Impact of Sea Level Rise on Foraging Habitats for Migratory Shorebirds in Cape May County, New Jersey

http://www.njaudubon.org/Research/CitizenScience/Shorebird_Surveys.html

Introduction

Cape May Peninsula's unique configuration and location concentrate large numbers of migratory birds, making it a key migratory corridor (USFWS, 1996). The beaches along the Delaware Bay side support the world's largest spawning population of horseshoe crabs (*Limulus polyphemus*) (USFWS, 2006). The increasingly rare red knot (*Calidris canutus*; a threatened species in New Jersey) as well as the sanderling (*C. alba*), least sandpiper (*C. minutilla*), dowitcher (*Limnodromus* spp.), and ruddy turnstone (*Arenaria interpres*) are some of the many shorebird species that feed on horseshoe crab eggs to gain weight for migration to their summer breeding grounds in the arctic (USFWS, 2006). As a result, the Delaware Bay shoreline has gained international recognition as a major shorebird staging area in North America with over a million birds, second only to the Copper River Delta in Alaska (CMBO, NJAS, 1997). The foraging habitats on 'North America's most famous birding spot' are critical for the conservation of North American shorebirds.

Research has shown that shorebirds on the Cape May Peninsula forage in the tidal salt marshes in addition to the beaches and mudflats (Burger *et al*., 1996) and all shorebirds move between the beaches and marshes for feeding, resting and roosting (WHSRN, 2003). While this mosaic of foraging habitat is essential in supporting the high concentration of migratory shorebirds in Cape May County, it is also highly vulnerable to predicted accelerating sea level rise. An assessment of the impact of future sea level rise on shorebird habitat is needed to make informed decisions regarding management and protection of shorebird habitat in Cape May that will have a direct impact on the conservation of migratory shorebird populations.

Background

Importance of Cape May Peninsula to Migratory Shorebirds

Because of its geographical location and orientation between Delaware Bay and the Atlantic Ocean, vast numbers of migratory birds congregate on the Cape May Peninsula to rest and feed before continuing on their journey to their breeding grounds. The Delaware Bay was the first site to be classified by the Western Hemisphere Shorebird Reserve Network and is considered a shorebird site of Hemispheric Importance (WHSRN, 2003). Hemispheric sites are those visited by 500,000 or more shorebirds a year, and which account for more than 30 percent of the biogeographic population for a species. Each year hundreds of thousands of shorebirds - nearly 80 percent of some populations such at the red knot and whimbrel (*Numenius phaeopus*) - stop to rest and feed here during their spring migration from Central and South America to their Arctic breeding grounds (CMBO: NJAS, 1997).

The northbound migration of shorebirds coincides with the spawning of the world's largest population of horseshoe crabs in Delaware Bay (USFWS, 2006). Shorebirds feed mostly on the eggs of the horseshoe crab on the bay beaches, but some species, such as dunlin (*Calidris alpina*) and short-billed dowitcher (*Limnodromus griseus*), and declining species such as the semipalmated sandpiper (*C. pusilla*) and sanderling, rely more heavily on marsh habitats (WHSRN, 2003). Four species account for 99% of migratory shorebirds observed on Delaware Bay beaches: semipalmated sandpipers 30-70%, ruddy turnstones 20-35%, red knots 15-20%, and sanderling 4-6%. Dunlin and short- and long-billed dowitchers account for another 2-8% (numbers fluctuate yearly) (WHSRN, 2003).

Species like red knots and dunlin that concentrate in large numbers in a single area are very vulnerable to future sea-level rise. Loss of a critical staging area could mean the destruction of a whole flyway population of shorebirds (WHSRN, 2003). For example, the 30,000 red knots feeding on horseshoe crab eggs in Mispillion Harbor, Delaware Bay, are highly vulnerable to a number of events such as future sea-level rise, human alteration of this resource, or even a catastrophic storm. Widespread declines continue in shorebird populations. If current trends continue, the red knot may become extinct in our lifetime. Where there is sufficient data to be reliable, it has been shown that nine shorebird species on the east coast of North America are declining and none are increasing (WHSRN, 2003).

During their migration, most shorebirds depend on intertidal flats (i.e., sand beaches or mudflats) for their foraging habitat. Research on the Cape May Peninsula has shown that migrating shorebirds also feed in a mosaic of habitat types ranging from mudflats to high marshes (Burger *et al*., 1996). The relative importance of marshes suggests the need to preserve and protect them for the conservation of shorebirds that migrate through Cape May County. To help in making informed decisions about land acquisition and management, it is imperative to understand which habitats serve an important role in shorebird foraging ecology (Burger *et al*., 1996).

Vulnerability of Shorebird Foraging Habitats to Sea-Level Rise

The effects of rising seas on these critical salt marsh habitats are complicated by the presence of man-made impediments to salt marsh migration inland, i.e. development and shore protection. The data addressing the response of salt marsh ecosystems and specific bird species to sea-level rise is limited to a small number of site-specific studies (Shellenbarger Jones *et al.*, 2009). While some studies address the effects of either sea-level rise or shore protection on coastal fauna, minimal literature is available on the combined effects of rising seas and shore protections (Shellenbarger Jones *et al.*, 2009).

Sea Level is expected to rise due to ocean thermal expansion and melting of the ice sheets. Recent historical levels of sea-level rise along the New Jersey coast are generally thought to be about 3-4 mm/yr, while predicted future rates are expected to increase to 6 mm/yr (Psuty, 2002). The International Panel on Climate Change (IPCC, 2009), estimates that over the next century mean sea level will rise between 0.6m and 1.2m above the 0.0 North American Vertical Datum (NAVD 88). Mean sea level is approximately 0.284 feet (3.4 inches) above 0.0 NAVD in this geographic region.

Predictions of wetland vulnerability to sea-level rise were made for the mid-Atlantic coast based on an opinion approach by a panel of scientists with expert knowledge of wetland accretionary dynamics (Cahoon *et al.*, 2009). As displayed in Figure 1, this method projects (with a moderate level of confidence) that salt marshes in New Jersey are keeping pace with twentieth century rates of sea-level rise (Scenario 1). However, these salt marshes would survive a 2 millimeter per year acceleration of sea-level rise (Scenario 2) only under optimal hydrology and sediment supply conditions ("marginal"), and would not survive ("loss") a 7 millimeter per year acceleration of sea-level rise (Scenario 3) (Cahoon *et al.*, 2009). Therefore, as the rate of sea-level rise accelerates–as is predicted (CCSP, 2009)–salt marshes in New Jersey will begin to degrade and eventually the salt marsh habitat critical to marsh-dependent shorebirds will be lost, with the potential for greatly reduced populations or loss of these avian species in New Jersey.

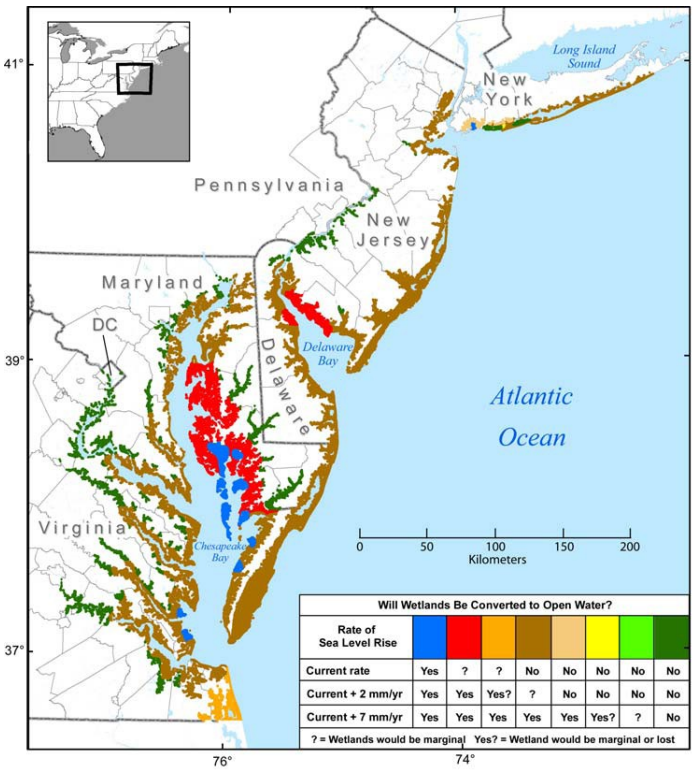

Figure 1 Wetland survival in response to three sea-level rise scenarios (Cahoon *et al.*, 2009).

The estuarine beaches used by migratory shorebirds are largely disappearing in developed areas where shoreline armoring is the preferred method of shore protection. The erosion or inundation of bay islands would also reduce the amount of beach habitat (Shellenbarger Jones *et al.*, 2009). Loss of tidal flats could lead to increased crowding in remaining areas, starvation if alternate areas are unavailable, and ultimately to reductions in local shorebird populations (Shellenbarger Jones *et al.*, 2009). Where horseshoe crabs decline because of loss of suitable beach substrate for egg deposition, there could be significant implications for migrating shorebirds, particularly the red knot, a candidate for protection under the federal Endangered Species Act.

In order to model projections of wetland vulnerability to sea-level rise with a reasonable degree of accuracy, it is important to understand the dynamics of wetland accretion, wetland migration, and the effects of land-use change as sea-level rise continues (Cahoon *et al.*, 2009). The potential effects on wetland ecology are understood in general terms, but minimal literature is available that shows how the interactions between rising seas and various types of shore protection and development may affect the abundance and distribution of shorebird species in the salt marshes (Shellenbarger Jones *et al.*, 2009).

Because sea-level rise impact assessments often rely on elevation data, it is important to understand the inherent accuracy of the underlying data and its effects on the uncertainty of any resulting vulnerability maps and statistical summaries (Cahoon *et al.*, 2009). Previous studies have relied on less than optimal elevation data, but newer high-resolution, high accuracy Light Detection and Ranging (LiDAR) elevation data is available and can result in improved capabilities for vulnerability assessments.

New Jersey Audubon Society (NJAS) Migratory Shorebird Surveys

Unpublished migratory shorebird survey data collected through the NJAS Citizen Science effort in collaboration with the New Jersey Department of Environmental Protection (NJDEP) Endangered and Nongame Species Program (ENSP), and Manomet Center for Conservation Science has been made available for this project. The NJAS ongoing study has been aimed at assessing status and changes in populations of shorebirds to better manage and conserve stopover areas. The data collected by dedicated and trained volunteers will be incorporated into the national database of the Program for Regional and International Shorebird Monitoring (PRISM), whose overall goal is to monitor trends in shorebird populations. In addition, the information will help identify areas important to migratory shorebirds, and define shorebird management goals for New Jersey.
Data has been collected in the Spring (once a week, May – June) and the Fall (3 times a week, July 15 – end of October) since 2004 for coastal beaches and marshes from Cape May to Sandy Hook and along the Delaware Bay. For purposes of this current project, approval has been obtained from Nellie Tsipoura at NJAS and Amanda Dey at ENSP for the use of data from 2006 to 2008 for Cape May County. A list of the names of the volunteers who collected the data for each of the 10 Cape May County survey sites is given in Appendix 1.
The specific data collected for these surveys included 1) general information (time, date, tide level, weather, location), 2) numbers of individuals of each species, 3) disturbance within 100 m (300 ft), numbers of adults and juveniles (fall surveys only), and 4) behavioral information. Only the number of individuals of each species is being used in the current project.

Objectives

In order to help make land management decisions in the interest of conservation of North American migratory shorebirds, information is needed regarding the locations and extent of their foraging habitats that are most at risk from future sea-level rise. The objective of this project is to assess the impact of sea-level rise on migratory shorebird feeding habitats along the coast of Cape May County, and consequently, the ability of these habitats to continue supporting important numbers of shorebirds. To this end, the following questions will be addressed:

1. What are the current locations and extent of intertidal flat (mudflat and sand beach) and tidal salt marsh foraging habitats along the coast of Cape May County?
2. What are the locations and extent of potential retreat zones where shorebird habitats are free to migrate inland as sea-level rises?
3. What are the locations of the beach and salt marsh habitats along the coast of Cape May County that are most vulnerable to sea-level rise, and how much are the extents of these habitats likely to change in response to predicted sea-level rise scenarios?

Additionally, the unpublished migratory shorebird survey data obtained from the NJAS Citizen Science effort will be used to help illustrate the importance of the Cape May Peninsula to migratory shorebirds and to demonstrate how sea-level rise might impact specific survey sites.

4. What are the species of migratory shorebirds that inhabit the study areas around the Cape May Peninsula and do the species and numbers differ among study sites?

Methods

To assess the impact that future sea-level rise will have on migratory shorebird foraging habitat, an analysis was performed to estimate the locations and extent of habitats along the coast of Cape May County that would be lost under several sea-level rise (SLR) scenarios, i.e., low end SLR (0.6m) , high end SLR (1.2m), and high end SLR (1.2m) plus a 5-year storm surge flood level (1.8m), i.e., 3m. The estimate for the 5-year storm surge was obtained from the Federal Emergency management Agency (FEMA) (Cooper, *et. al.,* 2005).

Geographic information system (GIS) software and the latest New Jersey Department of Environmental Protection land use/land cover (lu/lc) digital GIS data (2002) were used to map the existing locations of the different coastal habitat types used by foraging shorebirds, i.e., beaches to tidal salt marshes. A 500-meter buffer around the shorebird habitat locations was used to determine possible habitat retreat zones, i.e., undeveloped locations where beaches and salt marshes can migrate inland as sea level rises. The buffer was then restricted to elevations up to 3 meters to represent the high end SLR plus a 5-year storm surge. An additional analysis was done using a 1000m buffer and a 4 meter elevation to determine if there are any remaining habitat retreat zones at a SLR of 3m.

The lu/lc habitat data with the associated 500m or 1000m retreat zones were cross-tabulated with the three SLR scenarios described above to determine the location and areas of habitat loss. The source elevation data were digital elevation models obtained with Light Detection and Ranging (LiDAR) remote sensing technology. This data represents the newest, high resolution (2m horizontal resolution) and high accuracy (13cm vertical accuracy) elevation data available.

Financial assistance for the acquisition of LiDAR data was provided by the New Jersey Coastal Management Program through CZM Grant Awards #NA06NOS4190228 and NA07NOS4190186 awarded through the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration. Additional funding was provided by the New Jersey State Police through the FY2007 EMPG Program, the Natural Resource Conservation Service of the U.S. Department of Agriculture, the U.S. Army Corps of Engineers, Philadelphia, PA, the United States Geologic Survey, and the New Jersey Department of Environmental Protection, Office of Information Resources Management.

Summary information for the NJAS shorebird surveys is included on the analysis maps to help illustrate the effects of sea-level rise on specific sites. In addition, 4 maps were produced with statistical summaries

of the survey data to show differences in average and maximum number of species and average and maximum number of shorebirds by survey site and season. Tables were also produced in more detail, where average and maximum counts of shorebirds are summarized by year, season, survey site, and species. Data from each of the 3 years of the surveys (2006 – 2008) was combined only for the maps. A graduated symbol was used for all summary statistics reported on the maps.

For the maps of number of species seen at each survey visit and season, an average and a maximum for number of species were calculated across the visits for each season and for each survey site. A similar computation was made for total number of shorebirds seen at each survey visit. For the table with the average daily total number of shorebirds by year, season, survey site, and species, a summary table is given at the top that shows the number of survey visits by year, season and survey site (i.e., the denominators for calculating the averages in this table). The averages (means) are presented with the standard errors in the table for average daily counts. The maximum daily counts are also presented in a table, by year, season, survey site and species.

In addition, a table with a list of the total numbers of individual shorebird species seen is presented by season and overall. The table is sorted so that the most common species are presented at the top of each list. Finally, the survey summary information that is presented on the habitat analysis maps is the maximum for the number of species reported, calculated across all the visits, regardless of season, for simplicity.

Results

The summary statistics described in the Methods section for the NJAS survey data are presented in 4 sets of maps (each with a Spring and a Fall map) and 3 sets of tables in the Appendix. Table 1 below shows the number of visits made across the three years for each survey location and for each season. Note that there is a large variation in the number of visits made across sites, depending on the amount of time each volunteer was able to commit to the surveys. Also, some sites were surveyed by more than one volunteer and some volunteers surveyed more than one site. Two of the sites are located on Delaware Bay (Reed's

Beach and Norbury's Landing) and the other 8 are located on the Atlantic coast from Two-mile Beach at the southern end up to Whale Beach toward the north.

Table 1 Total number of survey visits performed at each survey location and each season

Total Number of Surveys			
Survey Location	**Spring**	**Fall**	**Total**
Avalon	5	8	13
Champagne Island	1	8	9
Norbury's Landing	4		4
North Wildwood		6	6
Nummy's Island		1	1
Reed's Beach	1		1
Stone Harbor Point	33	57	90
Two-mile Beach/FWS	15	23	38
Two-mile Beach/USCG	15	23	38
Whale Beach	9	31	40
Total	83	157	240

FWS = Fish & Wildlife Service
USCG = US Coast Guard

There tended to be more species as well as more shorebirds seen on a daily basis at the Stone Harbor Point site. Another general trend was that on a daily basis, more species and more shorebirds were seen in the fall than in the spring for Whale Beach and Two-mile Beach/FWS. The red knot and sanderling were the most commonly seen species in the Spring and the sanderling and semipalmated plover were the most common species seen in the Fall, There were a greater number of species seen in the Fall than in the Spring, and for most species, there were far more shorebirds of that species seen in the Fall than in the Spring.

The results of the shorebird habitat sea-level rise analyses are given in Figures 2 through 8. Each of these figures shows salt marsh in dark blue (the tidal waters are shown in light blue), beach in yellow, available retreat zones in green and limited retreat zones (due to development) in red. For Figures 2 through 7, the retreat zone is a 500m buffer up to an elevation of 3m, while both a 500m, 3m elevation retreat zone and a 1000m, 4m elevation retreat zone are displayed in Figure 8.

Figures 2 and 3 show enlarged sections of Cape May County on the Delaware Bay and Atlantic Ocean, respectively. Figure 2 is an example where there is a more substantial amount of area for inland habitat retreat compared to Figure 3 which shows an area where there is much development and therefore little room for the shorebird habitat to move inland with sea-level rise.

Figure 4 shows the existing shorebird habitat along with the available retreat zones for the whole county. More area for retreat is available on the coast of the Delaware Bay than on the Atlantic coast. Figures 5 through 7 show the inundation areas for the 0.6m, 1.2m, and 3m sea-level rise scenarios, respectively.

Figure 8 also shows the 3m sea-level rise, but with a total of 1000m for the retreat zone (up to a 4m elevation).

Table 2, below, shows the original acreage available for the shorebird habitat as well as the habitat retreat zone in the top row (0m SLR). The amount and percentage of area lost due to inundation is given for each of the three sea-level rise scenarios.

Table 2 Loss of shorebird habitat and habitat retreat zones under three sea-level rise scenarios

Shorebird Habitat			Habitat Retreat Zone		
SLR (m)	Area (acres)	Area Lost	SLR (m)	Area (acres)	Area Lost
0	43,800		0	13,260	
0.6	18,130	41%	0.6	215	2%
1.2	41,800	95%	1.2	4190	32%
3.0	43,350	99%	3.0	13,260	100%

Virtually all habitat and all of the 500 m retreat zones are inundated at a sea level rise of 3 meters since the retreat zone was only extended to areas with elevations of 3m or less. When the retreat zone is extended inland another 500m (i.e., 1000m from the existing habitat) for elevations up to 4 meters above 0.0 NAVD (shown in Figure 9), there will be only another 4,800 acres available for the inland migration of shorebird habitat when sea level has reached 3m above 0.0 NAVD.

Summary and Conclusions

Even the low end SLR of 0.6m results in a substantial loss of shorebird habitat. At 1.2m, virtually all of the existing shorebird habitat and 1/3 of the retreat zone is inundated. At 3m, an additional 500m buffer only results in 4,800 acres of potential shorebird habitat, compared to the existing 43,800 acres of habitat. The vast majority of the habitat is prevented from migrating inland by existing development. These results starkly illustrate the highly vulnerable state of existing migratory shorebird foraging habitat in Cape May County.

There are several caveats that should be mentioned concerning these analyses. First, the use of the retreat zones assumes there will be no future development in those areas, and also that no areas will be converted from developed to natural areas that could function as retreat zones. With the current population density of New Jersey and the desirability of owning developed property on the coast, it is unlikely that any significant amount of land will be converted from developed to natural areas. Therefore, it is likely that the existing shorebird habitat will not increase, but more habitat may be lost through additional development.

A second caveat is that there are factors other than elevation that influence the reaction of the terrain to sea level rise such as rates of wetland accretion and sediment availability ("biological impacts"). The U.S.

Fish and Wildlife Service has attempted to account for some of these factors in their Sea Level Affecting Marshes Model (SLAMM) (http://www.slammview.org). The model looks at sediment and organic matter accumulation on the marshes as well as erosion from tides and storms. The model also shows how these relationships will remain coupled as sea level rises. The USFWS has set up a user-friendly internet tool with a similar purpose in mind as this project, i.e., to show simulations and the effects of future sea-level rise under various scenarios. Their model includes simulations of some important estuaries, including Delaware Bay. While the analysis they present is more complex than that presented here, there is no question that predicted levels of future sea-level rise will have a devastating effect on migratory shorebird foraging habitats and consequently on shorebird populations in Cape May County. The analysis presented here gives valuable information on what areas that will be affected first and a prediction on how much habitat will be inundated with each sea-level rise scenario. This geospatial analysis can provide valuable guidance in making decisions regarding the protection and management of habitat so that the best possible outcome is achieved in conservation of habitat and populations of migratory shorebirds in Cape May County.

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Existing Shorebird Habitat and Areas Available for Inland Migration of Habitat in a Section of Cape May County, NJ

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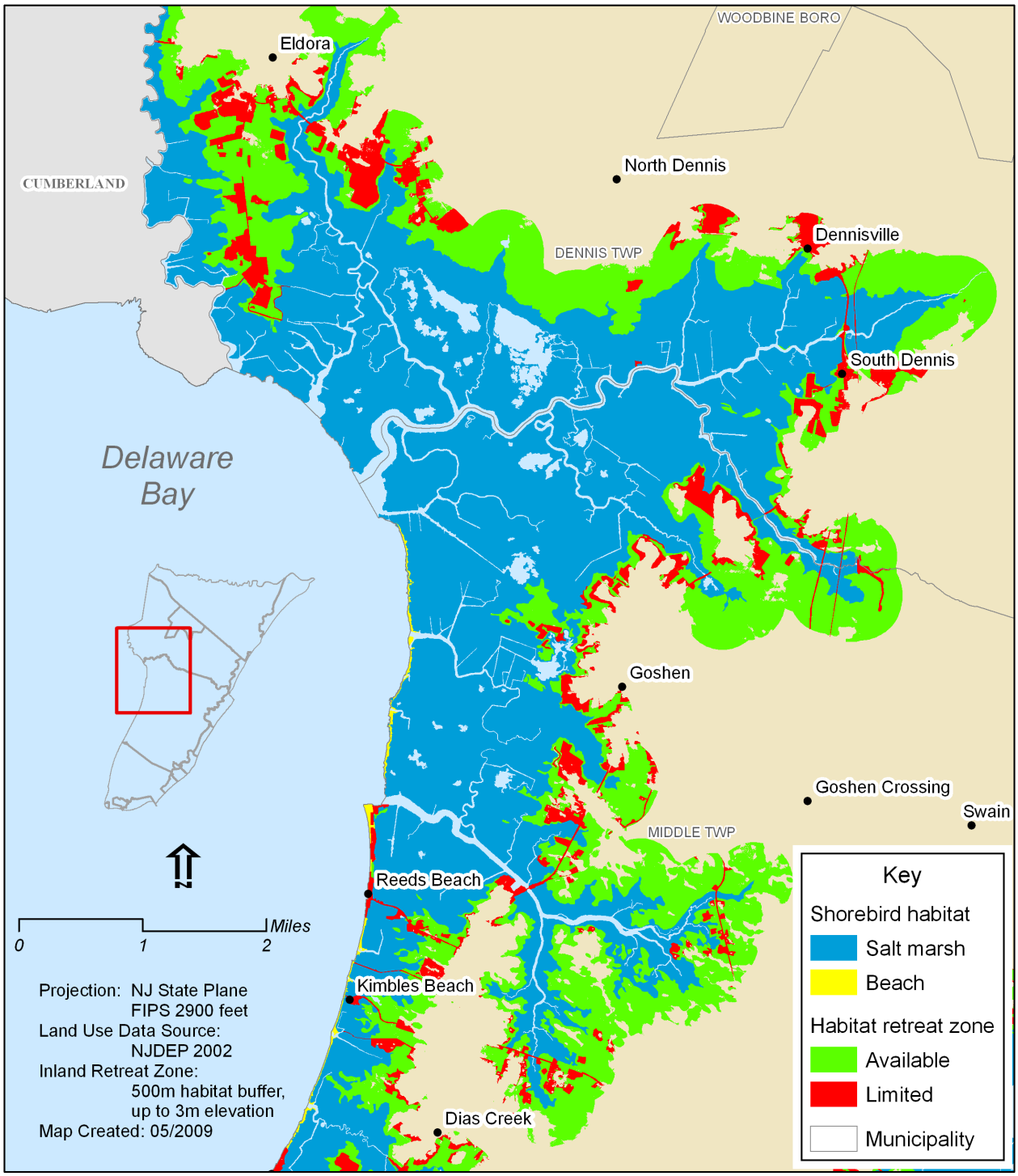

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Figure 2

Existing Shorebird Habitat and Areas Available for Inland Migration of Habitat in a Section of Cape May County, NJ

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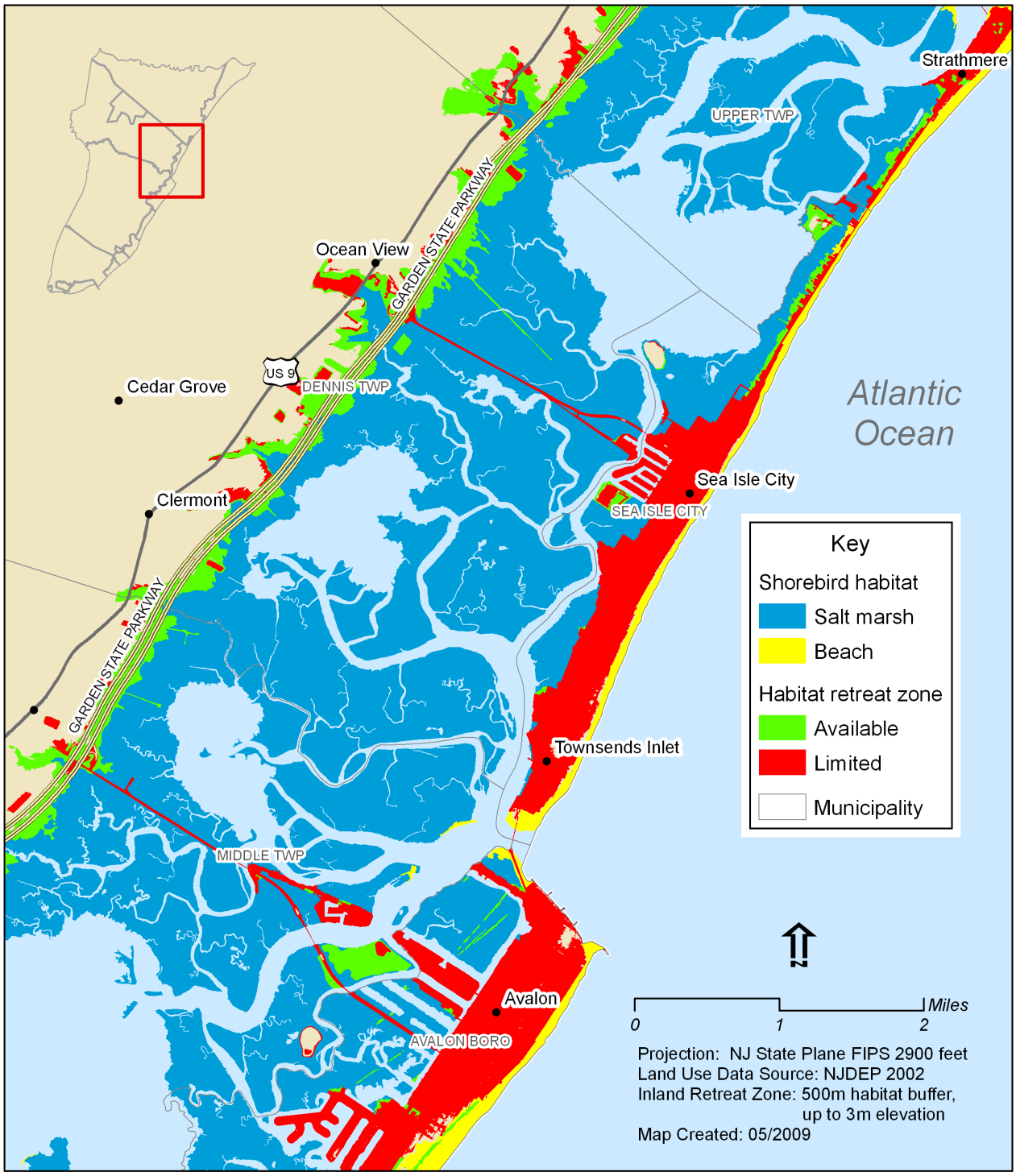

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Figure 3

Existing Migratory Shorebird Habitat, Retreat Zones, and Shorebird Survey Locations in Cape May County, NJ

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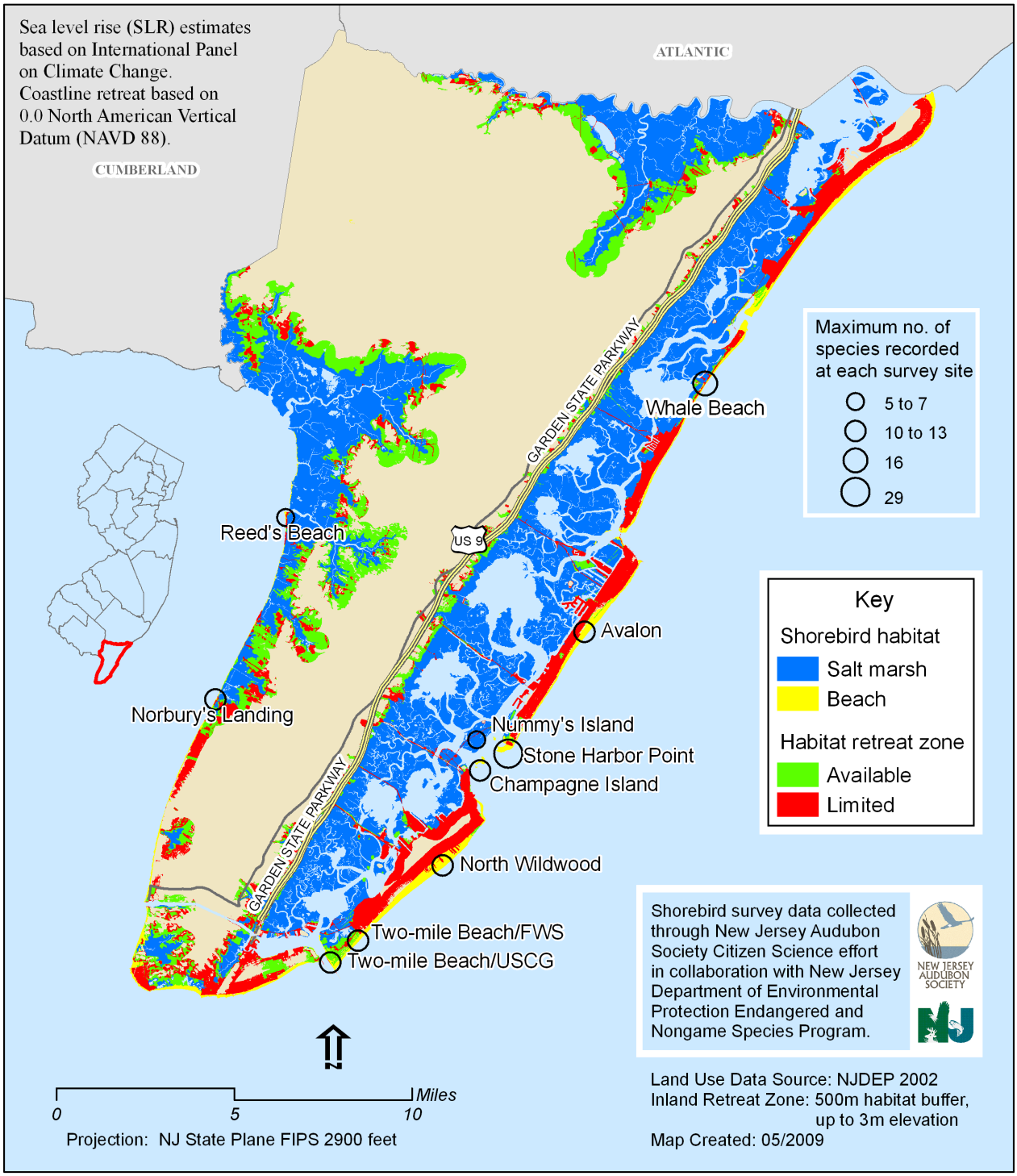

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Figure 4

Impact of 0.6m Sea Level Rise on Shorebird Habitat, Retreat Zones, and Survey Locations in Cape May County, NJ

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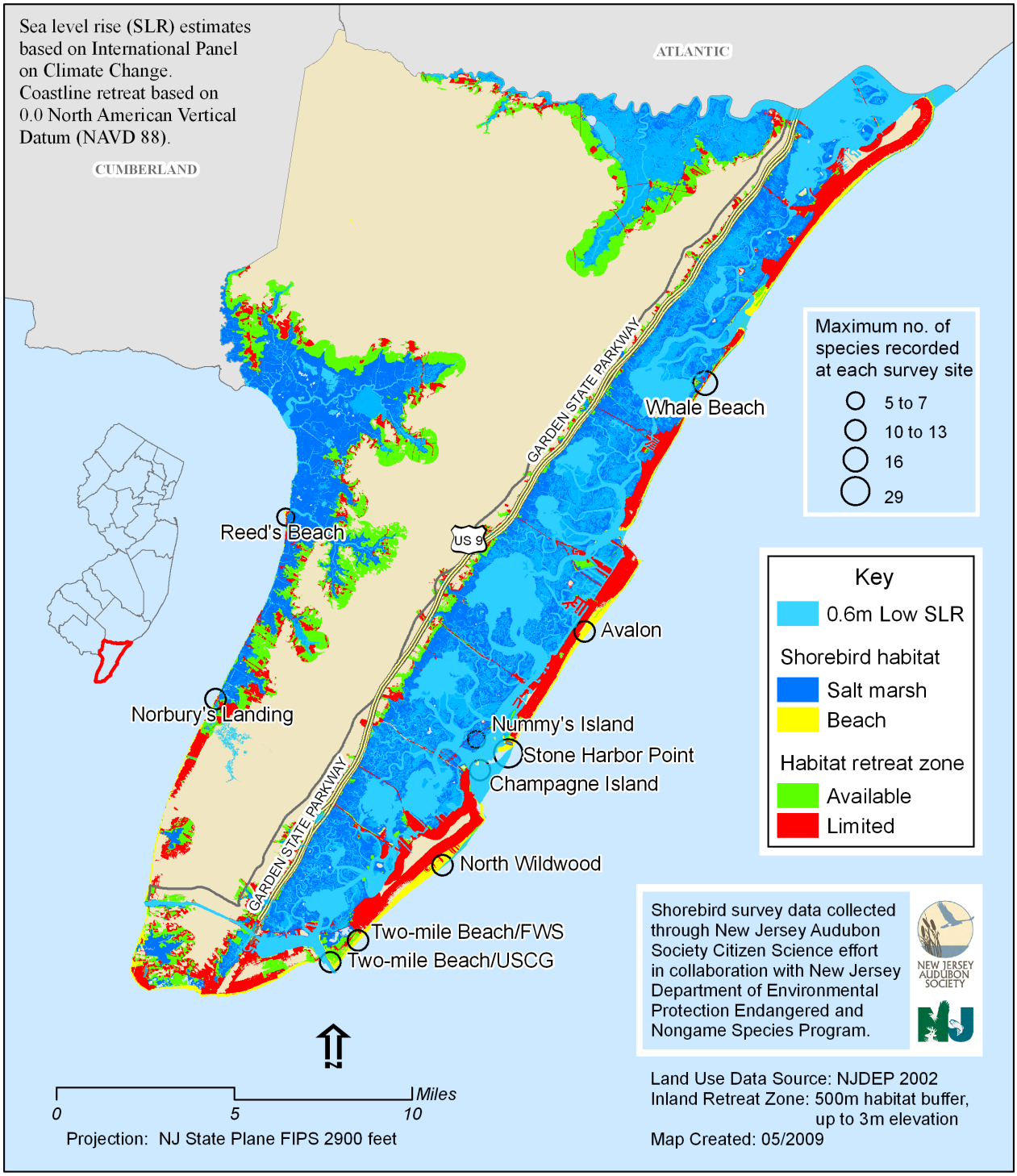

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Figure 5

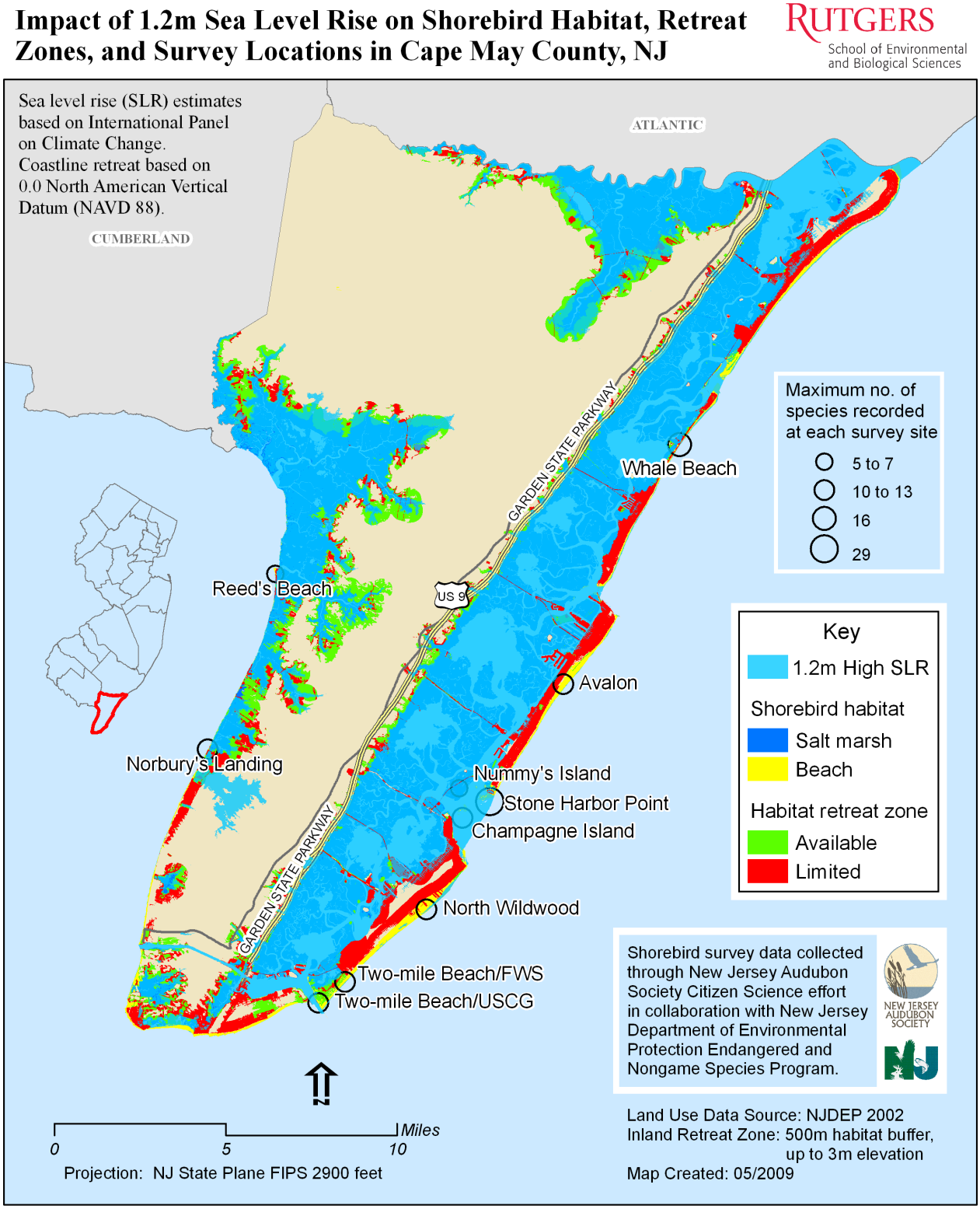

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Figure 6

Impact of 3.0m Sea Level Rise on Shorebird Habitat, Retreat Zones, and Survey Locations in Cape May County, NJ

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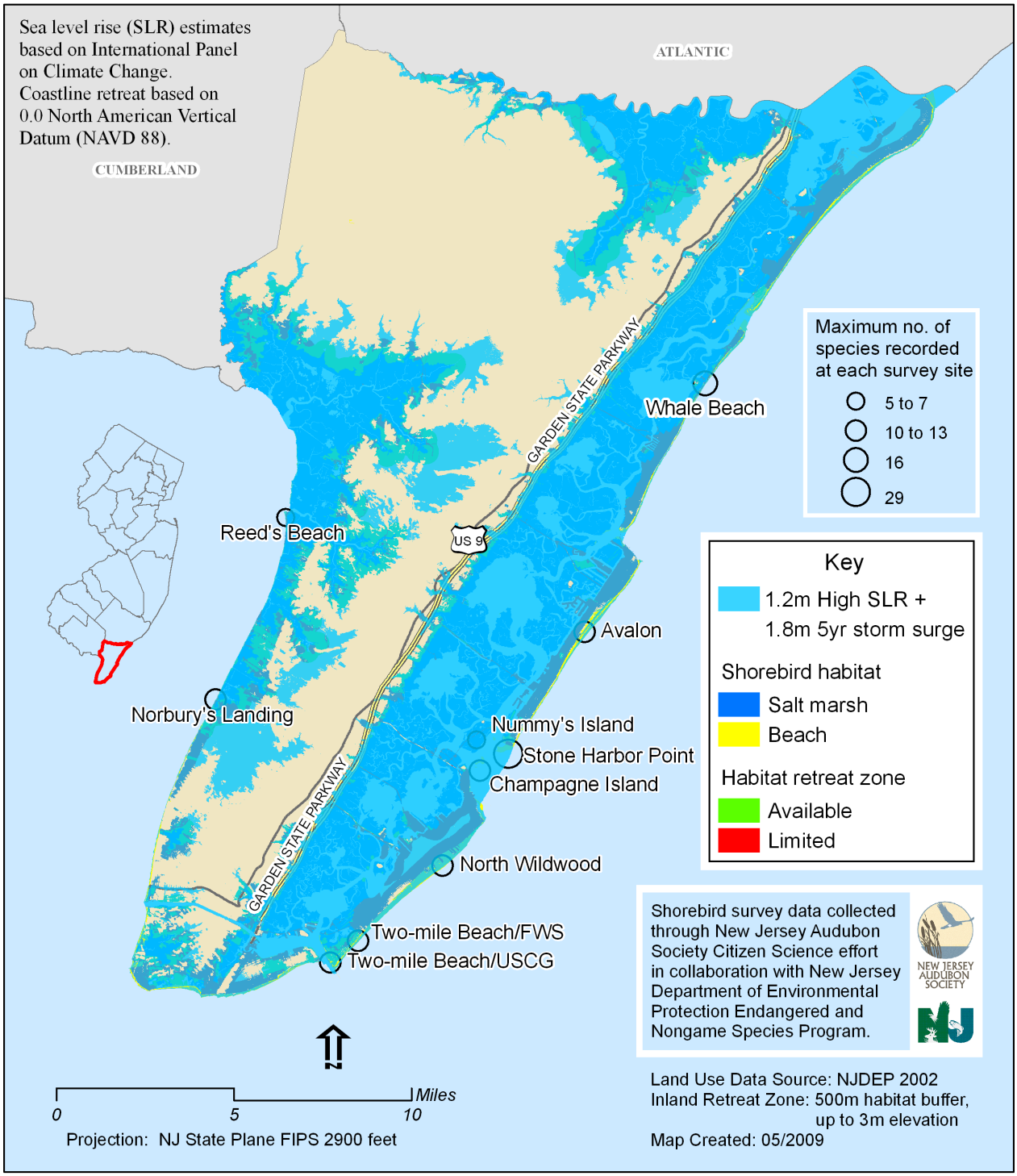

Financial assistance for the acquisition of LiDAR data was provided by the New Jersey Coastal Management Program through CZM Grant Awards #NA06NOS4190228 and NA07NOS4190186 awarded through the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration. Additional funding was provided by the New Jersey State Police through the FY2007 EMPG Program, the Natural Resource Conservation Service of the U.S. Department of Agriculture, the U.S. Army Corps of Engineers, Philadelphia, PA, the United States Geologic Survey, and the New Jersey Department of Environmental Protection, Office of Information Resources Management.

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Figure 7

Impact of 3.0m Sea Level Rise on Shorebird Habitat, Retreat Zones, and Survey Locations in Cape May County, NJ

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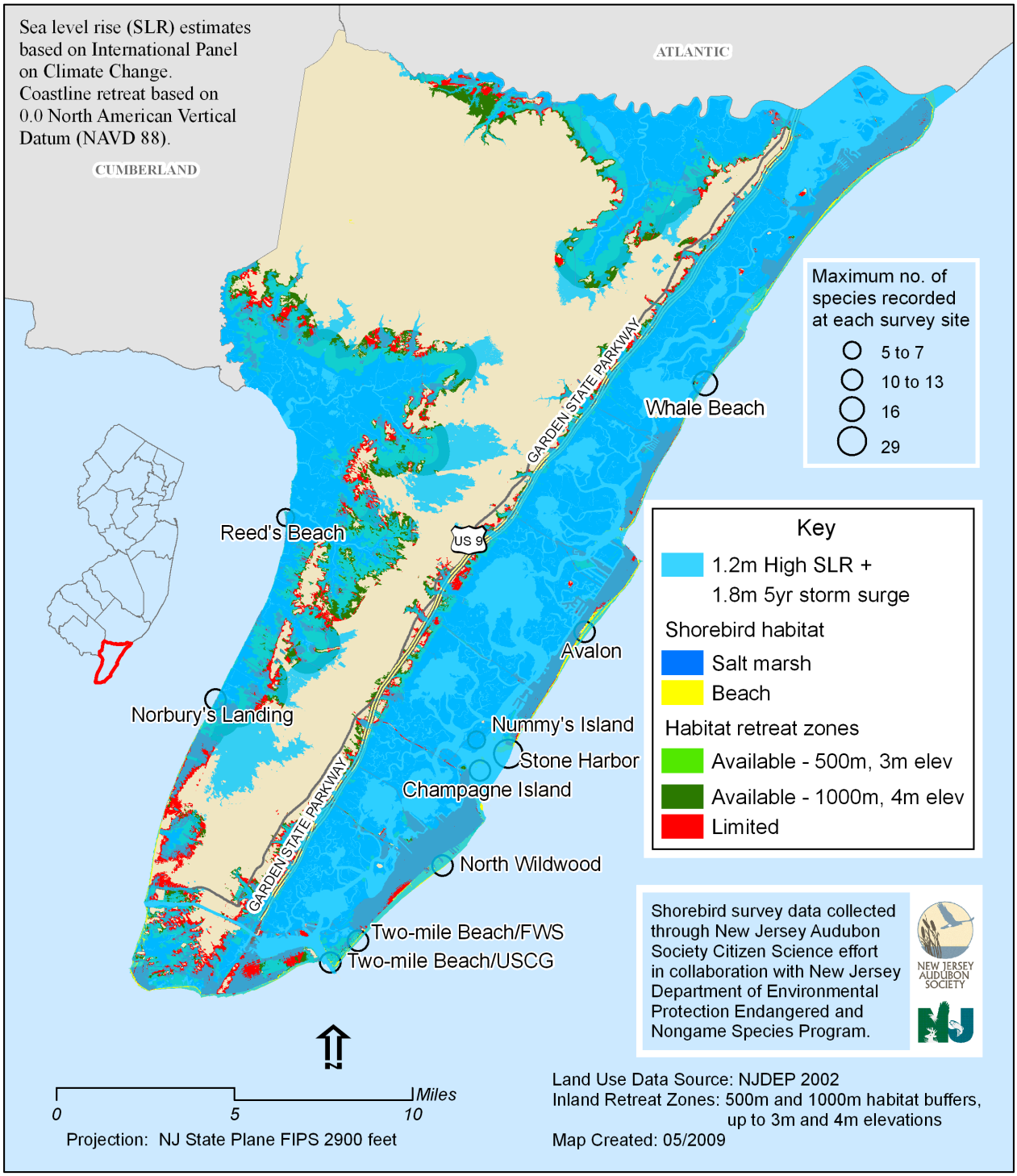

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Figure 8

APPENDIX
Summary Statistics for NJAS Citizen Science Migratory Shorebird Surveys

Average Number of Shorebird Species Reported During Spring Migration from 2006 to 2008 at 10 Survey Locations in Cape May County, NJ

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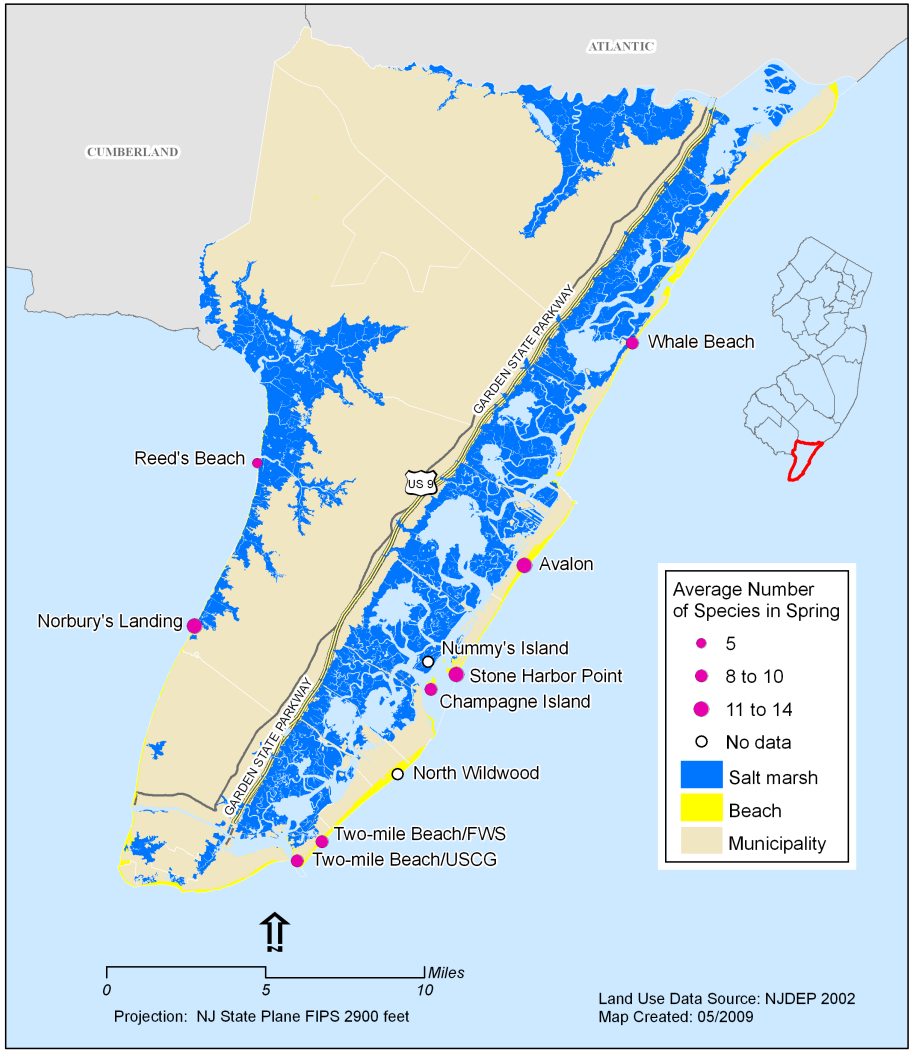

Shorebird survey data collected through New Jersey Audubon Society Citizen Science effort in collaboration with New Jersey Department of Environmental Protection Endangered and Nongame Species Program.

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Average Number of Shorebird Species Reported During Fall Migration from 2006 to 2008 at 10 Survey Locations in Cape May County, NJ

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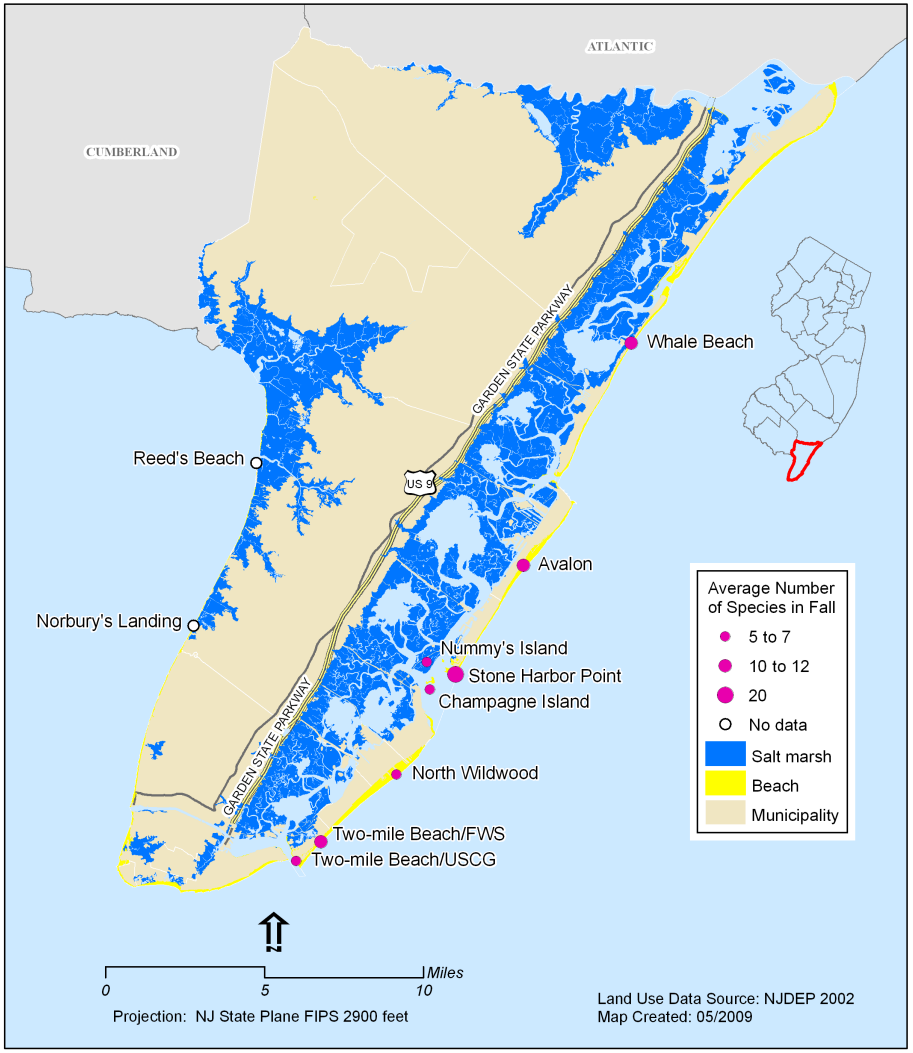

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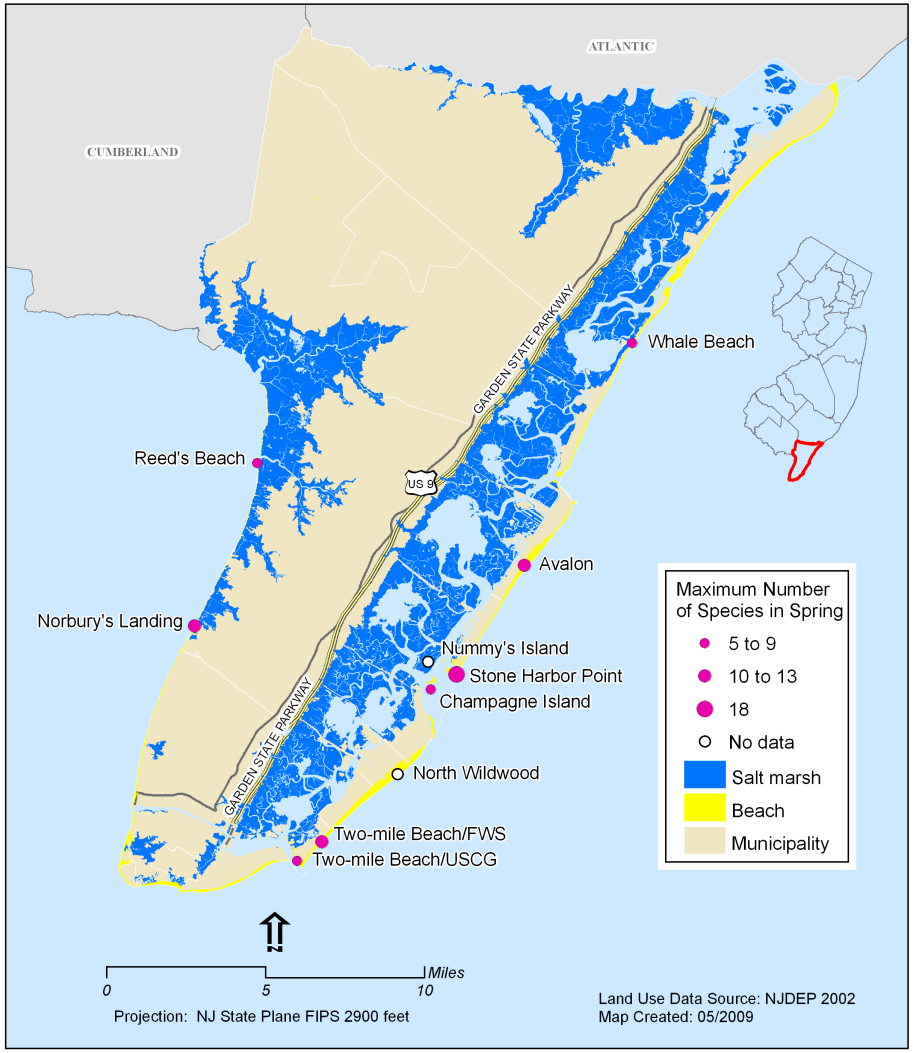

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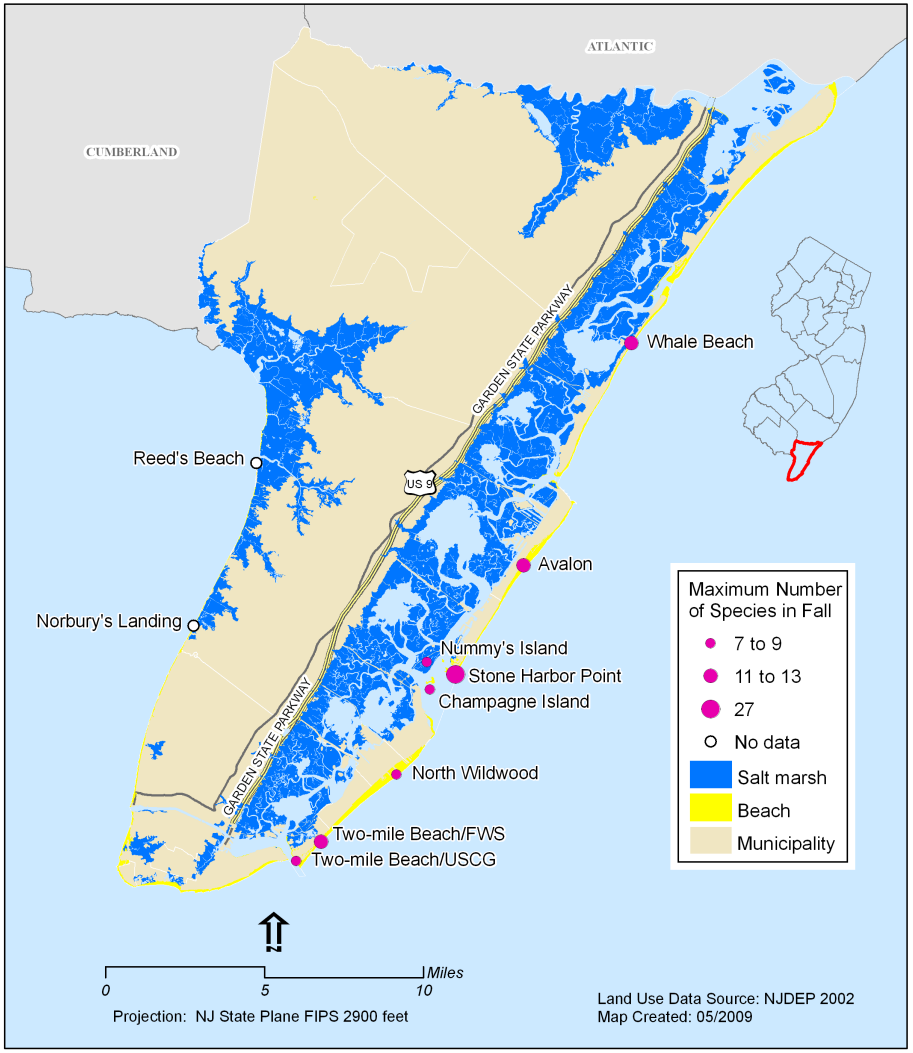

Shorebird survey data collected through New Jersey Audubon Society Citizen Science effort in collaboration with New Jersey Department of Environmental Protection Endangered and Nongame Species Program.

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Average Daily Count of All Shorebirds Reported During Spring Migration from 2006 to 2008 at 10 Survey Locations in Cape May County, NJ

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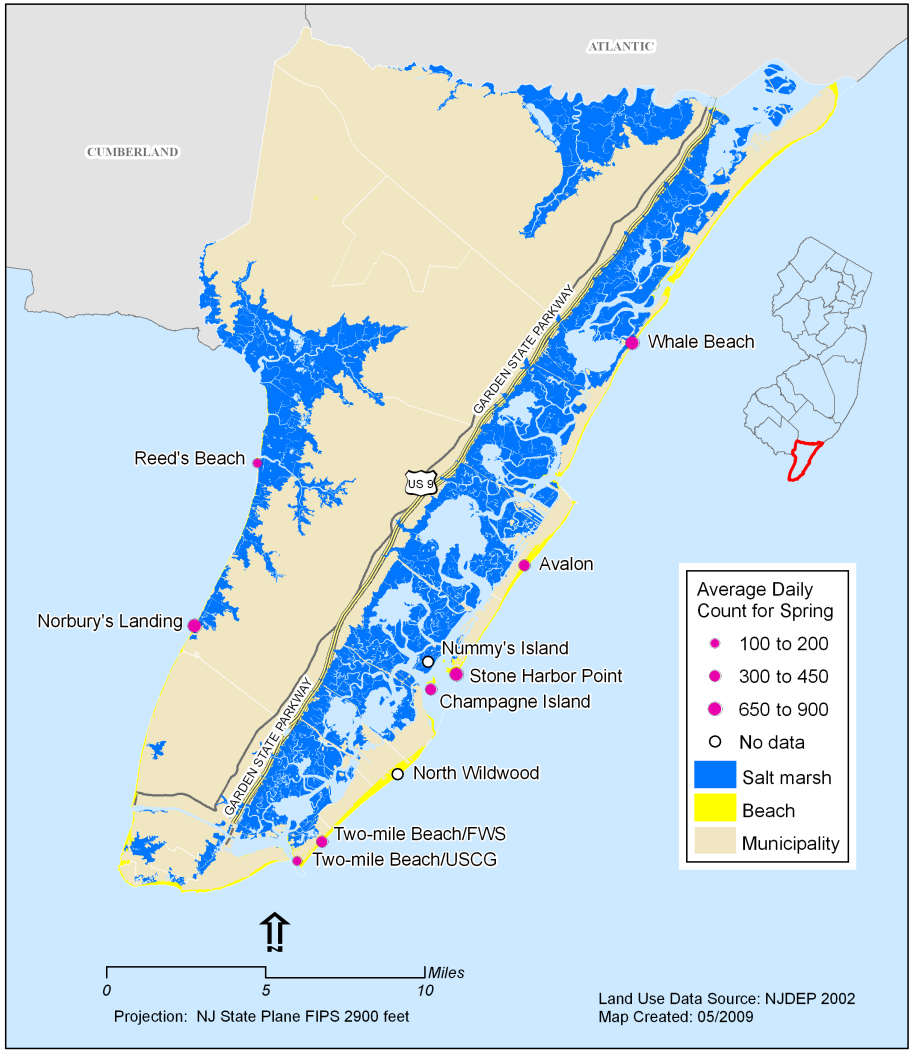

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Average Daily Count of All Shorebirds Reported During Fall Migration from 2006 to 2008 at 10 Survey Locations in Cape May County, NJ

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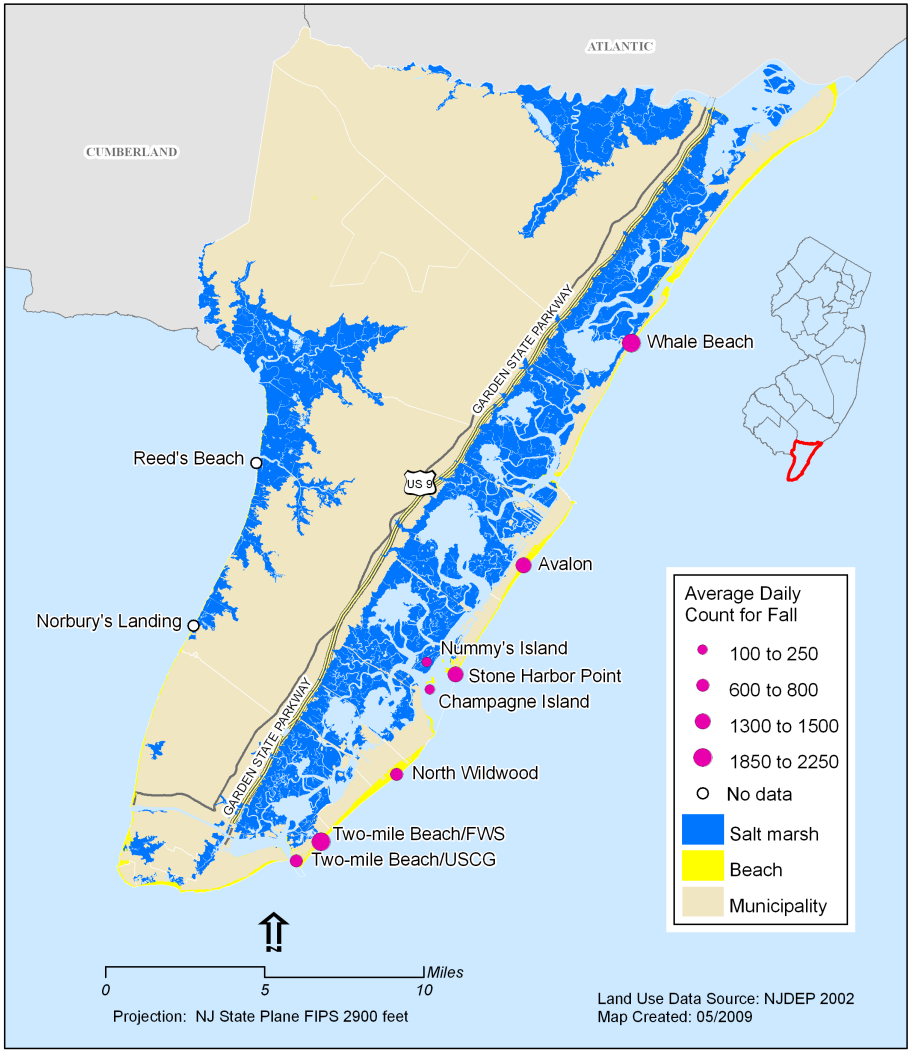

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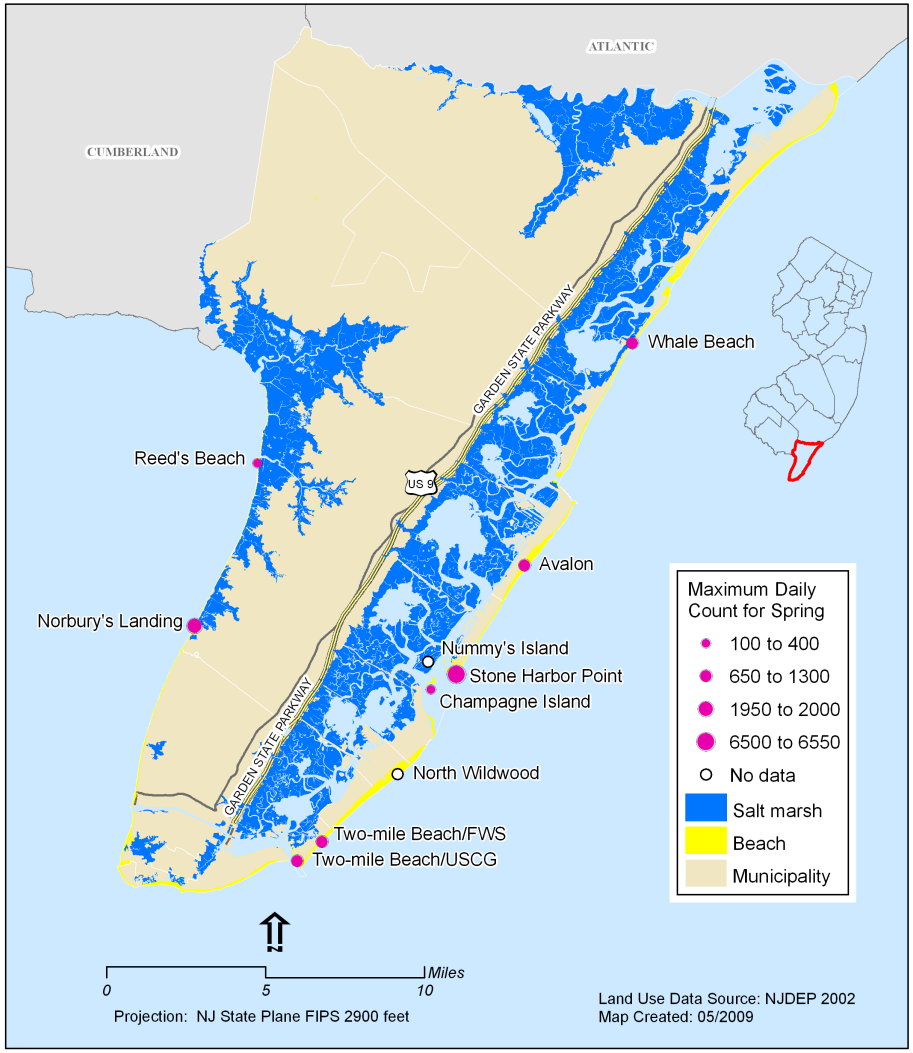

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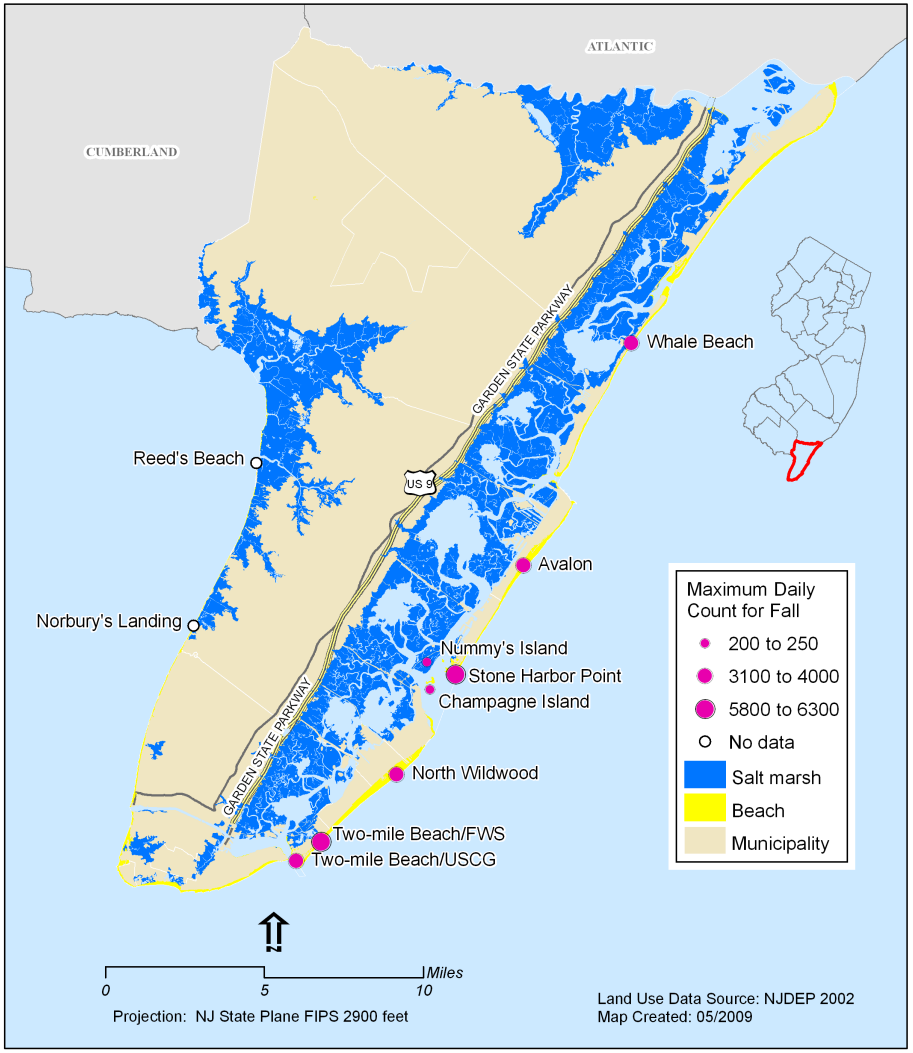

Shorebird survey data collected through New Jersey Audubon Society Citizen Science effort in collaboration with New Jersey Department of Environmental Protection Endangered and Nongame Species Program.

Total Number of Surveys	2006		2007		2008	
Survey Location	Spring	Fall	Spring	Fall	Spring	Fall
Avalon	5	8				
Champagne Island				2	1	6
Norbury's Landing					4	
North Wildwood				2		4
Nummy's Island				1		
Reed's Beach					1	
Stone Harbor Point	5	8	18	35	10	14
Two-mile Beach/FWS	5	8	5	8	5	7
Two-mile Beach/USCG	5	9	5	8	5	6
Whale Beach	5	11		10	4	10

Mean Daily Count Averaged Across Survey Visits		2006		2007		2008	
		Spring	Fall	Spring	Fall	Spring	Fall
Survey Site	Species	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Avalon	American Oystercatcher	4.2 ± 0.6	0.4 ± 0.3				
	Black-bellied Plover	0.2 ± 0.2	24.1 ± 14.9				
	Dunlin	4.4 ± 4.4	284.3 ± 273.8				
	Peep		3.1 ± 3.1				
	Piping Plover	5.0 ± 2.4	0.6 ± 0.4				
	Red Knot	3.4 ± 3.2	45.3 ± 43.5				
	Ruddy Turnstone	0.6 ± 0.6	1.9 ± 0.6				
	Sanderling	234.8 ± 109.2	715.0 ± 239.0				
	Semipalmated Plover	178.4 ± 111.8	208.5 ± 184.8				
	Semipalmated Sandpiper	5.0 ± 3.5	28.4 ± 24.6				
	Short-billed Dowitcher		1.9 ± 1.5				
	Western Sandpiper	0.8 ± 0.8	6.5 ± 6.2				
	Willet	0.8 ± 0.6					
Champagne Island	American Oystercatcher					16.0	13.5 ± 5.3
	Dunlin					30.0	
	Least Sandpiper					45.0	27.5 ± 19.9
	Piping Plover				6.0 ± 6.0		0.5 ± 0.3
	Red Knot				110.0 ± 10.0	42.0	
	Ruddy Turnstone					1.0	1.0 ± 0.6
	Sanderling					65.0	13.0 ± 9.8
	Semipalmated Plover					35.0	18.8 ± 10.6
	Semipalmated Sandpiper					125.0	20.8 ± 20.8
	Short-billed Dowitcher						0.3 ± 0.3
Norbury's Landing	American Oystercatcher					0.5 ± 0.3	
	Black-bellied Plover					5.0 ± 2.9	
	Dunlin					17.5 ± 11.8	
	Greater Yellowlegs					3.3 ± 2.9	
	Least Sandpiper					5.0 ± 5.0	
	Red Knot					63.0 ± 37.2	
	Ruddy Turnstone					93.8 ± 43.5	
	Sanderling					406.3 ± 258.3	
	Semipalmated Plover					17.8 ± 8.2	
	Semipalmated Sandpiper					260.0 ± 144.5	
	Short-billed Dowitcher					6.3 ± 6.3	
	White-rumped Sandpiper					1.0 ± 1.0	

Mean Daily Count Averaged Across Visits (cont.)		2006				2007				2008			
		Spring		Fall		Spring		Fall		Spring		Fall	
Survey Site	Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
North Wildwood	American Oystercatcher							67.5	67.5			3.3	0.5
	Black-bellied Plover							95.0	55.0				
	Dunlin							1200.0	1200.0				
	Red Knot							25.0					
	Ruddy Turnstone							60.0	60.0			5.3	4.3
	Sanderling							600.0					
	Semipalmated Plover											60.5	42.2
	Semipalmated Sandpiper											39.8	32.3
	Short-billed Dowitcher							1.5	0.5				
	Western Sandpiper											9.5	9.5
Nummy's Island	American Oystercatcher							112.0					
	Black-bellied Plover							25.0					
	Marbled Godwit							7.0					
	Red Knot							6.0					
	Ruddy Turnstone							10.0					
	Short-billed Dowitcher							18.0					
	Willet							59.0					
Reed's Beach	Dunlin									12.0			
	Least Sandpiper									18.0			
	Piping Plover									1.0			
	Ruddy Turnstone									26.0			
	Sanderling									60.0			
Stone Harbor Point	American Oystercatcher	3.2	1.1	82.3	74.1	8.0	3.3	44.7	6.9	4.6	0.8	13.9	6.2
	Black-bellied Plover	0.6	0.6	81.0	74.3	9.6	2.2	30.1	11.4	0.8	0.4	1.6	1.0
	Buff-breasted Sandpiper							0.0	0.0				
	Curlew Sandpiper					0.1	0.1						
	Dowitcher, spp	4.8	4.8	7.8	5.4			0.1	0.1				
	Dunlin	4.0	2.3	0.5	0.5	207.1	83.5	30.6	18.8	27.1	7.3	1.2	0.9
	Godwit							0.0	0.0				
	Greater Yellowlegs					0.3	0.2	2.1	0.5				
	Least Sandpiper			4.3	4.3	1.9	0.8	31.8	7.1	10.8	5.5	39.1	26.0
	Lesser Yellowlegs			0.3	0.3			0.2	0.2			0.1	0.1
	Long-billed Dowitcher							0.0	0.0			0.1	0.1
	Marbled Godwit			0.3	0.3			0.6	0.2				
	Pectoral Sandpiper							0.3	0.2				
	Peep			0.9	0.6								
	Piping Plover	5.4	2.0	0.5	0.3			0.3	0.2	0.2	0.2	3.7	2.4
	Red Knot	1296.0	1251.2	30.3	30.0	74.4	20.8	104.3	29.5	644.6	318.8	19.3	12.1
	Ruddy Turnstone	31.8	30.3	2.3	1.8	6.7	1.3	14.0	3.1	5.1	4.0	15.7	6.7
	Sanderling	75.8	33.5	331.0	147.7	31.2	10.4	315.5	48.1	104.3	27.9	1148.4	403.3
	Semipalmated Plover	180.6	118.8	235.1	174.4	70.8	27.8	244.8	37.5	55.8	21.0	396.7	186.2
	Semipalmated Sandpiper	3.2	2.7	178.8	167.4	205.6	57.5	233.1	46.1	30.8	13.8	220.4	155.0
	Short-billed Dowitcher	0.6	0.6			21.9	7.6	106.0	25.2	0.2	0.1	3.3	1.2
	Solitary Sandpiper							0.0	0.0				
	Spotted Sandpiper							0.5	0.1				
	Unidentified	3.0	3.0	132.9	90.1					20.0	20.0		
	Western Sandpiper			65.1	65.0	0.2	0.1	227.7	37.5			10.3	6.4
	Western Willet					0.1	0.1	0.8	0.6				
	Whimbrel					0.2	0.1	0.3	0.1				
	White-rumped Sandpiper					0.7	0.3						
	Willet			0.8	0.4	0.1	0.1	11.4	2.9			0.1	0.1
	Wilson's Phalarope							0.1	0.0				
	Wilson's Plover					0.1	0.1						
	Yellowlegs, spp			0.1	0.1			0.0	0.0				

Mean Daily Count Averaged Across Visits (cont.)		2006				2007				2008			
		Spring		Fall		Spring				Spring		Fall	
Survey Site	Species	Mean ± SE		Mean ± SE		Mean ± SE		Mean ± SE		Mean ± SE		Mean ± SE	
Two-mile Beach/FWS	American Oystercatcher	1.8 ± 0.8		3.0 ± 1.6		1.0 ± 0.4		2.6 ± 1.1		2.8 ± 1.1		0.6 ± 0.6	
	Black-bellied Plover	0.4 ± 0.2		1.5 ± 1.0		2.4 ± 1.5		0.1 ± 0.1		0.2 ± 0.2		0.3 ± 0.3	
	Dunlin	0.6 ± 0.6						3.1 ± 3.1		0.6 ± 0.6		0.6 ± 0.4	
	Piping Plover	0.2 ± 0.2		0.5 ± 0.5		2.2 ± 0.4		0.3 ± 0.2		1.0 ± 0.6		0.3 ± 0.2	
	Red Knot	3.0 ± 2.1		8.5 ± 6.4		9.0 ± 8.5		5.4 ± 5.0		32.2 ± 32.0		1.0 ± 0.7	
	Ruddy Turnstone	5.0 ± 2.5		15.4 ± 8.8		7.2 ± 4.7		4.5 ± 2.2		4.6 ± 1.4		13.7 ± 6.9	
	Sanderling	142.2 ± 39.4		1045.6 ± 314.0		201.0 ± 54.9		1074.6 ± 281.3		296.6 ± 129.5		1634.1 ± 487.2	
	Semipalmated Plover	44.8 ± 18.4		447.1 ± 361.8		54.8 ± 32.7		634.1 ± 237.5		62.2 ± 36.2		531.0 ± 245.7	
	Semipalmated Sandpiper	10.8 ± 7.1		11.9 ± 5.8		20.0 ± 7.7		105.9 ± 55.8		1.8 ± 1.2		163.7 ± 103.8	
	Short-billed Dowitcher			0.1 ± 0.1				0.1 ± 0.1					
	Spotted Sandpiper	0.2 ± 0.2											
	Western Sandpiper			0.8 ± 0.8				3.6 ± 2.4				0.3 ± 0.3	
	Willet									0.2 ± 0.2			
Two-mile Beach/USCG	American Oystercatcher	1.0 ± 0.4		0.2 ± 0.2		2.2 ± 0.7		0.4 ± 0.2		2.8 ± 0.4			
	Black-bellied Plover					0.6 ± 0.4				0.2 ± 0.2			
	Dunlin			16.7 ± 11.0				1.3 ± 1.3					
	Piping Plover	2.0 ± 0.5		0.2 ± 0.2		3.2 ± 0.4		2.5 ± 0.8		3.4 ± 1.2		0.3 ± 0.3	
	Red Knot	7.4 ± 4.9				0.2 ± 0.2		0.3 ± 0.3		8.0 ± 8.0			
	Ruddy Turnstone	2.2 ± 1.4		4.4 ± 2.4		1.6 ± 1.1		7.6 ± 5.4		5.2 ± 1.7		0.8 ± 0.7	
	Sanderling	92.2 ± 26.4		563.2 ± 231.4		145.4 ± 47.9		254.1 ± 117.6		71.6 ± 24.8		324.2 ± 126.4	
	Semipalmated Plover	45.8 ± 34.8		217.3 ± 129.3		88.2 ± 73.8		251.4 ± 191.1		67.4 ± 36.0		150.8 ± 132.3	
	Semipalmated Sandpiper	6.0 ± 3.1		22.8 ± 19.6		9.8 ± 6.6		5.9 ± 2.4		0.8 ± 0.5		1.0 ± 0.4	
	Western Sandpiper							1.0 ± 0.9					
	Willet									0.4 ± 0.4			
Whale Beach	American Oystercatcher	0.2 ± 0.2		6.4 ± 6.4						1.3 ± 0.5			
	Black-bellied Plover	1.6 ± 1.6		21.7 ± 14.1				58.1 ± 30.8		1.5 ± 1.0		1.8 ± 1.3	
	Dunlin	44.2 ± 43.7		38.7 ± 27.4				17.9 ± 12.0		0.3 ± 0.3		34.8 ± 24.0	
	Lesser Yellowlegs			0.1 ± 0.1									
	Peep							5.0 ± 5.0					
	Piping Plover	1.0 ± 0.8		0.2 ± 0.1				0.7 ± 0.3					
	Purple Sandpiper							0.1 ± 0.1				0.1 ± 0.1	
	Red Knot	7.8 ± 7.6		2.4 ± 1.7				7.7 ± 5.2					
	Ruddy Turnstone	1.8 ± 0.9		15.3 ± 7.9				6.5 ± 2.6		4.8 ± 2.1		7.6 ± 2.6	
	Sanderling	452.6 ± 83.8		1639.5 ± 142.6				1943.6 ± 307.5		349.0 ± 80.4		1897.0 ± 269.8	
	Sanderling + Dunlin							150.0 ± 150.0					
	Semipalmated Plover	199.0 ± 100.1		358.5 ± 156.8				600.1 ± 199.6		266.8 ± 158.0		78.3 ± 35.7	
	Semipalmated Sandpiper			49.8 ± 14.0				60.9 ± 16.9		17.3 ± 8.1		15.0 ± 5.0	
	Short-billed Dowitcher							1.5 ± 1.2		0.3 ± 0.3		0.1 ± 0.1	
	Spotted Sandpiper	0.2 ± 0.2											
	Western Sandpiper			2.6 ± 2.2				14.3 ± 4.6				0.5 ± 0.3	

Maximum Daily Count		2006		2007		2008	
Survey Location	**Species**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**
Avalon	American Oystercatcher	5	2				
	Black-bellied Plover	1	120				
	Dunlin	22	2200				
	Peep		25				
	Piping Plover	13	3				
	Red Knot	16	350				
	Ruddy Turnstone	3	5				
	Sanderling	501	2000				
	Semipalmated Plover	545	1500				
	Semipalmated Sandpiper	18	200				
	Short-billed Dowitcher		12				
	Western Sandpiper	4	50				
	Willet	3					
Champagne Island	American Oystercatcher					16	32
	Dunlin					30	
	Least Sandpiper					45	120
	Piping Plover				12		2
	Red Knot				120	42	
	Ruddy Turnstone					1	3
	Sanderling					65	60
	Semipalmated Plover					35	64
	Semipalmated Sandpiper					125	125
	Short-billed Dowitcher						2
Norbury's Landing	American Oystercatcher					1	
	Black-bellied Plover					10	
	Dunlin					50	
	Greater Yellowlegs					12	
	Least Sandpiper					20	
	Red Knot					150	
	Ruddy Turnstone					175	
	Sanderling					1100	
	Semipalmated Plover					39	
	Semipalmated Sandpiper					520	
	Short-billed Dowitcher					25	
	White-rumped Sandpiper					4	
North Wildwood	American Oystercatcher				135		4
	Black-bellied Plover				150		
	Dunlin				2400		
	Red Knot				25		
	Ruddy Turnstone				120		18
	Sanderling				600		
	Semipalmated Plover						185
	Semipalmated Sandpiper						135
	Short-billed Dowitcher				2		
	Western Sandpiper						38

Maximum Daily Count (cont.)		2006		2007		2008	
Survey Location	**Species**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**
Nummy's Island	American Oystercatcher				112		
	Black-bellied Plover				25		
	Marbled Godwit				7		
	Red Knot				6		
	Ruddy Turnstone				10		
	Short-billed Dowitcher				18		
	Willet				59		
Reed's Beach	Dunlin					12	
	Least Sandpiper					18	
	Piping Plover					1	
	Ruddy Turnstone					26	
	Sanderling					60	
Stone Harbor Point	American Oystercatcher	5	600	56	130	10	93
	Black-bellied Plover	3	600	30	380	4	13
	Buff-breasted Sandpiper				1		
	Curlew Sandpiper			1			
	Dowitcher, spp	24	45		5		
	Dunlin	10	4	1200	570	60	12
	Godwit				1		
	Greater Yellowlegs			4	10		
	Least Sandpiper		34	9	200	55	360
	Lesser Yellowlegs		2		6		1
	Long-billed Dowitcher				1		2
	Marbled Godwit		2		3		
	Pectoral Sandpiper				4		
	Peep		5				
	Piping Plover	12	2		8	2	34
	Red Knot	6300	240	367	762	2300	140
	Ruddy Turnstone	153	14	23	80	41	75
	Sanderling	205	958	160	1200	305	3575
	Semipalmated Plover	650	1410	400	800	185	2550
	Semipalmated Sandpiper	14	1350	800	1200	145	2200
	Short-billed Dowitcher	3		120	600	1	14
	Solitary Sandpiper				1		
	Spotted Sandpiper				3		
	Unidentified	15	660			200	
	Western Sandpiper		520	1	900		85
	Western Willet			1	18		
	Whimbrel			1	4		
	White-rumped Sandpiper			3			
	Willet		3	1	49		1
	Wilson's Phalarope				1		
	Wilson's Plover			1			
	Yellowlegs, spp		1		1		

Maximum Daily Count (cont.)		2006		2007		2008	
Survey Location	Species	Spring	Fall	Spring	Fall	Spring	Fall
Two-mile Beach/FWS	American Oystercatcher	4	14	2	8	6	4
	Black-bellied Plover	1	6	8	1	1	2
	Dunlin	3			25	3	3
	Piping Plover	1	4	3	1	3	1
	Red Knot	11	51	43	40	160	5
	Ruddy Turnstone	12	59	25	17	8	46
	Sanderling	246	2116	340	2572	748	3808
	Semipalmated Plover	100	2972	159	1656	199	1709
	Semipalmated Sandpiper	39	50	42	465	6	749
	Short-billed Dowitcher		1		1		
	Spotted Sandpiper	1					
	Western Sandpiper		6		16		2
	Willet					1	
Two-mile Beach/USCG	American Oystercatcher	2	2	4	1	4	
	Black-bellied Plover			2		1	
	Dunlin		75		10		
	Piping Plover	3	2	4	6	7	2
	Red Knot	24		1	2	40	
	Ruddy Turnstone	7	19	6	43	10	4
	Sanderling	186	1950	298	1001	135	789
	Semipalmated Plover	185	1175	383	1575	167	810
	Semipalmated Sandpiper	14	179	34	15	2	2
	Western Sandpiper				7		
	Willet					2	
Whale Beach	American Oystercatcher	1	70			2	
	Black-bellied Plover	8	118		279	4	12
	Dunlin	219	301		97	1	230
	Lesser Yellowlegs		1				
	Peep				50		
	Piping Plover	4	1		3		
	Purple Sandpiper				1		1
	Red Knot	38	18		51		
	Ruddy Turnstone	5	88		24	10	27
	Sanderling	780	2628		3356	583	3122
	Sanderling + Dunlin				1500		
	Semipalmated Plover	526	1603		1671	676	328
	Semipalmated Sandpiper		115		140	34	51
	Short-billed Dowitcher				12	1	1
	Spotted Sandpiper	1					
	Western Sandpiper		26		45		3

Most Common Species by Season and Overall – Total Counts for 2006 through 2008

Most Common Species in Spring	
Species (NJ Status)	Spring Count
Red Knot (T)	14,915
Sanderling (SC)	13,312
Semipalmated Plover	7,612
Semipalmated Sandpiper (SC)	5,530
Dunlin	4,380
Ruddy Turnstone	892
Short-billed Dowitcher	426
American Oystercatcher (SC)	309
Black-bellied Plover	238
Least Sandpiper	225
Unidentified	215
Piping Plover (E)	120
Dowitcher, spp	24
Greater Yellowlegs	19
White-rumped Sandpiper	16
Willet	9
Western Sandpiper	7
Whimbrel (SC)	3
Curlew Sandpiper	2
Spotted Sandpiper (SC)	2
Western Willet	1
Wilson's Plover	1
Buff-breasted Sandpiper	
Godwit	
Lesser Yellowlegs	
Long-billed Dowitcher	
Marbled Godwit	
Pectoral Sandpiper	
Peep	
Purple Sandpiper	
Sanderling (SC) + Dunlin	
Solitary Sandpiper	
Wilson's Phalarope	
Yellowlegs, spp	
Total	48,258

Most Common Species in Fall	
Species (NJ Status)	Fall Count
Sanderling (SC)	130,652
Semipalmated Plover	45,993
Semipalmated Sandpiper (SC)	16,836
Western Sandpiper	8,947
Dunlin	6,908
Red Knot (T)	5,022
Short-billed Dowitcher	3,811
Black-bellied Plover	2,984
American Oystercatcher (SC)	2,886
Least Sandpiper	1,860
Ruddy Turnstone	1,569
Sanderling (SC) + Dunlin	1,500
Unidentified	1,063
Willet	466
Piping Plover (E)	126
Peep	82
Greater Yellowlegs	75
Dowitcher, spp	67
Marbled Godwit	29
Western Willet	28
Spotted Sandpiper (SC)	16
Lesser Yellowlegs	13
Pectoral Sandpiper	10
Whimbrel (SC)	9
Long-billed Dowitcher	3
Purple Sandpiper	2
Wilson's Phalarope	2
Yellowlegs, spp	2
Buff-breasted Sandpiper	1
Godwit	1
Solitary Sandpiper	1
Curlew Sandpiper	
White-rumped Sandpiper	
Wilson's Plover	
Total	230,964

Most Common Species Overall			
Species (NJ Status)	Spring Count	Fall Count	Total Count
Sanderling (SC)	13,312	130,652	143,964
Semipalmated Plover	7,612	45,993	53,605
Semipalmated Sandpiper (SC)	5,530	16,836	22,366
Red Knot (T)	14,915	5,022	19,937
Dunlin	4,380	6,908	11,288
Western Sandpiper	7	8,947	8,954
Short-billed Dowitcher	426	3,811	4,237
Black-bellied Plover	238	2,984	3,222
American Oystercatcher (SC)	309	2,886	3,195
Ruddy Turnstone	892	1,569	2,461
Least Sandpiper	225	1,860	2,085
Sanderling (SC) + Dunlin		1,500	1,500
Unidentified	215	1,063	1,278
Willet	9	466	475
Piping Plover (E)	120	126	246
Greater Yellowlegs	19	75	94
Dowitcher, spp	24	67	91
Peep		82	82
Marbled Godwit		29	29
Western Willet	1	28	29
Spotted Sandpiper (SC)	2	16	18
White-rumped Sandpiper	16		16
Lesser Yellowlegs		13	13
Whimbrel (SC)	3	9	12
Pectoral Sandpiper		10	10
Long-billed Dowitcher		3	3
Curlew Sandpiper	2		2
Purple Sandpiper		2	2
Wilson's Phalarope		2	2
Yellowlegs, spp		2	2
Buff-breasted Sandpiper		1	1
Godwit		1	1
Solitary Sandpiper		1	1
Wilson's Plover	1		1
Total	48,258	230,964	279,222

E = Endangered in New Jersey
T = Threatened in New Jersey
SC = Special Concern in New Jersey