Evaluation of Environmentally Sensitive Areas to Water Craft Impacts in Barnegat Bay NJ

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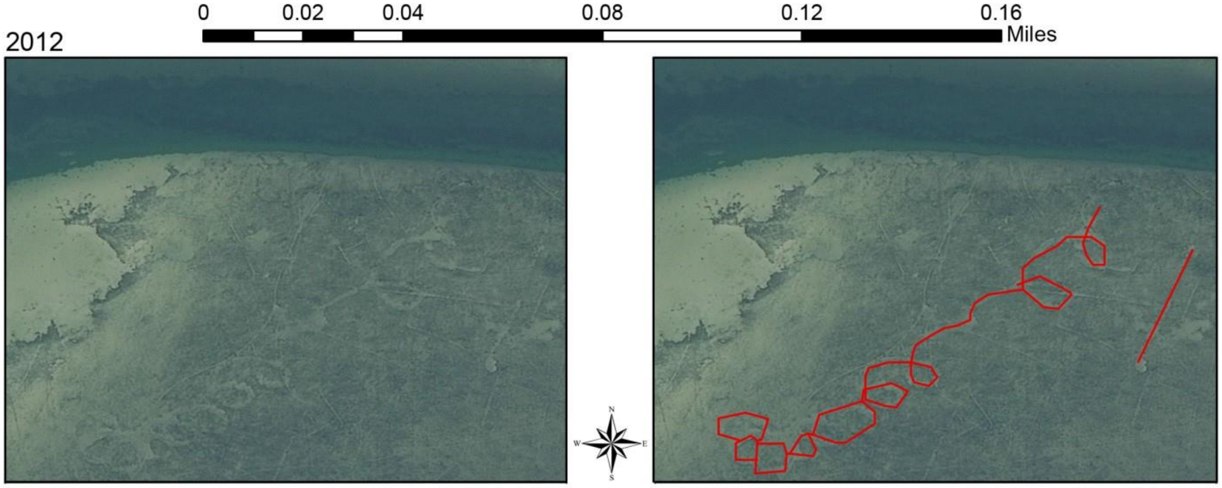

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Executive Summary

Point # 10 of the Barnegat Bay Action Plan is an action to Reduce Water Craft Impacts. While recreational boating is an economically important and popular activity on Barnegat Bay – Little Egg Harbor (BB-LEH), boating activities can have a direct negative effect on seagrasses, marshes, mudflats, and other key habitats as well as indirectly impact birds, turtles, fish, and crabs. To help address Action Plan Point #10, ecologically sensitive areas (ESAs) in Barnegat Bay – Little Egg Harbor were identified to receive special consideration and management to reduce boater impacts. Boundaries for sixteen ESAs were established and designated prior to the summer of 2012. The designation of these ESAs was based on best professional judgment and a GIS-based assessment conducted by NJDEP and Rutgers University Center for Remote Sensing & Spatial Analysis (CRSSA) staff using extant maps of habitat natural features including shellfish beds, SAV, presence of endangered species, and proximity to bird nesting areas.

One of the objectives of this project reported herein was to re-evaluate the delineation of the sixteen ESAs using historical as well as more recently acquired biological/environmental sampling data. We more fully compared the 16 ESAs vs. the remaining portions of the BB-LEH region to determine whether there are differences in habitat features, abundance and/or distribution/diversity of key species or other environmental characteristics. In terms of the overall water quality, the water quality characteristics within the ESAs are not significantly different than the remainder of the BB-LEH system. In terms of their biotic characteristics, the ESAs exhibit a greater distinction vs. the remaining portions of BB-LEH. This is not surprising in that several parameters such as seagrass distribution, colonial nesting bird or osprey presence that exhibit a difference, were critical determinants of the locations and boundaries of the ESAs. The sixteen ESAs, as they have been previously delineated, represent especially biologically rich areas as compared to the remainder of the BB-LEH system. To further examine the question as to whether the ESAs as they are presently delineated are adequate to protecting the sensitive ecological resources within the BB-LEH system, we analyzed the most recent data on colonial nesting bird nesting birds. We suggest that the NJDEP should consider expanding existing ESA boundaries or establishing new ESAs to include a number of important nesting bird colony locations that are presently not included within the ESA network.

We examined whether there has been a discernible change in ecological or environmental condition since the establishment of the ESAs, where there are comparable data sets allowing for a before vs. after analysis. To complete this task we examined the change in several long term colonial nesting bird population data sets. While these data sets span the pre- and post-ESA establishment time period, there was an insufficient number of years of data post-ESA establishment to do a rigorous statistical analysis. While our study was not able to conclusively document that the inclusion of a nesting colony in an ESA promoted higher nesting bird numbers or reproductive success, our review of the scientific literature supports the continuation, if not expansion of "green" boating practices to minimize the adverse effects of boating disturbances to colonial nesting birds.

SuperStorm Sandy did not have a major effect on the physical terrain (i.e. shoreline configuration and bottom topography) of the BB-LEH ESAs. Most ESAs experienced only modest changes. Notable areas that were significantly affected by shoreline erosion, sediment deposition and overwash were ESA 7 (Barnegat Light), ESA 9 (Gunning River area of the Edwin B. Forsythe National Wildlife Refuge), and ESA 18 (the bayside of the Holgate section of the Edwin B. Forsythe National Wildlife Refuge). These ESAs are associated with the dynamic tidal deltas of Barnegat and Little Egg Harbor Inlets.

As part of this project, we have assessed how the designated ESAs are at risk due to boating impacts. Our results document hotspots of boating activity within the boundaries of designated ESAs. Five ESAs accounted for nearly 90% of the activity: Island Beach South, Island Beach North, Forsythe South, Long Beach North and Forsythe North (ranked from higher to lower) and one ESA, Island Beach South, alone accounted for nearly 73% of the boating activity with many of those boats moored at what is known as Tice's Shoal. As demonstrated by the watercraft scarring mapping, these high levels of boating activity are negatively impacting the ESAs by disturbing the seagrass beds. Some of these watercraft scars can be quite severe and may take four or greater number of years for the seagrass bed to recover. Additional management to reduce boating impacts to the Tice's Shoal area of ESA Island Beach South should be considered. This might include greater signage, more restricted mooring areas, enhanced boater education and greater regulatory enforcement.

We also examined whether the development of a multi-metric assessment index is feasible for future monitoring and management of these ESAs. We suggest that the development of a multimetric index is not supported and unwarranted, rather the three indicators should be monitored and characterized individually to not obscure their messages. We recommend that the three fore-mentioned biological indicators (1) seagrass areal cover; 2) colonial nesting bird abundance and diversity; 3) osprey nest abundance; serve as the basis for future change monitoring of the ecological integrity of the ESAs individually and collectively. In composite, we suggest that the monitoring data for the ESAs be assessed on a 5 to 10 year time scale to determine their ecological integrity status.

The establishment of the BB-LEH ESAs, which builds on the earlier designation of the Sedge Island Marine Conservation Zone, as special management zones represents a novel experiment in coastal/estuarine ecological management. Our analysis supports the idea that these ESAs represent especially rich and productive biological areas important to the broader bay ecosystem. While there were initial efforts by the NJDEP at boater education and enforcement of regulations to reduce boating impacts during the first year of establishment, this same level of effort was not sustained. For the ESAs to fulfill their mission of sustaining the sensitive ecological systems within their borders, we suggest that more needs to be done to reduce boater impacts. Our study suggests that education, signage, or regulatory enforcement targeted in a few locations could have an outsized effect. We hope that this study along with other monitoring and mapping efforts will assist the NJDEP in determining appropriate management practices for the future.

Introduction

On December 9, 2010, Governor Chris Christie announced a 10 point Comprehensive Plan of Action to address the declining ecological health of the Barnegat Bay watershed that in turn was threatening the economic health of the region (NJDEP, 2011). Recognizing that a restoration to pristine conditions was not feasible, the goal of the plan was to prevent further ecological degradation and initiate some degree of restoration. One of the 10 points included an action to Reduce Water Craft Impacts (Point #10): *Boats and personal water craft such as jet skis can harm the Bay by damaging submerged aquatic vegetation and disrupting aquatic habitats. The DEP will review existing research that identifies the locations of these sensitive areas to evaluate the designation of a Conservation Zone.*

While recreational boating is an economically important and popular activity on Barnegat Bay – Little Egg Harbor (BB-LEH), boating activities can have a direct negative effect on seagrasses, marshes, mudflats, and other key habitats as well as indirectly impact birds, turtles, fish, and crabs. Concerns about boating impacts predate the Barnegat Bay Action Plan resulting in a series of efforts over the years. In 2000, a science workshop on “Impacts of Motorized Boats on Shallow Water Systems” was held at Rutgers University. That same year the “Boater’s Guide to Barnegat Bay and Little Egg Harbor” was published by the Barnegat Bay Program with financial support of the Marine Trades Association, NJ SeaGrant and NJ DEP (and others) with the objective of educating boaters as to environmentally responsible boating practices. The Boater’s Guide was updated and republished in 2004. The Sedge Island Marine Conservation Zone (SIMCZ) was designated in 2001 in a back-bay section of Island Beach State Park to ban personal watercraft and impose a no wake zone for other motorized watercraft. This was the first time the state had employed marine conservation zoning to regulate water craft in ecologically sensitive areas. All commercial activities, including shellfishing have been prohibited in the SIMCZ since its establishment. In 2014, the tidelands conveyance solidified the prohibition of all commercial activities in the SIMCZ and enforcement of the ban on commercial shellfishing was enhanced.

To address, Action Item #10, in 2011 - 2012 the New Jersey Department of Environmental Protection (NJDEP) met several times with a wide range of stakeholders to identify strategies and actions that would reduce the impacts of improper boating and personal water craft use on Bay ecology. To help address Action Plan Point #10, ecologically sensitive areas (ESAs) in Barnegat Bay – Little Egg Harbor (BB-LEH) were identified to receive special consideration and management to reduce boater impacts. Boundaries for sixteen ESAs were established and designated prior to the summer of 2012. The identified ESAs are generally shallow areas where submerged aquatic vegetation (SAV), tidal creeks and/or salt marsh islands with high ecological value were deemed to be especially sensitive to negative impacts from boating. These places provide feeding and breeding grounds for fish, crabs, birds, and other animals. The designation of these sixteen ESAs was based on best professional judgment and a GIS-based assessment conducted by NJDEP and Rutgers University Center for Remote Sensing & Spatial Analysis (CRSSA) staff using extant maps of habitat natural features including shellfish beds, SAV, presence of endangered species, and proximity to bird nesting areas, among others.

The purpose of the ESA establishment was in accordance with the DEP objective of restoring the ecological health of Barnegat Bay. The ESAs designate specific areas that are of particularly high ecological value to the broader BB-LEH system. Through detection of these areas, it is then possible to sustain or improve their health through monitoring and enforcement to reduce boater impacts. A map of the sixteen ESAs (Figure Intro.1) became part of a poster and flyer (available at http://www.nj.gov/dep/barnegatbay/docs/poster.pdf) that were developed for boaters to highlight these areas and showcase "green" boating practices that reduce the impact of boats and personal watercraft around these areas.

The New Jersey State Police Boating Safety manual includes regulations as well as suggested green boating practices relevant to reducing adverse boating impacts to sensitive ecological areas such as the ESAs (http://www.njsp.org/maritime/pdf/052212_boatsafetymanual.pdf) (Figure Intro.2). Additional information on green boating practices were posted on the NJDEP Action Plan website (http://www.nj.gov/dep/barnegatbay/plan-watercraft.htm) .These regulations and green boating practices include: 1) All power vessels shall reduce their speed to slow speed when passing through lagoons, canals or confined areas of less than 200 feet in width; 2) maintain a distance of 100 feet from natural shorelines and bay islands; 3) stay out of restricted wildlife areas; and 4) minimize wakes in shallow areas to reduce erosion and harm to aquatic life.

During the spring and summer of 2012, marine enforcement officers conducted three compliance and education sweeps and issued warnings or summons when boater regulations were being violated. These sweeps were complemented by visual assessments of the ESAs to determine the recreational use of these areas. In addition, in 2013, research to measure the impact and value of the Marine Conservation Zone at Island Beach State Park to the ecology of the estuary was initiated. The results of this study will aid the department in management decisions for other ecologically sensitive areas.

In 2013, the NJDEP funded the Rutgers University CRSSA to undertake a research project entitled "Evaluation of Environmentally Sensitive Areas to Water Craft Impacts in Barnegat Bay NJ." The project had several main objectives including an evaluation of the delineation and characterization of the ESAs based on newly available data sets, examination of changes to the ESAs post-establishment or post-SuperStorm Sandy, more detailed assessment of boating-related damages or potential risks to BB-LEH resources and recommendations on future monitoring and management. This document represents the final report on the results of this project. The project was composed of 5 major components:

1. ESA Characterization;
2. Post-establishment change in ESA ecological condition;
3. Boating risk assessment;
4. Post Sandy change assessment; and,
5. Develop multi-metric assessment index

Each of these five major tasks are broken into a separate section in this document where that task's objectives, methods, results, discussion, and conclusions are elaborated on.

Green Boating Practices for Barnegat Bay's Ecologically Sensitive Areas

Ecologically Sensitive Areas are locations where unique wildlife and submerged aquatic vegetation, such as eel grass, is found. These areas provide shelter and feeding grounds for numerous fish and wildlife, including shellfish, crabs, fish and shorebirds.

Take these actions to help keep the Bay vibrant and healthy:

- Maintain 100' distance (approximately six car lengths) from natural shorelines, Bay islands and sensitive ecological areas.
- Do not chase, harass or disturb nesting birds and other animals with your vessel.
- Bury mooring chains and lines to prevent them from scraping on the Bay bottom.
- Use pump-out boats and facilities to discharge wastewater from holding tanks.
- Reduce throttle to "no wake" speed when close to a shoreline or in small rivers to help prevent erosion.
- Do not operate in shallow water where your prop or pump intake can stir up bottom sediments and destroy aquatic plants.
- Reduce air pollution by cutting your engine and not idling in open water.

To learn more about the Governor's Action Plan for Barnegat Bay go to: www.barnegatbay.nj.gov

Figure Intro.1 NJDEP ESA poster map (http://www.nj.gov/dep/barnegatbay/docs/poster.pdf)

Be a Clean and Green New Jersey Boater

New Jersey's coastline and waterways are home to plants, fish, wildlife and people. Recreational boating opportunities abound on our thousands of miles of rivers, lakes, bays and ocean. Help protect water resources by being a green boater!

- **Use pump-out boats and facilities instead of discharging wastewater holding tanks into open water. NJ Pump-out Program - www.nj.gov/dep/fgw/artcva.htm**
- **Avoid giving invasive aquatic plants and animals a boat ride – clean boats and equipment thoroughly when transferring from one water body to another. Aquatic Invasive Species - www.njfishandwildlife.com/aquatic_invasives.htm**
- **Keep trash in secure containers and recycle monofilament fishing lines. Properly maintain boat and vehicle engines. Clean Marina Program - www.nj.gov/dep/njcleanmarina**
- **Stay out of restricted wildlife areas. Do not harass nesting birds and other wildlife. Beach nesting birds - www.state.nj.us/dep/fgw/ensp/beachnester_info.htm**
- **Maintain 100' distance from natural shorelines and bay islands and use marked navigational channels for travel.**
- **Minimize wakes in shallow areas to reduce erosion and harm to aquatic life – No wake for nature!**

Green boating practices are one of the key components of Governor Chris Christie's 10-Point Plan for Barnegat Bay. To learn more visit www.barnegatbay.nj.gov

Figure Intro.2 "Green" boating guidelines from back cover of New Jersey State Police Boating Safety manual. http://www.njsp.org/maritime/pdf/052212_boatsafetymanual.pdf

Section 1 Comparison of ESAs vs. Barnegat Bay – Little Egg Harbor

Objective: Compare the 16 ESAs vs. the remaining portions of the BB-LEH region to determine whether there are differences in habitat features, abundance and/or distribution/diversity of key species or other environmental characteristics.

Methods:

Inside vs. Outside ESA Bayesian Analysis

The sixteen original ESAs were further subdivided into eighteen geographically distinct parcels and labelled with a numeric identifier and mapped using ESRI ArcGIS software (Table 1.1, Figure 1.1). ESAs Island Beach South and Long Beach Central are each divided into three separate sections.

Data collected as part of the Years 1 and 2: 2013 NJDEP-supported Barnegat Bay research program was provided by the NJDEP and NJDEP-funded researchers including data on individual species, populations, chemistry, field observations, and benthic sediments (Table 1.2). Additional environmental data sets pertinent to the study were also obtained from credible sources (Table 1.2). Only data sets that covered the entire breadth of the Barnegat Bay-Little Egg Harbor (BB-LEH) study area were included. The sampling design and protocols for these disparate data sets were not originally developed and implemented with this comparative analysis in mind. Thus the sampling sizes for some of the parameters within the ESAs are quite small. However, other parameters were sampled or mapped much more extensively within the ESAs and provide insight into the characteristics of the ESAs vs. the broader BB-LEH area.

The data were geocoded (i.e. assigned a geographic coordinate location) and mapped to visually assess for geographic veracity. Data collection locations were then assigned as to whether the collection location fell within the ESA boundary or outside an ESA boundary (the former were classified as within ESA, the latter outside ESA). The ESAs that contain data for the specific parameter in question are noted in Table 1.2. Due to its continuous spatial distribution of the seagrass mapped data, the amount of seagrass inside the ESAs were compared with sixteen nonESA “test sites.” The test sites were chosen to be circular areas 2.2 km in diameter to approximate the mean size of the ESAs at 385 ha. The locations were allocated by generating random point locations in the nonESA areas of BB-LEH. A test site circle was then determined such that it was non-overlapping with any ESA as well as other test sites and continued a minimum of salt marsh (Figure 1.2). The percent area of mapped seagrass was then calculated as the metric for comparison inside vs. outside ESAs.

In most cases, each individual environmental parameter was analyzed independently. However, several of the biotic data sets where multiple species were recorded were transformed into a measure of species diversity using a Shannon-Wiener Diversity index:

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

The parameters so transformed included aquatic faunal surveys conducted by the Rutgers University Marine Field Station (RUMFS) and the colonial nesting bird surveys conducted by the NJDEP Division of Fish & Wildlife Endangered & Nongame Species Program.

Hierarchical Bayesian analysis was employed to examine whether there was a difference between the inside vs. outside ESA environmental/biological characteristics (i.e., the null hypothesis of no difference in the selected characteristics inside vs. outside the ESA and the alternative hypothesis that there is a difference). We prefer Bayesian to classical techniques. With the latter methods, investigators focus on the probability of observing the data they have seen (or more extreme data) *if* the hypothesis is true. We prefer the Bayesian approach of directly assessing the probability of the hypothesis given the data that was observed (*e.g.*, see Robert 1994). For most of the variables tested, we used Markov Chain Monte Carlo (MCMC) methods to estimate the posterior means of two groups (inside ESAs or outside ESAs). We diagnosed convergence by traces of the quantiles from the marginal posteriors of each parameter, and then running the MCMC routine for (at a minimum) twice as many iterations as the quantile traces suggested were required for convergence. We also established a 95% credible region for the differences between the means. If the credible region for the difference between two means does not include 0, then the posterior probability that the two means are different is at least 95%. For the purposes of this study, it doesn't matter whether one examines joint or marginal posterior distributions for an MCMC sampler. For example, suppose we have a sample from the joint posterior distribution of (θ_1, θ_2). If we restrict our attention to the marginal sample for, say, θ_1, then we are examining the marginal posterior of θ_1.

The basic hierarchical Bayesian model is as follows:

$$y_{ij} \sim N\left(\mu_i, \sigma_i^2\right)$$

$$\mu_i \sim N\left(\theta, \tau^2\right) \quad \sigma_i^2 \sim IG\left(0.001, 0.001\right) \quad i = 1,2$$

$$\theta \sim N\left(0, 1000000\right) \quad \tau \sim Unif\left(0, 10\right)$$

In this model, the observations for each parameter were modeled as realizations from a normal distribution with mean μ_1 if the observations were from an ESA or with mean μ_2 if they were from a nonESA. Vague priors were assigned to all variances and higher level parameters. The priors were non-informative so as to let the data drive out inferences. We assumed flat priors (normal with a mean of 0 but a very low precision (1.0E-06) for location parameters (i.e., means)), and IG (0.001, 0.001) for precision parameters. The latter distributions are flat in the range of observed data and consequently exert very little influence on the estimates.

Next the posterior distribution of the difference $(\mu_1 - \mu_2)$. was examined (i.e., mean parameter in ESAs minus mean parameter in nonESAs). The 2.5 and 97.5 percentiles were used to form a 95% credible interval for the difference. If this interval included 0 then it was concluded that 0 was a reasonable value for the difference and hence there was no significant difference between the ESA and nonESA areas for that particular response variable. If the 95% credible interval did not include zero and was entirely negative, then it was concluded that the mean for the parameter in question was lower for the ESAs than for the nonESAs. If the 95% credible interval did not include zero and was entirely positive, then it was concluded that the mean for the parameter in question was higher for the ESAs than for the nonESAs. Since a hierarchical model was fitted, it was not necessary to compute any Bonferroni-type corrections for multiple comparisons (Gelman et al., 2008).

For the diversity indices the following model was fitted:

$$
\begin{aligned}
&y_{ij} \sim N\left(\mu_i, \sigma^2\right), \\
&\mu_i \sim N(0, 10000) \\
&\sigma^2 \sim \mathrm{IG}(0.001, 0.001) \\
&\quad i = 1, 2;\ j = 1, 2, \ldots, n_i
\end{aligned}
$$

i = 1 for ESA sites and i = 2 for nonESA sites, and y_{ij} is the Shannon diversity observed at observation j for site i. The model was run for 200,000 iterations, discarded the first 50,000 and retained every-other iteration after that for the analysis. This resulted in a posterior sample of size 75,000. Next the 95% credible interval for the difference between μ_1 and μ_2 and diff = μ_1 - μ_2 was examined (i.e., mean diversity in ESAs minus mean diversity in nonESAs). If the interval does not contain 0, then that would mean the mean diversity is different between the two sites.

Adequacy of Existing ESA network: Colonial Nesting Birds

To further examine the question as to whether the ESAs as they are presently delineated are adequate to protecting the sensitive ecological resources within the BB-LEH system, we analyzed the most recent data on colonial nesting bird nesting birds.

The first data set, collected by the Endangered and Nongame Species Program of the Division of Fish &Wildlife (ENSP-NJDFW) of the NJ Department of Environmental Protection was sampled for the years 2007, and 2011-2014. These were collected via aerial flyover surveys (Contact: Christina Davis, Christina.Davis@dep.nj.gov). Waders and large gulls usually are done in one long day while gulls and terns take 3-4 consecutive days unless weather prevents it. ENSP-NJDFW protocols survey three times within two week spans and base estimates on the highest number of adults observed on the island. This can result in double sampling the same birds in different locations.

The second data set was provided by Joanna Burger of Rutgers University who has studied Barnegat Bay nesting birds for over 40 years and has provided the data for Common Terns from

1976-2014. Burger's surveys are conducted frequently throughout the season with a combination of aerial flyovers by helicopter, small boat, and on foot. The population numbers are integrated across the multiple surveys to account for double counting of birds.

Based on the ENSP-NJDFW and J. Burger data for the years 2007-2014 the colonial bird nesting colonies were classified as to whether they were presently inside or outside the ESA network. The colonies were then ranked in importance based on the total aggregate number for this time period.

Results:

Inside vs. Outside ESA Bayesian Analysis

A total of 25 environmental/biological parameters were analyzed. Table 1.2 enumerates the results of the above Bayesian hierarchical modeling approach. Our results suggest that the ESAs are not statistically different from the remaining portion of the Barnegat Bay-Little Egg Harbor (BB-LEH) system for a majority of the water quality parameters with the exception of pH (Table 1.2). There is some indication that the ESAs are composed of less Mud substrate than the remainder of the BB-LEH (Table 1.2).

The 95% credible region for the colonial nesting bird abundance and osprey nest density included 0 and thus suggests no statistical difference inside vs. outside the ESAs. However, examination of the Bayesian analysis posterior probability distribution of the difference between the two means revealed that the probabilities were all positive (colonial nesting bird abundance for years 2007, 2011-2014: 0.51, 0.71, 0.54, 0.058, and 0.30; and osprey nest abundance: 0.76) suggesting higher numbers inside vs outside the ESAs.

For the RUMFS faunal survey diversity indices, the 95% percent credible interval did not contain 0 and hence mean diversity is different between the two sites. Furthermore, the 95% credible interval was (0.25, 0.83). Since the interval is negative, this indicates that the mean diversity is greater for ESA sites than non-ESA sites. The analysis was repeated with log(diversity) as the response variable with identical results.

Several of the biological parameters stood out as being significantly different inside vs. outside the ESAs: 1) seagrass amount; 2) hard clam abundance; and 3) aquatic faunal diversity.

Adequacy of Existing ESA network: Colonial Nesting Birds

The ENSP-NJDFW data shows that Herring (HEGU), Laughing (LAGU) and Great-Black Backed gulls (GBBG) and Common (COTE) Forster's (FOTE) terns were the five most common species of colonial nesting birds in the BB-LEH system (Figure 1.3). The relative rank in terms of numbers of nesting bird for the full suite of colonies was determined with Figure 1.4 showing for all species (Table 1.3) from the ENSP-NJDFW data set and Figure 1.5 for solely Common terns from the J. Burger data set.

Discussion:

Inside vs. Outside ESA Bayesian Analysis

In terms of the overall water quality, the water quality characteristics within the ESAs are not significantly different than the remainder of the Barnegat Bay-Little Egg Harbor (BB-LEH) system. Given the restricted sampling sizes for most of the water quality data parameters within the ESAs, any conclusions based on this analysis must be treated with caution. Only two ESAs (ID# 3 and 6) have sampling stations as part of the NJDEP Estuarine water quality monitoring program. For example, the observed difference in pH is based on only one ESA (#6 Island Beach South III). One possible explanation for the observed difference in pH is that this ESA located along the eastern extent of the BB-LEH (i.e., along the backside of the barrier islands) where there is a minimum of freshwater input. Much of the freshwater input from coastal plain streams is high acidity low pH. Thus the applicability of pH as a parameter for future monitoring of the influence of human activities on the ecological integrity of the ESAs is tenuous at best.

The biotic parameters (including fecal coliform) had much wider spatial distribution and greater representation inside the ESAs. In terms of these biotic characteristics (such as seagrass distribution, hard clam abundance, aquatic species diversity), the ESAs exhibit a greater distinction vs. the remaining portions of BB-LEH. The analysis concerning the osprey and colonial nesting bird abundance and diversity was somewhat equivocal. The results of the Hierarchical Bayesian analysis suggests that while the differences were not statistically significant the ESAs showed a higher probability of bird abundance inside vs. outside the ESAs.

It is not surprising that sea grass distribution exhibited a difference inside vs. outside the ESAs, as this factor was taken into account when establishing the locations and boundaries of the ESAs. While we do not know the underlying causal factors as to why the ESAs might be different in terms of hard clam abundance or aquatic faunal species diversity, the higher amount of seagrass habitat in the ESAs may be a critical factor. Seagrass provides cover, habitat and food sources for a number of species.

Regardless, the sixteen ESAs as they have been previously delineated represent especially biologically rich areas as compared to the remainder of the BB-LEH system.

In summary, this inside vs. outside ESA analysis was designed to determine whether the ESAs as a whole were representative of the broader BB-LEH. Recognizing some of the caveats expressed as to the limited spatial distribution of some of the underlying data sets, the ESAs as a whole vs. the remainder of the BB-LEH do not show a significant difference in terms of water quality but do appear to exhibit a difference in terms of a number of biotic characteristics. The analysis was not designed to characterize or compare individual ESAs or examine whether non-ESA areas might be suitable for consideration as an ESA; for those types of questions further analysis of the specific data sets and ESAs in question would be required. In the next section, Task 2, the spatial distribution of colonial nesting birds will be further examined with these questions in mind.

Adequacy of Existing ESA network: Colonial Nesting Birds

Review of Figures 1.4 and 1.5 reveal that there are several islands or other marsh locations that hold significant populations of colonial nesting birds and more specifically common terns that are not included within any of the presently designated ESAs. The most important nesting colonies not included in the ESA network are the North and South Clam, Pettit Island, Little Sedge, Vol Island East and West, Oyster Creek Channel East, Sandy Island, Mordecai, North and South Lavalette Islands (Figure 1.6).

While the results of our study (see Section Task 2 below) was not able to conclusively document that the inclusion of a nesting colony in an ESA promoted higher nesting bird numbers or reproductive success, we suggest that the NJDEP should consider expanding existing ESA boundaries or establishing new ESAs to include these important nesting bird colony locations. For example, ESA #2 Northwest Point Island, ESA # 7 Barnegat Light, #8 Long Beach North, or #10 Forsythe South could be expanded to include a majority of the most important non-ESA nesting bird colonies. With enhanced boating education and enforcement, these new or expanded ESAs could benefit from the added protection.

Table 1.1 ESAs and their sizes in acres

ESA ID	Site Name	Area in acres
1	Mosquito Cove	484.2
2	NW Point Island	531.2
3	Island Beach North	2,091.0
4	Island Beach South I	332.5
5	Island Beach South II	326.2
6	Island Beach South III	1,239.7
7	Barnegat Light	452.9
8	Long Beach North	1,185.8
9	Forsythe North	1,563.3
10	Forsythe South	2,059.8
11	Ship Bottom	484.8
12	Egg Island	862.6
13	Long Beach Central I	239.1
14	Long Beach Central II	1,550.2
15	Long Beach Central III	1,052.2
16	Story Island East	929.9
17	Story Island West	1,058.4
18	Long Beach South	831.0

Table 1.2 Environmental parameters that were statistically analyzed along with the results.

Note: Significant differences between the parameter values within the ESAs vs. the outside ESA comparison areas are highlighted in red.

The ID# of the ESAs containing data for the parameter in question in noted in the final column, Spatial Distribution (i.e., only ESAs # 3 and 6 contain sampling locations for chlorophyll).

Characteristic	Dataset	Citation	Date Range	95% Credible Interval [1]	Interpretation	Spatial Distribution (in ESA #s)
Chlorophyll A (µg/L)	NJDEP National Water Quality Monitoring Council Data	NJDEP Barnegat Bay and NJDEP Bureau of Marine Water Monitoring http://www.waterqualitydata.us/orgs.jsp	9/8/2009 – 1/10/2012	(-5.38, 4.06)	No Significant difference	3, 6
Secchi Disk Depth (ft)	NJDEP National Water Quality Monitoring Council Data	NJDEP Barnegat Bay and NJDEP Bureau of Marine Water Monitoring http://www.waterqualitydata.us/orgs.jsp	9/8/2009 – 1/10/2012	(-17.88, 19.57)	No Significant difference	3, 6
Fecal Coliform (CFU/100mL)	NJDEP National Water Quality Monitoring Council Data	NJDEP Bureau of Marine Water Monitoring http://www.waterqualitydata.us/orgs.jsp	9/9/2011 – 1/11/2013	(-27.62, 0.90)	No Significant difference	1, 2, 3, 6, 9, 10, 11, 12, 14, 15, 18
pH	NJDEP National Water Quality Monitoring Council Data	NJDEP Barnegat Bay and NJDEP Bureau of Marine Water Monitoring http://www.waterqualitydata.us/orgs.jsp	1/10/2012 – 9/6/2012	(0.07,0.32)	Significant difference in pH; more basic in ESAs than outside	6
Salinity (ppt)	NJDEP National Water Quality Monitoring Council Data	NJDEP Barnegat Bay and NJDEP Bureau of Marine Water Monitoring http://www.waterqualitydata.	1/10/2012 – 9/6/2012	(-7.73, 8,22)	No Significant difference	3, 6

		us/orgs.jsp				
Water Temperature (˚C)	NJDEP National Water Quality Monitoring Council Data	NJDEP Barnegat Bay and NJDEP Bureau of Marine Water Monitoring http://www.waterqualitydata.us/orgs.jsp	9/8/2009 – 1/10/2012	(-4.91, 7.45)	No Significant difference	3, 6
Turbidity (NTU)	NJDEP National Water Quality Monitoring Council Data	NJDEP Barnegat Bay and NJDEP Bureau of Marine Water Monitoring http://www.waterqualitydata.us/orgs.jsp	1/10/2012 – 9/6/2012	(-5.85, 0.61)	No Significant difference	6
Dissolved Oxygen (mg/L)	NJDEP National Water Quality Monitoring Council Data	NJDEP Barnegat Bay and NJDEP Bureau of Marine Water Monitoring http://www.waterqualitydata.us/orgs.jsp	9/8/2009 – 1/10/2012	(-1.92, 0.09)	No Significant difference	3, 6
RUMFS Survey: Environmental Data (Temperature, Depth, Dissolved Oxygen, Salinity, pH)	James M. Vasslides, Jenna L. Rackovan, Jacalyn L. Toth, Roland Hagan, Ken Able	*Metadata Manual for Fish and Environmental Records at the Rutgers University Marine Field Station* https://rucore.libraries.rutgers.edu/rutgers-lib/32810/pdf/1/	2/21/2012 – 10/26/2012	Dissolved Oxygen (mg/L) (-1.92, 0.09) Bottom pH (-0.05, 0.09) Surface pH (-0.04, 0.09) Bottom Salinity (ppt) (-1.42, 2.20) Surface Salinity (ppt) (-1.37, 2.20) Bottom Water Temperature (◦C) (-0.69, 0.80) Surface Water Temperature (◦C) (-0.81, 0.72) Bottom Dissolved Oxygen (mg/L) (-0.45, 0.33) Surface Dissolved Oxygen (mg/L)	No Significant difference except Bottom Grab Sediment grain Size	2, 3, 5, 6, 8, 10, 12, 14, 15

				(-0.34, 0.29) Bottom Grab Grain Size Category 1 – Mud: (-0.54, -0.05) Category 2 – Muddy sand: (-0.07, 0.51) Category 3 – Sand: (-0.18,0.34) Water Depth (-0.75, 0.01)		
Seagrass	1979 and 1985 data from NJDEP available on the Division of Land Use Regulation website at http://www.nj.gov/dep/landuse/sav.html.sets CRSSA; Richard G. Lathrop Jr., Dan Merchant, Scott Haag	*Submerged Aquatic Vegetation Mapping in the Barnegat Bay National Estuary: Update to Year 2003* and *Assessment of Seagrass Status in the Barnegat Bay - Little Egg Harbor Estuary System: 2003 and 2009* http://crssa.rutgers.edu/projects/coastal/sav/downloads.htm	1968, 1979, 1985, 1996, 2003, 2009	(0.08, 0.42)	Significantly more seagrass in ESAs	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
Hard Clam Abundance (clams per foot squared)	2001 and 2011: Michael Celestino 1985, 1986, and 1987: Jim Joseph 2012: Kira Dacanay All excel data sets (1980s-2012) were provided by Celestino and Dacanay per request.	*Shellfish Stock Assessment of Little Egg Harbor (2011)* http://www.savebarnegatbay.org/wp-content/uploads/2014/05/Shellfish-Survey-for-Little-Egg-Harbor.pdf	1985, 1986, 1987, 2001, 2011, 2012, 2013	1985: (-0.0004, 0.005) 1986: (0.004, 0.014) 1987: (0.006, 0.008) 2001: (0.007, 0.019) 2011: (0.011, 0.026) 2012: (0.005, 0.011) 2013: (-0.002, 0.002)	Significant years in data: 1986, 1987, 2001, 2011, 2012, Higher probability of hard clams in the ESAs	2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17

RUMFS Aquatic Faunal Survey: (Fish, Vegetation, Arthropods, Cnidarians)	Ken Able, Paul Jivoff, Thomas M. Grothues, Roland Hagan, Bruce Ruppel, Gary Buchanan, Marc Ferko, Thomas Belton	*Metadata Manual for Fish and Environmental Records at the Rutgers University Marine Field Station* https://rucore.libraries.rutgers.edu/rutgers-lib/32810/pdf/1/	1997, 2001, 2009, 2010, 2011	Analyzed as Shannon-Wiener diversity index (0.25, 0.83)	More biodiversity inside the ESAs than outside	2, 3, 5, 6, 8, 10, 12, 14, 15
Colonial Nesting Birds (Piping Plover, Larids, Waders, Least Terns, Black Skimmers, American Oystercatchers)	Contact: Christina Davis	NJ Endangered & Nongame Species Program Colonial Nesting bird monitoring program	2007, 2011, 2012, 2013, 2014	Analyzed as Shannon-Wiener diversity index 2007:(-0.18, 0.19) 2011: (-0.13, 0.23) 2012: (-0.18, 0.19) 2013: (-0.33, 0.037) 2014: (-0.23, 0.13)	No significant difference	2, 10, 12, 13, 14, 15, 16, 17, 18
Osprey Nests (point locations)	Kathy Clark, Ben Wurst, Michael Davenport, Larissa Smith, Dave Golden	*The Osprey Project in New Jersey* http://www.state.nj.us/dep/fgw/ensp/raptor_info.htm	1982-2012	(-0.002, 0.008)	No significant difference	1, 2, 6, 9, 10, 11, 12, 15, 16, 17, 18

95% Credible Interval for difference between mean of variable in ESA and non-ESA areas. If the interval includes 0, the means are *not* significantly different at the 0.05 level.

Table 1.3 Abbreviation of colonial nesting bird species' names.

Abbreviation	**Species**
AMOY	American Oystercatcher
BCNH	Black-crowned Night Heron
BLSK	Black Skimmer
CATE	Caspian Tern
COTE	Common Tern
FOTE	Forster's Tern
GBBG	Great Black-backed Gull
GBTE	Gull-billed Tern
GLIB	Glossy Ibis
GREG	Great Egret
HEGU	Herring Gull
LAGU	Laughing Gull
LBHE	Little Blue Heron
LETE	Least Tern
PIPL	Piping Plover
SNEG	Snowy Egret
TRHE	Tricolored Heron
YCNH	Yellow Crowned Night Heron

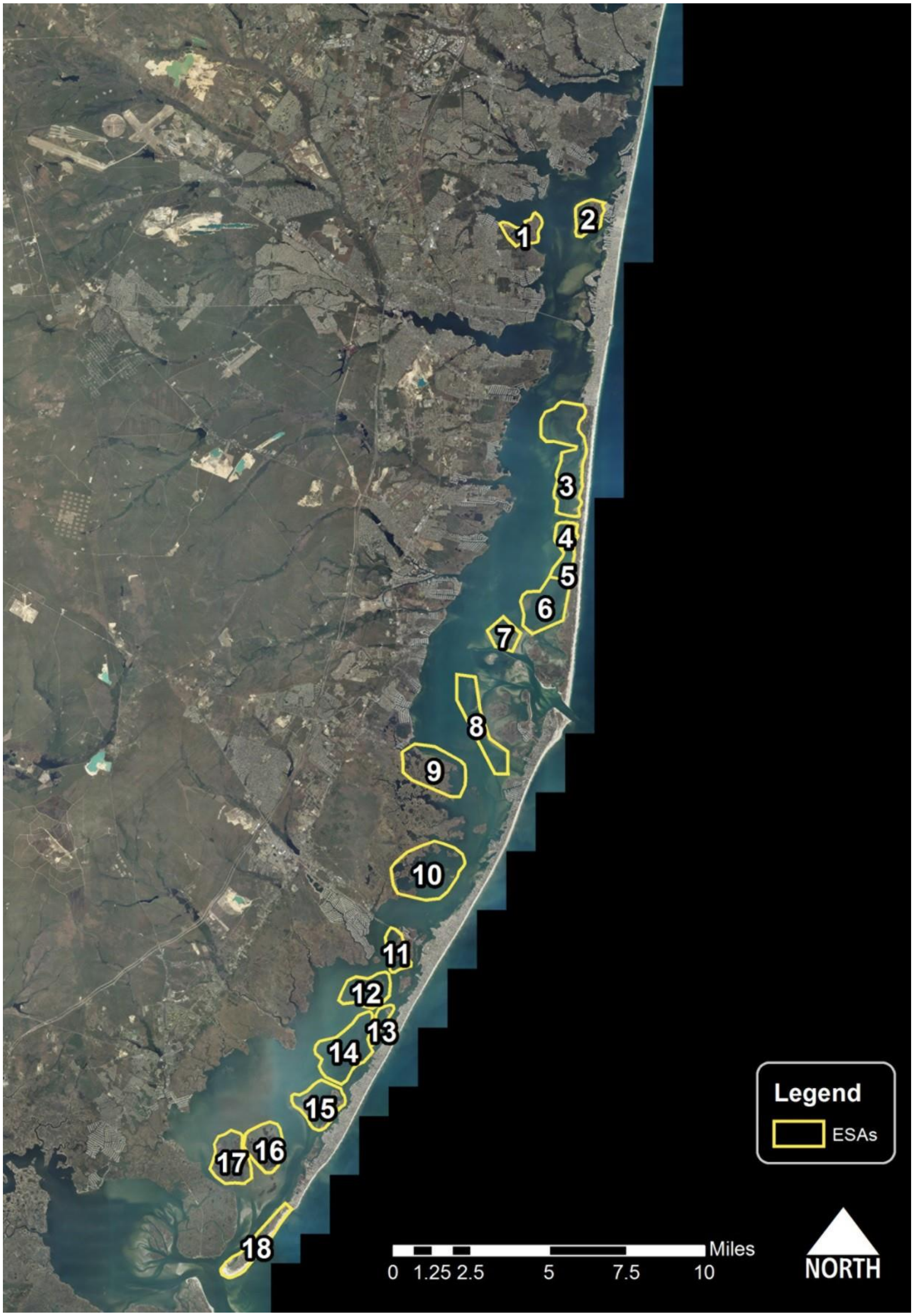

Figure 1.1 Map of sixteen Ecologically Sensitive Areas (ESA) in BB-LEH.

Figure 1.2 Location of non-ESA test site areas (purple circles) vs. ESAs (yellow polygons).

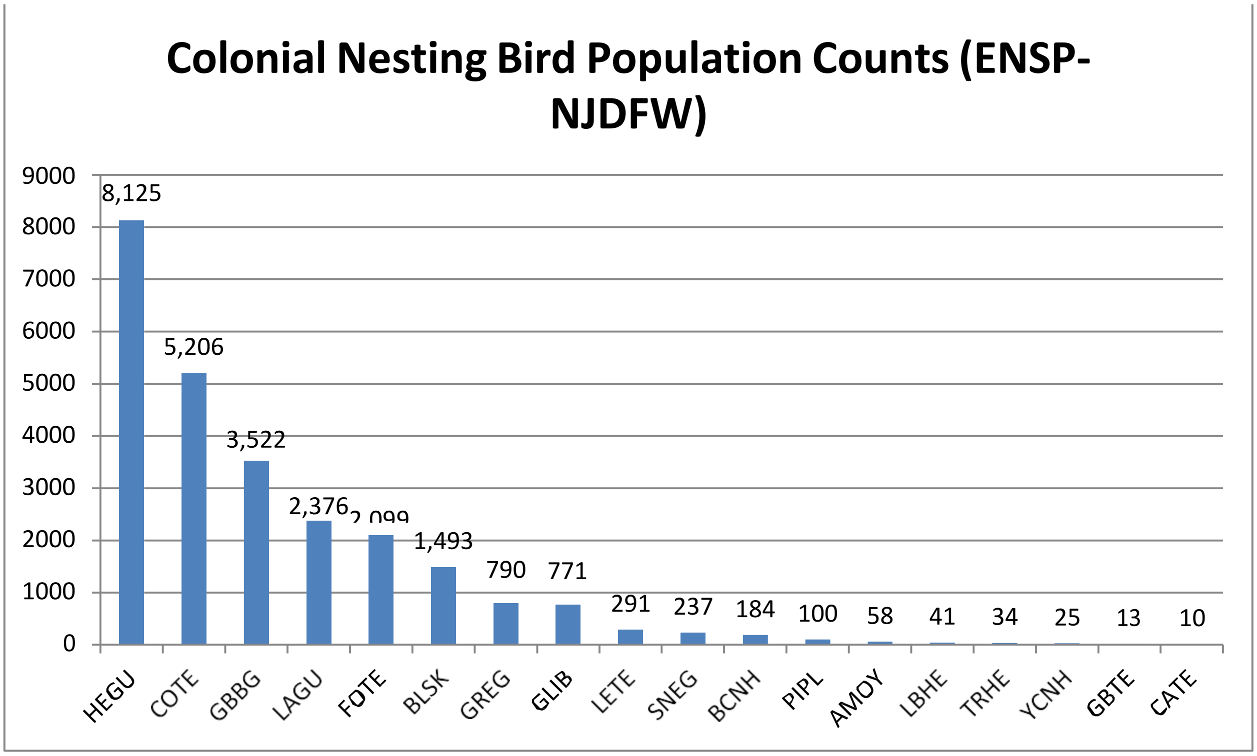

Figure 1.3 Summary of colonial nesting bird population counts observed by the ENSP-NJDFW for the years 2007, and 2011-2014 inside and outside ESAs combined.

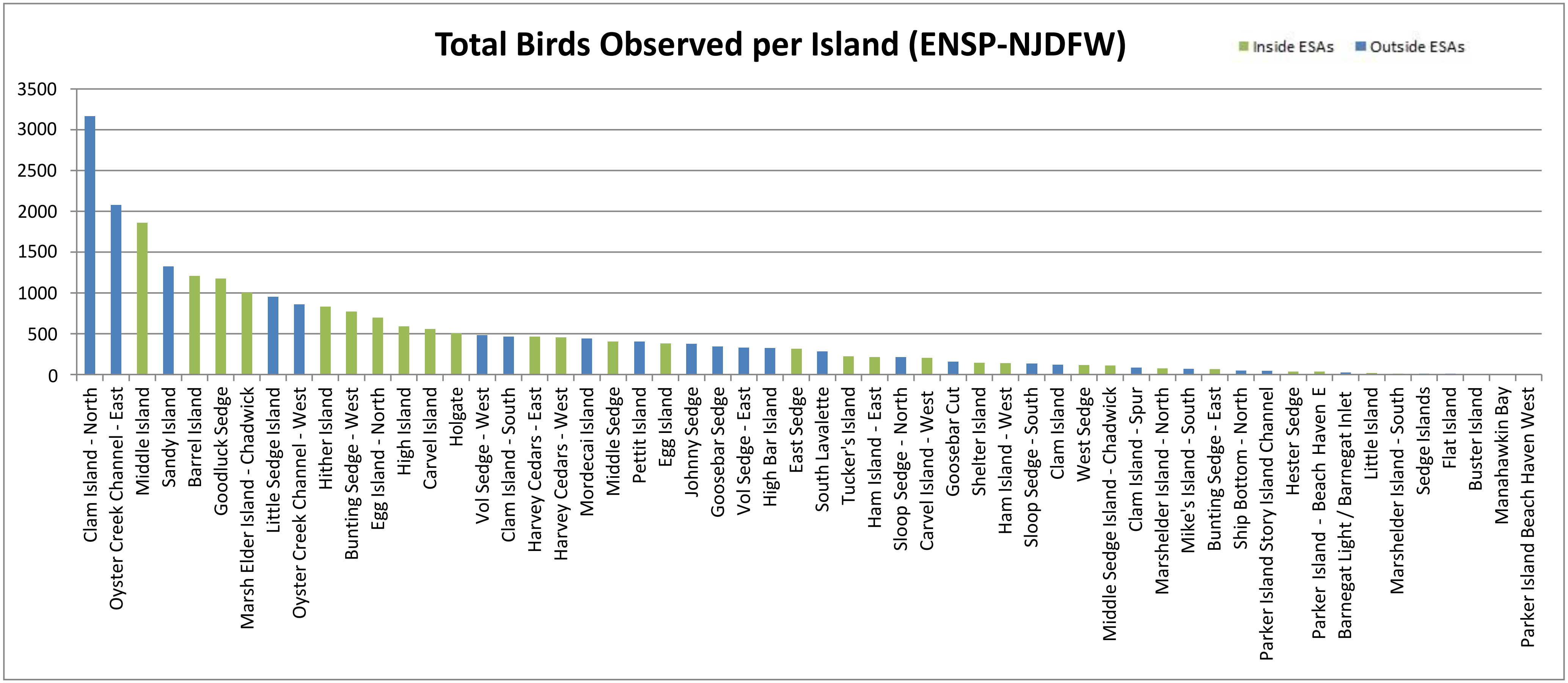

Figure 1.4 The spatial distribution of the colonial nesting birds by nesting island for the years 2007, and 2011-2014 both inside and outside the ESAs.

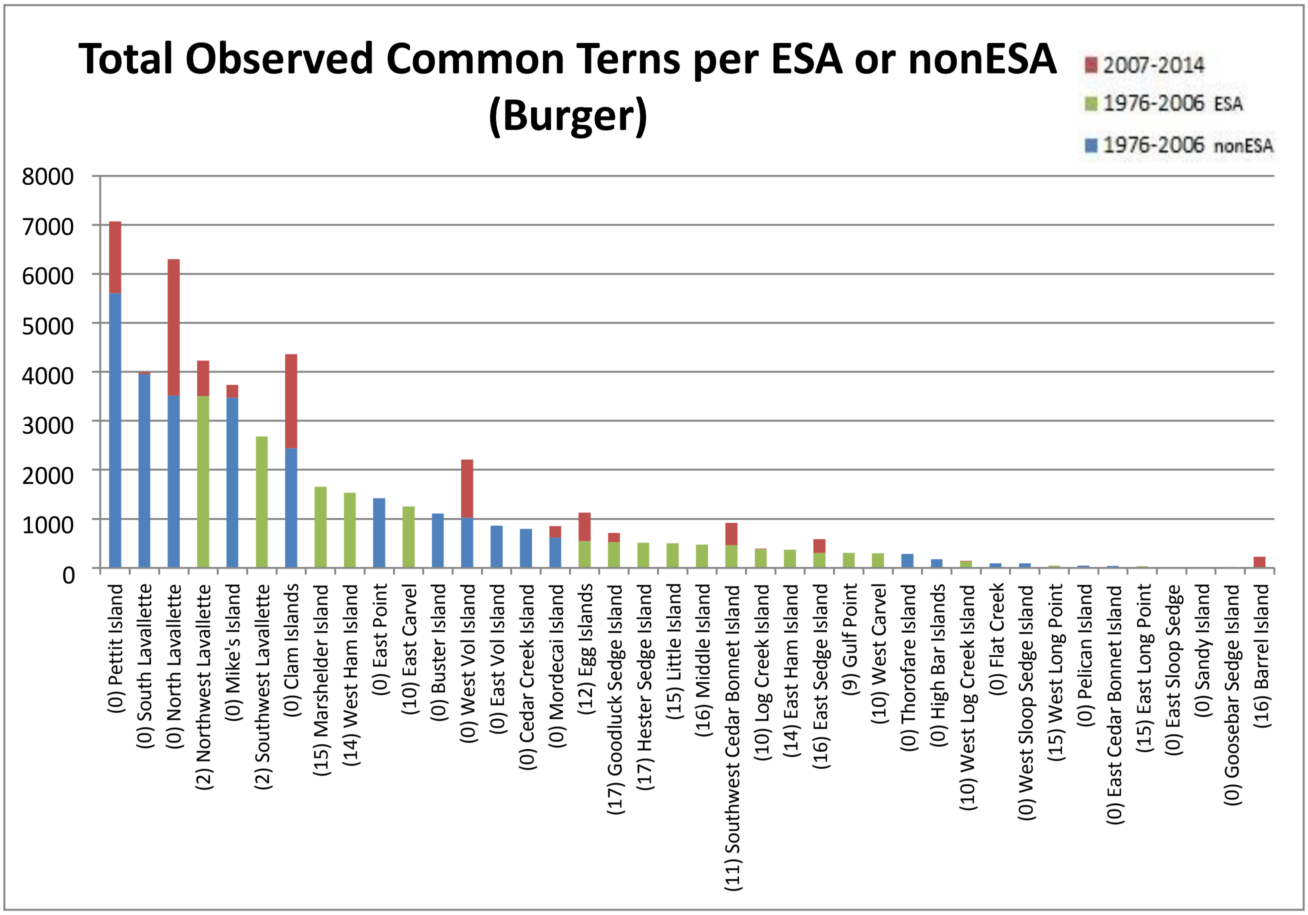

Figure 1.5 Spatial distribution of the nesting common terns by ESA (surveyed by Burger) from 1976-2014 (red), and inside (green) and outside (blue) ESAs for 1976-2006.

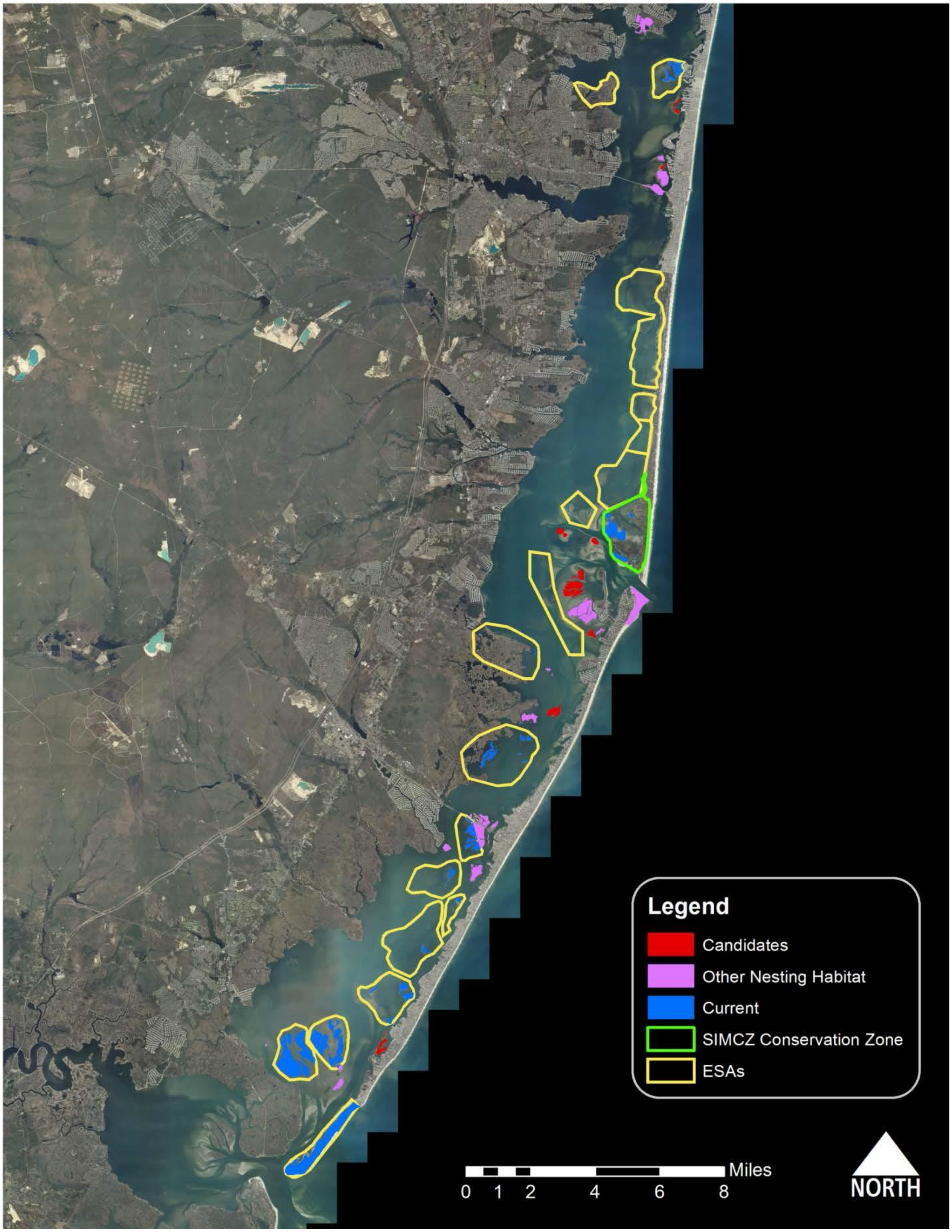

Figure 1.6 Map of colonial nesting bird colonies highlighting the most important nesting bird non-ESA colonies the should be considered as candidates for inclusion (colored as red) within the ESA network vs. other nesting colonies both inside (blue) and outside the ESAs (magenta).

Data sources:

Refer to Table 1.2

References:

Gelman, Andrew, Jennifer Hill, and Masanao Yajima. "Why We (Usually) Don't Have to Worry About Multiple Comparisons." *Journal of Research on Educational Effectiveness* 5.2 (2012): 189-211. Web. 12 Feb. 2016.

Robert, C.P. 1994. The Bayesian Choice: A Decision-Theoretic Motivation. Springer-Verlag, New York. 436 p.

Section 2 Pre-vs. Post ESA Establishment Comparison

Objective: Examine whether there has been a discernible change in ecological or environmental condition since the establishment of the ESA, where there are comparable data sets allowing for a rigorous before vs. after analysis.

Methods:

To complete this task we examined the availability of data sets that were collected in a consistent fashion before and after the establishment of the ESAs in 2012 and that might be responsibly expected to respond to the restriction of boating activities within the ESAs. Prior work by Burger (2002) had suggested that colonial nesting birds in BB-LEH were sensitive to exposure to recreational boating activities. We requested and received several long term colonial nesting bird population data sets to address this study task.

The first data set, collected by the Endangered and Nongame Species Program of the Division of Fish &Wildlife (ENSP-NJDFW) of the NJ Department of Environmental Protection was sampled for the years 2007, and 2011-2014. These were collected via aerial flyover surveys (Contact: Christina Davis, Christina.Davis@dep.nj.gov). Waders and large gulls usually are done in one long day while gulls and terns take 3-4 consecutive days unless weather prevents it. ENSP-NJDFW protocols survey three times within two week spans and base estimates on the highest number of adults observed on the island. This can result in double sampling the same birds in different locations.

The second data set was provided by Joanna Burger of Rutgers University who has studied Barnegat Bay nesting birds for over 40 years and has provided the data for Common Terns from 1976-2014. Burger’s surveys are conducted frequently throughout the season with a combination of aerial flyovers by helicopter, small boat, and on foot. The population numbers are integrated across the multiple surveys to account for double counting of birds.

Of the suite of colonial nesting birds monitored by these two research groups, only common tern (COTE) population data was in any way comparable between the two datasets. While these common tern data sets span the pre- and post-ESA establishment time period, there was an insufficient number of years of data pre- and post-ESA establishment to do a rigorous analysis. However, we did undertake a graphic comparison as way of exploratory data analysis.

Results:

The relative percent of colonial nesting bird numbers inside vs. outside the ESAs across the 2007-2014 time period were determined (Figure 2.1). The Year 2012 was anomalous as only populations of black skimmers were surveyed that year and all were present in the ESAs. Common Tern population count data were available for all years for the time period between 2007 and 2014 in the J. Burger data set and the years 2007, 2013 and 2014 for the ENSP-NJDFW data set (Figure 2.5).

Discussion:

There is not an appreciable difference in the numbers inside vs. outside the ESAs across the 2007-2014 time period (Figure 2.1). Both the ENSP-NJDFW and Burger data sets suggest a high degree of year-to-year variability in both the ESA and non-ESA populations. For the years when both surveys collected data (i.e., 2007, 2013 and 2014) the ENSP-NJDFW recorded higher overall population numbers. This may be a symptom of the data collection technique that may have resulted in a double-counting of some birds.

There is some indication of an overall decline in both the ESA and non-ESA population counts for the J. Burger data set over the 2007-2014 time period (Figure 2.2). The ENSP-NJDFW data shows lower common tern numbers inside the ESAs post-establishment , while the non-ESA population numbers remain more stable (Figure 2.2). While these data sets span the pre- and post-ESA establishment time period, there were an insufficient number of years of data post-ESA establishment to conclusively ascertain whether the establishment of the ESAs was having a positive or negative effect on Common Tern nesting colonies. There are a number of factors in addition to the impacts of boating activity that may potentially be affecting common tern nesting populations, including increased competition between species for prime nesting habitat, decrease in overall area of suitable nesting habitat availability due to encroaching sea level rise or storm surge, and/or the availability of forage fish.

A number of studies have documented that colonial nesting birds such as long-legged waders, gulls, terns, and skimmers are sensitive to human disturbance from boating activity as well as humans walking by or near colonies (Erwin, 1989; Rodgers and 1995; Carney and Sydeman, 1999; Burger 2002). Other studies have also documented human disturbance to foraging or loafing (resting/roosting) water birds, though the results were more variable in terms of response among individuals within the same species and among species, (Rodgers and Schwikert, 2002; Peters and Otis, 2006). While not considered colonial nesting birds per se, ospreys that are not habituated to human traffic may desert nests if disturbance appears suddenly and for extended period (Poole, 2009). Rodgers and Schwikert (2002) recommended buffer zone distances for both PWC and outboard-powered boats of 180 m for wading birds, 140 m for terns and gulls and 150 m for ospreys to minimize their disturbance at foraging or loafing sites in Florida. Erwin (1989) and Rodgers and Smith (1995) and recommended buffer zones of 180-200 meters for black skimmer and tern nesting colonies where human walking activity should be restricted.

Burger documented that nesting common terns in Barnegat Bay were sensitive to both personal watercraft (PWC) and motorboats (Burger, 2002). This study found that birds respond adversely to the presence of motorboats and PWC by increased numbers of birds flying from their nests, eventually abandoning nesting habitat to move farther form the disturbance. On a positive note, an education and enforcement campaign aimed at local PWC rental businesses and marinas reduced PWC traffic around tern nesting islands and most PWC operators reduced their speed. This helped to reduce the disturbance to the birds allowing increased reproductive success. However, two years later when active enforcement declined, the disturbance from PWC increased and the nesting birds were forced to move.

While our study does not provide conclusive evidence that the establishment of the ESAs have had a substantive effect on bay-wide populations of nesting common terns, it must be noted that the enforcement of the low impact boating regulations was only actively pursued during 2012. In other words, without active education and enforcement, the designation as to whether a colonial nesting bird colony fell inside or outside an ESA made little material difference to the nesting success of the birds. Based on our review of the scientific literature, we recommend that the “green” boating regulations designed to minimize adverse impacts on nesting bird colonies be continued, if not expanded. Present regulations/recommendations only mandate 31-62 m (i.e., 100-200 feet) buffer zones near shorelines and confined lagoons and channels. Amending these regulations should be considered to ensure that slow speed/no wake zones are mandated within 150 meters of active nesting colonies, especially within ESAs. Further these regulations should be expanded to exclude landing a boat or walking into or near nesting colonies both within and outside ESAs.

Posting of appropriate signage should be considered to better inform the boating community. As Burger’s work (2002) suggests for ESAs (or other similar policies designed to minimize the adverse impacts related to recreational boating activities) to be successful in promoting the nesting success of colonial nesting birds, boating education and enforcement must be implemented together and continued annually during the active boating season.

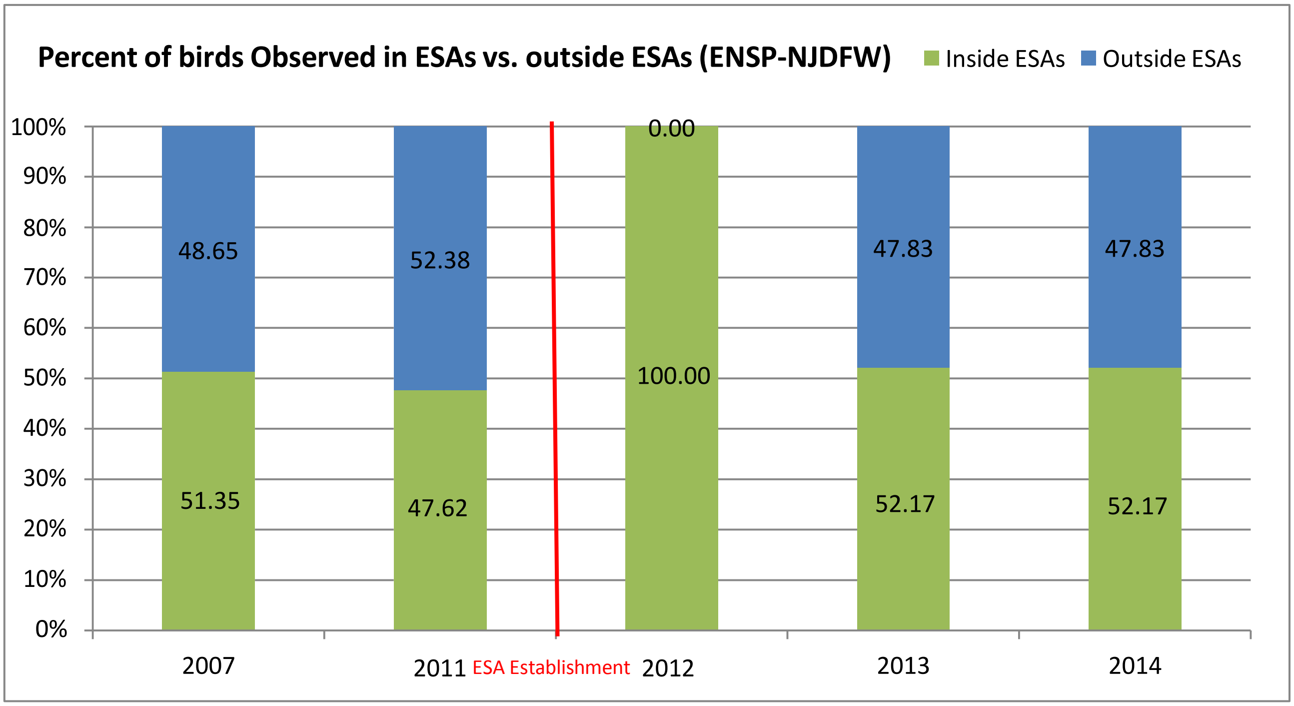

Figure 2.1 Graphic of all species of colonial nesting birds observed inside vs. outside the ESAs, both pre- and post-ESA establishment. Note 2012 numbers only included Black Skimmers and excluded from further analysis.

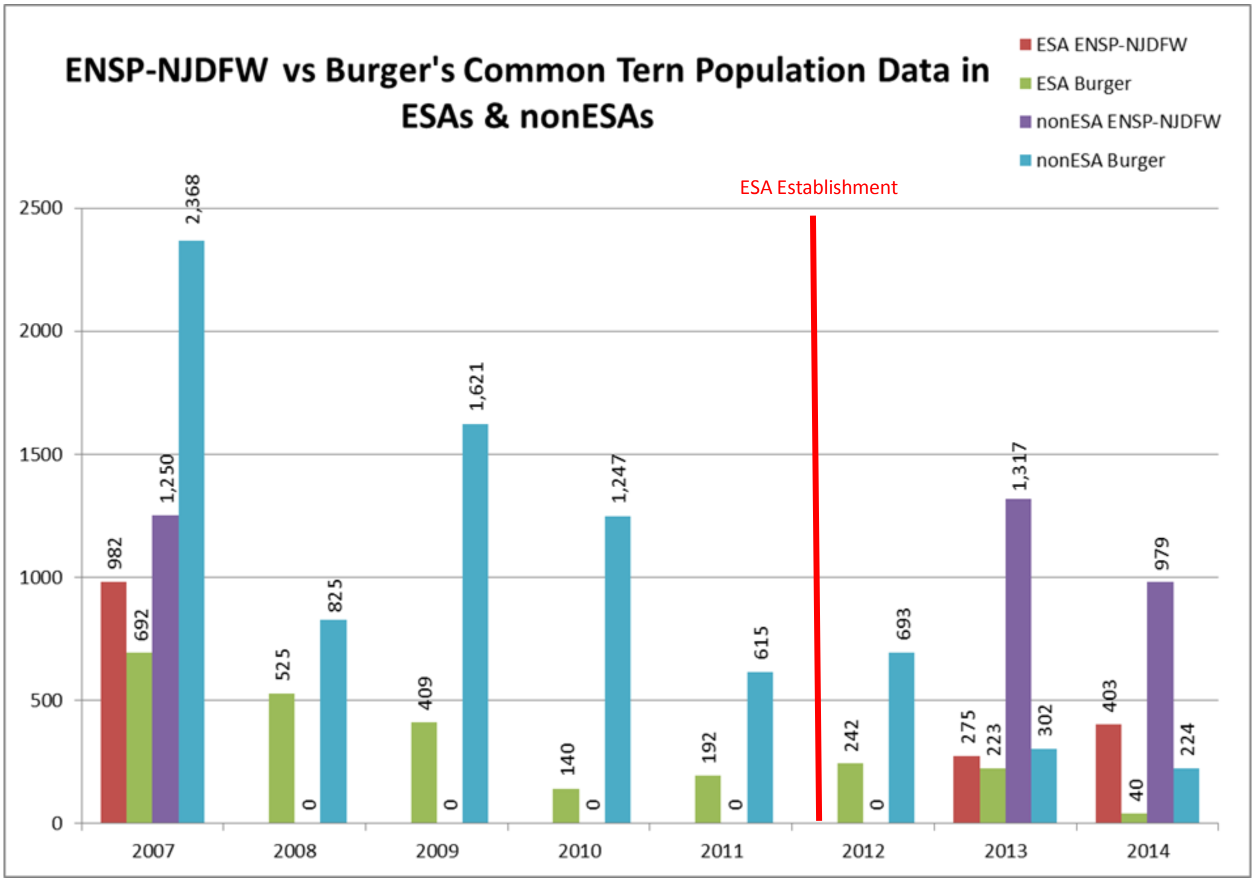

Figure 2.2 Comparison of ENSP-NJDFW and Burger's Common Tern population data for the period of 2007 to 2014.

Data sources:

New Jersey Division of Fish & Wildlife Endangered and Nongame Species Program data provided at request by Christina Davis for years 2007, 2011, 2012, 2013, and 2014

Contact: Christina.Davis@dep.nj.gov

Rutgers University's Dr. Joanna Burger Common Tern Nesting data from 1976-2014 provided at request.

Contact: Burger@Biology.Rutgers.Edu

References:

Burger, J. 2002. Effects of Motorboats and Personal Watercraft on Nesting Terns: Conflict Resolution and the Need for Vigilance. Journal of Coastal Research SI 37:7-17.

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Erwin, R. M. 1989. Responses to human intruders by birds nesting in colonies: Experimental results and management guidelines. Colonial Waterbirds 12:104-108.

Peters, K.A. and D.L. Otis. 2006. Wading Bird response to Recreational Boat Traffic: Does Flushing Translate into Avoidance. Wildlife Society Bulletin 34(5):1383-1391.

Poole, Alan F.. 2009. Osprey (*Pandion haliaetus*), Neotropical Birds Online (T. S. Schulenberg, Editor). Ithaca: Cornell Lab of Ornithology; retrieved from Neotropical Birds Online: http://neotropical.birds.cornell.edu/portal/species/overview?p_p_spp=119196

Rodgers, J.A. and H.T. Smith. 1995. Set-back Distances to Protect Nesting Bird Colonies from Human Disturbance in Florida. Conservation Biology 9(1):89-99.

Rodgers, J. A. and S. T. Schwikert. 2002. Buffer-zone Distances to Protect Foraging and Loafing Waterbirds from Disturbance by Personal Watercraft and Outboard-powered Boats. Conservation Biology 16:216–224.

Section 3 Documenting Boating Impact

Objectives:

To document the damage caused by recreational and commercial boating (both propeller driven and person watercraft-types of boats) to seagrass habitats in the Barnegat Bay-Little Egg Harbor. A secondary objective was to map hotspots of boating activity as these may be areas of higher risk of negative impacts.

Methods:

We used visual interpretation of high spatial resolution aerial photography to undertake a damage assessment to seagrass habitat within Barnegat Bay-Little Egg Harbor. Boat scars in seagrass beds were interpreted and mapped using a heads-up on-screen digitizing approach in accordance with the technique developed in the paper *Assessment of Seagrass Status in the Barnegat Bay – Little Egg Harbor Estuary System: 2003 and 2009* by Lathrop and Haag in 2011 to map 2009 boat scars. In addition, an inventory of boating activity was also recorded with individual boats mapped as to whether they were stationary (in the bay proper and not at a dock) or moving. One interpreter (Michael Ciappi, Rutgers CRSSA) was trained to recognize both boat scars and boats and was then employed to do the entire mapping survey.

True color imagery from a number of sources and years (2002, 2006, 2007, 2008, 2009, 2010, 2012, 2013) were employed. Most of the imagery was from the spring and summer season. Hallac et al. (2008) concluded that while their seagrass damage assessments which were acquired using aerial imagery tended to underestimate scarring (up to a factor of 10), they provided useful information on pattern and relative density.

The individual years of data were combined to create a composite view of boat scarring and boating activity. The composite data were further reviewed to identify individual boat scars appearing in multiple years to reduce double-counting. The resulting mapped information was then cross-referenced with the Environmental Sensitive Areas (ESAs) to determine the frequency of occurrence within individual ESAs, and percentages of the amount of scarring in ESAs have been created. Selected prominent watercraft scars were examined over successive years to determine the length of persistence across time.

Results:

There were hotspots of boating activity both between and within ESAs (Table 3.1). A few of the ESAs accounted for nearly 90% of the boating activity: Island Beach South, Island Beach North, Forsythe South, Long Beach North and Forsythe North (ranked from higher to lower). Island Beach South alone accounted for nearly 73% of the boating activity with many of those boats moored at what is known as Tice’s Shoal (Figure 3.1). Tice’s Shoal is a popular destination because boaters can moor in shallow water and easily access Island Beach State Park’s oceanside beaches via a bay-to-beach walkway.

A total of 191.9 miles of boat scarring was mapped as occurring within BB-LEH over the approximately 10 year period. Of these, 120 miles were in the ESAs, and 71.9 miles outside of the ESAs. Of the 191.9 miles of mapped boat scarring, 1.9 miles were persistent across years; thus there was approximately 190 miles of unique boat scars. Island Beach South ESA, followed by Island Beach North were identified as major hotspots of boat scarring accounting for over 76% of the boat scarring (Table 3.2; Figures 3.1, 3.2). Much of the scarring in Island Beach South is the result of recreational boats and personal watercraft traversing the ESA on their way to or from Tice's Shoal. The damage in Island Beach North is concentrated in the northern section of the ESA in close proximity to the developed portion of Seaside Park. In this ESA the seagrass beds occur on a series of sand flats separated by deeper channels. It appears that the damage is due to boats crossing over the beds between channels as well as accessing the backside of Island Beach State Park where there is a secondary locus of boats moored (Figure 3.1). Figure 3.3 presents composite view of the intensity of watercraft usage and boat scarring in relation to the Ecologically Sensitive Areas across the entire BB-LEH.

Watercraft scars often persist for longer than a single growing season and may be evident over successive years of aerial imagery. For example, one corkscrew-shaped scar that we attribute to a personal watercraft (PWC) (due to the tight radius of rotation) was evident for a 4 year time span (2009-2013) (Figure 3.4) Thus this scar persisted for at a minimum of 4 years. Figure 3.5 shows another potential impact of motorized watercraft activity in terms of the resuspension of bottom sediments due to the prop wash, creating extensive turbidity plumes.

Discussion:

Recreational and commercial boating has been documented to cause serious damage to seagrass beds at a number of locations along the Atlantic and Gulf Coasts of the United States (Fonseca et al. 1998; Crawford, 2002; Dunton and Schonberg, 2002; Kennish 2002; Kenworthy et al. 2002; Koch 2002; Hallac et al. 2008). Our results derived from this study are highly consistent with the severity and extent of damage documented in these other studies. Damage is cause by the direct action of propellers or jet wash cutting blades and/or uprooting rhizomes and to a lesser extent, boat-generated waves. The damage often results in a line of damaged or uprooted seagrass cutting through a seagrass bed and thus often referred to as a boat or prop scar. In Florida Bay (Hallac et al 2008), the majority of scarring was identified in depths less than 3 feet and scarring density tended to increase with decreasing depth. Dense scarring was found to be more likely in close proximity to marked and unmarked channels and shorelines and other heavily used boating areas. When vessels run aground, prop scars are often coupled with large holes ("blow holes") in the seagrass bed and bottom substrate created by the vessel operator attempting to use the motor's power to free the vessel (Whitfield et al. 2002). These scars can take several years to heal over. Recovery of one species of seagrass, turtle grass (*Thalassia testudinum*), into scarred bottom areas requires nearly a decade of time (Kenworthy et al. 2002) because of the slow production of rhizome meristems (Andorfer and Dawes 2002).

Our results document hotspots of boating activity within the boundaries of designated ESAs. Five ESAs accounted for nearly 90% of the activity: Island Beach South, Island Beach North, Forsythe South, Long Beach North and Forsythe North (ranked from higher to lower) and one ESA, Island Beach South, alone accounted for nearly 73% of the boating activity with many of those boats moored at what is known as Tice's Shoal. While not all boats observed in an ESA necessarily represent a negative impact to the ecological resources within that ESA, hotspots of high boating activity are potentially at higher risk of negative impacts. As demonstrated by the watercraft scarring mapping, motorboats and PWCs are negatively impacting the ESAs by disturbing the seagrass beds. Some of these watercraft scars can be quite severe and may take four or greater number of years for the seagrass bed to recover. Thus watercraft scarring can be considered a chronic disturbance; the degree to which the highest levels of damage may lead to temporary or permanent loss of a seagrass bed is unknown.

This chronic disturbance may be the reason that seagrass is noticeably sparse, if not absent, in the Tice's Shoal area in water depths and bottom substrates that support seagrass north and south of this location. In addition, there is significant scarring of seagrass meadows adjacent to Tices' Shoals, presumably due to boats approaching or leaving the area. Additional management to reduce boating impacts to the Tice's Shoal area of ESA Island Beach South is clearly warranted. This might include greater signage, more restricted mooring areas, and enhanced boater education to closing the cross-island passage.

It should also be noted that the last instance of seagrass mapping occurred in 2009. In order to have a better idea of seagrass fluctuations and what management practices should be undertaken, we suggest high spatial resolution aerial photography be implemented every 5-10 years to monitor changes within the seagrass beds. Using this imagery, it would also be possible to extract scarring data and boat presence in the bay, thereby creating a better overall understanding of the present conditions and changes through time.

Given the uncertainty and high cost of restoration of sea grass beds it would appear to be more prudent to give priority to protecting seagrass habitat from vessel damage rather than focus primarily on repair and restoration (Kenworthy et al 2013). The degree to which these high levels of boating activity are disturbing nesting birds or other wildlife, exacerbating water turbidity or negatively affecting other environmental qualities of the ESAs has not been explicitly quantified in this study.

Table 3.1 Boats Moored or Moving by ESA. Note: ESAs sorted by count for years 2002, 2007-2010, and 2012-2013.

ESA_ID	ESA	Count
5	Island Beach South II	586
3	Island Beach North	57
6	Island Beach South III	52
10	Forsythe South	42
8	Long Beach North	27
9	Forsythe North	25
2	NW Point Island	17
7	Barnegat Light	12
13	Long Beach Central I	12
4	Island Beach South I	11
15	Long Beach Central III	11
1	Mosquito Cove	10
17	Story Island West	10
11	Ship Bottom	9
12	Egg Island	6
16	Story Island East	4
14	Long Beach Central II	1

Table 3.2 Boat scarring length (miles) and frequency of occurrence by ESA. Note: sorted by total length sum (in miles) of boat scars for years 2002, 2007-2010, and 2012-2013.

ESA	ESA_ID	Count	Sum_miles
Island Beach North	3	710	43.08
Island Beach South I	4	832	28.96
Island Beach South III	6	217	10.80
Island Beach South II	5	224	8.65
NW Point Island	2	158	7.92
Egg Island	12	62	5.07
Long Beach Central II	14	54	3.66
Ship Bottom	11	51	3.16
Long Beach Central I	13	48	2.13
Forsythe North	9	76	2.05
Forsythe South	10	33	1.61
Long Beach North	8	28	1.17
Long Beach Central III	15	15	0.89
Barnegat Light	7	14	0.75
Mosquito Cove	1	3	0.11

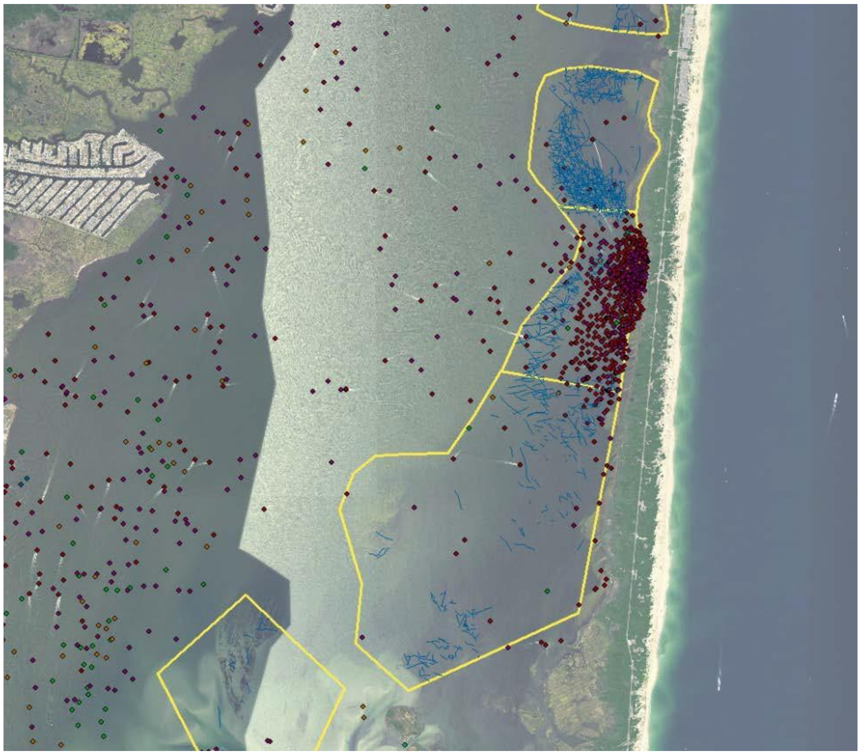


Figure 3.1 Island Beach South ESA with individual boats (as points) and boat scars (as lines). Compilation of all years of data (2002, 2007-2010, and 2012-2013).

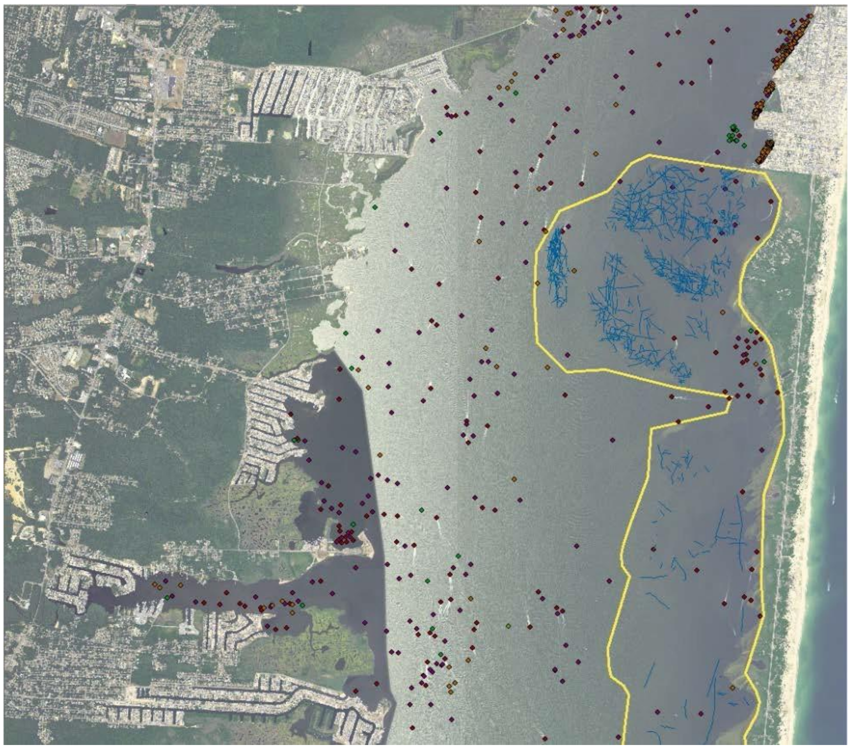
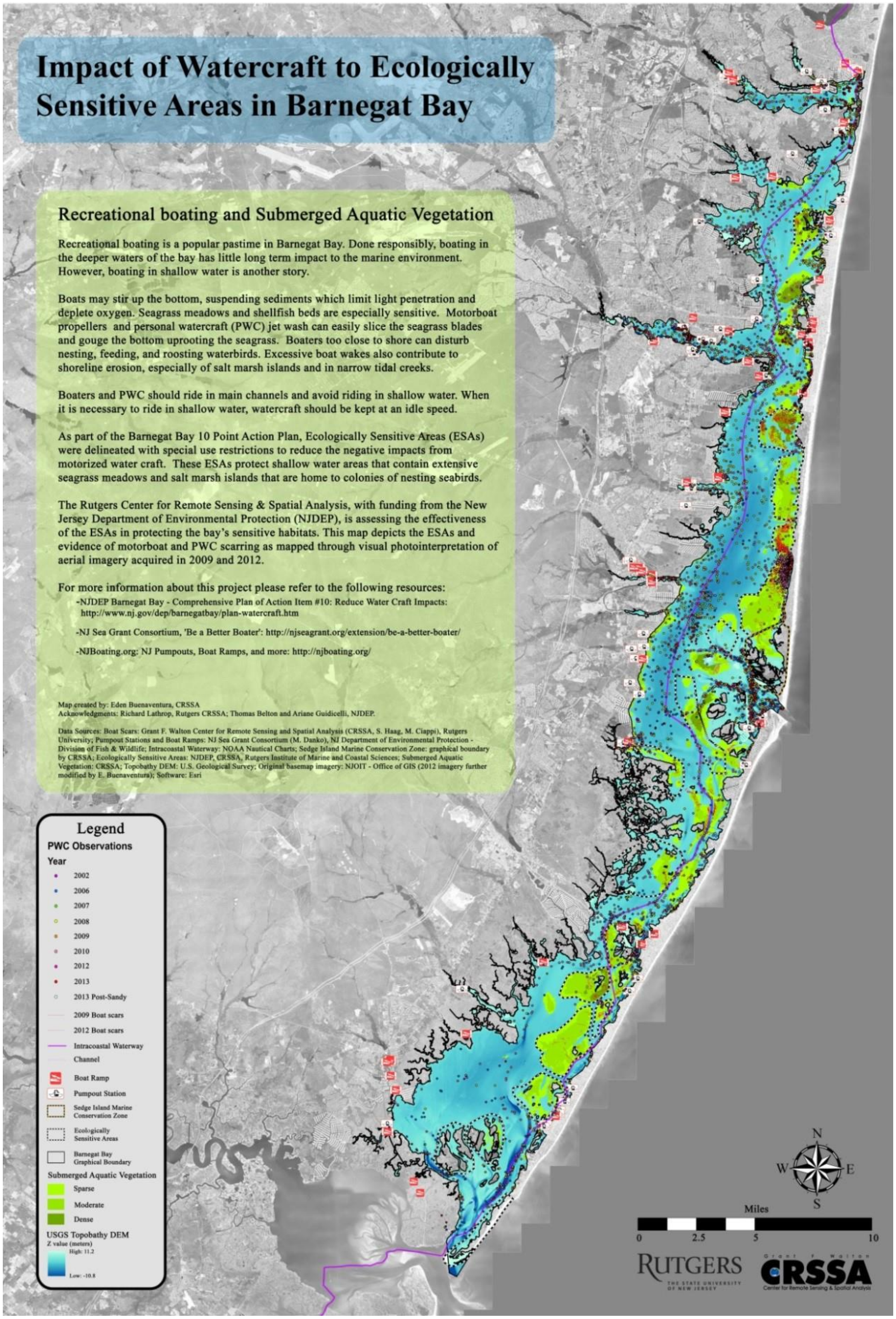


Figure 3.2 Island Beach North ESA with individual boats (as points) and boat scars (as lines) for all years of data (2002, 2007-2010, and 2012-2013).



Impact of Watercraft to Ecologically Sensitive Areas in Barnegat Bay

Recreational boating and Submerged Aquatic Vegetation

Recreational boating is a popular pastime in Barnegat Bay. Done responsibly, boating in the deeper waters of the bay has little long term impact to the marine environment. However, boating in shallow water is another story.

Boats may stir up the bottom, suspending sediments which limit light penetration and deplete oxygen. Seagrass meadows and shellfish beds are especially sensitive. Motorboat propellers and personal watercraft (PWC) jet wash can easily slice the seagrass blades and gouge the bottom uprooting the seagrass. Boaters too close to shore can disturb nesting, feeding, and roosting waterbirds. Excessive boat wakes also contribute to shoreline erosion, especially of salt marsh islands and in narrow tidal creeks.

Boaters and PWC should ride in main channels and avoid riding in shallow water. When it is necessary to ride in shallow water, watercraft should be kept at an idle speed.

As part of the Barnegat Bay 10 Point Action Plan, Ecologically Sensitive Areas (ESAs) were delineated with special use restrictions to reduce the negative impacts from motorized water craft. These ESAs protect shallow water areas that contain extensive seagrass meadows and salt marsh islands that are home to colonies of nesting seabirds.

The Rutgers Center for Remote Sensing & Spatial Analysis, with funding from the New Jersey Department of Environmental Protection (NJDEP), is assessing the effectiveness of the ESAs in protecting the bay's sensitive habitats. This map depicts the ESAs and evidence of motorboat and PWC scarring as mapped through visual photointerpretation of aerial imagery acquired in 2009 and 2012.

For more information about this project please refer to the following resources:

-NJDEP Barnegat Bay - Comprehensive Plan of Action Item #10: Reduce Water Craft Impacts: http://www.nj.gov/dep/barnegatbay/plan-watercraft.htm

-NJ Sea Grant Consortium, 'Be a Better Boater': http://njseagrant.org/extension/be-a-better-boater/

-NJBoating.org: NJ Pumpouts, Boat Ramps, and more: http://njboating.org/

Map created by: Eden Buenaventura, CRSSA
Acknowledgments: Richard Lathrop, Rutgers CRSSA; Thomas Belton and Ariane Guidicelli, NJDEP.

Data Sources: Boat Scars: Grant F. Walton Center for Remote Sensing and Spatial Analysis (CRSSA, S. Haag, M. Ciappi), Rutgers University; Pumpout Stations and Boat Ramps: NJ Sea Grant Consortium (M. Danko), NJ Department of Environmental Protection - Division of Fish & Wildlife; Intracoastal Waterway: NOAA Nautical Charts; Sedge Island Marine Conservation Zone: graphical boundary by CRSSA; Ecologically Sensitive Areas: NJDEP, CRSSA, Rutgers Institute of Marine and Coastal Sciences; Submerged Aquatic Vegetation: CRSSA; Topobathy DEM: U.S. Geological Survey; Original basemap imagery: NJOIT - Office of GIS (2012 imagery further modified by E. Buenaventura); Software: Esri

Figure 3.3 Composite view of the Intensity of Watercraft Usage and Boat Scarring in relation to Ecologically Sensitive Areas in Barnegat Bay-Little Egg Harbor for all years of data (2002, 2007-2010, and 2012-2013).

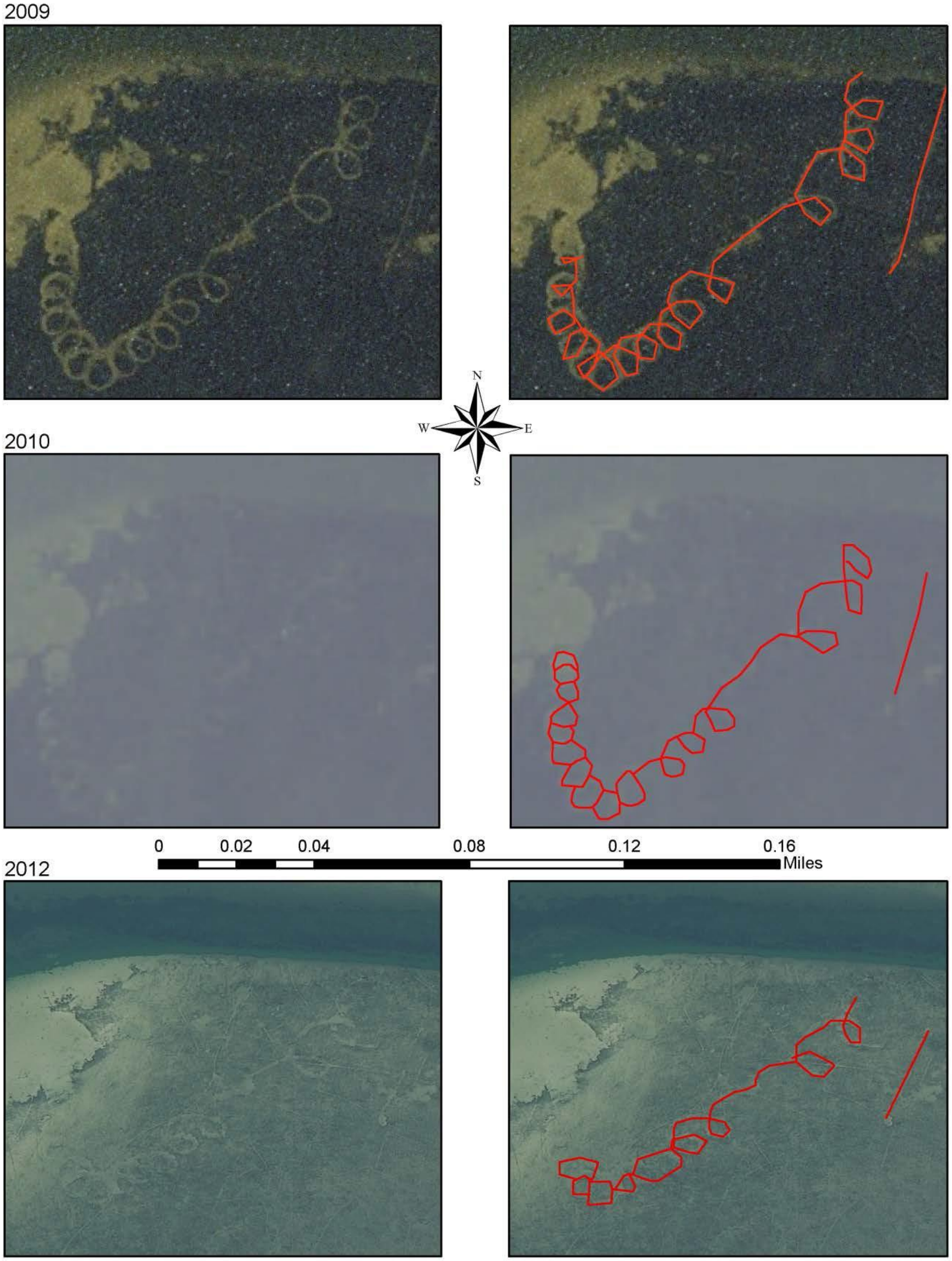


Figure 3.4 Example of Personal Watercraft Scarring Persistence from 2009-2012.

Figure 3.5 Examples of watercraft-induced turbidity plumes in 2012-2013.

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Section 4   Comparison of Pre- vs. Post-Sandy Environmental Change

Objectives:

Determine whether Superstorm Sandy changed any of the habitat features within the ESAs.

Methods:

Island/Marsh Shoreline Change

Barnegat Bay island shoreline edges and marsh area included in ESAs have been visually interpreted using heads-up digitizing for pre vs. post Sandy aerial photography. Pre-Sandy imagery was taken from the New Jersey Office of Information Technology (NJOIT) 2012 Natural Color 1-foot GSD pixel resolution orthophotography (Acquired March 2012). The post-Sandy aerial photography was taken from NOAA's Post-Sandy Response imagery flown October 31-November 6, 2012 (*NOAA Hurricane Sandy Response Imagery* http://storms.ngs.noaa.gov/storms/sandy/ ; *NJGIN WMS 2012* http://njgin.state.nj.us/download2/layerfiles/NJ_2012NaturalColor.lyr) and USDA's 2013 imagery flown August 2013.

Pre-Sandy and Post-Sandy imagery of the study area were extracted out of the larger datasets and mosaicked together to create faster and more efficient working imagery of Barnegat Bay. Imagery of existing islands within the ESAs was hand digitized from both the Pre-Sandy and Post-Sandy imagery. The resulting mapped polygons of the pre vs. post shorelines were analyzed to quantify and characterize change and to estimate the amount of land gained/lost. It should be noted that the two sets of imagery were flown at different tidal stages, so the delineation of the shoreline is approximate. We are assuming that any change noted between March 2012 and October-November 2012 is a result of Sandy and not ongoing shoreline erosion or some other specific high erosion event.

Bottom topography

The US Geological Survey released a digital elevation model dataset of the Pre (October 26, 2012) and Post-Sandy (November 1 & 5, 2012) EAARL-B Coastal Topography (Figures 4.1a, 4.1b). Pre-Sandy and Post-Sandy LiDAR data were mosaicked together using Quick Terrain Modeler v8.0.3.4. The USGS Post-Sandy bathymetric DEM was digitally differenced from the Pre-Sandy DEM (Figure 4.1c). There will always be residual error in this sort of comparison due to errors in both the vertical and horizontal dimensions.

To differentiate "real" vs. "artifactual" change an elevation threshold was determined. This 0.3m threshold was determined qualitatively by visual examination of areas of known change (e.g., Lyman Ave and Mantoloking Bridge overwash sites vs. background artifactual change) (Task 4.4). Figure 4.1d shows the area greater than this 0.3m thresholds over the entire study area colored as red.

Results:

Island/Marsh Shoreline Change

Our mapping suggests a decrease in islands and marsh area within the Barnegat Bay-Little Egg Harbor ESAs study area of approximately 52 hectares pre vs. post-Sandy (Table 4.1). These 52 hectares represents a loss of approximately 3.75% of island and marsh area across the entire ESAs (pre-Sandy area of approximately 1,383 hectares). Most ESAs experienced only modest changes (Figure 4.2). Notable areas included ESA 9 (3 ha; Gunning River area of the Edwin B. Forsythe National Wildlife Refuge which is directly across the bay from Barnegat Inlet) and ESA 18 (43 ha; the bayside of the Holgate section of the Edwin B. Forsythe National Wildlife Refuge). The barrier island portion of Holgate was severely eroded and overwashed during SuperStorm Sandy and represents 83% (43/52 ha) of the overall negative area change.

Bottom topography

Using a 0.3 meter elevation threshold, only those areas that were greater or equal to a +0.3m change were classed as overwash sediment deposit. Figure 4.3 illustrates this approach in a sub-section of the northern Barnegat Bay study area. The area classified as overwash represented approximately 66 ha of the 28,144 hectares in the Barnegat Bay-Little Egg Harbor study area; or about 0.23%.

The only ESAs to show a greater than 0.1% change in area mapped as overwash sediment deposit were

ESA 7 Barnegat Light
ESA 8 Long Beach North
ESA 17 Story Island West
ESA 18 Long Beach South

Based on this analysis, we conclude that SuperStorm Sandy did not deposit a significant amount of overwash sediment to the bay bottoms of the ESAs. Only ESA 7 (Barnegat Light) has more than 1% area change. This ESA includes the tidal delta interior to Barnegat Inlet and is a naturally dynamic zone. The other ESAs showing slight changes are also associated with the dynamic tidal deltas of Barnegat and Little Egg Harbor Inlets.

Discussion:

SuperStorm Sandy did not have a major effect on the physical terrain (i.e. shoreline configuration and bottom topography) of the BB-LEH ESAs. Most ESAs experienced only modest changes. Notable areas that were significantly affected by shoreline erosion and overwash were ESA 9 (Gunning River area of the Edwin B. Forsythe National Wildlife Refuge) and ESA 18 (the bayside of the Holgate section of the Edwin B. Forsythe National Wildlife Refuge). Only ESA 14 (Barnegat Light) experienced more than 1% area change in bottom topography due to the deposition of sediment. This ESA includes the tidal delta interior to

Barnegat Inlet and is a naturally dynamic zone. The other ESAs showing slight changes are also associated with the dynamic tidal deltas of Barnegat and Little Egg Harbor Inlets.

Overwash as discussed here referred to areas of sediment mobilized and deposited presumably due to Sandy storm surge. We do not mean to suggest that overwash as a negative process overall. Shoreline erosion, movement and overwash deposition are a natural process in dynamic coastal environments. Overwash deposited sediments can provide new habitats for beach-nesting birds, particularly rarer beach-nesting species such as the Piping Plover.

Table 4.1 Change in Environmentally Sensitive Area island land and marsh area pre- vs. post-Sandy. Note negative area change represents land lost.

ESA	Land/Marsh Area (ha)	Area Change (ha)	Percent change
1	139.4	-1.4	1.0
2	39.2	-0.2	0.4
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	336.1	-3.0	0.9
10	194.4	-0.7	0.4
11	48.4	-0.6	1.1
12	11.4	-1.3	11.1
13	4.2	-0.2	4.1
14	7.2	0	0
15	38.4	-0.7	1,8
16	140.0	-1.3	0.9
17	213.1	-0.4	0.2
18	211.6	-42.3	20.3
Total	1383.4	52.1	3.75

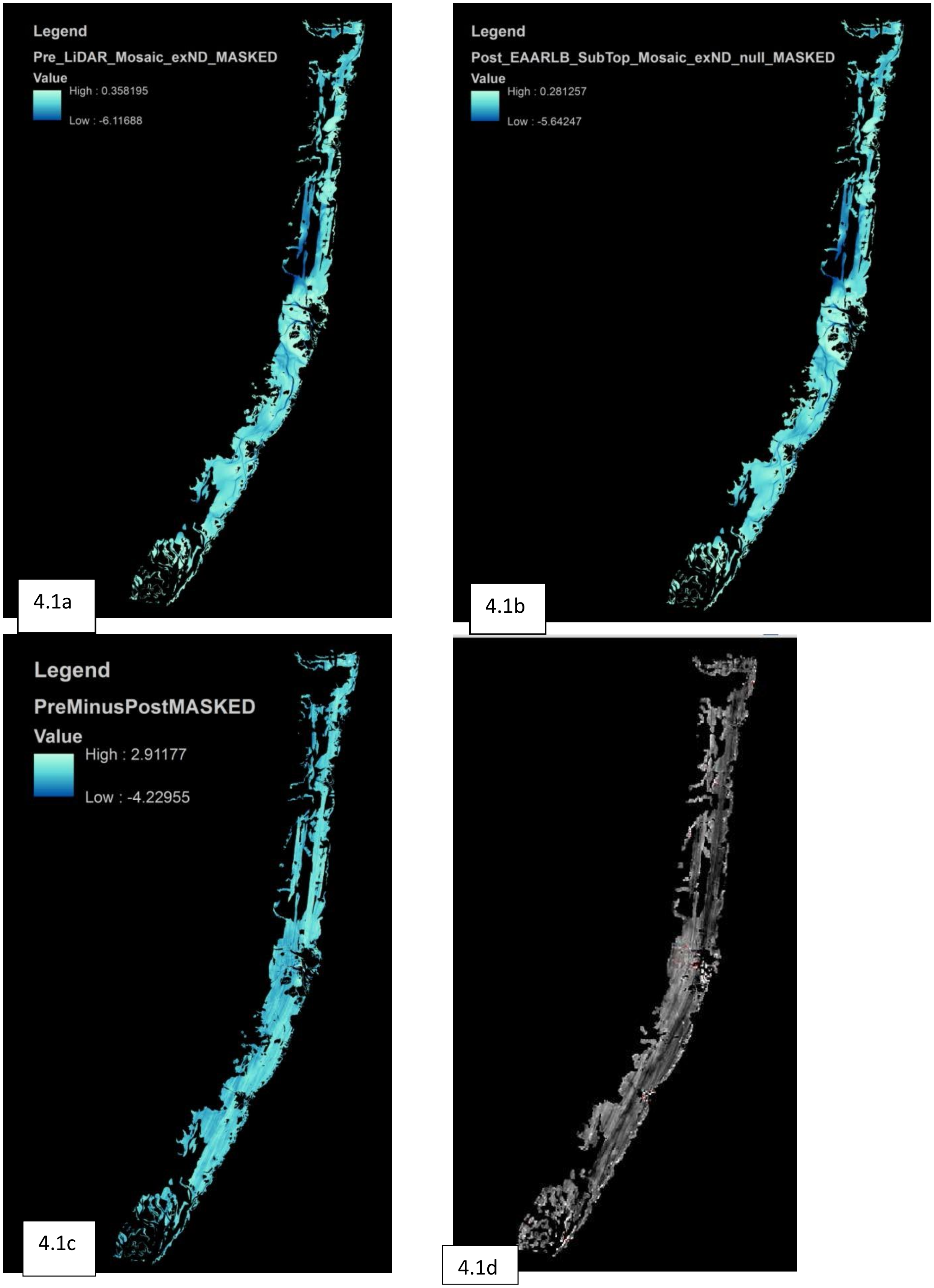

Figure 4.1. Assessment of Pre- vs. Post Sandy bathymetry. Units in meters. 4.1a Pre-Sandy; 4.1b Post-Sandy; 4.1c: image difference; 4.1d. classified using 0.3m difference threshold.

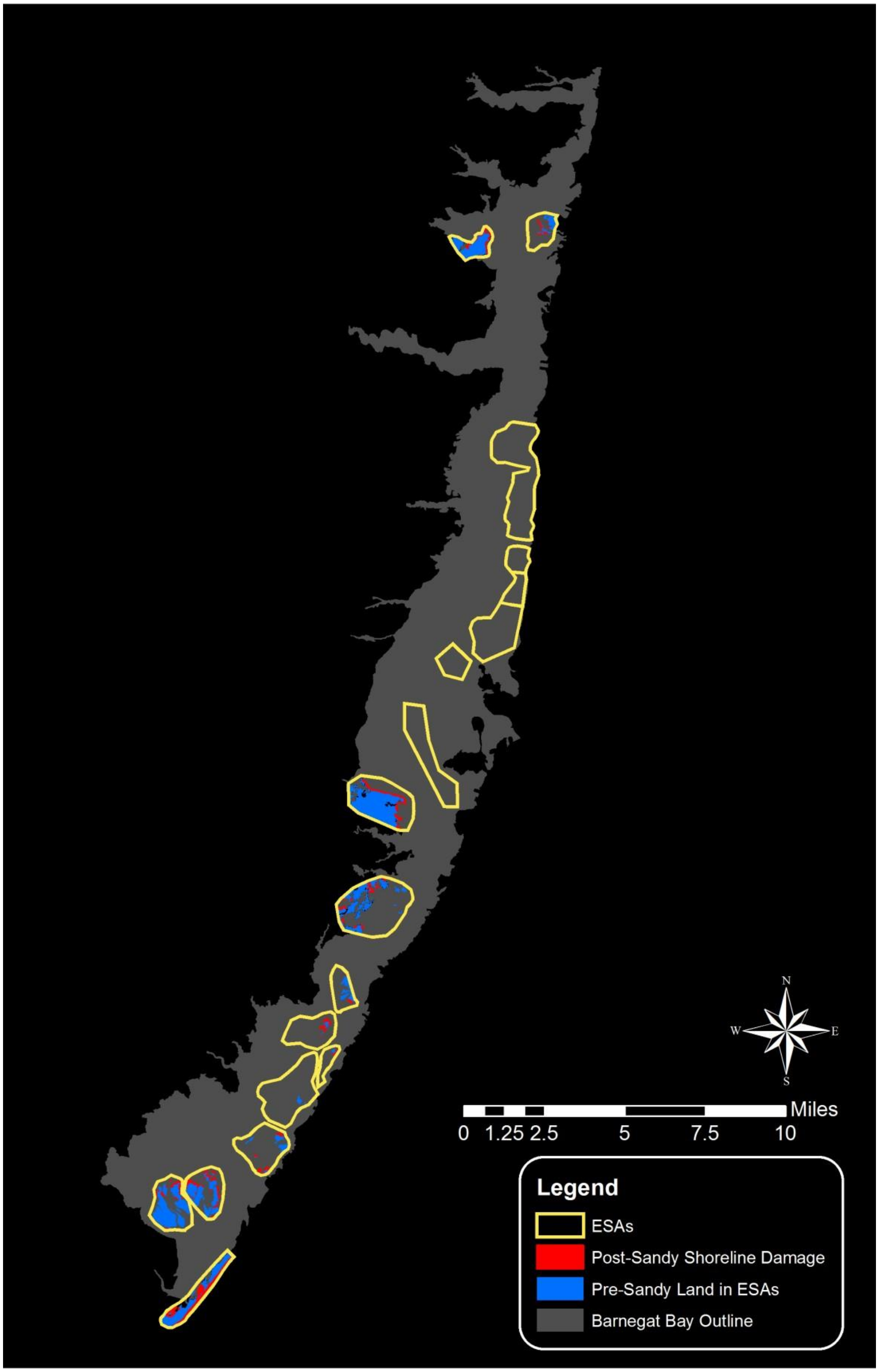

Figure 4.2 Change in Environmentally Sensitive Area island land and marsh area pre- vs. post-Sandy. Note: red area represents shoreline/land area damaged or eroded by Super-Storm Sandy.

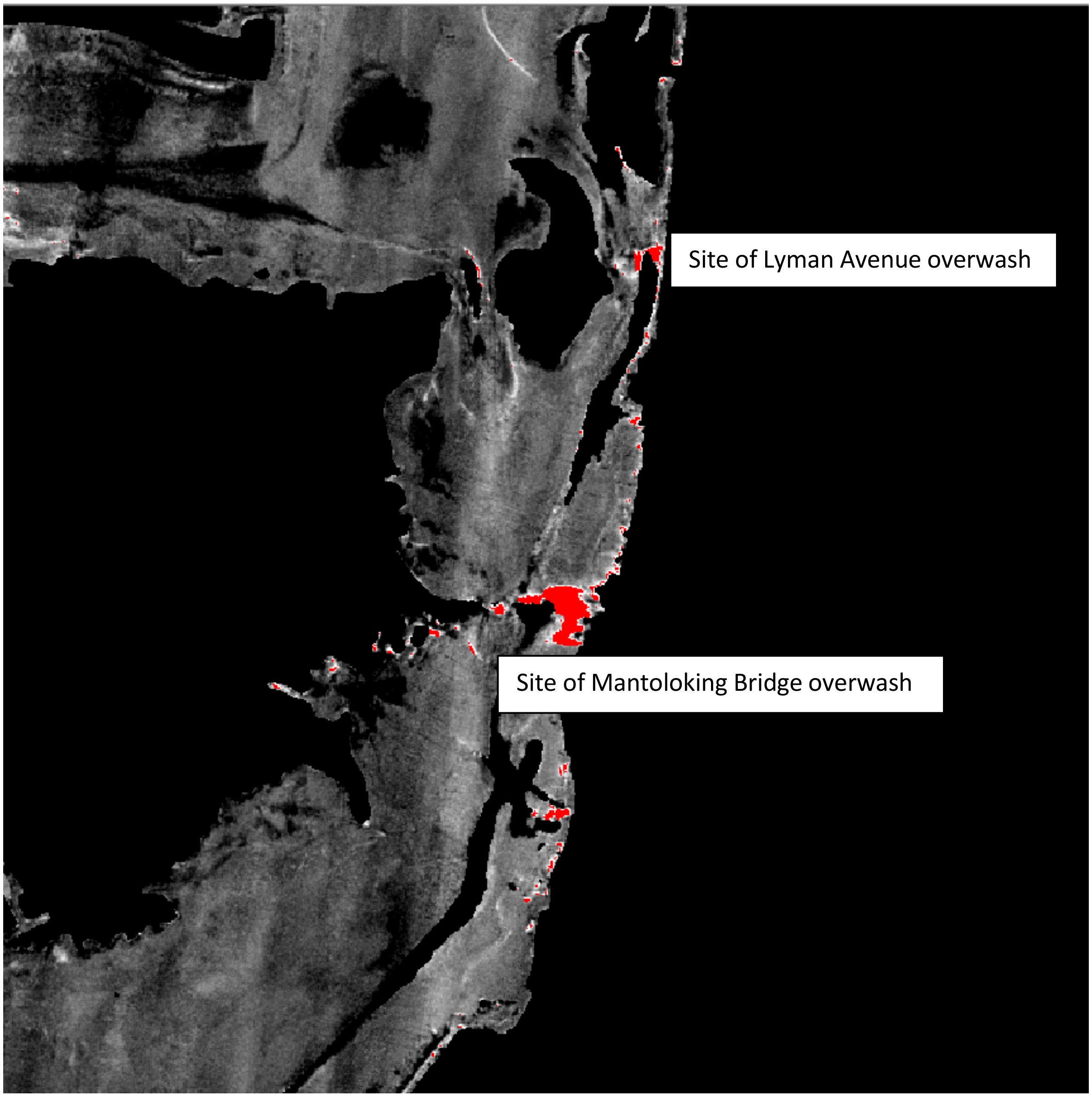

Figure 4.3 Example subset of northern Barnegat Bay showing areas with greater than 0.3m difference threshold in red.

Data sources:

NOAA’s Post-Sandy Response imagery flown October 31-November 6, 2012 (*NOAA Hurricane Sandy Response Imagery* http://storms.ngs.noaa.gov/storms/sandy/ ; *NJGIN WMS 2012* http://njgin.state.nj.us/download2/layerfiles/NJ_2012NaturalColor.lyr)

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Contact: Alexandra Fredericks (afredericks@usgs.gov)

Pre-Sandy imagery from USDA’s NAIP 2013:

USDA-FSA Aerial Photography Field Office. *NAIP Seam Lines by State.* 1-meter resolution. United States: ArcGIS Online, 2013. http://tiles.arcgis.com/tiles/LLVEmB8Lsae3Um4s/arcgis/rest/services/2013_NAIP_National_Metadata_Cache/MapServer

Section 5 Evaluation of a Multimetric Index

Objective:

Examine whether the development of a multi-metric assessment index is feasible for future monitoring and management of these ESAs.

Background:

Aquatic monitoring programs increasingly incorporate biological indicators or criteria in addition to physical or chemical indicators of water quality. Biological monitoring programs often rely on indicators or indices that are based on the comparison of attributes (i.e., species composition, richness/diversity, relative abundance, guild structure) of the biological communities in impaired vs. unimpaired "reference" ecological systems. Many entities combine a suite of indicators or metrics (one attribute per metric) into an overall numerical index (i.e. multimetric index) scaled to reflect the ecological health of the community (Emery et al., 2003). The objective is to summarize the biological condition of a selected location and derive an index that is highly sensitive to (and therefore a good predictor of) degrees of anthropogenic impairment (Schoolmaster et al. 2012). One of the first such indices used to assess aquatic communities (and subsequently adapted for use elsewhere) was the Index of Biotic Integrity (Karr, 1981; Karr and Chu, 1997).

Some of the purported advantages of combining multiple indicator values into a single number (i.e. a multimetric index) are that the resulting index is: 1. more precise than single indicators because it combines them; 2. able to summarize large datasets to reveal patterns in space and time; 3) flexible; and 4) combines empirical observation and theory (Stewart-Oaten et al. undated). Multimetric indices often find application in situations where natural resource managers are interested in the impacts of human disturbance on biological communities, but where the direct causal relationships linking human disturbance to the measured biological metrics are complex and unknown (Schoolmaster et al. 2012). However, combining indicators of different features or problems into a single multimetric index has also been criticized in that it obscures information needed by managers, scientists and the public (Stewart-Oaten et al., undated). Stewart-Oaten et al. go on to suggest that "if all indicators indicate the same problem, the methods for combining them should have known properties and achieve clear objectives, preferably quantitative; if they indicate different problems, then combining them obscures their messages."

Methods:

In Task 1, a number of biological and environmental parameters were analyzed to determine whether there are differences in habitat features, abundance and/or distribution/diversity of key species or other environmental characteristics for the 16 ESAs vs. the remaining portions of the BB-LEH region. We reviewed these results to assess whether the selected parameters would serve as useful indicators of the influence of human activities on the ecological integrity of the

ESAs, as compared to the rest of the BB-LEH System, and whether in composite they would serve as the basis for a multimetric index.

Results and Discussion:

Based on these results, only a few of the parameters stood out as being significantly different inside vs. outside the ESAs: 1) seagrass amount; and 2) hard clam abundance. While not significantly different, the following parameters were higher within the ESAs and evidence in the scientific literature suggest these are sensitive to boating activity: 3) colonial nesting bird abundance; and, 4) osprey nest abundance. Of the vast array of water quality parameters examined, only pH stood out as significantly different. As stated in Task 1, one possible explanation for this difference is that most of the ESAs are located along the eastern extent of the BB-LEH where there is a minimum of low pH freshwater input. Thus the applicability of pH as a parameter for future monitoring of the influence of human activities on the ecological integrity of the ESAs is tenuous at best.

Thus we suggest that future monitoring of the ESAs should be based on 1) seagrass areal cover; 2) colonial nesting bird abundance and diversity; and 3) osprey nest abundance. We come to this conclusion based on 1) the results of Task 1 as these are the parameters that stood out as uniquely characterizing the ESAs vs. the rest of the BB-LEH system; 2) these are ecological features that are especially sensitive to boating activity through either direct physical contact (e.g., boat scarring of seagrass meadows) or disturbance (e.g. noise, wakes and human presence); and 3) these are parameters that are either routinely monitored on an annual, semi-annual or decadal basis. While hard clams did appear more numerous inside vs. outside the ESAs, making a direct connection of hard clam abundance with boating impacts or special management within an ESA is difficult. Except for the Sedge Island Marine Conservation Zone, designation of the ESA does not specifically change the commercial or recreational harvesting or management of hard clams.

In reviewing the literature on multimetric indices of eco/biological integrity, most such indices are scaled to reflect the ecological health of the community by contrasting impaired vs. unimpaired reference sites. In our situation, there are no available reference sites for comparative purposes per se. This study does provide a baseline of data on which to base future change monitoring. There is no general universal profile for ESAs; each one is different. Thus each ESA should be monitored and change measured on an individual basis. Table 5.1 contains the data for the most recent two years of data for each of these indicators and can serve as the basis on which to examine future change.

It should be noted that it is difficult to set thresholds for management targets. For example, how much seagrass cover should an ESA have? And what change in future seagrass areal cover should precipitate a management decision? We do not have a solid empirical or theoretical justification to recommend specific target thresholds. One possibility would be to set a 10% change threshold as a red flag to justify further scrutiny as to casual factors. However, caution is warranted as there can be great annual variability in colonial nesting bird abundances as well as decadal variability in seagrass areal cover (Lathrop et al. 2001, 2006, 2014). Further this change in both colonial nesting bird abundance and seagrass distribution could be completely unrelated to ESA-specific boating impacts but due to baywide eutrophication, storm disturbance or other extrinsic factors.

In considering the applicability of a multimetric index, Suter (2001) suggests that indicators are often expressed in terms of indices or scores that obscure the actual conditions of the environment. He goes on to suggest that risk assessments should disaggregate multimetric indices to their components and choose only those that are appropriate. Further, we take the words of Stewart-Oaten et al. to heart when they suggest that "if all indicators indicate the same problem, the methods for combining them should have known properties and achieve clear objectives, preferably quantitative; if they indicate different problems, then combining them obscures their messages." In the case of the BB-LEH system and the three biotic indicators we have enumerated above, we do not believe that they are indicators of the same problems, i.e. change in seagrass areal cover and colonial nesting bird abundances represent different problems, related to different causal factors. Further the two bird indicators (colonial nesting birds and osprey nest abundance) are dissimilar enough that they don't necessarily represent indicators of the same problems. Thus we suggest that the development of a multimetric index is not supported and unwarranted, rather the three indicators should be monitored and characterized individually to not obscure their messages.

Recommendations:

We recommend that the three fore-mentioned biological indicators (1) seagrass areal cover; 2) colonial nesting bird abundance and diversity; 3) osprey nest abundance) serve as the basis for future change monitoring of the ecological integrity of the ESAs individually and collectively. Due to the great year-to-year variability in colonial nesting bird and osprey abundances, both by individual species and across the various guilds (e.g. gulls, terns, long-legged wading birds), monitoring should be undertaken on an annual or every other year basis. Seagrass areal cover should be mapped and monitored on a 5 to 10 year basis using a combination of both high spatial resolution aerial imagery and in situ measurements (Lathrop et al., 2014). It should be noted that seagrass has not been mapped in BB-LEH since 2009. In composite, we suggest that the monitoring data for the ESAs be assessed on a 5 to 10 year time scale to determine their ecological integrity status.

Table 5.1 Last two years of data on selected biological indicators by ESA.
Note: Colonial nesting bird date for Years 2013 and 2014. Osprey nest data for 2011 and 2012. Seagrass area data for Years 2003 and 2009.

Year	ESA	Gulls	Terns	Herons	Beach Nesting Birds	Egrets	Osprey Nests	Seagrass (Hectares)
Year 1	1	0	0	0	0	0	3	0.00
	2	647	0	0	0	22	0	92.74
	3	0	0	0	0	0	0	422.06
	4	0	0	0	0	0	0	125.44
	5	0	0	0	0	0	0	127.27
	6	0	0	0	0	0	0	434.05
	7	0	0	0	0	0	0	140.77
	8	0	0	0	0	0	0	219.76
	9	0	0	0	0	0	1	64.84
	10	504	0	0	0	0	0	104.29
	11	0	0	0	0	0	0	58.92
	12	286	107	0	12	0	0	280.98
	13	169	0	0	0	0	0	69.97
	14	144	0	0	0	0	0	563.41
	15	138	0	0	0	0	1	348.52
	16	1258	256	0	60	0	0	34.30
	17	290	156	0	0	0	0	0.00
	18	0	0	0	260	0	0	2.47
Year 2	1	0	0	0	0	0	5	4.47
	2	55	49	0	0	0	6	151.81
	3	0	0	0	0	0	0	548.74
	4	0	0	0	0	0	0	233.80
	5	0	0	0	0	0	0	232.05
	6	0	0	0	0	0	2	462.51
	7	0	0	0	0	0	0	25.88
	8	0	0	0	0	0	0	209.52
	9	0	0	0	0	0	3	113.60
	10	681	0	3	0	89	4	283.60
	11	0	0	0	0	0	0	101.33
	12	350	55	0	0	0	0	311.42
	13	132	0	14	0	151	0	53.00
	14	119	0	0	0	0	0	560.19
	15	11	0	0	0	0	0	200.79
	16	592	292	114	142	442	0	37.40
	17	1001	309	0	0	0	1	0.00
	18	0	0	0	429	0	0	0.00

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