Wetlands Condition of the Inland Bays Watershed

Volume 2: Tidal Wetlands

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EXECUTIVE SUMMARY

The Delaware Department of Natural Resources and Environmental Control (DE DNREC) assessed the condition of tidal wetlands in the Inland Bays watershed. The goal of this project was to determine the condition of estuarine intertidal emergent wetlands in the Inland Bays watershed and identify the presence of wetland stressors. This information will then be used to guide protection and restoration activities. Volume I of this report provides general watershed characteristics and information on nontidal wetlands in the Inland Bays watershed.

The Inland Bays watershed contains 9,825 acres of salt or brackish tidally-influenced wetlands along river and bay shorelines and behind barrier islands. High human population density especially near the coast has brought stressors associated with development that can impact wetlands and diminish the services and functions that they provide. Sudden wetland dieback (SWD) was first documented in Delaware in 2006 in the Inland Bays watershed. This condition is characterized by the rapid and partial or complete death of emergent saltmarsh vegetation or the failure of that vegetation to grow during one or several growing seasons.

We assessed the condition of wetlands using the MidAtlantic Tidal Rapid Assessment Method (MidTRAM) at 50 randomly selected sites in the watershed. We had an 89% success rate for gaining access to sites. Sites were equally dispersed between wetlands that had been affected versus not affected by SWD. At a subset of sites we also sampled vegetative biomass and the marsh bird community.

The average MidTRAM condition score was 70±10 on a scale of 0 to100; 28% were categorized as severely stressed, 56% moderately stressed and 16% minimally or not stressed. Hydrology was the highest scoring attribute group with an average of 74±10. The most common hydrology stressors across the watershed were wetland diking and tidal restriction mainly due to the Indian River Inlet, and wetland ditching and draining. The buffer attribute group averaged 68±21 and was most commonly scored down for landscape condition due to invasive plants and human disturbance. Also, we found that 30% of tidal wetlands had upland barriers to marsh migration such as bulkhead, houses or roads, with restrictions varying from 0 to 100% of the landward shoreline. The presence of development in the surrounding buffer was also a common stressor. The habitat attribute group averaged 70±16 and was most commonly scored down for the presence of *Phragmites australis*. Compared to the Murderkill and St. Jones watershed of the Delaware Bay, the Inland Bays had the greatest percent of wetlands that were severely stressed.

Overall, our comparison of MidTRAM scores to the marsh bird index of integrity and above and below ground vegetative biomass were inconclusive, likely due to small sample

sizes. However, there was a pattern of increasing marsh condition with higher amounts of below ground biomass which is concurrent with previous research.

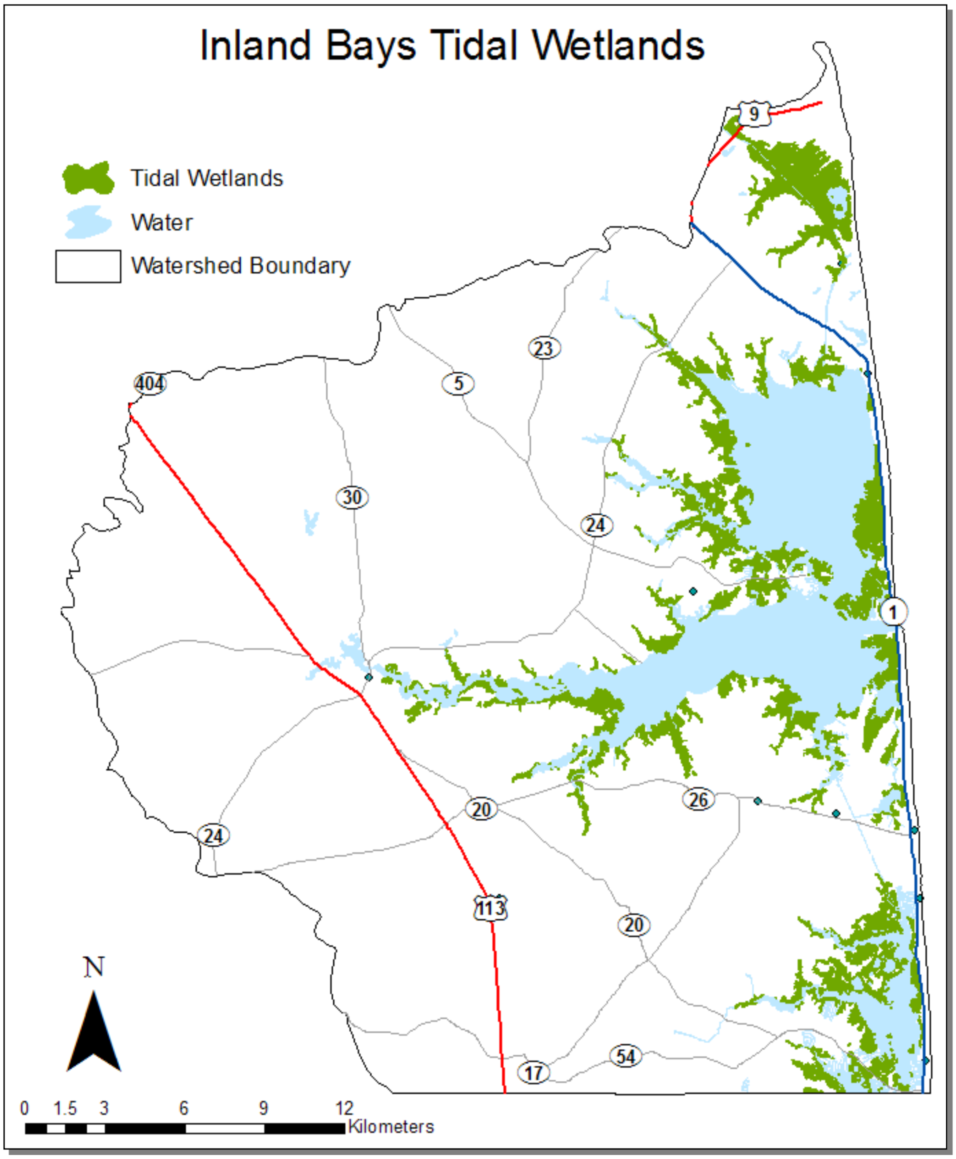
Comparisons between the 20 assessment sites affected by SWD and the 30 sites unaffected by SWD did not show any differences in overall condition or between the buffer, hydrology, and habitat attributes. The similarity in scoring between affected and not affected sites indicated that, based on the rapid indicators of MidTRAM, SWD did not have a lasting effect on the overall condition of tidal wetlands 2 years after it was first detected. More intensive vegetative cover and elevation data at four monitoring stations from 2006 to 2008 suggested that the resilience of the marsh vegetation to recover after SWD may be related to surface elevation. The 4 sites showed varying levels of recovery with elevation trends.

Based on our observations of tidal wetland condition in the Inland Bays we offer recommendations to improve the management of wetlands and identify additional data needs. These actions will improve the future of tidal wetlands in the Inland Bays:

1. Protect tidal wetlands from further degradation by minimizing activity in wetlands and in the adjacent buffers. Even small permitted activities can have large cumulative impacts across the watershed.
2. Enforce buffer regulations and allow migration of wetlands with future climate change. Riparian buffers will maintain wetland condition, will allow wetlands to shift with sea level rise and will ensure continued wetland services into the future.
3. Determine the stressors that are having the greatest impact on tidal wetland condition and focus on these for restoration and enhancement activities. Determine the relationships between wetland stressors and wetland functions to help direct management activities.
4. Further evaluate the relationship between wetland condition, elevation, and biomass to make informed decisions to improve tidal wetland resiliency to future stressors. This, in addition to more information on wetland subsidence and accretion rates, will provide information to understand how tidal wetlands will be affected by sea level rise, sudden wetland dieback and other future stressors as well as the best management action to limit negative impacts.
5. Monitor changes in wetland condition over time. Trends over time can then be used to implement adaptive management practices and adjust protection and restoration priorities and management actions.

INTRODUCTION

Worldwide, 40% of the human population lives in a coastal area (Gedan 2009, UNEP 2006). Tidal wetlands are highly fertile and productive, and provide coastal populations with more ecosystem services than any other habitat (Gedan et al. 2009) such as minimizing flooding from storms, controlling erosion, and improving and maintaining water quality by sequestering and storing excessive nutrients, sediments and toxic chemicals. Tidal wetlands serve as a biologically rich interface between upland and aquatic habitats that supports a variety of waterfowl and migratory birds, nursery habitat for fish and wetland-adapted plants. Tidal wetlands are valued for their aesthetics and sustain recreational (e.g. hunting and birding) and commercial (e.g. fishing and crabbing) industries.

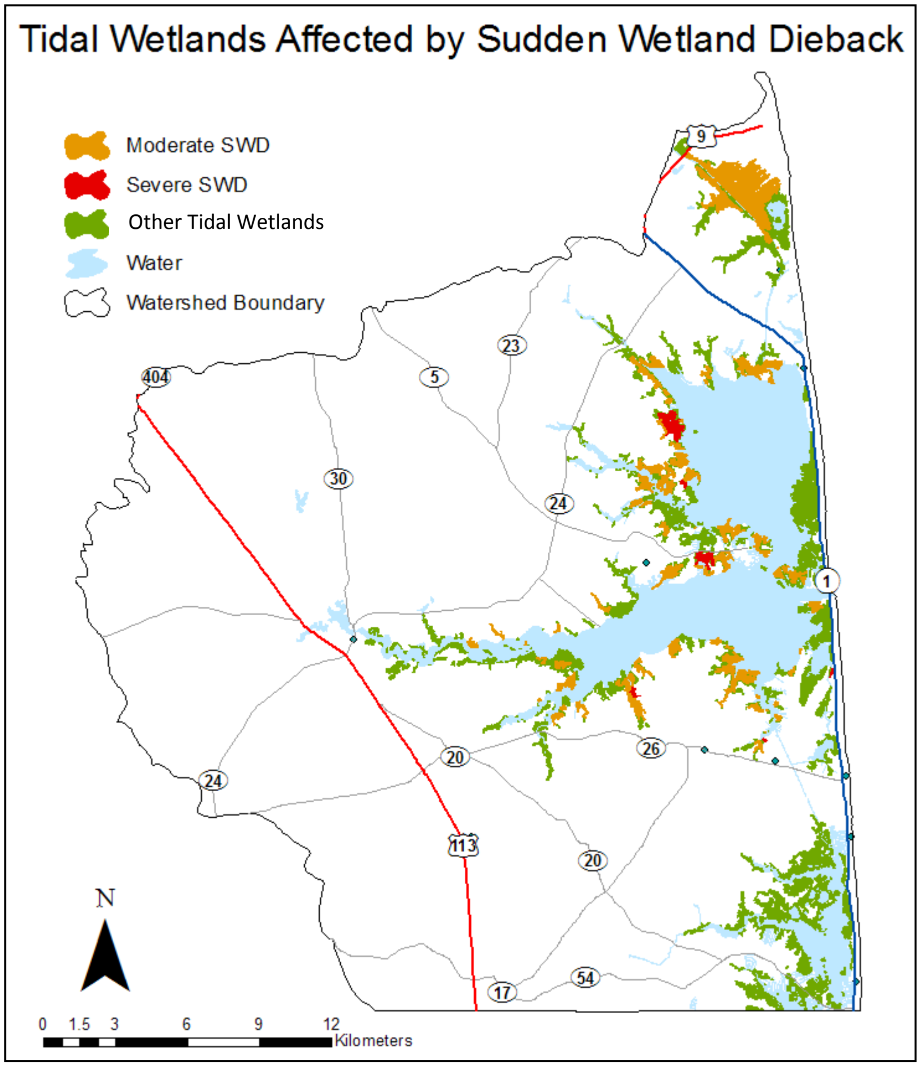


Map 1. Tidal wetland coverage in the Inland Bays watershed in 1992.

In 1992 the Inland Bays watershed contained 9,825 acres of salt or brackish tidally-influenced wetlands along river and bay shorelines and behind barrier islands (Map 1; State of Delaware 1994). Map 3 in Volume 1 of this report shows that the most highly developed areas in this watershed are within a few kilometers of open water. High human population density and stressors associated with development (such as nutrient and chemical inputs, the spread of invasive species such as *Phragmites australis*, mosquito ditching and benthic dredging) can impact wetland habitat and diminish the services and functions that they provide.

A detailed description of this watershed's history, landuse and characterization was given in Volume 1 of this report (Jacobs et al. 2009). In addition to direct anthropogenic impacts to wetlands, changing climate and increasing rates of sea level rise also pose additional stress on these systems. Rising sea levels are compounded by increasing shoreline hardening to protect adjacent development which, in turn, inhibits marshes from naturally migrating landward.

In 2006, Sudden Wetland Dieback (SWD) was first documented in the Delaware Inland Bays (Map 2). SWD is characterized by the rapid browning and senescence of tidal wetland vegetation or the failure of vegetation to grow during one or more growing seasons (Bason et al. 2007). Over the past decade, SWD has been documented in most states along the U.S. east coast, causing growing concern for tidal systems. The Center for the Inland Bays (CIB) and DNREC performed an aerial survey of tidal marshes in the Inland Bays in 2006 and 2007 to estimate the area of wetlands affected by SWD. In fall of 2006, 22% of the wetlands were surveyed and 42% of these were categorized as affected (moderately or severely) by SWD. In a similar survey in fall 2007, 76% of the wetlands were inventoried, 15% of which were categorized as affected.



Map 2. Wetlands impacted by Sudden Wetland Dieback in the Inland Bays watershed in September 2007.

The State of Delaware is dedicated to improving wetland habitat and waters of the State through restoration and protection efforts, research, and effective planning that encourages the benefits of wetlands to persist and flourish. The goal of this project was to assess the condition of tidal wetlands in the Inland Bays watershed and determine the stressors impacting them. We also assessed condition related to SWD to determine if sites that were affected in 2006 were in lower condition in 2008 than those that were not affected. Information on the condition of wetlands will be integrated with other watershed scale plans and used to improve management decisions. Current and local wetland information can be used by state and federal agencies as well as conservation partners to address water quality issues, to protect shorelines, to plan and evaluate wetland restoration projects, and to strengthen wetland activity permitting decisions.

METHODS

We assessed the status and condition of tidal wetlands in the Inland Bays watershed by determining changes in wetland acreage from pre-settlement to 1992 and by performing field evaluations of estuarine intertidal emergent wetlands. The MidAtlantic Tidal Rapid Assessment Method (MidTRAM) was performed on 50 randomly located sites to determine the condition of tidal wetlands in the watershed. Additionally, more intensive measures of marsh birds and biomass were evaluated at a subsample of the same sites.

3.1 Determining Changes in Wetland Acreage

Historic wetland acreage was determined using U.S. Department of Agriculture Natural Resource Conservation Service soil maps. Hydric soil map units from soil survey data were identified as historic tidal wetlands based on tidal soil indicators. Existing wetland acreage was determined using a wetland inventory based on 1992 aerial photography (SWMP; State of Delaware 1994). Changes in wetland acreage from pre-settlement to 1992 were determined by comparing the acreage of wetlands as classified by Cowardin et al. (1979).

3.2 Site Selection

EPA's Ecological Monitoring and Assessment Program (EMAP) in Corvallis, Oregon assisted with selecting 500 potential sample sites in the population of estuarine intertidal emergent wetlands on the 1992 SWMP maps using a generalized random tessellation stratified (GRTS) design (Stevens and Olsen 1999, 2000). Sample sites were randomly chosen from mapped wetlands to give each point an equal probability of being selected and to allow more than one point to fall within a wetland polygon. Sites were selected and sampled in numeric order as dictated by the EMAP design, lowest to highest. Sites were only excluded from sampling if access permission was unattainable, the site was of the wrong wetland classification, or the site was upland.

We evaluated our sample distribution to ensure that both wetlands affected by SWD and those not affected were represented. Wetland dieback categorization was performed by the Center for the Inland Bays (CIB, Rehoboth Beach, DE) using aerial photographs taken specifically for SWD reconnaissance in 2006 and 2007 (Bason et al. 2007). CIB made a visual classification of dieback severity based on the color of the marsh from oblique aerial photos using the greenest marshes in the system as a reference. Relative differences in marsh color from lush green to gray or brown were used to determine vegetation stress or areas converted to open water. A wetland polygon was classified if ≥50% of the polygon was photographed clearly and represented the entire polygon based on 2002 orthophotography. The following categories were used:

- NOT AFFECTED - 0-25% brown/gray
- AFFECTED - 25-75% brown/gray and/or showed signs of breaking apart/patchiness
- SEVERE - 75-100% brown/gray and that had 50% of the affected areas appearing devoid of vegetation were considered

For our analysis we combined the "severe" category with "affected". Based on our landowner permission and sampling access, our original design achieved an adequate sampling of both groups.

3.3 Data Collection

3.3.1 Assessing Wetland Condition

We evaluated the condition of wetlands using the MidTRAM. We performed the MidTRAM at the first 50 random points that we could access and that met our criteria of being of an estuarine subtidal emergent wetland. The MidTRAM was developed in 2007-2008 by adapting the New England Rapid Assessment Method (NERAM; Carullo et al. 2007) and the California Rapid Assessment Method (CRAM; Collins et al. 2008) to tidal wetlands in the MidAtlantic Region. MidTRAM consists of 15 scored metrics that depict the condition of the wetland buffer, hydrology, and habitat characteristics (Table 1). MidTRAM uses a combination of qualitative evaluation and quantitative sampling to record the presence and severity of stressors in the field and in the office using maps and digital orthophotos.

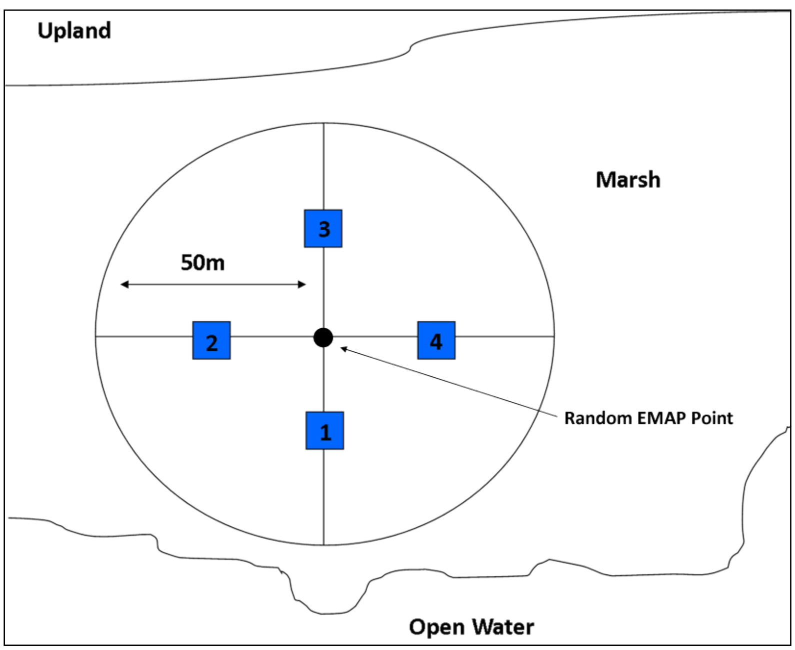


Figure 1. Assessment area and subplots used to collect data for the MidAtlantic Tidal Rapid Assessment Method.

An assessment area (AA) was established as a 50m radius circle centered on each random point (Figure 1). The buffer area was defined as a 250m radius area around the AA. If a 50m radius circle would go beyond the wetland into upland or open water, the circle was shifted over <50m or changed to a rectangle of equal area in order to stay within the wetland.

For metrics measured within the AA (Table 1) we evaluated indicators throughout the entire AA with the exception of the soil profile, plant fragments, and soil bearing capacity. For these 3 metrics, we established 4 1m² subplots within the AA along 2 100m transects that bisected the AA. One transect was oriented towards the nearest source of open water (>30m wide) and the other was perpendicular to the first. The 4 subplots were each placed 25m from the center of the AA and were numbered clockwise starting with the open water direction (Figure 1). If a subplot fell in a habitat type or patch that was not characteristic of the site (e.g. in a ditch) it was moved 1m along the transect.

Buffer width, surrounding development, percent of assessment area with a 5m buffer, and barriers to landward migration were completed in the office using ArcMap GIS software (ESRI, Redlands, California) and then verified visually in the field. The remaining metrics, with the exception of soil bearing capacity and plant fragments, were completed via visual inspection during the field visit. Soil bearing capacity was measured using a slide hammer technique on a random spot in each subplot (Figure 1). The slide hammer was raised and released 4 times to exert a consistent force on the soil surface. The final depth below the marsh surface of the bottom of the slide hammer was subtracted from the initial depth to get the change in depth due to the total force. We also measured plant fragments in each subplot by removing a 2cmx2cm piece of the soil from 2-4cm below the ground surface. We rinsed the sample to remove soil and measured the volume of the roots compressed in a plastic syringe to the nearest 0.1cc. Each metric was given a score of 3, 6, 9, or 12, except Plant Fragments which was on a 4, 8, 12 scale (APPENDIX D).

At the completion of the site visit and assessment, crew members gave each site a Qualitative Disturbance Rating (QDR) to rank the level of anthropogenic disturbance to the site's natural structure and biotic community. Descriptions of the disturbance ratings are in Table 2. The average time to sample a site was 2 hours. Detailed instructions for using MidTRAM are provided in the full protocol (Jacobs et al. 2009).

Table 1. Metrics comprising the MidAtlantic Tidal Rapid Assessment Method.

Attribute Group	*Metric Name*	*Description*	*Measured in AA or Buffer*	*Qualitative or Quantitative*
Buffer/Landscape	Percent of AA Perimeter with 5m-Buffer	Percent of AA perimeter that has ≥5m of natural or semi-natural condition land cover	Buffer	Quantitative Office
Buffer/Landscape	Average Buffer Width	Average buffer width surrounding the AA that is in natural or semi-natural condition	Buffer	Quantitative Office
Buffer/Landscape	Surrounding Development	Percent of residential and industrial developed land within 250m from the edge of the AA	Buffer	Quantitative Office/Field
Buffer/Landscape	250m Landscape Condition	Quality of the surrounding 250m based on vegetative community, substrate disturbance and extent of human visitation	Buffer	Qualitative Field
Buffer/Landscape	Barriers to Landward Migration	Percent of marsh/ upland shoreline within 250m that has physical barriers preventing marsh migration landward	Buffer	Quantitative Office/Field
Hydrology	Ditching & Draining	The presence and functionality of ditches in the AA	AA	Qualitative Field
Hydrology	Fill & Fragmentation	The presence of fill or marsh fragmentation from anthropogenic sources in the AA	AA	Qualitative Field
Hydrology	Diking/ Tidal Restriction	The presence of dikes or other restrictions altering the natural tidal range of the wetland	AA and Buffer	Qualitative Field
Hydrology	Point Sources	The presence of localized sources of pollution	AA and Buffer	Qualitative Field
Habitat	Bearing Capacity	Soil resistance using a slide hammer	AA subplots	Quantitative Field
Habitat	Plant Fragments	Volume of plant shoots and roots in the upper soil horizon	AA subplots	Quantitative Field

Habitat	Vertical Biotic Structure	Interspersion and complexity of the vegetation community	AA	Qualitative Field
Habitat	Number of Plant Layers	Number of plant layers in the AA based on plant height	AA	Qualitative Field
Habitat	Percent Co-dominant Non-Native Species	Percent of co-dominant species that are non-native in the AA	AA	Quantitative Field
Habitat	Percent Invasive	Percent cover of invasive species in the AA	AA	Qualitative Field

3.3.2 Sudden Wetland Dieback Monitoring Stations

We collected vegetation and marsh elevation data from 4 wetlands to evaluate dieback patterns and recovery. The sites were classified as 'not affected' (Center for Inland Bays), 'affected' (Burton Island West and Piney Point) and 'severe' (Cotton Patch). Within each site we recorded the percent cover of living and dead vegetation, and unvegetated (bare ground) in 3 randomly located $1m^2$ subplots (1x1m). Sites were sampled in late summer of 2006, 2007 and 2008. We used the subplot average for each site to report vegetation trends from 2006 through 2008.

We measured marsh elevation at each site in 2007 and 2008 using a real-time kinetic GPS system (RTK). We took 40-125 individual readings from each site, depending on wetland size and satellite coverage. Elevation readings were taken on a loose grid pattern that covered the 3 subplots and the surrounding wetland drainage area.

Table 2. Qualitative Disturbance Rating (QDR) category descriptions used to rank the level of anthropogenic disturbance to wetlands.

Qualitative Disturbance Rating: Assessors determine the level of disturbance in a wetland through observation of stressors and alterations to the vegetation, soils, hydrology in the wetland site, and the landuse surrounding the site. Assessors should use best professional judgment (BPJ) to assign the site a numerical Qualitative Disturbance Rating (QDR) from least disturbed (1) to highly disturbed (6) based on BPJ. General description of the minimal disturbance, moderate disturbance and high disturbance categories are provided below.

Minimal Disturbance Category (QDR 1 or 2): Natural structure and biotic community maintained with only minimal alterations. Minimal disturbance sites have a characteristic native vegetative community unmodified water flow into and out of the site, undisturbed microtopographic relief, and are located in a landscape of natural vegetation (250m buffer). Examples of minimal alterations include a small ditch that is not conveying water, low occurrence of non native species, individual tree harvesting, and small areas of altered habitat in the surrounding landscape, which does not include hardened surfaces along the wetland/upland interface. Use BPJ to assign a QDR of 1 or 2.

Moderate Disturbance Category (QDR 3 or 4): Moderate changes in structure and/or the biotic community. Moderate disturbance sites maintain some components of minimal disturbance sites such as unaltered hydrology, undisturbed soils and microtopography, intact landscape, or characteristic native biotic community despite some structural or biotic alterations. Alterations in moderate disturbance sites may include one or two of the following: a large ditch or a dam either increasing or decreasing flooding, mowing, grazing, moderate stream channelization, moderate presence of invasives, forest harvesting, high impact landuses in the buffer, and minimal hardened surfaces along the wetland/upland interface. Use BPJ to assign a QDR of 3 or 4.

High Disturbance Category (QDR 5 or 6): Severe changes in structure and/or the biotic community. High disturbance sites have severe alterations to the vegetative community, hydrology and/or soils. This can be a result of one or several severe alterations or more than two moderate alterations. These disturbances lead to a decline in the wetland's ability to effectively function in the landscape. Examples of severe alterations include extensive ditching or stream channelization, recent clear cutting or conversion to a non-native vegetative community, hardened surfaces along the wetland/upland interfaces for most of the site, and roads, excessive fill, excavation or farming in the wetland. Use PBJ to assign a QDR of 5 or 6.

3.3.3 Marsh Birds

We performed point count surveys for marsh birds at 25 sites that were also sampled with the MidTRAM; 7 in the Inland Bays, 10 in the Murderkill and 8 in the St. Jones watershed. We analyzed the combined dataset with all three watersheds to increase sample size and statistical power. We surveyed the first 7-10 random sites in each watershed. Sites were sampled once during each of two periods: May 5-15 and June 2-10 2008. We completed our surveys between 30 min before and 2 hr after sunrise (modified from Gibbs and Melvin 1993). We did not conduct surveys during precipitation, heavy fog, or wind speeds >12mph (Gibbs and Melvin 1993).

At each site, we recorded all species that were visually or audibly detected within 75m of our assessment point during a 5-minute passive survey when no calls were played, followed by a 6-minute callback survey. During the callback survey a portable CD player with a speaker was used to broadcast the calls of black rail (*Laterallus jamaicensis*), least bittern (*Ixobrychus exilis*), Virginia rail (*Rallus limicola*), king rail (*R. elegans*), clapper rail (*R. longirostris*), and American bittern (*Botaurus lentiginosus*). Each species' call was played for one minute with a 30-second listening period in between.

We calculated an index of marsh bird community integrity (IMBCI) to estimate the bird community condition based on DeLuca et al. (2004) and Pepper (2008). Following this technique, we took the species detected during the point count surveys, gave each species a score based on their wetland specializations, and compiled them to calculate a site score for each wetland. Wetlands with a richer diversity of wetland marsh birds scored a higher index value and indicated a healthy wetland ecosystem. For example, a wetland with an IMBCI score of 0 indicated that only generalist species were present whereas an IMBCI score of 12 indicated that several species detected had wetland specialist attributes.

The species scores were determined from 4 attribute values (L_s) listed below (values are listed in parentheses):

1. *Foraging habitat*. Primary foraging habitat. Scored as habitat generalist (1), marsh facultative (2.5) or marsh specialist (4).
2. *Nesting substrate*. Primary nesting location. Scored as non-marsh nesters (1), nesting in marsh vegetation (2.5) or marsh ground-nesters (4).
3. *Breeding range*. Restrictions for breeding habitat in North America. Scored as North America (1), North America only east of the Rocky Mountains (2), coastal North America (3), or North America east coast only (4).
4. *Conservation status*. Scored as low concern (1) moderate (2.5) or high (4) based on species' status according to state and federal wildlife agencies and scientific partnerships such as Partners in Flight.

Attribute values for each species were provided by DeLuca et al. (2004), Pepper (2008) or were determined using guides (National Geographic Society 1987) and species literature

(Burger 1996, McCrimmon et al. 2001, McGowan 2001, McNicholl et al. 2001, Nisbet 2002, Pierroti and Good 1994, Thompson et al. 1997). Calculations for the species' scores and wetland site scores (W_{IMBCI}) were calculated using the following formulas:

$$S_{IMBCI} = \sum L_s \qquad W_{IMBCI} = [(\sum S_{IMBCI} / S_N) + MO_N] - 4$$

Where S_{IMBCI} was the score for each species, L_s represented each attribute score, S_N was the total number of species detected at the site and MO_N was the total number of obligate marsh species detected at the site as determined by the nesting and foraging requirements of the species. We subtracted 4 to ensure a scoring scale that begins with a zero and remains constant (DeLuca et al. 2004). The example below demonstrates the calculation of a wetland site score.

Example: Site A

Species	**Foraging Habitat**	**Nesting Substrate**	**Breeding Range**	**Conservation Rank**	**Sum (S_{IMBCI})**
Boat-tailed grackle	1	2.5	4	1.5	9
Clapper rail *	4	4	3	1	12
Glossy ibis	1	2	4	1	8
Red-winged blackbird	1	2.5	1	1	5.5
Seaside sparrow *	4	2.5	4	3	13.5
Willet *	4	4	4	2	14

* indicates a marsh obligate species

$$\begin{aligned} W_{IMBCI} &= [((\sum S_{IMBCI}) / S_N) + MO_N] - 4 \\ &= [((9+12+8+5.5+13.5+14)/6) + 3] - 4 \\ &= 10.3 + 3 - 4 \\ &= 9.3 \end{aligned}$$

3.3.4 Vegetative Biomass

We collected vegetative above and below ground biomass samples from 22 sites across the Inland Bays (N=10), Murderkill (N=2) and St. Jones (N=10) watersheds. We sampled the first 2 to 10 random sites in each watershed that were also sampled with the MidTRAM. Most of the 22 sites were also sampled for marsh birds. We collected biomass from subplots 1, 2 and 3 August 21-26, 2008. We sampled above-ground biomass by clipping all vegetation within a 15.24cm radius circle randomly placed at the outside edge of the subplot. We sorted the vegetation to separate live stems from dead. We collected below-ground biomass by extracting sediment cores to 30cm below the marsh surface. We thoroughly rinsed the cores clean of any sediment, separated live from dead roots, and chilled the samples until they could be dried. Samples were dried (80-85°F) for approximately 72 hours until there was no additional weight loss detected with additional drying time. Each sample was weighed to the nearest 0.00g (Tuner et al. 2004) and we averaged the subplot values for each site.

3.4 Statistical Analysis

Attribute group scores were calculated by summing the metric scores and dividing by the total possible value, depending on the number of metrics in that group. That value was adjusted to be on a 0-100 scale since each metric can only score a minimum of 3 (or 4):

$$\text{Buffer} = ((((\sum(B1 \ldots B5))/60)-25)/75)*100$$
$$\text{Hydrology} = ((((\sum(H1 \ldots H4))/48)-25)/75)*100$$
$$\text{Habitat} = ((((\sum(HAB1 \ldots HAB6))/72)-25)/75)*100$$

Final MidTRAM condition scores range from 0-100 and were calculated by averaging the 3 attribute group scores:

$$\text{MidTRAM} = ((((\text{Buffer} + \text{Hydrology} + \text{Habitat})/3)$$

We used SAS (Version 9.1, Cary, NC) and Excel for our statistical analyses with an alpha level of 0.10. We used intense sampling data from 3 watersheds combined to increase our sample size. To determine if a relationship existed between MidTRAM and the bird survey data, we used linear regressions between IMBCI values and species richness, MidTRAM condition scores, and attribute group scores. We also used a linear regression between MidTRAM condition scores and above, below and above:below ground biomass to look for a relationship. We tested if IMBCI values or the amount of vegetative biomass differed between SWD affected and not affected sites using a t-test. To look for differences between SWD affected and not affected sites we used a t-test on MidTRAM condition scores and attribute group scores. For our monitoring stations, we compared percent cover of vegetation and mean elevation data collected from one site visit per year.

3.5 Presenting Wetland Condition

We present our results at the site and population level. Site level results are discussed by summarizing the range of scores that were found in sampled sites (e.g. Habitat attribute scores ranged from 68 to 98). Population level results are presented using weighted means and standard deviations (e.g. Habitat for tidal wetlands averaged 87±13) or weighted percentages (e.g. 20% of tidal wetlands had ditching present). Population level results have incorporated weights that corrected for any bias due to sample sites that could not be sampled and different rates of access on private and public lands. The cumulative results represent the total area of the respective wetland subclass for the entire watershed.

Sites were placed into 3 condition categories (Minimally or Not Stressed, Moderately Stressed, or Severely Stressed) following procedures used by EMAP. We determined breakpoints by applying a percentile calculation to the QDR's and MidTRAM condition scores from sites in the Inland Bays (N=60), St. Jones (N=50), and Murderkill (N=26) watersheds. We used the 25th percentile of MidTRAM scores for sites with a QDR of 1 or 2 to separate Minimally or Not Stressed from Moderately Stressed. We used the 75th percentile of MidTRAM scores from sites with a QDR of 5 or 6 to separate Moderately Stressed from Severely Stressed. For example, if 25 sites had a QDR of 1 or 2, and the 25th percentile of MidTRAM scores for those 25 sites was 85, then sites with a MidTRAM score of ≥85 would be categorized as Minimally or Not Stressed. Based on the 3 watersheds combined, the condition breakpoints were:

Minimally or Not Stressed	≥ 81.1
Moderately Stressed	<81.1 ≥ 62.9
Severely Stressed	< 62.9

We used a cumulative distribution function (CDF) to display the population level results. A CDF can be interpreted by drawing a horizontal line anywhere on the graph and reading that as: 'z' proportion of the area of tidal wetlands in the watershed falls above (or below) the score of 'w' for wetland condition. The advantage of these types of graphs is that they can be interpreted based on individual user goals, and break points can be placed anywhere on the graph to determine the percent of the population that is functioning within the selected conditions. For example, in Figure 2, roughly 60% of the wetland area scored below an 80 for wetland condition. Another interpretation is that almost 40% of the population had a wetland condition of 80 or greater. Using the condition breakpoints, almost 30% of the population was categorized as severely stressed.

Condition Breakpoint Criteria

Minimally or not stressed – Sites with MidTRAM condition score ≥25th percentile of the sites with a low disturbance QDR rating of 1 or 2.

Moderately stressed – Sites in between minimally and highly stressed.

Highly stressed – Sites with a MidTRAM condition score ≤75th percentile of the sites with a high disturbance QDR rating of 5 or 6.

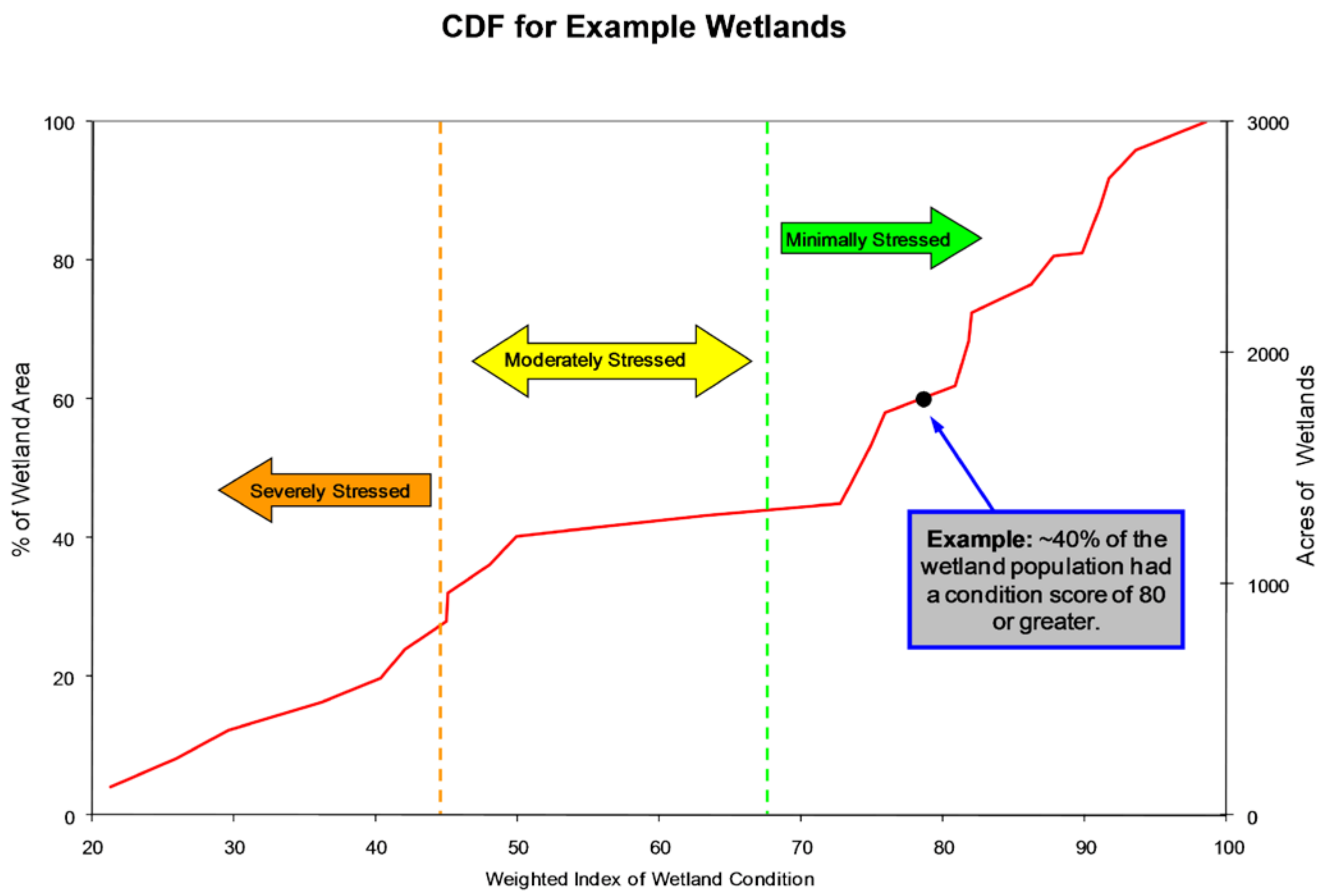
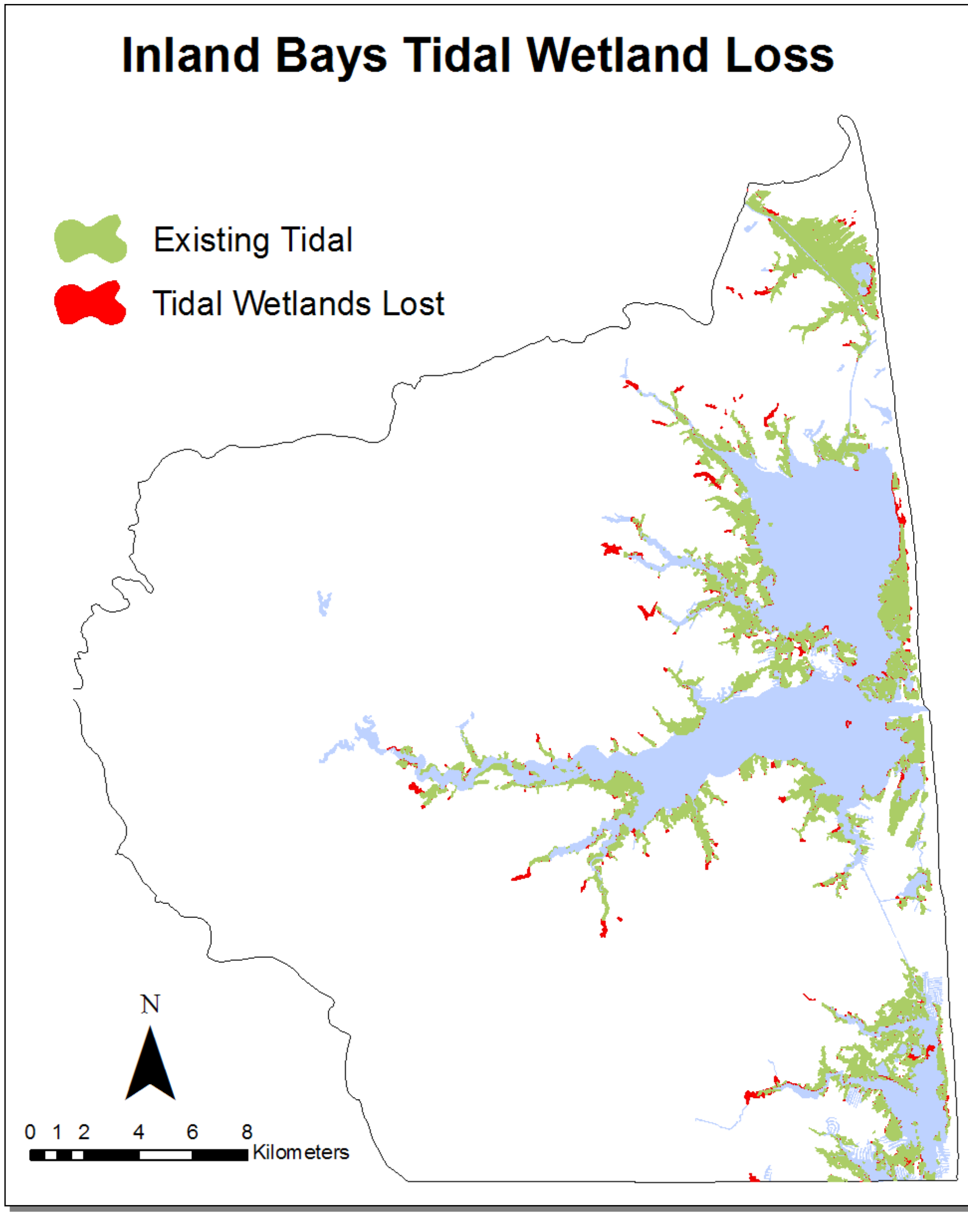


Figure 2. An example CDF showing wetland condition. The red line is the population estimate. The orange and green dashed lines show the breakpoints between condition categories.

RESULTS

4.1 Changes in Tidal Wetland Acreage

Historic wetland maps showed that the Inland Bays watershed contained approximately 10,800 acres of tidal wetlands (excluding unconsolidated bottom and shoreline habitat). Comparison with 1992 SWMP maps revealed that almost 1,300 acres, or 12% of the original acreage, has been lost (Map 4). The loss of tidal wetlands has been primarily due to development, sea level rise, dredging, creation of coastal ponds and impoundments, and natural impacts from storms (Tiner and Finn 1986, DE DNREC 2001). Areas of tidal marsh that have been converted to open water due to snow goose herbivory have also been documented largely in Little Assawoman Bay (http://www.inlandbays.org/cib_pm/pdfs/uploads/pdediebacktalk.pdf). There also appears to be a pattern of loss at the tidal headwaters of many of the tributaries to the bays. This loss is likely the result of channelization of streams and damming of streams to create mill ponds.



Map 3. Present (1992) and historic (pre-European settlement) distribution of tidal wetlands and wetlands in the Inland Bays watershed.

4.2 Landowner Contact and Site Access

We obtained landowner permission prior to accessing and sampling on private property sites. We identified landowners using county tax records and mailed a post card providing a brief description of our study goals, sampling techniques, and contact information. If a contact number was available, we followed the mailings with a phone call to discuss the site visit and secure permission.

Half (49.8%) of the tidal wetlands in the Inland Bays watershed were publicly owned or have a conservation easement. The remaining half (50.2%) of the tidal wetlands in the watershed were privately owned. Overall, we had an 89% success rate for gaining access to wetlands in the watershed (Figure 3). Of the 56 sites that we attempted to access, 4 could not be contacted, 2 denied permission and 50 accepted. Twenty-three sites were public (i.e. state or county owned or in a conservation easement) and 34 were private property. Our success rate for accessing privately owned sites was 82% (Figure 3) and we had full access to public wetlands.

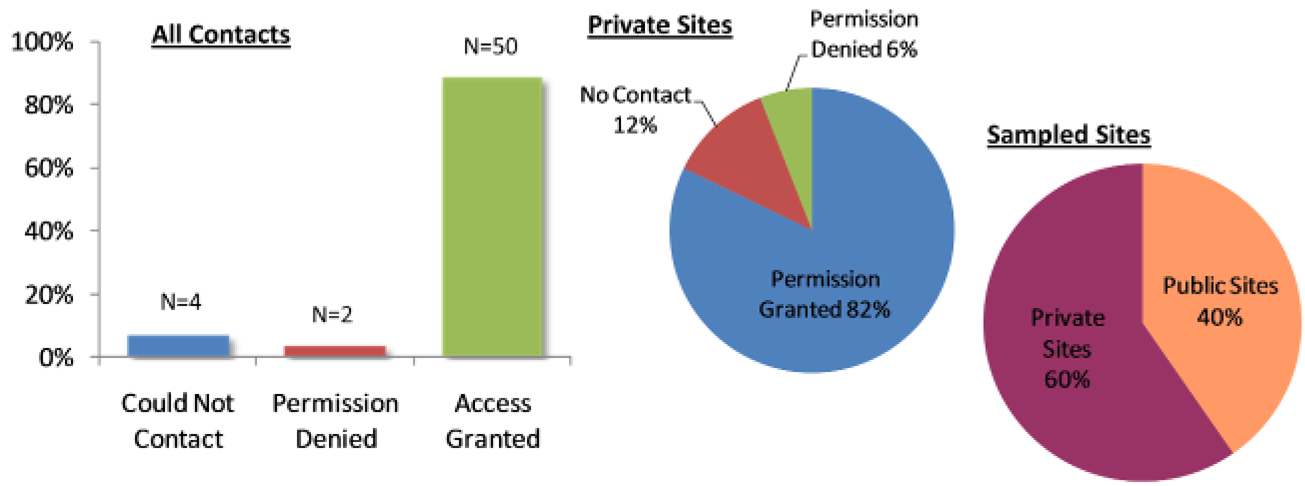


Figure 3. Overall landowner response rates (L), response rates for private sites (M), and ownership proportions for sampled sites (R) for tidal wetlands in the Inland Bays watershed 2007-2008.

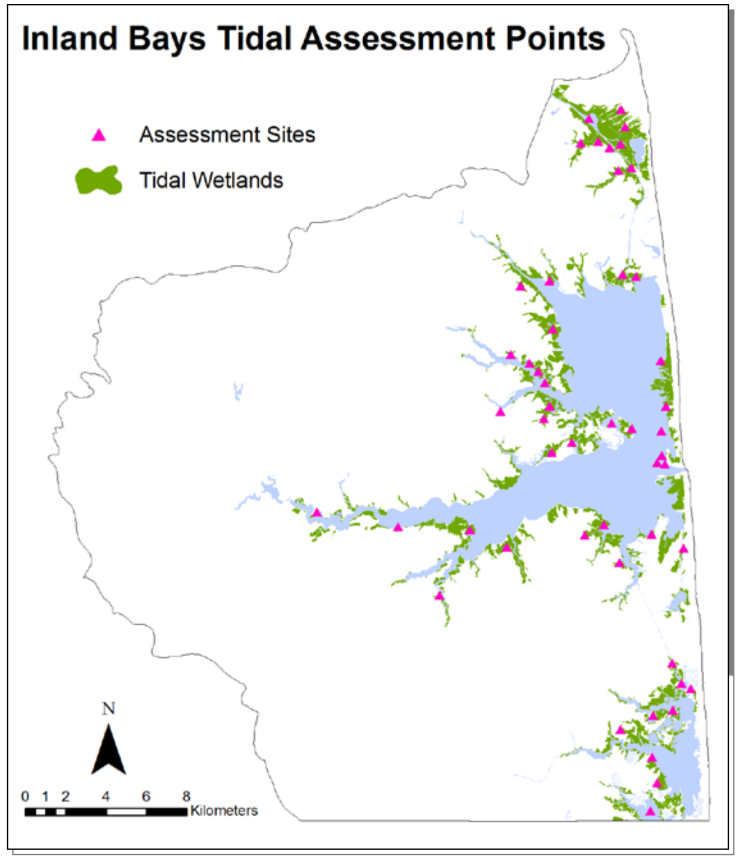
4.3 Wetland Condition

4.3.1 Inland Bays Overview

The 50 assessment sites were well disbursed throughout the watershed (Map 4) and encompassed a range of land uses in the buffer. For example, development in the buffer ranged from 0 to 50% of the total area within 500m of each site. The average condition score of tidal wetlands in the Inland Bays watershed was 70±10 and ranged from 48 to 85. Ten sites had a condition score of 80 or greater and were characterized by the absence of common stressors such as barriers to landward migration, invasive species, fill and fragmentation and had a high soil bearing capacity.

The cumulative distribution function graph for tidal wetlands in the Inland Bays watershed (Figure 4) represents the condition of the entire population of tidal wetlands and shows a fairly even slope across the population. A small proportion of the population was in high condition, illustrated by the leveling off of the curve above 81. Using the percentiles method to determine condition break points positioned the cutoffs close to the natural break points in the population (Figure 4).

Based on the MidTRAM condition scores, 28% of the tidal wetlands in the Inland Bays watershed were severely stressed, 56% moderately stressed, and 16% were minimally or not stressed (Figure 5 *right*). Highly stressed tidal wetlands averaged 11 stressors, moderately stressed wetlands averaged 8 stressors and minimally stressed wetlands averaged 6. In some cases, the number of stressors may be similar but the severity (5% fill or 75% fill) differed by



Map 4. Distribution of tidal wetland assessment sites in the Inland Bays watershed.

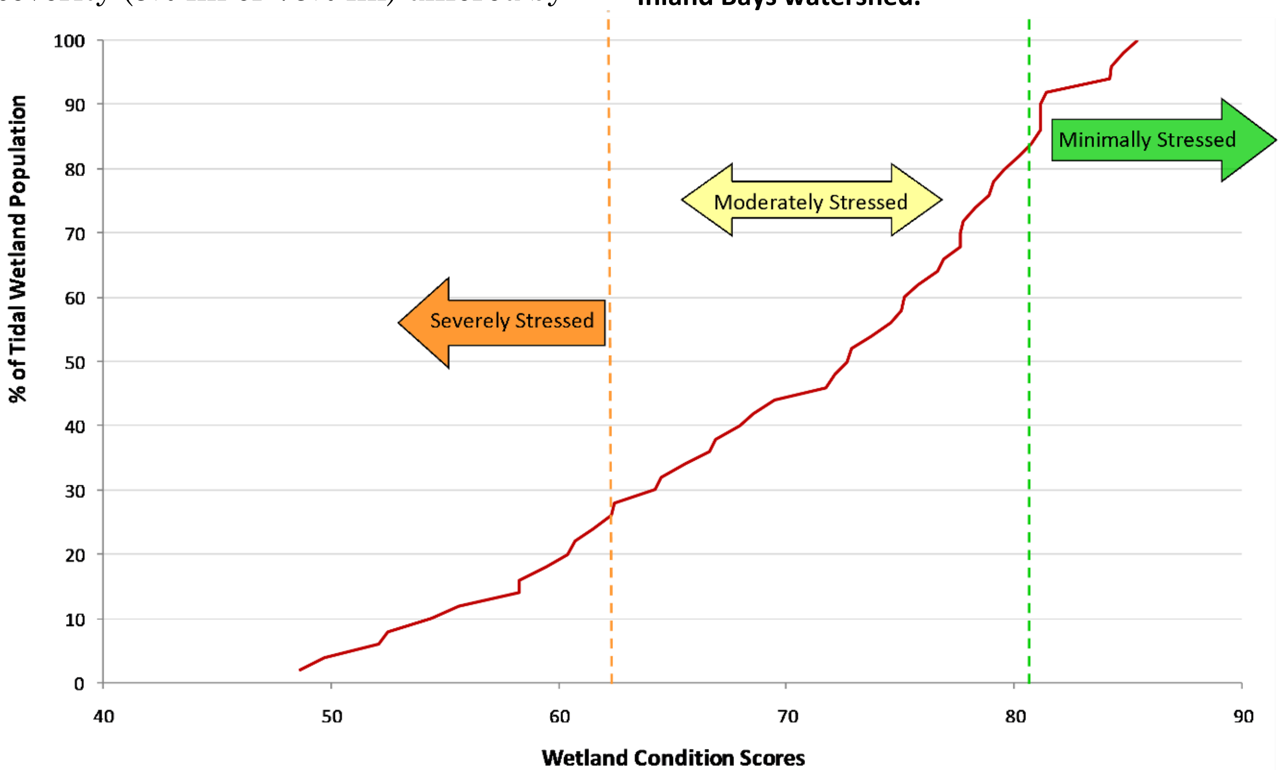


Figure 4. The Cumulative Distribution Function for tidal wetlands in the Inland Bays watershed. The orange and green dashed lines signify the condition category breakpoints dividing severely stressed from moderately and minimally stressed portions of the tidal wetland population.

overall condition. Some stressors were pervasive across condition groups such as ditching and draining (72% of population), diking and tidal restriction (88%), and disturbances to the buffer condition such as invasive species and soil disturbance (94%). We found that 30% of tidal wetlands had upland barriers to marsh migration such as bulkhead, houses or roads, with restrictions varying from 0 to 100% of the possible shoreline. Other stressors differed in occurrence by condition group (Figure 5 *left*). The presence of fill in the AA, cover by invasive plants, development in the buffer and barriers to landward migration increased between minimally and severely stressed wetlands. Results for the presence and severity of ditching or draining present did not correspond with condition category.

Metric Averages	Minimally Stressed	Moderately Stressed	Severely Stressed
proportion with ditching or draining present in AA	87%	75%	57%
% fill in AA	<1.0	<1.0	9
% cover by invasive plants in AA	<1.0	9	20
% development in 250m buffer	<1	6	23
% of buffer shoreline obstructed from marsh migration	0	3	50
buffer width (250m max)	212m	167m	176m

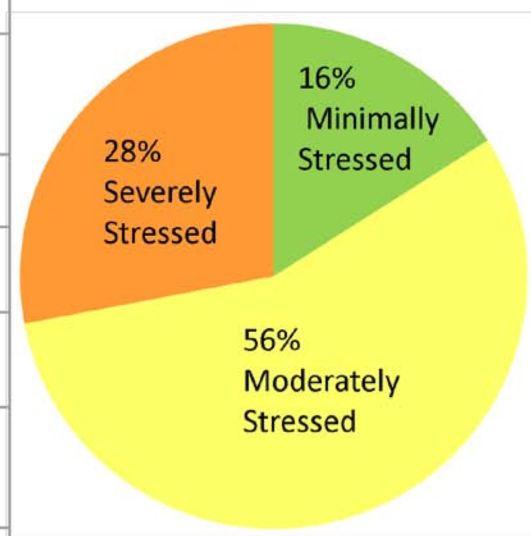


Figure 5. Stressor prevalence by condition group (left) and tidal wetland condition category proportions for the Inland Bays watershed (right).

The attribute groups (habitat, hydrology, and buffer) had similar averages ranging from 68 to 74 (Figure 6). The Habitat attribute group averaged 70±16 and ranged from 24 to 94. The presence of invasive plants in 56% of the tidal wetlands often lower scores in this group. Hydrology averaged 74±10 and ranged from 50 to 92. Overall, 88% of tidal wetlands had diking or tidal restriction present due to the presence of the stabilized inlet at the Indian River Bridge and 72% had

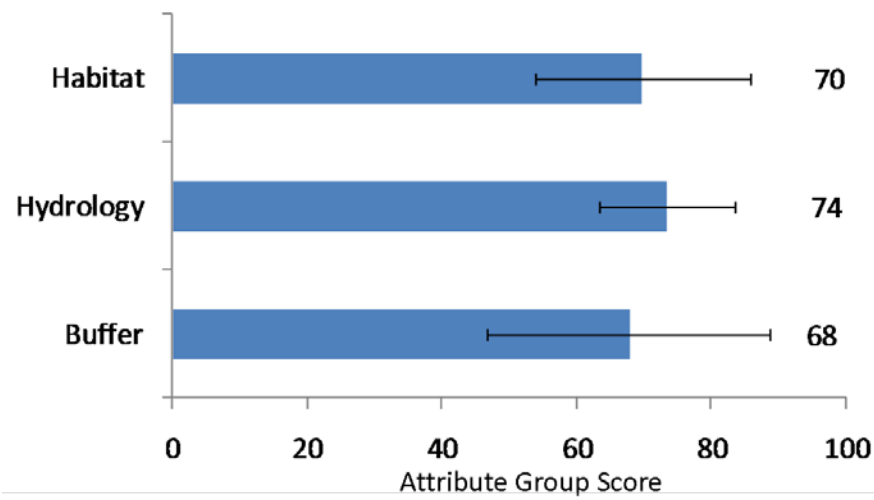


Figure 6. Attribute group averages and standard deviations for tidal wetlands in the Inland Bays watershed.

ditching and draining activities in the assessment area. The buffer attribute group averaged 68±21 and ranged from 7 to 100. A large portion of tidal wetland buffers across the watershed had some development (68%) or disturbances to landscape condition (94%; e.g. human visitation, soil compaction or nonnative plants) present within 250m.

4.3.2 Watershed Comparisons

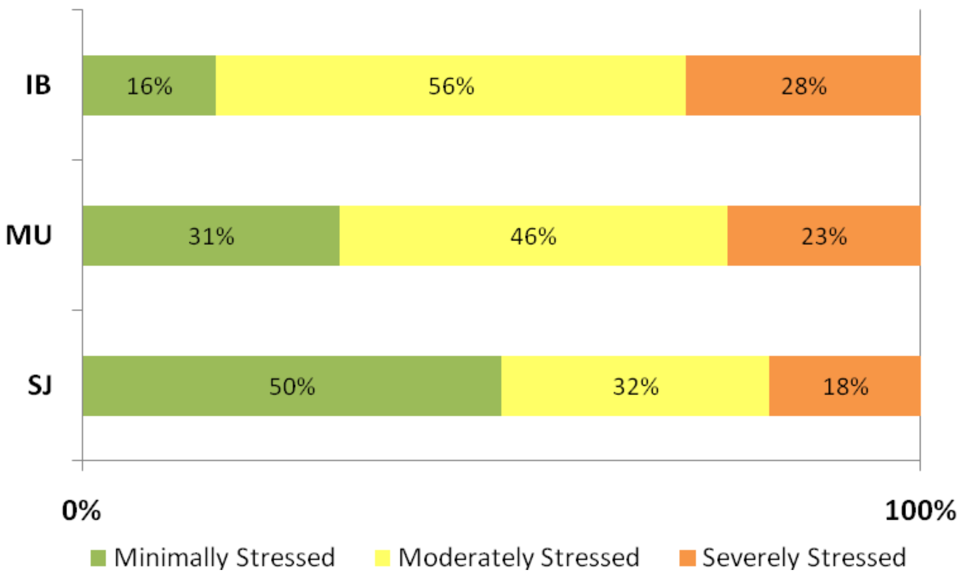


Figure 7. Condition of tidal wetlands in the Inland Bays, Murderkill and St. Jones watersheds in Delaware.

We compared the condition of tidal wetlands in the Inland Bays to those in the Murderkill and St. Jones watersheds. By combining the results of the 3 watersheds we can compare them and look for differences in watershed condition and stressor prevalence. The Inland Bays had the smallest portion of minimally stressed wetlands compared to the other watersheds, the largest portion of moderately stressed wetlands as well as the largest proportion of severely stressed (Figure 7).

4.3.3 Subwatershed Evaluation

We evaluated wetland condition across 3 subwatersheds in the Inland Bays: Indian River, Little Assawoman Bay and Rehoboth Bay. We compared the MidTRAM condition scores and 3 attribute groups (Table 3). The MidTRAM condition scores were similar between subwatersheds, averaging between 68 and 71. The attribute groups averaged between 54 and 79 and the lowest for each group was distributed across the 3 subwatersheds. Little Assawoman had the lowest buffer attribute score which was likely related to also having the highest proportion of development within 300m of the wetland site; 20% compared to 9% and 8% in the Indian River and Rehoboth Bay, respectively). We found a greater proportion of invasive species on our sites in the Indian River (19% cover) compared to in the Little Assawoman (7%) and Rehoboth (10%) subwatersheds which may have contributed to Indian River having the lowest habitat attribute score. Rehoboth Bay had the lowest hydrology attribute score and had a high instance of both ditching and filling. A larger sample size may have highlighted broader subwatershed patterns.

Table 3. Attribute group scores (±SD), MidTRAM score (±SD) and landuse values for Indian River, Little Assawoman and Rehoboth Bay subwatersheds of the Inland Bays watershed.

	Indian River N=13	Little Assawoman N=9	Rehoboth Bay N=28
Buffer	70±13	54±25	74±22
Hydrology	74±14	79±6	71±9
Habitat	60±19	76±12	72±14
MidTRAM	68.2±10	70±9	71.6±11

4.4 Impact of Sudden Wetland Dieback

4.4.1 Wetland Condition

MidTRAM condition scores and attribute group scores did not differ between sites that were or were not affected by SWD in 2006 (Table 4). Some indicators were the same between affected and not affected sites, such as average plant fragments (16.3cc vs. 17.0cc), average bearing capacity (2.8 vs. 2.7cm) and percent of shoreline with barriers to landward migration (17.5% vs. 14.2%). However, affected sites had ditching and draining present more often (85%) than not affected sites (63%). The presence of diking and tidal restriction also differed between affected (100%) and not affected sites (80%).

Table 4. Attribute group score and MidTRAM scores for tidal wetlands affected by and not affected by SWD in the Inland Bays watershed in 2008.

	Affected N=20		Not Affected N=30				
	x	SE	x	SE	df	t	*P*
Buffer	74	18	64	22	1, 48	-1.59	0.118
Hydro	71	10	75	11	1, 48	1.48	0.148
Habitat	68	17	71	15	1, 48	0.59	0.514
Condition Score	71	11	70	10	1, 48	-0.33	0.812

In comparing biomass values using means and standard deviations between the dieback groups, we did not detect any differences with our small data set for above ground biomass ($X_{affected}$=25g±7, N=5; $X_{not\_affected}$=22g±9, N=5), below ground biomass ($X_{affected}$=187g±63; $X_{not\_affected}$=221g±44), or above to below ground ratio ($X_{affected}$=0.14±0.04; $X_{not\_affected}$=0.10±0.06). If affected sites have less below ground biomass this could reduce plant and marsh stability, and contribute to marsh subsidence and possibly the susceptibility to other stressors such as future occurrences of SWD. A larger dataset is needed to fully determine if there are differences among sites.

4.4.2 Monitoring Recovery

The vegetation patterns for 2006-2008 from 4 monitoring sites are shown in Figure 8. The Center for Inland Bays plot was unaffected by dieback and has remained largely unchanged. Burton Island West has maintained live vegetation, but has an increasingly large portion of unvegetated, open marsh. Piney Point has shown the most recovery since 2006 with steady increases in live vegetation, decreases in dead patches and small proportions of unvegetated marsh. Cotton Patch was the most severely affected and showed some signs of recovery from dieback with increases in live vegetation and decreases in dead vegetation, but still had large areas of unvegetated marsh. Increases in the proportion of live vegetation indicated that the wetlands were recovering whereas increases or sustained levels of dead vegetation and/or unvegetated areas suggested either that the marsh was still being affected by SWD or that recovery was not occurring.

Marsh elevation averages for 2007 and 2008 are shown in Table 5. The only site not affected by SWD was Center for the Inland Bays which had a slightly higher elevation than Burton Island and Cotton Patch and increased in surface elevation between 2007 and 2008. Piney Point was affected by SWD in 2006 and had only 25% live vegetation at the end of the growing season (Figure 8). Although showing a decrease in elevation between 2007 and 2008, Piney Point had the highest elevation of the four marshes, the fastest recovery of the three sites that were affected, and had 80% live vegetation at the end of the growing season in 2008. Cotton Patch had the lowest elevation in 2007 and was also the most severely affected by SWD having < 5% live vegetation at the end of the growing season in 2006. Vegetation at this site showed slow recovery with increasing live vegetation. It also had an increase in elevation between 2007 and 2008. Burton Island West was the only site affected by SWD that consistently did not show an increase in live vegetation between 2006 and 2008. Surface elevation for Burton Island did not change over the 2-year period.

These monitoring data suggest that recovery of SWD may be linked to marsh elevation perhaps by facilitating recovery or influencing the rate of recovery. More information is needed to determine the factors that are influencing elevation trends (subsidence versus accretion).

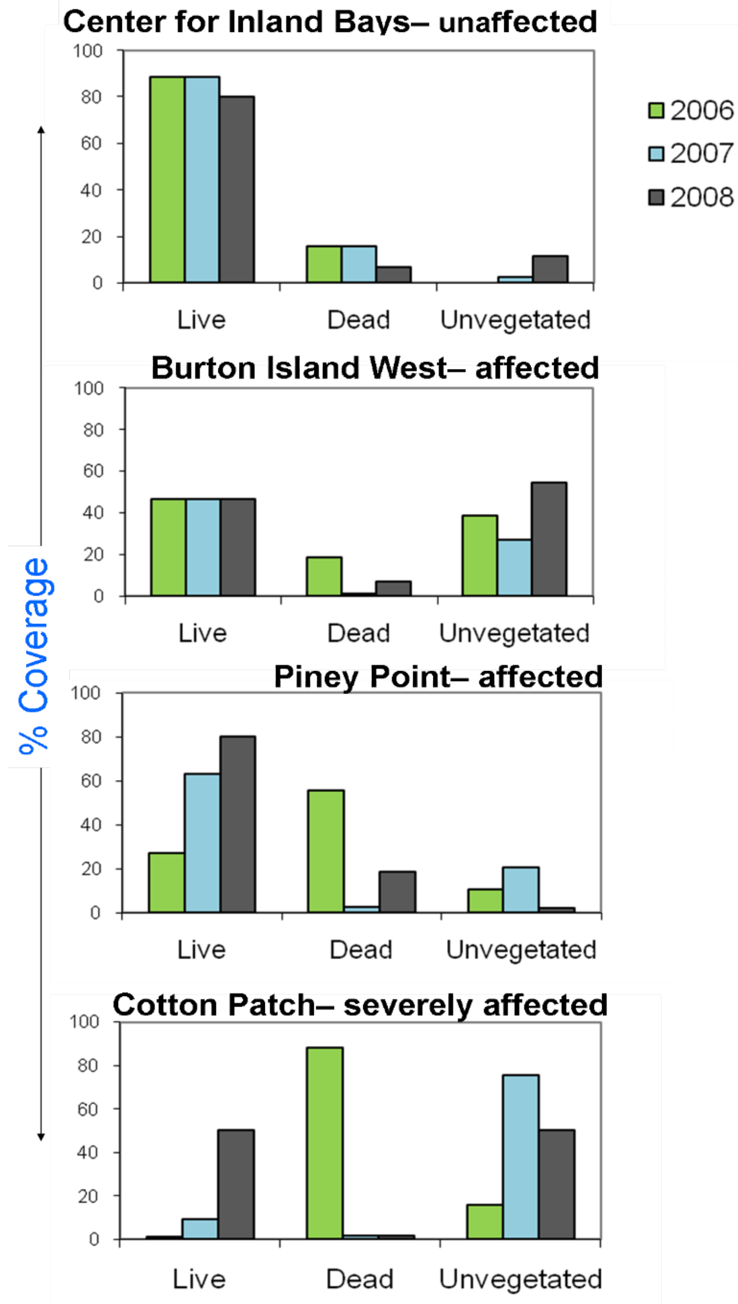


Figure 8. Vegetation patterns for dieback permanent plots in the Inland Bays.

Table 5. Mean elevations (feet) and standard deviations for sudden wetland dieback monitoring plots in the Inland Bays.

	2007 Average	2008 Average	*P*	Elevation Pattern
Center for Inland Bays (unaffected)	0.765±0.26	0.899±0.30	0.010	Increasing
Burton Island West (affected)	0.682±0.46	0.584±0.29	0.072	Stable
Piney Point (affected)	1.274±0.37	1.020±0.20	<0.001	Decreasing
Cotton Patch (severely affected)	0.645±0.26	0.734±0.26	0.024	Increasing

4.5 Comparison with Intensive Biotic Data

We compared the MidTRAM condition scores to more intensive measures of the biotic community using marsh birds and vegetative biomass. The MidTRAM was designed to give a basic wetland condition rating based on variables and metrics that are responsive to disturbance. Correlating MidTRAM data to more intensive measures of wetlands would validate the assessment method and increase confidence that it is able to distinguish and differentiate tidal wetlands on a disturbance gradient. Marsh birds were fairly easy to sample, represented a higher trophic level, and have been noted as indicators of marsh integrity previously (DeLuca et al. 2004, Banning 2007, Conway 2008). Biomass was an attribute of marsh systems that has been related to marsh condition (Turner et al. 2004) in regards to plant production, marsh stability and accretion.

4.5.1 Marsh birds

We documented 37 bird species at 25 sites assessed for marsh bird community integrity. Seaside sparrows, clapper rails and red-winged blackbirds were the most frequently detected. The W_{IMBCI} values ranged from 3.3 to 13.2 on a scale starting at 0. A comparison of the IMBCI values to the attribute group scores and to the MidTRAM condition scores did not show a relationship (P≥0.13). A regression of the relationship between MidTRAM and the IMBCI values by condition category showed weak separation (Figure 9). Interestingly, species richness showed a negative relationship with MidTRAM condition scores when they were regressed together. Further investigation of the relationship between rapid condition information and bird community integrity would require a larger sample size. Survey data for the 7 Inland Bays sites are in APPENDIX B.

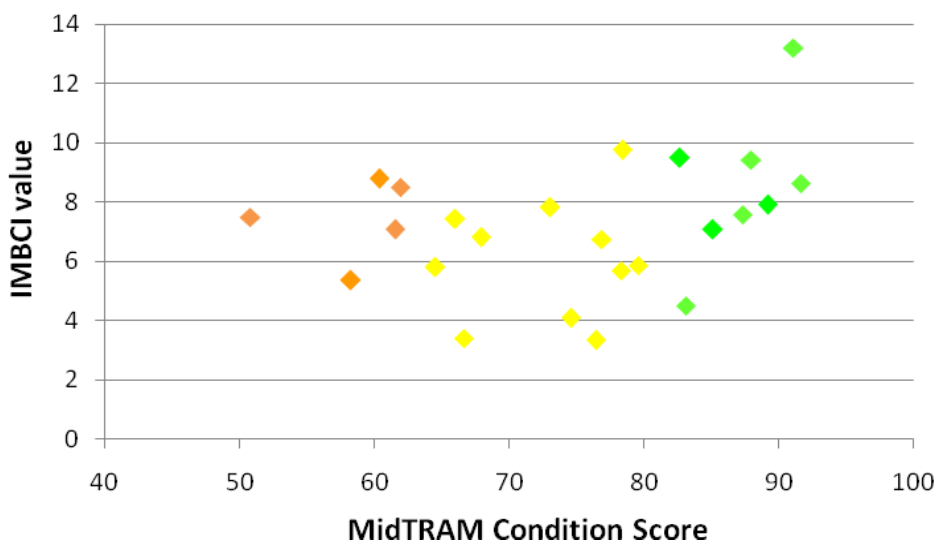


Figure 9. MidTRAM Condition scores and IMBCI values for tidal wetland sites in the Inland Bays, Muderkill and St. Jones watersheds, DE. Site points are colored by condition category: green (minimally stressed), yellow (moderately stressed), and orange (severely stressed).

4.5.2 Biomass

We found a positive relationship between below ground biomass and MidTRAM condition scores (r^2=0.24, P=0.022) indicating that sites with higher below ground biomass also had higher condition scores (Figure 10). We also found a negative relationship between the MidTRAM condition scores and above:below ground biomass (r^2=0.35, P=0.003) which suggested that with decreasing condition scores there is more above ground biomass compared to below ground. This is consistent with the idea that stressed wetland plants place more energy in above ground biomass production rather than below ground (Turner et al. 2004). In a healthy system, plants should be able to produce ample root mass which accumulates as biomass. We did not see a similar pattern with above ground biomass ($P>0.10$). This is concurrent with previous research in tidal wetlands that related healthy tidal wetlands to greater below ground biomass (Turner et al. 2004). We recommend that these relationships be further evaluated with a larger dataset. The vegetative biomass data for the 10 Inland Bays watershed sites are shown in APPENDIX C.

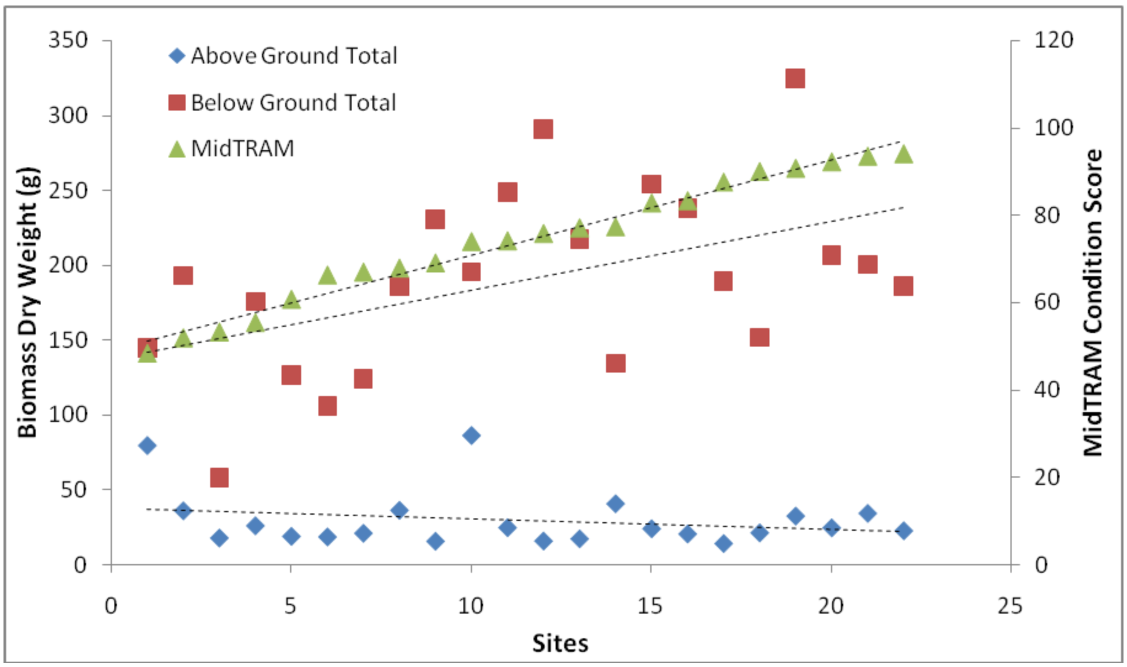


Figure 10. MidTRAM condition scores and above and below ground vegetative biomass for 22 tidal sites in the Inland Bays, Murderkill and St. Jones watershed, DE.

4.6 Method Evaluation

This report represents the first summary of assessment data using the MidTRAM to evaluate the condition of tidal wetlands in Delaware. As such, we took this opportunity to reflect on the method and its ability to indicate wetland condition and stressor trends as well as recommend areas for future refinement of the method. MidTRAM was able to identify wetland stressors that were common to the entire population as well as those that were more prevalent in different condition levels. Our evaluation of the metric and attribute scoring patterns suggested that the buffer metrics are playing the strongest role in determining the MidTRAM condition score (Figure 11). This may be a result of tidal wetlands being a habitat type that is naturally low in vegetative diversity and upon which the biotic measurements were based. The nature of this habitat makes it challenging to perceive fine changes in condition using rapid indicators. This may also indicate that we need to continue re-evaluating which hydrology and habitat metrics we use in the method or refine how they are measured and scored. Based on the low R^2 value above and the order of the attribute averages between condition groups (Figure 12) the hydrology metrics should be investigated further.

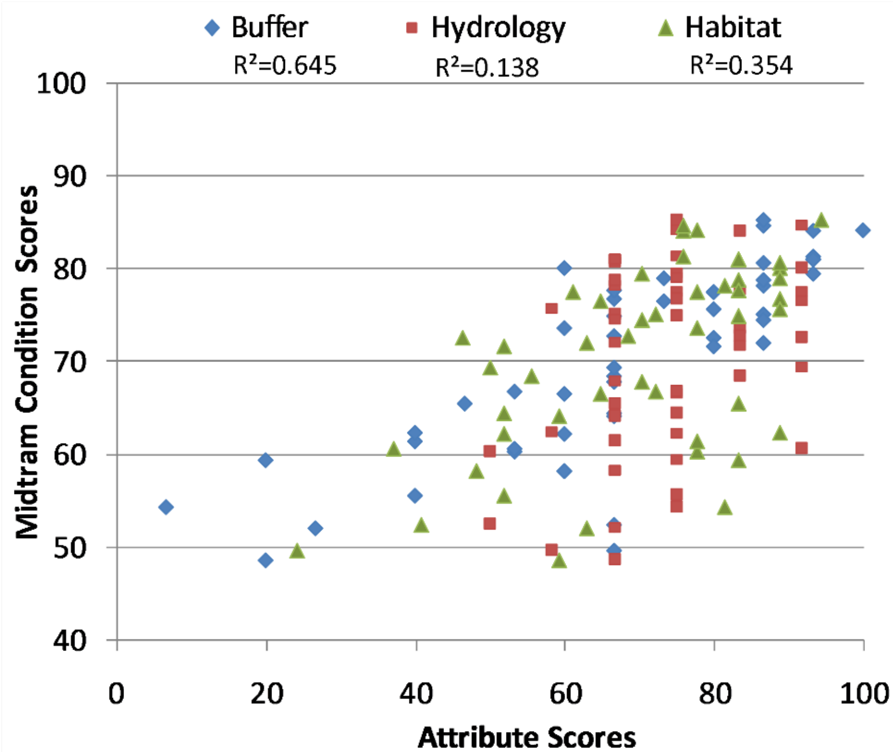


Figure 11. Attribute group and MidTRAM condition score regressions.

We found that MidTRAM can differentiate sites based on a set of rapid indicators that have been linked to tidal wetland condition. Additional research is needed to understand the specific relationships between the MidTRAM condition score, presence of stressors and wetland function.

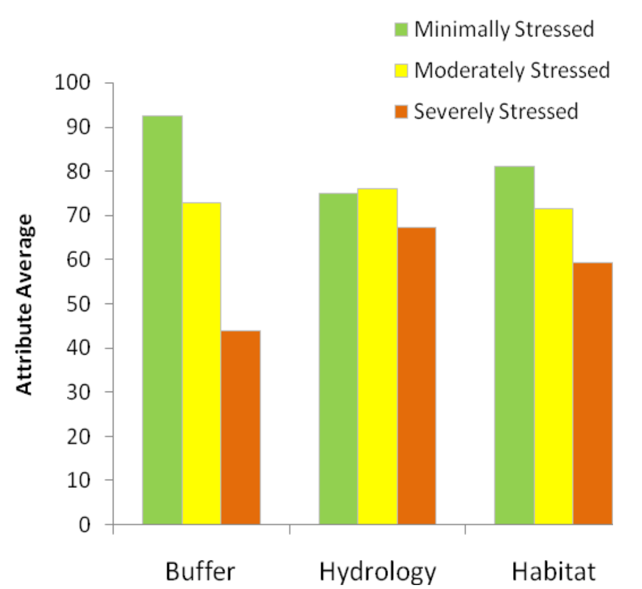


Figure 12. Mean attribute scores by condition group.

MANAGEMENT RECOMMENDATIONS

The majority of tidal wetlands in the Inland Bays watershed have been degraded. Several stressors are pervasive across the watershed such as wetland diking or tidal restriction in 88% of wetlands, ditching and draining activities in 72% of wetlands, development in the buffer in 68% of wetlands, and invasive species present in 56% of wetlands. Additionally, the Inland Bays had a greater proportion of wetlands in severely stressed condition than the Murderkill or St. Jones watersheds in the Delaware Bay estuary. Based on our observations, we offer the following recommendations to improve wetland management, to help identify additional data needs, and to encourage informed decisions concerning the future of tidal wetlands in the Inland Bays watershed.

1. **Protect tidal wetlands from further degradation by minimizing activity in wetlands and in the adjacent buffers**. Activities in tidal wetlands are regulated by the State of Delaware and the Army Corps of Engineers. Current state and federal regulations have the ability to control activities within wetlands such as dredging, filling, shoreline stabilization or building structures, but permits are often granted, especially for proposed small impacts. However, even these small impacts can degrade the condition of the wetlands, and over the watershed many small impacts lead to potentially large cumulative impacts.

   Nearly thirty percent of the tidal wetlands in the Inland Bays are severely stressed and 56% are moderately stressed. To prevent further degradation of tidal wetlands, no impacts should be permitted within minimally stressed wetlands or in their surrounding areas. Additionally, any activities in or surrounding moderately stressed or severely stressed wetlands should not allow further degradation of their condition.

2. **Enforce buffer regulations and allow migration of wetlands with future climate change.** Impacts that occur outside of the wetland in the adjacent upland areas also affect the condition of wetlands and their ability to provide services. The Inland Bays Pollution Control Strategy (DNREC 2008) recently established buffers up to 100ft for state regulated wetlands. The importance of buffers is supported by our data which showed that wetlands with lower buffer attribute scores also had lower habitat attribute scores. Buffers on tidal wetlands are also needed to allow landward migration of wetlands as sea level rises. Currently, 30% of tidal wetlands in the Inland Bays have shoreline barriers that will prevent landward migration, causing increased losses of wetlands due to sea level rise. No additional barriers should be permitted and wider buffers should be established in order to allow the best opportunity for wetlands to persist with future climate changes.

3. **Determine the stressors that are having the greatest impact on tidal wetland condition and focus on these for restoration.** MidTRAM offers an evaluation of wetland condition and stressors which is valuable for articulating the status of tidal wetlands on a watershed scale. Because of the nature of rapid assessment methods, many of the variables that comprise the methods are based on qualitative assessment of the presence of indicators or stressors. The removal of stressors will improve wetland condition. However, more research is needed to determine the relationship between specific stressors and wetland function (e.g. how is the presence of ditches in a wetland affecting the ability of a wetland to support a native plant community or store carbon?) and which stressors are having the greatest impact on wetland functions (e.g. do ditches or tidal restrictions have the greatest impact on the hydrology of the wetlands?). Once the stressors that are having the greatest impact on wetland function are determined, they should be a priority for restoration and enhancement activities.

4. **Further evaluate the relationship between wetland condition, elevation, and biomass to make informed decisions to improve tidal wetland resiliency to future stressors.** Although our data suggests that there was no lasting effect of SWD on the condition of wetlands in the Inland Bays based on the rapid indicators of the MidTRAM, more intensive data suggests that there may be a relationship between wetland condition, below ground biomass, tidal wetland elevation, and recovery from SWD. Preliminary data suggested that there was a difference in recovery rates with marsh elevation. More data is needed to further explore if these relationships exist and determine factors that will allow wetlands to be resilient to future stressors and changes. Understanding these relationships will determine management actions that could be used to maintain or increase marsh elevation to allow tidal wetlands to persist with increasing sea level and other future stressors on these systems. As part of this work, additional data on wetland subsidence and accretion rates are also needed.

5. **Monitor changes in wetland condition over time.** The MidTRAM should be used to monitor changes in wetlands over time and track improvement in wetland condition after restoration or enhancement activities. Evaluating trends over time will determine if various aspects of wetlands are changing (e.g. habitat versus hydrology metrics) as well as if certain stressors are becoming more or less pervasive (e.g. invasive species, development in buffer). This information can then be used to implement adaptive management practices and adjust protection and restoration priorities and management actions.

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APPENDIX A: MidTRAM VARIABLE AND METRIC DATA FROM INLAND BAYS TIDAL WETLAND SITES*

Site Number	QCR	H1: Ditching & Draining	(H2): Estimate amount of fill	H2: Fill & Fragmentation	H3: Diking & Restriction	H4: Point Source	(B1): %AA with 5m-buffer	B1:% AA 5m-Buffer	(B2): Average Buffer Width (m)	B2: Average Buffer Width	(B3): % Development	B3: Surrounding development	B4: 250m Landscape Condition
IB0001	4	12	0	12	3	12	20	3	105	6	75	3	3
IB0002	4	6	3	9	9	12	100	12	191	12	10	6	6
IB0003	4	6	10	6	9	9	45	9	216	12	3	9	6
IB0005	4	6	0	12	12	12	100	12	47	3	1	9	6
IB0006	4	6	0	12	9	12	100	12	184	9	15	6	6
IB0007	3	3	0	12	9	12	100	12	213	12	5	9	9
IB0008	5	12	0	12	9	12	100	12	171	9	0	12	6
IB0009	3	3	0	12	12	12	100	12	173	9	25	3	6
IB0010	2	6	0	12	9	12	100	12	204	12	0	12	9
IB0011	3	3	0	12	9	12	100	12	161	9	5	9	9
IB0012	3	12	0	12	9	12	100	12	106	6	0	12	6
IB0014	2	9	0	12	9	12	100	12	223	12	0	12	9
IB0015	5	12	0	12	9	12	100	12	178	9	0	12	6
IB0016	2	12	0	12	9	12	100	12	206	12	1	9	9
IB0017	3	6	3	9	12	12	100	12	236	12	5	9	6
IB0018	6	12	0	12	9	12	100	12	162	9	25	3	3
IB0019	6	12	1	9	9	6	90	9	209	12	40	3	6
IB0020	6	3	0	12	3	12	100	12	170	9	10	6	6
IB0022	5	12	40	3	9	12	55	6	172	9	45	3	3
IB0023	2	6	0	12	9	12	100	12	113	6	0	12	12
IB0024	2	6	0	12	9	12	100	12	250	12	0	12	12
IB0025	4	12	0	12	6	12	100	12	184	9	2	9	9
IB0026	3	12	0	12	9	9	100	12	178	9	2	9	6
IB0027	5	12	30	3	9	12	50	6	213	12	50	3	3
IB0028	4	6	2	9	9	12	100	12	204	12	0	12	6
IB0029	5	12	20	3	9	12	85	9	156	9	10	6	6
IB0030	4	12	0	12	9	12	100	12	169	9	6	6	6
IB0031	3	3	0	12	9	12	100	12	175	9	0	12	9
IB0032	4	3	0	12	9	12	100	12	166	9	7	6	6
IB0033	5	9	20	6	12	12	90	9	117	6	30	3	3
IB0034	2	6	0	12	9	12	100	12	244	12	0	12	9

IB0035	3	3	0	12	9	12	100	12	191	12	1	9	9
IB0036	4	6	1	6	9	12	100	12	125	6	17	3	3
IB0037	4	9	0	12	12	12	100	12	109	6	12	6	6
IB0038	5	6	0	12	3	12	100	12	206	12	3	9	6
IB0039	3	6	3	9	9	12	100	12	211	12	0	12	6
IB0040	2	6	2	9	9	12	100	12	250	12	0	12	9
IB0041	3	6	2	9	12	12	100	12	124	6	1	9	6
IB0043	4	9	0	12	3	12	100	12	182	9	12	6	6
IB0044	2	3	0	12	9	12	100	12	183	9	0	12	9
IB0045	3	3	0	12	9	12	100	12	250	12	0	12	9
IB0046	4	9	0	12	9	12	100	12	228	12	20	3	6
IB0047	4	6	0	12	9	12	100	12	163	9	5	9	6
IB0048	3	6	0	12	9	12	100	12	204	12	12	6	6
IB0050	2	3	0	12	9	12	100	12	161	9	0	12	12
IB0051	2	9	1	9	9	6	100	12	108	6	0	12	9
IB0053	4	9	1	9	9	12	100	12	105	6	25	3	6
IB0054	4	6	0	12	9	12	100	12	169	9	25	3	6
IB0055	4	12	2	9	9	12	100	12	122	6	5	9	6
IB0056	4	6	0	12	9	12	100	12	250	12	2	9	6

*Gray columns ( ) denote variable data; Green columns indicate metric scores; All sites were assessed in 2008 and scored with MidTRAM protocol version 2.0

APPENDIX A continued

Site Number	(B6): % Perimeter Obstructed	B6: Barriers to Landward Migration	(HAB2): Bearing Capacity	HAB2: Bearing Capacity	(HAB3:) Plant Fragments	HAB3: Plant Fragments	HAB4: Vertical Biotic Structure	(HAB5:) # of Plant Layers	HAB5: # of Plant Layers	(HAB6): % of Non-native co-dominant species	HAB6: % of Non-native co-dominant species	(HAB7): % Invasive	HAB7: % Invasive
IB0001	80	3	2.000	9	15.5	8	12	2	9	0	12	0	12
IB0002	20	6	3.375	9	14.0	8	6	3	9	50	3	20	9
IB0003	75	3	2.313	9	23.0	12	9	4	12	29	9	20	9
IB0005	0	12	3.313	9	17.5	12	6	3	9	0	12	0	12
IB0006	0	12	6.750	3	8.0	4	6	2	9	0	12	0	12
IB0007	0	12	0.938	12	17.3	8	9	3	9	0	12	0	12
IB0008	0	12	1.813	9	9.3	7	12	3	9	40	6	63	3
IB0009	0	12	2.250	9	12.0	8	9	3	9	20	9	7	9
IB0010	0	12	3.375	9	15.3	8	9	1	6	0	12	0	12
IB0011	24	6	3.063	9	11.5	8	6	2	9	0	12	0	12
IB0012	0	12	2.313	9	16.5	8	6	4	12	25	9	16	9
IB0014	0	12	1.938	9	13.8	8	9	2	9	0	12	0	12
IB0015	0	12	3.188	9	20.3	12	6	4	12	38	6	30	6
IB0016	0	12	2.938	9	16.8	8	9	3	9	0	12	0	12
IB0017	0	12	1.188	12	19.3	12	9	3	9	16	9	1	9
IB0018	0	12	6.375	3	13.3	8	12	2	9	50	3	95	3
IB0019	0	12	3.188	9	15.5	8	9	4	12	80	3	88	3
IB0020	0	12	3.688	9	5.8	4	3	4	12	50	3	20	9
IB0022	100	3	4.188	6	16.3	8	9	4	12	33	6	15	9
IB0023	0	12	1.250	12	17.5	12	12	2	9	0	12	0	12
IB0024	0	12	1.375	12	19.8	12	3	2	9	0	12	0	12
IB0025	0	12	6.688	3	6.0	4	12	4	12	20	9	30	6
IB0026	5	9	2.750	6	23.5	12	9	3	9	40	6	35	6
IB0027	100	3	3.313	9	10.5	4	9	4	12	29	9	1	9
IB0028	0	12	2.563	9	23.8	12	9	4	12	40	6	6	9
IB0029	100	3	2.500	9	17.8	12	9	4	12	20	9	15	9
IB0030	0	12	5.563	3	19.8	12	9	3	9	50	3	4	9
IB0031	0	12	2.000	9	12.8	8	6	2	9	0	12	0	12
IB0032	45	3	2.125	9	26.5	12	9	2	9	0	12	0	12

IB0033	50	3	1.500	12	22.5	12	9	4	12	18	9	15	9
IB0034	0	12	2.875	9	15.5	8	9	2	9	0	12	0	12
IB0035	0	12	2.063	9	17.5	12	9	3	9	0	12	0	12
IB0036	8	9	1.563	12	18.8	12	9	3	9	0	12	0	12
IB0037	0	12	2.875	9	19.3	12	12	4	12	0	12	1	9
IB0038	10	6	.	3	.	4	3	3	9	50	3	2	9
IB0039	0	12	2.250	9	8.25	4	9	4	12	22	9	15	9
IB0040	0	12	1.375	12	19.0	12	9	4	12	29	9	7	9
IB0041	0	12	1.813	12	19.8	12	9	3	9	0	12	0	12
IB0043	0	12	5.625	6	12.8	8	6	4	12	29	9	2	9
IB0044	0	12	1.438	12	19.8	12	9	2	9	0	12	0	12
IB0045	0	12	3.563	9	18.0	12	9	3	9	0	12	0	12
IB0046	0	12	4.625	6	19.5	12	12	3	9	0	12	0	12
IB0047	8	9	1.813	12	26.0	12	9	2	9	0	12	1	9
IB0048	0	12	1.688	12	21.8	12	9	3	9	0	12	0	12
IB0050	0	12	1.938	9	26.0	12	9	2	9	0	12	0	12
IB0051	0	12	1.688	12	26.5	12	9	2	9	0	12	0	12
IB0053	0	12	1.938	9	21.3	12	12	3	9	33	6	5	9
IB0054	50	3	2.625	9	10.0	4	12	3	9	66	3	7	9
IB0055	0	12	1.375	12	11.3	4	12	4	12	20	9	40	6
IB0056	100	3	2.188	3	9.5	4	12	4	12	33	6	25	9

*Gray columns and ( ) denote variable data; Green columns indicate metric scores; All sites were assessed in 2008 and scored with MidTRAM protocol version 2.0

APPENDIX B: BIRD SURVEY DATA FROM INLAND BAYS TIDAL WETLAND SITES

Species	SIMBCI	IB0002	IB0003	IB0006	IB0007	IB0009	IB0010	IB0011
American goldfinch	6.5	x						
bald eagle	7						x	
bank swallow	14							x
barn swallow	9.5	x		x			x	
boat-tailed grackle *	14				x			
Canada Goose	5			x	x			
Carolina chickadee	6					x		
clapper rail *	5.5	x	x	x	x		x	x
common grackle	4			x				
common merganser	4							x
common yellowthroat	4	x	x	x		x		
great-blue heron	5.5	x						
herring gull	4				x			
king rail*	5							x
laughing gull	4			x	x		x	x
least tern	4			x			x	x
lesser yellowlegs	7.5						x	
mallard	8							x
marsh wren*	6.5					x		
Osprey	6				x			
red-tailed hawk	4					x		
red-winged blackbird	7.5	x	x		x	x	x	x
seaside sparrow*	6	x	x	x	x		x	x
snowy egret	9						x	
spotted sandpiper	5						x	
swamp sparrow*	7.5		x					
tree swallow	5		x				x	x
Virginia rail*	7.5		x					
WIMBCI		5.36	8.79	5.81	5.69	3.4	5.86	6.8

* indicates an obligate marsh species

APPENDIX C: BIOMASS DATA FOR INLAND BAYS TIDAL WETLAND SITES

Site Number	Above Dead	Above Live	Above Total	Below Dead Total	Below Live Total	Below Total	Above : Below	Above Live: Below Live	Above Dead: Below Dead
IB0001	15.70	20.46	36.16	180.70	12.45	193.15	0.1872	1.6434	0.0869
IB0002	6.00	13.06	19.06	109.82	16.80	126.62	0.1505	0.7774	0.0547
IB0003	12.93	13.23	26.16	157.96	17.81	175.77	0.1488	0.7428	0.0819
IB0006	8.24	12.9	21.14	109.87	14.09	123.96	0.1705	0.9155	0.0750
IB0007	8.12	7.83	15.95	251.80	39.17	290.97	0.0548	0.1999	0.0322
IB0009	12.60	3.20	15.80	221.29	9.38	230.67	0.0685	0.3412	0.0569
IB0010	8.43	9.01	17.44	196.70	20.74	217.44	0.0802	0.4344	0.0429
IB0011	28.12	8.38	36.50	174.36	11.25	185.61	0.1966	0.7449	0.1613
IB0012	15.88	9.02	24.90	233.06	15.79	248.85	0.1001	0.5712	0.0681
IB0016	12.49	11.68	24.17	238.34	15.90	254.24	0.0951	0.7346	0.0524

Mid-Atlantic Tidal Wetland Rapid Assessment Method V2.0

Site #_______ Date ____/______/______

B1. Percent of Assessment Area Perimeter with 5m-Buffer

Record Estimated Percent ______________%	
Alternative States(not including open-water areas)	**Rating (circle one)**
Buffer is 100% of AA perimeter.	**12**
Buffer is 75-99% of AA perimeter.	**9**
Buffer is 50-74% of AA perimeter.	**6**
Buffer is <50% of AA perimeter.	**3**

B2. Average Buffer Width (max 250m)

Line	**Buffer Width (m)**
A	
B	
C	
D	
E	
F	
G	
H	
Average Buffer Width ______________	
Alternative States	**Rating (circle one)**
Average buffer width 190-250m	**12**
Average buffer width 130-189m	**9**
Average buffer width 65-129m	**6**
Average buffer width 0-64m	**3**

B3. Surrounding Development Within 250m of edge of AA

Estimate Development ______________%	
Alternative States	**Rating (circle one)**
0% development	**12**
>0-5% development	**9**
>5-15% development	**6**
>15% development	**3**

B4. 250m Landscape Condition

Alternative States	**Rating (circle one)**
AA's surrounding landscape is comprised of only native vegetation, has undisturbed soils, and is apparently subject to no human disturbance.	**12**
AA's surrounding landscape is dominated by native vegetation, has undisturbed soils, and is apparently subject to little or no human visitation.	**9**
AA's surrounding landscape is characterized by an intermediate mix of native and non-native vegetation, and/or a moderate degree of soil disturbance/compaction, and/or there is evidence of moderate human visitation.	**6**
AA's surrounding landscape is characterized by barren ground and/or dominated by invasive species and/or highly compacted or otherwise disturbed soils, and/or there is evidence of very intensive human visitation.	**3**

B5. Barriers to Landward Migration

% Perimeter Obstructed ______________%

Dist. From Center of AA _____________m

Alternative States	**Rating (circle one)**
Absent: no barriers	**12**
Low: <10% of perimeter obstructed	**9**
Moderate: 10-25% of perimeter obstructed	**6**
High: 26-100% of perimeter obstructed	**3**

Attribute 2: Hydrology

H1. Ditching/Draining (AA only)

Alternative States	Rating (circle one)
No Ditching	**12**
Low Ditching	**9**
Moderate Ditching	**6**
Severe Ditching	**3**

H2. Fill & Fragmentation (AA only)

Estimate amount of fill ______________% of AA	
Dimensions of Fill Pile ________________________	
Alternative States	**Rating (circle one)**
No fill or fragmentation	**12**
Low fill or fragmentation	**9**
Moderate fill or fragmentation	**6**
Severe fill or fragmentation	**3**

H3. Diking & Restriction (250m)

Description of restriction: ________________________________

Alternative States	Rating (circle one)
Absent: no restriction, free flow, normal range	**12**
Low: restriction presumed (<10% of normal range)	**9**
Moderate restriction (10-25% normal range)	**6**
High (26-100 of normal range)	**3**

H4. Point Sources (250m)

Alternative States	Rating (circle one)
Absent: no discharge	**12**
Low: one small discharge from a natural area	**9**
Moderate: one discharge from a developed area or two discharges from a natural area	**6**
High: ≥2 discharges from a developed area or ≥3 from a natural area	**3**

Attribute 3: Habitat (within AA)

HAB1. Bearing Capacity (Hummocks) **

	Mark Depth (cm)			
	Point 1	Point 2	Point 3	Point 4
Initial capacity				
Blow 1				
Blow 2				
Blow 3				
Blow 4				
Blow 5				
Final - Initial				

Av. of Final - Initial for the 4 Sub-plots		Rating (circle one)
≤1.8		**12**
1.9-4.0		**9**
4.1-6.2		**6**
>6.2		**3**

HAB2. Plant Fragments

	Record Measurement (cc)			
	Point 1	Point 2	Point 3	Point 4
2-4cm deep				

Average of Four Sub-plots	Rating (circle one)
≥17.45	**12**
<17.45 ≥11.5	**8**
<11.5	**4**

HAB3A. Vertical Biotic Structure

Alternative States	Rating (circle one)
Most of the vegetated plain of the AA has a dense canopy of living vegetation or entrained litter or detritus forming a "ceiling" of cover 10-20cm above the wetland surface that shades the surface and can provide abundant cover for wildlife.	**12**
Less than half of the vegetated plain of the AA has a dense canopy of vegetation or entrained litter as described above OR Most of the vegetated plain has a dense canopy but the ceiling it forms is much less than 10-20cm above the ground surface.	**9**
Less than half of the vegetated plain of the AA has a dense canopy of vegetation or entrained litter and the ceiling it forms is much less than 10-20cm above the ground surface.	**6**
Most of the AA lacks a dense canopy of living vegetation or entrained litter or detritus.	**3**

HAB3B. **Horizontal Vegetative Obstruction**

Sub-plot	1	2	3	4
0.25m				
0.50m				
0.75m				
Veg. type				

HAB4-6. **Plant Community Worksheet**

Floating or Canopy-forming	Invasive? Y/N	Co-dom?	Short <0.3m	Invasive?	Co-dom
Medium 0.3-0.75m	**Invasive?**	**Co-dom?**	**Tall 0.75-1.5m**	**Invasive?**	**Co-dom**
Very Tall >1.5m	**Invasive?**	**Co-dom?**			
			# of Plant Layers		
			Total # of Native co-dominant species for all layers combined		

			Total # of Non-native co-dominant species for all layers combined	
			% of Non-native co-dominant species for all layers combined	
			Percent Invasive	

HAB4. # of Plant Layers

Alternative States	Rating (circle one)
4-5 layers	**12**
2-3 layers	**9**
1 layer	**6**
0 layer	**3**

HAB5. % Co-Dominant Non-Native Species

Alternative States		Rating (circle one)
0-15%		**12**
16-30%		**9**
31-45%		**6**
46-100%		**3**

HAB6. % Invasive Plants

Alternative States	Rating (circle one)
0%	**12**
1-25%	**9**
26-50%	**6**
>50%	**3**

****HAB2. Bearing Capacity (Unvegetated Hollows)**				
	Mark Depth (cm)			
	Point 1	Point 2	Point 3	Point 4
Initial capacity				
Blow 1				
Blow 2				
Blow 3				
Blow 4				
Blow 5				
Final - Initial				