Accessing the Impact of Sea Level Rise
On Nesting Sites of Diamondback Terrapins (*Malaclemys terrapin, terrapin.)*
In Cape May County New Jersey
Joe Pignatelli

Introduction

The northern diamondback terrapin (*Malaclemys terrapin, terrapin.)* is native to New Jersey inhabiting the brackish waters of the coastal saltwater marshes, inlets, and estuaries. It is a diurnal species that is active between May and October in New Jersey's coast. In early June the female terrapin emerges from the brackish water and will venture to the same dunes every year, where she will lay approximately 10 eggs(Burger 1976). The terrapin prefers sparsely vegetated areas (Burger and Montevecch, 1975) with a substrate of sand (Roosenburg, 1994). After about 80 days of gestation, the eggs will hatch and the hatchling terrapins will quickly search for the cover of vegetation. (Ernst, Lovich and Barbour, 1994)

The northern diamondback terrapin is currently listed as a species of special concern by the New Jersey Department of Environmental Protection(http://www.state.nj.us/dep/fgw//ensp/pdf/spclspp.pdf), which means that its population in the state is declining. The terrapin has many natural predators which do not just pray on adults or hatchlings but rather seem to prefer the nests of unhatched eggs. In a study by Burger (1977) only 36% of nests were not destroyed by mammalian. Mammals are not the only organism ravaging nests for nourishment, in 1988, Steggmann and authors observed American Beach grass roots entering terrapin nests infiltrating and killing the eggs in order to uptake their nutrients. Of the nests not predated, only 69% of the eggs hatched and of that only 76% emerged from their nest. It was observed that of the over 2,200 eggs laid only 157 emerged from their nests (Burger, 1976). Once emerged, the young routinely fall victim to small mammals and avian predators, however the biggest threat to the survival of the terrapin is the human (Ernst, Lovich and Barbour, 1994).

Throughout the 18th and early 19th century the diamondback terrapin was routinely harvested for the dinner plate. It is said that the terrapin makes an excellent soup stock. Fortunately for the terrapin, harvest of its meat is now illegal in most of its range and the turtle is no longer effected by over harvest. However, this does not prevent drowning deaths of turtles incidentally captured in crab fishing pots(Wood, 1997). Today the biggest threat to the turtle is habitat loss as we increasingly develop our shorelines. With development comes pollution and waste which is damaging the habitat that was not drained for development. With development came roads, and these roads introduce the terrapin to one of its most formable enemies, the automobile. As the females leave the safety of the water to nest they are being forced to cross roads to find suitable nesting sites. The crossing of the roads leads to many gravid females dying in automobile altercations(Wood, et al, 2004). Despite a stabilized population and the work of conservation organizations like The Terrapin Conservation Group and The Terrapin

Institute the future for the Diamondback Terrapin is looking grim. In addition to dealing with illegal harvesting, bycatch death, nest predation, pollution, habitat loss, and cars the terrapin will soon have to combat sea level rise.

Background

The world has been experiencing a net rise in sea level of 2mmper year over the last 7,000 years, but vertical sediment accumulation has prevented any adverse effects, in New Jersey. Today, in New Jersey the number is closer to 3.5 mm per year, a drastic increase of 75% a year (Stanley, 2004). This increased rate of sea level rise is no longer being offset by vertical accumulation and the coastal deposition of sand and natural processes that restore and protect the coast line are failing to counteract the increased rate in the Garden State. As a result of the sea level rise New Jersey can expect to see the vulnerability of its coastal communities increase, permeate inundation in low lying areas, saline intrusion into the aquifer, as well as increased flooding and erosion. A model proposed by Coopers, Beevers, and Oppenheimer (2008) suggests that we will see a rise as great as 0.61 to 1.22 meters in the next century and cause 1-3% of the state to become permanently inundated. This model is particularly troubling for the state of New Jersey because its barrier islands only have an elevation of approximately 2 meters. It is also very likely that the northern diamondback terrapin will also be affected by the ecological changes.

A study of sea turtle nesting in the Caribbean island of Bonaire showed the effects of sea level rise. The beaches of Bonaire have an elevation of just .3 to 1.8 meters above the high water mark, which is similar to the gradual slopes of New Jerseys coast. There a .2 meter rise of sea level will inundate 14% of the beach and endanger 11% of the turtles nesting sites, a .5 meter rise will lead to a 23% endangerment and a .9 meter rise will endanger 50% of the known sea turtle nesting sites. If the models of sea level rise are correct the sea turtles of the Caribbean will simply run out of nesting sites, and the major reason for these results is the development beyond the beach. And it should be noted that the Jersey shore is much more developed then the beaches of the Caribbean.

Objectives

The specific objectives of this study are to:
- map and assess sea level rise for the year 2100 given 0.6 meter and 1.2 meter rise
- map current suitable diamondback terrapin nesting sites
- map suitable nesting sites given estimated sea level rise scenarios
- determine the percentage of primary and secondary nesting habitats affected by sea level rise

Methods

<u>Modeling and Assessing Sea Level Rise</u>

Sea level rise was modeled using LiDAR data from New Jersey Coastal Management Program. The data has a 13cm vertical accuracy and a 2m horizontal resolution. This data was able to provide a very accurate digital elevation model (DEM). This DEM was used as a raster data set and reclassified in Arc Map version 9.3 using the spatial analysis reclassify tool. The DEM was reclassified to show 0.0 meter rise, 0.6 meter rise 1.2 meter rise and spring high tides of all three rise scenarios by adding 2.4 feet to each.

All of the datasets were used as raster within the Universal
Transverse Mercator projection system using the North American Datum of 1983

Mapping Diamondback Terrapin Nesting Sites

Terrapin nesting site suitability was determined using the criteria developed by Jeremy Feinberg and Russell Burke on nesting ecology of terrapins in Gateway National Recreation Area, New York and correspondence with researchers at the Wetlands Institute of Stone Harbor. Nesting sites were defined as sandy well drained soils with a land use land cover of agriculture, forest or barren, which included beaches. Within 250 meters of zero sea level and beyond the spring high water mark. Any areas that were obstructed by bulkheads were classified as unsuitable. Soil type was determined by using the Natural Resources Conservation Service, SSURGO (Soil Survey Geographic database) from 2006. Urban, agriculture and barren land uses as determined using the New Jersey Department of Environmental Protection (NJDEP) land use/land cover dataset for 2002. Bulkheads were identified using NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA) Shoreline Typing for Coastlines of New Jersey Along Its Atlantic and Inland Bays data set for 1993. The 250 meter potential nesting zone was developed by using ERDAS Imagine version 9.2 which reclassified the DEM for 0.0 rise was imported into Imagine and the GIS Analysis search tool was used to set the distance to search in pixels to 125, because of 2m horizontal resolution. The outputs were opened in Arc Map and converted to polygons using the spatial analysis, convert feature, rater to raster to feature tool.

Map suitable nesting sites given estimated sea level rise scenarios

The same technique was applied to determine possible nesting sites for all sea level rise scenarios of 0.6 and 1.2 meter rise.

Determine the percentage of primary and secondary nesting habitats

The x tools pro tool bar was added to Arc Map and the table operations; calculation tool was used to determine the acres of optimal and secondary nesting habitats. The percentages of nesting sites under each scenario were determined by taking the amount of optimal and secondary nesting sites available and dividing it by the total area of the 250 meter zone not affected by the spring high water line.

Results

Assessing Sea Level Rise for 2100

Sea level rise of 0.6 meters with inundate 63765.392599 acres in Cape May County, which is approximately 1.3% of the county. A rise scenario of 1.2 meters will inundate 75821.328369 which is approximately 1.57% of the county.

Assessing Nesting Sites of Diamondback Terrapins

At 0 sea level rise the diamondback terrapin will have 856.3364 acres of optimal nesting habitat in Cape May County. It will also have 1962.698 acres of secondary nesting habitat along road ways. Of the available habitat 5.1% of the land in the 250 meter buffer would be suitable for nesting with 3.6% secondary nesting habitat and 1.57% being optimal. Given 0.6 meter rise there is a slight decrease in secondary habitat of 77.09 acres to 1885.604 and a substantial increase in optimal sites to 2235.474.of the total land in the 250 meter buffer 5.8% is secondary nesting sites and 6.96% is optimal. Under the 0.6 meter rise we see an increase in the total amount of habitat to 2424.078 acres. With 1.2 meter sea level rise we will see a drastic increase in optimal nesting sites and almost no secondary left. There will be 8643.24 acres of optimal sites and only 32.13 acres of secondary site remaining. Of land area in the 250 m buffer 26.2246 % will be optimal nesting sites.

scenerio	optimal	secondary	total	Percent Secondary	Percent Optimal
no rise	856.3364	1962.698	54403.77	3.607650341	1.574039
.6 rise	2235.474	1885.604	32095.88	5.874908219	6.964988
1.2 rise	8643.243	32.13464	32958.53	0.097500215	26.2246

Discussion

Prior to completing the model is was believed that sea level rise would inundate the know nesting sites and the 250 meter nesting zone would fall on developed land drastically decreasing the amount of terrapin nesting sites. This was not the case. The increase in nesting sites is due to the fact that sea level rise is inundating the developed coast line and the new nesting sites are actually more inland then the human developed landscape. This point is reiterated by the decrease in secondary nesting sites. The secondary sites are located along road ways. Once the roadways become inundated there will no longer be criteria for secondary nesting sites. Less secondary sites means less human infrastructure.

Caveats

It must be noted that this model is not perfect. It was unable to determine specific vegetation communities, and percentages of cover which are vital to the terrapin nesting habitat. It is also impossible to determine how these communities will change by 2100 and thus any predicted optimal sites may not be suitable do to vegetation. Soil was used as one of the main criteria for evaluating sites suitability for terrapin nesting. In the 0.0

meter rise scenario a larger percentage of nesting sites were ruled unsuitable due to soil type then in either of the two rise scenarios. This is due to the fact that wetland and routinely flooded soils are more common around the coast and when we moved inland with sea level rise the soil data remained constant. A second model would have to be used to determine the new soil types before a site can be rules as optimal. There was also a problem using the soil data in that there are dredged islands in Cape May County that the terrapins do utilize for nesting, but they did not show up having different soil types then the surrounding areas. Finally the terrapin prefers to nest on dunes, this was very hard to determine for the 0.0 meter rise scenario and impossible to predict in the future

Conclusion

Today the diamondback terrapin is predominately nesting at the secondary nesting sites along roadsides. As these nesting sites become inundated new optimal or natural sites will emerge. As sea level continues to rise the secondary nesting sites will be all but lost and the new natural sites will be the predominate nesting sites used by diamondback terrapins. This model suggests that the diamondback terrapin which is listed as a species of special concern will benefit from seal level rise. As sea level rises the turtle will see an increase in natural habitat, a decline in the use of secondary nesting sites which will directly lead to decrease in road mortalities.

Work cited

Burger, J. 1977. Determinants of hatching success in Diamondback Terrapin, Malaclemys terrapin. American Midland Naturalist 97:444–464.

Burger, J. and W. A. Montevecchi. 1975. Nest site selection in the terrapin Malaclemys terrapin. Copeia 1975:113–119.

Cooper, M.J., Beevers, M.D., Oppenheimer, M. (2008) The potential impacts of sea level rise on the coastal region of New Jersey, USA Climatic Change (2008) 90:475–492.

Feinberg, J.A and R.L. Burke. Nesting Ecology and Predation of Diamondback Terrapins, Malaclemys terrapin, at Gateway National Recreation area, New York. Journal of Herpetology 27(3) :517-526.

Fish M.F., I.M. Cote, J.A. Gill, A.P. Jones, A. Renshoff, and A.R. Watkinson (2003) Predicting the Impact of Sea-Level Rise On Caribbean Sea Turtel Nesting Habitat. Conservation Biology 19(2): 482-491.

Ernst, C. H., J. E. Lovich, and R. W. Barbour. 1994. Turtles of the United States and Canada. Washington (DC): Smithsonian Institution Press.

Intergovernmental Panel on Climate Change (IPCC) (2007) Climate change 2007: The physical science basis, Summary for Policymakers. IPCC, Geneva, 1–18. (cited in Cooper e)

Psuty NP, Ofiara DD (2002) Coastal hazard management, lessons and future directions from New Jersey. Rutgers, New Brunswick

Stanley A, Miller KG, Sugarman PJ (2004) Holocene sea-level rise in New Jersey: an interim report. New Jersey Department of Environmental Protection, Trenton, NJ, USA

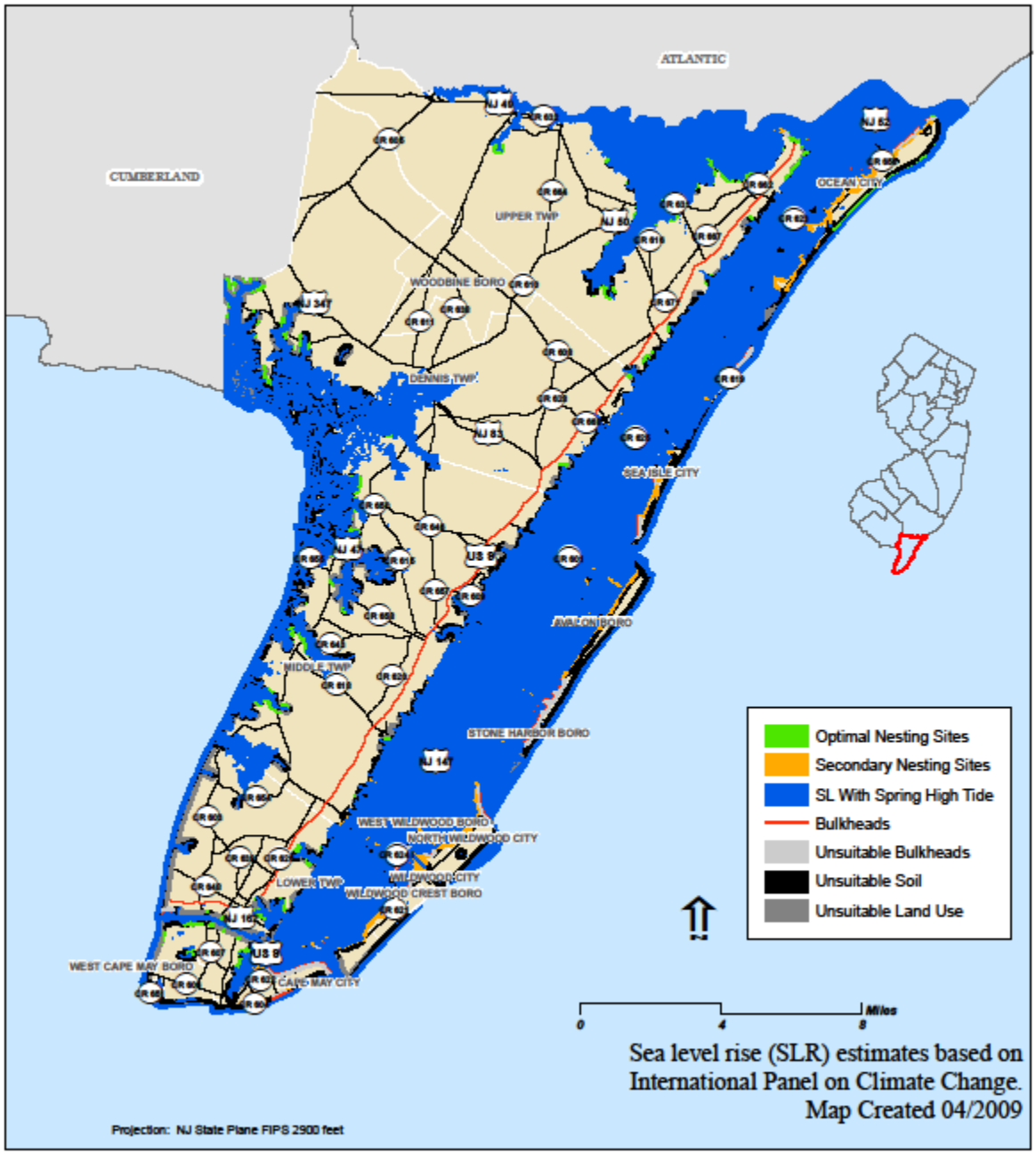
Stegmann, E. W., R. B. Primark, and G. S. Ellmore. 1988. Absorption of nutrient exudates from terrapin eggs by roots of Ammophila breviligulata. Canadian Journal of Botany 66:714–718.

Wood, Roger C. 1997. The impact of commercial crab traps on northern diamondback terrapins, *Malaclemys terrapin terrapin. In* J. Van Abbema (ed.), Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—An International Conference, pp. 21–27. 1993

Wood, Roger C. and Rosalind Herlands. 1997. Turtles and Tires: The impact of roadkills on northern diamondback terrapins, *Malaclemys terrapin terrapin*, populations on the Cape May Penunsula, southern New Jersey. *In* J. Van Abbema (ed.), Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—An International Conference, pp. 46–53. 1993

Accessing
Diamondback Terrapin Nesting Site Suitability for Cape May County, NJ

RUTGERS
School of Environmental and Biological Sciences

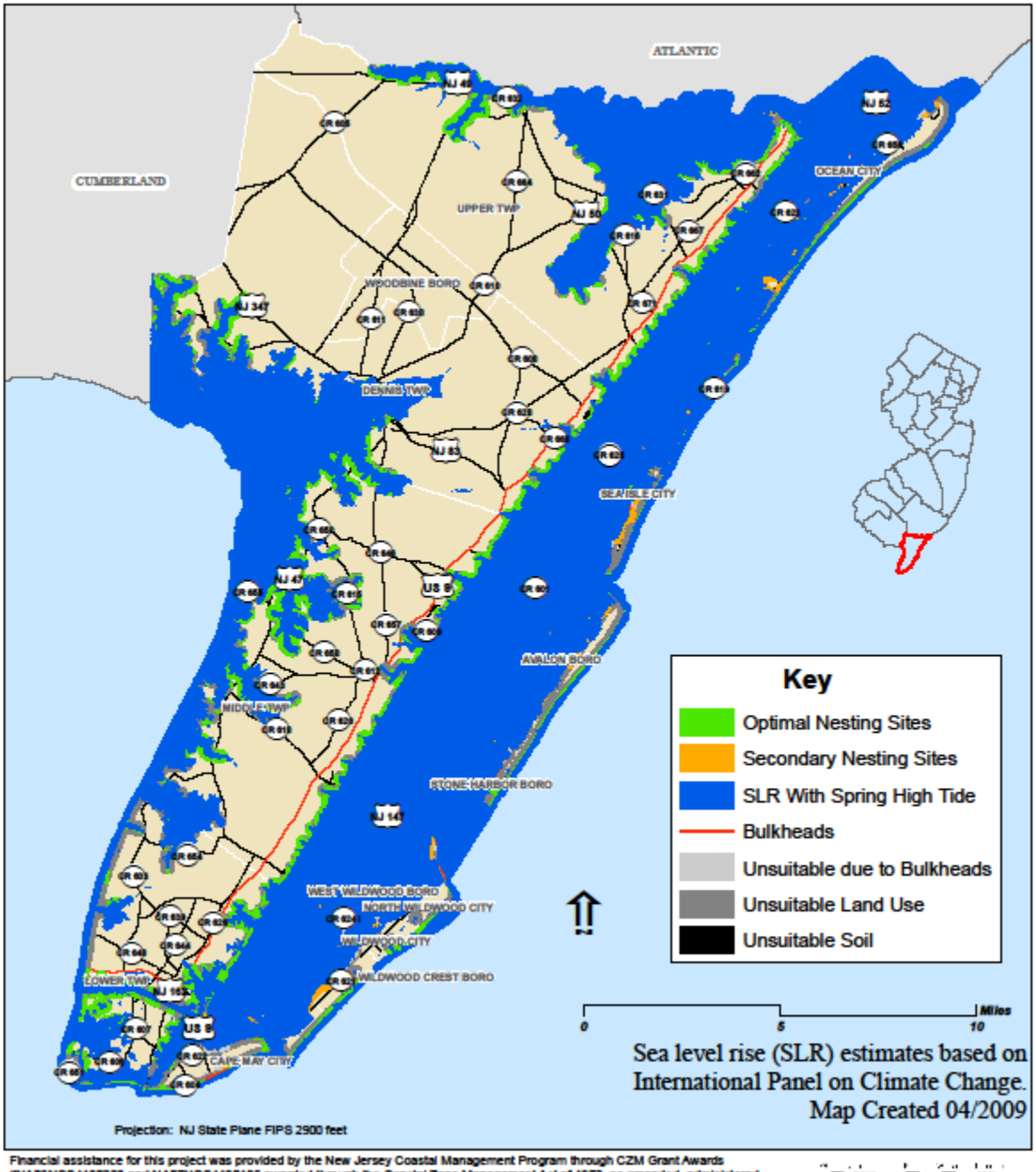


Financial assistance for this project was provided by the New Jersey Coastal Management Program through CZM Grant Awards #NA06NOS4190228 and NA07NOS4190186 awarded through the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National 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.

CRSSA

Accessing The Implications of 0.6m Sea Level Rise on Diamondback Terrapin Nesting Site Suitability for Cape May County, NJ

RUTGERS
School of Environmental and Biological Sciences

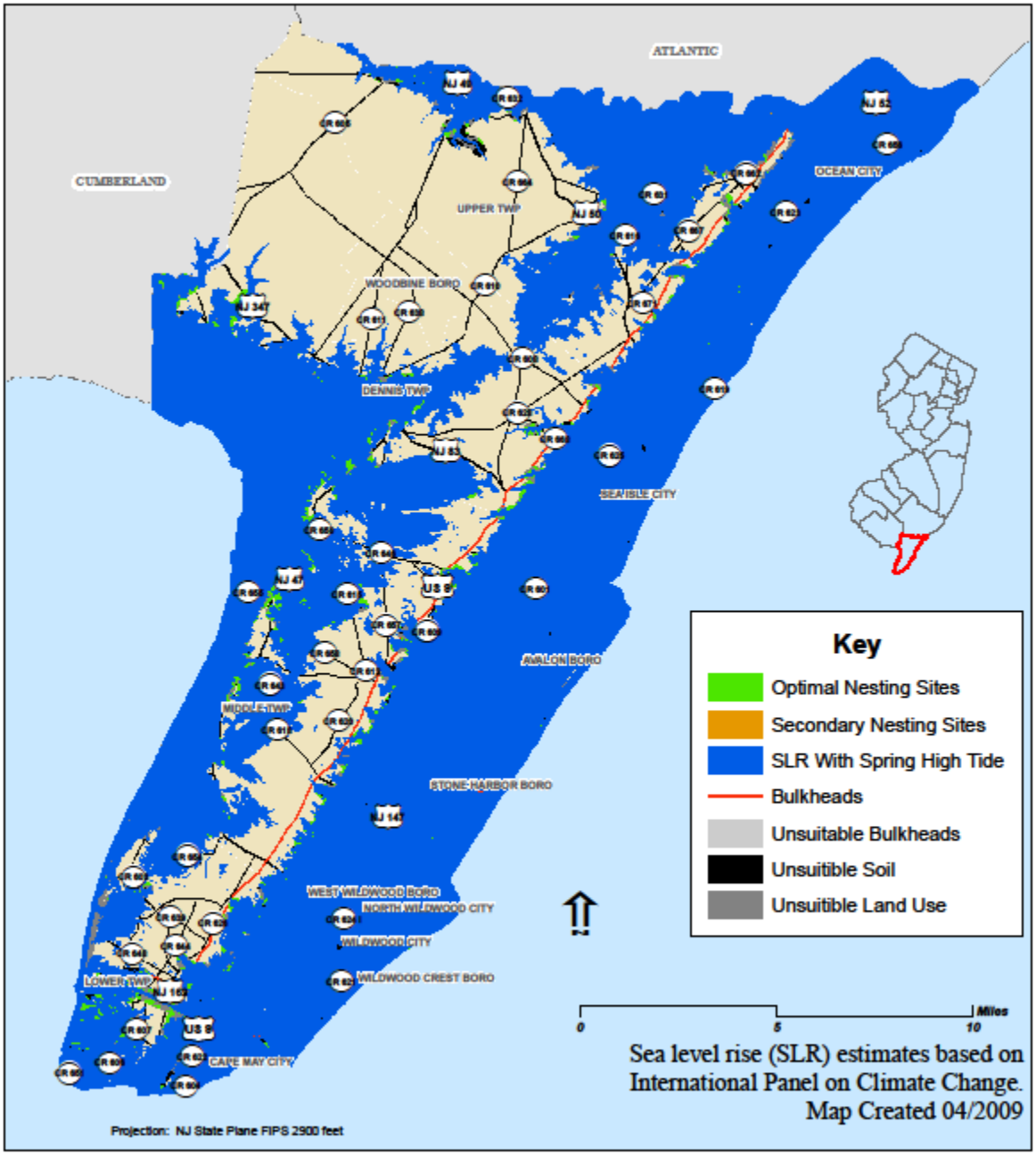


Financial assistance for this project was provided by the New Jersey Coastal Management Program through CZM Grant Awards #NA06NOS4190228 and NA07NOS4190186 awarded through the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National 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.

CRSSA

Accessing The Implications of 1.2m Sea Level Rise on Diamondback Terrapin Nesting Site Suitability for Cape May County, NJ

RUTGERS
School of Environmental and Biological Sciences



Financial assistance for this project 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.

CRSSA

scenerio	optimal	secondary
no rise	856.3364	1962.698
.6 rise	2235.474	1885.604
1.2 rise	8643.243	32.13464

Percent Secondary	Percent Optimal
3.607650341	1.574039
5.874908219	6.964988
0.097500215	26.2246