Condition of Wetlands in the Broadkill River Watershed, Delaware

Final report submitted to U.S. Environmental Protection Agency Region III for Assistance # CD-96312201-0 to the Delaware Department of Natural Resources and Environmental Control

A. Rogerson[1], M. Jennette, A. Howard

[1]Delaware Department of Natural Resources and Environmental Control
Watershed Stewardship Division, Watershed Assessment and Management Section
Dover, Delaware 19904

Last Updated: March, 2013

The citation for this document is:

Rogerson,A.B., M.A. Jennette, and A.M. Howard. 2013. Condition of wetlands in the Broadkill River Watershed, Delaware. Delaware Department of Natural Resources and Environmental Control, Watershed Assessment and Management Section, Dover, USA. 59p.

ACKNOWLEDGMENTS

Funding for this project was provided by EPA REMAP and Region III Wetland Program Development Grant Assistance # CD-96312201-0, and the Delaware Department of Natural Resources and Environmental Control. This research and report were made possible by many who contributed their time and expertise. Tom Kincaid and Tony Olsen with the EPA Office of Research and Development Lab, Corvallis, Oregon provided technical support with the developing the data frame and statistical weights. Many individuals dedicated their time and hard work to collecting out assessment data, including seasonal hires Jocelyn Robinson and Megan Pulver and multiple volunteers. In addition, we thank the Environmental Lab Section for use of their biomass storage and oven space and the DNERR St. Jones Reserve for use of their boat.

Contents

Maps

Tables

Figures

EXECUTIVE SUMMARY

The Delaware Department of Natural Resources and Environmental Control (DE DNREC) assessed the status and condition of wetlands in the Broadkill River watershed in 2010. The goal of this project was to determine the condition of both tidal and nontidal wetlands throughout the Watershed, changes in wetland acreage, and identify prevalent wetland stressors. We will use wetland condition, stressor information, and watershed wide trends to guide and improve future protection and restoration activities, education, and effective planning to ensure the conservation of Delaware's wetland resources.

Located in Sussex County, Delaware, the Broadkill watershed encompasses 27,500ha (68,500ac) within the Delaware Bay and Estuary Basin. The Broadkill River runs 40km (25mi) to meet the Delaware Bay at the Roosevelt Inlet. Twenty percent of the watershed is covered in wetlands. Flat wetlands, usually forested, form the headwaters of the Broadkill River in the western portion of the watershed. Riverine wetlands follow tributaries and streams throughout the central portion of the watershed, and expansive brackish to tidal wetlands run along the Broadkill River until it reaches the Delaware Bay. Pockets of depressions, including rare coastal plain ponds, are scattered throughout the watershed.

To assess the condition of wetlands and identify the prominent stressors affecting wetland health, we applied a rapid assessment method to random sites across the watershed in nontidal flat, riverine, and depressions, and in tidal wetlands. Sites were located on both private and public lands and selected utilizing a probabilistic sampling design developed by the EPA Ecological Monitoring and Assessment Program (EMAP) that allowed us to extrapolate sample results to represent the entire wetland population in the watershed.

We also evaluated changes in wetland acreage for major wetland subclasses by comparing historic wetland acreage based on hydric soils to the 1992 and 2007 state wetland inventories. Our comparison indicated 11% (2000ac) of the wetland acreage originally in the Broadkill River watershed at the time of settlement was lost by 1992. Between 1992 and 2007 the watershed lost 75ac of palustrine wetlands to development and agriculture. Concurrently there was a 170ac gain in palustrine wetlands in the Broadkill River watershed, almost exclusively as stormwater ponds. The loss of nontidal wetlands has been the greatest overall, due largely to conversion to agriculture. Tidal wetland loss has historically occurred due to conversion to open water and coastal development in Prime Hook and Broadkill Beaches.

We completed rapid condition assessments on 32 flats, 30 riverine, 3 depressions, and 29 estuarine tidal wetland sites. Each assessment evaluated indicators of condition and wetland stressors related to plant community, hydrology and wetland buffers. We also collected more comprehensive data from a subsample of sites, including detailed vegetation measurements, soil characterizations, and quantification of vegetative biomass.

Tidal wetlands, comprising nearly half of the wetlands in the watershed, were in fair condition with an average condition score of 74, ranging from 53 to 88. Invasive plant cover and alterations in the buffer contributed to most of the differences observed among condition classes. Using condition categories to separate the tidal wetland population 23% were minimally stressed, 63% were moderately stressed, and 13% were severely stressed. Common across all condition classes were the presence of mosquito ditches, a lack of complex plant communities, and the presence of human disturbance in the buffer.

Vegetative biomass sampling indicated that below ground biomass increased with wetland condition scores. Below ground biomass is thought to be influenced by marsh health, and further validates the MidTRAM procedure. Bearing capacity (soil resistance) was also positively related to several biomass quantities.

Much of the wetlands converted prior to 2007 in the Broadkill River watershed were nontidal flats, which currently make up 24% of the wetland acreage. Flats serve as headwaters for nontidal coastal plain streams and are valued as key wildlife habitats. On the Index of Wetland Condition, flats scores ranged widely from 28 to 95, and averaged 78. Only 16% of flats in the watershed were minimally stressed, and 59% were moderately stressed by wetland impacts, leaving 25% classified as severely stressed. Common stressors for flat wetlands of all condition classes included recent timber harvesting and the presence of invasive species.

Riverine wetlands, or riparian wetlands, represent 26% of the watershed's wetland population and serve an important role in water quality and storage, and as valuable habitat corridors. Of the 30 sites we assessed, only 1 (3% of the riverine wetland population) was severely stressed where the majority (77%) were moderately stressed, and 20% were minimally or not stressed. Greater than one third (37%) of riverine wetlands were associated with streams that were channelized or incised. Agriculture and residential development was also common in the buffers of riverine wetlands.

The Broadkill River watershed contained fewer minimally stressed wetlands than the Inland Bays, St. Jones, and Murderkill River watersheds. However, the Broadkill also contained the fewest severely stressed wetlands and had the greatest proportion of moderately stressed wetlands. Invasive plant species, ditching, and disturbed buffers were common to all wetland types.

Based on the findings in this study we propose 9 management recommendations and needs for further data. One, improve the protection of headwater flat wetlands by protecting them from land use conversion and urging the use of sustainable practices for forestry harvesting. Two, improve the protection of nontidal wetlands by creating state legislation and supporting enforcement. Three, improve nontidal wetland buffer regulations and codes to increase the natural protection of property and improve the quality of life for Delawareans. Four, update tidal wetland regulatory maps using 2007 wetland maps to increase effective permitting. Five, develop incentives to maintain natural buffers for tidal wetlands. Six, control the extent and spread of the non-native, invasive common reed (*Phragmites australis*) through state- and federally-funded DNREC programs. Seven, improve enforcement of wetland permitting and mitigation monitoring by cooperating with other regulatory branches and incorporating wetland assessment tools into the process. Eight, design a wetland restoration plan that includes the Broadkill River watershed. Finally, following Delaware's Bayshore Initiative, secure funding to implement a wetland restoration plan for the Broadkill River watershed to protect high condition wetlands and restore impacted wetlands to a higher level.

INTRODUCTION

Wetlands in the Broadkill River watershed provide many benefits to people, support natural processes, and provide habitats that are an integral part of the landscape. Wetlands transition between terrestrial and aquatic habitats and are one of the most productive ecosystems in the world. Wetlands minimize flooding from storms, control erosion, and improve water quality by removing nutrient runoff and pollutants from non-point sources. Wetlands remove and retain sediment loads from waters that can be elevated due to agricultural practices, land clearing, construction, and bank erosion before they enter tidal and nontidal waterways. They also have substantial cultural and economic value as a source of recreation (e.g. hunting, fishing, birding) and livelihood (e.g. fishing, crabbing, fur-bearer trapping). Tidal wetlands are biologically rich habitats and are a critical resource for migrating shorebirds and wintering waterfowl, and serve as nurseries for commercial fish and shellfish species. Freshwater wetlands process and funnel ground and surface waters into our waterways, and provide wildlife habitat for a wide array of species.

Tidal wetland near the Broadkill River.

Wetlands have a rich history across the region and their aesthetics have become a symbol of the Mid-Atlantic Coast. The State of Delaware remains committed to improving wetlands through protection and restoration efforts, education, and effective planning to ensure that wetlands will continue to provide these services to the citizens of Delaware (DE DNREC 2008a). In addition to assessing changes in wetland acreage over time, monitoring wetland condition is necessary to guide management and protection efforts. The Delaware Department of Natural Resources and Environmental Control

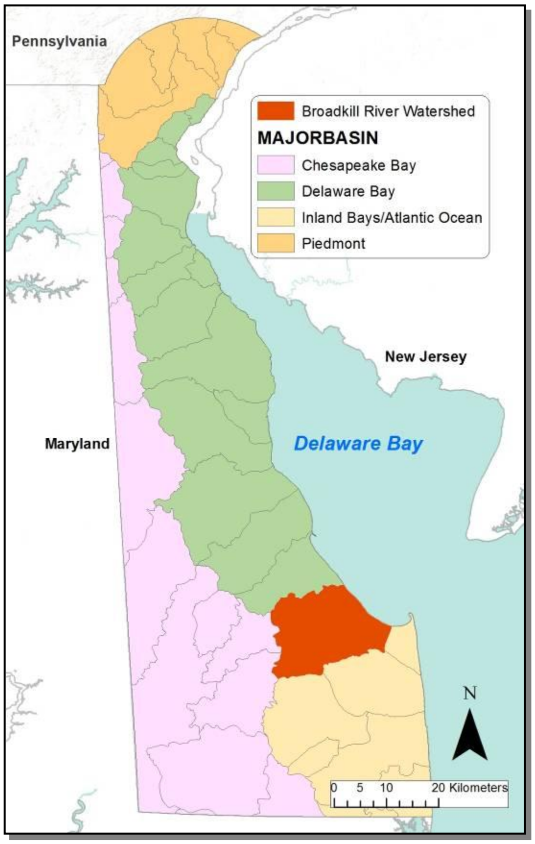
Atlantic White Cedar growing in a riverine wetland in the Broadkill River watershed.

(DE DNREC) has developed and implemented a wetland assessment and monitoring program to evaluate the health of wetlands. Evaluating wetland health or condition, including the stressors that are degrading wetlands on a watershed scale, compiles useful information that watershed organizations, state planning and regulatory agencies, and other stakeholders can use to improve wetland restoration and protection efforts. Protection efforts can be directed towards wetlands in good condition, while allowing restoration efforts to target altered and degraded wetlands to increase functions and services. Wetland assessment information identifies specific stressors that are commonly altering wetlands, and can direct restoration projects and set priorities.

DNREC has developed scientifically valid methods to assess the condition of wetlands on a watershed scale. These methods are used to generate an overall evaluation of the ambient condition of wetlands in a watershed, as well as to identify common stressors by wetland type. In this report, we review the changes in wetland acreage, highlight potential changes in wetland function, summarize the condition of tidal and freshwater wetlands, identify common stressors degrading wetlands, and provide recommendations for improving the wetlands of the Broadkill River watershed.


A hardwood flat wetland in the Broadkill River watershed.

WATERSHED OVERVIEW



Map 1. Location of the Broadkill River watershed and the major basins of Delaware.

The Broadkill River watershed in central Sussex County, Delaware is one of 16 watersheds that comprise the Delaware Bay and Estuary Basin in the State. The Broadkill watershed is bound by the Cedar Creek watershed to the north. It shares its western boundary with the Gravelly Branch and Deep Creek watersheds in the Chesapeake Bay Basin, and its southern boundary with the Lewes-Rehoboth Canal, Indian River, and Rehoboth Bay watersheds in the Inland Bays/Atlantic Ocean Basins (Map 1). The Broadkill River watershed covers 27,500ha (68,500ac) and is primarily comprised of agricultural land with urban development and wildlife refuge. The Broadkill River headwaters originate near the Town of Milton and flow 40km (25mi) eastward towards Broadkill Beach where it outlets to the Delaware Bay through the Roosevelt Inlet.

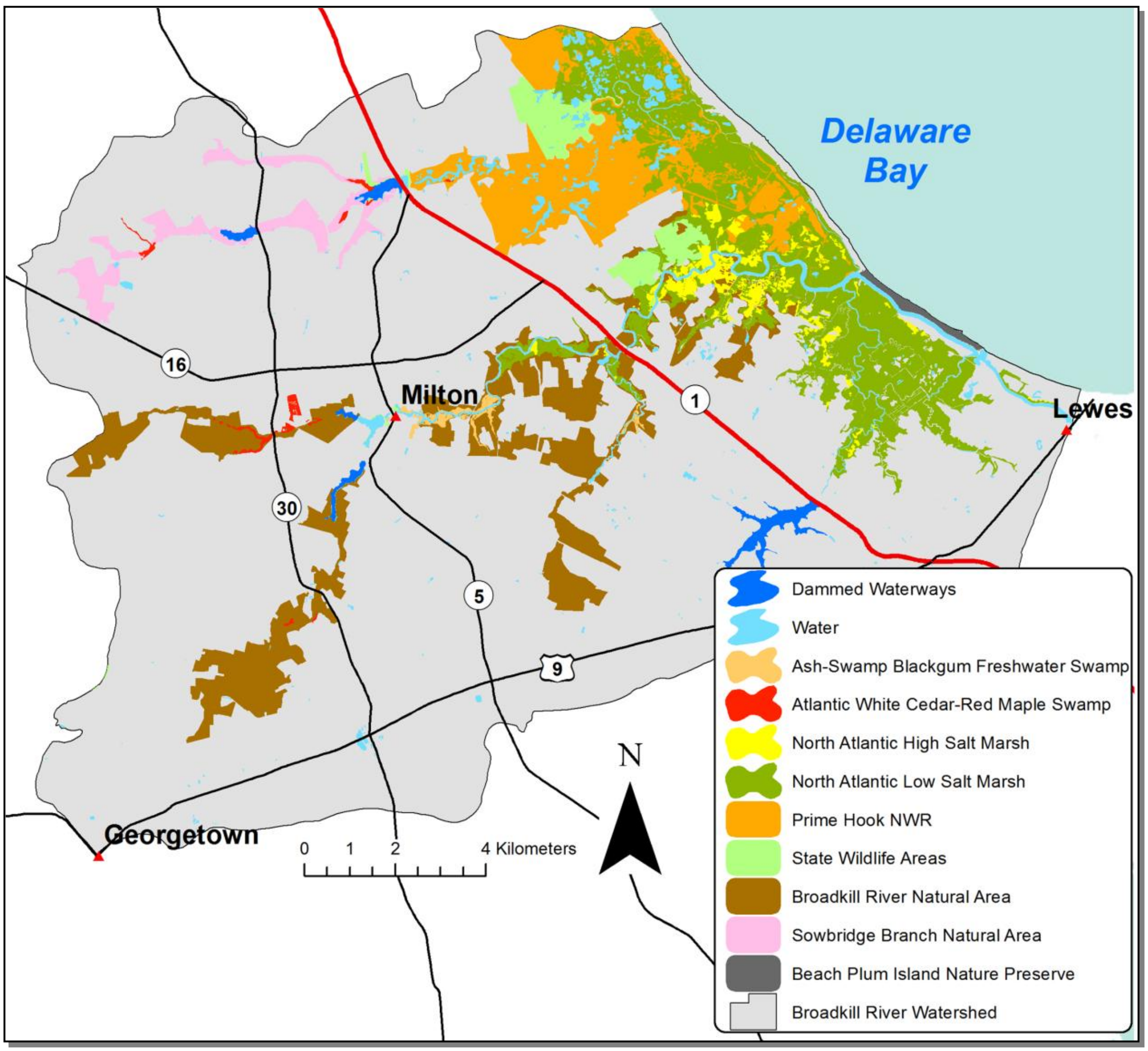
2.1 Geologic History

The Broadkill River watershed falls within the Atlantic Coastal Plain Physiographic Province south of the Appalachian Piedmont Fall Zone. The geologic formation of this area was due to a combination of glacier activity and sediment deposition and compaction. Most of present day Delaware was covered by ocean water before the last ice age (DE DNREC 2005). Large amounts of sediments from the ancient Appalachians were carried down the Delaware River, Susquehanna River and others, and settled onto the coastal plain of Delmarva (DE DNREC 2005). These sediments compacted over time, lowering the land surface elevation.

2.2 Watershed Hydrogeomorphology

The Broadkill River watershed contains 3 of the 4 hydrogeomorphic regions (as defined by topography, geology, hydrogeology and soils) that are found in the Delaware Bay and Estuary Basin: poorly-drained uplands, well-drained uplands, and beaches/tidal marshes/ lagoons/barrier islands (DE DNREC 2005). Portions along the western edge of the watershed are poorly drained uplands and contain most of the headwater flat wetlands in the watershed. The middle of the watershed is mostly well-drained uplands where riverine wetlands form on floodplains adjacent to natural streams and rivers. Tidal wetlands along with beaches, lagoons and barrier islands, are found in the eastern portion of the watershed which runs from 5 feet above mean sea level to mean sea level as you approach the Delaware Bay.

The Broadkill River watershed contains many key natural heritage and wildlife habitats such as impoundments and unique wetland types. There are also several State Natural Areas, State Wildlife Areas, and Prime Hook National Wildlife Refuge (Prime Hook NWR; Map 2).

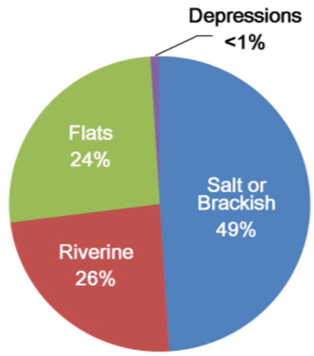


Map 2. Key habitats and public lands in the Broadkill River watershed, Delaware.

The unconfined aquifer (water table) and several deeper confined aquifers, throughout the Delaware Bay and Estuary area, support the ground water for the basin and are the source of potable water in the Broadkill River watershed (DE DNREC 2005). The unconfined aquifer flows through gravelly sands and is recharged through precipitation in areas where permeable sediments allow water to infiltrate down to the aquifer. The water table aquifer is drawn from for agricultural, industrial and municipal uses.

2.3 Wetlands

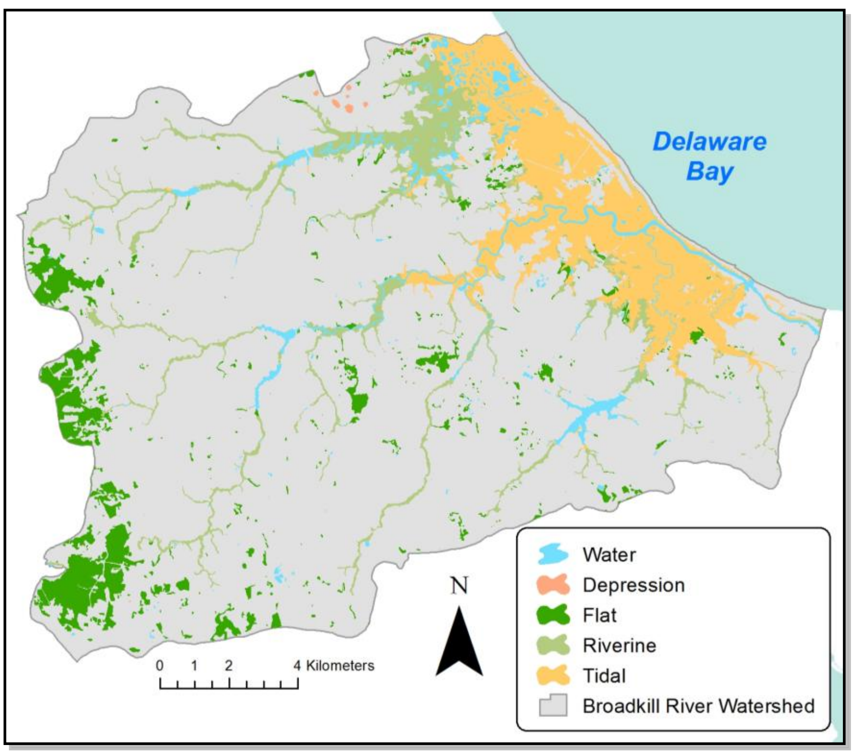
Wetlands comprise 20% of the land area within the watershed. Tidal wetlands are most prevalent followed by riverine and flat wetlands (Figure 1).



Wetland Type	Hectares (Acres)	Proportion
Salt or Brackish	2,657 (6,566)	49
Riverine	1,427 (3,527)	26
Freshwater Flats	1,324 (3,271)	24
Depressions	22 (55)	<1
Total	5,430 (13,419)	100

Figure 1. Wetland proportions and area by wetland type for the Broadkill River watershed, Delaware.

Tidal wetlands associated with salt to brackish waters dominate the eastern portion of the watershed as the Broadkill River approaches the Delaware Bay and are found along the coast and upstream past Route 1. Nontidal freshwater wetlands, such as riverines and flats, dominate the western portion of the watershed, along the Broadkill River and its tributaries starting just below Milton, and up to headwater areas. (Map 3). A small pocket of



Map 3. Distribution of tidal and nontidal wetland across the Broadkill River watershed, Delaware based on 2007 mapping.

freshwater depression wetlands are found along the watershed's northern boundary near Route 1, but are otherwise scattered sparsely throughout the watershed (Map 3). The Broadkill River watershed contains 2,400ha (5,900ac) of key wetland habitats for plants, animals, and insect communities, as outlined in the Delaware Wildlife Action Plan (DE DNREC 2006). Almost all (95%) of this acreage are comprised of salt marsh communities located on the eastern portion of the watershed and are home to State endangered species, such as black rails (*Laterallus jamaicensis*) and commercially significant species, like blue crabs (*Callinectes sapidus*). The Broadkill River watershed is also one of six watersheds in the state that contain large stands of Atlantic White Cedar (*Chamaecyparis thyoides*), located along Pemberton and Sowbridge Branches (Map 2).

The Ramsar Convention on Wetlands (www.ramsar.org) recognizes the wetlands of the Delaware Bay and Estuary as 'international wetlands of importance' because of their role in shorebird migration and waterfowl wintering habitat. In 1986, The Delaware Bay and Estuary was recognized as the first Western Hemisphere Shorebird Reserve site of Hemispheric Importance (WHSRN 2009). This is the highest rank recognized by the global organization and indicates that at least 500,000 shorebirds visit annually, or that at least 30% of the biogeographic population for a species is supported by the site.

2.4 Land Use Changes and Wetland Issues

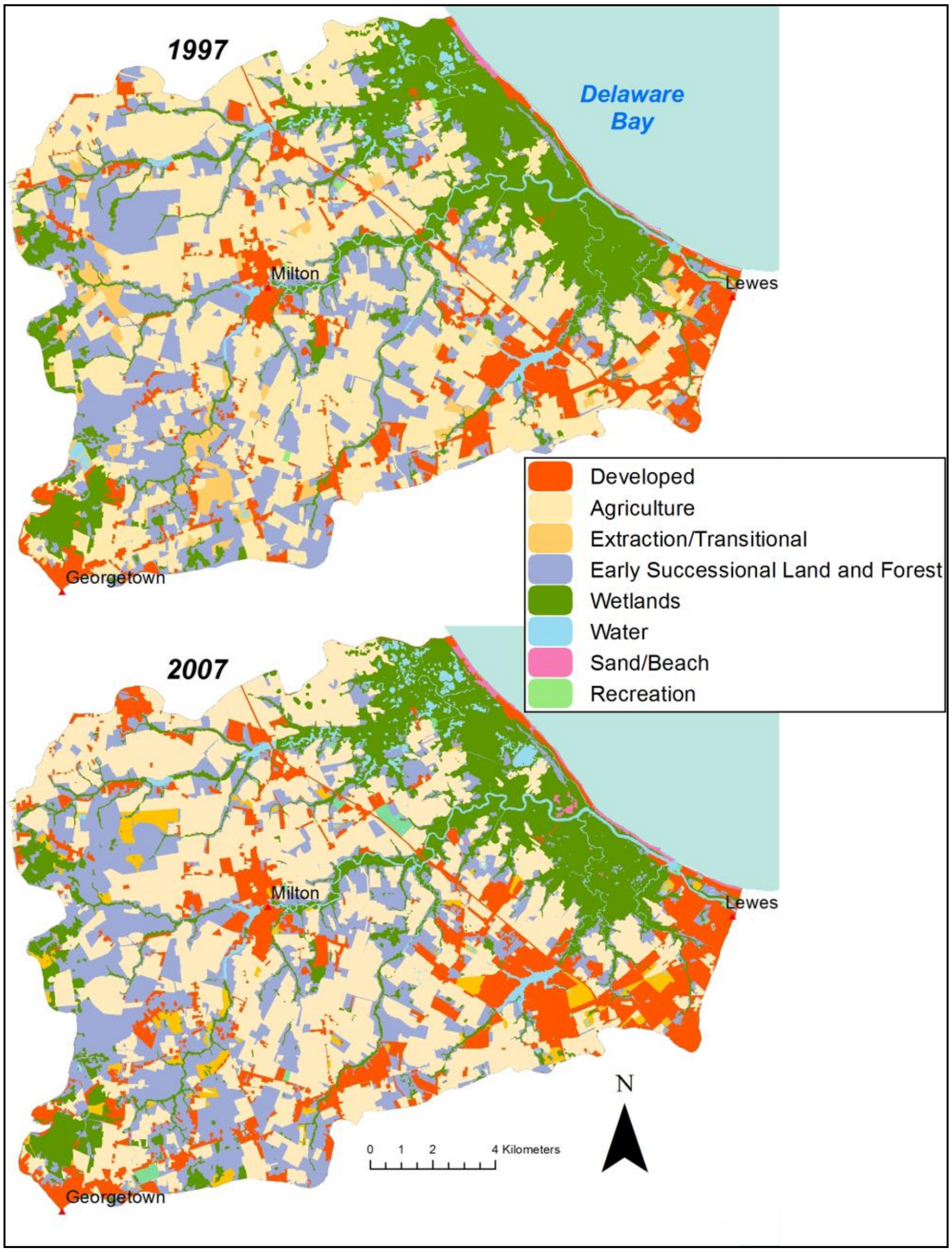
Based on 2007 National Land Cover Dataset (NLCD), 39% of the Broadkill watershed acreage is in agricultural land uses (Table 1). Agriculture is a broad category that includes row crops, orchards, nurseries, confined feedlots, rangeland and farmsteads. Large tracts of agricultural land dominate the landscape across the watershed (Map 4). Between 1997 and 2007, development increased 4% in the

Table 1. Land use changes for the Broadkill River watershed between 1997 and 2007 based on NLCD.

Land Use Category	1997 (% area)	2007 (% area)	10-year % Change
Agriculture	42.0	38.6	-3.4
Developed	10.8	14.8	+4.0
Extraction/Transitional	3.0	2.4	-0.6
Early Successional Land and Forest	22.7	22.5	-0.2
Wetlands	18.8	18.0	-0.8
Water	2.3	2.9	+0.5
Sand/Beach	0.2	0.4	+0.2
Recreation	0.2	0.5	+0.3

Broadkill watershed, primarily in Milton, Lewes, and along the Route 9 corridor. Concurrently, the watershed saw an equal loss in agricultural and transitional lands (Table 1). Land that is in the early phase of being cleared and developed when aerial photos are taken is classified as extraction/transitional. The NLCD resolution is coarser than Delaware's current wetland dataset (2007 SWMP/NWI), which resulted in a slightly different estimated wetland acreage (2%)

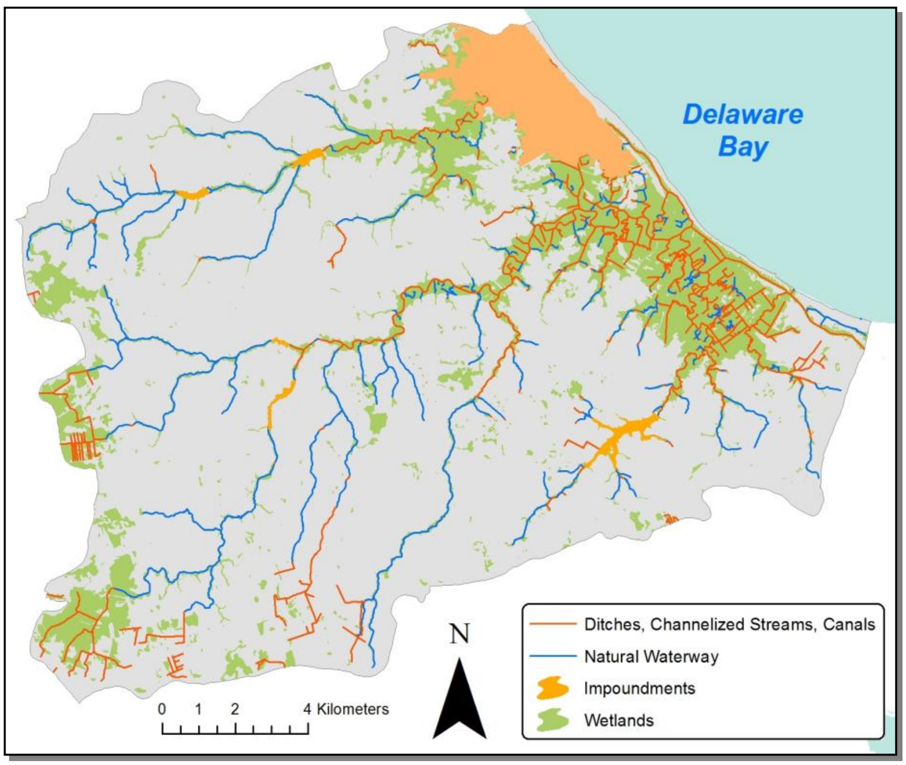
Land use affects the health of wetlands directly through conversion from wetland to other land use types, including row crops or houses, as well as indirectly from activities adjacent to wetlands that impact wetland condition. Common stressors to wetlands are alterations to the hydrology from drainage ditches, water quality issues related to nutrient and chemical runoff, and the disruption and compaction of soil layers. In the Broadkill River watershed, high nutrient levels, specifically nitrogen and phosphorus, and extremely low dissolved oxygen levels have been primary water quality concerns reported in the proposed TMDL



Map 4. Land cover for the Broadkill River watershed in 1997 and 2007 based on NLCD land use categories.

report (DE DNREC 2006). The creation of residential developments results in a large increase in impervious surfaces causing more storm water flashes and soil erosion, and reducing the groundwater recharge potential. Runoff pollution from roads (e.g. oil, salt, heavy metals) as well as lawn fertilizers and pesticides also affect water quality. TMDLs were established by DNREC in 2006 for the Broadkill River and its tributaries to address nonpoint nutrient loading and low dissolved oxygen levels. A DNREC pollution control strategy for the Broadkill River watershed has been drafted and is undergoing internal review.

Extensive stream channelization and ditching for agricultural drainage and mosquito control in both tidal and nontidal wetlands has led to changes in wetland hydrology, the creation of deposited fill, and alterations to the natural functions of wetlands in the watershed. (DE DNREC 2005). In addition to 135 miles of ditched or channelized waterways across the Broadkill watershed (60% of all waterways), the watershed contains a number of sizable impoundments created for wildlife management and major road crossings (Map 5). Also, the spread of the invasive common read, *Phragmites australis,*is pervasive throughout fresh and brackish wetlands across the watershed. As natural hydrology patterns are altered by impoundments, dams, tidal restrictions and fill, *Phragmites* is able to aggressively out-compete native species and create large monotypic stands that provide poor habitat and food resources (DE DNREC 2005).



Map 5. Distribution of impoundments, natural waterways, and artificial or altered waterways in the Broadkill River watershed.

Sea level rise and the effects of climate change continue to be a concern for all coastal watersheds. Assuming a modest scenario for sea level rise (0.5m), bathtub models predict 9% of nontidal wetlands and 98% of tidal wetlands will become inundated by the year 2100 (State of Delaware 2012). Coastal development and hardened shorelines reduce the ability of wetlands to migrate inland with increasing sea level, restricting these systems until they convert to open water. Shorelines without the protection of coastal wetlands are vulnerable to storm surges and erosion. As sea level rises, salt water will intrude further upstream into freshwater systems and disrupt natural processes. In the upcoming decades wetlands will not only be impacted by sea level rise but also by increased storm surges, changes in tidal amplitudes, more extreme precipitation, and altered temperatures.

Managed wildlife habitats within Prime Hook NWR are also in flux due to recent changes to the landscape. Established in 1963, the 10,000 acre refuge covers much of the northeast corner of the Broadkill watershed and has three impoundments ranging from freshwater to brackish (US FWS 2012). Overwashes of the artificial dunes were uncommon until recent decades when more frequent and intense coastal storms have damaged the dune line and breached impoundments multiple times. Of particular interest are changes to the Unit II impoundment, one managed as a shallow freshwater habitat and is used extensively by birds and other wildlife. Saltwater from the Delaware Bay now enters the Unit II impoundment through multiple breaches which stresses the freshwater vegetation communities and has converted much of the impoundment to open water. Prime Hook NWR and DNREC are currently exploring management options to meet the refuge's goals, outlined in its Comprehensive Conservation Plan (US FWS 2012).

METHODS

We assessed the condition of tidal and nontidal wetlands in the Broadkill River Watershed in the summer of 2010. We used a probabilistic survey approach to assess wetlands on private and public lands within the watershed. For tidal wetlands, we used the Mid-Atlantic Tidal Rapid Assessment Method Version 3.0 (MidTRAM; Jacobs et al. 20010) and for nontidal wetlands we used the Delaware Rapid Assessment Protocol (DERAP, Jacobs 2007) to evaluate wetland condition and identify wetland stressors. We used comprehensive wetland data to validate our rapid methods.

3.1 Site Selection

EPA's Ecological Monitoring and Assessment Program (EMAP) in Corvallis, Oregon assisted with selecting 200 potential sample sites in estuarine intertidal emergent wetlands and 250 potential sample sites in nontidal wetlands using a generalized random tessellation stratified (GRTS) design (Stevens and Olsen 1999, 2000). The target population was mapped wetlands from the state wetland maps (State of Delaware 1994), which are based on 2007 aerial photography. Sampling sites were randomly chosen points within mapped wetlands, which give each point an equal probability of being selected and allows more than one point to fall in 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 permission for access was denied, the site was inaccessible, the site was of the wrong wetland classification, or if the site was upland. Our goal was to sample 30 tidal sites and 30 nontidal sites in each subclass (riverine, flats, and depression). For the nontidal sites, once we sampled 30 sites of one subclass we did not sample additional sites of that subclass but rather would continue to sites of the remaining subclasses in order of the EMAP selection.

3.2 Changes in Wetland Acreage

To accompany our assessment of wetland condition, we used state wetland maps to determine the distribution of wetlands across the Broadkill River watershed, along with where wetland loss has occurred in recent decades and since the settlement of Delaware. We determined historic wetland acreage using U.S. Department of Agriculture Natural Resource Conservation Service soil maps. We identified hydric soil map units from soil survey data (which are based on soil indicators such as drainage class, landform, and water flow) as 'historic wetlands'. We added the historic wetland units to the 1994 wetland units to create an estimated pre-settlement wetland layer. We used the 1994 SWMP layer to identify recent wetland distribution (State of Delaware 1994). We identified current wetlands using the most recent State/NWI wetland mapping based on 2007 aerial photography (State of Delaware 2007). We determined changes in wetland acreage across the watershed by comparing the acreage of existing wetlands to both recent and historic wetlands. Mention of wetland functions are based on estimates from landscape-level analysis using the USFWS NWIPlus (Tiner 2010).

3.3 Data Collection

3.3.1. Assessing Tidal Wetlands

3.3.1.a Rapid Sampling of Tidal Wetlands

We evaluated the condition of tidal wetlands using the MidTRAM protocol. 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 14 scored metrics that represent the condition of the wetland buffer, hydrology, and habitat characteristics (Table 2). MidTRAM uses a combination of qualitative evaluation and quantitative sampling to record the presence and severity of stressors in the field or in the office using maps and digital orthophotos.

We completed the MidTRAM at the first 29 random points that we could access and that met our criteria of being of an estuarine intertidal emergent wetland. We established a site assessment area (AA) as a 50m radius circle centered on each random point (Figure 2). We defined the AA buffer area as a 250m radius area around the AA. If a 50m radius circle would go beyond the wetland into upland or open water, we moved the circle <50m or changed to a rectangle of equal area to have the entire AA within the wetland. The AA buffer could extend into upland or open water.

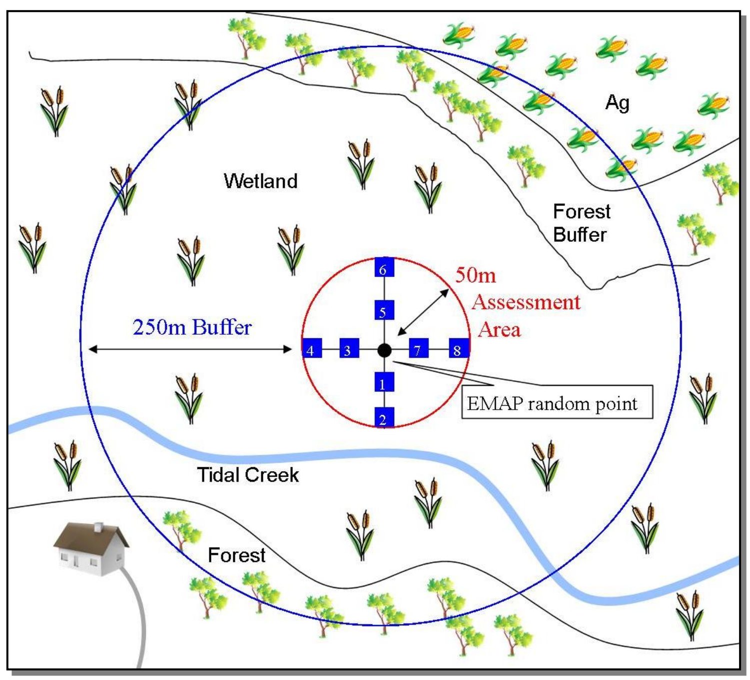


Figure 2. Assessment area and subplots used to collect data for the MidAtlantic Tidal Rapid Assessment Method.

For metrics measured within the AA (Table 2) we evaluated indicators throughout the entire AA with the exception of horizontal vegetative obstruction and soil bearing capacity. To assess these metrics, we established 8-1m² subplots within the AA along 2-100m transects that bisected the AA. We oriented one transect perpendicular to the nearest source of open water (>30m wide) and the other was perpendicular to the first. We placed subplots 25m and 50m from the center of the AA along each transect. Subplots were numbered clockwise starting with the 25m plot towards the open water, followed by the 50m one towards open water (Figure 2). If a subplot fell in a habitat type or patch that was not characteristic of the site (e.g. in a ditch) we moved it 1m along the transect.

We completed all metrics within the AA via visual inspection during the field visit, with the exception of horizontal vegetative obstruction and soil bearing capacity. Horizontal vegetative obstruction was quantified at subplots 1, 3, 5, and 7 with a 1m profile board, divided into decimeters. With the profile board held at 0.25m, 0.5m, and 0.75m above the wetland surface the observer stood 4m away from the profile board, and directly counted the number of decimeter segments visible through the vegetation at eye level with the profile board. We summed the 3 profile board readings for each subplot and recorded the average over the 4 subplots. We measured soil bearing capacity using a slide hammer technique on a random spot in each subplot. To take the measurement, we raised the slide hammer and released it 4 times to exert a consistent force on the soil surface. We subtracted the final depth below the marsh surface of the bottom of the slide hammer from the initial depth to get the change in depth due to the total force. Each metric was scored a 3, 6, 9, or 12, based on the narrative or numeric criteria in the protocol.

Table 2. 14 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 at least 5m of natural or semi-natural condition land cover	Buffer	Quantitative Office
Buffer/Landscape	Average Buffer Width	The average buffer width surrounding the AA that is in natural or semi-natural condition	Buffer	Quantitative Office
Buffer/Landscape	Surrounding Development	Percent of developed land within 250m from the edge of the AA	Buffer	Quantitative Office/Field
Buffer/Landscape	250m Landscape Condition	Condition of surrounding landscape based on vegetation, soil compaction, and human visitation within 250m	Buffer	Quantitative Office/Field

Attribute Group	***Metric Name***	***Description***	***Measured in AA or Buffer***	***Qualitative or Quantitative***
Buffer/Landscape	Barriers to Landward Migration	Percent of landward perimeter of marsh within 250m that has physical barriers preventing marsh migration inland	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/Restriction	The presence of dikes or other restrictions altering the natural hydrology 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	Horizontal Vegetative Obstruction	The amount of visual obstruction due to vegetation	AA subplots	Qualitative Field
Habitat	Number of Plant Layers	Number of plant layers in AA based on plant height	AA	Qualitative Field
Habitat	Percent Co-dominant Invasive Species	Percent of co-dominant species that are invasive in the AA	AA	Qualitative Field
Habitat	Percent Invasive	Percent cover of invasive species in the AA	AA	Qualitative Field

We assessed buffer metrics (i.e. buffer width, surrounding development, percent of assessment area with a 5m buffer, 250m landscape condition, and barriers to landward migration) in the office using ArcMap GIS software (ESRI, Redlands, CA, USA) before visually verifying our estimates in the field.

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 provided in Appendix A. The average field time to sample each site was 2h. Metrics completed in the office took up to ½ hour to complete. Detailed instructions for using MidTRAM are provided in the protocol (Jacobs et al. 2009a).

We calculated attribute group scores by summing the metric scores and dividing by the total possible value. That value was adjusted to be on a 0-100 scale since each metric can only score a minimum of 3:

Attribute Group score = $((((\sum(\text{metric}_{1...n})/\text{MAX}_a)*100)-\text{floor}_x)/\text{ceiling}_x$

where $\text{metric}_{1...n}$=metric scores for the buffer, hydrology or habitat group, MAX_a=the maximum possible attribute group score, floor_x = the minimum calculated score for each group multiplied by 100 (e.g.), and ceiling_x= 100-floor_x (e.g. 75). Final MidTRAM condition scores were calculated by averaging the 3 attribute group scores and ranged from 0-100:

MidTRAM condition score =
(Buffer Attribute Score + Hydrology Attribute Score + Habitat Attribute Score)/ 3

Example: Site B
Buffer group score= ((((9+9+6+12+3)/60)*100)-25)/(100-25)= 0.53*100=53
Hydrology group score= ((((12+9+6+12)/48)*100)-25)/(100-25)= 0.75*100=75
Habitat group score= ((((3+3+6+12+9)/60)*100)-25)/(100-25)= 0.40*100=40

MidTRAM condition score = (53+75+40)/3 = 56

We used Statistix (Version 9, Tallahassee, FL. USA) and Excel for all of our statistical analyses with an alpha level of 0.10.

3.3.1.b Intensive Vegetative Biomass Sampling in Tidal Wetlands

We compared MidTRAM condition scores to more intensive measures of the biotic community using vegetative biomass. 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 validates the assessment method and increases our confidence that it is able to distinguish and differentiate tidal wetlands based on changes in biological communities. Vegetative biomass is a comprehensive attribute of marsh systems that has been related to marsh condition in regards to plant production, and marsh stability and accretion (Deegan et al. 2012; Turner et al. 2004).

We collected vegetative above- and below-ground biomass samples from 5 tidal sites in the Broadkill River watershed and combined that data with 30 sites across the Inland Bays (*n*=10), Murderkill (*n*=10) and St. Jones (*n*=10) watersheds. Biomass study sites were dominated by smooth cordgrass (*Spartina alterniflora*) and were selected in numeric order until we reached our desired sample of 5. Above- and below-ground biomass samples were collected from subplots 1, 3, and 5 (see Figure 2). We sampled above-ground biomass by clipping all vegetation within a 15.24cm radius circle randomly placed at the outside edge of the subplot and sorted the vegetation to separate live stems from dead. We collected below-ground biomass by extracting sediment cores to 15cm below the marsh surface. We thoroughly rinsed the cores clean of any sediment, separated live from dead roots, and chilled the samples until we could dry them. We dried the samples (80-85ºF) for approximately 72h until there was no additional weight loss detected with additional drying time. We weighed each sample to the nearest 0.01g.

Averages of the 3 subplots at each site were used for all biomass comparisons and analyses. Outliers were identified with box plots and removed (n = 6) from the dataset prior to final analyses. We used a nonparametric Spearman's ranking correlation to look for, and measure, the relationship between MidTRAM condition scores and total above-ground (biomass), total-below ground, above-ground live, above-ground dead, below-ground live, below-ground dead, above-ground live:below-ground live ratio, above-ground dead:below-ground dead ratio, and total above-ground:total below-ground ratio. Correlations between soil bearing capacity and above- and below-ground biomass values were also measured with Spearman's ranking correlation.

3.3.2 Assessing Nontidal Wetlands

3.3.2.a Rapid Sampling in Nontidal Wetlands

We assessed the condition of nontidal wetlands in the Broadkill River watershed using the DERAP. DERAP collects data on the presence and intensity of stressors related to habitat, hydrology, and buffer features to assess the condition of wetlands by watershed. DERAP scores are calibrated to comprehensive wetland condition data collected using the Delaware Comprehensive Assessment Procedure (Jacobs et al. 2008), separately for each HGM subclass.

We sampled 65 nontidal wetland sites in the Broadkill River watershed using DERAP (N_{FLAT}=32, N_{RIV}=30, N_{DEP}=3) in 2010. We established a 40m radius AA and 140m radius buffer around a random EMAP point (Figure 3). If the 40m radius circle extended beyond the wetland edge into upland or open water, we moved the AA <40m or changed to a rectangle of equal area in order to stay within the wetland. The stressors evaluated using the DERAP are provided in Table 3. A complete list of stressor names and abbreviations is in Appendix B. The DERAP takes a field crew of 2 people 30min to 2h to complete depending on field conditions. Forestry activity and buffer stressors were assessed using historic aerial photography and verified in the field.

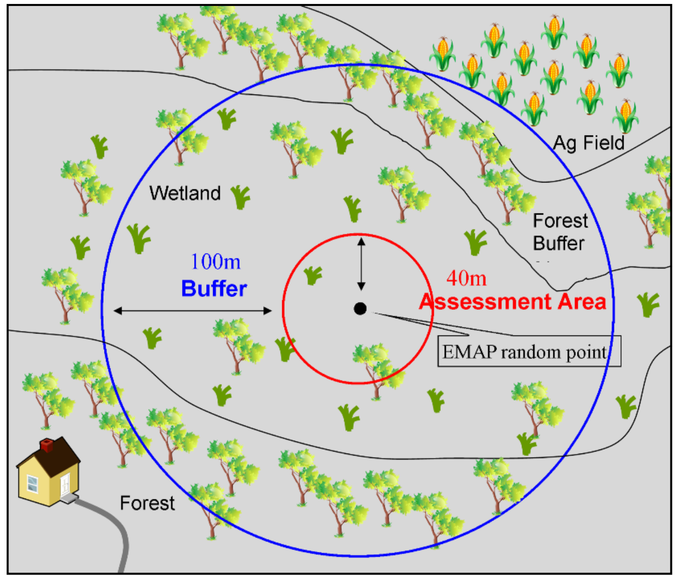


Figure 3. Assessment area and buffer used to collect data for nontidal rapid and comprehensive assessments.

Table 3. Stressors evaluated using the Delaware Rapid Assessment Procedure.

Habitat Stressors	Hydrology Stressors	Buffer Stressors
Forestry activity (time since last activity)	Presence and depth of ditches	Development-commercial/ industrial/ residential
Managed or converted to pine	Channelized stream	Roads
Chemical defoliation	Channel incision	Landfills
Mowing	Damming	Channelized streams or ditches
Farming	Stormwater Inputs	Row crops/ Nursery/ Orchard
Grazing	Point sources	Poultry/Livestock operation
Cleared land	Filling, Excavation	Forest Harvesting within 15 Yrs
Invasive species	Excessive sedimentation	Golf course
Excessive Herbivory/ Pinebark Beetle/ Gypsy Moth Burned	Soil subsidence/Root exposure	Mowing
Dense algal mats	Microtopography alterations	Sand/ Gravel operation
Presence of nutrient indicators		
Roads		

Scoring for the DERAP to produce one overall score of condition was developed through a process to calibrate the presence of stressors at a site to comprehensive wetland condition data using the DECAP Index of Wetland Condition (IWC). We developed the DECAP IWC using a process to screen hydrogeomorphic (HGM) variables specific to wetland subclass to select the strongest variables that would represent the condition of the primary wetland attributes of plant community, hydrology, and buffer (Jacobs et al. 2009). The DERAP was then calibrated to the DECAP IWC using a data set of over 250 sites from the Nanticoke, Inland Bays, and Delaware Bay watersheds in Delaware (Sifneos et al. 2010).

We selected stressors using step-wise multiple regression and Akaike's Information Criteria (AIC) approach to develop the best model that correlated with comprehensive assessment data without over-fitting the model to this specific dataset. Coefficients or weights associated with each stressor were assigned using multiple linear regression (Appendix C). We calculated the DERAP IWC score by summing the stressor coefficients for each of the selected stressors that were present and subtracting the sum from the linear regression intercept. For all wetland subclasses, 23 stressors were selected to be included in the DERAP IWC calculation: 7 habitat stressors, 6 hydrology stressors, and 10 landscape or buffer stressors (Appendix C).

$\text{DERAP IWC}_{\text{FLATS}} = 95 - (\sum\text{stressor weights})$
$\text{DERAP IWC}_{\text{RIVERINE}} = 91 - (\sum\text{stressor weights})$
$\text{DERAP IWC}_{\text{DEPRESSION}} = 82 - (\sum\text{stressor weights})$

The DERAP stressor dataset from 32 flats, 30 riverine and 3 depression sites in the Broadkill watershed are provided in Appendix F, G, and I, respectively.

3.3.2.b Comprehensive Sampling in Nontidal Wetlands

We collected DECAP data from 1 riverine wetland in the Broadkill watershed, from which DERAP was also sampled. We followed the Delaware Comprehensive Assessment Procedure as outlined in the protocol (Jacobs et al. 2008). These data will be combined with other DECAP data from sites throughout Delaware to continue to validate and calibrate the DERAP. Data from this riverine site is provided in Appendix H.

3.4 Presenting Wetland Condition

We present our results at both the site and population level. We discuss site level results by summarizing the range of scores that we 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 riverine wetlands had channelization present). Population level results have incorporated weights

Condition Breakpoint Criteria –*calculated for each subclass (tidal, flats, riverine, depression)*

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

Moderately stressed – Sites in between minimally and highly stressed.

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

based on the probabilistic design and correct for any bias due to sample sites that could not be sampled and different rates of access on private and public lands to be able to extrapolate to the total area of wetland in the watershed. The cumulative results represent the total area of the respective wetland subclass for the entire watershed.

Sites in each HGM subclass were placed into 3 condition categories (Minimally or Not stressed, Moderately stressed or Severely stressed; Table 4). We determined breakpoints by applying a percentile calculation to the QDR's and condition scores from sites in several watersheds. For the tidal portion we used sites from the St. Jones, Murderkill, and Inland Bays watershed (n=136) combined for a larger, regional sample. 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. Based on the 3 watersheds combined, the condition breakpoints for tidal sites are provided in Table 4. For the nontidal portion, we used assessment sites from the Nanticoke and Inland Bays, Murderkill, and St. Jones watersheds (n=160) to determine condition breakpoints separately for flat and riverine wetlands. Based on the three watersheds combined, the condition breakpoints for nontidal sites that we applied in the Broadkill watershed are provided in Table 4.

Table 4. Condition categories and breakpoint values for tidal, and nontidal flats and riverine wetlands in the Broadkill River watershed as determined by wetland condition scores.

Wetland Type	Method	Minimally or Not Stressed	Moderately Stressed	Severely stressed
Tidal	MIDTRAM	≥81	<81 and ≥ 63	<63
Nontidal Riverine	DERAP	≥85	<85 and ≥47	<47
Nontidal Flats	DERAP	≥88	<88 and ≥65	<65
Nontidal Depression	DERAP	≥73	<73 and ≥53	<53

We used a cumulative distribution function (CDF) to display wetland condition on the population level. A CDF extrapolates assessment results to the entire population and 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 within the selected conditions. For example, in Figure 4 roughly 40% of the wetland area scored above an 80 for wetland condition. A CDF also highlights clumps or platueas where either a large or small portion of wetlands are in similar condition. In the example, there is a condition plateau from 50 to approximately 75, illustrating that only a small portion of the population had condition scores in this range.

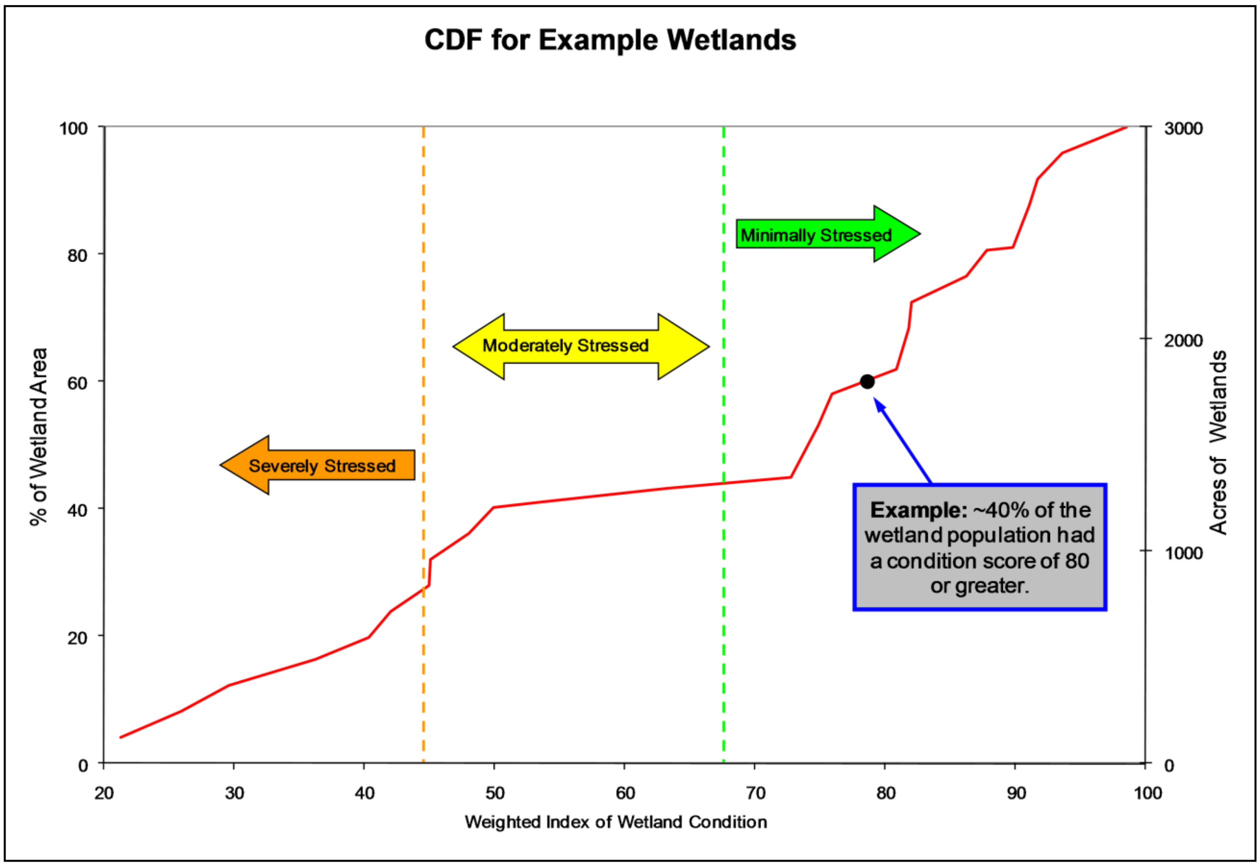
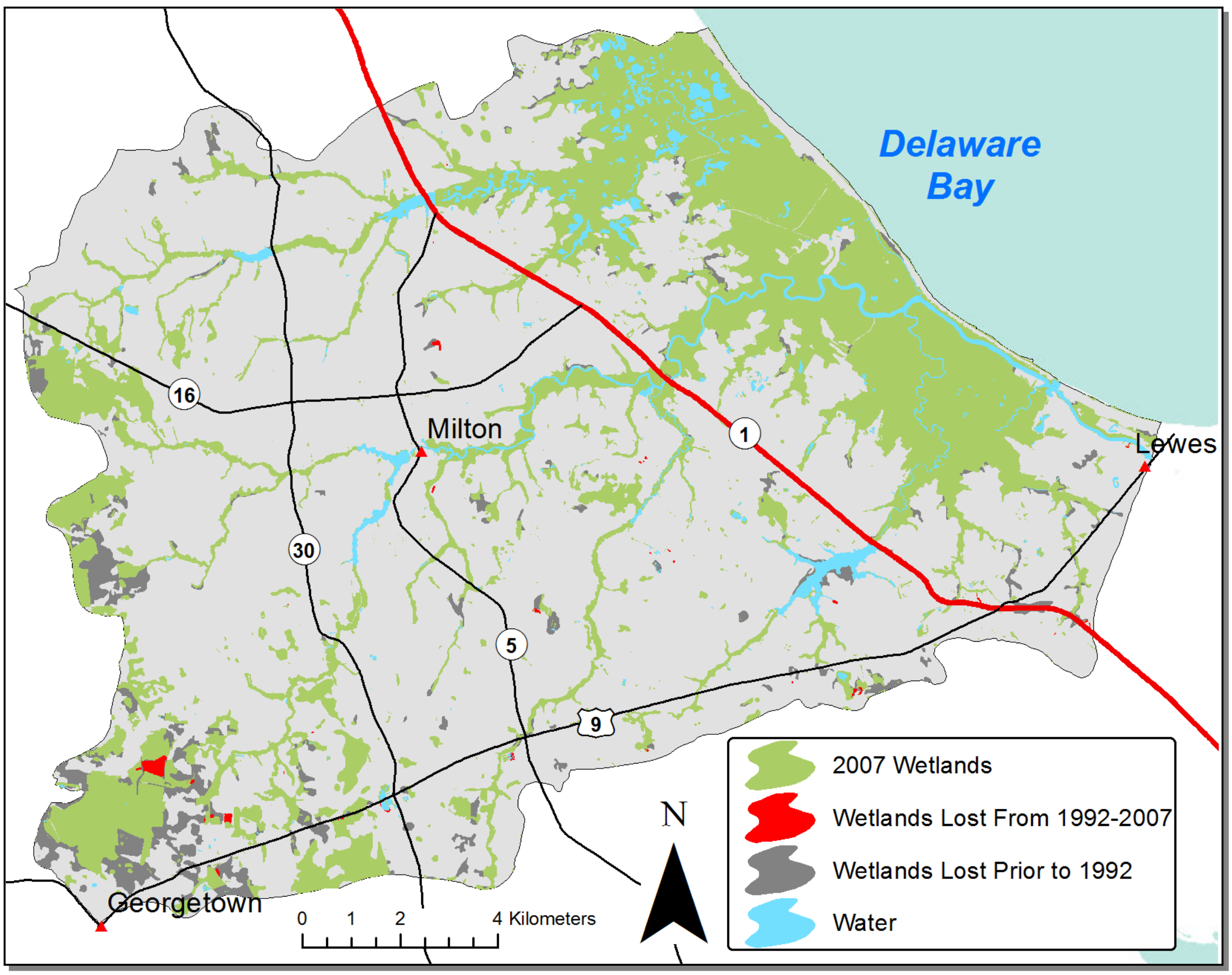


Figure 4. An example CDF showing wetland condition. The red line is the population estimate. The orange and green dashed lines show the breakpoints between condition categories.

RESULTS

4.1 Changes in Wetland Acreage

Wetlands historically covered over 18,000 acres across the Broadkill River watershed. Our comparison of estimated historic wetlands to 2007 wetlands indicated that 11% of wetland acreage was lost within the watershed through conversion between the time of settlement and 2007 (Map 6). Historic wetland losses occurred throughout much of the watershed but were primarily located in nontidal flats north of Georgetown. Large impoundments created at major road crossings were also a notable source of riverine wetland loss in this watershed, with five impoundments along State Routes 1, 5, and 30 totaling 400ac of open water (Map 6).



Map 6. Past and present wetland coverage in the Broadkill River watershed, Delaware.

From 1992 to 2007, wetland maps indicated 75ac of wetlands have been lost to conversion, with a loss of 64ac of flat wetlands, and 11ac of ponds and depressions. There were no losses to riverine or tidal wetlands during that period. Common to statewide trends, freshwater forested wetlands continued to sustain the greatest losses, often in isolated and seasonally saturated wetland blocks that are more difficult to identify and protect. From 1992 to 2007, 170ac of wetlands were created in the Broadkill River watershed, resulting in a 0.6% net gain (95ac). The small increase in wetland acreage was largely (98%) due to the creation of ponds and fill borrow pits as well, as the expansion of existing mapped wetlands resulting from refined mapping methods. Although acreage in this watershed technically increased, a statewide wetland trends analysis reported an overall loss in acreage and confirmed that the majority of gains were in low functioning stormwater ponds (Tiner et al. 2011).

As a result of recent changes in wetland acreage, the wetland functions potentially provided in the Broadkill River watershed have further been altered. A recent landscape-level analysis of wetland function predicted that, as a result of wetland losses between 1992 and 2007, the potential for existing wetlands to perform nutrient transformation, sediment retention, surface water detention, and serve as wildlife habitat were reduced (Tiner 2011). The direct replacement of natural wetlands with stormwater retention ponds can also negatively affect wildlife that utilize these habitats for breeding, nesting, or foraging. In developed landscapes, unnatural hydroperiods and the accumulation of contaminants in stormwater ponds can create ecological traps for birds, reptiles, and amphibians (Brand et al. 2010).

Tidal wetlands are regulated through state wetland permitting in combination with federal regulations which inhibit large losses. Despite mapping no losses to tidal wetlands between 1992 and 2007, these habitats are threatened today by rising sea levels and conversion to open water. Conversion of coastal wetlands to open water is one topic being addressed as DNREC plans for adapting to sea level rise and climate change (State of Delaware 2012). Many nontidal riverine wetlands are also afforded some protection under federal regulations, unlike flats and depressions in Delaware, which likely contributed to no recent losses to riverine systems in the Broadkill River watershed.

4.2 Landowner Contact and Site Access

We obtained landowner permission prior to accessing and sampling all 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.

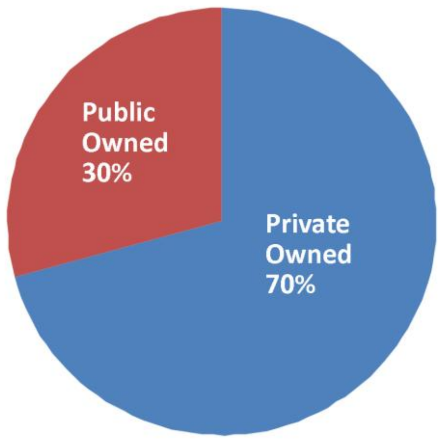


Figure 5. Ownership of sampled wetland sites in the Broadkill River watershed, Delaware in 2010.

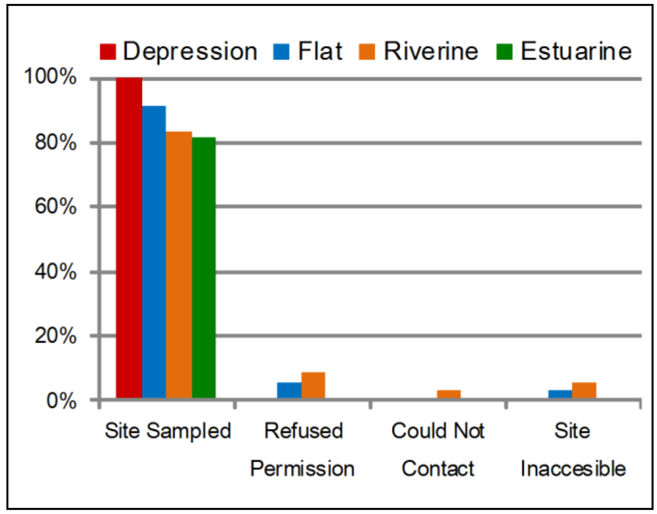


Figure 6. Success rates for privately owned wetland sites in the Broadkill River watershed Delaware in 2010 by wetland subclass.

The majority of our sampled sites were privately owned (Figure 5). Across all wetland types we were granted access from 92% from landowners of privately owned sites (Figure 6). We were granted access to all 38 targeted tidal sites, though site visits revealed that 9 sites were palustrine tidal and were not appropriate for our population sample Of the 29 tidal sites we sampled, 15 (52%) were on public lands. We attempted to gain access to 35 flat sites of which two were denied and one proved inaccessible. Of the 32 flat sites that were sampled, 75% were privately owned. We considered 36 riverine sites for sampling and were denied access to 3 sites, could not contact one of the landowners, and could not safely access 2 of the sites. Of the 30 riverine sites sampled, 29 (97%) were privately owned. Depression wetlands made up a very low proportion of sites in the Broadkill watershed and only 3 were identified in the 250 potential points. All 3 sites were sampled, 2 (67%) were found on private lands.

4.3 Wetland Condition

4.3.1 Tidal Wetland Condition

Tidal estuarine wetlands comprise 49% (6,566ac) of the total wetland acreage in the Broadkill River watershed and provide coastal populations with more ecosystem services than any other habitat. They are highly fertile and productive, and are able to minimize flooding from storms, control erosion, and improve and maintain water quality by sequestering and storing excess nutrients, sediments, and toxic chemicals.

Tidal wetlands in the Broadkill River watershed were in fair condition with an average condition score of 74±9 and ranged from 53 to 88. The top 10% of the tidal population scored >85 and were characterized as having intact hydrology, wide buffers with minimal disturbance, and very little invasive plant cover. Conversely, wetlands scoring in the bottom 14% had condition scores <60 with developed landscapes, diking or otherwise restricted hydrology, and invasive species present. Appendix D provides the raw values and scored metric data for the 29 tidal wetland sites.

The cumulative distribution function takes the sample population and extrapolates condition results onto the entire wetland population in the watershed. The cumulative distribution function for the tidal wetland population in the Broadkill showed a distribution skewed towards higher condition, with a minimum score of just 53 (Figure 7). Throughout the total range of wetlands there was a fairly uniform distribution of condition above 75, with a grouping of sites below that sharing a condition score near 68.

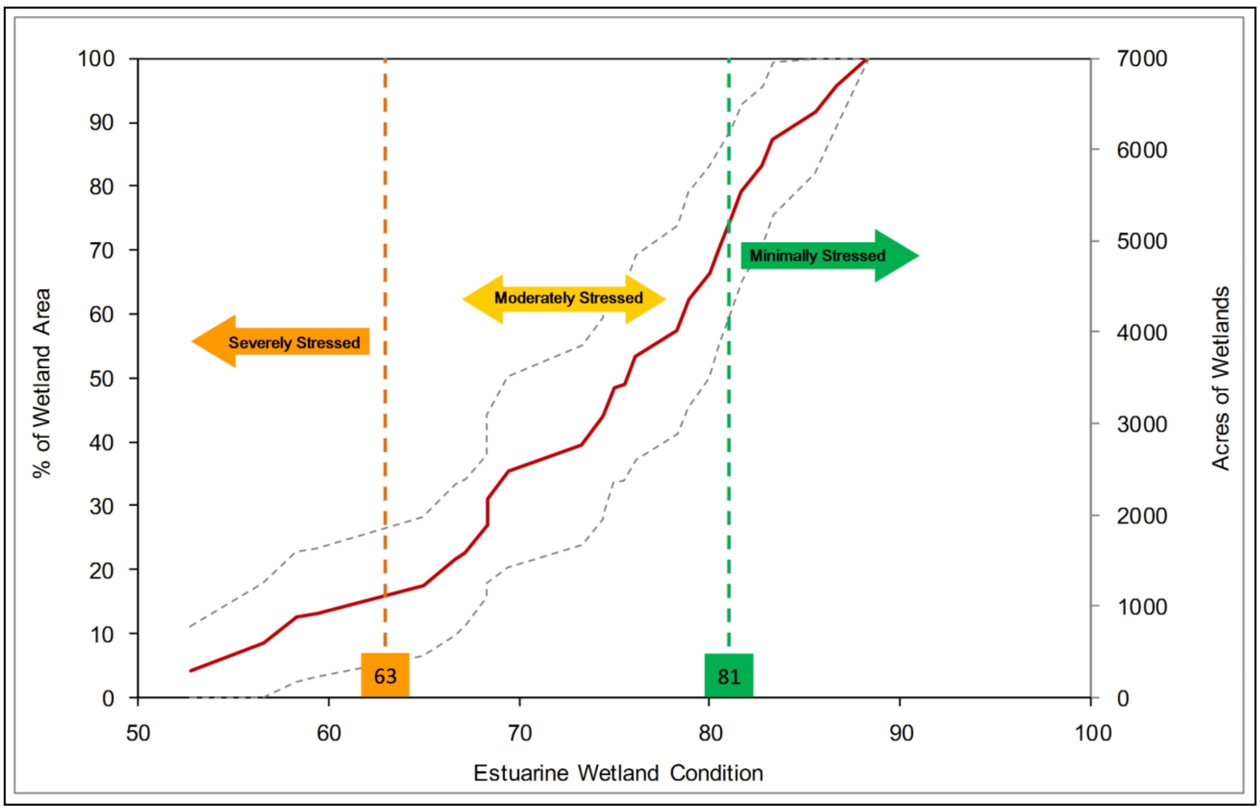
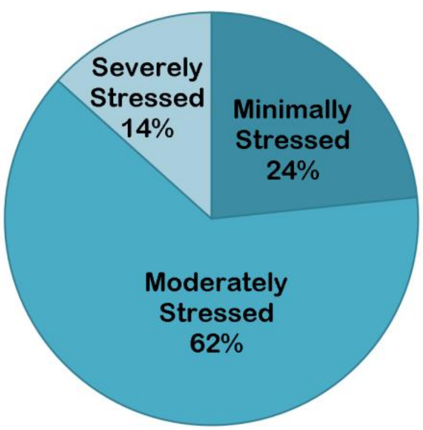


Figure 5. The Cumulative Distribution Function for tidal wetland condition based on the MidTRAM in the Broadkill River watershed, Delaware in 2010. The orange and green dashed lines designate the condition category breakpoints. The gray dashed lines represent the 95% confidence intervals.

Overall, 24% of tidal wetlands in the Broadkill River watershed were minimally or not stressed (Figure 8 *left*). A majority of the wetlands (62%) were moderately stressed and 14% were severely stressed (Figure 8 *left*). Minimally stressed wetlands averaged 5 stressors compared to 7 for moderately stressed and 9 for severely stressed wetlands.

In addition to the number of stressors, the intensity of several stressors increased with decreasing condition category (Figure 8 *right*). Buffers to minimally and moderately stressed wetlands were, on average, wide and largely undisturbed, while natural buffers to severely stressed wetlands were nearly half the size. Diking and tidal restriction was absent from minimally stressed wetlands, but present in all of the severely stressed wetlands. While the composition and relative cover of plants differed among sites, 90% of wetlands had 2-3 plant layers and received a moderate score for this attribute. The presence of invasive plants also increased with decreasing wetland condition. Ditching was pervasive throughout the watershed and was not responsive to condition category. Wetland buffers to every wetland had some degree of human disturbance, though the intensity of disturbance varied greatly among sites.



Metric	Minimally Stressed *n* = 7	Moderately Stressed *n* = 18	Severely Stressed *n* = 4
% Cover of Invasive Plants in AA	1	20	64
Average Bearing Capacity (cm)	3.5	3.4	4.0
% of Wetlands with Diking/Restriction	0	39	100
Buffer Width (max=250m)	230	220	120
% Development in 250m Buffer	0.2	4	6
% of Buffer Shore-line Obstructed from Marsh Migration	0	2	23

Figure 6. Tidal wetland condition proportions (*left*) and stressor prevalence (*right*) for the Broadkill River watershed, Delaware in 2010.

After grouping the 14 tidal metric scores into three wetland attribute group values, the means varied slightly (Figure 9). The habitat attribute group averaged the lowest score due to a lack of plant layers, the percent of invasive plant cover, and poor horizontal vegetative cover. The hydrology attribute score was markedly higher due to an absence of point source inputs and lack of fill material, although a majority of the tidal wetlands have been ditched. Compared to other watersheds in Delaware, the Inland Bays and Broadkill River watersheds had more tidal wetlands with ditching (72% each) than the nearby Murderkill River watershed (60%) and St. Jones River watershed (36%). The buffer attribute group had the highest average score, which was influenced by relatively expansive wetland buffers and few occurrences of residential or industrial development, though agricultural land was found in nearly every wetland buffer. Concurrently, the proportion of wetlands with hardened shorelines that inhibit landward marsh migration was much lower in the Broadkill River watershed (7%) than those in the St. Jones (30%), Inland Bays (28%), and Murderkill watersheds (22%).

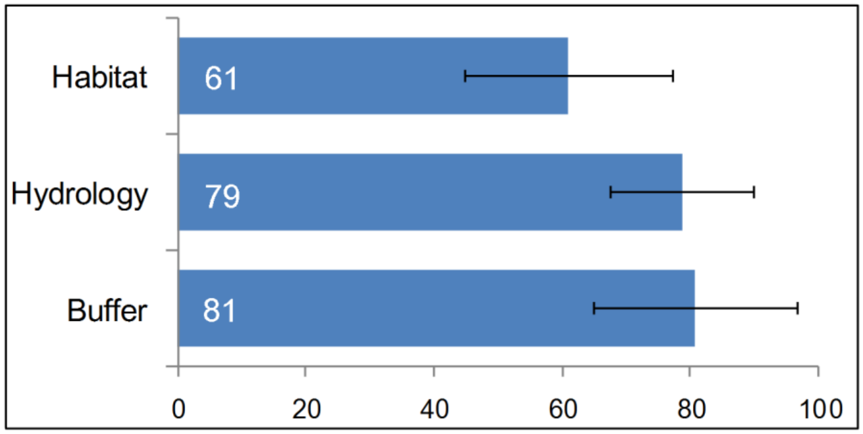


Figure 7. Mean attribute group values and standard deviations for tidal wetlands in the Broadkill River watershed, Delaware.

4.3.1.a. Intensive Biomass Data

Our combined rapid condition scores were related to several biomass parameters in *Spartina*-dominated marshes across four watersheds in Delaware. We found a significant positive relationship between condition scores and all three recorded below-ground biomass measures (Table 5). These findings are supported by the theory that environmental factors influence energy partitioning, as stressed wetland plants allocate more energy

Table 5. Correlation between MidTRAM condition scores and biomass values for 29 tidal wetland sites in the Broadkill River, St. Jones River, Murderkill River, and Inland Bays watersheds, Delaware.

Biomass Variable	r^2	*P*	Trend
Below Live	0.51	0.005	+
Below Total	0.39	0.040	+
Below Dead	0.35	0.060	+
Above Live	0.31	0.099	+

to above-ground shoot production and divert energy from root and rhizome production (Turner et al. 2004). In a healthy system, plants allocate energy towards root growth which accumulates as biomass and increases marsh stability. Inconsistent with this theory was a marginally significant (P=0.099) correlation between above-ground live biomass and MidTRAM condition score, though many variables influence above-ground biomass and it is not a good predictor of marsh condition (Turner et al. 2004).

We did not observe a significant relationship between MidTRAM condition scores and above-ground dead biomass (P=0.500) or above-ground total biomass (P=0.665). We also failed to observe a correlation with MidTRAM condition scores and the ratio of above-ground live:below-ground live (P=0.596), above-ground dead:below-ground dead (P=0.118), or above-ground total:below-ground total (P=0.203). Consistent with literature, these variables are all influenced by above-ground biomass values which is not directly linked with marsh health (Darby and Turner 2008; Turner et al. 2004)

We also found that soil bearing capacity was related to vegetative biomass in several ways. Bearing capacity was correlated with below-ground dead biomass (r^2=0.44, P=0.018; Figure 10), below-ground total (r^2=0.40, P=0.031), and above-ground live: below-ground live ratio (r^2=0.47, P=0.010). These relationships should be expected given that below-ground biomass increases marsh stability and, in turn, soil bearing capacity. Strong relationships between bearing capacity and biomass have been important when re-evaluating and rescoring rapid MidTRAM metrics with intensive indicators. Vegetative biomass data for the 5 Broadkill River sites are provided in APPENDIX E.

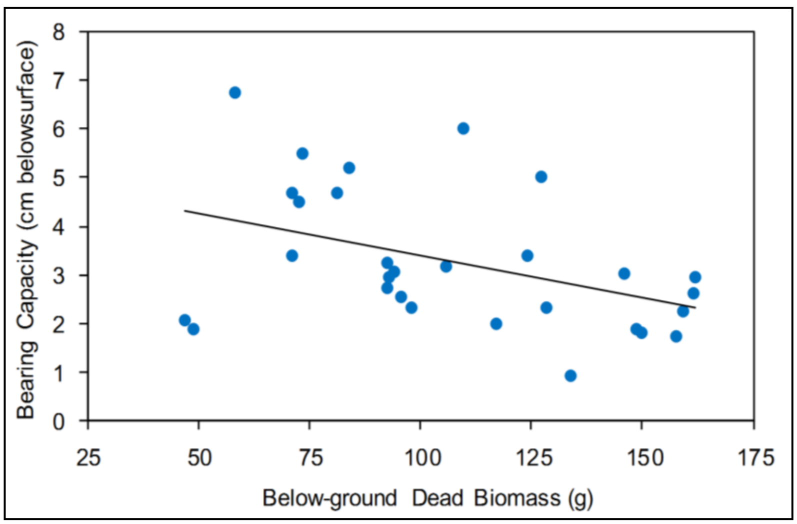


Figure 8. Relationship between below-ground dead biomass and soil bearing capacity in Broadkill River, St. Jones River, Murderkill River, and Inland Bays watersheds, Delaware.

4.3.2 Nontidal Wetland Condition

4.3.2.a Flats

Flat wetlands make up 24% (3,271ac) of wetlands across the Broadkill River watershed, occurring in areas with low, gradual slopes. Flats are typically found on the periphery of the watershed in forested or fallow areas and are especially prevalent in the poorly drained western portion of the watershed (Map 3). Flats are valued for their ability to help store and slowly release water to prevent downstream flooding, to improve water quality by filtering precipitation and runoff from surrounding upland land uses, and by providing important wildlife habitat in large forested areas.

The cumulative distribution function of the Broadkill flats population is skewed towards higher condition, with 75% of the wetlands scoring 79 or better (Figure 11). Roughly 20% (500ac) of the existing flat wetlands in the Broadkill River watershed are estimated to be minimally stressed (Figure 11). The lower 10% of population ranked below 60 and was recently clear cut or otherwise heavily impacted. The top 10% of the population was characterized by having intact hydrology, wide natural buffers, and mostly native plant species.

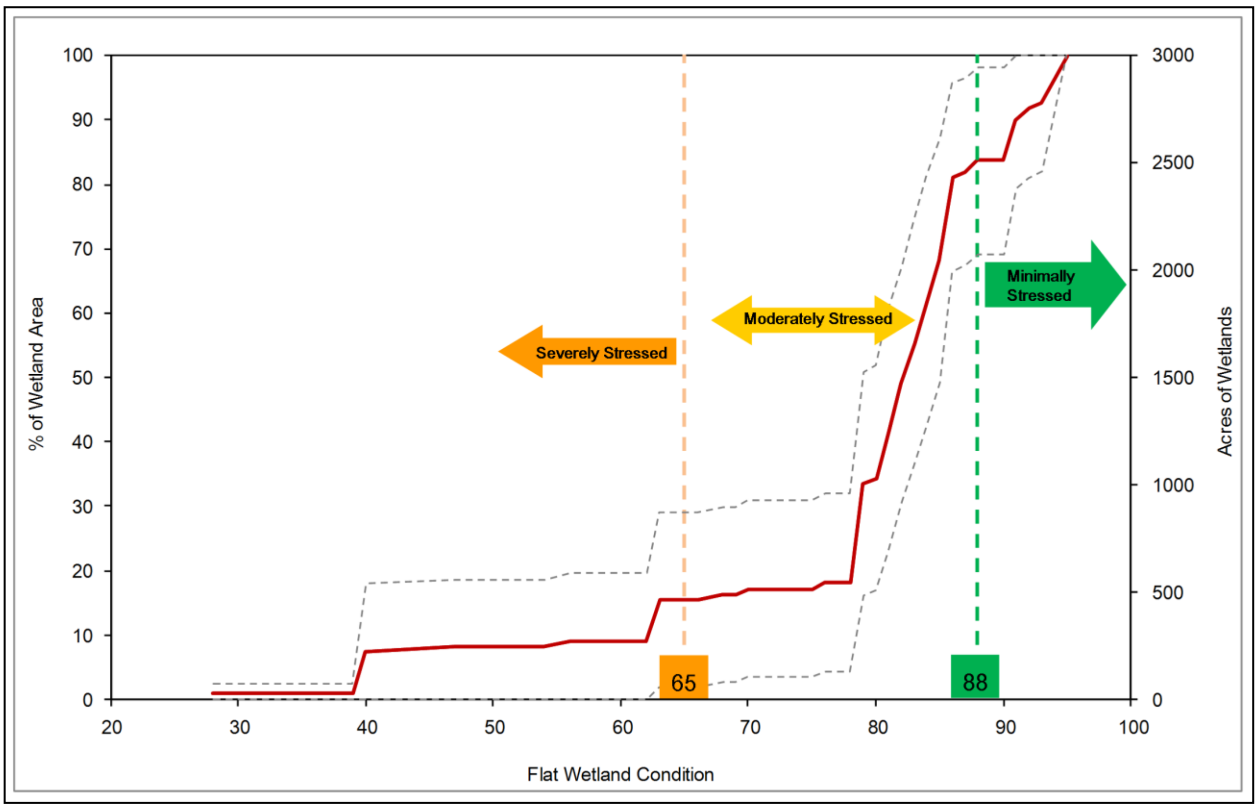
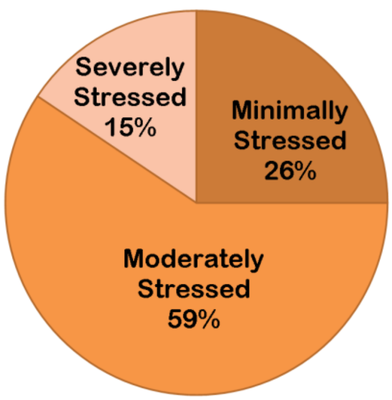


Figure 9. Cumulative Distribution Function for nontidal flat wetlands in the Broadkill River watershed, Delaware in 2010. The orange and green dashed lines signify condition category breakpoints dividing severely, moderately and minimally stressed portions of the flats wetland population. The gray dashed lines represent the 95% confidence intervals.

Wetland condition scores for flats ranged widely from 28 to 95 and averaged 78±16. Over one half (59%) of flats were moderately stressed, 26% were minimally or not stressed, and 15% were severely stressed (Figure 12 *left*). Forestry activity occurred throughout the Broadkill watershed (41% of flats), but each of the severely stressed wetlands were clear cut within the last 2 years. Invasive plants were present in flats of every condition category. Conversion from a natural forest community to pine plantation occurred in 60% of the severely stressed wetlands and in 13% of the overall flat wetland population. Ditching and disturbance to wetland buffers also increased with decreasing condition (Figure 12 *right*). Elevated dirt or paved roads were common (43%) in flat wetlands across the watershed.



Stressor	Proportion of Sites with Stressor Present		
	Minimally Stressed *n* = 8	Moderately Stressed *n* = 19	Severely Stressed *n* = 5
Forest clear cutting	0%	11%	100%
Invasive plants in the AA	50%	37%	40%
Ditches in the AA	0%	26%	60%
Microtopographic alterations	13%	26%	80%
Roads in the wetland buffer	0%	47%	40%

Figure 10. Condition proportions *(left)* and stressor occurrence *(right)* for the flat wetlands population in the Broadkill River watershed, Delaware in 2010.

In general, the most common habitat stressors for flats were forestry activity and the presence of invasive species, and common hydrology stressors were ditching and fill materials in the wetland AA. Residential or commercial development was found in only 13% of wetland buffers, while agricultural activities occurred in 28% of wetland buffers. Agricultural activities, along with recent forestry activity, represented the most common buffer stressors. The rapid assessment stressor dataset from 32 flats sites in the Broadkill River watershed are provided in Appendix F.

4.3.2.b Riverine

Riverine wetlands, also called riparian or floodplain wetlands, occur along downstream portions of rivers and streams and make up 26% (3,527ac) of the Broadkill watershed's wetlands. They are valued for their water quality maintenance through sediment retention and nutrient uptake. They also provide storm water storage, either holding runoff water from upland areas or allowing overbank flood water storage. Riverine wetlands also provide rich habitat for fish, wildlife and plants and serve as an important landscape link between surface waters and upland habitats.

The cumulative distribution function for Broadkill riverine wetlands showed a population with condition scores that ranged widely with some distinct groupings of sites (Figure 13). Similar to flat wetlands in the Broadkill River watershed, roughly 500ac of the remaining riverine wetland population is considered minimally stressed. The largest grouping of wetlands (30%) had a condition score of 83-84. These sites had a presence of invasive species and buffer stressors, but few occurrences of alterations to the waterway. A smaller subset of wetlands (10%) shared a condition score of 62 and was found to have invasive plant species, incised channels, and developed buffers.

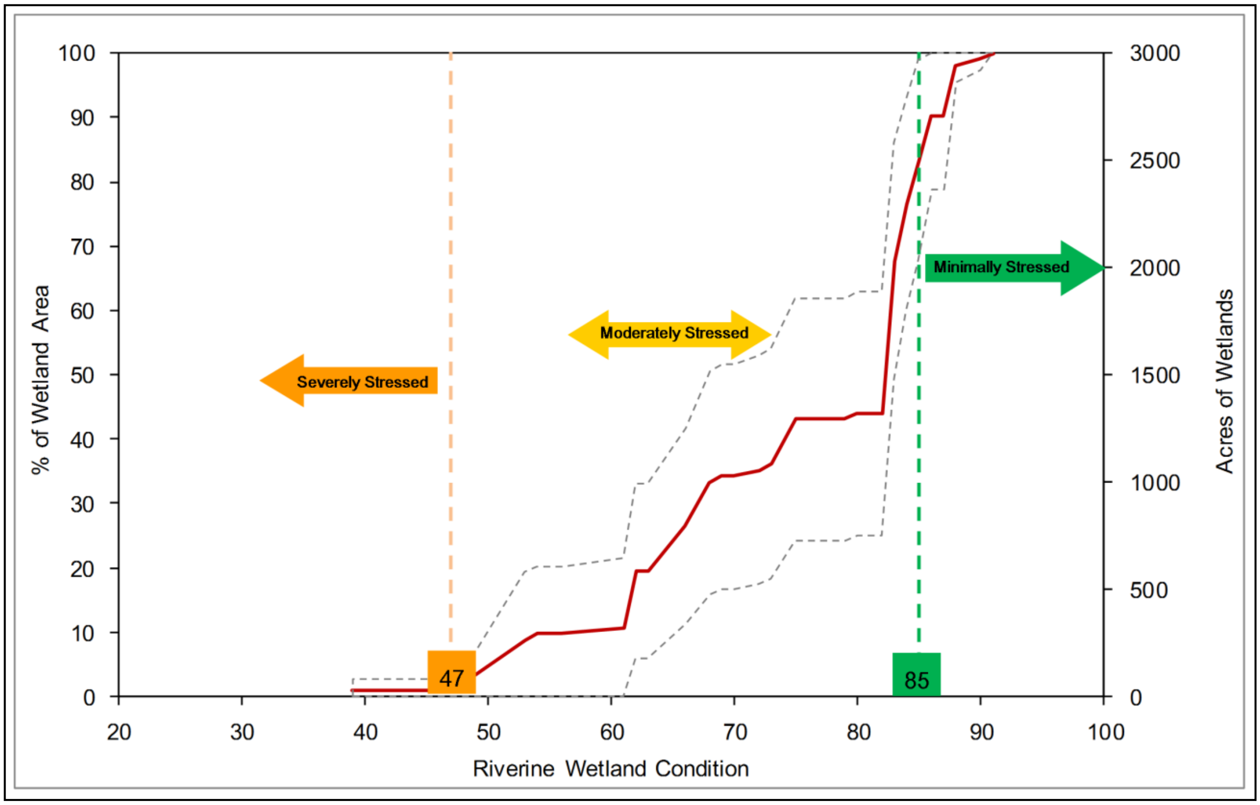
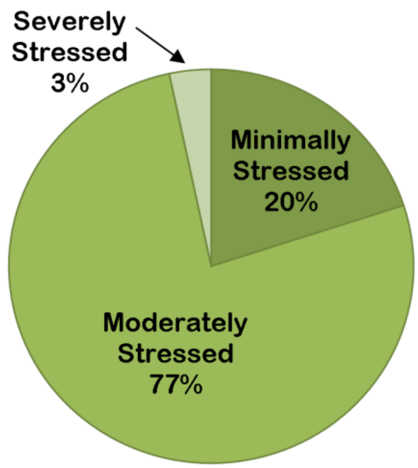


Figure 11. Cumulative Distribution Function for nontidal riverine wetlands in the Broadkill River watershed, Delaware in 2010. The orange and green dashed lines signify the condition category breakpoints dividing severely, moderately and minimally stressed portions of the riverine wetland population. The gray dashed lines represent the 95% confidence intervals.

The wetland condition scores for riverine wetlands in the Broadkill watershed ranged from 39 to 91 and averaged 74±14. Only one site (3% of the population) was severely stressed, so conclusions can not accurately be drawn for stressors common to this condition class. The majority (77%) of wetlands were moderately stressed, and 20% were minimally or not stressed (Figure 14 *left*). Invasive plants were widespread throughout the population and were found in 77% of riverine wetlands, including 91% of moderately stressed sites (Figure 14 *right*). Stream alterations were also found in nearly half (43%) of the moderately stressed sites, as either stream channelization or natural channel incision. Unlike flats, intensive timber management such as forest clearcutting or conversion to pine plantations did not occur in any of the riverine wetlands sampled.



Stressor	Proportion of Sites with Stressor Present	
	Minimally Stressed *n* = 6	Moderately Stressed *n* = 23
Stream channelization or incision	0%	43%
Invasive plants in the AA	17%	91%
Microtopographic alterations	17%	13%
Residential development in the buffer	33%	61%
Agriculture in the buffer	67%	65%

Figure 12. Condition proportions *(left)* and stressor occurrence *(right)* for riverine wetlands in the Broadkill River watershed, Delaware in 2010.

Aside from the presence of invasive species, few habitat stressors were common in Broadkill riverine wetlands. The only other riverine habitat stressor of significance was selective cutting (27%). Stream channelization or incision was found in 37% of wetlands and was the most common hydrology stressor. In general, buffers to riverine wetlands contained multiple stressors, including agriculture (67%), development (53%), roads (47%), and recent forestry activity (33%). The rapid assessment stressor dataset from 30 riverine sites in the Broadkill River watershed are provided in Appendix G.

4.3.2.c Depressions

Depression wetlands occur throughout the watershed in low-lying areas and topographical depressions. They are fed by groundwater, rainfall or snow melt in the spring and winter and are often dry on the surface in the summer and fall. Although depressions make up a small portion (<1%) of the Broadkill River wetland population they are important because they include rare habitats, such as coastal plain ponds. These unique wetlands provide critical habitat to many rare and threatened plants and animals, including pink tickseed (*Coreopsis rosea)* and tiger salamanders (*Ambystoma tigrinum*). Depressions also collect and moderate storm water, cycle nutrients, and improve water quality through sediment retention and nutrient uptake.

Our limited sampling of depressions in the Broadkill River watershed did not allow us to report on the condition of the population in detail with any certainty.

However, combining assessment data from depressions in the Broadkill, St. Jones, and Murderkill watersheds (*n*=10) revealed that 80% of the wetlands contained invasive species, 70% had recent forestry activity, 60% had fill material deposited in the wetland AA, and 60% of the wetland buffers contained agricultural land. The rapid assessment data from 3 Broadkill depression sites are provided in Appendix I.

4.4 Overall Condition and Watershed Comparison

For an overall view of wetland condition in the Broadkill River watershed, and to compare alongside three other recently assessed watersheds, we combined the condition proportions for the major wetland types (tidal, flat, riverine and depression) based on the acreage of each type in the watershed (Figure 15).

Moderately stressed wetlands dominated each major wetland type in the Broadkill River watershed and made up 65% of the total population. Compared to other watersheds in Delaware, the Broadkill River watershed contained less minimally stressed wetlands than any other watershed (23%; Figure 15). However, the Broadkill watershed also contained fewer severely stressed wetlands than the other three watersheds.

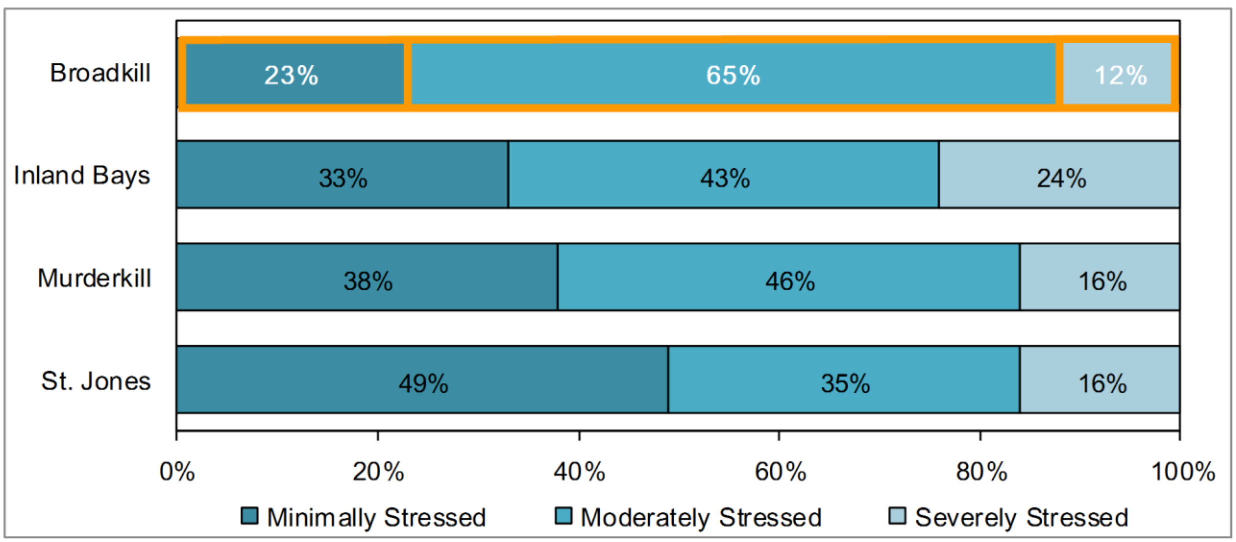


Figure 13. Combined condition of tidal, flat, riverine and depression wetlands in the Broadkill River watershed, Delaware in 2010 and its comparison to wetland condition of the St. Jones River, Murderkill River, and Inland Bays watersheds, Delaware in 2005-2009, based on the DERAP and MidTRAM.

MANAGEMENT RECOMMENDATIONS

Based on our study, we offer the following 9 recommendations to improve wetland management, identify additional data needs, and encourage informed and effective decisions concerning the future of wetland resources in the Broadkill River watershed.

1. **Improve the protection of flats**. The greatest historic wetland losses occurred in headwater flats, and these habitats continue to be the most frequently converted wetlands in the watershed. Our study found that 1/4 of remaining flats were in high condition and our priority is to ensure that they remain intact. Protecting the top condition portion of the population will capitalize on their role in the watershed for improving water quality, providing important habitat, and storing flood waters. Also, to ensure that moderate condition flats, which were mostly impacted by forestry activities, are being harvested using sustainable practices will allow them to regenerate to native forest communities and retain natural wetland hydrology.

2. **Improve protection of nontidal wetlands**. Activities in nontidal wetlands are not regulated by the State of Delaware. Every additional wetland filled or destroyed contributes to a reduction of water quality, wildlife habitat, and flood abatement services, and increases societal costs for providing man-made alternatives to these services. Improved protection for nontidal wetlands is needed to fill the gaps left by recent Supreme Court decisions and to provide a comprehensive and clear means to protect wetlands across the state. A state regulatory program in concert with county and local programs would reduce the ambiguity surrounding which wetlands are regulated and provide a comprehensive and clear means to protect wetlands in the entire state. Local regulations can be incorporated into municipal and/or county code and home owner associations to protect wetland areas of special significance. Also, consider protecting high quality wetlands using fee simple acquisitions and conservation easements. We can encourage better protection at the state and local level by educating the public and decision makers on the importance of wetlands within the watershed.

3. **Improve nontidal wetland buffer regulations and codes**. By allowing generous stream and wetland buffers, nontidal wetland services including water quality improvement, wildlife habitat, and flood water retention will be preserved. Sussex County code[1] establishes 50ft riparian buffers extending from the ordinary high water mark of perennial streams (Article 25 § 115-193). Under current wording, nontidal wetlands that extend >50ft from

[1] http://ecode360.com/SU1223 February 2013

perennial streams are not protected. Recent regulations to increase buffer widths to 100ft in Sussex County were included in the Inland Bays Pollution Control Strategy (DE DNREC 2008b) but were challenged by the County and found to be invalid. Establishing and enforcing wetland buffers that specifically start at the wetland edge would strengthen protection and improve water quality. Also, requiring wetland and riparian buffers to have forested vegetation would maximize nutrient removal from groundwater, surface water runoff and in-stream flow, while improving corridor habitat.

4. **Update tidal wetland regulatory maps**. In addition to improving the protection of nontidal wetlands, it is prudent to maximize the authority that already exists within DNREC. Tidal wetland impacts are regulated by the State of Delaware and permit reviewers need accurate and recent wetland maps to guide wetland permitting. Currently 1988 wetland maps are used, which must be verified in person and are difficult to read. Evidence of recent coastal development and inundation of coastal wetlands due to sea level rise creates a greater need to adopt updated wetland maps as regulatory maps.

5. **Develop incentives to maintain natural buffers of tidal wetlands**. As sea levels rise and extreme storm events bring more flooding, the importance of wetland buffers between water and upland is taking center stage. The need exists to inform Delawareans on the importance of allowing tidal wetlands to migrate inland unobstructed by roads, rip-rap and bulkheads. Barriers to landward migration do not allow marshes to keep pace with sea level rise and when these habitats are converted to open water it prevents them from buffering coastal storms. The low occurrence of hardened shorelines in Broadkill River watershed is uncommon in Delaware and should be preserved. In addition to awareness, an incentive program could attract an interest in maintaining natural buffers between wetlands and development.

6. **Control the extent and spread of the non-native, invasive common reed (*Phragmites australis*)**. Invasive plants such as *Phragmites* are capable of spreading rapidly, outcompeting native species, reducing plant diversity in undisturbed areas, and reducing the success of other organisms by changing habitat structure and food availability. The DNREC Phragmites Control Program in the Division of Fish and Wildlife has treated more than 20,000 acres on private and public property since 1986. Without continued support from state funds and federal State Wildlife Grant funds *Phragmites* will degrade more wetlands. If *Phragmites* was eradicated from tidal wetlands, the average habitat scores would increase 13% from 61% to 74% and only 3% of the tidal wetlands in the Broadkill River watershed would be severely stressed (down from 14%).

7. **Improve enforcement of wetland permitting and mitigation monitoring**. Enforcing wetland impact criteria and following up with mitigation monitoring is labor intensive and can be difficult to quantify. Delaware's DNREC is working with the Army Corps to improve the effectiveness and efficiency of wetland permitting by incorporating the Delaware Rapid Assessment Procedure and develop value-added metrics to account for non-condition related wetland features. Additional enforcement staff and federal oversight will also improve Delaware's wetland protection efforts.

8. **Design a wetland restoration plan for the Lower Delaware Bay Basin that includes the Broadkill River watershed**. This involves a science-based process that uses existing data to identify restoration and protection priority properties pertinent to forestry, agriculture, wetlands, restoration, soils, wildlife and botany branches of state, federal and non-profit organizations. The plan would lead to the implementation of restoration and conservation opportunities on private and public property across the Delaware Bay Basin and Broadkill River watershed. A basin-wide plan will combine resources, time, and manpower. Roughly 8,700 acres of wetlands in the Broadkill were moderately stressed which identified a need for restoration to restore the structure and function of their biological community. The Broadkill River watershed contains fewer high-quality wetlands than other previously assessed watersheds, so these should be a priority for protection. Enhancement and restoration should be a priority in the watershed to reduce impacts to wetland resources and improve wetland functions.

9. **Support Delaware's Bayshore Initiative by securing funding for wetland restoration and preservation**. As part of President Obama's America's Great Outdoors initiative, the Delaware Bayshore Initiative was created to preserve Delaware's coastal heritage and increase recreation utilizing landscape-scale conservation practices. Thirty square miles of the Broadkill River watershed is within the targeted Bayshore region, including most of the watershed's tidal marshes and a number of sizable Coastal Plain Ponds. The most proactive approach to conserving wetland resources is to protect wetlands in high condition that have not been impacted by significant stressors. The Delaware Bayshore Initiative will pool conservation resources to efficiently improve coastal habitat access and preservation.

LITERATURE CITED

Brand, A.B, J. W. Snodgrass, M.T. Gallagher, R. E. Casey, R. Van Meter. 2010. Lethal and sublethal effects of embryonic and larval exposure of *Hyla versicolor* to stormwater pond sediments. Archives of Environmental Contamination and Toxicology 58:325-331.

Carullo, M., B.K. Carlisle, and J.P. Smith. 2007. A New England Rapid Assessment Method for Assessing Condition of Estuarine Marshes; A Boston Harbor, Cape Cod and Islands Pilot Study. Massachusetts Office of Coastal Zone Management, Boston, USA.

Collins, N.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2008. California Rapid Assessment Method (CRAM) for Wetlands, Version 5.0.2 <http://www.cramwetlands.org/documents/2008-09-30_CRAM%205.0.2.pdf> Accessed 28 May 2009.

Cowardin, L.M, V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington D.C., USA.DE DNREC 2005.

Darby, F.A. and R. E. Turner. 2008. Effects of eutrophication on salt marsh root and rhizome biomass accumulation. Marine Ecology Progress Series 363: 63-70.

DE DNREC. 2005. Delaware Bay and Estuary Whole Basin Assessment Report. Delaware Department of Natural Resources and Environmental Control Document Number 40-01-01/05/02/01, Dover, USA.

DE DNREC. 2006. Broadkill River Watershed Proposed TMDLs. Delaware Department of Natural Resources and Environmental Control, Dover, USA.

DE DNREC. 2006. Delaware Wildlife Action Plan 2007-2017. Delaware Department of Natural Resources and Environmental Control, Dover, USA.

DE DNREC. 2008a. Delaware Wetlands Conservation Strategy. Delaware Department of Natural Resources and Environmental Control, Dover, USA.

DE DNREC. 2008b. Regulations governing the pollution control strategy for the Indian River, Indian River Bay, Rehoboth Bay and Little Assawoman Bay watersheds. Delaware Department of Natural Resources and Environmental Control, Dover, USA.

Deegan, L.A., D.S. Johnson, R.S. Warren, B.J. Peterson, J.W. Fleeger, S. Fagherazzi, and W.M. Wollheim. 2012. Coastal eutrophication as a driver of salt marsh loss. Nature 480: 388-392.

Jacobs, A.D. 2007. Delaware Rapid Assessment Procedure Version 5.1. Delaware Department of Natural Resources and Environmental Control, Dover, Delaware, USA.

Jacobs, A.D., D. Whigham, D. Fillis, E. Rehm, and A. Howard. 2008. Delaware Comprehensive Assessment Procedure Version 5.1. Delaware Department of Natural Resources and Environmental Control, Dover, Delaware, USA.

Jacobs, A.D., M.E. Kentula, and A.T. Herlihy. 2009. Developing an index of wetland condition from ecological data: an example using HGM functional variables from the Nanticoke watershed, USA. Ecological Indicators.

Jacobs, A.D., A.M. Howard, and A.B. Rogerson. 2010. Mid-Atlantic Tidal Wetland Rapid Assessment Method Version 3.0. Delaware Department of Natural Resources and Environmental Control, Dover, USA.

Sifneos, J.C., A.T. Herlihy, A.D. Jacobs and M.E. Kentula. 2010. Calibration of the Delaware rapid assessment protocol to a comprehensive measure of wetland condition. Wetlands 30:1011-1022.

State of Delaware. 1994. Statewide Wetland Mapping Project (SWMP). Prepared for the State of Delaware's Department of Natural Resources and Environmental Control (DNREC) and for the Department of Transportation (DELDOT), Dover, USA.

State of Delaware. 2007. Statewide Wetland Mapping Project (SWMP). Prepared for the State of Delaware's Department of Natural Resources and Environmental Control (DNREC), Dover, USA.

State of Delaware. 2012. Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability Assessment of the State of Delaware. Prepared for the Delaware Sea Level Rise Advisory Committee by the Delaware Coastal Programs of the Department of Natural Resources and Environmental Control (DNREC). Dover, USA.

Stevens, D.L. Jr., and A.R. Olsen. 1999. Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics 4:415-428.

Stevens, D.L. Jr., and A.R. Olsen. 2000. Spatially-restricted random sampling designs for design-based and model-based estimation. Pages 609-616 *in* Accuracy

2000: Proceedings of the 4th International symposium on spatial accuracy assessment in natural resources and environmental sciences. Delft University Press, Delft, The Netherlands.

Tiner, R.W. 2010. NWIPlus: Geospatial database or watershed-level functional assessment. Environmental Law Institute, National Wetlands Newsletter 32(3):4-7. http://www.fws.gov/northeast/wetlands/Publications%20PDFs%20as%20of%20March_2008/Mapping/NWIPlus_NWN.pdf

Tiner, R.W., M.A. Biddle, A.D. Jacobs, A.B. Rogerson and K.G. McGuckin. 2011. Delaware Wetlands: Status and Changes from 1992 to 2007. Cooperative National Wetlands Inventory Publication. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA and the Delaware Department of Natural Resources and Environmental Control, Dover, DE. 35pp.

Turner R.E., E.M. Swenson, C.S. Milan, and T.A. Oswald. 2004. Below-ground biomass in healthy and impaired salt marshes. Ecological Research 19:29-35.

US FWS. 2012. Prime Hook National Wildlife Refuge: Final Comprehensive Conservation Plan and Environmental Impact Statement. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA.

APPENDIX A: Qualitative Disturbance Rating (QDR) Category Descriptions

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 land use 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 the narrative criteria below. General description of the minimal disturbance, moderate disturbance and high disturbance categories are provided below.

Minimal Disturbance Category (QDR 1 or 2): <u>Natural structure and biotic community maintained with only minimal alterations.</u> 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 (100 or 250 m buffer). Examples of minimal alterations include a small ditch that is not conveying water, low occurrence of invasive 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): <u>Moderate changes in structure and/or the biotic community.</u> 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 invasive plants, forest harvesting, high impact land uses in the buffer, and hardened surfaces along the wetland/upland interface for less than half of the site. Use BPJ to assign a QDR of 3 or 4.

High Disturbance Category (QDR 5 or 6): <u>Severe changes in structure and/or the biotic community</u>. High disturbance sites have severely disturbed vegetative community, hydrology and/or soils as a result of ≥1 severe alterations or >2 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 an invasive 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.

APPENDIX B: Nontidal Rapid Assessment Stressor Codes and Definitions

Habitat Category (within 40m radius of sample point)	
Hmow	Mowing in AA
Hfarm	Farming activity in AA
Hgraz	Grazing in AA
Hnorecov	Cleared land not recovering
Hfor31	Forest age 31-50 years
Hfor16	Forest age 16-30 years
Hfor3	Forest age 3-15 years
Hfor2	Forest age ≤2 years
Hcc10	≤10% of AA clear cut within 50 years
Hcc50	11-50% of AA clear cut within 50 years
Hcc100	>50% of AA clear cut within 50 years
Hforsc	Selective cutting forestry
Hherb	Excessive Herbivory/Pinebark Beetle/Gypsy Moth
Hinvdom	Invasive plants dominating AA
Hinvless	Invasive plants not dominating
Hchem	Chemical Defoliation
Hpine	Managed or Converted to Pine
Htrail	Non-elevated road
Hroad	Dirt or gravel elevated road in AA
Hpave	Paved road in AA
Hnutapp	Nutrient indicator species dominating AA
Halgae	Nutrients dense algal mats
Hydrology Category (within 40m radius of sample point)	
Wditchs	Slight Ditching; 1-3 shallow ditches (<.3m deep) in AA
Wditchm	Moderate Ditching; 3 shallow ditches (<.3m deep) in AA or 1
Wditchx	Severe Ditching; >1 ditch .3-.6 m deep or 1 ditch > .6m deep
Wditchfloodplain	Ditching in floodplain (not including main channel)
Wchannm	Channelized stream not maintained
Wchan1	Spoil bank only one side of stream
Wchan2	Spoil bank both sides of stream
Wincision	Stream channel incision
Wdamdec	WeirDamRoad decreasing site flooding
Wimp10	WeirDamRoad/Impounding water on <10% of AA
Wimp75	WeirDamRoad/Impounding water on 10-75% of AA
Wimp100	WeirDamRoad/Impounding water on >75% of AA
Wstorm	Stormwater Inputs
Wpoint	Point Source (non-stormwater)
Wfill10	Filling, excavation on <10% of AA
Wfill75	Filling, excavation on 10-75% of AA

Hydrology Category (continued)	
Wfill100	Filling, excavation on >75% of AA
Wmic10	Microtopo alterations on <10% of AA
Wmic75	Microtopo alteations on 10-75% of AA
Wmic100	Microtopo alterations on >75% of AA
Wsed	Excessive Sedimentation on wetland surface
Wsubsid	Soil Subsidence/Root Exposure
Landscape/Buffer Category (within 100m radius outside site/AA)	
Ldevcom	Development- commercial or industrial
Ldevres3	Residential >2 houses/acre
Ldevres2	Residential ≤2 houses/acre
Ldevres1	Residential <1 house/acre
Lrdgrav	Roads (buffer) mostly dirt or gravel
Lrd2pav	Roads (buffer) mostly 2- lane paved
Lrd4pav	Roads (buffer) mostly 4-lane paved
Llndfil	Landfill/Waste Disposal
Lchan	Channelized Streams or Ditches >0.6m deep
Lag	Row crops, nursery plants, orchards
Lagpoul	Poultry or Livestock operation
Lfor	Forest Harvesting Within Last 15 Years
Lgolf	Golf Course
Lmow	Mowed Area
Lmine	Sand/Gravel Operation

APPENDIX C: Nontidal Rapid Assessment IWC Stressors and Weights

<table>
<tr><th>Category/Stressor Name*</th><th>Code</th><th colspan="3">Stressor Weights**</th></tr>
<tr><td colspan="2">*DERAP stressors excluded from this table are not in the rapid IWC calculation.</td><td>Flats</td><td>Riverine</td><td>Depression</td></tr>
<tr><td colspan="5">Habitat Category (within 40m radius site)</td></tr>
<tr><td>Mowing in AA</td><td>Hmow</td><td rowspan="4">15</td><td rowspan="4">3</td><td rowspan="4">24</td></tr>
<tr><td>Farming activity in AA</td><td>Hfarm</td></tr>
<tr><td>Grazing in AA</td><td>Hgraz</td></tr>
<tr><td>Cleared land not recovering in AA</td><td>Hnorecov</td></tr>
<tr><td>Forest age 16-30 years</td><td>Hfor16</td><td rowspan="2">5</td><td rowspan="2">4</td><td rowspan="2">2</td></tr>
<tr><td>≤10% of AA clear cut within 50 years</td><td>Hcc10</td></tr>
<tr><td>Forest age 3-15 years</td><td>Hfor3</td><td rowspan="4">19</td><td rowspan="4">7</td><td rowspan="4">12</td></tr>
<tr><td>Forest age ≤2 years</td><td>Hfor2</td></tr>
<tr><td>11-50% of AA clear cut within 50 years</td><td>Hcc50</td></tr>
<tr><td>>50% of AA clear cut within 50 years</td><td>Hcc100</td></tr>
<tr><td>Excessive Herbivory</td><td>Hherb</td><td>4</td><td>2</td><td>2</td></tr>
<tr><td>Invasive plants dominating</td><td>Hinvdom</td><td>2</td><td>20</td><td>7</td></tr>
<tr><td>Invasive plants not dominating</td><td>Hinvless</td><td>0</td><td>5</td><td>7</td></tr>
<tr><td>Chemical Defoliation</td><td>Hchem</td><td rowspan="2">5</td><td rowspan="2">9</td><td rowspan="2">1</td></tr>
<tr><td>Managed or Converted to Pine</td><td>Hpine</td></tr>
<tr><td>Non-elevated road in AA</td><td>Htrail</td><td rowspan="3">2</td><td rowspan="3">2</td><td rowspan="3">2</td></tr>
<tr><td>Dirt or gravel elevated road in AA</td><td>Hroad</td></tr>
<tr><td>Paved road in AA</td><td>Hpave</td></tr>
<tr><td>Nutrient indicator species dominating AA</td><td>Hnutapp</td><td rowspan="2">10</td><td rowspan="2">12</td><td rowspan="2">10</td></tr>
<tr><td>Nutrients dense algal mats</td><td>Halgae</td></tr>
<tr><td colspan="5">Hydrology Category (within 40m radius site)</td></tr>
<tr><td>Slight Ditching</td><td>Wditchs</td><td rowspan="2">10</td><td>0</td><td rowspan="3">5</td></tr>
<tr><td>Moderate Ditching</td><td>Wditchm</td><td>0</td></tr>
<tr><td>Severe Ditching</td><td>Wditchx</td><td>17</td><td>0</td></tr>
<tr><td>Channelized stream not maintained</td><td>Wchannm</td><td>0</td><td>13</td><td>0</td></tr>
<tr><td>Spoil bank only one side of stream</td><td>Wchan1</td><td>0</td><td rowspan="2">31</td><td>0</td></tr>
<tr><td>Spoil bank both sides of stream</td><td>Wchan2</td><td>0</td><td>0</td></tr>
<tr><td>Stream channel incision</td><td>Wincision</td><td>0</td><td>21</td><td>0</td></tr>
<tr><td>WeirDamRoad decreasing site flooding</td><td>Wdamdec</td><td rowspan="4">2</td><td rowspan="4">2</td><td rowspan="4">2</td></tr>
<tr><td>WeirDamRoad/Impounding <10%</td><td>Wimp10</td></tr>
<tr><td>WeirDamRoad/Impounding 10-75%</td><td>Wimp75</td></tr>
<tr><td>WeirDamRoad/Impounding >75%</td><td>Wimp100</td></tr>
<tr><td>Stormwater Inputs</td><td>Wstorm</td><td rowspan="3">2</td><td rowspan="3">2</td><td rowspan="3">2</td></tr>
<tr><td>Point Source (non-stormwater)</td><td>Wpoint</td></tr>
<tr><td>Excessive Sedimentation</td><td>Wsed</td></tr>
</table>

*** Stressors with weights in boxes were combined during calibration analysis and are counted only once, even if more than one stressor is present.*

APPENDIX C continued

Hydrology Category (continued)				
Filling, excavation on <10% of AA	Wfill10	2	0	8
Filling, excavation on 10-75% of AA	Wfill75	16	11	2
Filling, excavation on >75% of AA	Wfill100			
Soil Subsidence/Root Exposure	Wsubsid	7	0	0
Microtopo alterations on <10% of AA	Wmic10			
Microtopo alteations on 10-75% of AA	Wmic75	16	11	2
Microtopo alterations on >75% of AA	Wmic100			
Buffer Category (100m radius around site)				
Development- commercial or industrial	Ldevcom	1 buffer stressor = 3	1 buffer stressor = 1	1 buffer stressor = 4
Residential >2 houses/acre	Ldevres3			
Residential ≤2 houses/acre	Ldevres2			
Residential <1 house/acre	Ldevres1			
Roads (buffer) mostly dirt or gravel	Lrdgrav	2 buffer stressors = 6	2 buffer stressors = 2	2 buffer stressors = 8
Roads (buffer) mostly 2- lane paved	Lrd2pav			
Roads (buffer) mostly 4-lane paved	Lrd4pav			
Landfill/Waste Disposal	Llndfil			
Channelized Streams/ditches >0.6m deep	Lchan			
Row crops, nursery plants, orchards	Lag	≥ 3 buffer stressors = 9	≥ 3 buffer stressors = 3	≥ 3 buffer stressors = 12
Poultry or Livestock operation	Lagpoul			
Forest Harvesting Within Last 15 Years	Lfor			
Golf Course	Lgolf			
Mowed Area	Lmow			
Sand/Gravel Operation	Lmine			
Intercept/Base Value		95	91	82
Flats IWCrapid= 95 -(∑weights(Habitat+Hydro+Buffer))				
Riverine IWCrapid= 91 -(∑weights(Habitat+Hydro+Buffer))				
Depression IWCrapid= 82 -(∑weights(Habitat+Hydro+Buffer))				

*** Stressors with weights in boxes were combined during calibration analysis and are counted only once, even if more than one stressor is present.*

APPENDIX D: Tidal Wetland Raw Data and Scored Metrics from MidTRAM for Broadkill River Sites * **

Site Number (color coded by condition group)	QDR	H1: Ditching & Draining Score	(H2): % Cover of fill	H2: Fill & Fragmen-tation Score	H3: Diking & Restriction Score	H4: Point Source Score	(B1): % of AA with 5m-buffer	B1: % of AA with 5m-buffer Score	(B2): Average Buffer Width (m)	B2: Average Buffer Width Score	(B3): % develop-ment	B3: Surrounding Development Score	B4: 250m Landscape Condition Score
BRT011	2	9	0	12	12	12	100	12	250	12	0	12	9
BRT026	2	12	0	12	12	12	100	12	220	12	0	12	9
BRT009	3	6	0	12	12	12	100	12	208	12	0	12	9
BRT001	2	6	0	12	12	12	100	12	250	12	0	12	9
BRT004	3	6	0	12	12	12	100	12	208	12	0	12	9
BRT007	2	3	0	12	12	12	100	12	244	12	0	12	9
BRT012	3	9	0	12	12	12	100	12	230	12	1.5	9	9
BRT019	3	6	2	9	12	12	100	12	202	12	5	9	9
BRT013	2	3	2	9	12	12	100	12	250	12	0	12	9
BRT028	3	6	0	12	12	12	100	12	218	12	0	12	9
BRT038	2	6	0	12	12	12	100	12	233	12	0	12	9
BRT024	3	3	0	12	12	12	100	12	250	12	0	12	9
BRT030	4	6	1	9	12	12	100	12	214	12	3	9	6
BRT034	4	12	0	12	12	12	100	12	177	9	42.5	3	6
BRT018	2	6	1	9	6	12	100	12	250	12	0	12	9
BRT035	4	6	0	12	12	12	100	12	200	12	25	3	6
BRT003	4	6	0	12	12	12	100	12	185	9	1.5	9	6
BRT017	2	6	5	6	12	12	100	12	189	9	0	12	9
BRT005	4	3	0	12	12	12	100	12	250	12	0	12	6

* Green columns indicate scored metric values; blue columns indicate raw variable values. Site numbers are colored by condition category, see Figure 8.

** Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

Site Number (color coded by condition group)	QDR	H1: Ditching & Draining Score	(H2): % Cover of fill	H2: Fill & Fragmen-tation Score	H3: Diking & Restriction Score	H4: Point Source Score	(B1): % of AA with 5m-buffer	B1: % of AA with 5m-buffer Score	(B2): Average Buffer Width (m)	B2: Average Buffer Width Score	(B3): % develop-ment	B3: Surrounding Development Score	B4: 250m Landscape Condition Score
BRT022	3	3	7	9	9	12	100	12	201	12	2.55	9	9
BRT027	4	12	0	12	9	12	100	12	250	12	0	12	6
BRT032	4	12	0	12	3	12	100	12	250	12	0	12	6
BRT036	5	12	0	12	3	12	100	12	250	12	0	12	6
BRT025	5	9	0	12	3	12	100	12	148	9	0	12	6
BRT029	4	12	0	12	3	12	100	12	250	12	0	12	6
BRT037	5	12	0	12	9	12	100	12	80	6	10	6	3
BRT020	5	9	0	12	6	12	95	9	150	9	10	6	6
BRT008	5	12	0	12	6	12	100	12	104	6	4.9	9	3
BRT015	6	6	0	12	3	12	100	12	144	9	0.3	9	3

* Green columns indicate scored metric values; blue columns indicate raw variable values. Site numbers are colored by condition category, see Figure 8.

** Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

APPENDIX D continued laterally

Site Number (color coded by condition group)	QDR	(B5): % Obstructed Shoreline	B5: Barriers to Landward Migration Score	(HAB1): Avg Bearing Capacity (cm)	HAB1: Bearing Capacity Score	(HAB2:) Avg. Veg Obstruction	HAB2: Vegetative Obstruction Score	(HAB3): Number of Plant Layers	HAB3: Number of Plant Layers Score	(HAB4): % Co-dominant Invasive Plant Species	HAB4: % Co-dominant Invasive Plant Species Score	(HAB5): % Cover of Invasive Plants	HAB5: % Invasive Score
BRT011	2	0	12	1.81	12	20	6	3	9	0	12	0	12
BRT026	2	0	12	7.10	3	5.75	12	3	9	0	12	1	9
BRT009	3	0	12	1.72	12	18.5	6	2	9	0	12	0	12
BRT001	2	0	12	5.21	6	11.25	9	2	9	0	12	0	12
BRT004	3	0	12	3.45	9	14.75	6	3	9	0	12	3	9
BRT007	2	0	12	1.28	12	20	6	2	9	0	12	0	12
BRT012	3	0	12	3.80	9	15.5	6	2	9	0	12	3	9
BRT019	3	0	12	1.03	12	18.5	6	2	9	0	12	0	12
BRT013	2	0	12	1.88	12	20	6	3	9	0	12	0	12
BRT028	3	0	12	5.25	6	26	3	2	9	0	12	0	12
BRT038	2	0	12	7.22	3	20.5	6	3	9	0	12	0	12
BRT024	3	0	12	2.69	9	15	6	3	9	0	12	2.5	9
BRT030	4	0	12	1.47	12	25	3	2	9	0	12	0	12
BRT034	4	7	9	5.04	6	5	12	3	9	0	12	2	9
BRT018	2	0	12	1.34	12	20.5	6	2	9	0	12	1	9
BRT035	4	0	12	3.16	9	15	6	4	12	0	12	2	9
BRT003	4	0	12	2.59	9	12.5	6	3	9	0	12	1	9
BRT017	2	0	12	1.38	12	24.75	3	2	9	0	12	0.25	9
BRT005	4	0	12	3.02	9	22.25	3	3	9	33	6	5	9
BRT022	3	25	6	1.38	12	22.5	3	3	9	0	12	0	12
BRT027	4	0	12	5.59	6	4.25	9	1	6	50	3	98	3

* Green columns indicate scored metric values; blue columns indicate raw variable values. Site numbers are colored by condition category, see Figure 8.

** Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

Site Number (color coded by condition group)	QDR	(B5): % Obstructed Shoreline	B5: Barriers to Landward Migration Score	(HAB1): Avg Bearing Capacity (cm)	HAB1: Bearing Capacity Score	(HAB2:) Avg. Veg Obstruction	HAB2: Vegetative Obstruction Score	(HAB3): Number of Plant Layers	HAB3: Number of Plant Layers Score	(HAB4): % Co-dominant Invasive Plant Species	HAB4: % Co-dominant Invasive Plant Species Score	(HAB5): % Cover of Invasive Plants	HAB5: % Invasive Score
BRT032	4	0	12	3.06	9	10.5	9	3	9	50	3	60	3
BRT036	5	0	12	3.72	9	9.75	9	3	9	80	3	90	3
BRT025	5	0	12	5.38	6	17	6	3	9	25	9	3	9
BRT029	4	0	12	6.81	3	5.25	12	2	9	100	3	95	3
BRT037	5	0	12	5.41	6	3.6	12	1	6	100	3	98	3
BRT020	5	0	12	5.94	6	5.25	12	3	9	67	3	80	3
BRT008	5	40	3	1.03	12	10.25	9	2	9	67	3	78	3
BRT015	6	50	3	3.47	9	26	3	1	6	0	12	0.5	9

* Green columns indicate scored metric values; blue columns indicate raw variable values. Site numbers are colored by condition category, see Figure 8.

** Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

APPENDIX E: Vegetative Biomass Data for Broadkill River Tidal Sites 2010

Site Number	Above Live	Above Dead	Total Above	Below Live	Below Dead	Total Below	Above Live: Below Live	Above Dead: Below Dead	Total Above: Total Below
BRT001	22.087	6.153	28.240	22.250	83.803	106.053	0.266	0.993	0.073
BRT005	6.987	5.717	12.703	30.730	145.933	176.663	0.072	0.227	0.039
BRT009	9.053	4.917	13.970	25.220	157.633	182.853	0.076	0.359	0.031
BRT011	8.723	2.843	11.567	17.520	149.950	167.470	0.069	0.498	0.019
BRT013	9.707	4.377	14.083	23.090	148.683	171.773	0.082	0.420	0.029

APPENDIX F: Nontidal Flat Wetland Rapid Assessment Stressors for Sites in the Broadkill River watershed in 2010*

Stressor descriptions are listed in Appendix B (page 42). '1' indicates the stressor presence; '0' indicates stressor absence.

Habitat and Plant Community Stressors

Site Number (color coded by condition group)	QDR	Hmow	Hfarm	Hgraz	Hnorecov	Hfor31	Hfor16	Hfor3	Hfor2	Hcc10	Hcc50	Hcc100	Hforsc	Hherb	Hinvdom	Hinvless	Hchem	Hpine	Htrail	Hroad	Hpave	Hnutapp	Halgae
BR0011	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0037	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0071	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0034	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
BR0031	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0058	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0002	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
BR0035	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0049	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BR0070	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BR0028	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0029	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0021	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
BR0001	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0022	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
BR0026	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
BR0061	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0
BR0012	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BR0042	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BR0048	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0017	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
BR0019	3	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
BR0032	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0060	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0062	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0046	5	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BR0054	5	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
BR0013	6	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	0
BR0044	5	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	1	0	0	0	0
BR0038	5	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BR0009	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
BR0066	6	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	0

* Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

Appendix F continued

Hydrology Stressors

Site Number (color coded by condition group)	QDR	Wditchs	Wditchm	Wditchx	Wditchfloodplain	Wchannm	Wchan1	Wchan2	Wincision	Wdamdec	Wimp10	Wimp75	Wimp100	Wstorm	Wpoint	Wsed	Wfill10	Wfill75	Wfill100	Wmic10	Wmic75	Wmic100	Wsubsid
BR0011	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0037	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0071	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0034	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0031	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0058	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0002	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0035	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BR0049	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0070	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0028	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0029	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0021	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0001	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0022	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
BR0026	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0061	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0012	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
BR0042	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0048	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0017	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BR0019	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0032	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BR0060	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BR0062	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0046	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0054	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0013	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0044	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BR0038	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
BR0009	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
BR0066	6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0

* Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

Appendix F continued

Buffer Stressors

Site Number (color coded by condition group)	QDR	Ldevcom	Ldevres3	Ldevres2	Ldevres1	Lrdgrav	Lrd2pav	Lrd4pav	Llndfil	Lchan	Lag	Lagpoul	Lfor	Lgolf	Lmow	Lmine
BR0011	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0037	2	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0
BR0071	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0034	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0031	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BR0058	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BR0002	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0035	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0049	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BR0070	2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0028	2	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0
BR0029	2	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0
BR0021	4	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
BR0001	4	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0
BR0022	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0026	4	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0
BR0061	3	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
BR0012	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BR0042	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0048	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
BR0017	3	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0
BR0019	3	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
BR0032	3	0	0	0	1	0	1	0	0	1	1	0	0	0	0	0
BR0060	3	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0
BR0062	2	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
BR0046	5	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
BR0054	5	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
BR0013	6	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
BR0044	5	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
BR0038	5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BR0009	5	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
BR0066	6	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0

* Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

APPENDIX G: Nontidal Riverine Wetland Rapid Assessment Stressors for Sites in the Broadkill River watershed in 2010*

Stressor descriptions are listed in Appendix B (page 42). '1' indicates the presence of that stressor, '0' indicates the absence.

Habitat and Plant Community Stressors

Site Number (color coded by condition group)	QDR	Hmow	Hfarm	Hgraz	Hnorecov	Hfor31	Hfor16	Hfor3	Hfor2	Hcc10	Hcc50	Hcc100	Hforsc	Hherb	Hinvdom	Hinvless	Hchem	Hpine	Htrail	Hroad	Hpave	Hnutapp	Halgae
BR0051	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0068	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0007	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
BR0076	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
BR0006	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0003	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0015	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0085	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0100	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0018	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0020	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0030	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
BR0052	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0053	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0075	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0050	5	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
BR0024	4	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0
BR0040	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0039	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
BR0072	5	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
BR0008	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0014	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
BR0005	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0065	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0089	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0083	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
BR0057	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0025	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
BR0063	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
BR0047	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

* Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

Appendix G continued

Hydrology Stressors

Site Number (color coded by condition group)	QDR	Wditchs	Wditchm	Wditchx	Wditchfloodplain	Wchanmm	Wchan1	Wchan2	Wincision	Wdamdec	Wimp10	Wimp75	Wimp100	Wstorm	Wpoint	Wsed	Wfill10	Wfill75	Wfill100	Wmic10	Wmic75	Wmic100	Wsubsid
BR0051	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0068	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0007	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
BR0076	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0006	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BR0003	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0015	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0085	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0100	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0018	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0020	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0030	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0052	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0053	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0075	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0050	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0024	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
BR0040	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BR0039	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0072	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0008	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0014	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0005	5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0065	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0089	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0083	3	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
BR0057	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
BR0025	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0063	5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0047	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

Appendix G continued

Buffer Stressors

Site Number (color coded by condition group)	QDR	Ldevcom	Ldevres3	Ldevres2	Ldevres1	Lrdgrav	Lrd2pav	Lrd4pav	Llndfil	Lchan	Lag	Lagpoul	Lfor	Lgolf	Lmow	Lmine
BR0051	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0068	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BR0007	3	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0
BR0076	3	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0
BR0006	2	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0
BR0003	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BR0015	2	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
BR0085	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
BR0100	2	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
BR0018	4	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0
BR0020	5	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0
BR0030	4	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0
BR0052	5	0	0	0	1	0	1	0	0	1	1	0	0	0	0	0
BR0053	3	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0
BR0075	2	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0
BR0050	5	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0
BR0024	4	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
BR0040	3	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
BR0039	5	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
BR0072	5	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
BR0008	2	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
BR0014	4	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
BR0005	5	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0
BR0065	3	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0
BR0089	4	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0
BR0083	3	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
BR0057	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BR0025	3	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
BR0063	5	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
BR0047	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

* Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

APPENDIX H: Nontidal Riverine Comprehensive Metric and Variable Data from Broadkill River watershed site COMP1*

Site #	COMP1
Qualitative Condition Ranking	1
Vveg history	1.00
FACU Tree IV	0.15
Vtreecomp	0.25
Tree Basal Area m^2/ha	46.60
Vtba	1.00
Vmicrotopo	1.00
% Veg Plots with Rubus	0
Vrubus	1.00
Shrub Density (shrubs/ha)	7427
Vshrubden	1.00
Buffer Tree Basal Area (m^2/ha)	30.84
Vbufferba	0.86
% Buffer High Impact Land Use	0
Vbuffuse200	1.00
AA Floodplain Alterations	0
Vfloodplain	1.00
% Coverage Invasive Herbs	0.31
Vinvasive understory	0.75
% Channelization 500m from AA	0
Vchannel_out	1.00
Vinstream	1.00
Vhydroalt_out	0.75
Average CoC	4.68
FQAI'	46.38
Vfqai	1.00
Distance to Nearest Road (m)	400
Vdist_to_road	1.00

*Shaded lines highlight calculated variable scores; unshaded lines denote raw values.
The site was assessed in 2010 and scored with the Riverine Variable Scoring Protocol version 2.0.

APPENDIX I: Nontidal Depression Wetland Rapid Assessment Stressors for Sites in the Broadkill River watershed in 2010*

Stressor definitions are listed in Appendix B (page 42). '1' indicates the presence of that stressor, '0' indicates the absence.

		Habitat and Plant Community Stressors																					
Site Number (color coded by condition group)	QDR	Hmow	Hfarm	Hgraz	Hnorecov	Hfor31	Hfor16	Hfor3	Hfor2	Hcc10	Hcc50	Hcc100	Hforsc	Hherb	Hinvdom	Hinvless	Hchem	Hpine	Htrail	Hroad	Hpave	Hnutapp	Halgae
BR0059	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0016	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0
BR0036	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1

		Hydrology Stressors																					
Site Number (color coded by condition group)	QDR	Wditchs	Wditchm	Wditchx	Wditchfloodplain	Wchannm	Wchan1	Wchan2	Wincision	Wdamdec	Wimp10	Wimp75	Wimp100	Wstorm	Wpoint	Wsed	Wfill10	Wfill75	Wfill100	Wmic10	Wmic75	Wmic100	Wsubsid
BR0059	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0016	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR0036	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

		Buffer Stressors														
Site Number (color coded by condition group)	QDR	Ldevcom	Ldevres3	Ldevres2	Ldevres1	Lrdgrav	Lrd2pav	Lrd4pav	Llndfil	Lchan	Lag	Lagpoul	Lfor	Lgolf	Lmow	Lmine
BR0059	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BR0016	4	0	0	0	1	0	1	0	0	0	1	0	1	0	1	0
BR0036	3	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0

* Site numbers are colored by condition category (Green is minimally stressed, yellow is moderately stressed, orange is severely stressed)

This report and other watershed condition reports, assessment methods, and scoring protocols can be found on the Delaware Wetlands website:

Delaware Wetlands

Purify Provide Protect

www.dnrec.delaware.gov/admin/delawarewetlands