Mid Atlantic Coastal Wetland Assessment

Mid-Atlantic Tidal Rapid Assessment

2014 Update

Mullica River and Dennis Creek

Barnegat Bay Partnership
Research · Educate · Restore

Partnership for the Delaware Estuary Inc.

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Partnership for the Delaware Estuary

Mid-Atlantic Tidal Rapid Assessment
2014 Update: Mullica River and Dennis Creek, New Jersey

Partnership for the Delaware Estuary with
The Barnegat Bay Partnership

The Partnership for the Delaware Estuary is a nonprofit organization established in 1996 to take a leadership role in protecting and enhancing the Delaware Estuary, where fresh water from the Delaware River mixes with salt water from the Atlantic Ocean. It is one of 28 Congressionally designated National Estuary Programs throughout the coastal United States working to improve the environmental health of the nation's estuaries. Its staff works with partners in three states to increase awareness, understanding, and scientific knowledge about the Delaware Estuary, the region's most important cultural, economic, and recreational resource.

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Acknowledgments

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Cover photographs of collecting Mid-TRAM data in the Mullica River watershed, just north of Atlantic City, NJ (skyline in background) and performing Mid-TRAM within a red cedar snag forest in Dennis Creek courtesy of Partnership for the Delaware Estuary 2014.

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Executive Summary

A four tier coastal wetland monitoring and assessment program, called the Mid Atlantic Coastal Wetland Assessment (MACWA), was designed and implemented by the Partnership for the Delaware Estuary (PDE) and the Barnegat Bay Partnership (BBP). This program provides rigorous, comparable data across all tidal wetlands of the Mid Atlantic, especially those in the Delaware and Barnegat Bay Estuaries. Tier 2 consists of condition assessments that seek to ground truth landscape-wide desktop analyses of coastal wetland condition (Tier 1). These ground-truthing assessments are carried out using the Mid-Atlantic Tidal Rapid Assessment (Mid-TRAM). These assessments use field-based techniques to infer the average condition of a number of sample points (typically 30). Each point consists of a 50 m^2 assessment area (AA). Each AA score includes measurements on hydrological, habitat, landscape, and shoreline attributes. Average final scores for the array of sample points are interpreted to characterize a watershed as minimally (final score >81.4), moderately, or severely (<66) stressed. To date, about 49 HUC 12s have been assessed with Mid-TRAM, which accounts for ~37% of the total watersheds Mid-TRAM aims to assess in the Delaware and Barnegat Bay Estuaries. In upcoming years, PDE and partners will seek to continue assessing new watersheds to cover a majority of the remaining area in order to get a more comprehensive understanding of spatial variation in wetland conditions.

In 2014, 45 points were assessed in two watersheds using Mid-TRAM version 3.0. Thirty of these were in the Dennis Creek watershed, located in Cape May county, southern New Jersey. The Dennis Creek average Mid-TRAM score (81.04) suggested that it was moderately stressed. Dennis score particularly low for the habitat attribute, likely due to soft substrates. In comparison to other adjacent watersheds of the Delaware Estuary, the Dennis Creek watershed is "good", as the final score is second highest of all watersheds assessed. The fifteen points in the Mullica River watershed, located south of Barnegat Bay in New Jersey, suggested minimal stress (final score = 81.9). This may reflect how preservation initiatives (e.g. by USFW and the Pinelands Preservation Act) have made positive impacts on marsh condition. Dennis and Mullica had high incidence of eroding shorelines (low shoreline scores). Unsustainable rates of erosion is a large contributor of coastal wetland loss within the Mid-Atlantic. Mid-TRAM results suggest that eroding shoreline conditions are pervasive in the Delaware and Barnegat Bay Estuaries.

With coastal wetland restoration becoming a main focus of managers, state officials, and communities, the use of MACWA data to plan and validate restoration efforts has become increasingly important. Many watersheds assessed through Mid-TRAM have locations that will be targeted for restoration projects, so making Mid-TRAM data, as well as other MACWA data products, available to managers and planners is a MACWA priority.

MID ATLANTIC COASTAL WETLAND ASSESSMENT

Introduction

Orientation to the Mid Atlantic Coastal Wetland Assessment

Until about 7 years ago, there was no coordinated and consistent means to assess tidal wetland condition across the Mid Atlantic region, hampering efforts to assess wetland condition and function thereby also preventing estuary wide estimates of marsh resilience. Inconsistent and patchy data also thwarts decision-making by coastal managers who are pressed to choose where and how to invest limited funds to protect or enhance wetland resilience.

Due to their importance in the entirety of the Mid-Atlantic region, coastal wetland protection and research became one of the top priorities for the Partnership for the Delaware Estuary (PDE) and the Barnegat Bay Partnership (BBP) in 2006. In the time since then, PDE and BBP has worked with diverse partners to implement a region-wide "coastal wetland strategy", which is continuously being updated and strengthened. A 4-tier monitoring and assessment program was envisioned that would provide rigorous, comparable data across all tidal wetlands of the Mid Atlantic, especially those in the Delaware Estuary and Barnegat Bay. This strategy is referred to as the Mid Atlantic Coastal Wetland Assessment, or MACWA.

The strategy of MACWA follows EPA national guidance (U.S. EPA 2001) (Figure 1):

Tier 1: Landscape census surveys (remote sensing) of extent and loss

Tier 2: Probabilistic sampling on-the-ground across the study region to assess condition

Tier 3: Intensive studies to examine relationships among condition, function, and stressor impacts

Tier 4: Intensive monitoring function at networked array of fixed stations

Each tier is designed to substantiate other tiers. For instance, Tier 2, or ground-truthing assessments, are used to verify projections of marsh loss as attained from satellite imagery studies in Tier 1. Tier 4 is designed to monitor the function of marshes over long periods of time, and can be used as a data mine for other short term studies, such as those which attempt to estimate ecosystem services (i.e. Tier 3). Tier 2 and 4's objectives are carried out by two subprograms: Mid Atlantic Tidal Rapid Assessment Method (Mid-TRAM or RAM; Tier 2) and Site Specific Intensive Studies (SSIM, Tier 4). Although these subprograms are designed to be independent, data collected through them are not exclusive. Cross linking is an extremely important aspect of the MACWA strategy and serves to validate each tier and provide robust, comprehensive analysis of coastal wetlands. For more information on cross-linking studies, SSIM, or other tiers, see the 2014 MACWA Annual report, available through the Partnership for the Delaware Estuary's website (www.delawareestuary.org).

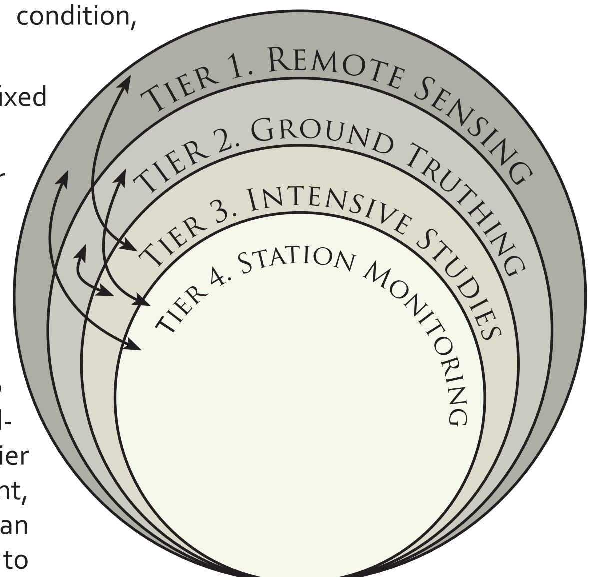

Figure 1. Four tiers of the Mid-Atlantic Coastal Wetlands Assessment with cross linking (arrows).

The Mid Atlantic Tidal Rapid Assessment Method (Mid-TRAM)

Various rapid wetland assessments have been developed around the nation, but none incorporate the distinctive tidal wetlands of the Mid-Atlantic region. In the early 2000's, the Delaware Department of Natural Resources and Environmental Control (DNREC) drew from the New England Rapid Assessment Method (NERAM) and the California Rapid Assessment Method (CRAM), while working with the Maryland Department of Natural Resources and the Virginia Institute of Marine Sciences, to create the Mid-Atlantic Tidal Rapid Assessment Method (Mid-TRAM). The goal of Mid-TRAM is to ground truth remote sensed data analyses of coastal wetland condition in this region. It aims to summarize entire watersheds (HUC12) thereby providing spatially explicit data on realized tidal wetland conditions.

To achieve this, Mid-TRAM uses on-the-ground techniques to infer the condition of multiple sample point, each consisting of a 50 m^2 assessment area, using hydrological, habitat, landscape, and shoreline attributes. Each attribute is composed of several metrics. Buffer metrics consider stressor or landward migration impediments within 250 meters of a sample point assessment area (AA). The shoreline metrics consider erosion or hardening on the seaward side of a sample point AA. Hydrological metrics are observations of anthropogenic changes to the hydrology within the wetland including ditching, fill, or diking. Habitat metrics attempt to capture plant community composition and invasive cover, which are proxies for the structural complexity and ecological function (productivity) of each AA. These attributes are designed to gauge the degree of disturbance, imperilment, or impairment to long term resilience, which serves to define what is meant by coastal wetland *condition*. Thirty assessment points are typically surveyed in each watershed. Attributes are then averaged to compute a final score. The distribution of final scores is used to categorize assessment areas as minimally, moderately, or severely stressed.

Twelve watersheds have been assessed using Mid-TRAM prior to this report (Figure 2; Table 1). Detailed results are described in this report for two of the most recent watershed assessments in New Jersey: Mullica River and Dennis Creek. Results from all watersheds completed to date will be used for comparison purposes; individual reporting on each of these watersheds can be found in the 2014 Annual MACWA report. The ultimate goal of the Mid-TRAM program is to systematically expand the number of watershed assessments and eventually repeat assessments within representative watersheds (e.g., every 10-20 years) to facilitate tracking future change.

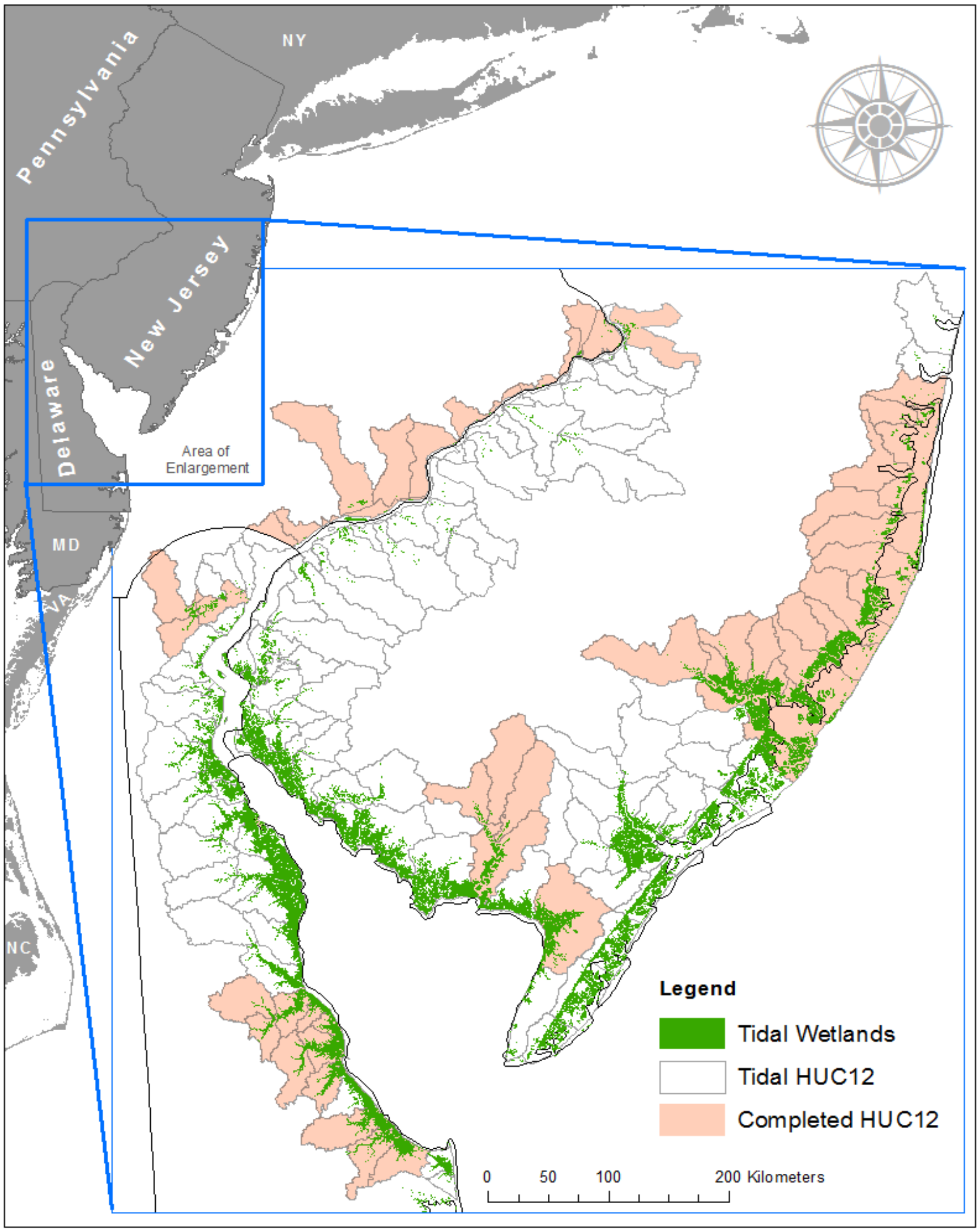

Figure 2. Watersheds (HUC12) where tidal condition assessments (Mid-TRAM) have been performed.

Table 1. RAM Watersheds completed as part of MACWA.

RAM Location	State	Year	Performed By	# HUC12s in Study	Total Tidal Habitat (ha)	Number of RAM Points	# Hectares per Point
PA Tidal†	PA	2010	PDE	10	316	30	11
Crosswicks†	NJ	2012/13	PDE	1	272	30	9
Christina†	DE	2011	PDE	3	857	30	29
St. Jones	DE	2007/08	DNREC	2	2,910	30	97
Murderkill	DE	2007/08	DNREC	4	2,460	30	82
Mispillion	DE	2012	DNREC	3	3,890	34	114
Broadkill	DE	2010	DNREC	3	3,760	37	102
Maurice	NJ	2011	PDE	5	2,490	30	83
Dennis	NJ	2014	PDE	1	3,570	30	119
North BB	NJ	2012	PDE & BBP	7	2,620	30	87
South BB	NJ	2013	PDE & BBP	5	6,110	30	204
Mullica	NJ	2014	PDE & BBP	5	12,400	15	827

† Freshwater tidal

Methodology

Wetland Classification Scheme

The target habitat type for MACWA Mid-TRAM consists of emergent vegetated coastal (i.e. tidal) wetlands. To isolate these types of wetlands the National Wetlands Index (NWI; U. S. Fish & Wildlife Service) wetland GIS layers were edited to remove non-vegetated or non-tidal wetlands from the original layer. This layer can be found on the National Wetlands Inventory website at: http://www.fws.gov/wetlands/Data/DataDownload.html. The NWI Cowardin classifications that were used to identify coastal wetlands are listed in Table 2. For our assessments to date, we have enlisted the assistance of US EPA's Western Ecology Division, and their environmental statistician Anthony R. Olsen, to randomly drop an array of points within predetermined emergent vegetated coastal wetlands for each watershed. A Generalized Random Tessellation Stratified (GRTS) survey design for an aerial resource is used. The GRTS design included reverse hierarchical ordering of the selected sites. Though only 30 sites are usually assessed per watershed, 250 sample points are provided from the GRTS for overdraft as the National Wetlands Inventory could contain errors, points may not meet the requirements of Mid-TRAM, or site access may be denied by property owners. Sites were assessed in the order the GRTS yielded.

Table 2. National Wetland Index codes used to identify coastal wetland habitats.

NWI Classification Code	Cowardin Description
Removed	
P	Palustrine Systems - except those of R, S, T, V (see below)
L	Lacustrine Systems (Lakes and Ponds)
R1UBL	Riverine Unconsolidated Bottom
E1UBL	Estuarine Unconsolidated Bottom
E2US	Estuarine Unconsolidated Shore
Retained	
M	Marine Systems
E	Estuarine Systems
R	Palustrine - Freshwater Tidal - Seasonally Flooded
S	Palustrine - Freshwater Tidal - Temporarily Flooded
T	Palustrine - Freshwater Tidal - Semipermanently Flooded
V	Palustrine - Freshwater Tidal - Permanently Flooded

Sample Points and Logistics

It takes approximately three people two hours to perform the Mid-TRAM at a particular sample point, once it has been reached. Typically, two sample points can be assessed per day, but in tidal wetlands, the stage of tide and the time to get to sites also needs to be taken into account, as does variation in weather conditions. More time is often needed in freshwater or brackish marshes due to the taller canopy and difficulty traversing the marsh platform, compared to salt marshes. The Mid-TRAM should be completed for at least 30 sites per watershed to reach sufficient sample density to obtain a representative estimate of the watershed's condition. Given that two points can be assessed each day, it takes approximately one month to complete a Mid-TRAM study in one watershed. This month is usually between July and August, as these months are also the time that plants reach peak growth or biomass in the Mid-Atlantic; assessments should be completed during this time to ensure interannual consistency.

Sample Plot Layout and Approach

Center points were mapped from the GRTS coordinates; a 50 m radius assessment area (AA) and a 250 m buffer area was established in ArcMap (v. 10) around each point before field assessments began. In the field, a team would then locate the AA center, from which four 50-meter transects were run at 90 degree angles from each other. The first transect was directed towards the main water way (tidal-influenced open water >30m wide), and the other three transects were extended from the center, clockwise from the first transect. At the center point, surface salinity, photographs and approximate organic soil depth were taken. Moving from the center along each transect, plant community and hydrology were recorded. Metrics were assessed at 25 and 50 meters from the center on each transect. Within each attribute there are multiple metrics (Table 3). Each metric is given a score between 3 and 12 and then combined with the other metrics in the attribute, which is adjusted to fit on a 0-100 scale (Equation 1a-d). A brief description of good condition expectations for each metric can be found in Appendix A. After all transects were measured, direct observations and aerial photography were used to make observations on hydrology, buffer condition, and overall plant community structure. The attributes are then averaged to provide a composite Mid-TRAM final score (Equation 1e).

Each site evaluated was given a specific name, as well as a Qualitative Disturbance Rating (QDR). A QDR rating is based on the best professional judgment of the trained field crew given observed stressors or alterations to vegetation, soils, hydrology, and land use disturbance within or surrounding the AA. A scale of least disturbed (score of 1) to highly disturbed (score of 6) is used. Generally, a minimal disturbance (QDR of 1 or 2), is a natural structure and biotic community maintained with only minimal alterations. A moderately disturbance category (QDR of 3 or 4), is comprised of moderate changes in structure and/or the biotic community. A high disturbance category (QDR of 5 or 6) demonstrates severe changes in structure and/or the biotic community which could lead to a decline in wetland resilience. The QDR method is further defined in the Mid-TRAM Version 3.0.

Breakpoints

The overall distribution of total scores are analyzed by plotting a Cumulative Distribution Function (CDF). All Mid-TRAM points assessed to date are sorted first by QDR ratings. The 25th percentile of sites with QDR ratings of 1 and 2 are taken and this number is the break point for minimally stressed sites (final score ≥ 81.4). This is repeated with the 75th percentile of QDR rankings of 5 and 6; this number is the break point for severely stressed sites (final score ≤ 66). This method allows the sites to be sorted by relative condition to provide quantitative categories for different levels of stress. These stress level categories were designed to facilitate easy interpretation of results by managers or the public and to allow for comparisons among watersheds.

For a more detailed description of Mid-TRAM version 3.0 methods, please refer to the protocol document, which is available from the PDE website at: http://www.delawareesuary.org/Wetland_Assessment. This version of Mid-TRAM is also used by DNREC, and can be accessed through their website at: http://www.dnrec.delaware.gov/Admin/DelawareWetlands/Pages/Wetland-Monitoring-and-Assessment.aspx.

Quality Assurance and Quality Control

Quality Assurance and Quality Control (QA/QC) are important to any scientific study. In order to enhance and retain consistency, the rapid assessment (Tier 2) as well as site specific studies (Tier 4) are encompassed under an "umbrella" Quality Assurance Protection Programs (QAPPs) for MACWA. This allowed for other projects falling under the MACWA program to reference already approved QAPPs, thereby ensuring that all data would be cross comparable. The "umbrella" QAPP for Mid-TRAM is the Rapid Assessment Monitoring Program for Tidal Wetlands of Delaware,

Table 3. Summary table of Mid-TRAM Attributes, Metrics, and their description.

Attribute	Metric	Abbrev.	Description
QDR	**Qualitative Disturbance Rating**	QDR	Score of 1 - 6 assigned to the site using best professional judgment of overall condition
Buffer Score	**Percent of AA with 5 m Buffer**	B1	Percent of AA perimeter that has at least 5 m of natural or semi-natural condition land cover
	Average Buffer Width	B2	The average buffer width surrounding the AA that is in natural of semi-natural condition
	Surrounding Development	B3	Percent of developed land within 250 m from the AA
	250 m Landscape Condition	B4	Landscape condition within 250 m buffer based on the nativeness of vegetation, disturbance to substrate and extent of human visitation
	Barriers to Landward Migration	B5	Percent of landward perimeter of wetland within the 250 m buffer that has physical barriers preventing wetland migration
Hydrology Score	**Ditching and Draining**	H1	The presence of ditches in the AA
	Fill and Fragmentation	H2	The presence of fill or wetland fragmentation from anthropogenic sources in the AA
	Diking and Tidal Restrictions	H3	The presence of dikes or other tidal flow restrictions
	Point Sources	H4	The presence of localized sources of pollution
Habitat Score	**Bearing Capacity**	HAB1	Soil resistance using a slide hammer
	Vegetative Obstruction	HAB2	Visual obstruction by vegetation < 1 m measured with a cover board
	Number of Plant Layers	HAB3	Number of plant layers based on plant height
	% Co-Dominant Invasive Species	HAB4	Percent of co-dominant invasives species in AA
	% Invasive Cover	HAB5	Percent cover of invasive species in the AA
Shoreline Score	**Shoreline Erosion**	S1	Shoreline condition at shoreline transect points based on the erosion:accretion ratio
	Shoreline Alteration	S2	Presence of built structures or non-natural materials along the shorelines at transect points

Equation 1. Equations used to ascertain attribute scores (a-d) and then compute Mid-TRAM final score (e). For metric abbreviations (e.g. H1, HAB5) see Table 3.

a. **Buffer** = $((((\Sigma(B1 \ldots B5))/60)\cdot 100)-25)/75)\cdot 100$

b. **Hydrology** = $((((\Sigma(H1 \ldots H4))/48)\cdot 100)-25)/75)\cdot 100$

c. **Habitat** = $((((\Sigma(HAB1 \ldots HAB5))/60)\cdot 100)-25)/75)\cdot 100$

d. **Shoreline** = $((((\Sigma(S1 \ldots S2))/24)\cdot 100)-25)/75)\cdot 100$

e. **Final** = $((\text{Buffer} + \text{Hydrology} + \text{Habitat} + \text{Shoreline}) /4)$

New Jersey & Pennsylvania (MACWA RAM QAPP 1.0). This QAPP has been approved and signed off by the EPA Office of Wetlands, Oceans and Watersheds, EPA Region 2 and NJDEP. Please also see the Addendum to Rapid Assessment Monitoring Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania (MACWA RAM Umbrella QAPP 1.0) and the Rapid Assessment of Tidal Wetlands in Representative Watersheds of the Delaware Estuary: MACWA RAM Project QAPP 1.2 for EPA Grant #83458901-0. The addendum to the umbrella QAPP was signed off by the QA officer (Chuck Spooner) and the EPA Office of Wetlands, Oceans and Watersheds (Gregg Serenbetz) on June 17, 2010. This addendum QAPP references not only the umbrella MACWA QAPP but also the EPA approved DNREC QAPP (Rapid Assessment Monitoring Program for Tidal Wetlands of Delaware, New Jersey & Pennsylvania (MACWA RAM Umbrella QAPP 1.0). The QAPP also gives examples of data and field team audit sheets.

Site Descriptions

Dennis Creek

The Dennis Creek HUC12 watershed is located in Cape May County, New Jersey (Figure 3). Dennis Creek drains directly into the Delaware Bay. Notable townships in the watershed include Dennisville and Cape May Court House. According to the NWI, this watershed consists of approximately 9,432 acres (3816 hectares) of saline, intertidal,

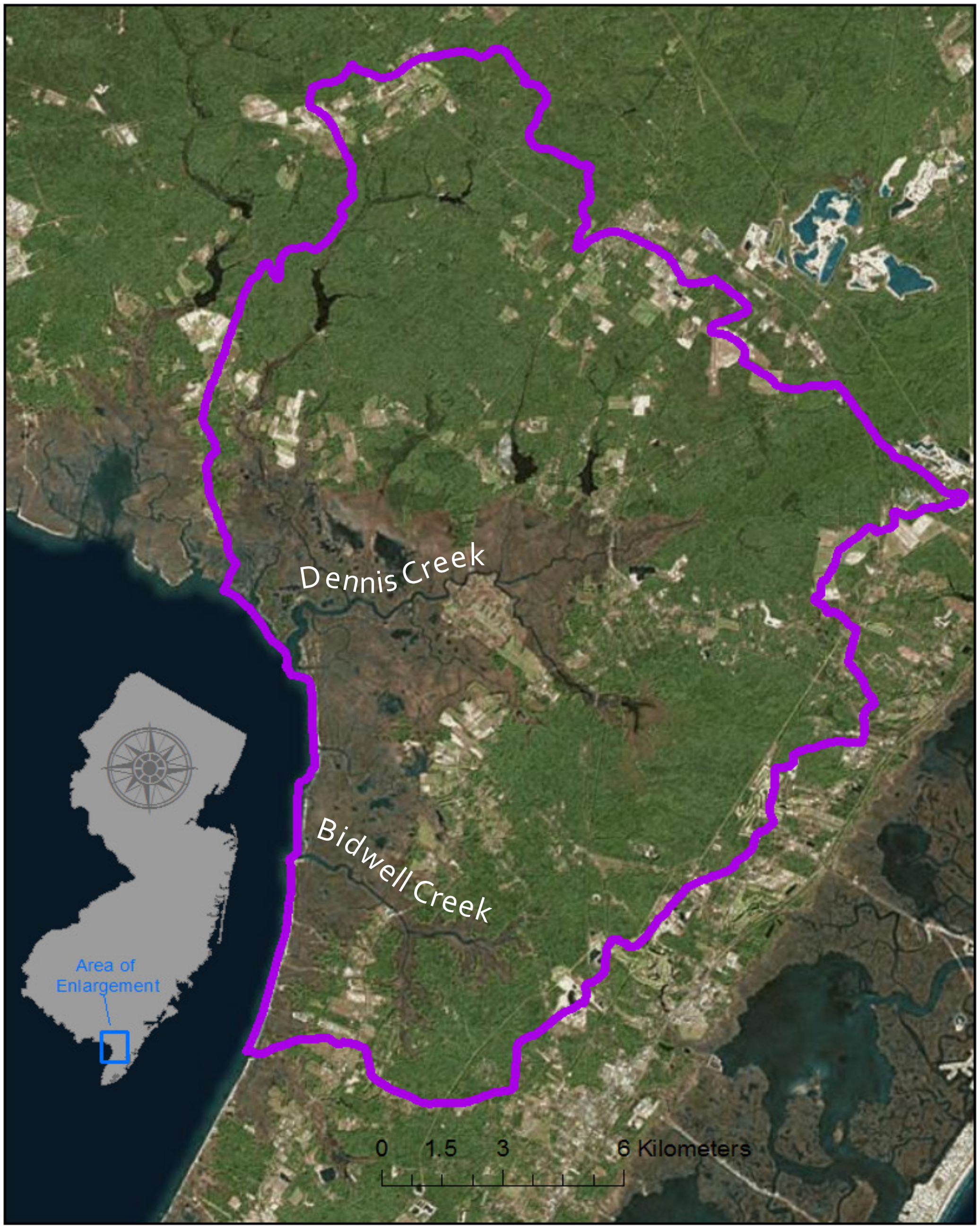

Figure 3. Dennis Creek watershed (HUC12; purple outline).

emergent marshes dominated by *Spartina alterniflora.* A unique feature of Dennis Creek salt marshes is the prevalence of red cedar (*Juniperus virginiana*) snag forests that line the upland margins, especially along the northern shore (Figure 4). Major tributaries include East Creek and Sluice Creek. To the south, Bidwell Creek is also part of the Dennis Creek HUC12, although it also drains directly into the bay. Tidal amplitude, or the distance between mean higher high water and mean lower low water, at Dennis Creek is about 1.9 meters. This is similar to other marshes along the Delaware Bayshore.

NJDEP's land use land cover data from 2012 show that the Dennis Creek watershed consists of 4% open water. The remaining 96% is mostly forest (27%), freshwater wetlands (36%), and estuarine wetlands (20%; 3,570 hectares). Some agriculture (4.5%) and development (10.5%) are evident. Incidence of development is relatively low in Dennis Creek, especially compared to other previously assessed watersheds such as North Barnegat Bay, which was rife with development (41%[1]).

In the mid to late 1800's, Dennisville was a center of commerce, supporting large scale excavation of ancient white cedar (*Chamaecyparis thyoides*) for shingle making, which eventually depleted much of this resource by the turn of the century (Cultural Resources Digest 2005). At that time, it was also home to several large scale schooner building companies. Little of this infrastructure remains, as shifts in technology caused a cessation of activity more than 100 years ago. Only the causeways that were constructed across Dennis Creek and its major tributaries remain. Another industry found in the watershed is salt marsh hay (*Spartina patens*) farming. Although mostly an older agricultural practice, there are some salt marsh hay farmsteads along Dennis Creek. This type of farming intentionally alters tidal flow through sluices and levees. Alterations to enable both historical commerce and farming likely have lasting effects on marsh condition and resilience.

Figure 4. Cedar snag forests near upland margins at three different sites on the northern shore of Dennis Creek.

1. North Barnegat is 27% open water, 73% land; 41% is the proportion of land covered by development. Half of this consists of single unit (medium density) homes. Many of these homes abut land-bay interfaces, so hardened shoreline structures are pervasive. For more information, see PDE's 2014 MACWA Annual Report.

Mullica River

The Mullica River watershed is located along the eastern seaboard of New Jersey, in Atlantic County (Figure 5). The Mullica River flows into the Great Bay, which is enveloped by fringing salt marsh complexes. This bay is separated from Southern Barnegat Bay in the north by these marsh complexes, although joined by the bifurcation of Little Egg Inlet towards its north. Open waters, as those of tidal creeks which cut through marsh complexes and Great Bay, account for 23% of the entire watershed. The remaining 77% of the watershed was dominated by estuarine wetlands (36%) and forest (32%) (NJDEP LULC 2012). According to NWI data, the Mullica River HUC12 contains approximately 12,400 hectares of estuarine wetlands (Figure 7). Non-tidal freshwater wetlands accounted for slightly less of the land cover (23%). There was also slightly less development (6%) and agriculture (0.6%) than the Dennis Creek watershed. The Mullica River, as well as it's major tributaries, Bass River, Wading River, and the Batsto River, drain large tracts of pine barrens, which are protected from development through the Pinelands Preservation Act (1979). There is only one large housing development, Mystic Island, which occupies the NNW corner of Great Bay.

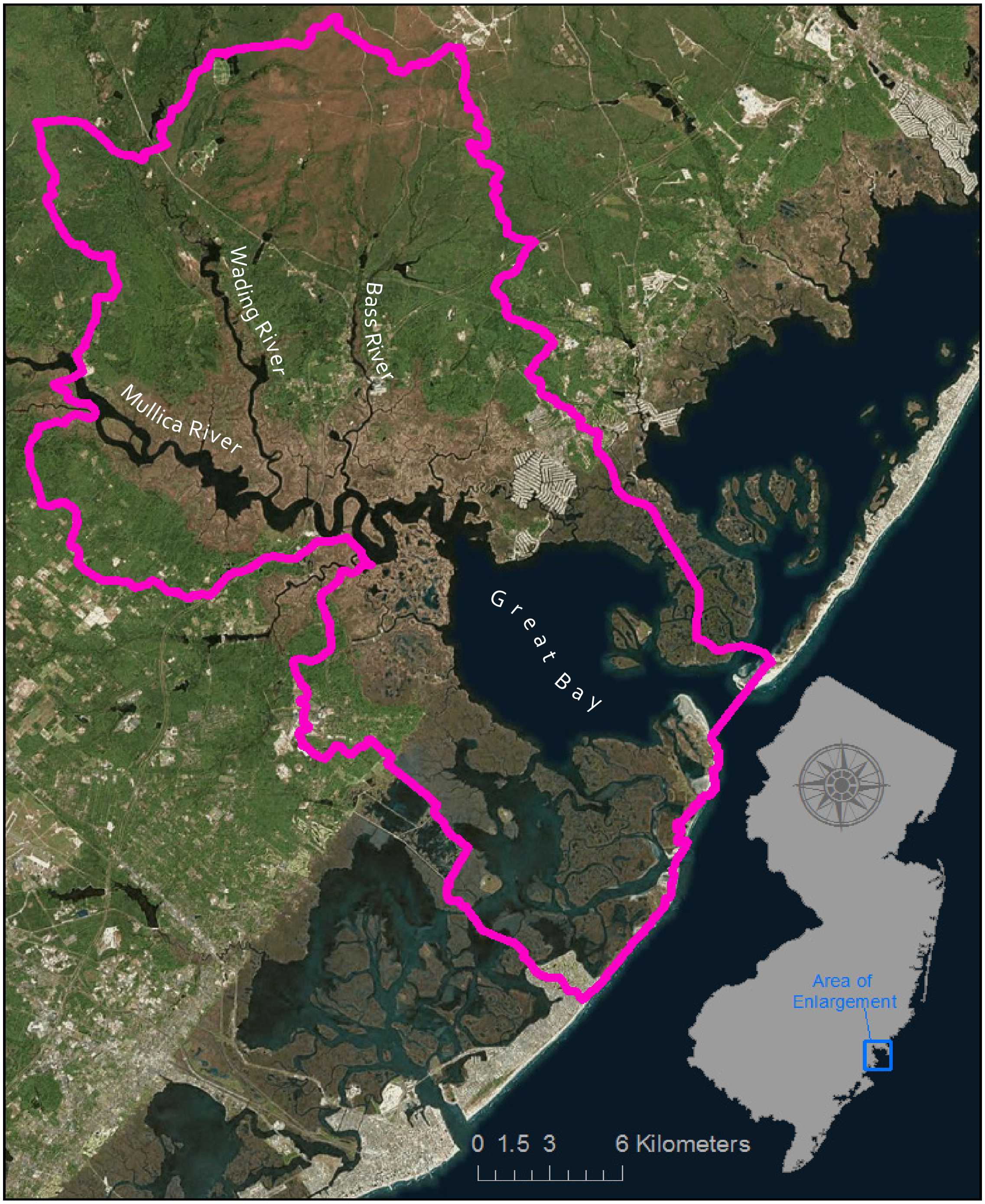

Figure 5. Mullica River watershed (HUC12; pink outline).

Figure 6. Photograph collage of two landmarks within the Mullica River/Great Bay fringing salt marsh complex: above is the skyline of Atlantic City, NJ, south of the Bay; below is an abandoned fish processing factory located on an island in the eastern portion of Great Bay.

A large portion of the salt marshes along the SSW of Great Bay are protected and actively managed as an avian sanctuary by the Edwin B. Forsythe National Wildlife Refuge (NWR) Brigantine of the United State Fish and Wildlife Service (USFW), which was established in 1939 (Figure 6). In 2008 and 2009, USFW performed their Salt Marsh Integrity Index (SMI), a study on marsh condition congruent with Mid-TRAM, on their properties in the Mullica River watershed along Great Bay. Their findings could eventually be used in parallel with our Mid-TRAM results to offer a robust, cross-agency validation on salt marsh condition assessments within the Mid-Atlantic. Furthermore, SMI is used in other areas of the conterminous coastal U.S., which would allow us to gauge our Mid-TRAM condition results on a nation-wide scale as those reports become available.

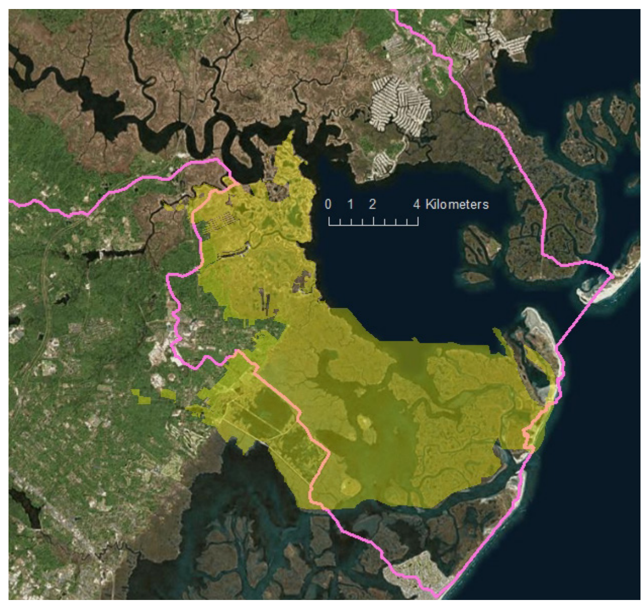

Figure 7. Marshes along the SSW shore of Great Bay owned by U.S. Fish and Wildlife Forsythe (yellow).

Historically, many of the salt marshes within Mullica were ditched for mosquito control, although not to the extent and intensity as other watersheds in New Jersey. Upstream portions of the Mullica River watershed are part of New Jersey's Pinelands Preservation. These pine barren habitats are noted for imparting a deep brownish red coloration to drainage waterways ("tea-colored") and are typically acidic (pH ≤5.0), cultivating a distinctive array of flora and fauna. Agriculture near the headwaters, currently and historically, is dominated by cranberry and blueberry farming. These two crops are of the limited types that are successful in the unique edaphic conditions of pine barrens. Cranberry farms are maintained by the creation or amendment of bogs, which may alter hydrological conditions, but likely have little effect on the resilience or condition of salt marshes much farther downstream, especially compared other crops which require heavy applications of nitrogen rich fertilizers, such as corn. Protection from development, as dictated by the Pinelands Preservation Act, has allowed much of the upstream portions of the Mullica River to remain pristine despite increasing pressure to develop coastal areas, which likely has a positive effect on the health and condition of the tracts of salt marsh downstream.

Results and Discussion

Dennis Creek

In August 2014, 30 points in the Dennis Creek watershed were assessed through Mid-TRAM. The final score of Dennis Creek was 81.04 (out of 100), suggesting that Dennis Creek is moderately stressed (<81.4, but>66). The distribution of points in the tidal salt marshes of the Dennis Creek watershed, color coded by their stress level (severely, moderately, and minimally), are in Figure 8. Summary data for Dennis Creek is in Appendix B.1; raw data is in Appendix C.1.

Buffer and Hydrology

The Dennis watershed is largely forested, with very little agriculture and low housing densities. Impacts to buffer condition were minimal and the buffer score for Dennis was quite high (82.22 out of 100). Obstructions to marsh migration was evident at 5 out of the 30 sites assessed and development was observed in only 9 out of 30. Dennis' hydrology score, which also describes anthropogenic disturbances, scored very high (94.4). Although ditching was prevalent in Dennis, the degree and intensity of ditching was low in comparison to other salt marshes where development is more pervasive and pressure to control mosquito populations is higher. Few alterations to tidal flow were observed within the AAs, but some features (e.g. tide gates, levees) altering flow along the main channel were noted traveling to sites. No point sources or fill were observed.

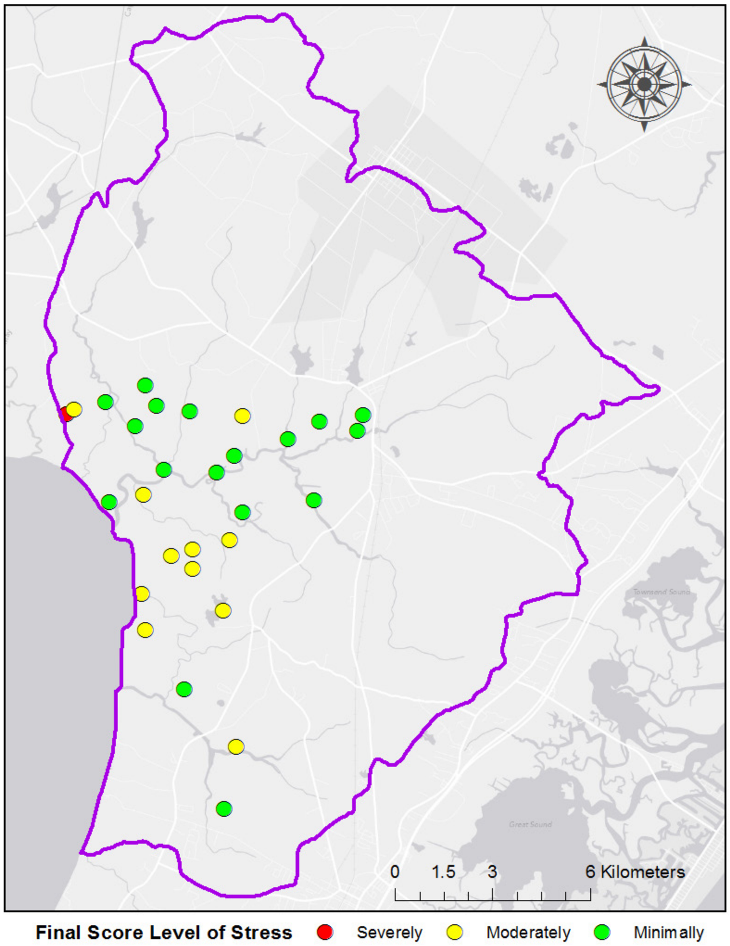

Figure 8. Geographic distribution of stress levels at assessment areas in the Dennis Creek watershed.

Habitat

Habitat scores at Dennis averaged relatively low (66.4). There was a low incidence of invasive plant species. The vertical complexity of plant communities was high but horizontal vegetation obstruction (a proxy for canopy robustness) was moderately low. Plant communities with substantial height, but low horizontal obstruction likely have low canopy density. Bearing capacity measurements at Dennis were very low. The bearing capacity score was lower than any other watersheds previously assessed, including naturally muckier freshwater watersheds. Low canopy densities and softer substrates may suggest that plant communities lack dense root systems, a necessary characteristic for sea level rise resilience. Muckier than average substrates could be caused by a mixture of historical disturbance and climate change. The effects of climate change are complex and more research is necessary to fully understand the extent and influence it bears on marsh resilience at Dennis Creek. It is apparent, however, that marshes at Dennis Creek are vulnerable to sea level rise and focus should be brought to the condition of the marsh platform.

Shoreline

Accretion and erosion dynamics, when in balance, cause the marsh to undergo no net change. When conditions are altered, such those alterations carried out anthropogenically or meteorologically, tip the balance towards erosion, resilience is lost. Therefore, the condition of marsh shorelines is as much of an indicator of marsh resilience as platform condition. Finding evidence of imbalance between erosion and accretion is an integral part of categorizing shoreline condition. From data collected through Mid-TRAM, we have observed that many sites within the Delaware and Barnegat Bay Estuaries are undergoing widespread erosion, with little evidence of accretion along shorelines. This also appears to be the case at Dennis Creek. The shoreline score was 58.9, with few observations on shoreline alteration, which indicates that the score was lowered mostly by observations of eroding shorelines. The average shoreline erosion metric score was -0.58 (where scores of +1 were assigned to accreting shorelines, zero to no trend, and -1 to eroding shorelines). The tidal prism at Dennis is large (~1.9 m), so the system is quite energetic. Creek widening and marsh loss associated with eroding shorelines may be balanced by accretion on top of the marsh platform. The rate of accretion may be assisted by high energy, adding to the long term resilience of the marsh. Such vertical accretion plays an important role in ensuring marshes keep pace with sea level rise. In the future, long term monitoring data from the Dennis Creek Site Specific Intensive Monitoring Station may be useful in providing insight on how vertical accretion and horizontal shoreline movements balance to maintain resilience with sea level rise.

A box plot comparing each attribute score is in Figure 9. Shoreline and Habitat attributes scored low in the Dennis Creek watershed, likely driving the final score to be moderately stressed.

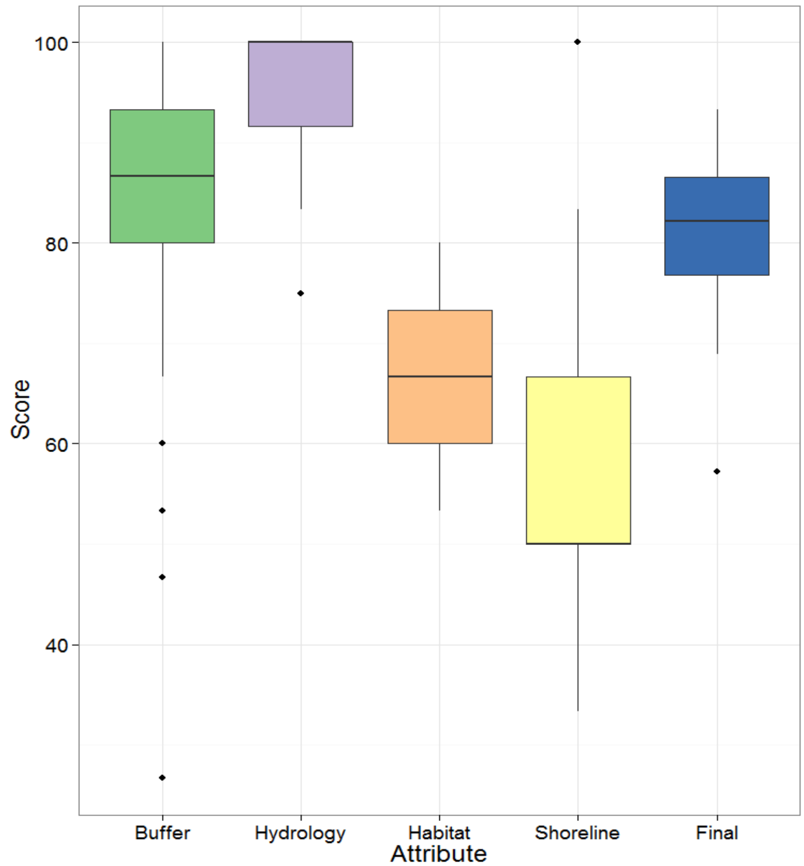

Figure 9. Boxplot of Dennis Creek attribute and final scores.

Mullica River

In July 2014, 15 points in the Mullica River watershed were assessed through Mid-TRAM. The final score was 81.85. This means that the Mullica River is minimally stressed (81.85 is > 81.4). It is important to note that this score, and the attribute scores, may be elevated, as only 15 points were assessed for this watershed, as opposed to the usual 30. The distribution of points in the tidal salt marshes of the Mullica River watershed, color coded by their stress level (severely, moderately, and minimally), are in Figure 10. Data for the Mullica River is in Appendix B.2; raw data is in Appendix C.2.

Buffer and Hydrology

Because of the expansive tracts of fringing marshes surrounding the Great Bay and bordering the Mullica River, the buffer scores within this watershed were the highest of other watersheds assessed using Mid-TRAM (85.3). Not only are marshes in this watershed expansive, there are few developments surrounding in the landscape or within the marsh itself. This is in stark contrast to sites in Northern and Southern Barnegat Bay (assessed in 2012 and 2013, respectively; hydrology scores of 72.5 and 67.5 respectively). Absence of developments mean less barriers to migration and lower incidences of hardened marsh interfaces. Another key difference between Barnegat and Mullica marshes is the intensity and prevalence of ditching for mosquito control. Although ditching is apparent in the Mullica watershed, it is at dramatically lower levels than those in Barnegat Bay. There was also no open marsh water management (OMWM) in the Mullica study sites despite it being a common practice in Barnegat Bay. Mullica AAs yields a high hydrology score (92.22). So, even though ditching pressure exists in Mullica, it is not high enough to create marked declines in condition.

Habitat

Habitat scores in the Mullica averaged 68.0. This was the highest score for any salt marsh assessed using Mid-TRAM. This score indicates that the marsh platform was firm, plant communities were complex and robust, and there was little invasive cover.

Shoreline

The shoreline score in the Mullica River was 57.58. Average erosion was -0.7 (-1 designates erosion). Many observations were made on deteriorated shorelines including undercut and slumped banks. These conditions were also pervasive in the Barnegat Bay and suggest that there are underlying mechanisms related to the energy and hydrological characteristics of these back barrier bays along the east coast of New Jersey. Understanding these processes are

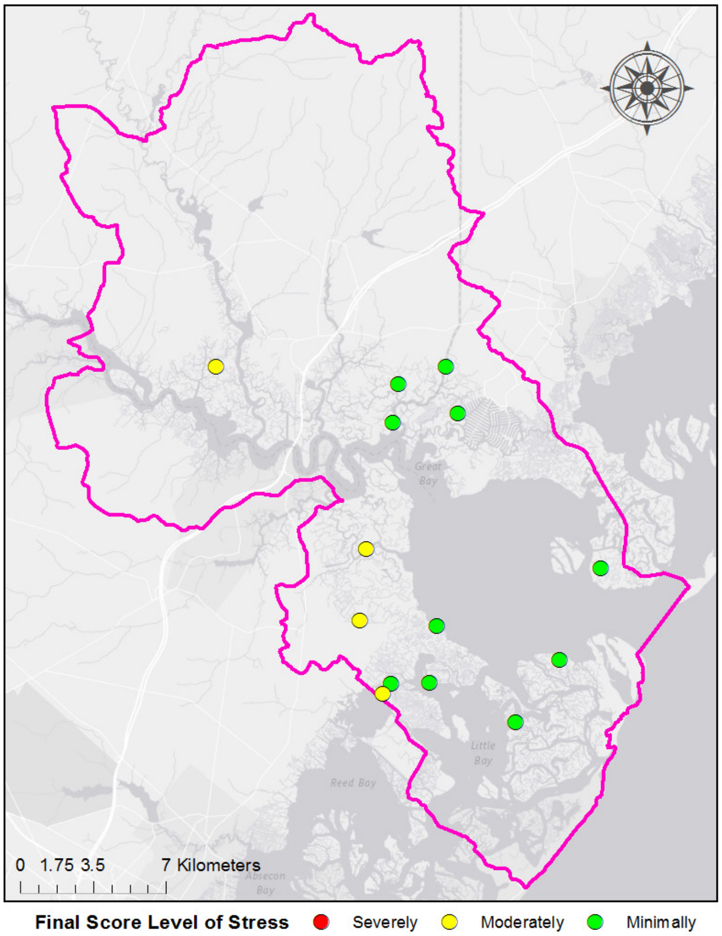

Figure 10. Geographic distribution of stress levels at assessment areas in the Mullica River watershed.

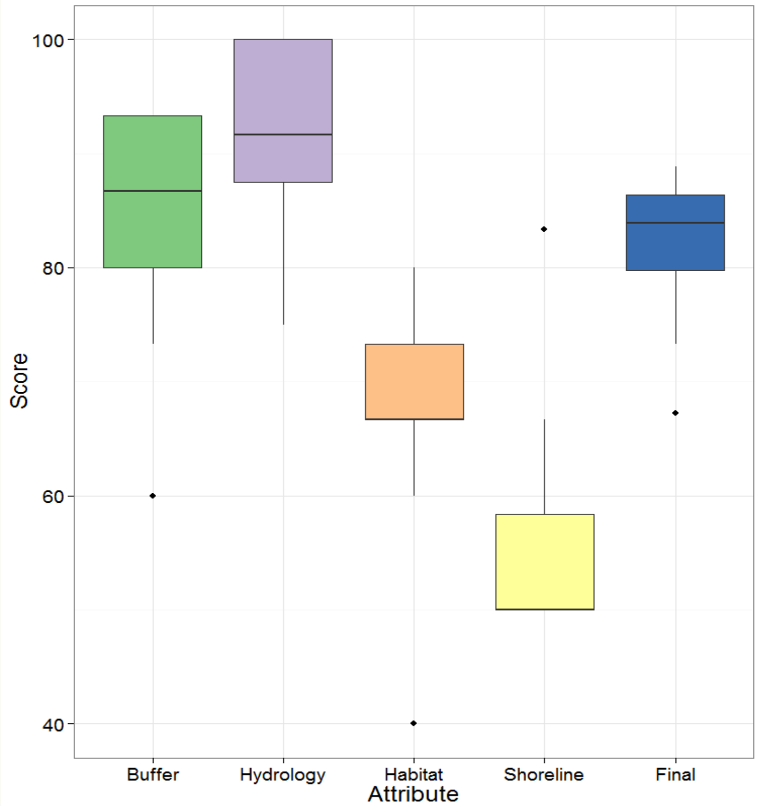

Figure 11. Boxplot of Mullica River attribute and final scores.

an important part of estimating the resilience of marshes, especially as more intense storm events are increasing with climate change. Although other attributes in Mullica scored reasonably well, it should be noted that shoreline condition may threaten the future condition of these marshes.

A box plot comparing each attribute score is in Figure 11. Shoreline attribute scores were balanced by high buffer, habitat and hydrology scores, allowing us to designate it minimally stressed.

Watershed Comparisons

The main goal of Mid-TRAM is to assess wetland condition spatially. So, final scores of assessment areas across one watershed are averaged and categorized by breakpoints to enable comparison among other watersheds in the region. The break points for level of stress (minimally, moderately, or severely) are calibrated through the integration of data from every assessed watershed, and so categorical scoring is relative between watersheds. Such comparison are an important aspect of condition assessments because they allow researchers and managers to identify the most stressed wetlands in the area, find patterns in common stressors, and determine where these patterns vary within watersheds. In identifying highly stressed wetlands and the prevailing conditions that shaped them, management and restoration efforts can be focused. Common conditions observed in representative tracts of marsh are indicative of watershed-wide stressors that can be managed over time to offer the greatest positive outcome for the largest tracts of marsh.

A comparison of final score distributions of all watersheds assessed through Mid-TRAM is in Figure 12, where box plots are colored by their respective level of stress (red - severe, yellow - moderate, green - minimal). Mullica is the only watershed to be on average minimally stressed and had no severely stressed AAs (Figure 13). Mullica also had the least number of assessment points (n=15), but despite this, it was not significantly different ($p<0.05$; Tukey HSD) than any watershed deemed moderately stressed. Christina and Barnegat Bay North were qualified as severely stressed. These scores are not significantly different from each other, likely because Christina had a large range of stress levels among sites. Both of these sites were significantly different from all other sites, however. These sites also had the highest proportion of severely stressed AAs (Figure 13). Tukey HSD p-values among watersheds can be found in Appendix C.2.

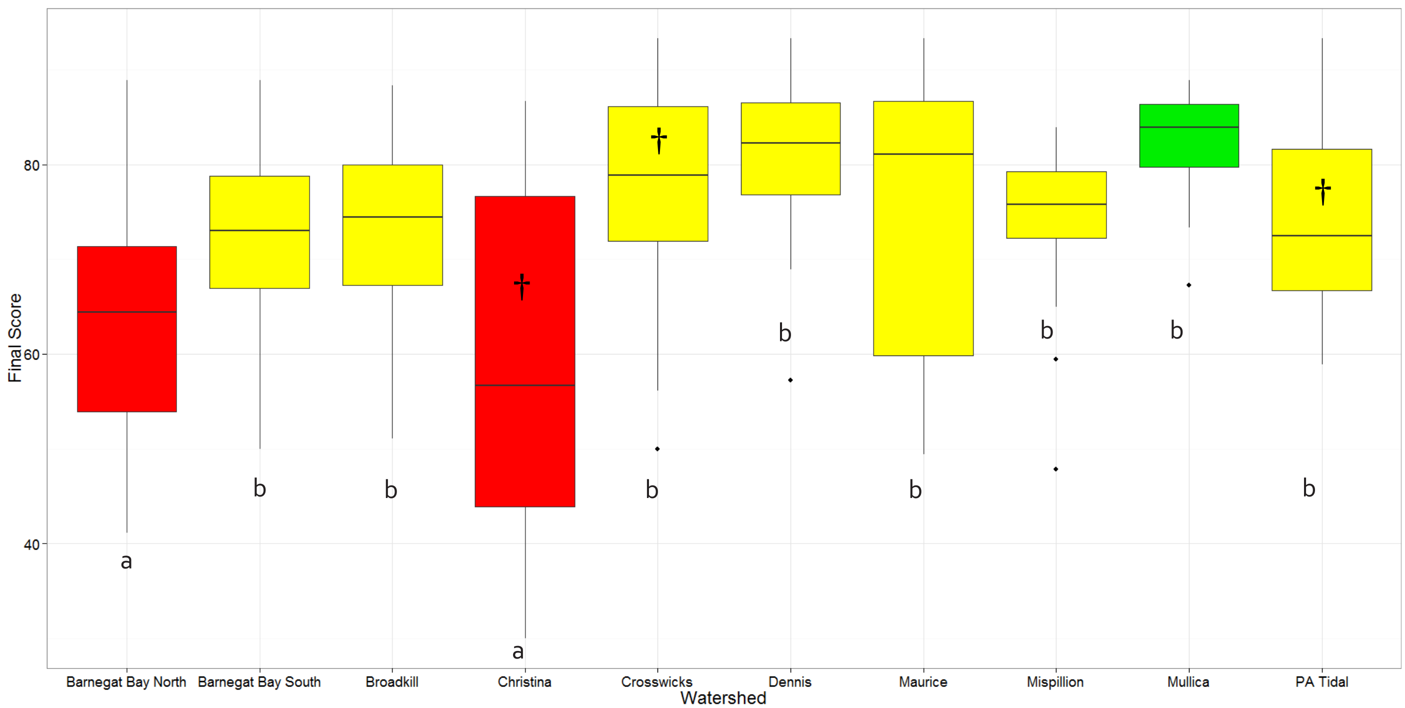

Figure 12. Box plot of final scores of watersheds assessed using Mid-TRAM colored by stress level: severe (red), moderate(yellow), and minimal(green). Different letters are significantly different ($p < 0.05$; TukeyHSD). Dagger symbols indicate freshwater tidal wetlands.

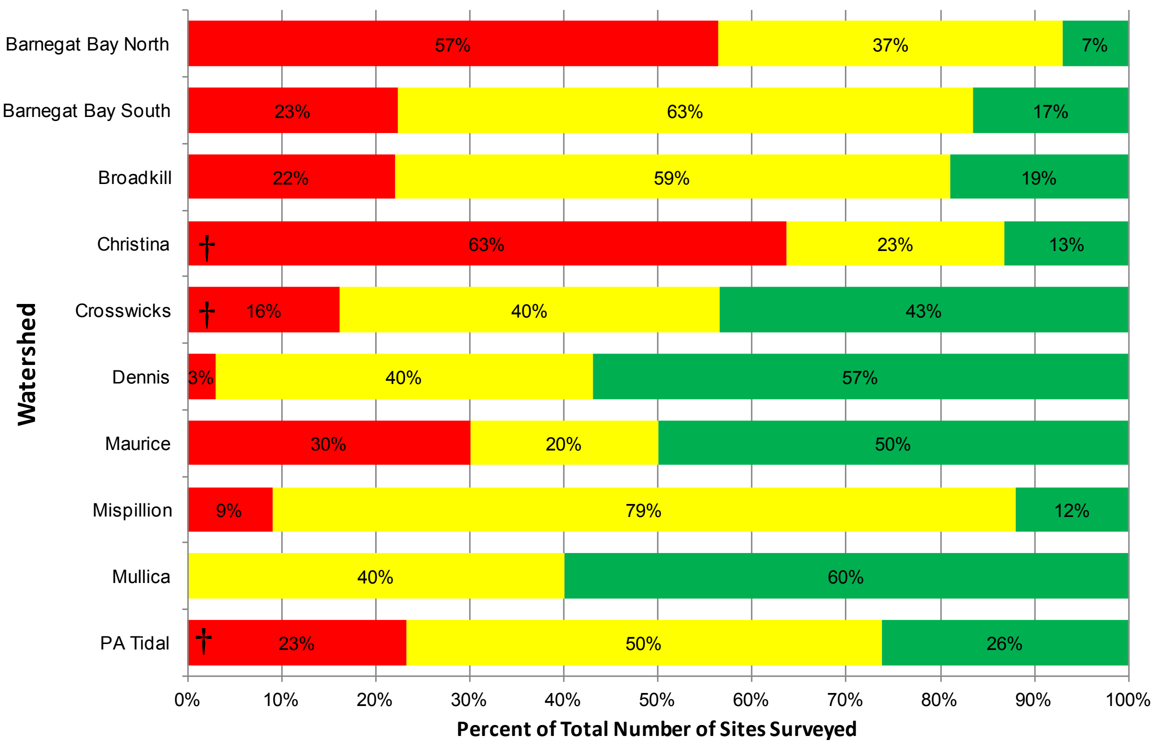

Figure 13. Proportions of stress levels at each assessment watershed. Dagger symbols indicate freshwater tidal wetlands.

Although final scores are a good way to understand and compare watersheds as a whole, a better understanding of specific stressors can be obtained through comparing differences in attribute scores for each watershed. Table 4 highlights attribute scores for each watershed. Freshwater tidal watersheds (Christina, Crosswicks, and PA tidal) all suffer from low buffer scores due to the extent of urbanization in these areas. Another notable point of comparison is between North and South Barnegat Bay. Although these are along a continuous water body (that of Barnegat Bay), it is apparent that stressors in each region vary such that North Barnegat Bay scored more poorly than the south. This difference is likely driven by more stressed plant communities as is reflected in the habitat score, coupled with short buffers and close proximities to developments in the north. Table 4 highlights the levels of stress for each attribute per watershed.

Table 4. Breakdown of average Mid-TRAM attribute scores per watershed. Scores less than 66 (severely stressed) are bold and outlined in red; scores greater than 81.4 (minimally stressed) are green, bold and italicized. Standard errors are in parenthesis.

Watershed	Shoreline*		Habitat		Hydrology		Buffer		Final	
Barnegat Bay North	**55.0**	**(3.7)**	**59.6**	**(2.3)**	67.5	(2.1)	**62.7**	**(3.7)**	**63.2**	**(3.9)**
Barnegat Bay South	**50.0**	**(0.0)**	67.1	(1.8)	72.5	(1.4)	77.8	(3.4)	72.5	(2.7)
Broadkill	**63.9**	**(5.5)**	**63.6**	**(1.8)**	79.7	(3.1)	75.5	(2.0)	72.9	(3.6)
Christina†	**58.8**	**(11.8)**	**61.8**	**(3.2)**	66.6	(3.0)	**49.8**	**(5.1)**	**59.4**	**(4.4)**
Crosswicks†	***81.5***	***(6.7)***	73.6	(2.1)	***94.4***	***(2.0)***	**65.6**	**(1.9)**	77.9	(4.3)
Dennis	**59.0**	**(5.4)**	66.4	(1.2)	***94.4***	***(1.1)***	***82.2***	***(1.4)***	81.0	(2.7)
Maurice	**61.5**	**(7.2)**	**65.8**	**(2.6)**	***89.7***	***(2.6)***	72.7	(3.4)	76.1	(3.6)
Mispillion	***88.5***	***(6.1)***	**58.4**	**(1.3)**	79.9	(2.3)	***84.5***	***(1.8)***	74.3	(2.7)
Mullica	**57.6**	**(3.8)**	68.0	(1.0)	***92.2***	***(1.6)***	***85.3***	***(1.6)***	***81.9***	***(1.6)***
PA Tidal†	75.4	(6.2)	70.4	(2.5)	***90.0***	***(2.2)***	**59.3**	**(3.7)**	73.5	(6.0)

*Shoreline scores are not currently used to calculate final scores; † Freshwater tidal

Summary

A total of 45 points were assessed in 2014 using Mid-TRAM. Thirty of these points were in the Dennis Creek watershed, in southern New Jersey. Dennis Creek average Mid-TRAM score suggested it was moderately stressed. The lowest scores in Dennis was for habitat metrics, likely due to muckier than average substrates. This characteristic could have been driven by historical industry, like cedar excavation or salt marsh hay harvesting. The condition of Dennis compared with other watersheds is very good, as the final score is second highest, but still is of average or typical condition. The fifteen points in the Mullica River watershed, located south of Barnegat Bay in New Jersey, averaged to be minimally stressed. This is the only minimally stressed watershed that has been assessed via Mid-TRAM by the PDE, DNREC, and the BBP; is it also has the smallest sample size. Overall Mullica AAs had minimal impacts to hydrology and also the highest habitat score among saline watersheds. These scores may reflect how preservation of large tracts of marsh and upstream forest, through the USFW Service and the Pinelands Preservation Act respectively, has positive effects on marsh condition by thwarting human mitigated disturbance.

Although shoreline attribute scores are not currently used to calculate final scores, they reflect the growing concern that pervasive erosion rates may be a significant driver in marsh loss. Most salt marshes, including Dennis and Mullica (see Table 4), in the Mid-Atlantic suffer from unsustainable rates of erosion, which, through obvious necessity, has become the focus of restoration efforts. For instance, management practices engage methods that deploy softer shoreline structures that stem these erosion rates and enhance marsh productivity, contributing to increases in ecosystem service value. Some watersheds, who score low in the Habitat attribute, may also benefit from research on marsh platform topography, to better understand what drives abnormal vegetation structure. Such an understanding of vegetation structure would allow researchers to pinpoint how managers may use tactics, such as beneficial reuse, that enhance the vegetation community for increased resilience with continually rising sea level.

Next Steps

The main goals of Mid-TRAM are to supply valuable ground-truthing data as well as provide more detailed condition data on a large spatial scale. The spatial area that Mid-TRAM caters to covers about 131 HUC12s in New Jersey, Delaware, and Pennsylvania. To date, about 49 HUC12s have been assessed, which accounts for about 37% of the total watersheds Mid-TRAM aims to assess. In the upcoming years, PDE and partners will seek to continue assessing new watersheds to cover a majority of the remaining area in order to get a more resolved understanding of spatial variation in wetland conditions of the Barnegat and Delaware Bay Estuaries. As this goal is reached, previously assessed watersheds can be revisited to obtain data on how condition metrics are changing over time.

With coastal wetland restoration becoming a main focus of managers, state officials, and communities, the use of MACWA data to plan and validate these efforts has become increasingly important. Serendipitously, many watersheds assessed through Mid-TRAM have locations that will be targeted for restoration projects, so making Mid-TRAM data, as well as other MACWA data products, available to managers and planners is a PDE MACWA priority. With this, PDE has undertaken projects that support the Marsh Futures effort, which seeks to find efficient ways to map different aspects of marsh condition in targeted areas in order to identify what types of restoration (living shorelines, beneficial reuse) would be most appropriate and effective. Marsh Future tactics deploy Mid-TRAM and other MACWA field techniques for these purposes and the existing, spatially diverse dataset is an essential part of discerning which marsh characteristics portray good or poor conditions. PDE and BBP will also be calibrating long term Site Specific Intensive Monitoring data with Mid-TRAM field techniques (Figure 14). This allows us to study, with improved resolution, how Mid-TRAM defined marsh condition changes over time with respect to fixed and intensive datasets that include surface elevation tables, excavated above and below ground biomass, as well as data on the quality of water and soil. Such studies will also allow us to understand the hysteresis of marsh conditions, that is, what processes and previous conditions contribute to current conditions. This fits into restoration efforts as a better understanding of conditions through time, and what contributed to those conditions, can be used to gauge the resilience, stability, and long term efficacy of certain projects over time.

Figure 14. PDE and BBP staff using Mid-TRAM field techniques: on the left, bearing capacity; on the right, looking through *Spartina alterniflora* to obtain horizontal vegetation obstruction (i.e. canopy density)

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Appendices

Appendix Table 1. Descriptions of Mid-TRAM metrics and good condition expectations.

Attribute	Metric	Metric Description	Good Condition Expectations
Buffer Score	**Percent of AA with 5 m Buffer**	Percent of AA perimeter that has at least 5 m of natural or semi-natural condition land cover	High percentages suggest low negative impacts
	Average Buffer Width	The average buffer width surrounding the AA that is in natural of semi-natural condition	High averages suggest low impacts
	Surrounding Development	Percent of developed land within 250 m from the AA	High percentages suggest low negative impacts
	250 m Landscape Condition	Landscape condition within 250 m buffer based on the nativeness of vegetation, disturbance to substrate and extent of human visitation	High ratings (of 12) suggest good condition; lower ratings (that of 3 or 6) suggest large negative impacts
	Barriers to Landward Migration	Percent of landward perimeter of wetland within the 250 m buffer that has physical barriers preventing wetland migration	High percentages suggest low negative impacts
Hydrology Score	**Ditching and Draining**	The presence of ditches in the AA	High ratings (of 12) translate no ditching/draining, suggests good condition
	Fill and Fragmentation	The presence of fill or wetland fragmentation from anthropogenic sources in the AA	High ratings (of 12) translate no fill/fragmentation, suggests good condition
	Diking and Tidal Restrictions	The presence of dikes or other tidal flow restrictions	High ratings (of 12) translate no dikes/restrictions, suggests good condition
	Point Sources	The presence of localized sources of pollution	High ratings (of 12) translate no point sources, suggests good condition
Habitat Score	**Bearing Capacity**	Soil resistance using a slide hammer	Firm substrates (high bearing capacity) suggest good conditions
	Vegetative Obstruction	Visual obstruction by vegetation < 1 m measured with a cover board	Robust (dense) vegetation suggests good conditions
	Number of Plant Layers	Number of plant layers based on plant height	Numerous plant layers convey vegetation complexity, suggests good condition
	% Co-Dominant Invasive Species	Percent of co-dominant invasives species in AA	Low invasive dominance suggests minimally disturbed conditions
	% Invasive Cover	Percent cover of invasive species in the AA	Low invasive cover suggests minimally disturbed conditions
Shoreline Score	**Shoreline Erosion**	Shoreline condition at shoreline transect points based on the erosion:accretion ratio	Shoreline scores that average zero (neutral) suggest good condition
	Shoreline Alteration	Presence of built structures or non-natural materials along the shorelines at transect points	Low incidence of shoreline structures suggests good condition

Appendix B.1

Appendix Table 2. Mid-TRAM metric and attribute data for Dennis Creek. For abbreviation descriptions see Table 7 on page 23.

FID	DATE	WS	B1	B2	B3	B4	B5	B_SCORE	H1	H2	H3	H4	H_SCORE	HAB1	HAB2	HAB3	HAB4	HAB5	HAB_SCORE	S_1	S_2	S_SCORE	FINAL
3001	8/26/2014	Dennis	12	12	3	6	3	46.67	12	12	12	12	100.00	3	9	9	12	9	60.00				68.89
3002	8/13/2014	Dennis	12	9	12	6	12	80.00	3	12	12	12	75.00	3	6	9	12	9	53.33				69.44
3003	8/27/2014	Dennis	12	12	9	6	6	66.67	12	12	12	12	100.00	3	6	12	12	9	60.00				75.56
3004	8/14/2014	Dennis	12	12	12	12	9	93.33	9	12	12	12	91.67	6	9	9	12	12	73.33	12	6		86.11
3007	8/5/2014	Dennis	12	12	12	6	12	86.67	6	12	12	12	83.33	3	9	9	12	12	66.67	12	3	50.00	78.89
3008	8/4/2014	Dennis	12	9	12	12	12	93.33	12	12	12	12	100.00	6	6	9	12	12	66.67	12	9	83.33	86.67
3011	8/14/2014	Dennis	12	12	12	6	12	86.67	9	12	12	12	91.67	3	6	9	12	12	60.00				79.44
3012	8/27/2014	Dennis	12	12	12	9	12	93.33	12	12	12	12	100.00	9	9	9	12	9	73.33				88.89
3013	8/13/2014	Dennis	12	12	12	6	12	86.67	3	12	12	12	75.00	6	6	9	12	12	66.67				76.11
3014	8/19/2014	Dennis	12	12	9	9	12	86.67	12	12	12	12	100.00	6	6	9	12	12	66.67	6	6	33.33	84.44
3015	8/6/2014	Dennis	12	6	12	12	12	86.67	12	12	12	12	100.00	6	6	9	12	12	66.67	12	9	83.33	84.44
3023	8/13/2014	Dennis	12	9	12	6	12	80.00	12	12	12	12	100.00	6	6	9	12	9	60.00	12	3	50.00	80.00
3024	8/4/2014	Dennis	12	6	12	12	12	86.67	12	12	12	12	100.00	6	9	9	12	12	73.33	12	3	50.00	86.67
3027	8/20/2014	Dennis	12	9	12	9	12	86.67	9	12	12	12	91.67	9	6	9	12	12	73.33	12	3	50.00	83.89
3028	8/25/2014	Dennis	12	9	12	12	12	93.33	12	12	12	12	100.00	9	6	9	12	12	73.33	12	12	100.00	88.89
3029	8/4/2014	Dennis	12	6	12	6	12	73.33	9	9	9	12	75.00	9	6	9	12	12	73.33	12	3	50.00	73.89
3030	8/14/2014	Dennis	12	12	12	12	12	100.00	12	12	12	12	100.00	9	6	9	12	12	73.33				91.11
3035	8/11/2014	Dennis	12	12	12	12	12	100.00	12	12	12	12	100.00	6	6	9	12	12	66.67				88.89
3036	8/21/2014	Dennis	9	6	3	6	3	26.67	9	12	12	12	91.67	3	6	9	12	9	53.33				57.22
3039	8/5/2014	Dennis	12	12	12	6	12	86.67	9	12	12	12	91.67	3	6	9	12	12	60.00				79.44
3040	8/21/2014	Dennis	12	12	6	6	3	53.33	12	12	12	12	100.00	3	9	9	12	12	66.67				73.33
3041	8/18/2014	Dennis	12	9	6	6	9	60.00	12	12	12	12	100.00	6	6	9	12	12	66.67	12	3	50.00	75.56
3042	8/19/2014	Dennis	12	12	9	6	12	80.00	12	12	12	12	100.00	3	12	9	12	9	66.67				82.22
3043	8/6/2014	Dennis	12	6	12	12	12	86.67	12	12	12	12	100.00	6	6	9	12	12	66.67	12	6	66.67	84.44
3045	8/18/2014	Dennis	12	12	12	9	12	93.33	6	12	12	12	83.33	3	6	9	12	12	60.00				78.89
3046	8/20/2014	Dennis	12	12	12	9	12	93.33	9	12	12	12	91.67	6	6	9	12	12	66.67	12	3	50.00	83.89
3047	8/7/2014	Dennis	12	9	9	9	12	80.00	12	12	9	12	91.67	9	6	9	12	12	73.33	12	3	50.00	81.67
3049	8/18/2014	Dennis	12	12	12	6	12	86.67	12	12	12	12	100.00	9	6	9	12	12	73.33				86.67
3050	8/26/2014	Dennis	12	12	12	12	12	100.00	12	12	12	12	100.00	6	12	9	12	12	80.00				93.33
3051	8/11/2014	Dennis	12	9	12	12	12	93.33	12	12	12	12	100.00	3	3	9	12	12	53.33				82.22

Appendix Table 3. Mid-TRAM metric and attribute data for Mullica River. For abbreviation descriptions see Table 4 on this page.

FID	DATE	WS	B1	B2	B3	B4	B5	B_SCORE	H1	H2	H3	H4	H_SCORE	HAB1	HAB2	HAB3	HAB4	HAB5	HAB_SCORE	S_1	S_2	S_SCORE	FINAL
3329	7/16/2014	Mullica	12	12	12	9	12	93.33	12	12	12	12	100.00	9	6	6	12	12	66.67	12	3	50.00	86.67
3313	7/16/2014	Mullica	9	12	12	9	12	86.67	6	12	12	12	83.33	9	6	9	12	12	73.33				81.11
3314	7/17/2014	Mullica	6	12	12	9	12	80.00	12	12	12	12	100.00	9	3	9	12	12	66.67	12	3	50.00	82.22
3302	7/17/2014	Mullica	9	12	12	12	12	93.33	12	12	12	12	100.00	6	6	9	12	12	66.67	12	3	50.00	86.67
3318	7/17/2014	Mullica	12	9	12	12	12	93.33	12	12	12	12	100.00	9	6	9	12	12	73.33	12	3	50.00	88.89
3317	7/18/2014	Mullica	12	12	12	9	12	93.33	12	12	12	12	100.00	6	6	9	12	12	66.67	12	9	83.33	86.67
3306	7/18/2014	Mullica	9	12	12	12	12	93.33	12	12	12	12	100.00	6	3	9	12	12	60.00	12	9	83.33	84.44
3320	7/21/2014	Mullica	12	12	12	3	12	80.00	12	12	12	12	100.00	9	12	6	3	3	40.00				73.33
3325	7/22/2014	Mullica	12	12	12	6	12	86.67	9	12	12	12	91.67	9	6	12	12	12	80.00	12	3	50.00	86.11
3305	7/22/2014	Mullica	12	12	9	6	12	80.00	9	12	12	12	91.67	9	6	9	12	12	73.33	12	3	50.00	81.67
3330	7/23/2014	Mullica	12	12	12	6	12	86.67	9	12	12	12	91.67	12	3	9	12	12	73.33	12	3	50.00	83.89
3327	7/23/2014	Mullica	12	12	3	3	12	60.00	9	12	6	12	75.00	6	6	9	12	12	66.67				67.22
3311	7/23/2014	Mullica	12	12	12	9	12	93.33	12	9	12	12	91.67	9	3	9	12	12	66.67	12	6	66.67	83.89
3303	7/24/2014	Mullica	12	12	12	6	12	86.67	3	12	12	12	75.00	9	6	9	12	12	73.33				78.33
3335	7/25/2014	Mullica	9	9	12	6	12	73.33	6	12	12	12	83.33	9	6	9	12	12	73.33	12	3	50.00	76.67

Appendix Table 4. Abbreviations of Mid-TRAM metrics used in Appendix Tables 2 and 3.

Attribute	Metric	Abbrev.
Buffer Score	Percent of AA with 5 m Buffer	B1
	Average Buffer Width	B2
	Surrounding Development	B3
	250 m Landscape Condition	B4
	Barriers to Landward Migration	B5
Hydrology Score	Ditching and Draining	H1
	Fill and Fragmentation	H2
	Diking and Tidal Restrictions	H3
	Point Sources	H4
Habitat Score	Bearing Capacity	HAB1
	Vegetative Obstruction	HAB2
	Number of Plant Layers	HAB3
	% Co-Dominant Invasive Species	HAB4
	% Invasive Cover	HAB5
Shoreline Score	Shoreline Erosion	S1
	Shoreline Alteration	S2

Appendix Table 5. Raw Mid-TRAM metric* data for Dennis Creek. For abbreviation descriptions see Table 7 on page 25.

Name, Date, Location							Descriptive Data				Buffer Attribute				Shoreline		Habitat Attribute						
FID	QDR	DATE	WS	LADEC	LODEC	MOVE	DIST_UPLD	DIST_WATER	ORG_LYR_cm	SAL_ppt	%BUF_5M	AVG_BUF	%DE-VELOP	%OB-STRUC	SL_AL-TER	SL_EROS	BEARING	V_OBSTR	TOTAL_LYRS	NAT_LYRS	INV_LYRS	%INV_CO	INCOV-ER
3001	4	8/26/2014	Dennis	39.145	-74.862	No	57	127	40	16	100	193	45	95	null	null	10.344	9.75	3	3	0	0	1.5
3002	4	8/13/2014	Dennis	39.154	-74.870	No	153	1274	>18	17	100	155	0	0	null	null	9.375	19.25	3	3	0	0	0
3003	3	8/27/2014	Dennis	39.186	-74.856	Yes	6	864	30	14	100	245	2	12	null	null	7.19	19.75	4	4	1	5	5
3004	3	8/14/2014	Dennis	39.166	-74.856	No	764	168	>25	20	100	249	0	0	0	-0.4	6	18.75	3	3	0	0	0
3007	4	8/5/2014	Dennis	39.154	-75.870	No	1147	82	30	18	100	219	0	0	0		8.844	11.5	2	2	0	0	0
3008	1	8/4/2014	Dennis	39.184	-74.886	Yes	965	84	>60	N/A	100	185	0	0	0	-0.2	5.375	22.25	2	2	0	0	0
3011	4	8/14/2014	Dennis	39.160	-74.860	Yes	603	310	26	15	100	250	0	0	null	null	6.656	21	2	2	0	0	0
3012	2	8/27/2014	Dennis	39.193	-74.883	No	89	845	33	15	100	237	0	0	null	null	3.938	13.5	3	2	0	0	2
3013	4	8/13/2014	Dennis	39.156	-74.876	No	726	795	>20	16	100	250	0	0	null	null	5.438	20.5	3	3	0	0	0
3014	3	8/19/2014	Dennis	39.183	-74.824	No	586	26	45	14	100	195	3	0	-0.4	-0.4	5.86	16	3	3	0	0	0
3015	1	8/6/2014	Dennis	39.175	-74.878	Yes	1705	5	32	22	100	69	0	0	0	-0.2	5.031	19.5	3	3	0	0	0
3023	4	8/13/2014	Dennis	39.170	-74.884	No	2217	63	18	15	100	156	0	0	0		5.844	15.5	3	3	0	0	1
3024	2	8/4/2014	Dennis	39.168	-74.893	No	2837	31	>40	N/A	100	123	0	0	0		5.906	11	3	3	0	0	0
3027	2	8/20/2014	Dennis	39.178	-74.858	No	631	61	20	15	100	142	0	0	0	-0.6	3.688	20	2	2	0	0	0
3028	2	8/25/2014	Dennis	39.189	-74.894	Yes	843	24	>63	17	100	140	0	0	0	0	6.156	14.75	3	3	0	0	0
3029	3	8/4/2014	Dennis	39.148	-74.884	Yes	1018	3	>50	N/A	100	124	0	0	0		3.813	18.75	3	3	0	0	0
3030	2	8/14/2014	Dennis	39.185	-74.835	Yes	475	372	38	14	100	250	0	0	null	null	3.719	15.25	2	2	0	0	0
3035	1	8/11/2014	Dennis	39.187	-74.871	No	285	93	59	17	100	213	0	0	null	null	6.93	18.5	2	2	0	0	0
3036	5	8/21/2014	Dennis	39.187	-74.905	Yes	24	841	>52	18	85	119	40	100	null	null	7.688	9	2	2	1	0	5
3039	4	8/5/2014	Dennis	39.158	-74.870	No	466	341	45	18	100	210	0	0	null	null	8.906	17.25	2	2	0	0	0
3040	4	8/21/2014	Dennis	39.188	-74.903	Yes	122	742	40	16	100	234	15	45	null	null	7.344	8.25	3	3	0	0	0
3041	4	8/18/2014	Dennis	39.115	-74.858	No	9	28	>50	21	100	149	8	3	0	-0.6	5.875	14.75	3	3	0	0	0
3042	4	8/19/2014	Dennis	39.186	-74.823	No	231	389	2	11	100	247	5	0	null	null	8.06	6	2	1	1	10	10
3043	1	8/6/2014	Dennis	39.174	-74.863	Yes	1756	6	>35	14	100	97	0	0	0	-0.4	4.063	19.75	3	3	0	0	0
3045	3	8/18/2014	Dennis	39.140	-74.883	No	1734	236	45	23	100	250	0	0	null	null	6.438	19.75	2	2	0	0	0
3046	2	8/20/2014	Dennis	39.181	-74.844	Yes	756	227	12	15	100	250	0	0	0	-0.6	5.563	20	3	3	0	0	0
3047	3	8/7/2014	Dennis	39.168	-74.836	Yes	400	4	50	16	100	137	2	0	0	-0.8	3.688	17.5	2	2	0	0	0
3049	3	8/18/2014	Dennis	39.128	-74.872	No	365	250	>70	25	100	248	0	0	null	null	3.594	20	3	3	0	0	0
3050	2	8/26/2014	Dennis	39.102	-74.861	No	13	357	33	25	100	250	0	0	null	null	4.438	11.5	3	3	0	0	0
3051	1	8/11/2014	Dennis	39.189	-74.880	No	281	777	12	16	100	186	100	0	null	null	8.25	20.75	3	3	0	0	0

*Hydrology data are not included in this table as observations (i.e. the raw data) on these conditions are recorded as ratings, which are in Table 2 of this Appendix (page 22).

Appendix Table 6. Raw Mid-TRAM metric* data for Mullica River. For abbreviation descriptions see Table 7 on this page.

Name, Date, Location							Descriptive Data				Buffer Attribute				Shoreline		Habitat Attribute						
FID	QDR	DATE	WS	LADEC	LODEC	MOVE	DIST_UPLD	DIST_WATER	ORG_LYR_cm	SAL_ppt	%BUF_5M	AVG_BUF	%DEVELOP	%OBSTRUC	SL_ALTER	SL_EROS	BEARING	V_OBSTR	TOTAL_LYRS	NAT_LYRS	INV_LYRS	%INV_CO	INCOVER
3329	2	7/16/2014	Mullica	39.582	-74.396	No	307	2618	>44	8	100	250	0	0	0		2.97	18.75	1	2	0	0	0
3313	3	7/16/2014	Mullica	39.577	-74.417	Yes	274	1012	49	19.5	97	250	0	0			3.72	17.25	2	2	0	0	0
3314	2	7/17/2014	Mullica	39.496	-74.400	Yes	1699	0	>39.2	26	70	250	0	0	0		2.56	23	2	2	0	0	0
3302	1	7/17/2014	Mullica	39.464	-74.366	Yes	5754	136	40	30	94	220	0	0	0		4.41	18.5	2	1	0	0	0
3318	1	7/17/2014	Mullica	39.485	-74.347	Yes	6384	14	>53	29	100	153	0	0	0		1.88	18.25	2	3	0	0	0
3317	2	7/18/2014	Mullica	39.350	-75.350	Yes	1581	464	>39.6	30	100	250	0	0	0	-0.2	4.28	20.5	2	2	0	0	0
3306	1	7/18/2014	Mullica	39.515	-74.329	No	5327	324	53	31	80	250	0	0	0	-0.2	4.28	23.75	3	1	0	0	0
3320	5	7/21/2014	Mullica	39.582	-74.495	No	1020	699	>18	7	100	250	0	0			3.19	1.25	1	0	1	96	96
3325	2	7/22/2014	Mullica	39.567	-74.391	Yes	335	543	>36	18	100	250	0	0	0		2.38	19	4	3	0	0	0
3305	2	7/22/2014	Mullica	39.564	-74.419	No	1720	56	>41	21	100	190	1	0	0.2	-0.6	2.34	20.75	2	3	0	0	0
3330	3	7/23/2014	Mullica	39.477	-74.420	No	1093	116	>46	30	100	248	0	0	0	-0.3	1.43	22.25	2	2	0	0	0
3327	4	7/23/2014	Mullica	39.473	-74.423	Yes	1072	146	>56	35	100	201	20	0			4.78	20.75	2	2	0	0	0
3311	2	7/23/2014	Mullica	39.477	-74.403	No	4811	0	19	35	100	225	0	0	0.2	-0.4	2.69	23.25	3	3	0	0	0
3303	4	7/24/2014	Mullica	39.498	-74.433	No	122	2134	>40	21	100	250	0	0			1.81	20	3	1	0	0	0
3335	3	7/25/2014	Mullica	39.522	-74.431	Yes	1760	0	>42	20	97	173	0	0	0		2.59	21.5	3	3	0	0	0

*Hydrology data are not included in this table as observations (i.e. the raw data) on these conditions are recorded as ratings, which are in Table 2 of this Appendix (page 23).

Appendix Table 7. Description of column headers in Appendix Tables 5 and 6.

Column Name	Description
FID	Identification Number
QDR	Qualitative Disturbance Rating
WS	Watershed
LADEC	Latitude
LODEC	Longitude
MOVED	Moved from original location?
DIST_UPLD	Distance to upland (m)
DIST_WATER	Distance to open water (m)
ORG_LYR_cm	Organic layer depth (cm)
SAL_ppt	Surface salinity (ppt)
%BUF_5M	Percent AA with a 5 meter buffer
AVG_BUF	Average buffer width from AA to 250 m buffer area (m)
%DEVELOP	Percent development within 250 m buffer area
%OBSTRUC	Percent of 5 m buffer with obstruction to migration (with SLR)
SL_ALTER	Shoreline alterations (m)
SL_EROS	Shoreline erosion (1, 0, -1)
BEARING	Bearing capacity (cm)
V_OBSTR	Vegetation obstruction (# decimeter board segments visible)
TOTAL_LYRS	Total number of plant layers
NAT_LYRS	Number of native plant layers
INV_LYRS	Number of invasive plant layers
%INV_CO	Percent co dominant invasive plant cover
INCOVER	Total invasive plant cover

Appendix Table 8. P-values for TukeyHSD comparisons of watershed final scores.

	Christina	Barn. Bay North
Barn. Bay South	0.000	0.047
Dennis	0	0.000
Mullica	0	0.000
Crosswicks	0	0.000
Maurice	0.000	0.000
Mispillion	0.000	0.003
PA Tidal	0.000	0.015
Broadkill	0.000	0.016

MID ATLANTIC COASTAL WETLAND ASSESSMENT