced little live *Spartina alterniflora* which died throughout the season. The previous year's crop of cordgrass thatch remains standing.

Table 1. Location, years, and acreage of SWD on the US Gulf and East Coasts.

Location	Confirmed Year(s) of Occurence	Maximum Acreage Affected	Source
Florida Panhandle	1990 - 1995	--	[14]
New England	1999 - 2006	--	[9]
Maine			
Rhode Island			
Connecticut			
New York			
Massachusetts			
Cape Cod Nat. Seashore	2003 - 2006	--	[7]
Louisiana	2000 - 2003	126,000	[6]
Georgia	2001 - 2002	1,976	[8]
Virginia on Delmarva	2004	--	[8]
Delaware Inland Bays	2006	22% of marshes	(this paper)
Delaware Bay (Prime Hook)	2006	patches	[33]
Maryland Coastal Bays	2006	--	[34]
Chesapeake Bay	2006	--	[35]

Figure 2. Severe dieback at Boathouse Cove marsh on Long Neck in Indian River Bay.

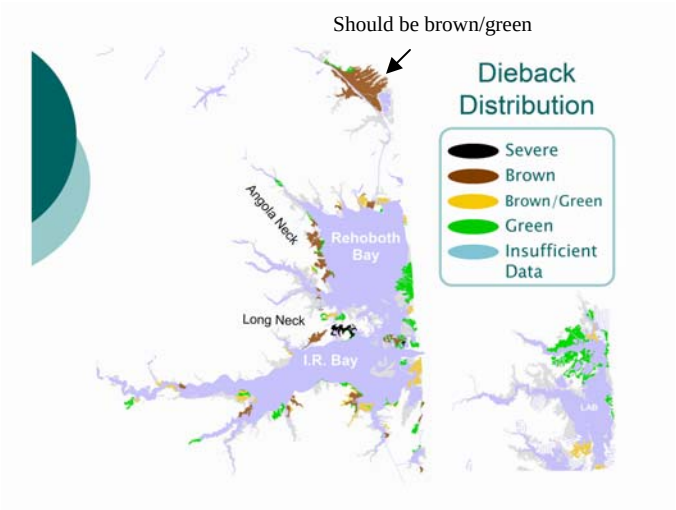

Figure 3. Distribution of dieback for sites observed during aerial survey, September 2006. I.R. = Indian River, LAB = Little Assawoman Bay.

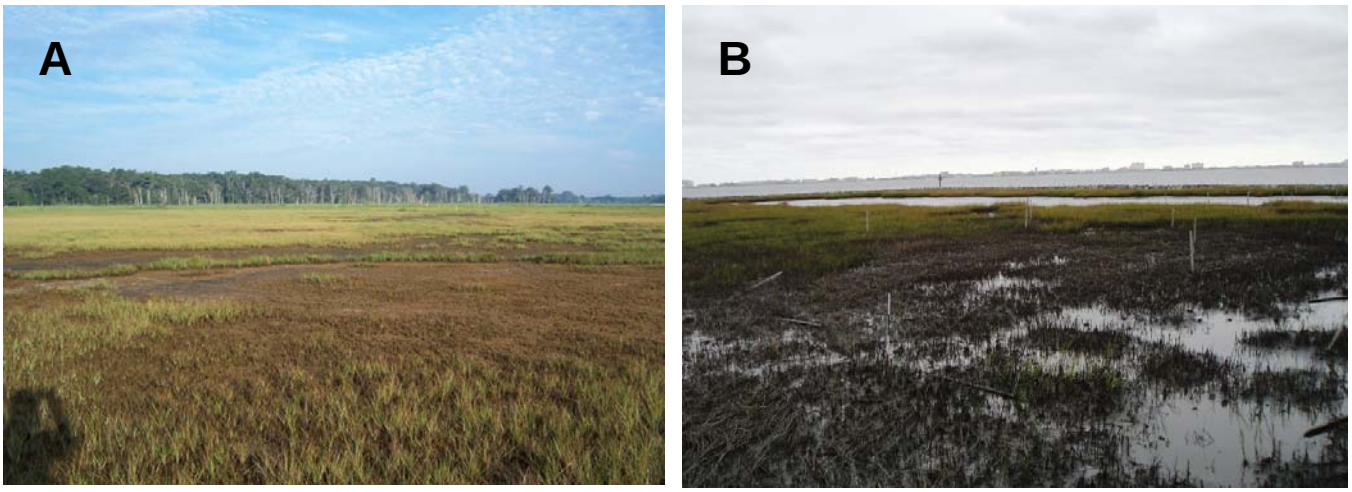

Figure 4. Dieback in low marsh of A) Prime Hook National Wildlife Refuge, DE, and B) Isle of White Bay restoration site, Maryland Coastal Bays. Photo credits to Marnie Pepper and Roman Jesien respectively.

Table 2. Sudden Wetland Dieback Task Group meeting participants.

Name	Affiliation
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