Historical Analysis and Map of Vegetation Communities, Land Covers, and Habitats of Assawoman Wildlife Area
Sussex County, Delaware

Little Assawoman Bay and Indian River Bay Watersheds

Submitted to:

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CHAPTER 1: INTRODUCTION AND METHODS

Setting of Assawoman Wildlife Area

Assawoman Wildlife Area is located in southeastern Sussex County, Delaware (Figure 1.1). Four tracts totaling 2,899 acres comprise the wildlife area. Two tracts, Miller Neck (1,312 acres) and Muddy Neck (1,028 acres) are located to the east of Roxanna on the western shore of Little Assawoman Bay. The Piney Neck Tract (473 acres) is located at the eastern end of Piney Neck on Indian River Bay. The South Bethany Tract (86 acres) is located just south of the town of Bethany Beach on the Coastal Strand, east of Little Assawoman Bay.

Figure 1.1. Location of tracts within Assawoman Wildlife Area

History and Formation of Assawoman Wildlife Area

Early History of the Land

Thomas Fenwick owned and used the land that is now Assawoman Wildlife Area, for farming and forestry products in the early 1700's. At this time there Little Assawoman Bay had an inlet leading into it called Little Assawoman Inlet[1], which later filled in the 1800's. A commercial wharf was located at Mulberry Landing in the late 1800's, helped in part by the opening of Assawoman Canal in 1891, which connects Little Assawoman Bay with White Creek, a tributary to Indian River Bay[2]. The canal remains today and was recently dredged in 2010. Later Mulberry Landing along with Strawberry Landing became popular swimming holes. At the start of the 20th century, a group of eight families farmed parcels ranging from 35 to 303 acres.[3]

Formation of Assawoman Wildlife Area

In 1935-1936 the Delaware Forestry Project of the Land Utilization Division under the U.S. Department of Agriculture purchased the land which later became Assawoman Wildlife Area. Between 1936 and 1943, forests were cleared of underbrush in order to prevent forest fires. At this same time the roads in the area were said to "wind through acres of pine and holly" and "small ponds are planted in widgeon grass for waterfowl." The primary use of the land was for hunting and for the logging of eastern red cedar.[4]

Beginning in 1943, the Delaware Board of Fish and Game Commissioners leased the lands comprising Delaware Forest Project DL-LU-1 for 99 years from the U.S. Department of Agriculture.[5] The lease was modified in 1946 to include additional properties. While under lease, six tidal salt marshes comprising a total of 264 acres were impounded to increase freshwater abundance and shorebird habitat. In the late 1940's, Camp Barnes was established in the northern part of the current Miller Neck Tract.[6] In 1954 the lands under the lease were surrendered to the State of Delaware to become Assawoman Wildlife Area. Since 1954 two additional properties, Piney Point Tract and the South Bethany Tract, have been added to the Wildlife Area.

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[1] Jones, Frederick Robertson. 1904. The History of North America: Vol. 4: The Colonization of the Middle States and Maryland. (Philadelphia: George Barrie and Sons).

[2] United States, Government Printing Office. 1922. Congressional Serial Set 8006. House Documents Vol. 18.

[3] Gano, Robert D. 1988. Comprehensive Wildlife Management Plan for the Assawoman Wildlife Area-Baltimore Hundred, Sussex County, Delaware. Delaware Division of Fish and Wildlife and the Fish and Game Advisory Council.

[4] Todd, Michael. Date unknown. Assawoman Bay Wildlife Area Management Plan. Delaware Division of Fish and Wildlife.

[5] Todd, Michael. Date unknown. Assawoman Bay Wildlife Area Management Plan. Delaware Division of Fish and Wildlife.

[6] Olsen, Marilyn. 2001. State Trooper: America's state troopers and highway patrolmen. (Paducah: Turner Publishing Company).

Soils and Geology of Assawoman Wildlife Area

Underlying Geology

As best as can be told, given that a comprehensive geologic map has not been completed for this area, all of the tracts of the Assawoman Wildlife Area are underlain by the Omar Formation, a geological formation common to the Inland Bays region. The Omar Formation is described as "a heterogeneous unit consisting of fine to coarse sand, silty sand, clayey silt, and silty clay."[7]

Soil

Five soils are prominent in Assawoman Wildlife Area including Broadkill Mucky Peat (in salt marshes), Hurlock sandy loam, Hurlock loamy sand, Klej loamy sand, and Mullica mucky sandy loam. Other minor soils include Purnell peat, Transquaking and Mispillion soils, Askecksy loamy sand, Hammonton sandy loam, Hammonton loamy sand, and Mullica-Berryland complex. Most of Assawoman Wildlife Area lies below five feet above mean sea level (msl); making it one of the most vulnerable wildlife areas to sea level rise in the near future.

[7] Groot, Johan J., Kelvin W. Ramsey, and John F. Wehmiller. 1990. The Ages of the Bethany, Beaverdam, and Omar Formations of Southern Delaware. Delaware Geological Survey, Report of Investigations, No.47.

Miller Neck Tract Soils

Four soils are prominent in the Miller Neck Tract and include Hurlock Loamy Sand (262 acres), Broadkill Mucky Peat (250 acres), Klej Loamy Sand (248 acres), and Water (231 acres). Other minor soils include Transquaking and Mispillion Soils (74 acres), Askecksy Loamy Sand (67 acres), Mullica Mucky Sandy Loam (63 acres), and Manahawkin Muck (58 acres).

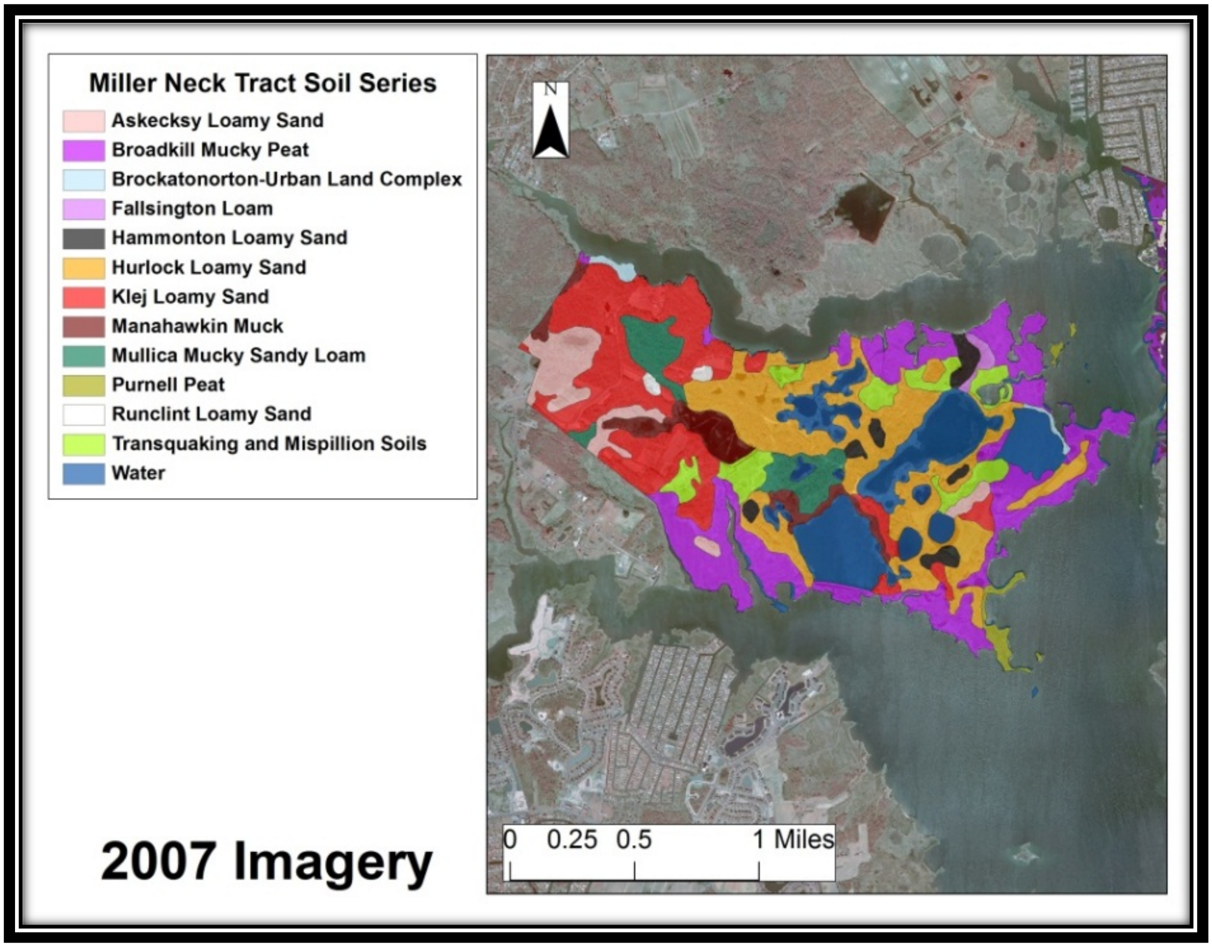

Figure 1.2. Miller Neck Tract Soil Map

Muddy Neck Tract Soils

Three soils are prominent in the Muddy Neck Tract and include Hurlock Sandy Loam (342 acres), Mullica Mucky Sandy Loam (182 acres), and Broadkill Mucky Peat (162 acres). Other minor soils include Mullica-Berryland Complex (74 acres), and Transquaking and Mispillion Soils (70 acres).

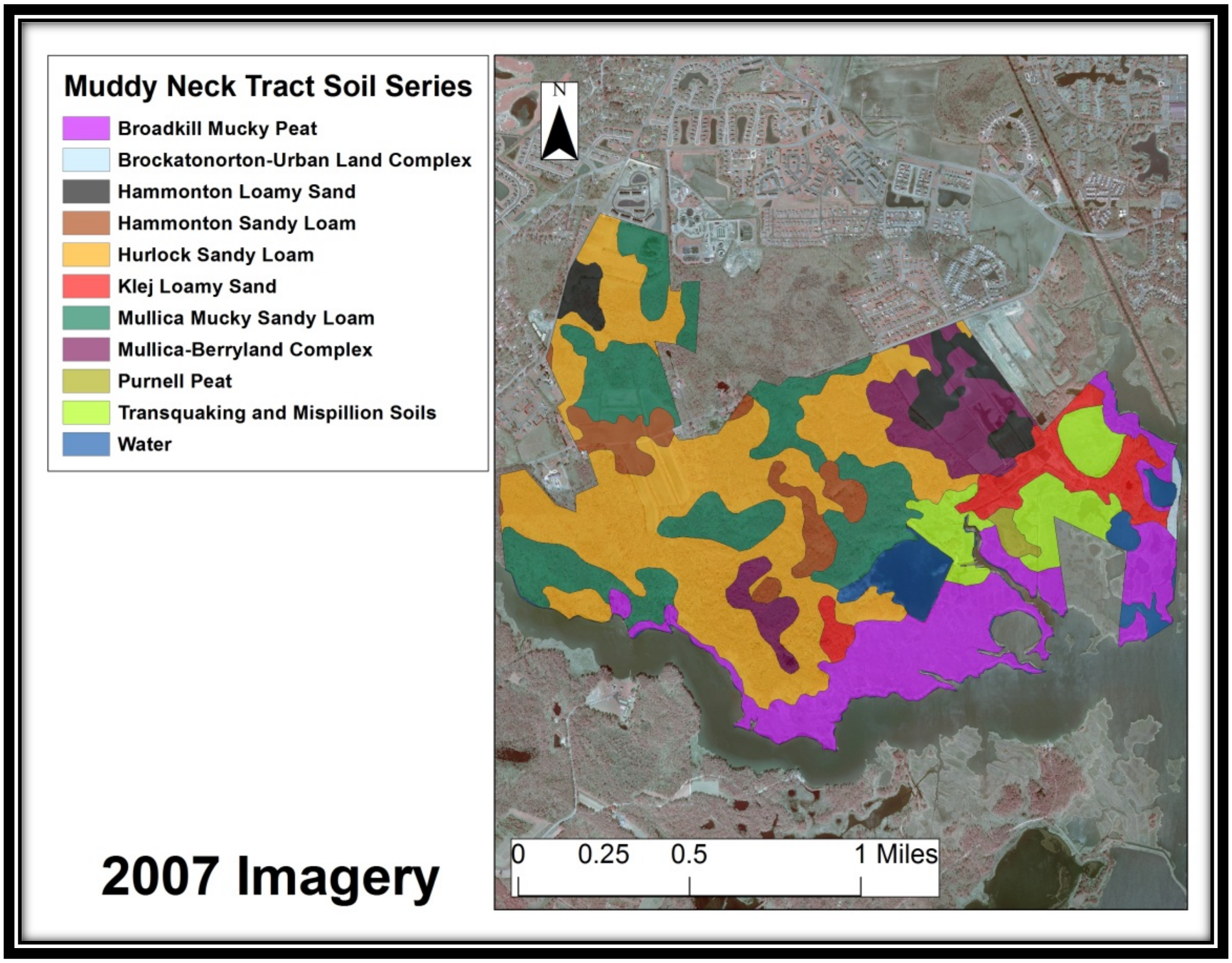

Figure 1.3. Muddy Neck Tract Soil Map

Piney Point Tract Soils

Two soils are prominent in the Piney Point Tract and include Broadkill Mucky Peat (170 acres) and Klej Loamy Sand (104 acres). Purnell Peat (57 acres) is the only minor soil.

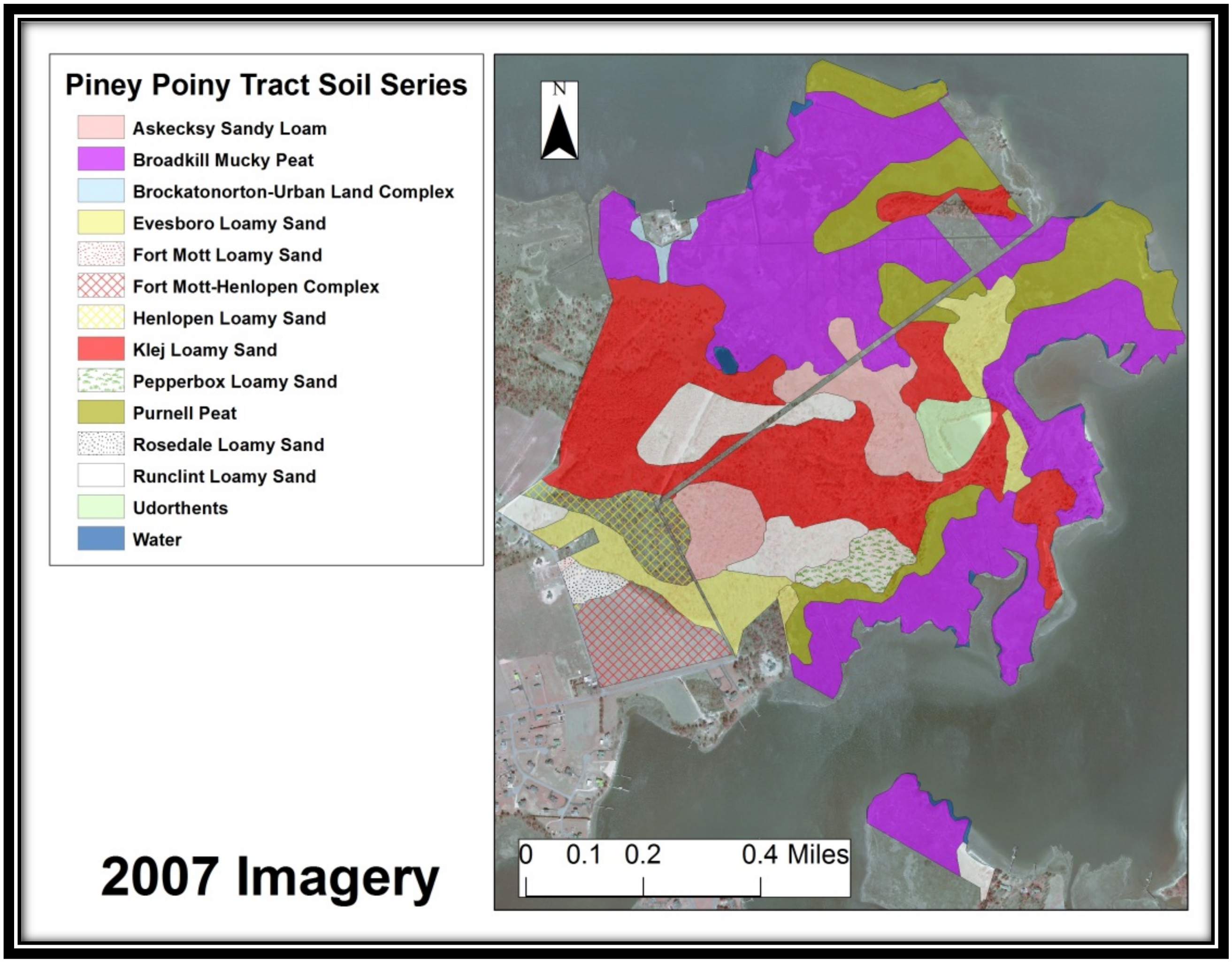

Figure 1.4. Piney Point Tract Soil Map

South Bethany Tract Soils

Two soils are prominent in the South Bethany Tract and include Purnell Peat (35 acres) and Acquango-Beaches Complex (28 acres). Saltpond Mucky Sand (10 acres) is the only minor soil.

Figure 1.5. South Bethany Tract Soil Map

Elevation

The elevation of Assawoman Wildlife Area ranges from sea level at the bays to about 10 feet at the office in the Miller Neck Tract.

Discussion of vegetation communities in general and why they are important in management

While Natural Communities provide the optimal habitats and structure that are needed for animals to exist, vegetation communities provide an approximation of natural communities. The differences in the vegetation communities are governed by non-biotic factors and biotic factors. Non-biotic factors include things such as geology (soil type, availability of moisture, and exposure), climate, and fire regime. Biotic factors include: number and amount of predators and prey, biodiversity of the community and presence and absence of contributors to ecosystem health such as ants, fungi and bacteria and size of forest blocks. Historically these factors have not changed much other than changes brought about by larger climate shifts. Since the time of modern European settlement of Eastern North America (i.e. from about 1600 A.D.), physical factors such as fire regime and moisture availability have changed and nearly all of the biotic factors have changed resulted in a markedly different landscape today than what the original settlers saw. Today, instead of having Natural Communities, we have Vegetation Communities, which only approximate Natural Communities and are essentially artificial shells of what they could be.

Discussion of Sea-Level Rise and why it may affect the vegetation communities at Assawoman Wildlife Area

To understand the effects of sea-level rise on vegetation communities near the coast one can look at what has happened historically. From the late Pleistocene period to 5,000 years ago, sea-level rise in Delaware was about 3 cm/decade (30 cm/100 years). From 3,000 years to the recent past it has been rising 1 cm/decade (10 cm/100 years).[8] More recent data from the Indian River Inlet (1972-1983) shows the rate of rise to be 3.73 mm/year and at Lewes (1919-2009), 3.24 mm/year[9]. More recent historical ground data from the National Aeronautics and Space Administration (NASA) from 1870 to 2000 has shown a sea level rise of 1.7 mm/year or 1.7 cm/decade. Even more recent data from the Jason satellites (1993-present) has shown an increase in the rise to 3.28 mm/year or 3.3 cm/decade.[10] This is above the fast rate of rise seen from the Late Pleistocene to 5,000 years ago. Jay Custer in his book Prehistoric cultures of the Delmarva Peninsula states that "Rising sea-level had three major effects on the environments of the Delmarva Peninsula: changes in the availability and distribution of coastal resources, changes in interior water tables, and potential changes in local air mass distributions and weather patterns. Changing availability of coastal resources with sea-level is related both to the rate of sea-level rise and changing shoreline topography. Before 3,000 years ago the rate of sea-level rise was so great that stable estuarine environments did not have time to develop". The slower sea-level rise after this time has allowed estuaries and marshes to increase in size, by lateral erosion.[11] Sea-level rise can also cause water tables to rise, water logging swamps away from the coast, a fact that has been

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[8] Belknap, D.F. and J.C. Kraft. 1977. Holocene relative sea-level changes and coastal stratigraphic units on the northwest flank of the Baltimore Canyon geosyncline. Journal of Sedimentary Petrology 47(2): 610-629 in Custer (1989).
[9] Data from Permanent Service for Mean Sea Level website (www.psmsl.org)
[10] NASA Global Climate Change Website (http://climate.nasa.gov/keyindicators) December 12, 2010 update.
[11] Custer, Jay F. 1989. Prehistoric cultures of the Delmarva Peninsula: archaeological study. (Cranbury, NJ: Associated University Presses, Inc.), 447 pp.

stated in elsewhere in the Mid-Atlantic [12], [13], [14]. The rising rate of rise may factor into the difference between the Indian River Inlet and Lewes tidal stations. The Lewes station has been operating longer and has a more complete data set than the Indian River Inlet station.

Other sources have stated the rise on the Mid-Atlantic Coast to be 3-4 mm/year, while the global average is 1.8 mm/year[15] , the difference of which is caused by geological subsidence from the glaciers of the last ice age. The rate sea-level rise now is equal to the time historically when estuaries and marshes did not have time to develop. Marshes have been accreting about 3 mm/year for the past 100 years [16], but the current rate of sea level rise is above the accretion rate resulting in losses. It is projected to go much higher with rates of 10 cm/decade (1 m/100 years) as a median[17]. Kraft and Khalequzzaman project that most of the fringing salt marshes in Delaware will be eliminated in 200-300 years and by extinct in 1,500 to 1,700 years.[18] Other investigators have pointed out that there is a lack of temporal scale to a lot of the studies and that there may be a significant time lag between sea level rise and anthropogenic inputs of carbon dioxide. [19] These changes would also impact the fisheries and economy related to it in the area.

Components of Sea Level Rise

There are many factors that all come together to produce the observed rise above. These include Eustatic (rise due to increased water volume), stearic (rise due to increased temperature and salinity), and isostatic (rise due to geological subsidence).

Eustatic Rise

Most people think of this factor when they talk about sea level rise. This is the contribution of increased water volume coming from the melting of glaciers, snowpack, and groundwater extraction. Using the figure for Indian River Inlet above this accounts for about 1.2 mm/year of the rise when

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[12] Rappleye, L. and W.M. Gardner. 1979. A cultural resources reconnaissance and impact assessment of the Great Dismal Swamp National Wildlife Refuge, City of Suffolk, Chesapeake, and Nansemond Counties, Virginia. Manuscript on file. Department of Anthropology, Catholic University, Washington, DC in Custer (1989).

[13] Whitehead, D.R. 1972. Developmental and environmental history of the Dismal Swamp. Ecological Monographs 42:301-15 in Custer (1989).

[14] Gardner, W.M. 1978. Comparison of Ridge and Valley, Blue Ridge, Piedmont, and Coastal Plain Archaic Period Site Distribution: An idealized transect (preliminary model). Paper presented at the 1978 Middle Atlantic Archeological Conference, Rehoboth Beach, Delaware in Custer (1989).

[15] Johnson, Zoe Pfahl. 2000. A Sea Level Rise Response Strategy for the State of Maryland. Maryland Department of Natural Resources.

[16] Nikitina, Daria L., James E. Pizzuto, Reed A. Schwimmer, and Kelvin W. Ramsey. 2000. An updated Holocene sea-level curve for the Delaware Coast. Marine Geology 171 (1-4): 7-20.

[17] Barth, M.C. and J.G. Titus. 1984. Greenhouse Effect and Sea Level Rise: A Challenge for this Generation. (New York: Van Nostrand Reinhold Co., Inc.) 238 pp.

[18] Kraft, John C. and Md. Khalequzzaman. 1992. Geologic and human factors in the decline of the tidal salt marsh lithesome: the Delaware Estuary and Atlantic coastal zone. Sedimentary Geology 80 (3-4): 233-246.

[19] Larsen, C.E. and I. Clark. 2006. A search for scale in sea-level studies. Journal of Coastal Research 22(4): 788-800.

subtracted from the other factors[20]. Added to this is newer research that shows groundwater depletion is adding 0.8 mm/year to sea level rise[21]. From this you have to subtract the amount of water that has been impounded on land. Chao, et al. states that about 10,800 cubic kilometers has been impounded in the last half century which subtracts about 0.55 mm/year from the rise[22]. When added together, eustatic factors account for 1.45 mm/year of the rise.

[20] Davis, George H. 1987. Land Subsidence and Sea Level Rise on the Atlantic Coastal Plain of the United States. Environmental Geology 10 (2): 67-80.
[21] Wada, Y., L.P.H. van Beek, C.M. van Kempen. J.W.T. Reckman, S. Vasak, and M.F.P. Bierkens. 2010. Global depletion of groundwater resources. Geophysical Research Letters 37
[22] Chao, B.F., Y.H. Wu, and Y.S. Li. 2008. Impact of Artificial Reservoir Water Impoundment on Global Sea Level. Science 320(5873): 212-214.

Stearic Rise

This factor comes from thermal expansion of ocean water and salinity currents. This factor contributes about 0.9 mm/year of the observed rise[23]. Yin et al states that this factor could account for more than the global mean in the future through a weakening of the meridional overturning circulation in the Atlantic[24], accounting for much more rise than in earlier studies. They go further to say that these contributions in New York City could result in a rise of 15 cm, 20 cm, or 21 cm, under low, medium, and high rates of emissions, respectively[25]. Other studies have pointed out that variations in rise in the Mid-Atlantic can be 20 cm and persist for years due to the North Atlantic Subtropical Gyre[26].

Isostatic Rise

Geological land subsidence adds the most to the rise currently accounting for about 1.6 mm/year[27] in the Mid-Atlantic region. Another study has given an amount ranging from 1.02 to 1.53 mm/year[28]. Liu, et al gives a similar for New York City stating a sea level rise of 2-4 mm/year to which glacio-isostatic factors account for about 40%[29].

All of these factors added together

If we add all of these factors together using the data above we get a range of 3.15 mm to 3.95 mm/year.

E= Eustastic (1.45 mm/yr)
S= Stearic (0.9 mm/yr)
I= Isostatic (1.6 mm/yr-Davis, 1.02-1.53 mm/yr-Engelhart, et al., 0.8 mm-1.6 mm/yr-Liu)

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[23] Ditto
[24] Yin, Jianjun., S.M. Griffies, M. Schlesinger, R.J. Stouffer. 2010. Regional Sea Level Rise Projections on the Northeast Coast of the United States. American Geophysical Union, Fall 2010 meeting.
[25] Yin, Jianjun, M.E. Schlesinger, R.J. Stouffer. 2009. Model Projections of Rapid Sea Level Rise on the Northeast Coast of the United States. Nature Geoscience 2(4): 262-266.
[26] Hong, Byung-Gi. 1998. Decadal variability in the North Atlantic Subtropical Gyre: Can it explain variability in sea level along the East Coast of the United States. Ph.D. Thesis, The Florida State University, 77 pp.
[27] Davis, George H. 1987. Land Subsidence and Sea Level Rise on the Atlantic Coastal Plain of the United States. Environmental Geology 10(2): 67-80.
[28] Englehart, S.E., B.P. Horton, B.C. Douglas, W.R. Peltier, T.E. Tornqvist. 2008. Spatial variability in the 20th century record of sea level rise along the US Atlantic Coast. American Gophysical Union, Fall 2008 Meeting.
[29] Liu, J., R. Horton. 2007. Impacts of combined sea level rise and coastal subsidence, New York City Metropolitan Area. American Geophysical Union. Fall 2007 Meeting.

Using vegetation communities to map sea level rise and changes in the landscape

One of the first studies in Delaware to use vegetation communities to map human induced changes in the landscape was done by a Victor Klemas at the University of Delaware in the early 1970s[30]. Victor compared aerial imagery from 1954 and 1968 on a qualitative basis and looked at changes in the marshes and other man-made features. He incorporated some multispectral analysis to determine some of the vegetation types. Though he did not refer to specific vegetation communities as we know them now, he did look at vegetation assemblages (Low marsh, high marsh, and salt shrub) that are very similar to the groupings now. No figures were given in his paper regarding the overall changes. He did note, however, that the shoreline at Cape Henlopen had receded 4 to 21 feet per year from 1843 to 1939[31]. Other papers have also used historical aerial imagery to map vegetation change[32],[33] and salinity factors can impact on those changes[34].

More recent studies looking at both changes in tidal marshes[35] and coastal forests[36] have shown that both can suffer effects of a rising sea level. Matthew Kirwan states that a tidal marsh can keep up with sea level rise through accretion if the amount of sediment is adequate, but that reforestation and dam building has restricted the sediment inflows[37]. Shirley and Battaglia come roughly to the same conclusion on the Gulf of Mexico coast, stating that they do not believe the marshes are keeping pace with the aquatic to terrestrial transition, but it is hard to map in the Coastal Plain because of major land use changes[38]. Kimberlyn Williams states that some of the factors leading to forest decline in coastal areas result from; soil flooding—resulting in low oxygen availability and reducing conditions, elevated soil and groundwater salinity, and saltwater intrusion.

One study in the Delaware River Estuary stipulated that freshwater tidal marshes are needed to help the development of brackish and salt marshes[39] in areas where the coast was submerging. The freshwater marshes help produce the environmental conditions later needed by the more saline marshes.

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[30] Klemas, Vytautas. 1972. Use of remote sensing to determine natural and man-made changes in the coastal zone. Transactions of the Delaware Academy of Science. 2: 13-34.

[31] Vytautas, Klemas. 1972. Use of remote sensing and to determine natural and man-made changes in the coastal zone. Transactions of the Delaware Academy of Science 2:13-34.

[32] Kadmon, R. and R. Harari-Kremer. 1999. Studying the long term vegetation dynamics using digital processing of historical aerial photographs. Remote Sensing of the Environment 68:164-176.

[33] Smith, Carrie, Merryl Alber, and Alice Chalmers. 2001. Linking shifts in historic estuarine vegetation to salinity changes using a GIS. Proceedings of the 2001 Georgia Water Resources Conference.

[34] Earle, J.C. and K.A. Kershaw. 1988. Vegetation patterns in James Bay coastal marshes. III. Salinity and elevation as factors influencing plant zonations. Canadian Journal of Botany 67: 2967-2974.

[35] Kirwan, Matthew L. and A. Brad Murray. 2007. A coupled geomorphic and ecological model of tidal marsh evolution. Proceedings of the National Academy of Science 104(15):6118-6122.

[36] Williams, Kimberlyn, et al. 1999. Sea-level rise and coastal forest retreat on the west coast of Florida, USA Ecology

[37] Kirwan, Matthew L. and A. Brad Murray. 2007. A coupled geomorphic and ecological model of tidal marsh evolution. Proceedings of the National Academy of Science 104(15):6118-6122.

[38] Shirley, Laura and Lorretta L. Battaglia. 2006. Assessing vegetation change in coastal landscapes of the northern Gulf of Mexico. Wetlands 26(4): 1057-1070.

[39] Orson, Richard A., Robert L. Simpson, and Ralph E. Good. 1992. The Paleoecological development of a late Holocene, Tidal Freshwater Marsh of the Upper Delaware River Estuary. Estuaries and Coasts 15(2): 130-146.

Purpose of the Study

This study was conducted with the following goals in mind:

1. Classify and map vegetation communities, land covers, and assess habitat conditions for Species of Greatest Conservation Need (SGCN)[as defined in the Delaware Wildlife Action Plan (DEWAP)] for Assawoman Wildlife Area based on 1937, 2002, and 2007 aerial imagery and field observations.
2. Use the maps above to determine changes in the vegetation communities and the effects of sea level rise and to determine the relative rate of sea level rise in the wildlife area.
3. Determine the forest blocks located within or partially within the wildlife area.
4. Produce Ecological Integrity Assessments (EIAs) for vegetation communities that ranked S2 or higher.

Surveys were conducted during 2010 by Robert Coxe, an Environmental Scientist with the Delaware Natural Heritage and Endangered Species Program (DNHESP) within the Delaware Division of Fish and Wildlife, Department of Natural Resources and Environmental Control (DNREC).

Vegetation Community and Land Cover Surveys

Vegetation communities and land covers were determined by qualitative analysis using observations made in the field and aerial photo-interpretation using 1937, 2002, and 2007 imagery. Vegetation communities are named according to the *Guide to Delaware Vegetation Communities* [40]which follows the National Vegetation Classification System (NVCS). The NVCS classifies vegetation on a national scale for the United States and is linked to international vegetation classification. The NVCS helps provide a uniform name and description of vegetation communities found throughout the country and helps determine relative rarity. Descriptions of the vegetation communities are provided in Chapter 5 and of the land covers in Chapter 6. A crosswalk to the Delaware Wildlife Action Plan (DEWAP) and the Northeast Habitat Classification (NHC) is provided at the top of each individual description.

Analysis of Historical Imagery

Historical imagery of Assawoman Wildlife Area from 1937, 2002 and current imagery from 2007 were examined. A vegetation community map was produced for each year in order to compare vegetation and land cover change over a 5, 65, and 70 year time frame. Changes in the respective vegetation communities and land covers are discussed in the vegetation community and land cover descriptions while broader changes are discussed in the wildlife area and tract discussions. There is more imagery available (1954, 1961, 1968, 1992, and 1997) but these sets were not used due to geo-registration problems in the image tiles.

Ecological Integrity Assessment (EIA)

An EIA was conducted for those communities in the wildlife area that are ranked S2 or higher in Delaware. EIAs are an analysis being developed by Natureserve to determine the relative quality of vegetation communities across North America. Using Natural Heritage methodology, communities are ranked according to rarity (Appendix I). The vegetation communities at Assawoman Wildlife Area included in the EIA analysis are listed in Table 2.3 and mapped in Figures 2.1-2.3.

Forest Block Analysis

Current forest blocks within or partially within the wildlife area that are greater than 100 acres were mapped. Each current block is described for current total acres and current forest interior habitat, potential acres, potential forest interior habitat, vegetation communities currently present, and major drainage (Table 2.4 and Figure 2.4). A block is defined as contiguous forest habitat that is contained with 30 feet of non-forested and is the method used by the Maryland's Strategic Forest Lands Assessment.[41] Forest interior is forested area that is 100m from a forest edge. Potential blocks were extended out to areas of noncontiguous habitat (such as roads, power line right-of-ways, and developed

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[40] Coxe, Robert. 2010. Guide to Delaware Vegetation Communities-Summer 2010 Edition. Unpublished report.

[41] Maryland Department of Natural Resources. 2003. Strategic Forest Lands Assessment. Co-op Project between Maryland Department of Natural Resources, Watershed Services, and Maryland Forest Service. 40 p.

areas) that were considered to be immovable. Most of the area that could be reverted to forest is currently old field habitat or in agricultural use. These blocks were determined for future planning in regards to improving and increasing forest interior habitat.

Sea Level Rise Analysis

An analysis was performed for the wildlife area as whole using the DNREC Sea Level Rise Scenarios to project the amount of acres lost.

Natural Capital Analysis

The natural capital of each vegetation community was determined using a table in Costanza, et al.[42] The values from the table were calculated per acre of the vegetation community and then adjusted using an inflation calculator (DollarTimes.com) from 1994 values to 2012 values. Using these methods the following values were obtained:

Estuaries (water): $9,247/acre/year

Temperate Forest (Upland forests): $122/acre/year

Wetlands

-General (not as below): $5,988/acre/year

-Tidal Marsh: $4,046/acre/year

-Swamps/floodplains: $7,930/acre/year

Lakes (Impoundments): $3,442/acre/year

Cropland: $37/acre/year

Grassland/fields: $94/acre/year

Open Ocean: $102/acre/year

Values were rounded off to the nearest whole dollar. Calculating the natural capital provides a consistent way to compare wildlife areas and state parks as far as value. Even if you do not agree with the values, it still provides a relative measure of the areas.

[42] Costanza, Robert, et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253-260.

Chapter 2: Results of EIAs, Forest Blocks, and General Observations

Summary of Findings from this study

1. **Vegetation Communities:** Twenty-eight vegetation communities and nine land covers were found at Assawoman Wildlife Area. Coastal Loblolly Pine Wetland Forest (809 acres) is the largest vegetation community, followed by North Atlantic Low Salt Marsh with 518 acres. Impoundment (233 acres) is the largest land cover followed by Agricultural field with 138 acres.

2. **Rare Plants:** Thirty rare plants are known to exist in Assawoman Wildlife Area (Table 2.1).

Scientific Name	Common Name	Rank	Last Observed
Agalinus maritima var. *maritima*	Saltmarsh False-Foxglove	S1	???
Asclepias lanceolata	Smooth Orange Milkweed	S1	2003
Bidens mitis	Small-fruit Beggar Ticks	S2	1992
Boltonia asteroides var. *glastifolia*	Aster-like Boltonia	S2	2003
Centella erecta	Erect Coinleaf	S2	???
Coelorachis rugosa	Wrinkled Jointgrass	S1	2003
Dichanthelium accuminatum var. *longiligulatum*	Coastal Plain Panicgrass	S1	2007
Dichanthelium dichotomum var. *roanokense*	Witch grass	S2	1993
Eleocharis rostellata	Beaked Spikerush	S2	2003
Eriocaulon compressum	Flattened Pipewort	S2	2001
Eryngium aquaticum	Marsh Rattlesnake Master	S2	2003
Fimbristylis caroliniana	Carolina Fimbry	S2	???
Gymnopogon ambiguus	Broadleaf Beardgrass	S1	1995
Hypericum denticulatum	Coppery St. John's Wort	S2	???
Lycopus amplectens	Sessile-leaved Bugleweed	S2	1992
Myriophyllum pinnatum	Cut-leaf Water Milfoil	S2	1991
Paspalum dissectum	Walter's Paspalum	S3	???
Phyla lanceolata	Fog-fruit	S2	1992
Rhexia aristosa	Awned Meadowbeauty	S1	2003
Rhynchospora filifolia	Thread-leaved Beakrush	S1.1	2003
Rhynchospora harperi	Harper's Beakrush	S1	???
Rhynchospora inundata	Drowned Beakrush	S1	???
Sabatia campanulata	Slender Marsh Pink	S1	2003
Sabatia difformis	Two-formed Pink	S1	1991
Scleria reticularis	Reticulated Nutrush	S3	1997
Sclerolepis uniflora	One-flowered Bog Button	S2	2003
Spiranthes vernalis	Twisted Ladies' Tresses	S2	1993
Utricularia inflata	Large Swollen Bladderwort	S1	???
Xyris smalliana	Small's Yellow-eyed grass	S2	2001

Table 2.1. Rare Plants at Assawoman Wildlife Area

3. **Rare Animals:** Four rare animals are known to exist in Assawoman Wildlife Area (Table 2.2).

Scientific Name	Common Name	Rank	Last Observed
Cincidela marginata	A Tiger Beetle	S1	
Coragyps atratus	Black Vulture	S2B	
Haliaeetus leucocephalus	Bald Eagle	S2B, S3N	
Thamnophis sauritis	Eastern Ribbon Snake	S2	

Table 2.2. Rare Animals at Assawoman Wildlife Area

Ecological Integrity Assessment (EIA)

Six vegetation communities are ranked S2 or higher. These include Buttonbush Shrub Swamp, Creeping Rush-Boltonia Coastal Plain Pond, Loblolly Pine Dune Woodland, Maritime Red Cedar Woodland, Mid-Atlantic Coastal Maritime Forest, and Needlerush High Marsh. These areas are mapped by tract in Figures 2.1-2.3 and summarized in Table 2.3.

Miller Neck Tract EIAs (Figure 2.1)

The Miller Neck Tract contains three EIA occurrences of three communities, Creeping Rush-Boltonia Coastal Plain Pond, Mid-Atlantic Coastal Maritime Forest, and Needlerush High Marsh. The Miller Neck Tract contains the only extant occurrences of Creeping Rush-Boltonia Coastal Plain Pond and Mid-Atlantic Coastal Maritime Forest in the wildlife area.

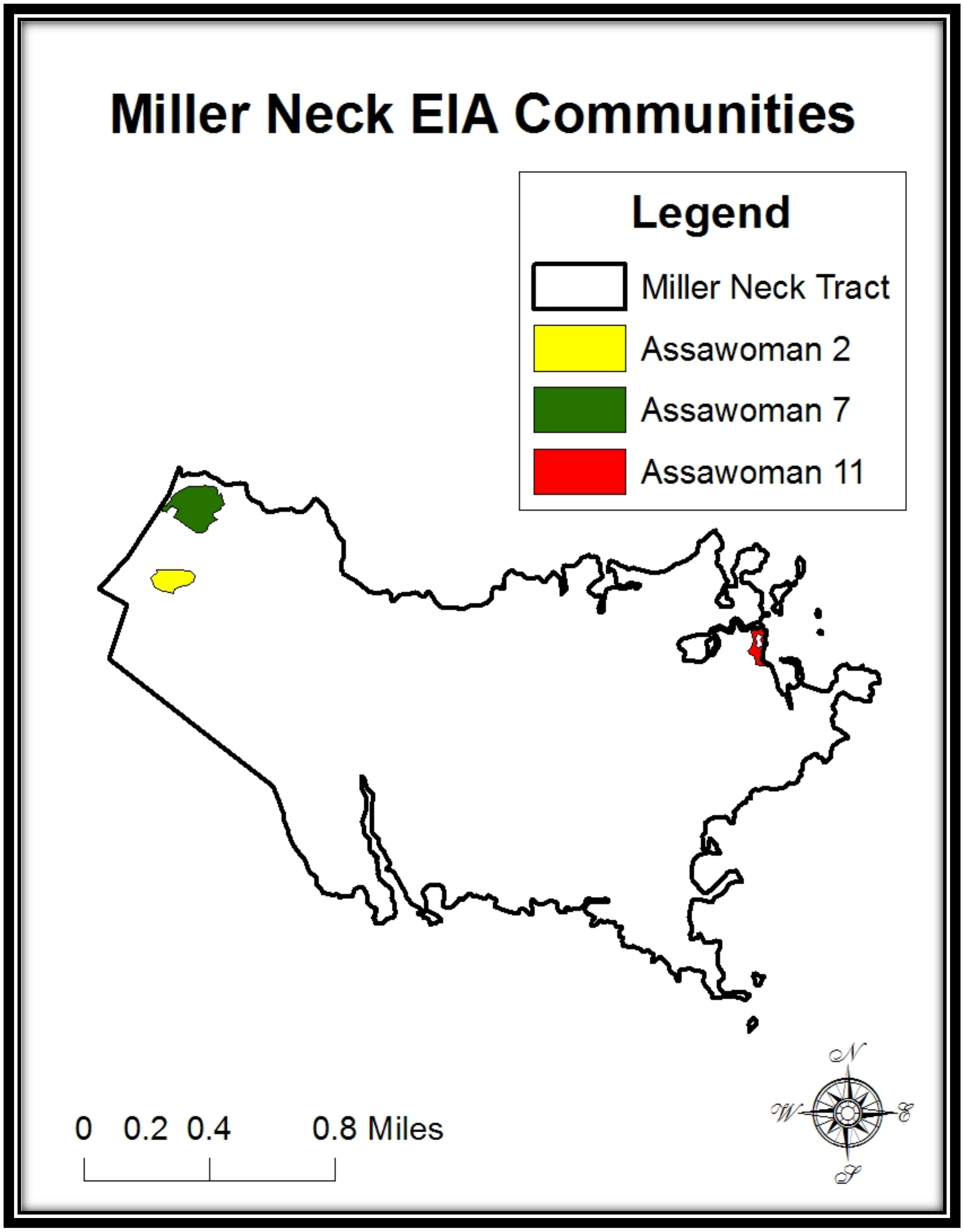


Figure 2.1. EIA Occurrences in the Miller Neck Tract

Muddy Neck Tract EIAs (Figure 2.2)

The Muddy Neck Tract contains three EIA occurrences of two communities, Buttonbush Shrub Swamp and Needlerush High Marsh. The Muddy Neck Tract contains the only extant occurrence of Buttonbush Shrub Swamp in the Wildlife Area.

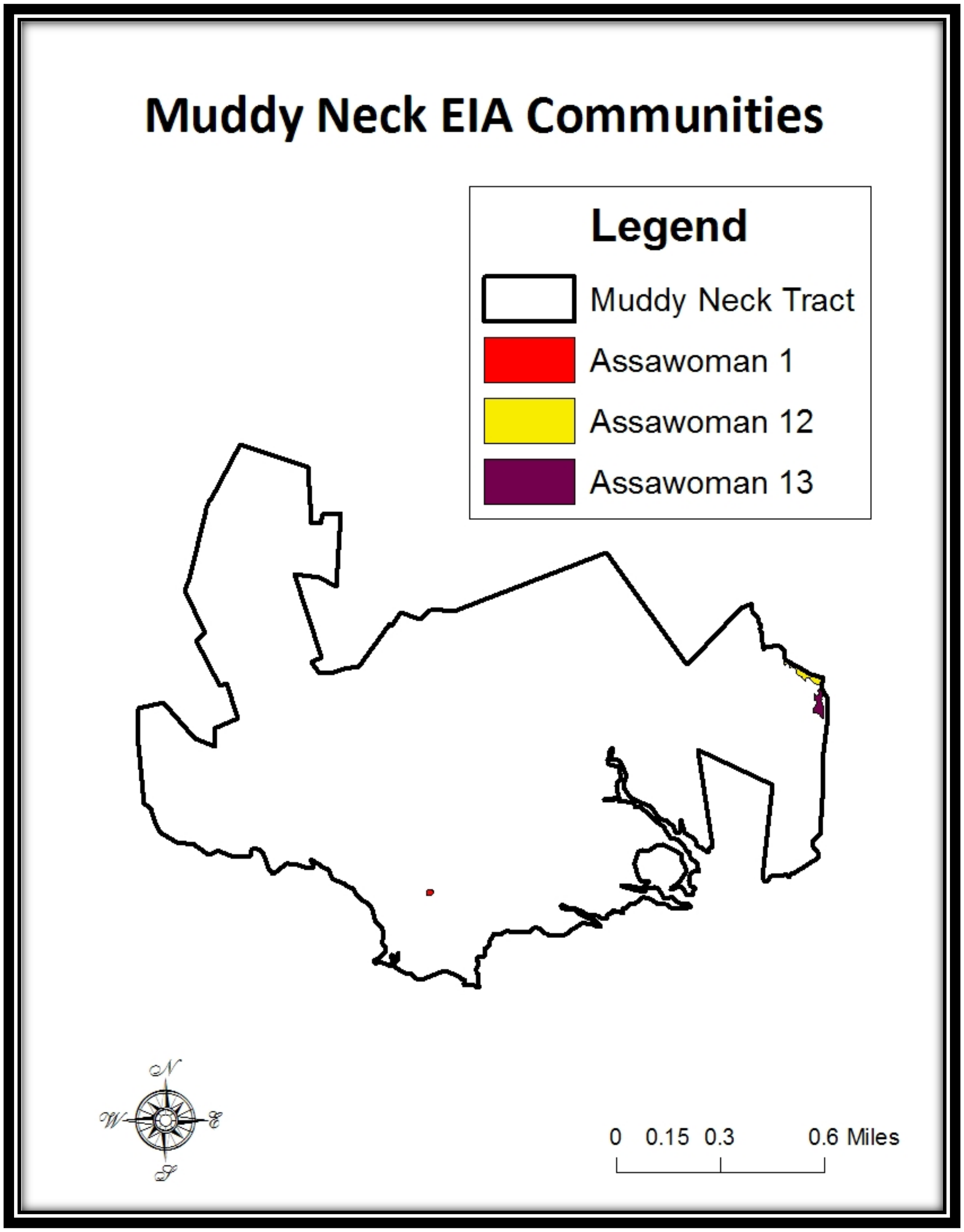


Figure 2.2. EIA occurrences in the Muddy Neck Tract

South Bethany Tract EIAs (Figure 2.3)

The South Bethany Tract contains seven EIA occurrences of two communities, Loblolly Pine Dune Woodland and Needlerush High Marsh. The South Bethany Tract contains the only extant occurrences of Loblolly Pine Dune Woodland in the wildlife area.

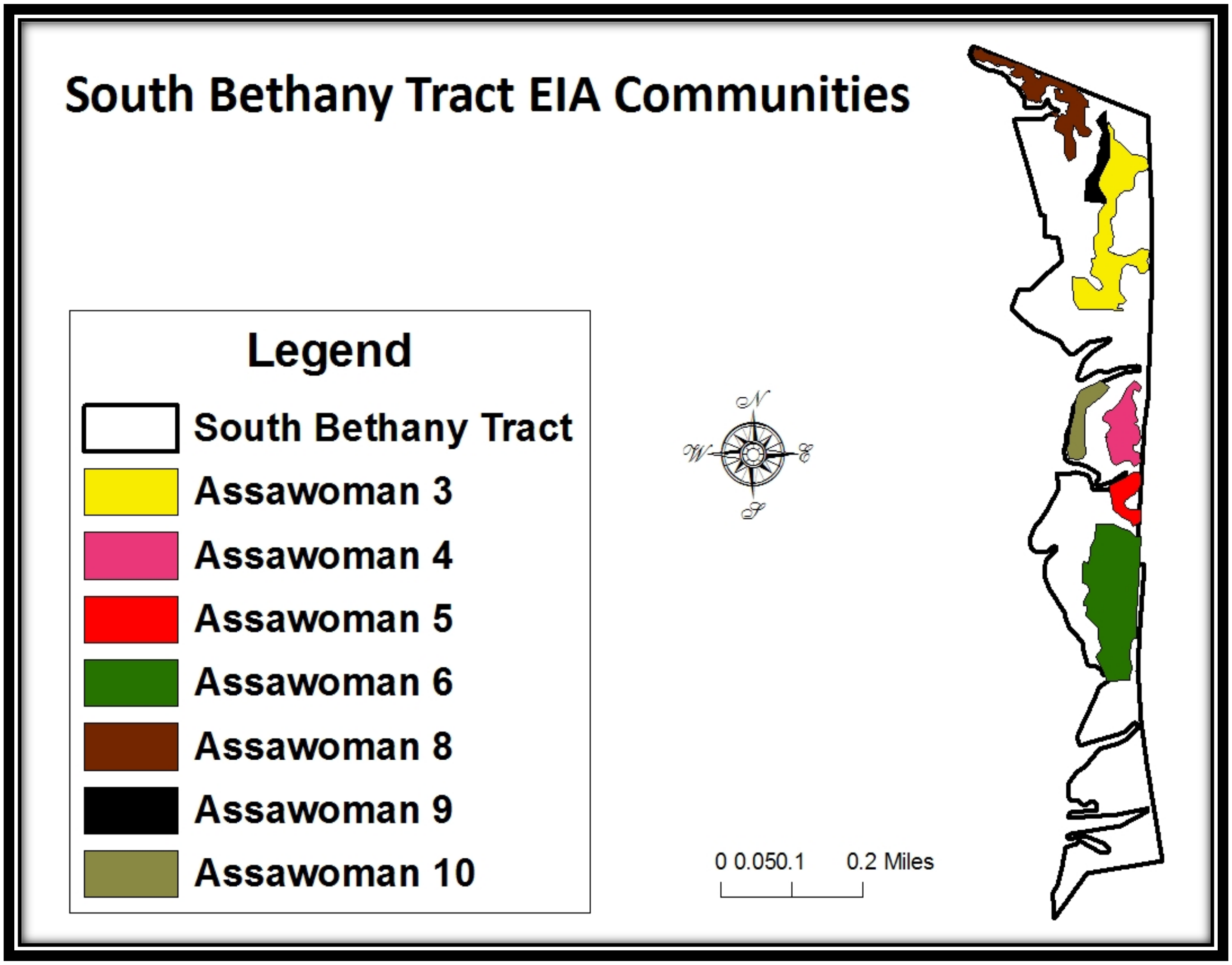
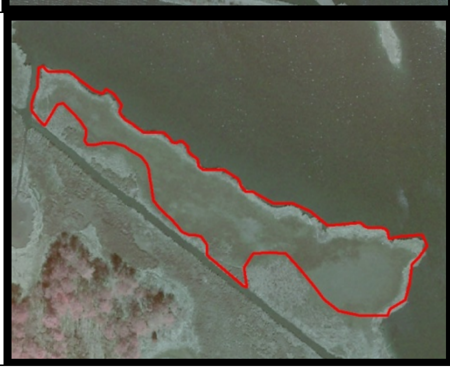


Figure 2.3. EIA occurrences in the South Bethany Tract

Table 2.3. EIA Vegetation Communities located in Assawoman Wildlife Area

Community Map	Community Name/EIA Score	Description
	**Assawoman 1** **Buttonbush Shrub Swamp (0.2 acres)** **EIA = 3.55 (B rank)**	This shrubland community is located in a seasonally flooded depression.
	**Assawoman 2** **Creeping Rush-Boltonia Coastal Plain Pond (5 acres)** **EIA = 4.53 (A rank)**	This Coastal Plain Pond community is the only one known of its type in Delaware. It is located in a topographic depression near the northwest end of the Miller Tract.
	**Assawoman 3** **Loblolly Pine Dune Woodland (7 acres)** **EIA = 3.00 (C rank)**	This woodland community is located at the north end of the South Bethany Tract. It is surrounded by marsh on the west side and DE 1 on the east side.
	**Assawoman 4** **Loblolly Pine Dune Woodland (3 acres)** **EIA= 2.7 (C rank)**	This woodland community is located on the South Bethany Tract. Like the other woodland examples, it is surrounded by marsh on the west and DE 1 on the east.

Community Map	Community Name/EIA Score	Description
	**Assawoman 5** **Loblolly Pine Dune Woodland (1 acre)** **EIA=2.7 (C rank)**	This woodland community is located on the South Bethany Tract. Like the other woodland examples, it is surrounded by marsh on the west side and DE 1 on the east.
	**Assawoman 6** **Loblolly Pine Dune Woodland (9 acres)** **EIA=3.24 (C rank)**	This woodland community is located on the South Bethany Tract. It is surrounded by marsh on the west side and DE 1 on the east.
	**Assawoman 7** **Mid-Atlantic Coastal Maritime Forest (12 acres)** **EIA=3.43 (B rank)**	This forest community is located at the northwestern end of the Miller Neck Tract on the south-side of Miller Creek.
	**Assawoman 8** **Needlerush High Marsh (3 acres)** **EIA=3.53 (B rank)**	This marsh community is located at the northern end of the South Bethany Tract. It is surrounded by development and appears to be shrinking a little from its historical extent.

Community Map	Community Name/EIA Score	Description
	**Assawoman 9** **Needlerush High Marsh (1 acre)** **EIA=3.93 (B rank)**	This marsh community and area of higher ground in a thin-strip between shrubland and the lower North Atlantic Low Salt Marsh to the west.
	**Assawoman 10** **Needlerush High Marsh (2 acres)** **EIA=4.3 (B rank)**	This marsh community is located at the eastern edge of Little Assawoman Bay on the South Bethany Tract.
	**Assawoman 11** **Needlerush High Marsh (2 acres)** **EIA=4.7 (B rank)**	This marsh occupies an area of slightly higher ground on the west side of Little Assawoman Bay on the Muddy Neck Tract. It has a Successional Maritime Forest in the center of it.
	**Assawoman 12** **Needlerush High Marsh (1 acre)** **EIA=4.46 (B rank)**	This marsh community is located on the west side of Little Assawoman Bay on the Muddy Neck Tract.

Community Map	Community Name/EIA Score	Description
	**Assawoman 13** **Needlerush High Marsh (1 acre)** **EIA=4.46 (B rank)**	This marsh community is located on the west side of the Assawoman Canal on the Muddy Neck Tract. This occurrence appears to be increasing in size over time.

Forest Block Analysis

Importance of Forest Blocks

Forest blocks are important for a number of animals such as bobcat and neo-tropical migratory birds which nest in forest interiors (those places that are 100 meters from the edge of a forest). Many neotropical migratory birds are considered to be breeders in forest interior areas. Due to development, road building, which causes fragmentation, agricultural fields and other non-forest land uses, habitats for these birds are increasingly being eliminated leading to reductions in populations. Predators are better able to get the birds in small woodlands and edge habitats. In Ontario it was found that 80% of the neo-tropical bird nests in small woodlands (<100 ha) were lost to predators[43]. Nests in interior forests are less susceptible to predation and are not taken over by cowbirds, which is another hazard on edge habitats. Examples of birds that may be affected by a lack of large forest tracts include Barred Owl, Black and White Warbler, Worm-Eating Warbler, Acadian Flycatcher, Ovenbird, Kentucky Warbler, Red-Shouldered Hawk and many others.

Management of wildlife areas has traditionally favored forest game species such as wild turkey, ruffed grouse and American woodcock, which require old fields and edges running counter to the habitat needed for forest interior birds. Protecting forest interior birds runs contrary to the idea that artificially created edges creates more diversity. While this technique creates more diversity of some aggressive species it diminishes the populations of other species.

In protecting forest blocks, those blocks which are circular contain the most interior area per unit area. The next best shape is a square and linear configurations produce the least forest interior due to shape.

A study by Robbins et al. (1989) showed that most forest interior species require a forest of at least 150 ha (370 acres) in size. Very few forest tracts in Delaware are at least this size, one of the more notable being the Great Cypress Swamp.

Analysis of Forest Blocks at Assawoman Wildlife Area

Five forest blocks are present that are more than 100 acres in size and are located in whole or part in the wildlife area (Figure 2.4 and Table 2.4). All forest blocks are bounded by a road, agricultural field, or other non-forested habitat. These areas are considered to be barriers to the passage of forest dwelling wildlife. Descriptions are provided for each forest block in Table 2.4 and mapped in Figure 2.4.

[43] Ontario Landowner Resource Centre. 2000. Conserving the Forest Interior: A threatened wildlife habitat. Ontario Ministry of Natural Resources.

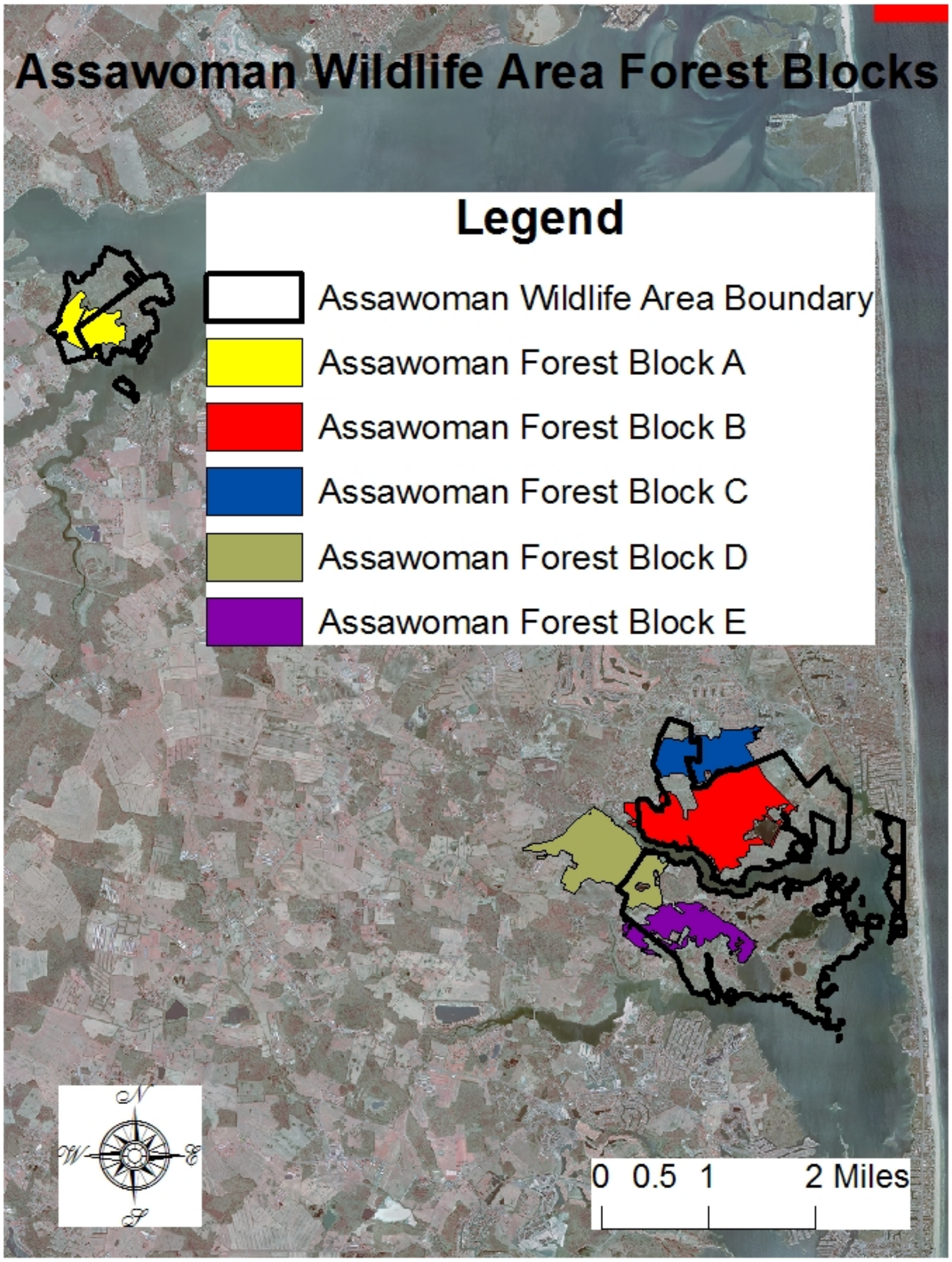
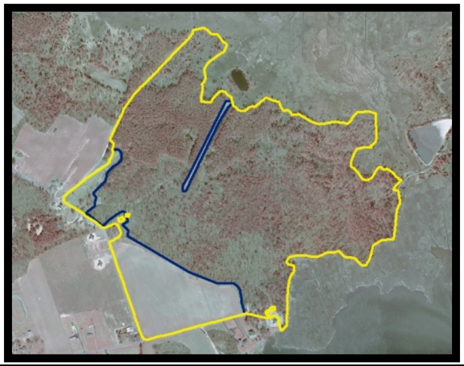
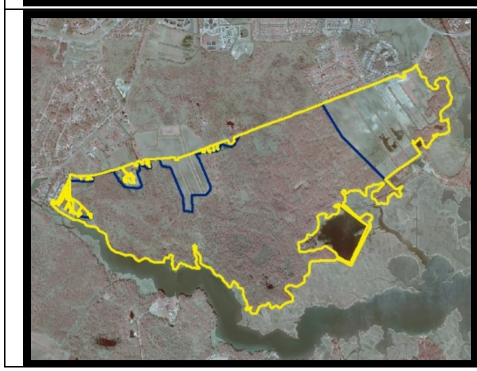
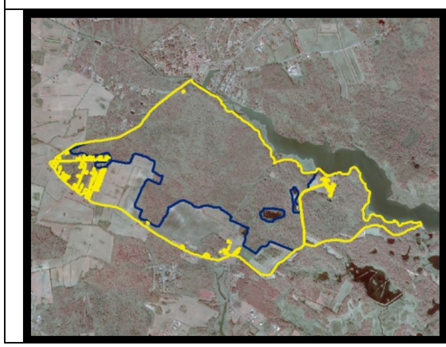
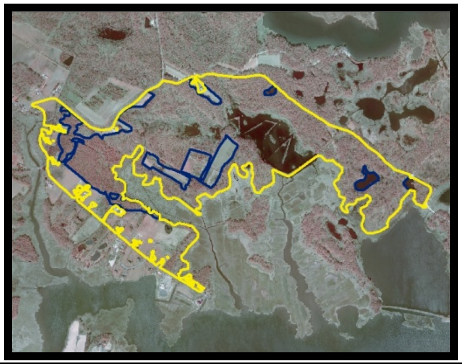


Figure 2.4. Forest Blocks located in Assawoman Wildlife Area

Table 2.4. Forest Blocks located in whole or part in Assawoman Wildlife Area

Forest Block Map	Block Name/Acreage	Description
	**Assawoman A** **Current Block = 141 acres (0 acres interior)** **Potential Block = 167 acres (0 acres interior)**	Assawoman A encompasses most of the wooded area present in the Piney Point Tract of Assawoman Wildlife Area. It is bounded by Road 335 on the west, agricultural field and a driveway on the north, and salt marsh on the east and south. Five vegetation communities are located within this block and include Early to Mid-Successional Loblolly Pine Forest, Loblolly Pine/Wax-myrtle/Salt Meadow Cordgrass Meadow, Red Maple-Sweetgum Swamp, Southern Red Oak-Heath Forest, and Successional Maritime Forest. Indian River Bay is the drainage for this block. Currently this block contains no interior habitat. Potentially this block could be 167 acres in size, but still not contain any interior habitat.
	**Assawoman B** **Current Block = 491 acres (40 acres interior)** **Potential Block = 661 acres (74 acres interior)**	Assawoman B covers most of the forested area of the Muddy Neck Tract south of Road 363. It is bounded by on the north by Road 363, on the east by agricultural field and salt marsh, on the south by salt marsh and Miller Creek, and on the west by developed area. Four vegetation communities are located within this block and include Coastal Loblolly Pine Wetland Forest, Early to Mid-Successional Loblolly Pine Forest, Mesic Coastal Plain Oak Forest, and Red Maple-Sweetgum Swamp. Miller Creek is the drainage for this block. Currently this block contains 40 acres of interior habitat. Potentially this block could be 661 acres in size and contain 74 acres of interior habitat.

Forest Block Map	Block Name/Acreage	Description
	**Assawoman C** **Current Block = 214 acres (0 acres interior)** **Potential Block = 363 acres (2 acres interior)**	Assawoman C is located at the north end of the Muddy Neck Tract. It is bounded by Road 363 on the south, developed area on the east, agricultural field and developed area on the north, and Road 362 on the west. Four vegetation communities are located within this block and include Early to Mid-Successional Loblolly Pine Forest, Mesic Coastal Plain Oak Forest, Red Maple-Sweetgum Swamp, and Red Maple-Sweetgum Swamp. Tributaries to Miller Creek are main drainages for this block. Currently this block contains no interior habitat. Potentially this block could be 363 acres in size and contain 2 acres of interior habitat.
	**Assawoman D** **Current Block = 362 acres (26 acres interior)** **Potential Block = 629 acres (116 acres interior)**	Assawoman D is located at the western end of the Miller Neck Tract west Road 364 going to Camp Barnes. It is bounded on the west by Road 363, on the north by Miller Creek and salt marsh, on the east by Road 364, and on the south by Camp Barnes Road. Four vegetation communities are located within this block and include Coastal Loblolly Pine Wetland Forest, Early to Mid-Successional Loblolly Pine Forest, Red Maple-Sweetgum Swamp, and Southern Red Oak/Heath Forest. Miller Creek drains this block. Currently this block contains 26 acres of interior habitat. Potentially this block could be 629 acres in size and contain 116 acres of interior habitat.

Forest Block Map	Block Name/Acreage	Description
	**Assawoman E** **Current Block = 200 acres (0 acres interior)** **Potential Block = 276 acres (0 acres interior)**	Assawoman E covers the south end of the Miller Neck Tract. It is bounded by salt marsh and developed area on the south, salt marsh on the east, Road 364 on the north, and Road 364 on the west. Three vegetation communities are located within this block and include Coastal Loblolly Pine Wetland Forest, Early to Mid-Successional Loblolly Pine Forest, and Red Maple-Sweetgum Swamp. Dirickson Creek and its tributaries are the main drainages for the block. Currently this block contains no interior habitat. Potentially this block could be 276 acres in size, but would still contain no acres of interior habitat due to the adjacent salt marsh.

The Natural Progression of vegetation communities on the shores of the Inland Bays

Vegetation communities located adjacent to the shore of Delaware Bay or the Inland Bays go through natural progression of retreating backwards as sea level rises. For centuries this has meant that as sea level rises the forested communities will progress into shrubland, the shrubland will progress into marsh, and then the marsh will convert to open water, perhaps with a brief period as a mudflat. Further gradations can be noticed via different forests, shrublands, and marshes (high and low), and can be used to map out the effects of sea level rise and increasing salinity in the area. In the recent past (70 years) this natural progression appears to be eroding because of sea levels which are rising too fast for the natural progression to continue. In addition some communities reach a hardened shoreline, rip-rap or some other artificial barrier which prevents the progression.

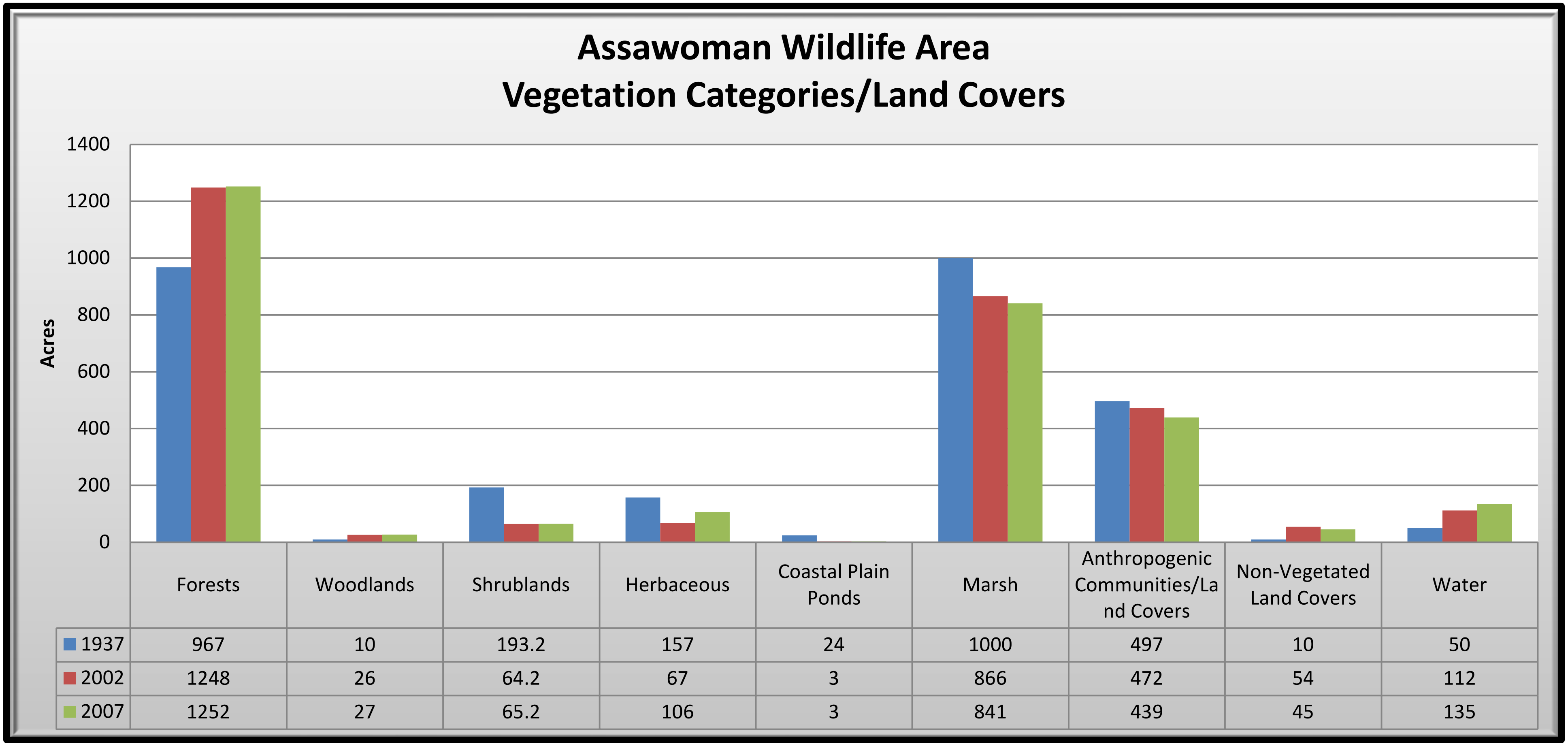
At Assawoman Wildlife Area it was observed in places that the marsh is coming into the forested areas and appears to be largely skipping over the shrubland stage (Figure 2.5). Other areas of Coastal Loblolly Pine Wetland Forest are showing signs of salt stress (Figure 2.6). The amount of North Atlantic High Salt Marsh has decreased markedly from 1937 levels and has converted to North Atlantic Low Salt Marsh. Artificial impoundments which are scattered throughout the wildlife area have eliminated about half of the marshland present 1937. These impoundments stand as ticking time bombs waiting for the water level to rise up there dams and be captured. Once an impoundment is captured it will likely revert to open water and will not allow for natural marsh development. Ditching in the marshes conducted in the early to middle part of the 20th century is helping to convert more marsh to water by acting as a direct injection mechanism into the marsh for high water events and for sea level rise.

<u>Natural Capital</u>

Assawoman Wildlife Area is expressive of a paradox between loss of tidal marsh and gains in water coverage due to sea level rise, erosion, and other factors. Estuaries are more valuable than tidal marsh as filters and nutrient cyclers, but the extra value held by estuaries may not stay once the tidal marshes are eliminated. In a sense the estuaries are undergoing a financial bubble that will burst once the marsh is eliminated resulting in massive losses in ecosystem services.

Figure 2.5. Pines that have died from salt water encroachment from the marsh (Muddy Neck Tract)

Figure 2.6. Salt Stressed Pines in a cove on the Piney Point Tract (Note the pines with brown tops in the background)



	Forests	Woodlands	Shrublands	Herbaceous	Coastal Plain Ponds	Marsh	Anthropogenic Communities/Land Covers	Non-Vegetated Land Covers	Water
1937	967	10	193.2	157	24	1000	497	10	50
2002	1248	26	64.2	67	3	866	472	54	112
2007	1252	27	65.2	106	3	841	439	45	135

Figure 3.1. Assawoman Wildlife Area Vegetation Categories/Land Covers (1937, 2002, and 2007)

Assawoman Wildlife Area Broad Trends (Figure 3.1): During the study period (1937-2007), forests, woodlands, non-vegetated land covers, and water all gained area, while all other categories lost ground. Most of the herbaceous communities present in 1937 have succeeded into forests and marsh has lost ground to water inundation and tidal mudflats. Coastal Plain ponds have suffered the largest relative decrease due to capture by adjoining marsh and groundwater infiltration. Water coverage has almost tripled in amount since 1937.

DNREC Sea Level Rise Analysis (Table 3.1)

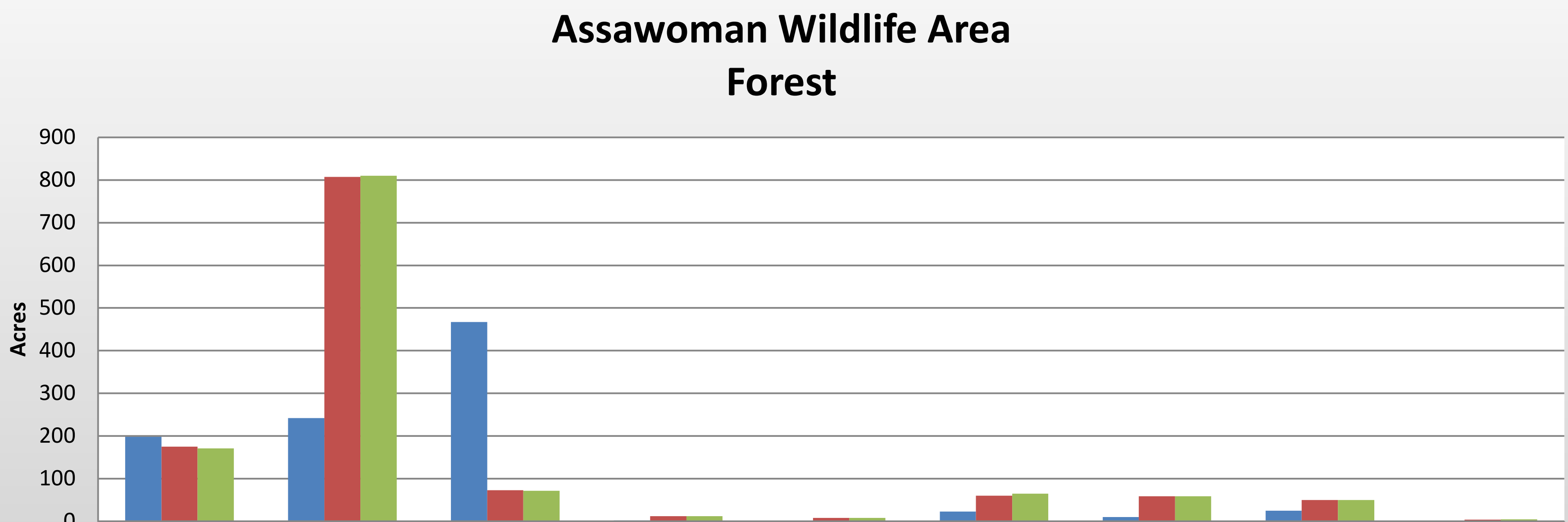
More half of Assawoman Wildlife Area will be inundated with 0.5 m of sea level rise. At 1 m of rise, about ¾ of the wildlife area will be underwater. Another 0.5 m of rise will inundated almost 84% of the wildlife area.

Table 3.1. Projected acres of Assawoman Wildlife Area Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	1,819 acres
1 m	2,149 acres
1.5 m	2,423 acres

Natural Capital (Table 3.2)

The natural capital of Assawoman Wildlife Area has been going up with the maturation of forests and the encroachment of estuarine water. Paradoxically, sea level rise is causing the value to increase, but this may be a temporary condition until the marsh disappears.

Table 3.2. Natural Capital of Assawoman Wildlife Area	
Year	**Natural Capital (in 2012 dollars)**
1937	$11,819,871/year
2002	$19,664,637/year
2007	$19,838,165/year



	Chesapeake Bay Non-riverine Wet Hardwood Forest	Coastal Loblolly Pine Wetland Forest	Early to Mid-Successional Loblolly Pine Forest	Mid-Atlantic Coastal Maritime Forest	Northeastern Modified Successional Forest	Red Maple-Sweetgum Swamp	Southern Red Oak/Heath Forest	Successional Maritime Forest	Successional Sweetgum Forest
1937	198	242	467	2	0	23	10	25	0
2002	175	807	73	12	8	60	59	50	4
2007	171	810	72	12	8	65	59	50	5

Figure 3.2. Forest at Assawoman Wildlife Area (1937, 2002, and 2007)

Assawoman Wildlife Area Forest (Figure 3.2): Forests have increased the most from 1937 to 2007 within Assawoman Wildlife Area. Places that were formerly clear-cuts or Northeastern Old Field in 1937 have grown into Coastal Loblolly Pine Wetland Forest where moist soil is present and Southern Red Oak/Heath Forest in areas of drier soil. Red Maple-Sweetgum Swamp has increased as former Creeping Rush Boltonia Coastal Plain Ponds are inundated. Some former Northeastern Old Fields have grown into Chesapeake Bay Non-riverine Wet Hardwood Forest.

DNREC Sea Level Rise Analysis (Table 3.3)

0.5 m of sea level rise will inundate about 1/3 of the forests in Assawoman Wildlife Area. 1 m of rise will inundate ½ of the forestland and 1.5 m of rise will inundate almost 2/3 of the forestland present at Assawoman Wildlife Area.

Table 3.3. Projected acres of Assawoman Wildlife Area Forest Impacted by Sea Level Rise

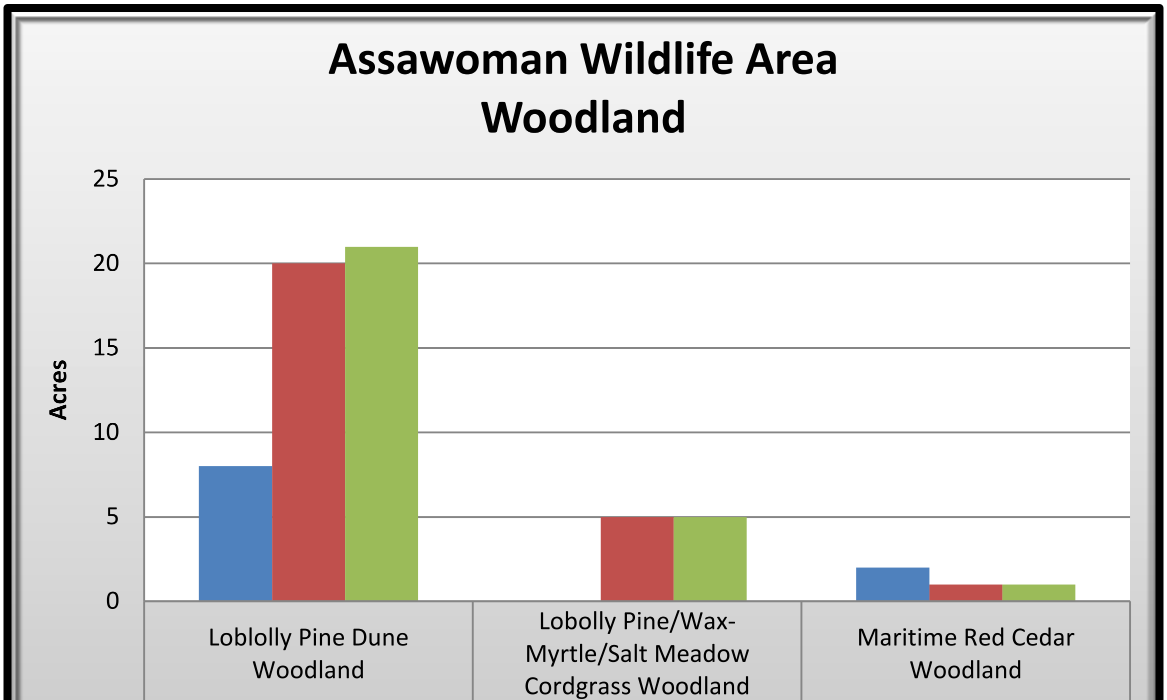
Rise	Acres
0.5 m	422 acres
1 m	666 acres
1.5 m	899 acres

Natural Capital (Table 3.4)

Maturation of forests is the primary factor in the increase in natural capital for Assawoman Wildlife Area. These values may start to decrease when sea level rise starts to take hold.

Table 3.4. Natural Capital of Assawoman Wildlife Area Forest

Year	Natural Capital (in 2012 dollars)
1937	$13,764,310/year
2002	$22,457,773/year
2007	$22,687,214/year



	Loblolly Pine Dune Woodland	Lobolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland	Maritime Red Cedar Woodland
1937	8	0	2
2002	20	5	1
2007	21	5	1

Figure 3.3. Woodland at Assawoman Wildlife Area (1937, 2002, and 2007)

Assawoman Wildlife Area Woodland (Figure 3.3): Woodlands increased up to 2002 in large part to an increase in the amount of woodland (Loblolly Pine Dune Woodland) on the South Bethany Tract and gain of one community (Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland) in the tracts (Miller Neck, Muddy Neck, and Piney Point) on the western bayside. The amount of woodland present in the wildlife area has been stable in the recent period (2002-2007). Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodlands in Assawoman Wildlife Area are present at the marsh/forest interface and represent the transitional phase of Coastal Loblolly Pine Wetland Forest converting from forest to shrubland or marsh. Maritime Red Cedar Woodland that was once common in the area before the establishment of the wildlife area, declined by half during the study period.

DNREC Sea Level Rise Analysis (Table 3.5)

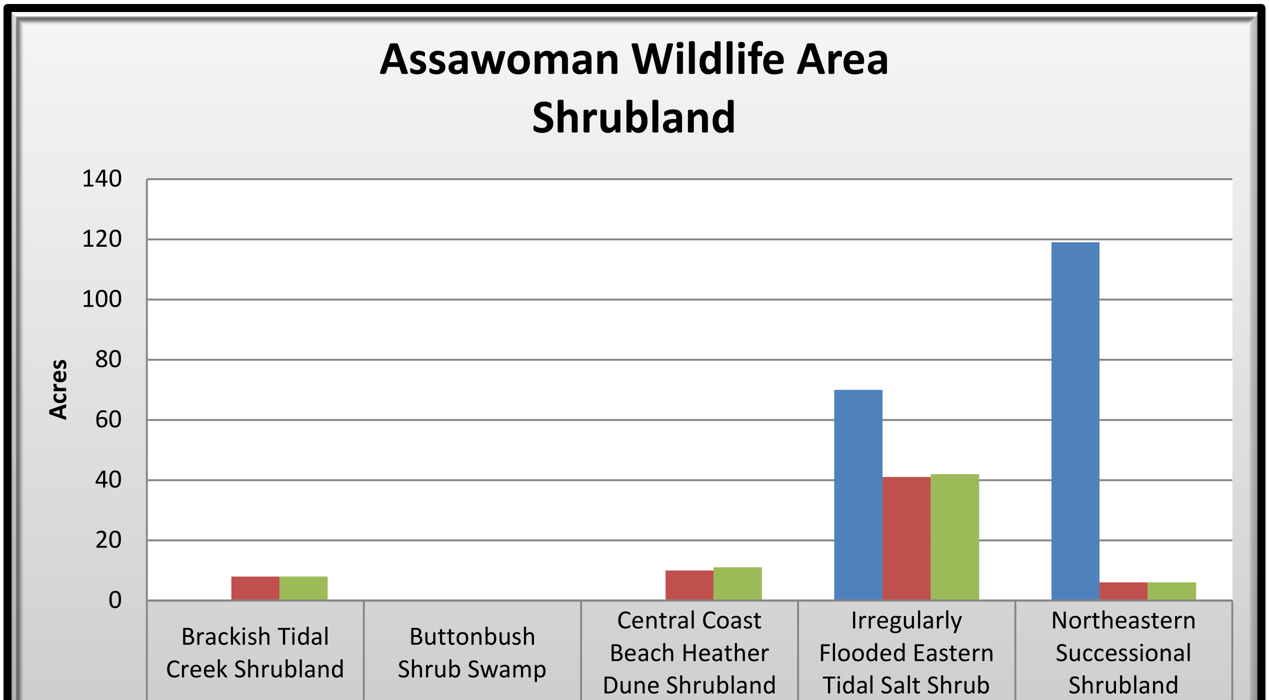
Most of the woodland present in Assawoman Wildlife Area will be inundated with 0.5 m of sea level rise. An additional 0.5 m will be essentially eliminated all of the woodland in its current extent.

Table 5.1. Projected acres of Assawoman Wildlife Area Woodland Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	22 acres
1 m	25 acres
1.5 m	25 acres

Natural Capital (Table 3.6)

Woodland does not have much capitalization in the wildlife area. It reaches its highest amount in 2002 and has decreased slightly since.

Table 3.6. Natural Capital of Assawoman Wildlife Area Woodland	
Year	**Natural Capital (in 2012 dollars)**
1937	$1,891/year
2002	$69,211/year
2007	$69,022/year



	Brackish Tidal Creek Shrubland	Buttonbush Shrub Swamp	Central Coast Beach Heather Dune Shrubland	Irregularly Flooded Eastern Tidal Salt Shrub	Northeastern Successional Shrubland
1937	0	0	0.2	70	119
2002	8	0.2	10	41	6.07
2007	8	0.2	11	42	6.05

Figure 3.4. Shrubland at Assawoman Wildlife Area (1937, 2002, and 2007)

Assawoman Wildlife Area Shrubland (Figure 3.4): The amount of shrubland in Assawoman Wildlife Area has decreased overall from 1937 to 2007, as Northeastern Successional Shrubland has converted to more mature forest communities and Irregularly Flooded Eastern Tidal Salt Shrub has died into marshland. The die-off of Irregularly Flooded Eastern Tidal Salt Shrub may be a result of increased rates of sea level and the plants inability to migrate with the rise, but the exact cause is beyond the scope of this study. Brackish Tidal Creek Shrubland did increase and is a community that can form from the forest/marsh interface. Central Coast Beach Heather Dune Shrubland has been populating areas that were bare sand in 1937 and is steadily increasing. The reason for this increase is unclear at this time, but it could be due to the stabilization of the dunes from development. Buttonbush shrub swamp has appeared since 1937 and may be the result of more groundwater in a depression on the Muddy Neck Tract where it is located.

DNREC Sea Level Rise Analysis (Table 3.7)

Most of the shrubland in the wildlife area will be inundated with 0.5 m of rise. At 1 m of rise nearly all of the shrubland will be inundated and an additional 0.5 m of rise will inundate all of the shrubland.

Table 3.7. Projected acres of Assawoman Wildlife Area Shrubland Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	53 acres
1 m	63 acres
1.5 m	65 acres

Natural Capital (Table 3.8)

Shrubland capitalization has oscillated through time with the highest amount in 1937. The amount has increased between 2002 and 2007, driven by gains in Irregularly Flooded Eastern Tidal Salt Shrub and Central Coast Beach Heather Dune Shrubland.

Table 3.8. Natural Capital of Assawoman Wildlife Area Shrubland	
Year	**Natural Capital (in 2012 dollars)**
1937	$501,382/year
2002	$464,950/year
2007	$483,764/year

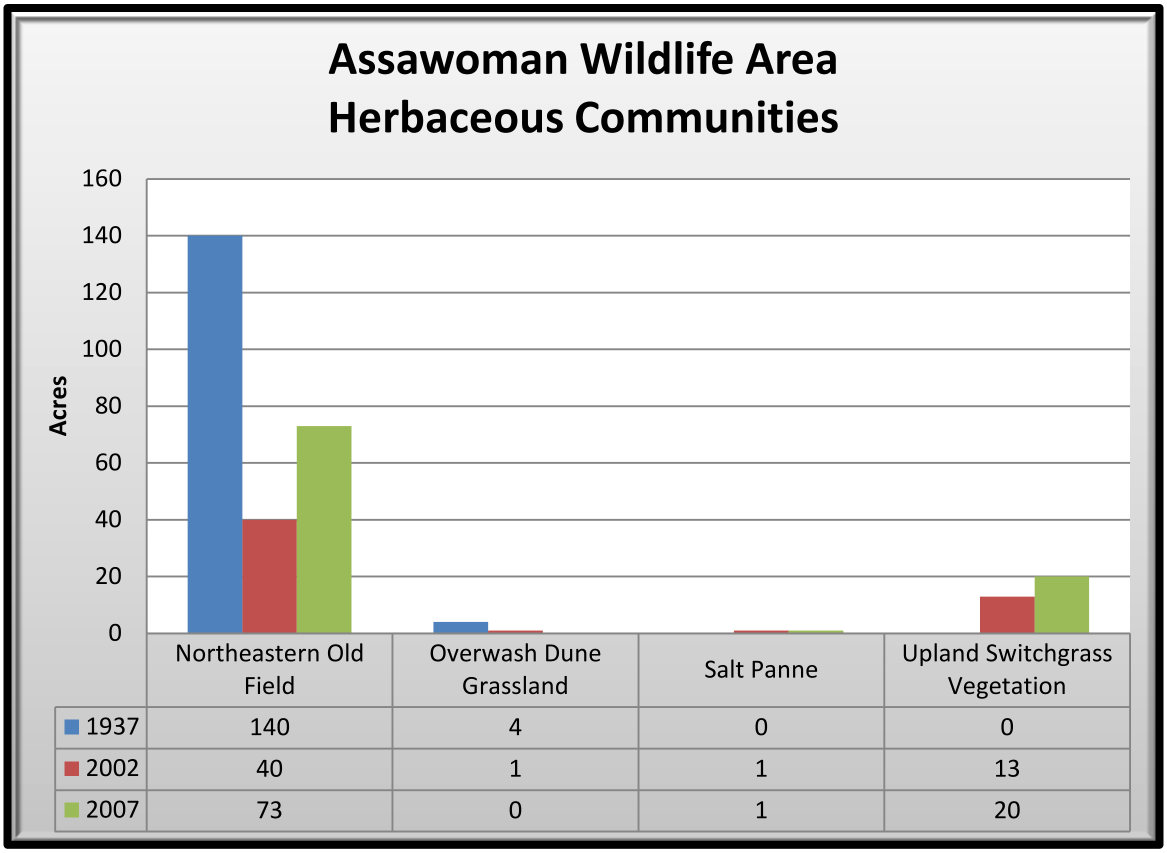


Figure 3.5. Herbaceous Communities at Assawoman Wildlife Area (1937, 2002, and 2007)

Assawoman Wildlife Area Herbaceous Communities (Figure 3.5): In 1937 there was a lot more acreage of Northeastern Old Field at Assawoman Wildlife Area due in large part to a high amount of regenerating clear-cuts and areas that had been abandoned from agriculture but had yet to develop into forests. Overwash Dune Grassland is an ephemeral community resulting from sand that is pushed over the marsh and waxes and wanes depending on storm frequency. At the current time this community is present in the wildlife area, but it may reappear with the next storm. Salt Pannes may be more frequent owing that they are hard to distinguish specifically in aerial imagery from tidal mudflats. Salt Pannes may have been present in 1937, but the 1937 imagery does not bring out its features as well as the color imagery from 2002 and 2007. Upland Switchgrass Vegetation is an artificial community at Assawoman Wildlife Area that is planted on the edges of agricultural Fields as a vegetated buffer.

DNREC Sea Level Rise Analysis (Table 3.9)

A lot of the herbaceous communities in Assawoman Wildlife Area are located in places of higher elevation and the numbers below show this. At 0.5 m of sea level rise only 35 acres are inundated representing about a third of the total. 1 m of rise will inundate another 8 acres and 1.5 m of rise will inundate 48 acres or about half of the total.

Table 3.9. Projected acres of Assawoman Wildlife Area Herbaceous Communities Impacted by Sea Level Rise

Rise	Acres
0.5 m	35 acres
1 m	43 acres
1.5 m	48 acres

Natural Capital (Table 3.10)

Capitalization of herbaceous communities has been going up with the planting of Upland Switchgrass Vegetation on the edges of agricultural fields. It is not known whether the planting will continue or not.

Table 3.10. Natural Capital of Assawoman Wildlife Area Herbaceous Communities

Year	Natural Capital (in 2012 dollars)
1937	$22,875/year
2002	$7,868/year
2007	$13,259/year

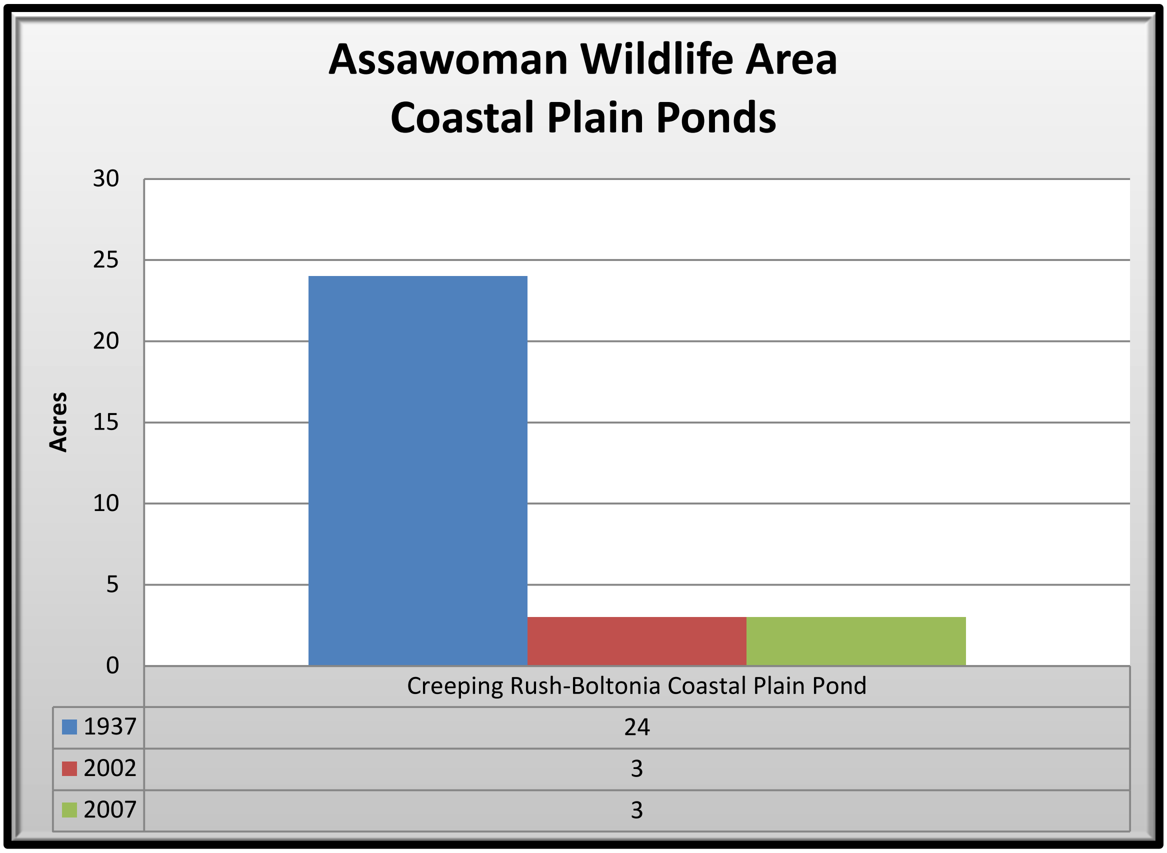


Figure 3.6. Coastal Plain Ponds at Assawoman Wildlife Area (1937, 2002, and 2007)

Assawoman Wildlife Area Coastal Plain Ponds (Figure 3.6): Creeping Rush-Boltonia Coastal Plain Pond is the only Coastal Plain pond community still present in the wildlife area. In 1937 there were more ponds present totaling 24 acres, but impoundments and marsh succession eliminated all but one of three acres. Bill McAvoy, botanist with the Delaware Natural Heritage Program, has noticed that a lot of the ponds have been converting to more brackish species over time and he may have seen in the field what I have noticed from imagery and that is the conversion of the ponds from freshwater to more brackish conditions as the sea level meets their elevation.

DNREC Sea Level Rise Analysis (Table 3.11)

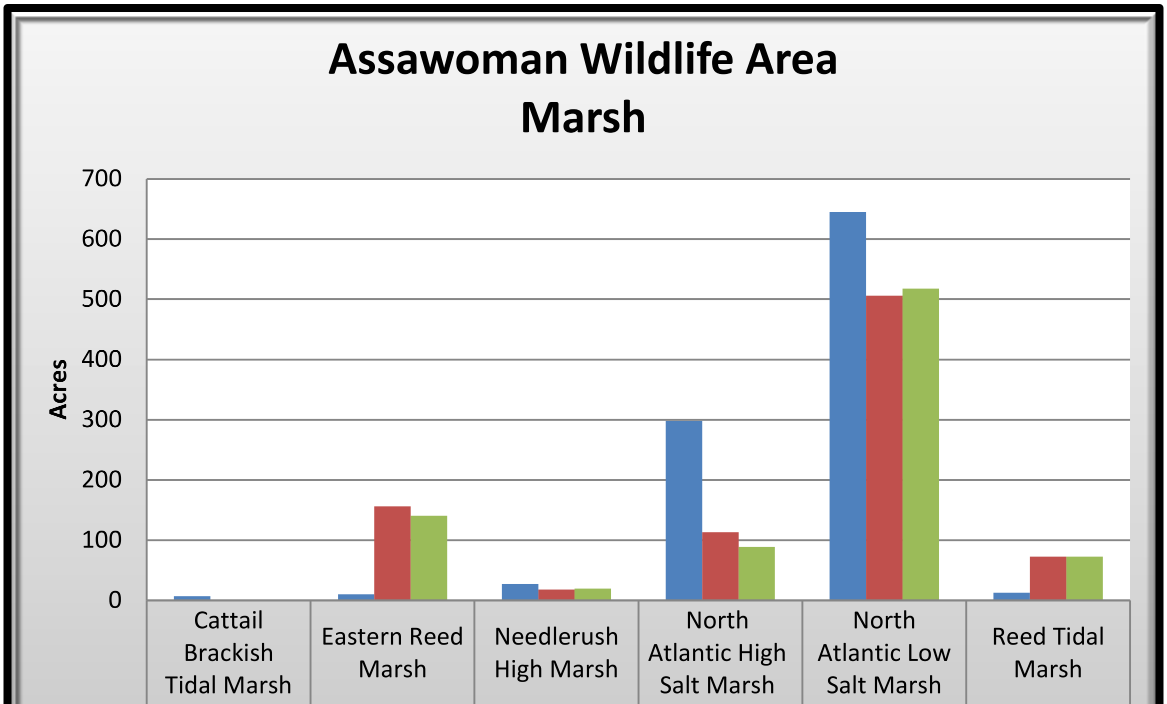
The current coastal plain ponds in Assawoman Wildlife Area are located in topographic lows but will not be affected until between 1 m and 1.5 m of sea level rise occurs.

Table 3.11. Projected acres of Coastal Plain Ponds Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	0 acres
1 m	0 acres
1.5 m	3 acres

Natural Capital (Table 3.12)

The amount of capital in Coastal Plain ponds has gone down greatly with the “capture” of a lot of the ponds in Miller Neck and Muddy Neck. These ponds will likely last in the near future but will disappear at some point between 1 m of 1.5 m of rise.

Table 3.12. Natural Capital of Assawoman Wildlife Area Coastal Plain Ponds	
Year	**Natural Capital (in 2012 dollars)**
1937	$222,754/year
2002	$27,844/year
2007	$27,844/year



	Cattail Brackish Tidal Marsh	Eastern Reed Marsh	Needlerush High Marsh	North Atlantic High Salt Marsh	North Atlantic Low Salt Marsh	Reed Tidal Marsh
1937	7	10	27	298	645	13
2002	0	156	18	113	506	73
2007	0	141	20	89	518	73

Figure 3.7. Marsh at Assawoman Wildlife Area (1937, 2002, and 2007)

Assawoman Wildlife Area Marsh (Figure 3.7): The total acreage of all marsh types in the wildlife area has gradually decreased from 1937 to 2007. North Atlantic High Marsh has incurred the largest losses due to impoundment development in the 1950's and 1960's and conversion to Reed Tidal Marsh and North Atlantic Low Salt Marsh. It is uncertain whether the amounts seen in the 1930's were artificially high due to salt hay farming, but whatever the cause, the acreages have definitely decreased and is a decrease that can be seen in the recent period (2002-2007) that is still happening. Cattail Brackish Tidal Marsh has been eliminated from the wildlife area as the marshes have become more salty. Eastern Reed Marsh has increased around the impoundments that were formerly North Atlantic Low Salt Marsh. Needlerush High Marsh has experienced an overall decrease but could increase in the future with increased average temperatures, if it can progress landward and if the marsh habitats remain. Some places in the Piney Point Tract have experienced increases in needlerush recently, perhaps showing an early response to climate change. However, the habitat it occupies is the same as the North Atlantic High Salt Marsh and this habitat seems to be rapidly declining.

DNREC Sea Level Rise Analysis (Table 3.13)

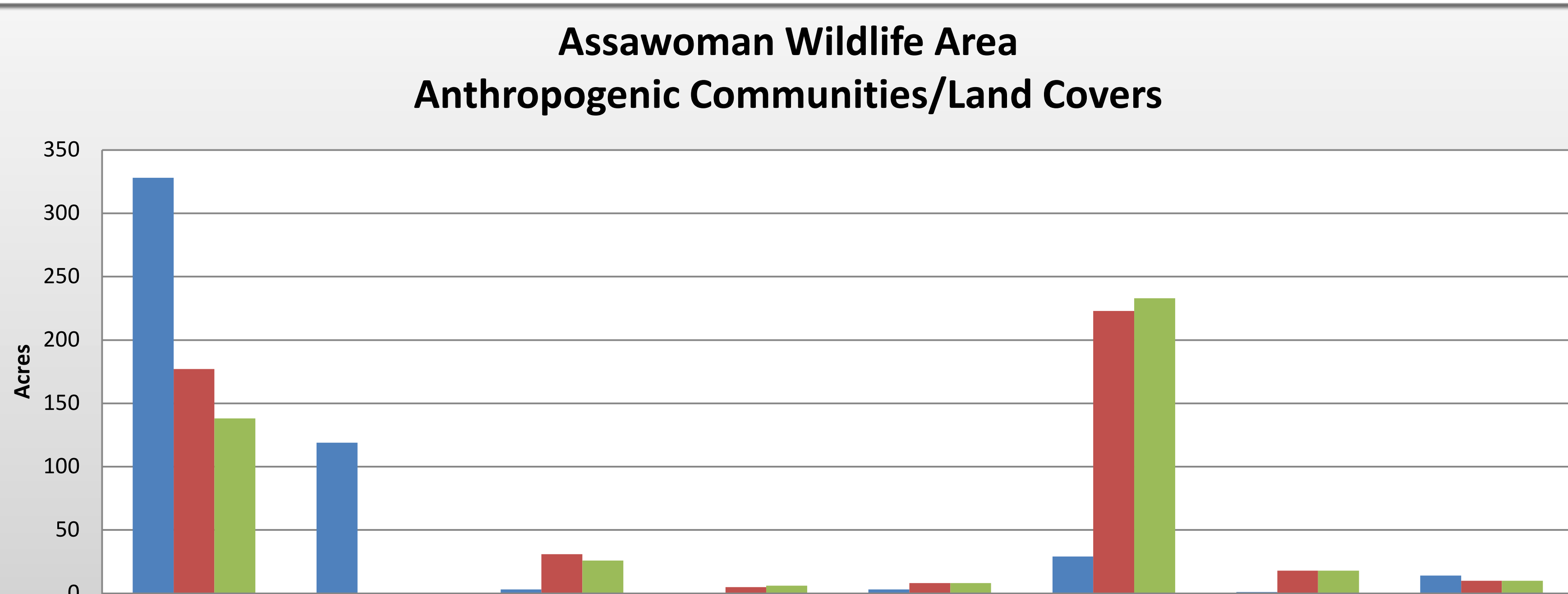
All of the current marshland present in Assawoman Wildlife Area will be lost with just 0.5 m of rise. It is not known whether marshland will reform but given the rates of rise it is not likely.

Table 3.13. Projected acres of Assawoman Wildlife Area Marsh Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	838 acres
1 m	838 acres
1.5 m	838 acres

Natural Capital

Natural capital of marsh has been going down with decreases in marsh amounts. This trend is expected to continue and in fact increase with higher rates of sea level rise.

Table 3.14. Natural Capital of Assawoman Wildlife Area Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$6,282,587/year
2002	$5,909,301/year
2007	$5,694,825/year



	Agricultural Field	Clear-cut	Cultivated Lawn	Farm Pond/Artificial Pond	Impervious Surface	Impoundment	Modified Land	Semi-impervious Surface
1937	328	119	3	0	3	29	1	14
2002	177	0	31	5	8	223	18	10
2007	138	0	26	6	8	233	18	10

Figure 3.8. Anthropogenic Communities at Assawoman Wildlife Area (1937, 2002, and 2007)

Assawoman Wildlife Area Anthropogenic Communities/Land Covers (Figure 3.8): Agricultural fields have decreased through abandonment of agriculture in the wildlife area. Losses in agricultural fields have been more than made up for with impoundment increases which have eliminated acres of high and low marsh. The impoundments at Assawoman Wildlife Area were built mostly in the 1950 to 1960's with some being built in the 1930's during the ownership of the USDA. After the building of the impoundments the amount of acreage has continued to increase which can be seen in the vegetation maps and could be due to a rise in the water table level caused by sea level rise. Farm Pond/Artificial Ponds mainly due to a borrow pit have appeared in the wildlife area since 1937. Modified land is located in the Muddy Neck Tract where dredge spoil is being placed from the Little Assawoman Canal. Semi-impervious surface has remained nearly constant with some loss from paving of roads that were formerly packed sand.

DNREC Sea Level Rise Analysis (Table 3.15)

More than half of the current anthropogenic communities will be inundated with 0.5 m of rise. An additional 0.5 m of rise will inundate another 40 acres or 2/3. 1.5 m of rise will inundate most of the anthropogenic communities located in the wildlife area.

Table 3.15. Projected acres of Anthropogenic Communities/Land Covers Impacted by Sea Level Rise

Rise	Acres
0.5 m	288 acres
1 m	328 acres
1.5 m	360 acres

Natural Capital (Table 3.16)

Most of the land covers and vegetation communities in this category do not have any ecological service value and therefore no capital. However the capital of the impoundments has been going up with increases in acreage.

Table 3.16. Natural Capital of Assawoman Wildlife Area Anthropogenic Communities/Land Covers

Year	Natural Capital (in 2012 dollars)
1937	$173,529/year
2002	$1,210,548/year
2007	$1,283,003/year

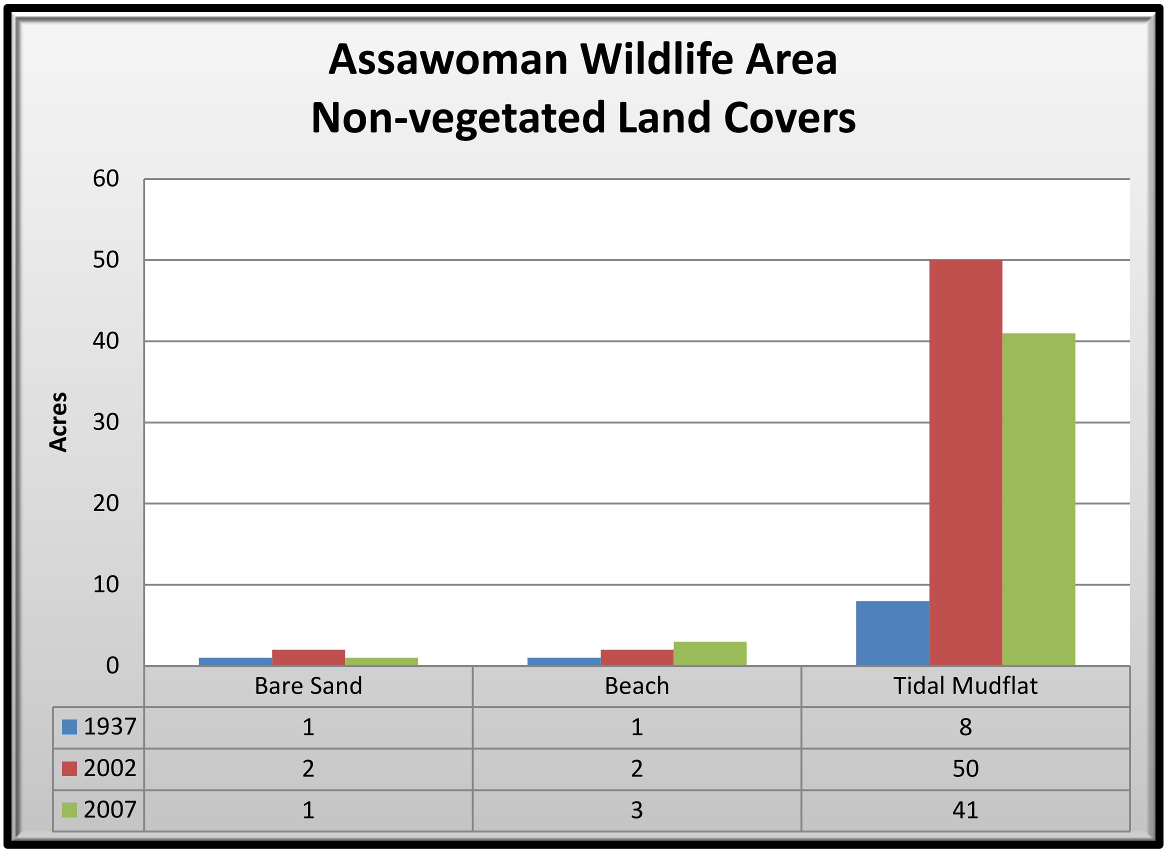


Figure 3.9. Non-vegetated Land Covers at Assawoman Wildlife Area (1937, 2002, and 2007)

Assawoman Wildlife Area Non-vegetated Land Covers (Figure 3.9): Non-vegetated land covers gained acreage due to tidal mudflats, which could be due to salt marsh dieback (prevalent at the time of the 2007 imagery), sea level rise, goose eat-outs, or a combination of the three. The amount of beach has increased and could be due to freed marsh sediments, erosion of tidal mudflats on the bayside, or beach renourishment projects.

DNREC Sea Level Rise Analysis (Table 3.17)

All of the non-vegetated communities are located in the marsh or near the water making them vulnerable to inundation and as such with 0.5 m of sea level rise, all of these communities will be inundated in their current extent.

Table 3.17. Projected acres of Assawoman Wildlife Area Non-vegetated Communities Impacted by Sea Level Rise

Rise	Acres
0.5 m	43 acres
1 m	44 acres
1.5 m	44 acres

Natural Capital (Table 3.18)

The capitalization of these communities has been going up with increases in tidal mudflats. This is likely a temporary condition however, as the tidal mudflats are generally a transition land cover from marsh to water.

Table 3.18. Natural Capital of Assawoman Wildlife Area Non-vegetated Land Covers

Year	Natural Capital (in 2012 dollars)
1937	$43,899/year
2002	$316,074/year
2007	$258,378/year

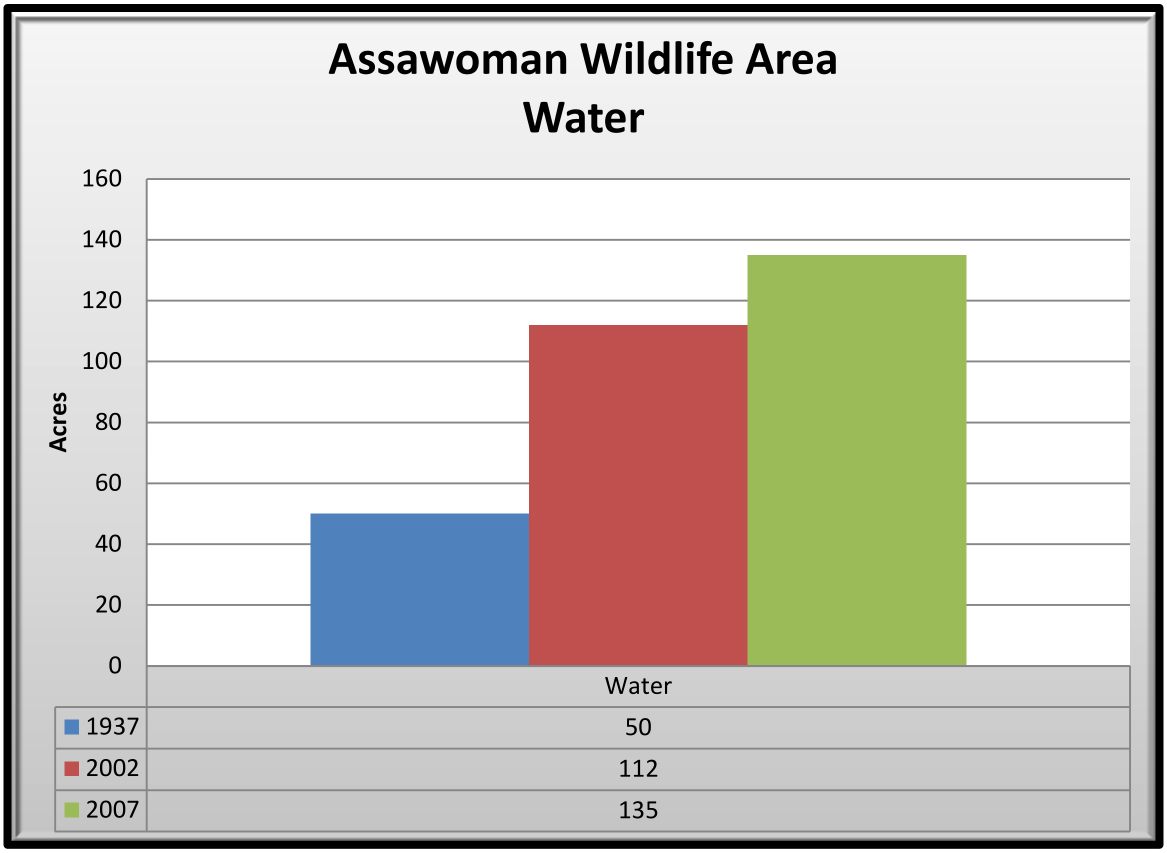


Figure 3.10. Water coverage (non-impoundment) at Assawoman Wildlife Area (1937, 2002, and 2007)

Assawoman Wildlife Area Water (Figure 3.10): This category includes water which is subject to sea level rise either through tidal water or rises in the water table (excluding impoundments and farm ponds/artificial ponds). Water acreage has risen in the 1937 to 2007 period and appears to be rising at a faster rate in the recent period (2002 to 2007) than the historical average (1937 to 2007). More discussion is presented in the water category of the land cover discussion.

Natural Capital (Table 3.19)

Most of the capitalization of this land cover is located in the estuary of Little Assawoman Bay. Estuaries are valuable nutrient cyclers and carry a lot of value. The value has been going up with sea level rise as it inundates other communities and land covers.

Table 3.19. Natural Capital of Assawoman Wildlife Area Water	
Year	**Natural Capital (in 2012 dollars)**
1937	$716,643/year
2002	$1,605,279/year
2007	$1,949,268/year

Chapter 4: Vegetation Communities by Tract

1. Miller Neck Tract

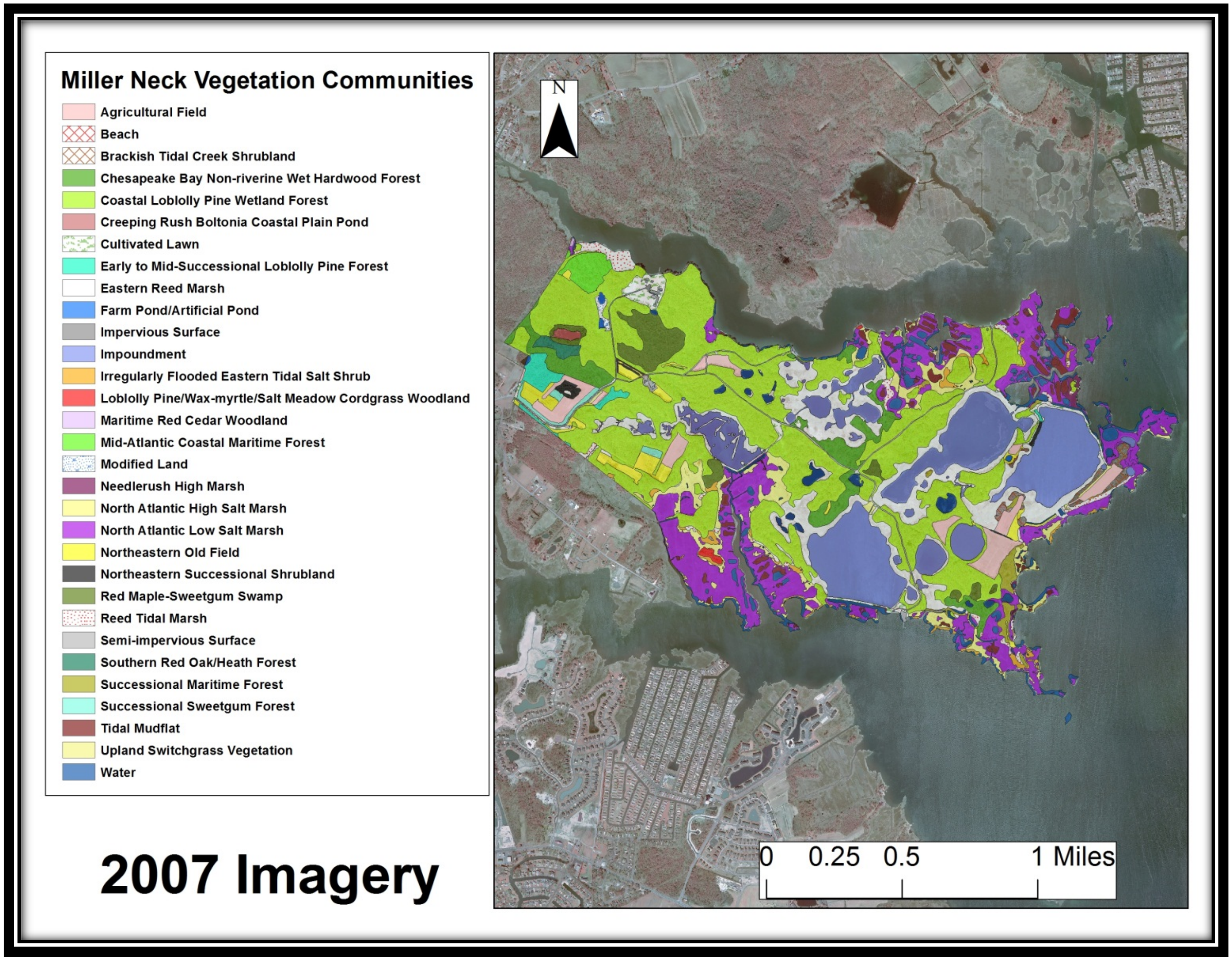


Figure 4-1.1. 2007 Vegetation Community map of the Miller Neck Tract

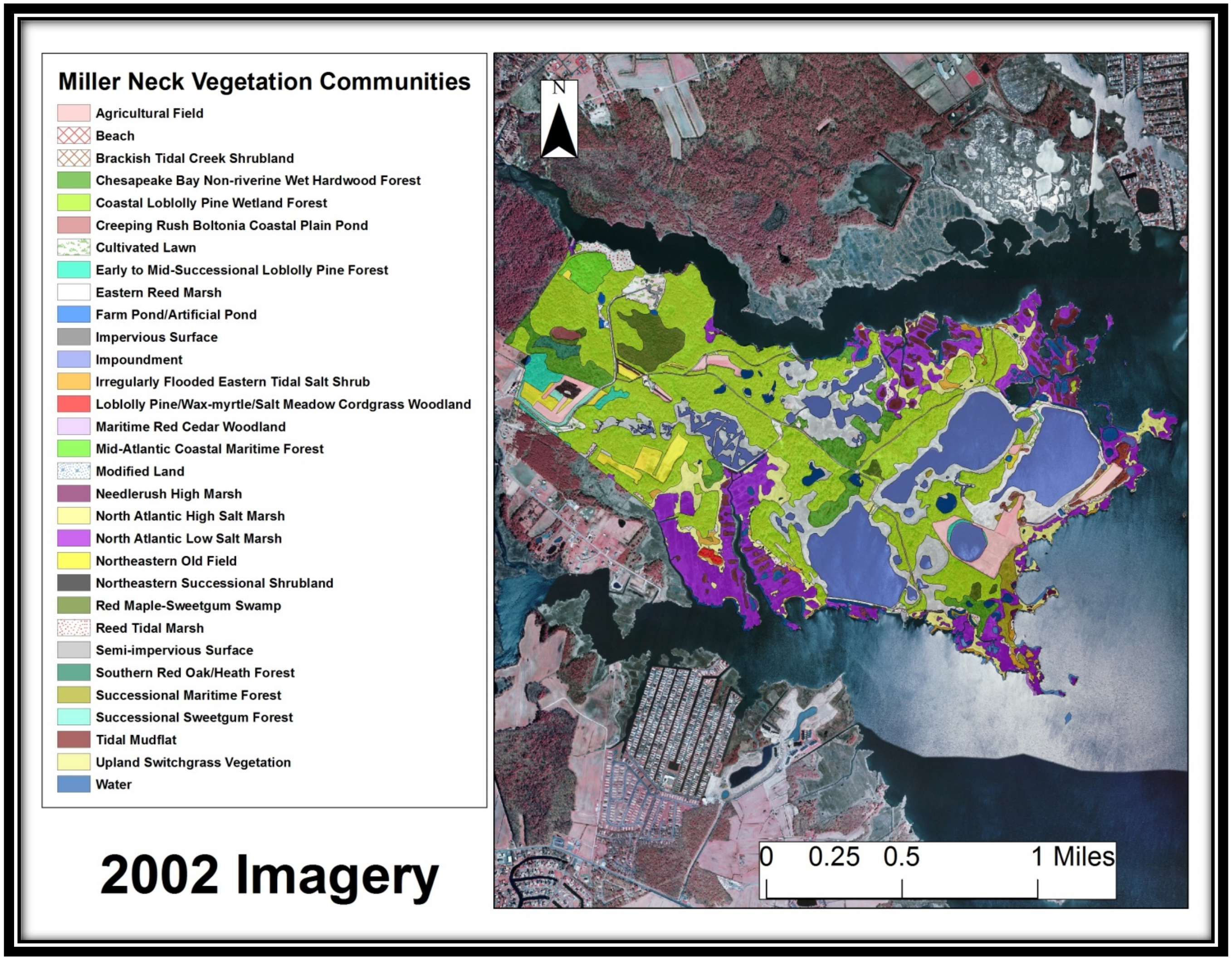


Figure 4-1.2. 2002 Vegetation Community of the Miller Neck Tract

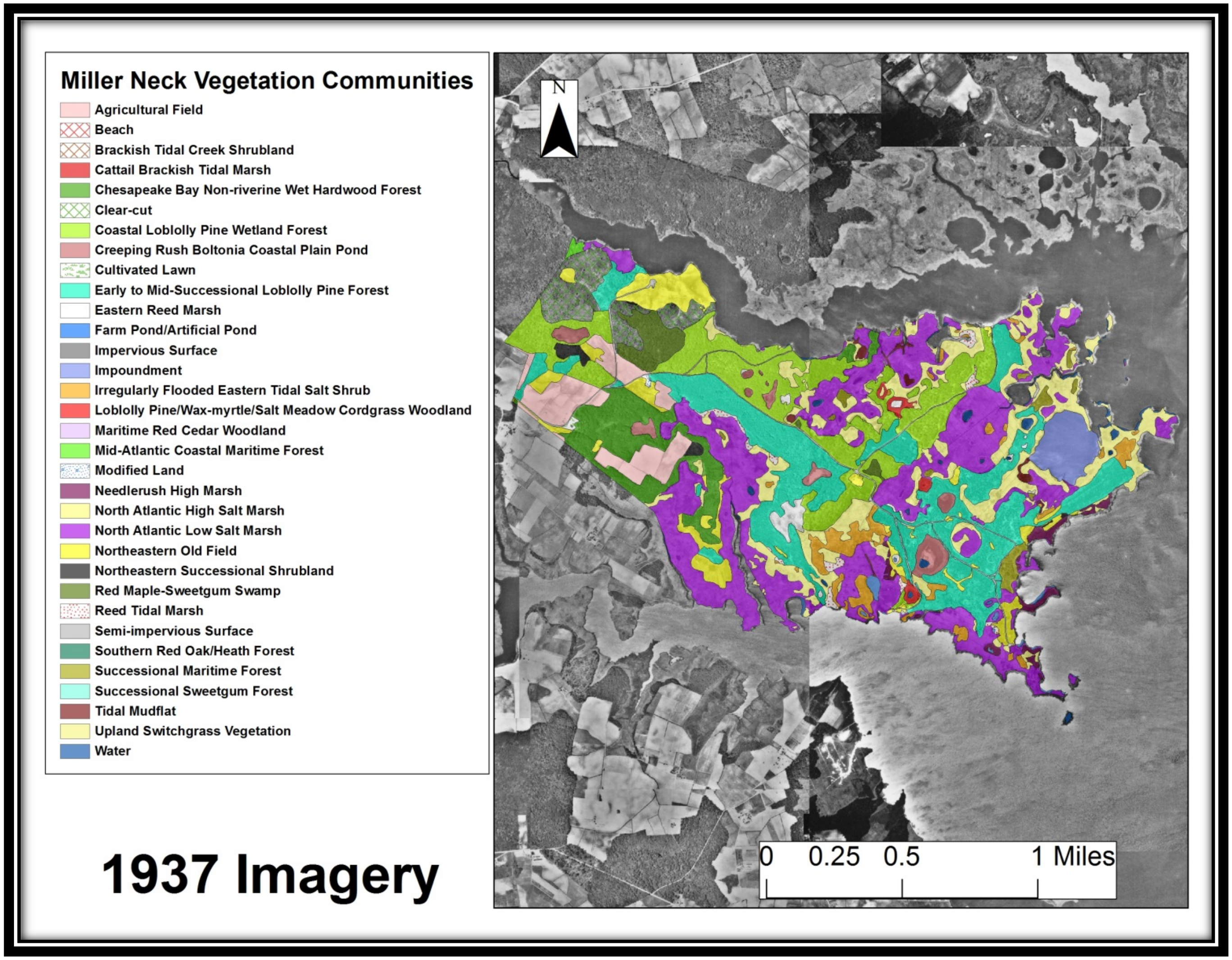
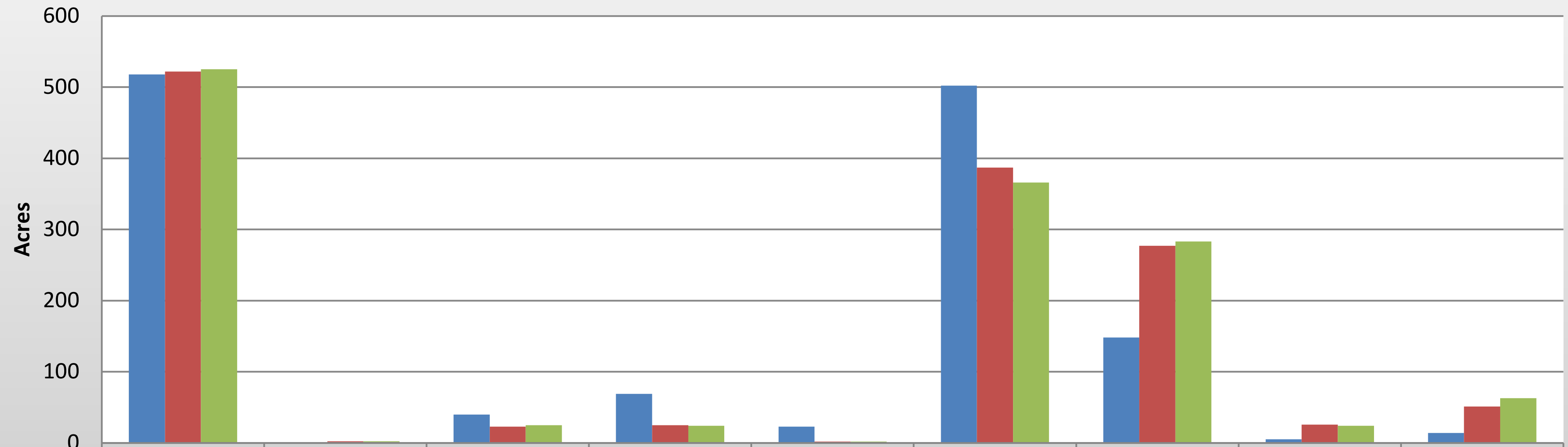


Figure 4-1.3. 1937 Vegetation Community map of the Miller Neck Tract



	Forests	Woodlands	Shrublands	Herbaceous	Coastal Plain Ponds	Marsh	Anthropogenic Communities/Land Covers	Non-Vegetated Land Covers	Water
1937	518	0	40	69	23	502	148.2	5.05	14
2002	522	2.2	23	25	2	387	277	25.5	51
2007	525	2.2	25	24	2	366	283	24	63

Figure 4-1.4. Miller Neck Tract Vegetation Categories/Land Covers (1937, 2002, and 2007)

Miller Neck Tract Broad Trends (Figure 4-1.4): Forests have remained at about the same acreage in the Miller Neck Tract over the study period. A very small amount of woodlands have appeared that are presumably due to sea-level rise converting Coastal Loblolly Pine Wetland Forest to Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland. Shrublands have decreased largely due to the losses of Irregularly Flooded Eastern Tidal Salt. Herbaceous communities have declined overall as these communities succeed to other more mature wooded communities. Coastal Plain ponds are gradually being taken over by marshland. Marshes have suffered a double punch from sea level rise and development of impoundments losing almost 150 acres. Anthropogenic communities have decreased mainly from the abandonment of agricultural fields. Non-vegetated communities have increased through the increase in tidal mudflats. Water inundation has increased over the study period reflecting a trend across all tracts, but the rise in the Miller Neck Tract appears to be the most rapid.

DNREC Sea Level Rise Analysis (Table 4-1.1)

Most of the Miller Neck Tract will be inundated with 0.5 m of sea level rise with each successional 0.5 m rise adding about 100 acres to the total. The Miller Neck Tract is one of the most vulnerable tracts in a wildlife area that is the most vulnerable to sea level rise.

Table 4-1.1. Projected acres of the Miller Neck Tract Impacted by Sea Level Rise

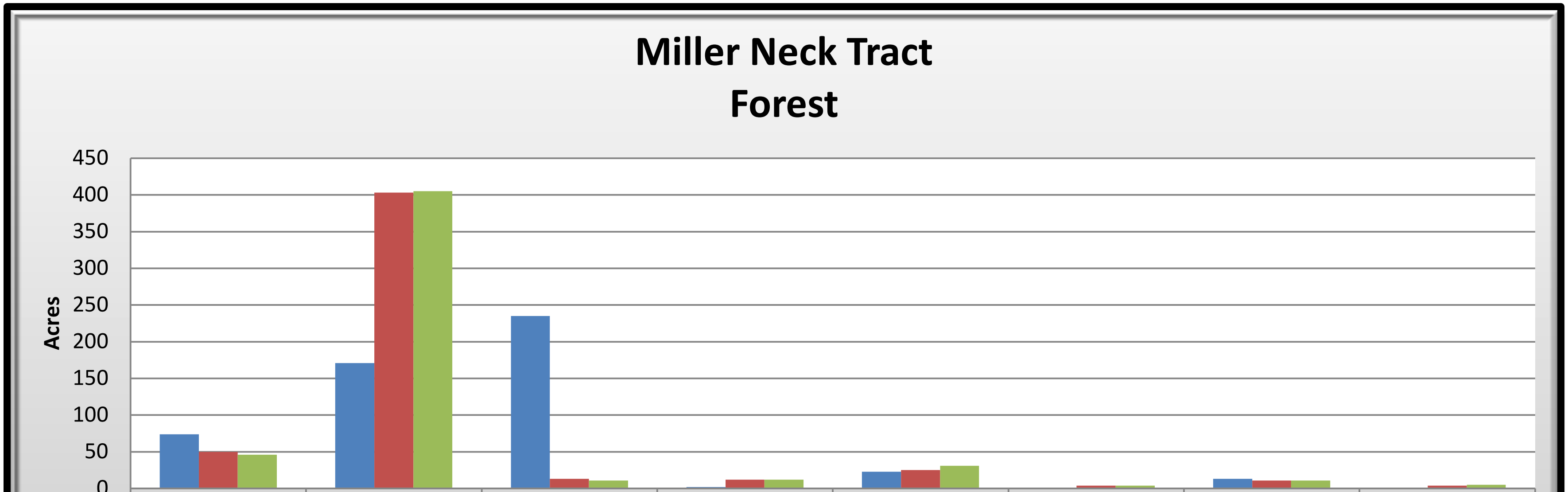
Rise	**Acres**
0.5 m	1,001 acres
1 m	1,141 acres
1.5 m	1,220 acres

Natural Capital (Table 4-1.2)

The natural capital of the Miller Neck has consistently increased since 1937 with reforestation and the amount of water coverage.

Table 4-1.2. Natural Capital of the Miller Neck Tract

Year	**Natural Capital (in 2012 dollars)**
1937	$7,347,318/year
2002	$10,857,968/year
2007	$10,958,305/year



	Chesapeake Bay Non-riverine Wet Hardwood Forest	Coastal Loblolly Pine Wetland Forest	Early to Mid-Successional Loblolly Pine Forest	Mid-Atlantic Coastal Maritime Forest	Red Maple-Sweetgum Swamp	Southern Red Oak/Heath Forest	Successional Maritime Forest	Successional Sweetgum Forest
1937	74	171	235	2	23	0	13	0
2002	50	403	13	12	25	4	11	4
2007	46	405	11	12	31	4	11	5

Figure 4-1.5. Miller Neck Tract Forest (1937, 2002, and 2007)

Miller Neck Tract Forests (Figure 4-1.5): The Miller Neck Tract contains the most Coastal Loblolly Pine Wetland Forest of any tract in the wildlife area, most of which has come from the maturation of Early to Mid-Successional Loblolly Pine Forests present in 1937. Red Maple-Sweetgum has increased as depressions are gradually filled with water. Southern Red Oak/Heath Forest has come about through forest maturation since 1937 and is found on the higher parts of the tract, which are few. Successional Sweetgum Forest has developed on some of the former agricultural fields and continues to make small increases. Mid-Atlantic Coastal Maritime Forest has populated an area of higher ground in the northern part of the tract. While present in small amount in 1937 it has grown in time. This forest may eventually succeed to a Southern Red Oak/Heath Forest if the pines are eventually replaced by hardwoods. It is unknown whether this a climax forest type in this area. Successional Maritime Forest has decreased slightly, largely from losses due to the conversion to maritime shrubland and marsh.

The natural capital of forest in the Miller Neck Tract has been rising as more forest matures on the tract. A lot the forest acreage in the Miller Neck Tract could be considered to be a wetland (Coastal Loblolly Pine Wetland Forest and Red Maple-Sweetgum Swamp) leading to a high value for the Miller Tract Forests.

DNREC Sea Level Rise Analysis (Table 4-1.3)

A lot of the forested areas, with the exception of Successional Maritime Forest and Coastal Loblolly Pine Wetland Forest, are located at the higher areas of the tract. As a result only about half will be inundated by 0.5 m of sea level rise. However with 1 m and higher rise even these areas will be greatly reduced.

Table 4-1.3. Projected acres of the Miller Neck Tract Forests Impacted by Sea Level Rise

Rise	Acres
0.5 m	281 acres
1 m	393 acres
1.5 m	457 acres

Natural Capital (Table 4-1.4)

Maturation of the forest from previously open land has contributed the most natural capital to the Miller Neck Tract. This figure has continued to increase but may start to transfer some capital to other categories such as marsh or water as sea level rises.

Table 4-1.4. Natural Capital of Miller Neck Tract Forest

Year	Natural Capital (in 2012 dollars)
1937	$3,341,397/year
2002	$5,883,657/year
2007	$5,932,634/year

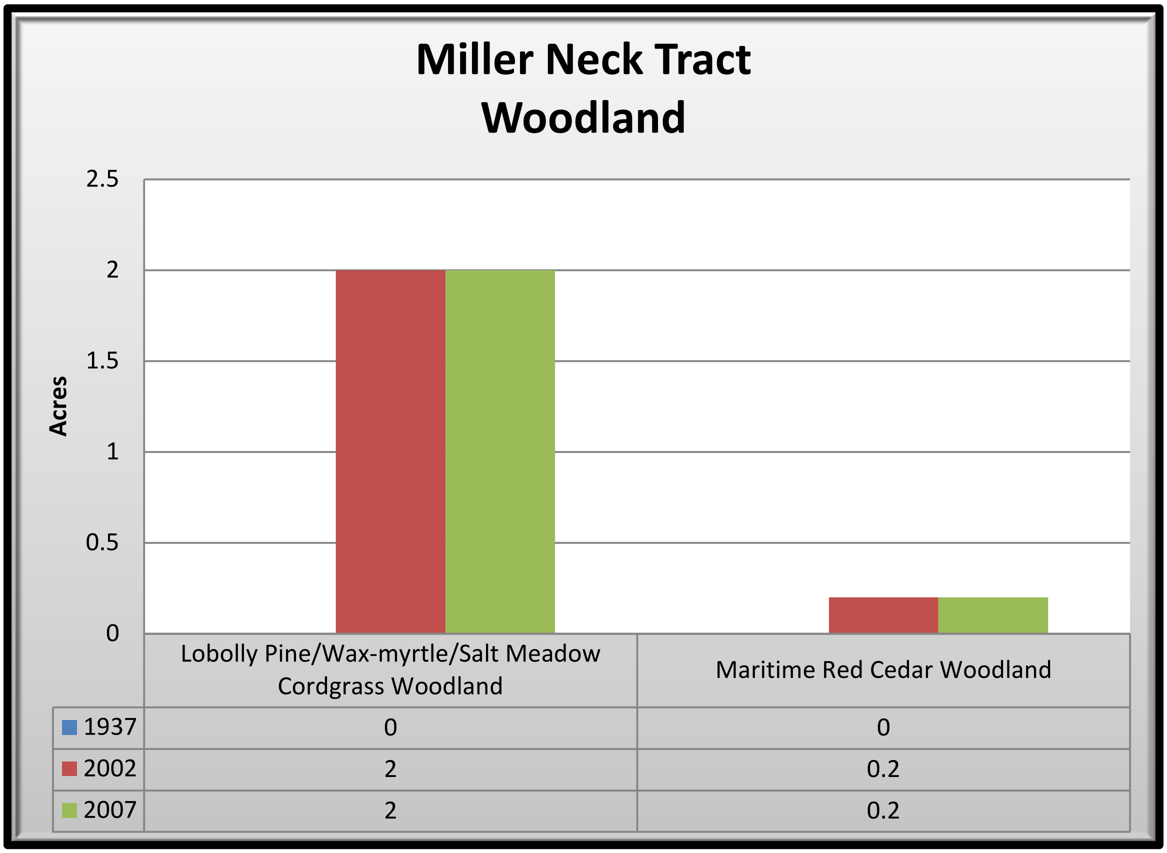


Figure 4-1.6. Miller Neck Tract Woodland (1937, 2002, and 2007)

Miller Neck Tract Woodland (Figure 4-1.6): Woodlands were not present in the Miller Neck Tract in 1937. Maritime Red Cedar Woodland is reported in literature in the 1920's but eastern red cedar (*Juniperus virginiana*) was logged out shortly before the 1937 imagery and before the time of the wildlife area. Since 1937, two woodlands have taken hold. Loblolly Pine/Wax-myrtle/Salt Meadow Cordgrass Woodland has likely come about by the conversion of Coastal Loblolly Pine Wetland Forest from sea level rise and likely represents an intermediate community between the former community and shrubland or marsh. The small amount of Maritime Red Cedar Woodland may have come back through the buried seed bank.

Both of the woodland communities present in the Miller Neck Tract are non-wetland and are valued at $122/year for ecosystem services. Woodlands were not present in 1937 but came about in 2002 and have remained at the same acreage since.

DNREC Sea Level Rise Analysis (Table 4-1.5)

All of the woodlands present in the Miller Neck will be inundated by 0.5 m of sea level rise in their current extent.

Table 4-1.5. Projected acres of Miller Neck Woodland Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	2 acres
1 m	2 acres
1.5 m	2 acres

Natural Capital (Table 4-1.6)

Woodlands were not present in 1937 and have since come into the wildlife area with conversion of Coastal Loblolly Pine Wetland Forest. Currently the capital of woodlands has remained at $415 in the short-term (2002-2007).

Table 4-1.6. Natural Capital of Miller Neck Tract Woodland	
Year	**Natural Capital (in 2012 dollars)**
1937	0 (not present)
2002	$24,621/year
2007	$24,621/year

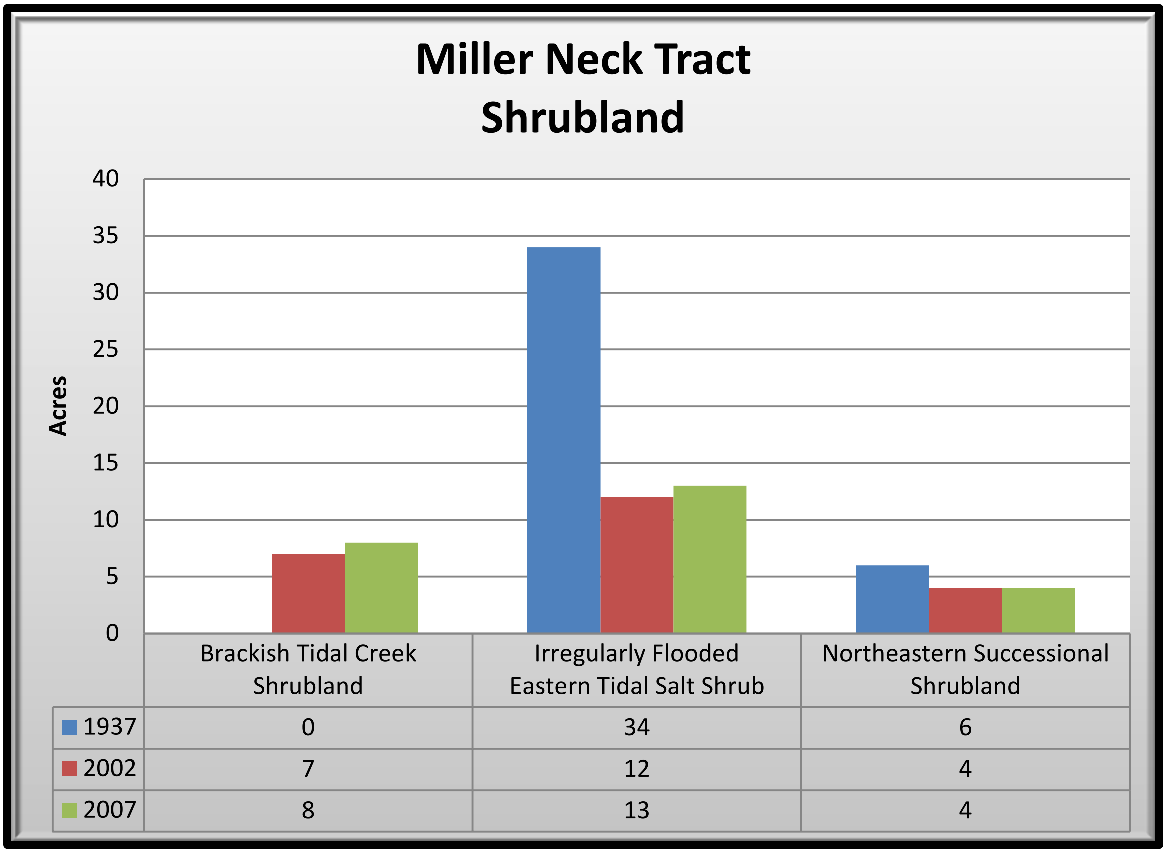


Figure 4-1.7. Miller Neck Tract Shrubland (1937, 2002, and 2007)

Miller Neck Tract Shrubland (Figure 4-1.7): Shrublands on the Miller Neck Tract have decreased since 1937, driven largely from losses in Irregularly Flooded Eastern Tidal Salt Shrub, a trend seen in other tracts and areas. This decrease has been offset by the appearance and increase in Brackish Tidal Creek Shrubland and the stability of Northeastern Successional Shrubland.

The natural capital of Miller Neck Tract shrubland was at its greatest in 1937 but has recently rebounded somewhat from 2002 with an increase in acreage from both Brackish Tidal Creek Shrubland and Irregularly Flooded Eastern Tidal Salt Shrub.

DNREC Sea Level Rise Analysis (Table 4-1.7)

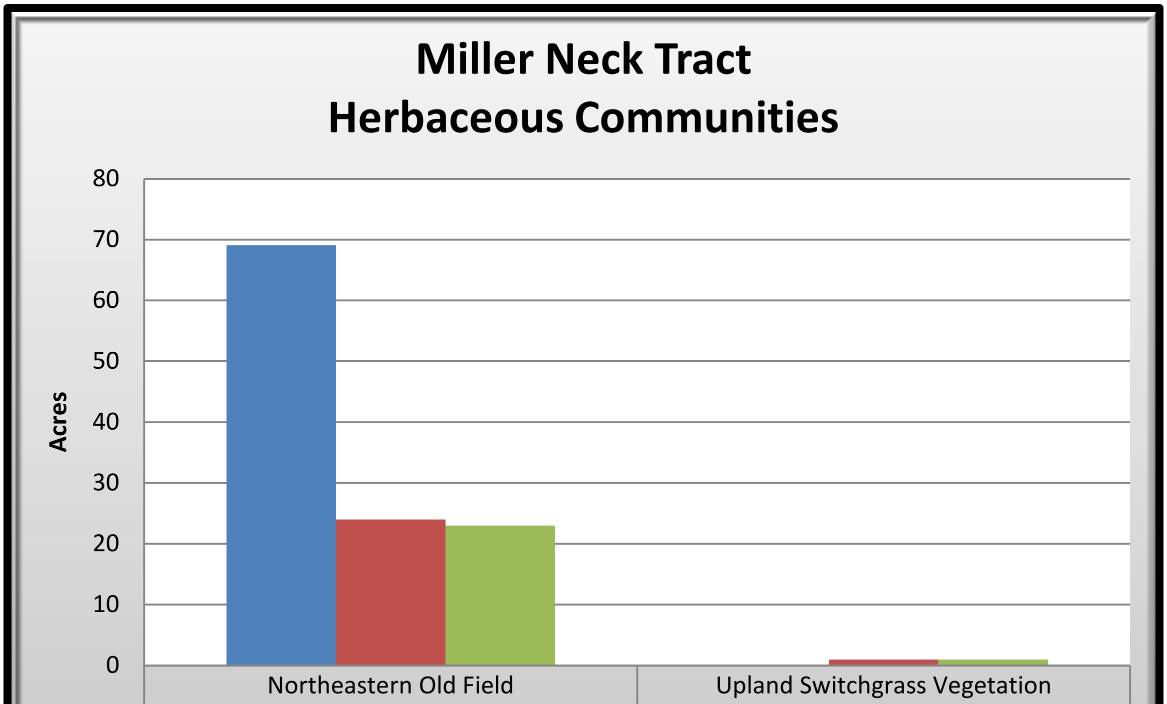
Two of the shrub communities in the Miller Neck Tract, Brackish Tidal Creek Shrubland and Irregularly Flooded Eastern Tidal Salt Shrub, will be eliminated with 0.5 m of sea level rise in their current extent with 21 acres in total being inundated. With 1 m of rise an additional 2 acres will be inundated and 1 acre more with 1.5 m of rise.

Table 4-1.7. Projected acres of Miller Neck Tract Shrubland Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	21 acres
1 m	23 acres
1.5 m	24 acres

Natural Capital (Table 4-1.8)

Natural Capital of shrubland was at its highest in 1937, and reached its lowest in 2002 with a rebound in 2007 with an increase in Irregularly Flooded Eastern Tidal Salt Shrub.

Table 4-1.8. Natural Capital of Miller Neck Tract Shrubland	
Year	**Natural Capital (in 2012 dollars)**
1937	$214,098/year
2002	$119,738/year
2007	$132,280/year



	Northeastern Old Field	Upland Switchgrass Vegetation
1937	69	0
2002	24	1
2007	23	1

Figure 4-1.8. Miller Neck Tract Herbaceous Communities (1937, 2002, and 2007)

Miller Neck Tract Herbaceous Communities (Figure 4-1.8): Northeastern Old Field has been in decline since 1937 as the initial surge of clear-cuts and abandoned agriculture fields have succeeded to more mature forested community types. Upland Switchgrass Vegetation has been planted in the wildlife area for vegetated buffers around agricultural fields and mitigation areas and may continue to increase as more is planted.

The contribution of herbaceous communities to the Miller Neck has declined with the maturation of these communities into more mature shrublands and forests. Without management, this trend is expected to continue.

DNREC Sea Level Rise Analysis (Table 4-1.9)

About half of the current herbaceous communities will be inundated with 0.5 m of sea level rise. At 1 m of rise 17 acres will be inundated and at 1.5 m of rise, 20 acres will be inundated.

Table 4-1.9. Projected acres of Miller Neck Tract Herbaceous Communities Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	12 acres
1 m	17 acres
1.5 m	20 acres

Natural Capital (Table 4-1.10)

The natural capital of herbaceous communities has been steadily going downward with the transfer of the capital into more mature communities such as shrubland and forests.

Table 4-1.10. Natural Capital of Miller Neck Tract Herbaceous Communities	
Year	**Natural Capital (in 2012 dollars)**
1937	$10,053/year
2002	$3,643/year
2007	$3,497/year

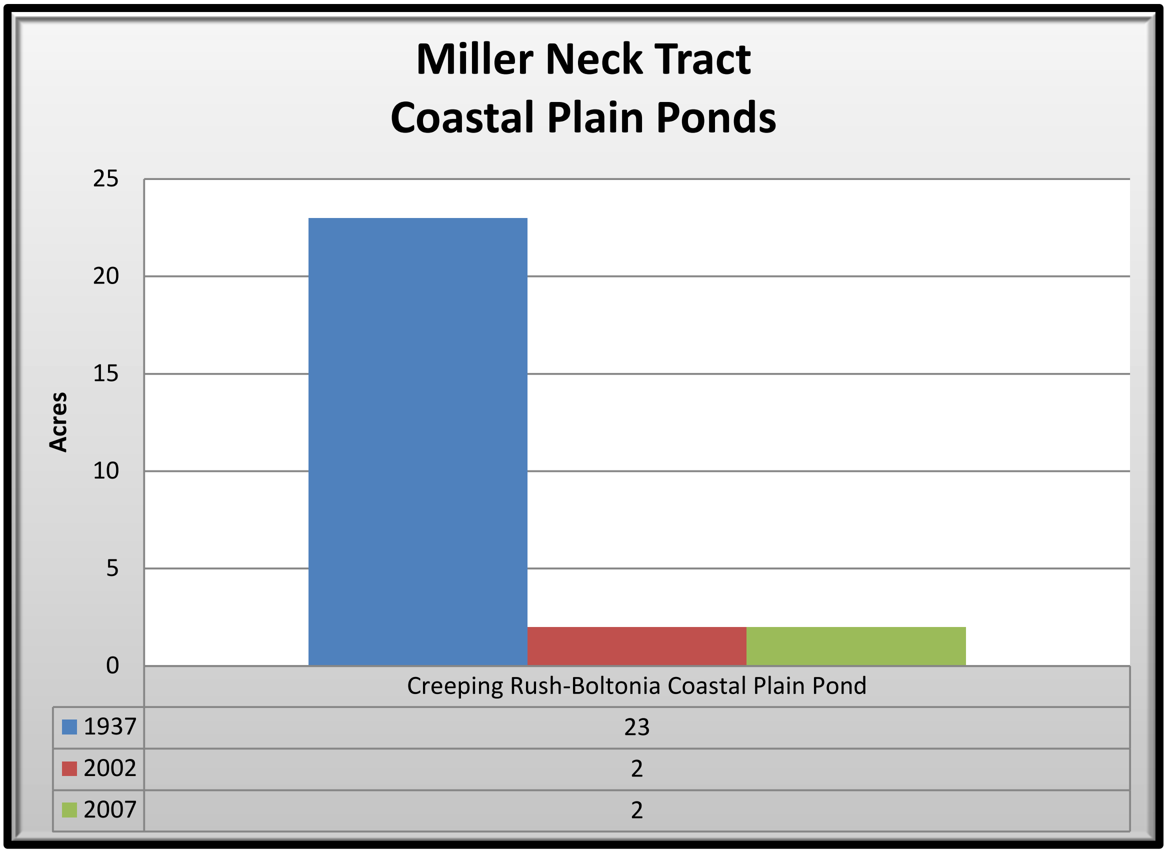


Figure 4-1.9. Miller Neck Tract Coastal Plain Ponds (1937, 2002, and 2007)

Miller Neck Tract Coastal Plain Ponds (Figure 4-1.9): Creeping Rush-Boltonia Coastal Plain Pond has been the only coastal plain pond community present on the wildlife area since 1937. While once present also on the Muddy Neck Tract, occurrences of this community have gradually succumbed to encroachment of the marsh either from tidal marsh or impoundments. Currently this community is located only in one location, which is topographically protected from tidal influence, but may not be from groundwater table rise. This pond is the location of Hirst's panic grass (*Dichanthelium hirstii*) which could be jeopardy from sea-level rise effects. The one pond located here is the only one of its type in Delaware.

DNREC Sea Level Rise Analysis (Table 4-1.11)

The one remaining coastal plain pond in Miller Neck is located in a topographic low area that is protected by higher ground. This area will be protected until 1.5 m of sea level rise at which point it will be inundated.

Table 4-1.11. Projected acres of Miller Neck Tract Coastal Plain Ponds Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	0 acres
1 m	0 acres
1.5 m	2 acres

Natural Capital (Table 4-1.12)

Coastal Plain ponds were once more plentiful in the Miller Neck but are now reduced to one. Most of the capital in these ponds was transferred or lost to marsh.

Table 4-1.12. Natural Capital of Miller Neck Tract Coastal Plain Ponds	
Year	**Natural Capital (in 2012 dollars)**
1937	$213,472/year
2002	$18,563/year
2007	$18,563/year

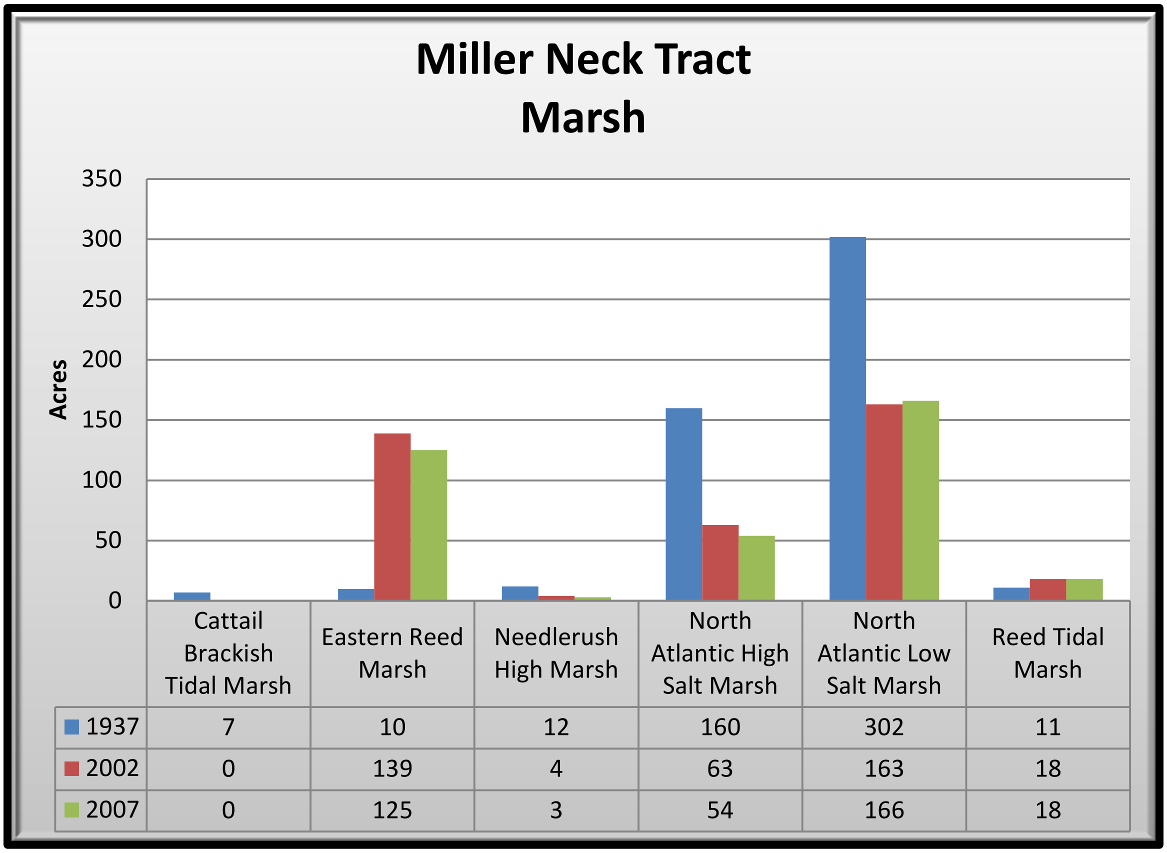


Figure 4-1.10. Miller Neck Tract Marsh (1937, 2002, and 2007)

Miller Neck Tract Marshes (Figure 4-1.10): Marshes at the Miller Neck Tract have declined due to the development of impoundments which have wiped out large amounts of North Atlantic High Salt Marsh and Low Salt Marsh and to a lesser extent sea level rise and erosion. Cattail Brackish Tidal Marsh has been eliminated from the tract presumably because of higher salinities brought about by higher sea levels, although the exact cause is unknown. Needlerush High Marsh has largely been replaced by other marshes reflecting a trend an overall decline in the wildlife area and reflecting the decreases of the North Atlantic High Salt Marsh that occupies the same habitat. It is thought that Needlerush High Marsh may increase in Delaware with warming temperatures from climate change but elimination of the high marsh habitat may prevent its migration. Eastern Reed Marsh has greatly increased due to the impoundments but has declined recently likely due to eradication efforts. North Atlantic High Salt Marsh has declined significantly from impoundment development and replacement to Reed Tidal Marsh and North Atlantic Low Salt Marsh. Reed Tidal Marsh increased from 1937 to 2002, but has been stable in amount from 2002 to 2007.

DNREC Sea Level Rise Analysis (Table 4-1.13)

All of the marshland present in the Miller Neck Tract will be inundated in its current extent with 0.5 m of sea level rise.

Table 4-1.13. Projected acres of Miller Neck Tract Marsh Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	366 acres
1 m	366 acres
1.5 m	366 acres

Natural Capital (Table 4-1.14)

The natural capital of marsh has been steadily going downward in the Miller Neck Tract with losses of high marsh.

Table 4-1.14. Natural Capital of Miller Neck Tract Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$3,178,294/year
2002	$2,845,397/year
2007	$2,671,558/year

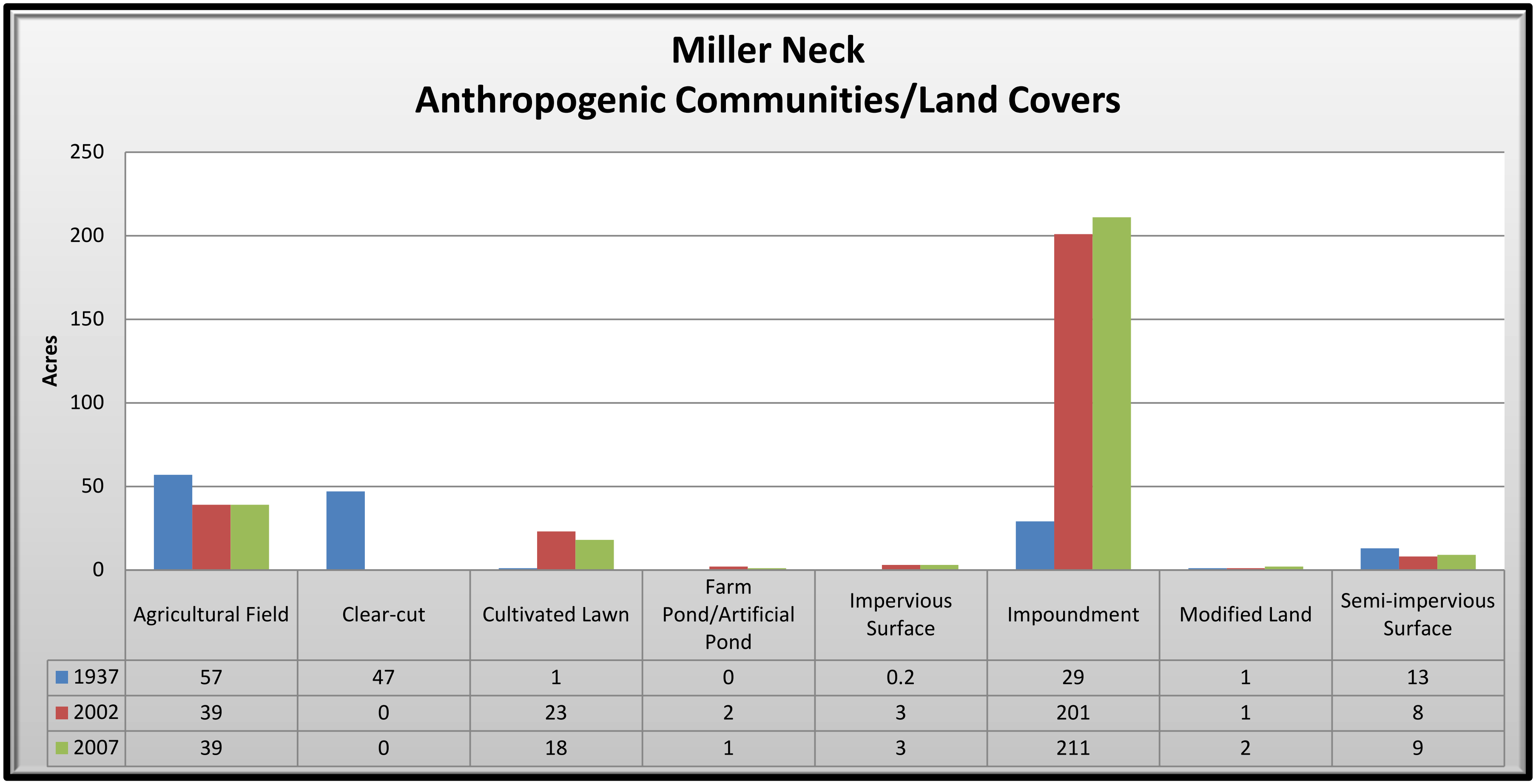


Figure 4-1.11. Miller Neck Tract Anthropogenic Communities/Land Covers (1937, 2002, and 2007)

Miller Neck Tract Anthropogenic Communities/Land Covers (Figure 4-1.11): Anthropogenic communities have increased overall during the period of study in spite of decreased agricultural fields, clear-cuts, and cultivated lawn. The increases in anthropogenic communities are driven by impoundment development in the 1950's and 1960's.

DNREC Sea Level Rise Analysis (Table 4-1.15)

Anthropogenic Communities/Land Covers will lose 233 acres with 0.5 m of sea level rise, including all of the impoundment area. An additional 0.5 m of sea level rise will consume another 19 acres and 1.5 m, another 9 acres.

Table 4-1.15. Projected acres of Miller Neck Tract Anthropogenic Communities/Land Covers Inundated by Sea Level Rise

Rise	Acres
0.5 m	233 acres
1 m	252 acres
1.5 m	261 acres

Natural Capital (Table 4-1.16)

The amount of capital in anthropogenic communities/land covers has steadily gone up over the study period. Cultivated lawns and impervious surfaces do not have any capital value from a natural standpoint but do incur losses with sea level rise if they are replaced.

Table 4-1.16. Natural Capital of Miller Neck Tract Anthropogenic Communities/Land Covers

Year	Natural Capital (in 2012 dollars)
1937	$157,987/year
2002	$1,074,592/year
2007	$1,127,943/year

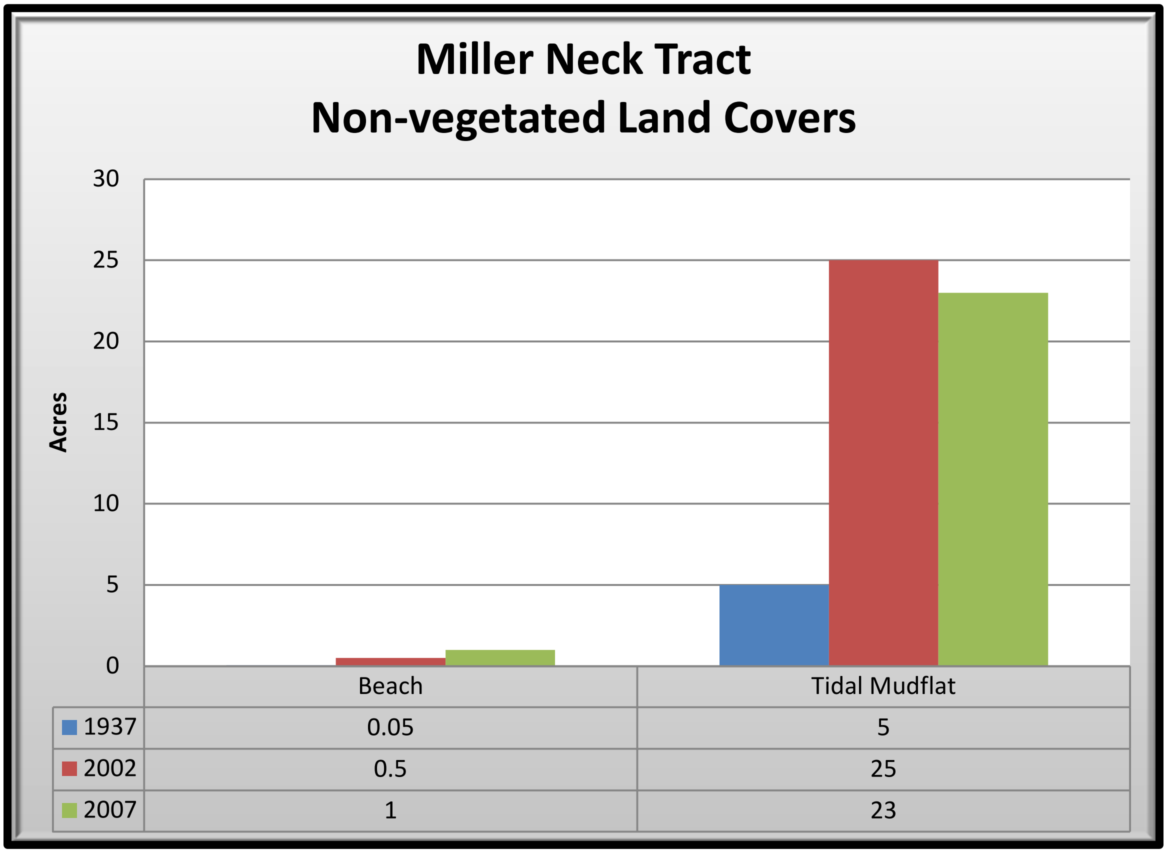


Figure 3-1.12. Miller Neck Tract Non-vegetated Land Covers (1937, 2002, and 2007)

Miller Neck Tract Non-vegetated Land Covers (Figure 3-1.12): Non-vegetated land covers have increased on the Miller Neck Tract being driven mostly by gains in Tidal Mudflat up to 2002 and then a decrease in 2007. Beaches have remained a very minor part of the tract. The gains in tidal mudflat may be coming from sea level rise, salt marsh dieback, goose eat-outs or a combination of the three.

DNREC Sea Level Rise Analysis (Table 4-1.17)

All of the non-vegetated land covers will be inundated with 0.5 m of sea level rise in their current extent.

Table 4-1.17. Projected acres of Miller Neck Tract Non-vegetated Land Covers Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	23 acres
1 m	23 acres
1.5 m	23 acres

Natural Capital (Table 4-1.18)

The natural capital on non-vegetated land covers was at its lowest in 1937 and highest in 2002. Since 2002 it has declined with declines in tidal mudflats.

Table 4-1.18. Natural Capital of Miller Neck Tract Non-vegetated Land Covers	
Year	**Natural Capital (in 2012 dollars)**
1937	$31,357/year
2002	$156,783/year
2007	$144,240/year

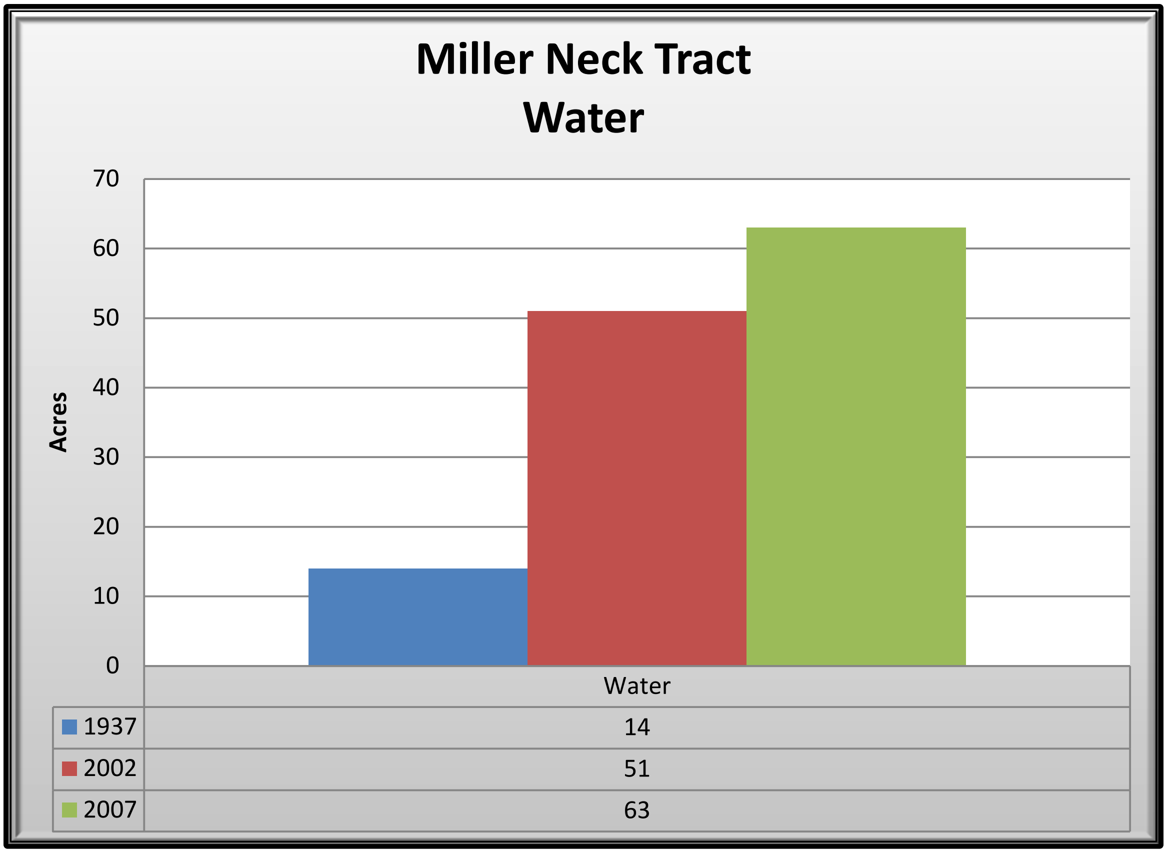


Figure 4-1.13. Miller Neck Tract water coverage (1937, 2002, and 2007)

Miller Neck Tract water coverage (Figure 3-1.13): Water inundation has steadily increased in rate during the study period and has essentially doubled from the historical rate in the Miller Neck Tract. From 1937 to 2007 the water inundation averaged 0.64 acres/year. But from 2002 to 2007 the average inundation was 1.4 acres/year. The average for the 1937 to 2002 period was 0.58 acres/year. The increase in the more recent period shows either an increase the rate of sea level rise (possibly reflected at the Lewes sea level station) or could be due to topological effects with the water hitting an area of low elevation or flat area.

Natural Capital (Table 4-1.19)

Sea level rise is causing the value of water to go up over time. This increase may be part of the bubble from sea level rise which may collapse once the marshland is consumed by submersion.

Table 4-1.19. Natural Capital of Miller Neck Tract Water	
Year	**Natural Capital (in 2012 dollars)**
1937	$200,660/year
2002	$730,975/year
2007	$902,970/year

2. Muddy Neck Tract

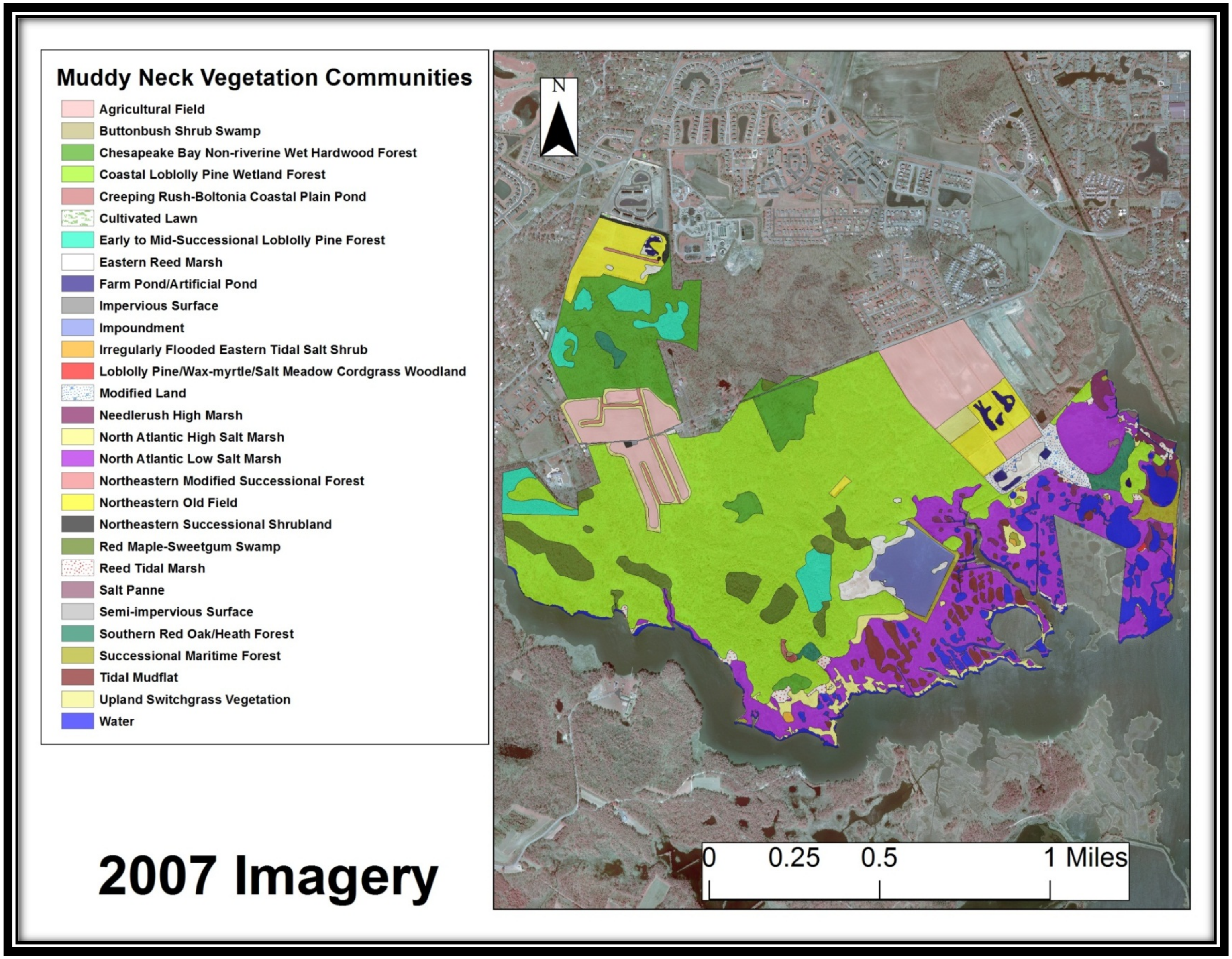


Figure 4-2.1. 2007 Vegetation Community map of the Muddy Neck Tract

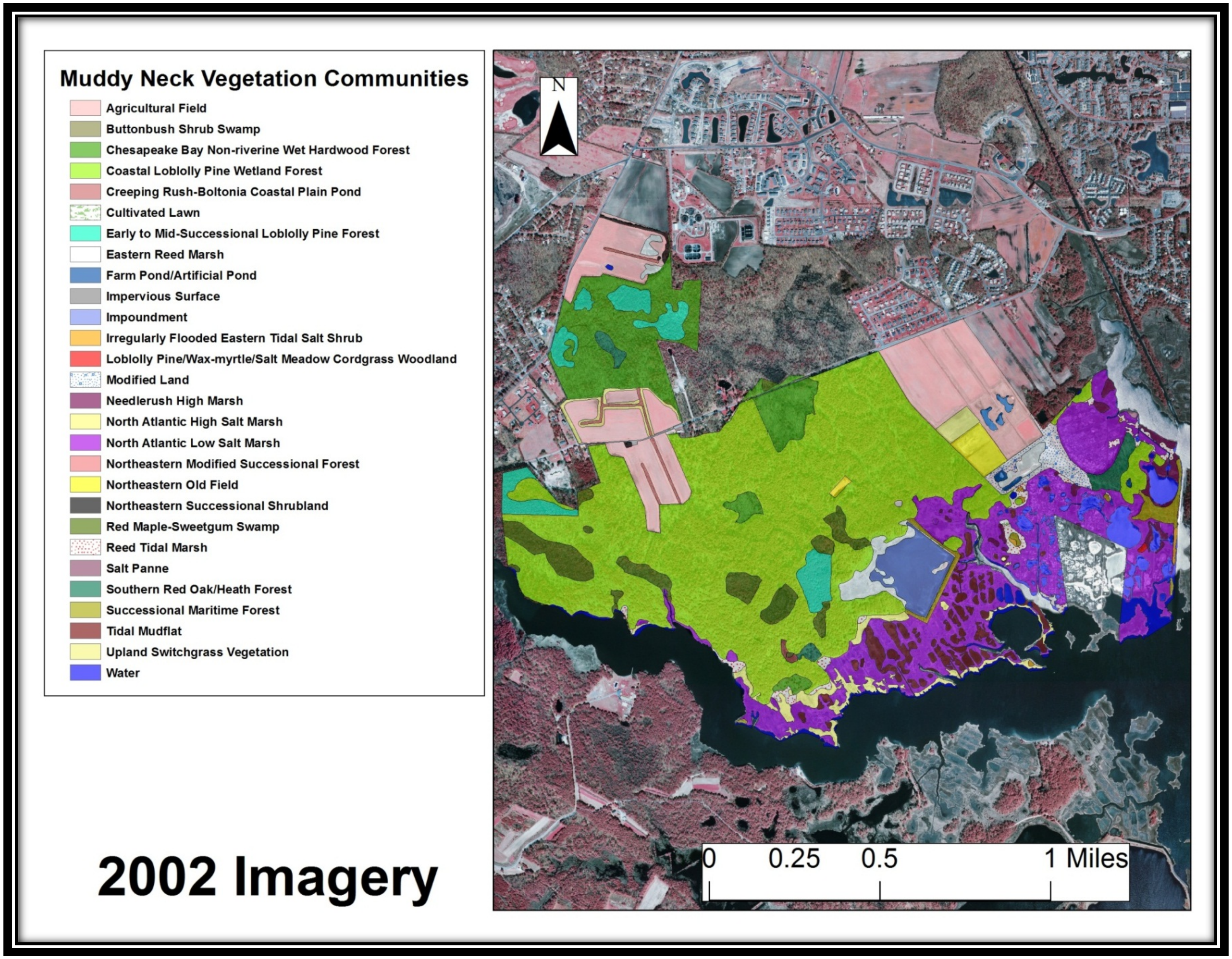


Figure 4-2.2. 2002 Vegetation Community map of the Muddy Neck Tract

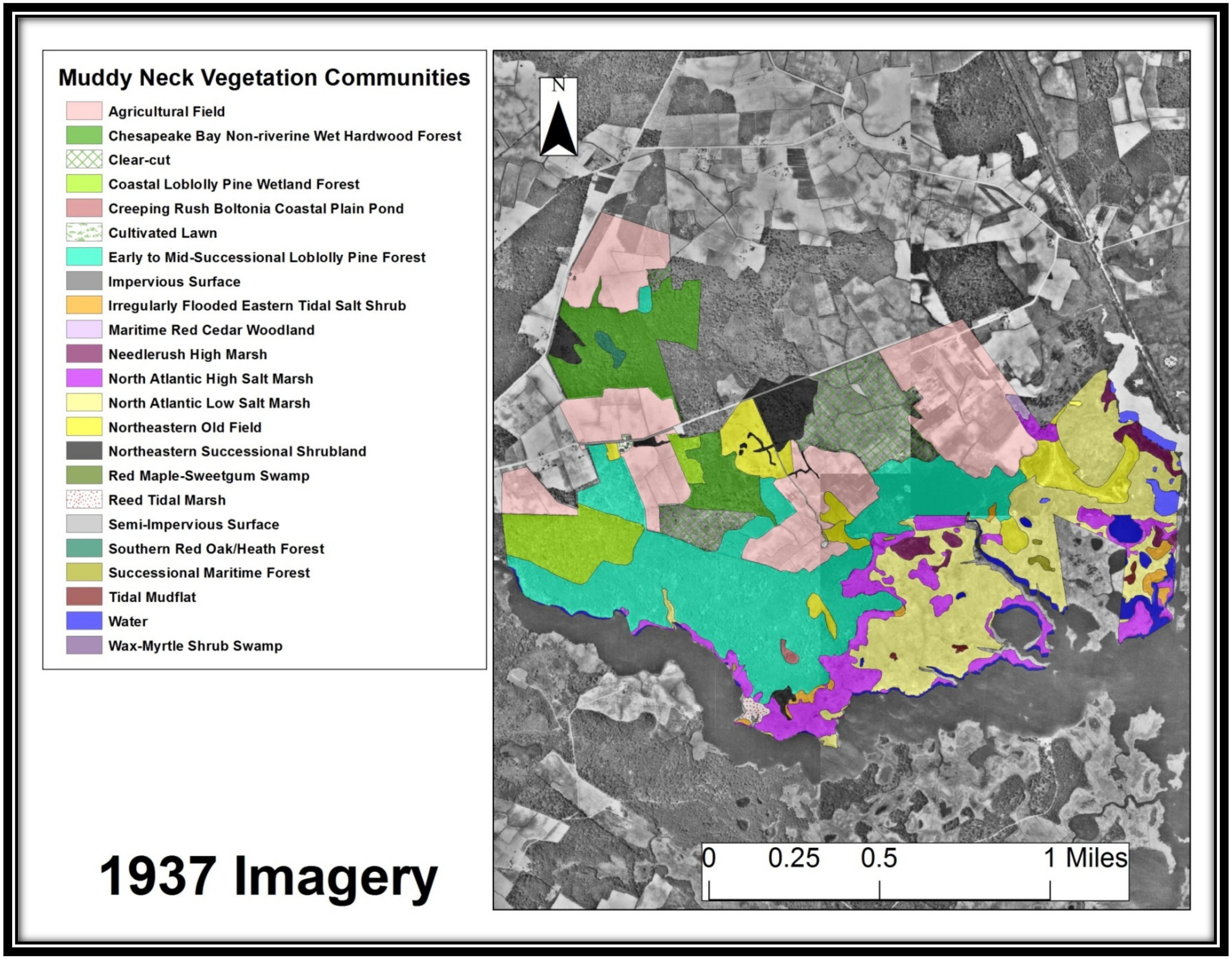
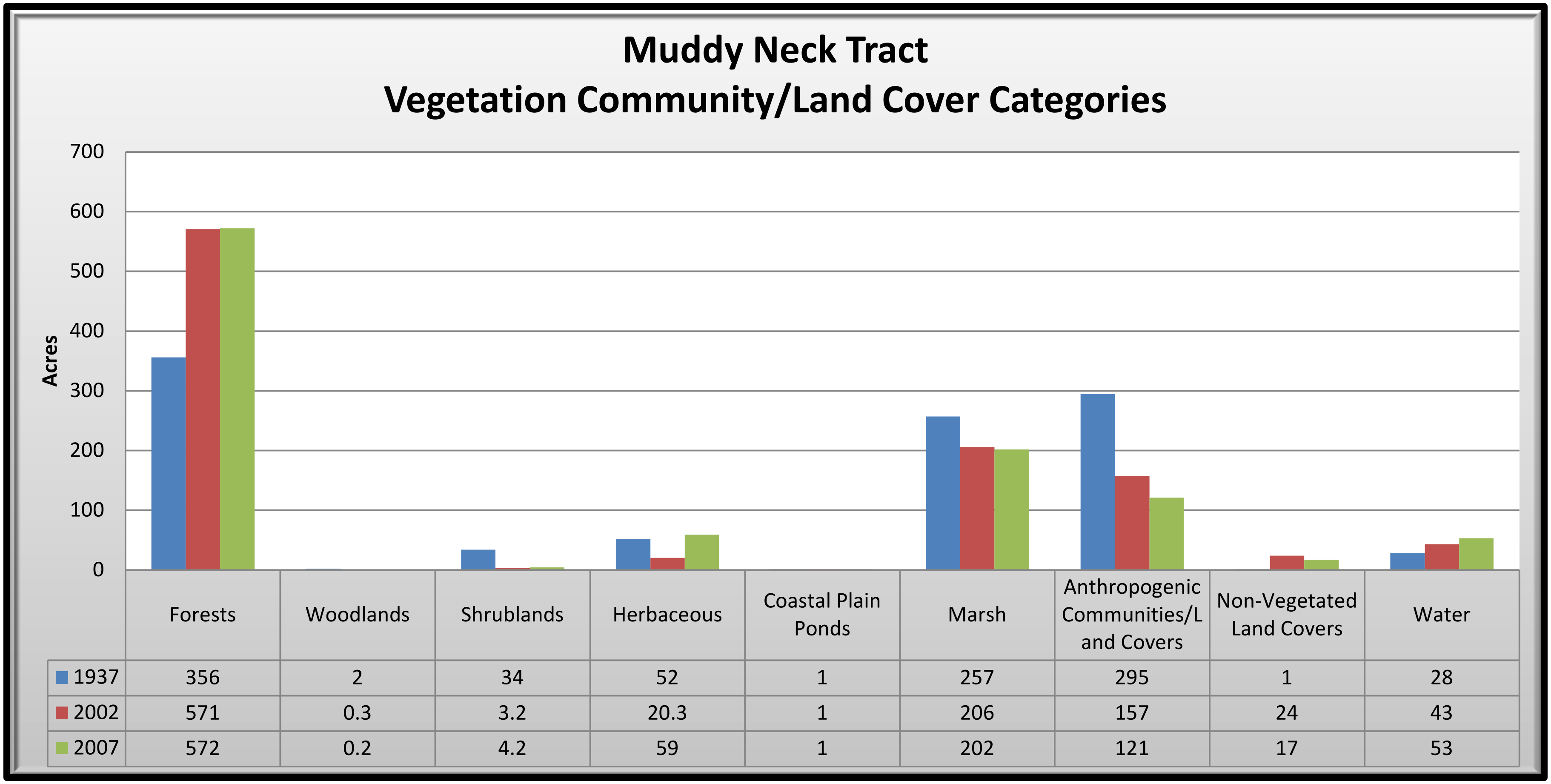


Figure 4-3.3. 1937 Vegetation Community map of the Muddy Neck Tract



	Forests	Woodlands	Shrublands	Herbaceous	Coastal Plain Ponds	Marsh	Anthropogenic Communities/Land Covers	Non-Vegetated Land Covers	Water
1937	356	2	34	52	1	257	295	1	28
2002	571	0.3	3.2	20.3	1	206	157	24	43
2007	572	0.2	4.2	59	1	202	121	17	53

Figure 4-2.4. Muddy Neck Tract Vegetation Community/Land Cover Categories (1937, 2002, and 2007)

Muddy Neck Tract Broad Trends (Figure 4-2.4): During the study period forests have greatly increased, while anthropogenic communities have greatly decreased. The forests of today have arisen from the agricultural fields of yesterday. Coastal Plain ponds that were once present in 1937 are no longer present. Shrublands and marshes have seen decreases likely due in part to sea level rise and erosion. Water inundation like in the other tracts has increased.

DNREC Sea Level Rise Analysis (Table 4-2.1)

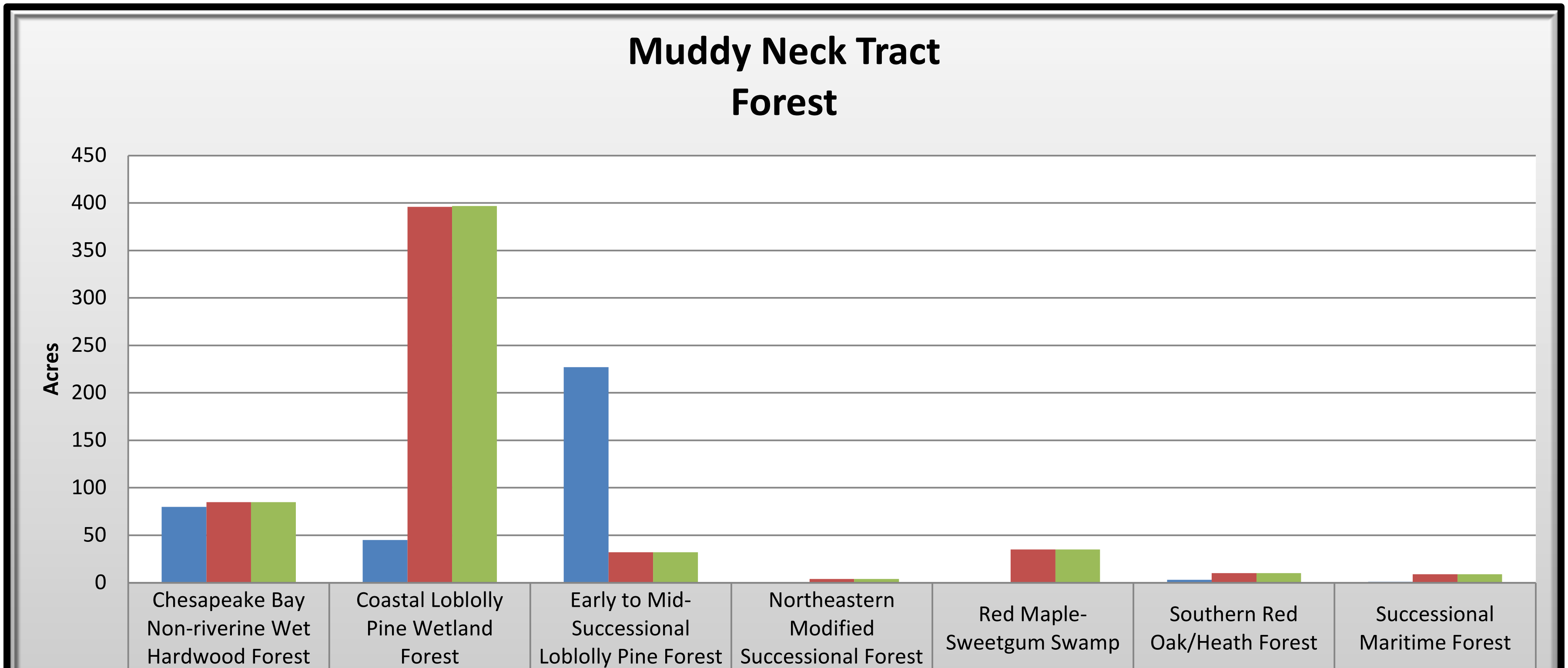
The Muddy Neck Tract lies at a slightly higher elevation than the Miller Neck and hence does not have the same losses of acreage with the same amount of rise. At 0.5 m of sea level rise, the Muddy Neck Tract will lose 442 acres to inundation. At 1 m, 541 acres will be lost or a little more than half will be inundated. At 1.5 m of rise about ¾ of the tract will be inundated.

Table 4-2.1. Projected acres of the Muddy Neck Tract Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	442 acres
1 m	541 acres
1.5 m	698 acres

Natural Capital (Table 4-2.2)

Behind the Miller Neck Tract, the Muddy Neck Tract is the next most valuable tract in the wildlife area as far capitalization.

Table 4-2.2. Natural Capital of Muddy Neck Tract	
Year	**Natural Capital (in 2012 dollars)**
1937	$3,677,121/year
2002	$8,618,882/year
2007	$8,737,809/year



	Chesapeake Bay Non-riverine Wet Hardwood Forest	Coastal Loblolly Pine Wetland Forest	Early to Mid-Successional Loblolly Pine Forest	Northeastern Modified Successional Forest	Red Maple-Sweetgum Swamp	Southern Red Oak/Heath Forest	Successional Maritime Forest
1937	80	45	227	0	0	3	1
2002	85	396	32	4	35	10	9
2007	85	397	32	4	35	10	9

Figure 4-2.5. Muddy Neck Tract Forests (1937, 2002, and 2007)

Muddy Neck Tract Forest (Figure 4-2.5): All of the forest types on the Muddy Neck Tract have increased except for the Early to Mid-Successional Loblolly Pine Forest which has succeeded into Coastal Loblolly Pine Wetland Forest and other types. In 1937 there were 356 acres of forest within the tract; by 2007 it had increased to 572 acres. Coastal Loblolly Pine Wetland Forest is currently the most common forest in the tract followed by Chesapeake Bay Non-riverine Wet Hardwood Forest. Two forest types, Chesapeake Bay Non-riverine Wet Hardwood and Northeastern Modified Successional Forest, have appeared in the tract since 1937 from former Northeastern Old Fields.

The Chesapeake Bay Non-riverine Wet Hardwood Forest is located in flatwoods areas and is very similar to the Red Maple-Sweetgum Swamp, with the exception that is not in a depression. A former Coastal Plain pond that harbored a Creeping Rush-Boltonia Coastal Plain Pond in 1937 is now the location of a Red Maple-Sweetgum Swamp.

DNREC Sea Level Rise Analysis (Table 4-2.3)

Forests at the Muddy Neck Tract will lose 102 acres with 0.5 m of sea level rise in their current extent. An additional 0.5 m of rise will inundated another 81 acres and 1.5 m of rise will inundated a total of 317 acres or a little more than half.

Table 4-2.3. Projected acres of the Muddy Neck Tract Forest Inundated by Sea Level Rise

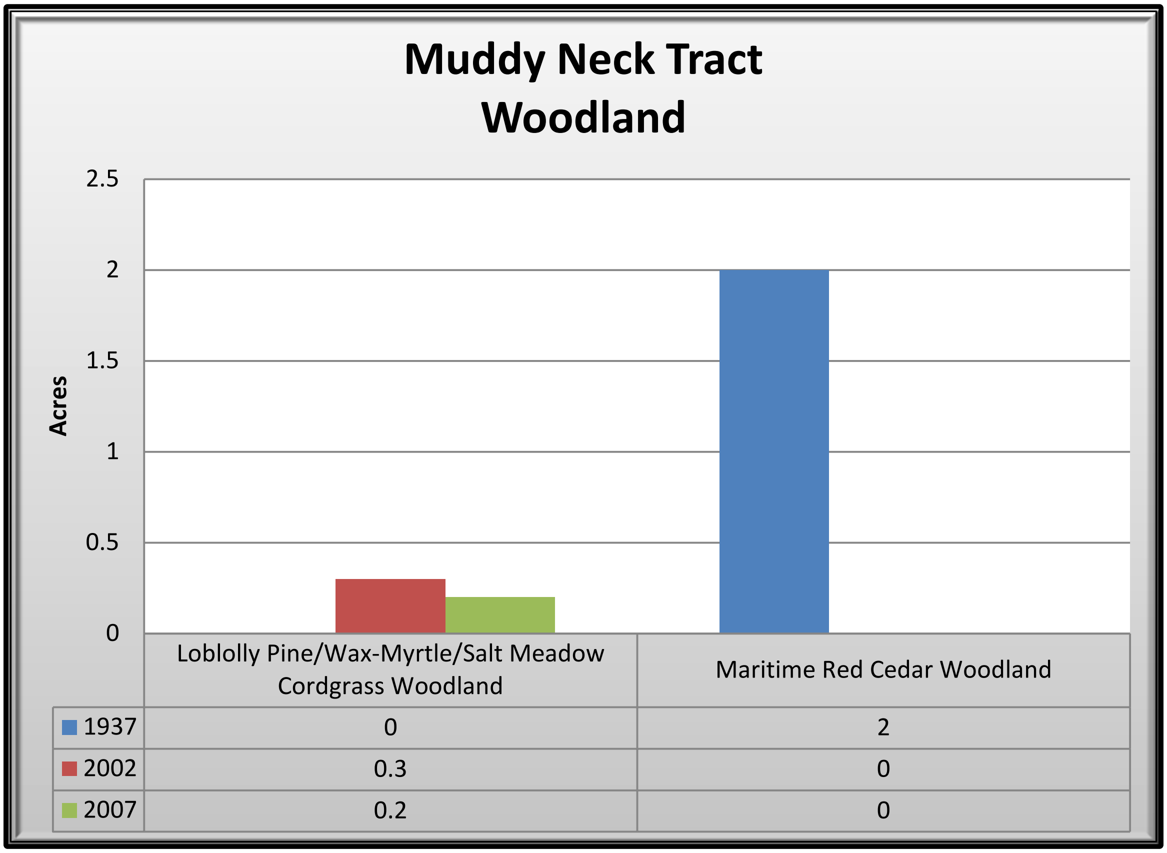
Rise	Acres
0.5 m	102 acres
1 m	183 acres
1.5 m	317 acres

Natural Capital (Table 4-2.4)

The natural capital of forests has been going as up and younger successional communities mature into forest.

Table 4-2.4. Natural Capital of Muddy Neck Tract Forest

Year	Natural Capital (in 2012 dollars)
1937	$1,580,120/year
2002	$6,352,815/year
2007	$6,365,106/year



	Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland	Maritime Red Cedar Woodland
1937	0	2
2002	0.3	0
2007	0.2	0

Figure 4-2.6. Muddy Neck Tract Woodland (1937, 2002, and 2007)

Muddy Neck Tract Woodland (Figure 4-2.6): In the period studied (1937-2007), woodlands have not been a prominent vegetation type in the tract. In 1937, Maritime Red Cedar Woodland, was the most prominent woodland, during a time when eastern red cedar (*Juniperus virginiana*) was actively being logged, resulting in the community type being eliminated from the tract. In 2002 and 2007 a very small amount of Loblolly Pine/Wax-myrtle/Salt Meadow Cordgrass Woodland had appeared in the tract, likely due in part to sea level rise and increased salinity as Coastal Loblolly Pine Wetland Forest begins the conversion to shrubland and thence to marsh or from forest straight to marsh.

DNREC Sea Level Rise Analysis (Table 4-2.5)

All of the extant woodland in the Muddy Neck will be inundated with 0.5 m of sea level rise.

Table 4-2.5. Projected acres of the Muddy Neck Tract Woodland Inundated by Sea Level Rise

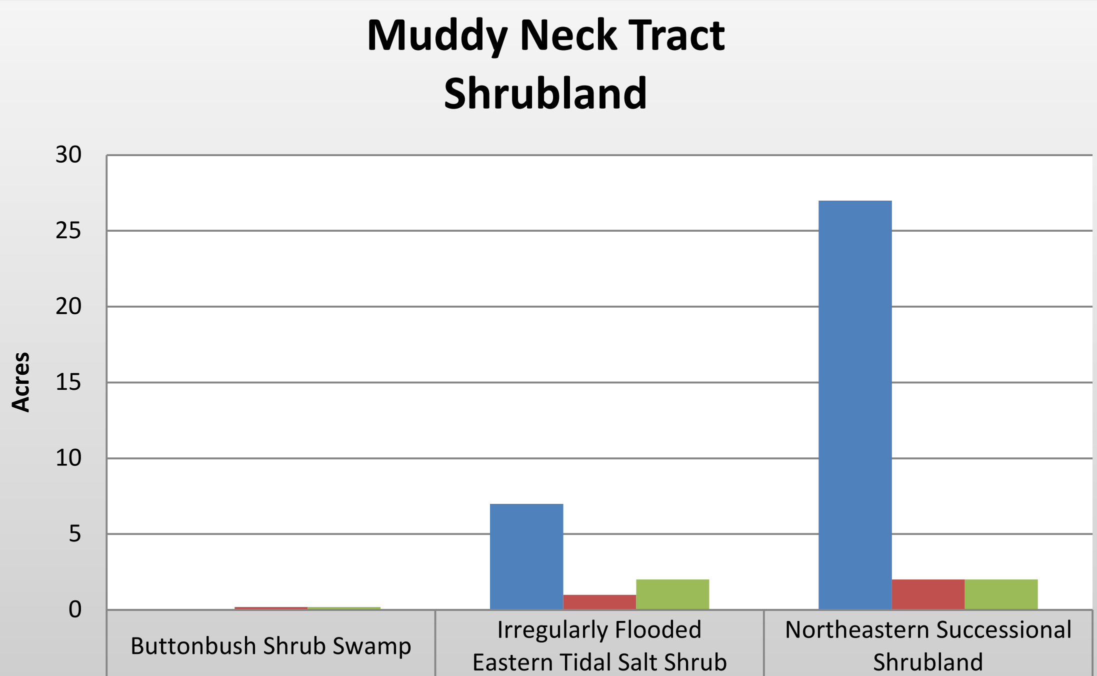
Rise	Acres
0.5 m	0.2 acres
1 m	0.2 acres
1.5 m	0.2 acres

Natural Capital (Table 4-2.6)

The capitalization of woodland has consistently been transferred to other communities as the amount of woodland has gone down.

Table 4-2.6. Natural Capital of Muddy Neck Tract Woodland

Year	Natural Capital (in 2012 dollars)
1937	$378/year
2002	$3,687/year
2007	$3,687/year



	Buttonbush Shrub Swamp	Irregularly Flooded Eastern Tidal Salt Shrub	Northeastern Successional Shrubland
1937	0	7	27
2002	0.2	1	2
2007	0.2	2	2

Figure 4-2.7. Muddy Neck Tract Shrubland (1937, 2002, and 2007)

Muddy Neck Tract Shrubland (Figure 4-2.7): Shrublands have decreased overall in the Muddy Neck Tract since 1937. Northeastern Successional Shrubland was the most prominent shrubland in 1937 and is tied for prominence with Irregularly Flooded Eastern Tidal Salt Shrub in 2007. Irregularly Flooded Eastern Tidal Salt Shrub has decreased since 1937 reflecting the trend throughout the wildlife area, but bucked the trend very slightly from 2002 to 2007, increasing by one acre. Buttonbush shrub swamp has appeared in one of the seasonally flooded depressions at some point between 1937 and 2002.

DNREC Sea Level Rise Analysis (Table 4-2.7)

Only 2 acres of shrubland, mainly Irregularly Flooded Eastern Tidal Salt Shrub, will be inundated under all of the scenarios.

Table 4-2.7. Projected acres of the Muddy Neck Tract Shrubland Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	2 acres
1 m	2 acres
1.5 m	2 acres

Natural Capital (Table 4-2.8)

Shrubland had its highest capital in 1937, but has since gone with maturation of Northeastern Successional Shrubland and losses in Irregularly Flooded Eastern Tidal Salt Shrub.

Table 4-2.8. Natural Capital of Muddy Neck Tract Shrubland	
Year	**Natural Capital (in 2012 dollars)**
1937	$47,833/year
2002	$6,563/year
2007	$12,834/year

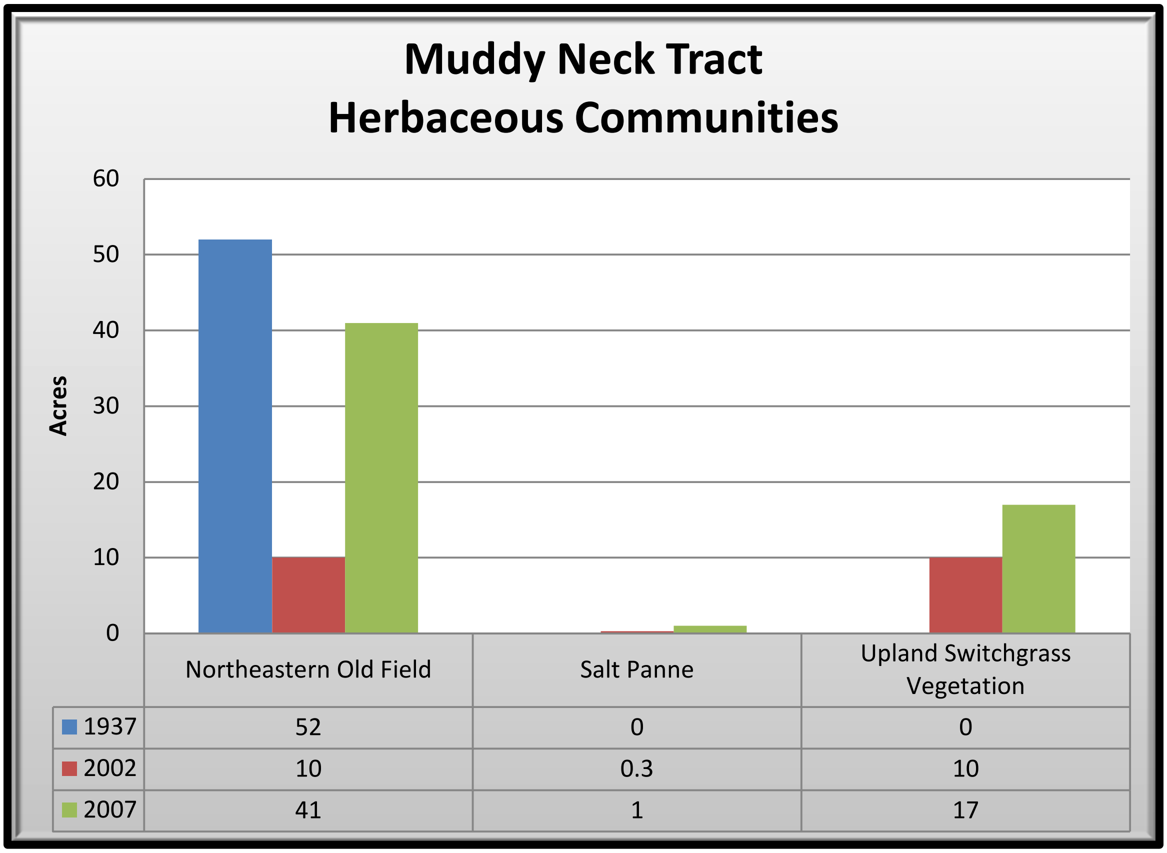


Figure 4-2.8. Muddy Neck Tract Herbaceous Communities

Muddy Neck Tract Herbaceous Communities (Figure 4-2.8): Herbaceous communities have increased overall since 1937. Northeastern Old Field was the most prominent herbaceous community in 1937 but dipped to a low level in 2002 which rebounded in 2007 with restoration activities in the tract. Upland Switchgrass Vegetation has been actively planted around agricultural fields and other areas to provide a vegetated buffer adding additional acreage. Salt Pannes have low prominence but they can be hard to distinguish in aerial imagery and the figure above is not to say that they were not present in 1937.

DNREC Sea Level Rise Analysis (Table 4-2.9)

Twenty-two acres of herbaceous communities will be inundated with 0.5 m of sea level rise. An additional 0.5 m of rise will inundated an additional acre and 1.5 m of rise will another acre. Salt Panne is the most impacted community and will be eliminated with 0.5 m of rise.

Table 4-2.9. Projected acres of the Muddy Neck Tract Herbaceous Communities Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	22 acres
1 m	23 acres
1.5 m	24 acres

Natural Capital (Table 4-2.10)

After losing capitalization, herbaceous communities have started to gain with increases in Northeastern Old Field and Upland Switchgrass Vegetation.

Table 4-2.10. Natural Capital of Muddy Neck Tract Herbaceous Communities	
Year	**Natural Capital (in 2012 dollars)**
1937	$7,576/year
2002	$4,795/year
2007	$14,722/year

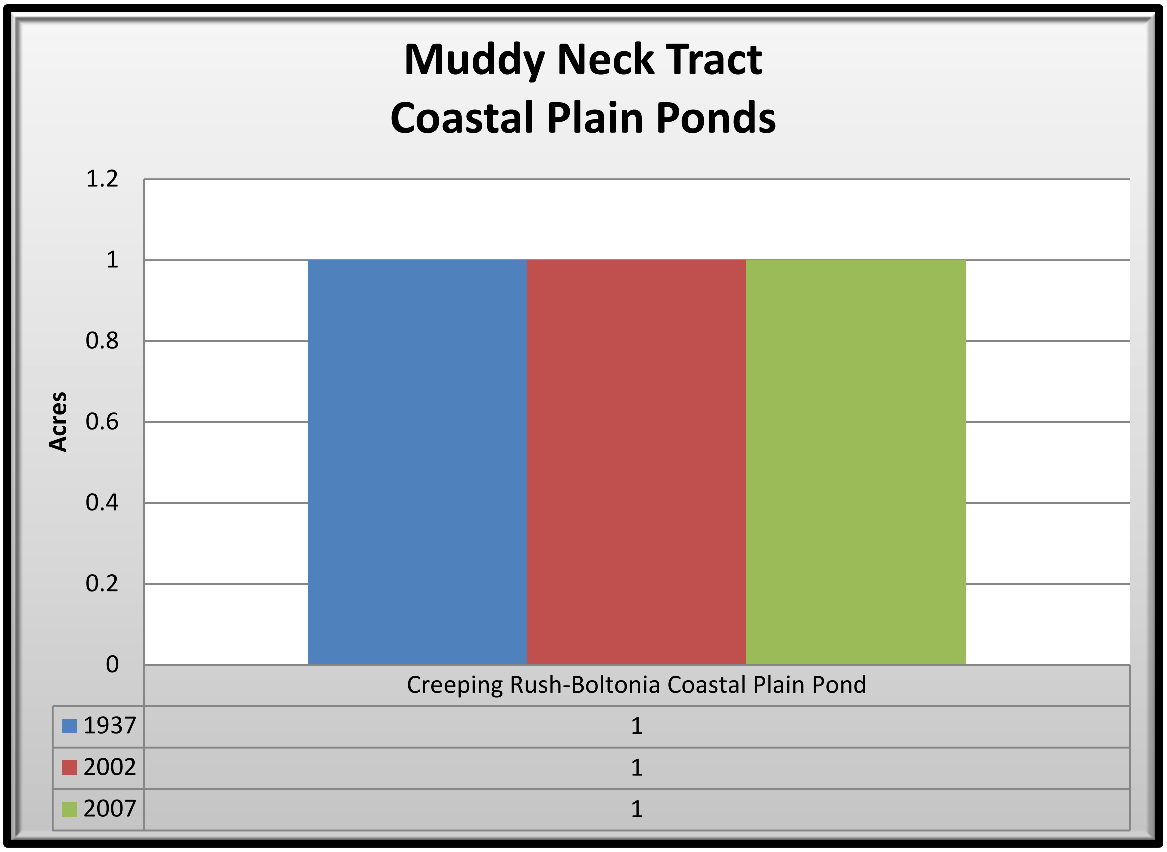


Figure 4-2.9. Muddy Neck Tract Coastal Plain Ponds (1937, 2002, and 2007)

Muddy Neck Tract Coastal Plain ponds (Figure 4-2.9): Creeping Rush-Boltonia Coastal Plain Pond is one of the rarest vegetation communities in Delaware. One occurrence is located on the Muddy Neck tract contains a somewhat different vegetation than one present on the Miller Neck tract (Assawoman Pond). This occurrence has been here at least since 1937 and appears to be gradually treeing in.

DNREC Sea Level Rise Analysis (Table 4-2.11)

The one coastal plain pond present in the Muddy Neck Tract will be eliminated with 1 m of sea level.

Table 4-2.11. Projected acres of the Muddy Neck Tract Coastal Plain Ponds Inundated by Sea Level Rise

Rise	Acres
0.5 m	0 acres
1 m	1 acre
1.5 m	1 acre

Natural Capital (Table 4-2.12)

The capital of coastal plain ponds has been constant during the study period.

Table 4-2.12. Natural Capital of Muddy Neck Tract Coastal Plain Ponds	
Year	**Natural Capital (in 2012 dollars)**
1937	$9,281/year
2002	$9,281/year
2007	$9,281/year

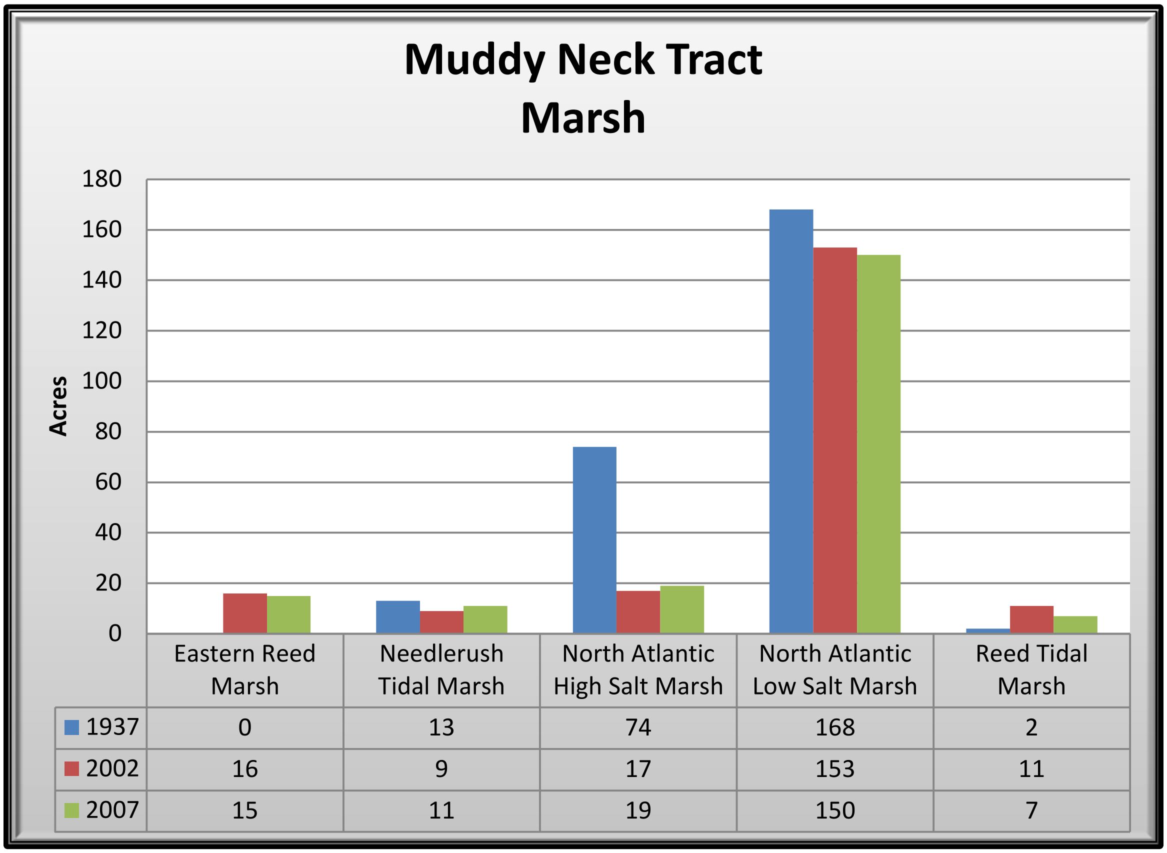


Figure 4-2.10. Muddy Neck Tract Marshes (1937, 2002, and 2007)

Muddy Neck Tract Marsh (Figure 4-2.10): Marshes have shown a gradual decline in the Muddy Neck Tract from 1937 to 2007. In 1937, North Atlantic Low Salt Marsh and North Atlantic High Salt Marsh were the most prominent marsh types. In 2007, North Atlantic Low Salt Marsh remains the most prominent, while North Atlantic High Salt Marsh has experienced drastic declines. This trend has been noted on other tracts in Assawoman Wildlife Area and in other wildlife areas on the Delaware Bay. Needlerush Tidal Marsh has gradually increased in time, bucking a trend in the wildlife area, but is projected to continue increasing with higher average temperatures from climate change if there is habitat present. Eastern Reed Marsh and Reed Tidal Marsh are dominated by eastern reed (*Phragmites australis*) a plant that may not have been present in 1937 in the wildlife area. By 2002 this plant had colonized, but declined very slightly with eradication efforts by 2007.

DNREC Sea Level Rise Analysis (Table 4-2.13)

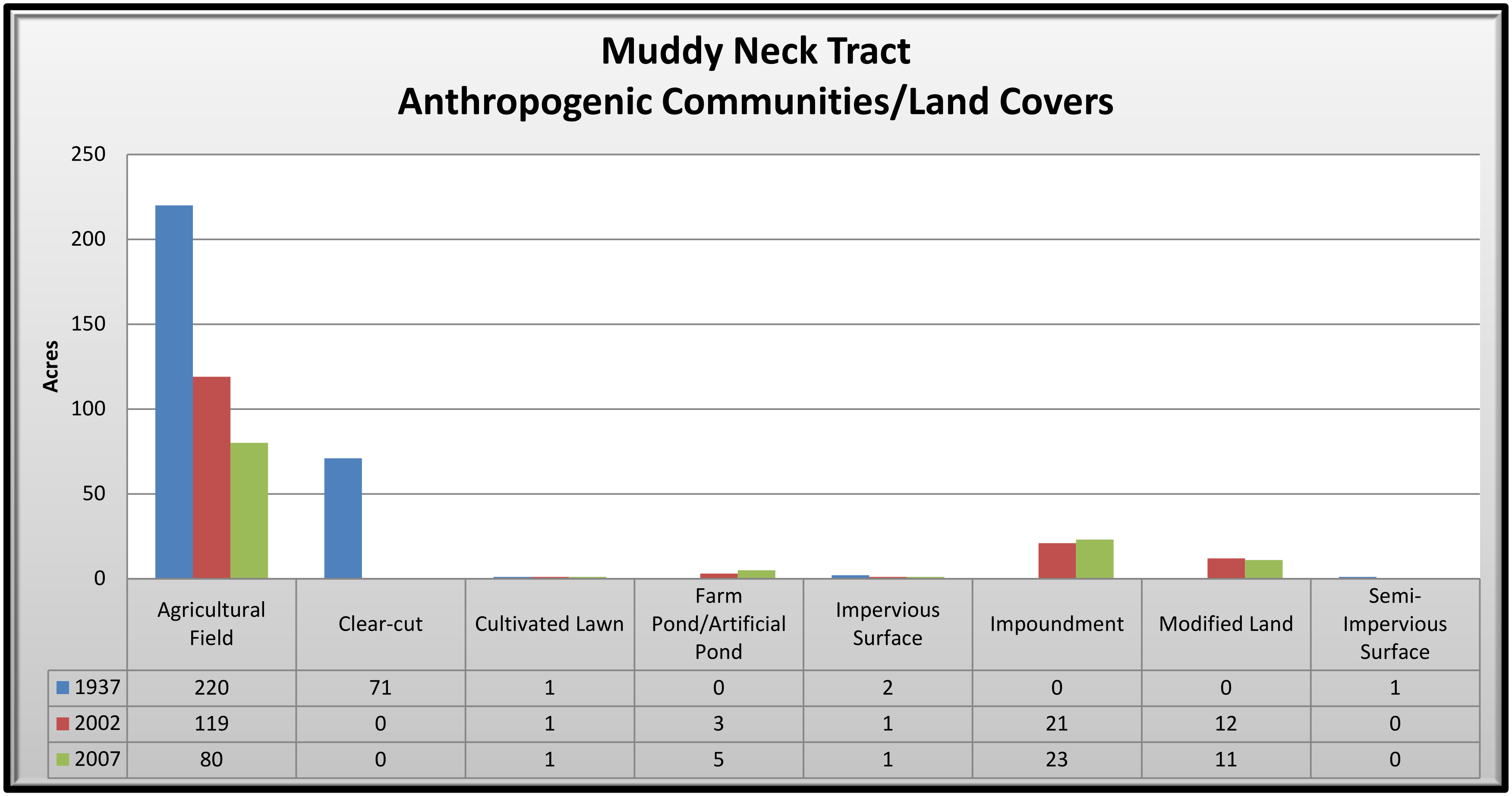
All of the marshland present in the Muddy Neck Tract will be lost with 0.5 m of sea level rise.

Table 4-2.13. Projected acres of the Muddy Neck Tract Marsh Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	200 acres
1 m	200 acres
1.5 m	200 acres

Natural Capital (Table 4-2.14)

The natural capital of marsh in the Muddy Neck Tract, like the Miller Neck Tract, has declined over time mainly on losses in the high marsh.

Table 4-2.14. Natural Capital of Muddy Neck Tract Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$1,611,724/year
2002	$1,340,049/year
2007	$1,311,954/year



	Agricultural Field	Clear-cut	Cultivated Lawn	Farm Pond/Artificial Pond	Impervious Surface	Impoundment	Modified Land	Semi-Impervious Surface
1937	220	71	1	0	2	0	0	1
2002	119	0	1	3	1	21	12	0
2007	80	0	1	5	1	23	11	0

Figure 3-2.11. Muddy Neck Tract Anthropogenic Communities/Land Covers (1937, 2002, and 2007)

Muddy Neck Tract Anthropogenic Communities/Land Covers (Figure 3-2.11): Agricultural field was the most prominent anthropogenic community in 1937 and remains the most prominent in 2007 with a significant decline as less land is tilled resulting in increased forest area. At the current time there are no active clear-cuts as there were in 1937. Since 1937 and by 2002 about 21 acres of impoundment and 12 acres of dredge spoil area (modified land) have been developed on the Muddy Neck Tract. Farm Pond/Artificial Ponds have been developed in some of the restoration areas. Impervious Surface and Cultivated Lawn compose a very small amount of the tract and while cultivated lawn has increased overall impervious surface has declined.

DNREC Sea Level Rise Analysis (Table 4-2.15)

At 0.5 m of sea level rise, 45 acres of anthropogenic communities/land covers will be inundated including all of the impoundment area. Another 0.5 m of rise will inundate 16 more acres and 1.5 m of rise will inundate a total of 83 acres.

Table 4-2.15. Projected acres of the Muddy Neck Tract Anthropogenic Communities/Land Covers Inundated by Sea Level Rise

Rise	Acres
0.5 m	45 acres
1 m	61 acres
1.5 m	83 acres

Natural Capital (Table 4-2.16)

Most of the capitalization of this category comes from the impoundments which have increased with transfers from former marsh area.

Table 4-2.16. Natural Capital of Muddy Neck Tract Anthropogenic Communities/Land Covers

Year	Natural Capital (in 2012 dollars)
1937	$12,617/year
2002	$134,867/year
2007	$153,971/year

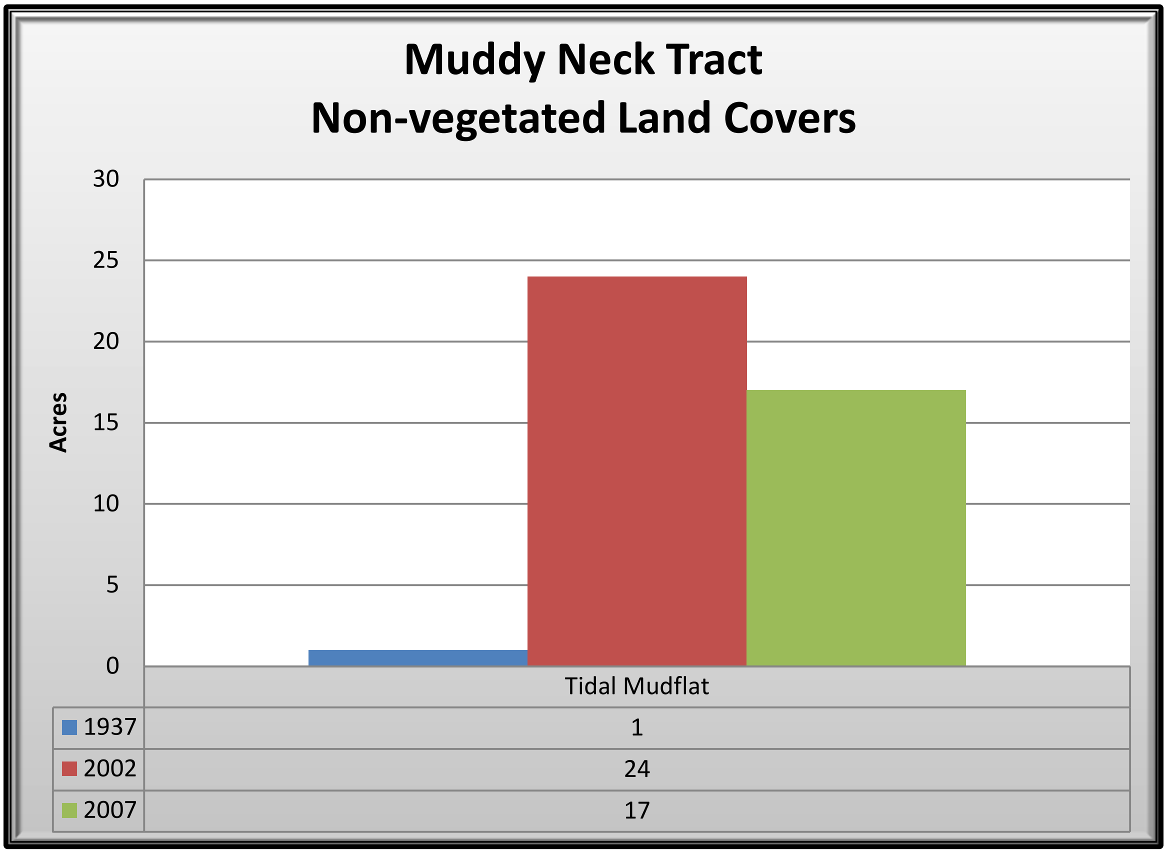


Figure 4-2.12. Muddy Neck Tract Non-vegetated Land Covers (1937, 2002, and 2007)

Muddy Neck Tract Non-vegetated Land Covers (Figure 4-2.12): Tidal mudflat is the only non-vegetated land cover present in the Muddy Neck Tract. Mudflats often come about through sea level rise, goose eat-outs, and die off of the salt marsh. It can be a transition from marsh to open water or the salt marsh may go directly from marsh to water. Tidal mudflats have increased overall (1937-2007) and have been declining in the recent period (2002-2007).

DNREC Sea Level Rise Analysis (Table 4-2.17)

All of the current tidal mudflats will be inundated with 0.5 m of rise and greater.

Table 4-2.17. Projected acres of the Muddy Neck Tract Non-vegetated Land Covers Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	17 acres
1 m	17 acres
1.5 m	17 acres

Natural Capital (Table 4-2.18)

Natural capital of non-vegetated land covers increased up to 2002 and then has decreased as sea level rise has inundated mudflats transferring the capital to water. This trend is expected to continue.

Table 4-2.18. Natural Capital of Muddy Neck Tract Non-vegetated Land Covers	
Year	**Natural Capital (in 2012 dollars)**
1937	$6,271/year
2002	$150,511/year
2007	$106,612/year

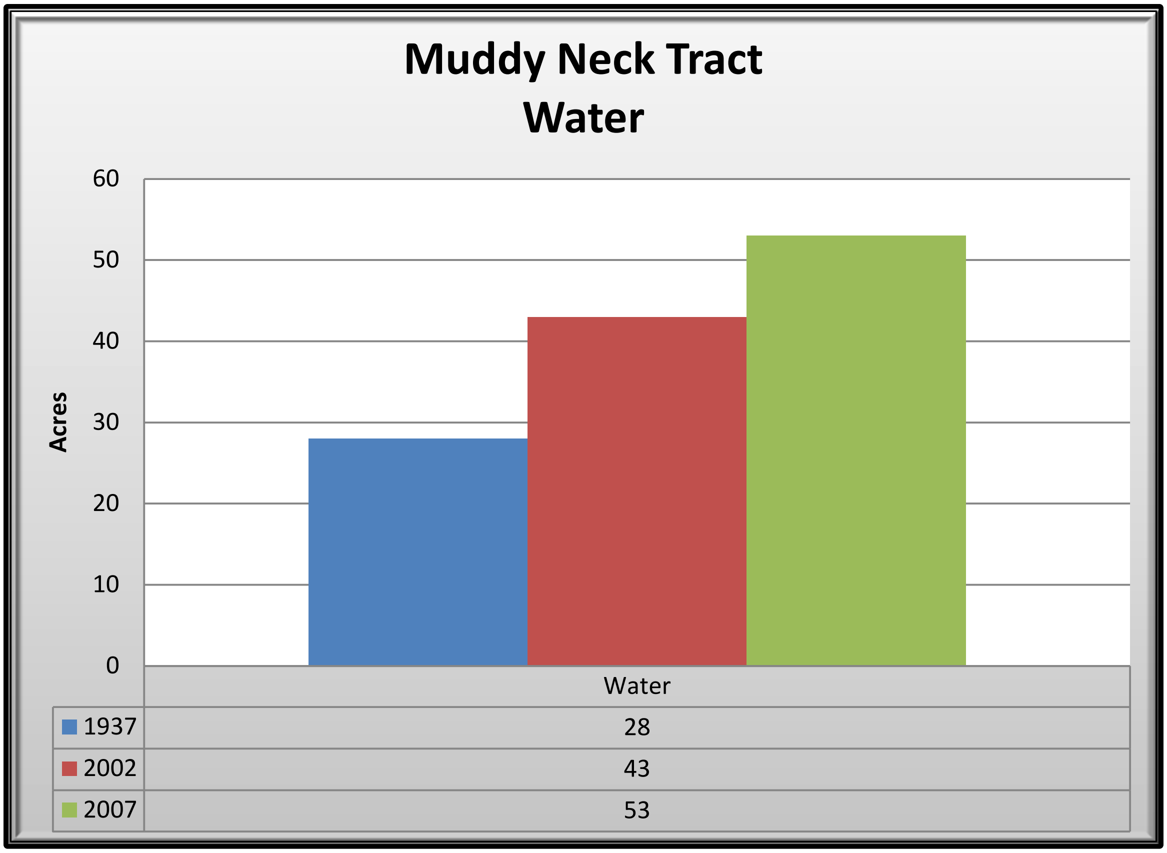


Figure 4-2.13. Muddy Neck Tract Water Coverage (1937, 2002, and 2007)

Muddy Neck Tract Water (Figure 4-2.13): The amount of water coverage has increased at a steady but slightly increasing rate in the Muddy Neck Tract. The historical (1937-2007) average inundation rate for this tract is 0.36 acres/year. During the recent period (2002-2007) the average inundation rate was 2.0 acres/year. From 1937 to 2002 the average inundation rate was 0.23 acres/year. This shows an increase from 0.23 acres/year to 2.0 acres/year in the recent period. Differences in increases among the tracts could be due to different topographic conditions, an increase in the rate of sea level rise or some combination of the two. Erosion from increased boating traffic on Miller Creek could also play a part by cutting into the marsh.

Natural Capital (Table 4-2.19)

The value of water has continued to increase as sea level inundates marsh and other lands.

Table 4-2.19. Natural Capital of Muddy Neck Tract Water	
Year	**Natural Capital (in 2012 dollars)**
1937	$401,320/year
2002	$616,313/year
2007	$759,641/year

3. Piney Neck Tract

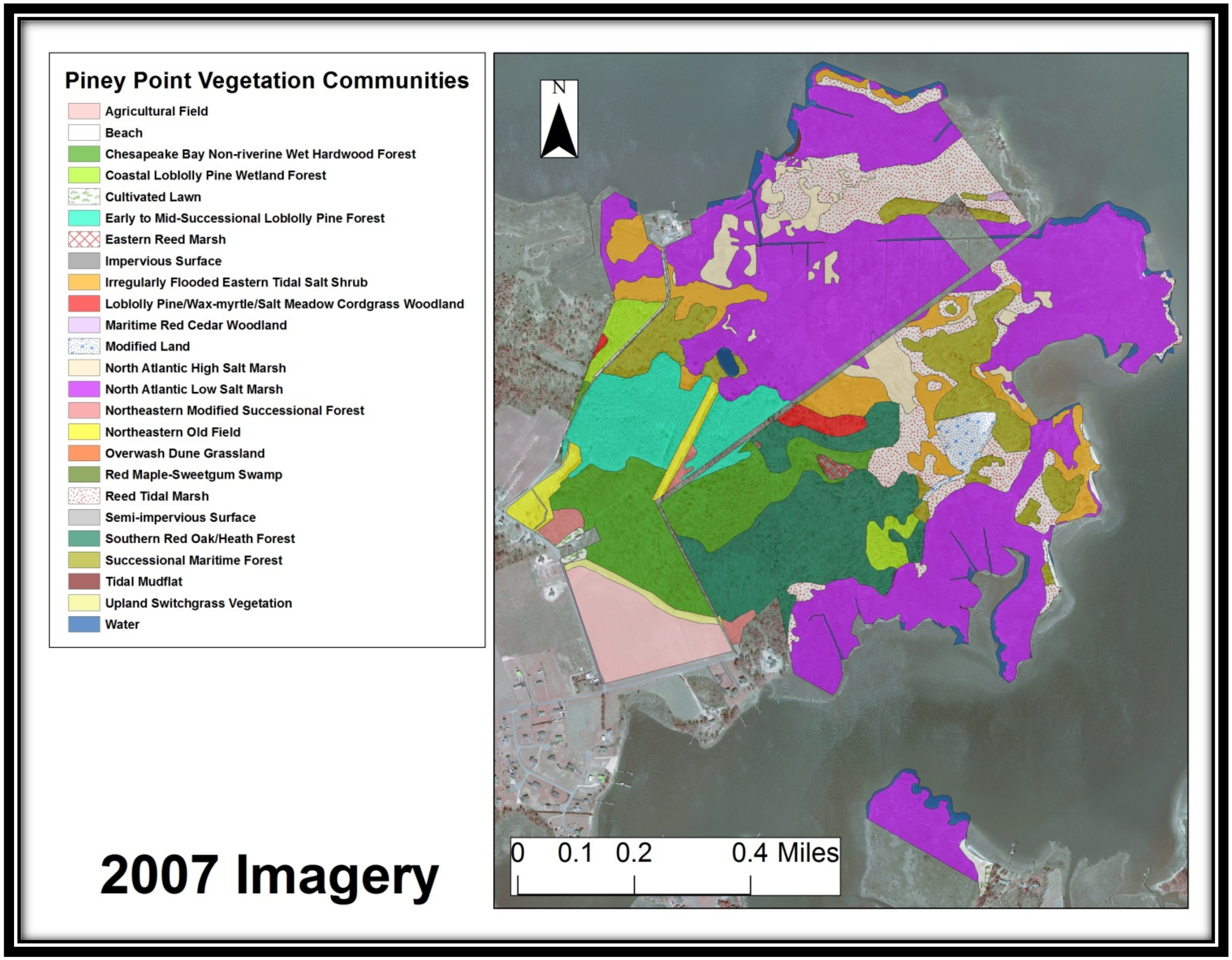


Figure 4-3.1. 2007 Vegetation Community map of the Piney Point Tract

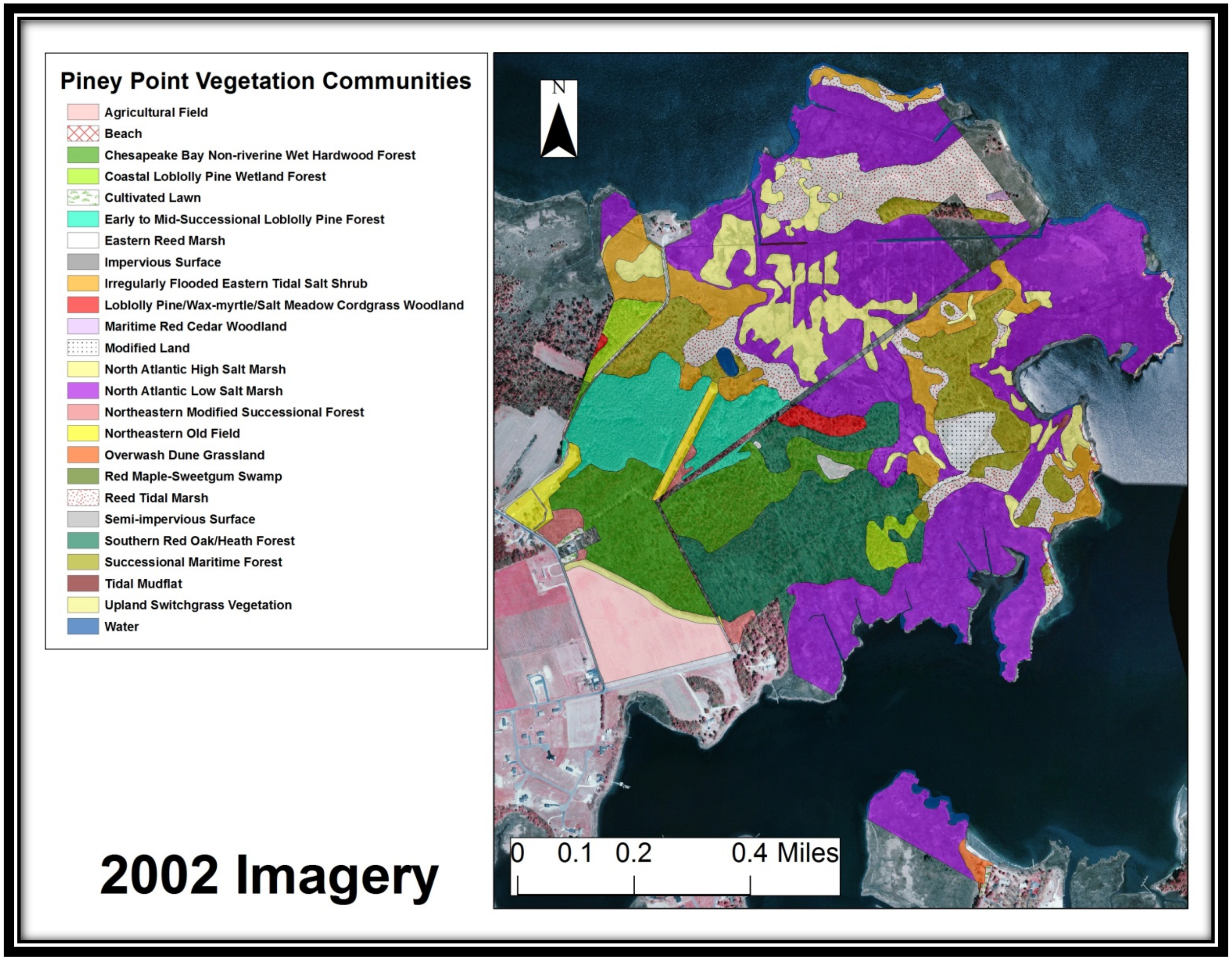


Figure 4-3.2. 2002 Vegetation Community of the Piney Point Tract

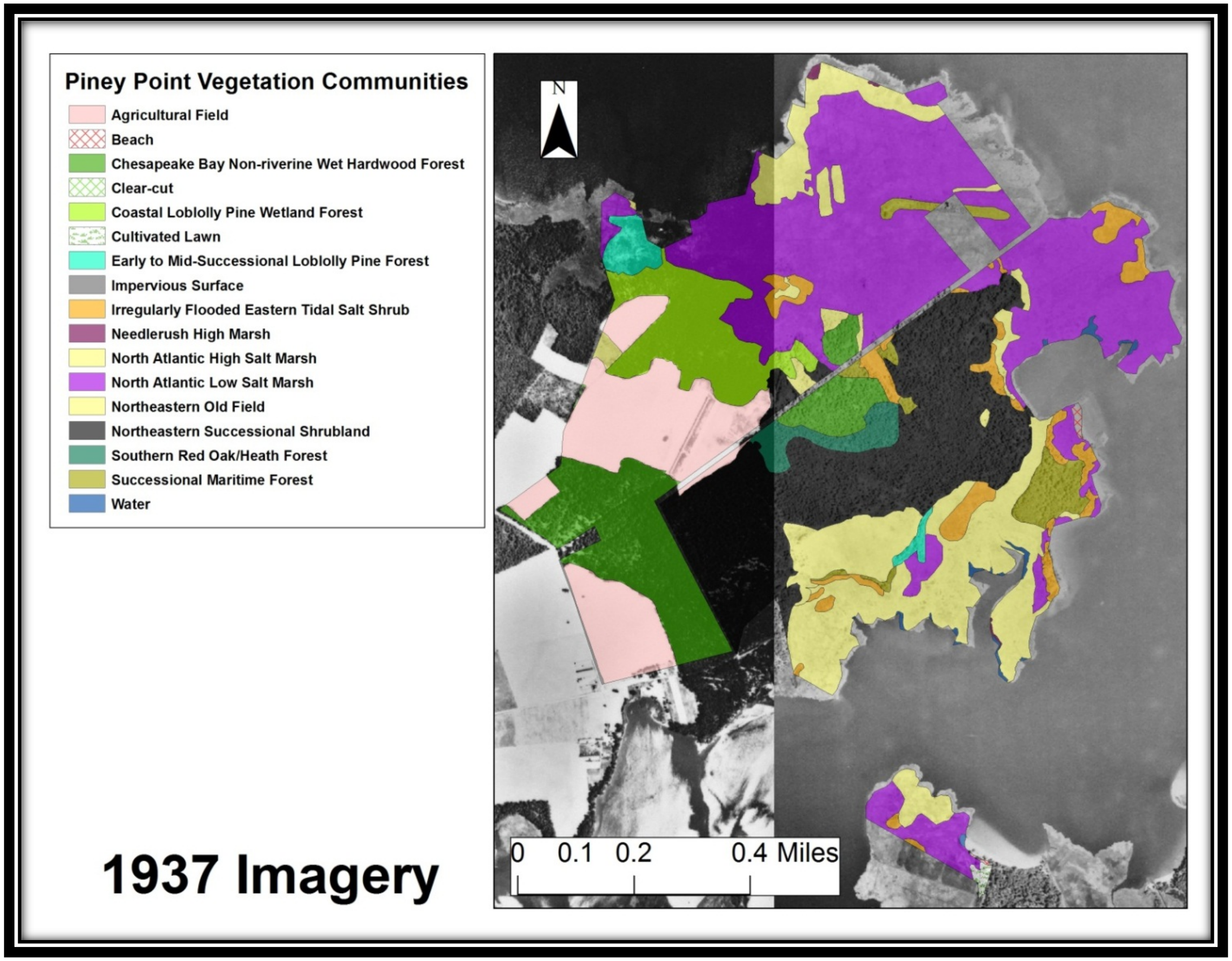
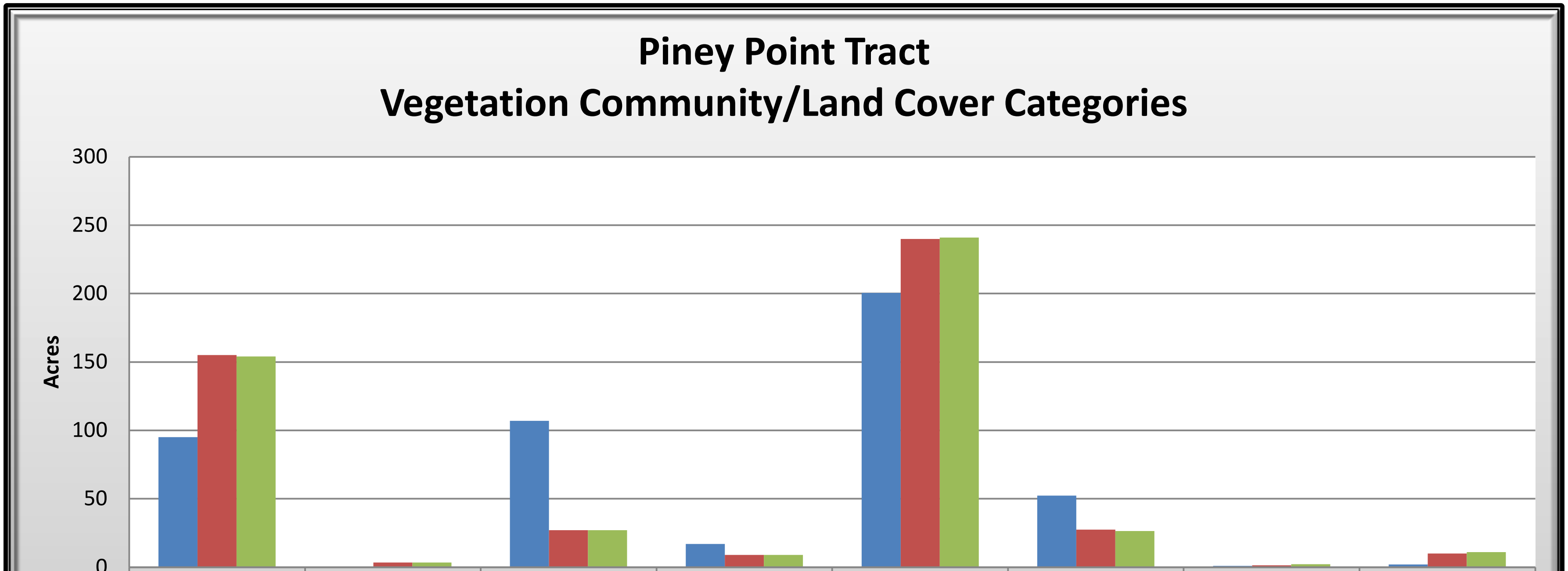


Figure 4-3.3. 1937 Vegetation Community map of the Piney Point Tract



	Forests	Woodlands	Shrublands	Herbaceous	Marsh	Anthropogenic Communities/Land Covers	Non-Vegetated Land Covers	Water
1937	95	0	107	17	200.4	52.4	1	2
2002	155	3.3	27	9	240	27.4	1.4	10
2007	154	3.3	27	9	241	26.4	2.2	11

Figure 4-3.4 Piney Point Tract Vegetation Communities/Land Covers (1937, 2002, and 2007)

Broad Trends at the Piney Point Tract (Figure 4-3.4): The Piney Point Tract is located in the Indian River Bay watershed north of the other tracts, which are in the Little Assawoman Bay watershed. During the study period forests decreased in amount, mostly due to conversion to marsh which has increased. Anthropogenic communities are few compared to the other tracts and have decreased with the abandonment of agriculture. Woodlands have developed since 1937, likely due to sea level rise and increasing salinity of the bay. Non-vegetated land covers have oscillated somewhat during the study period.

DNREC Sea Level Rise Analysis (Table 4-3.1)

About ¾ of the Piney Point Tract is inundated with 0.5 m of sea level rise. At 1 m of rise an additional 59 acres is inundated. A rise of 1.5 m nearly submerges this tract making it the most vulnerable tract in the wildlife area to sea level rise.

Table 4-3.1. Projected acres of the Piney Point Tract Inundated by Sea Level Rise

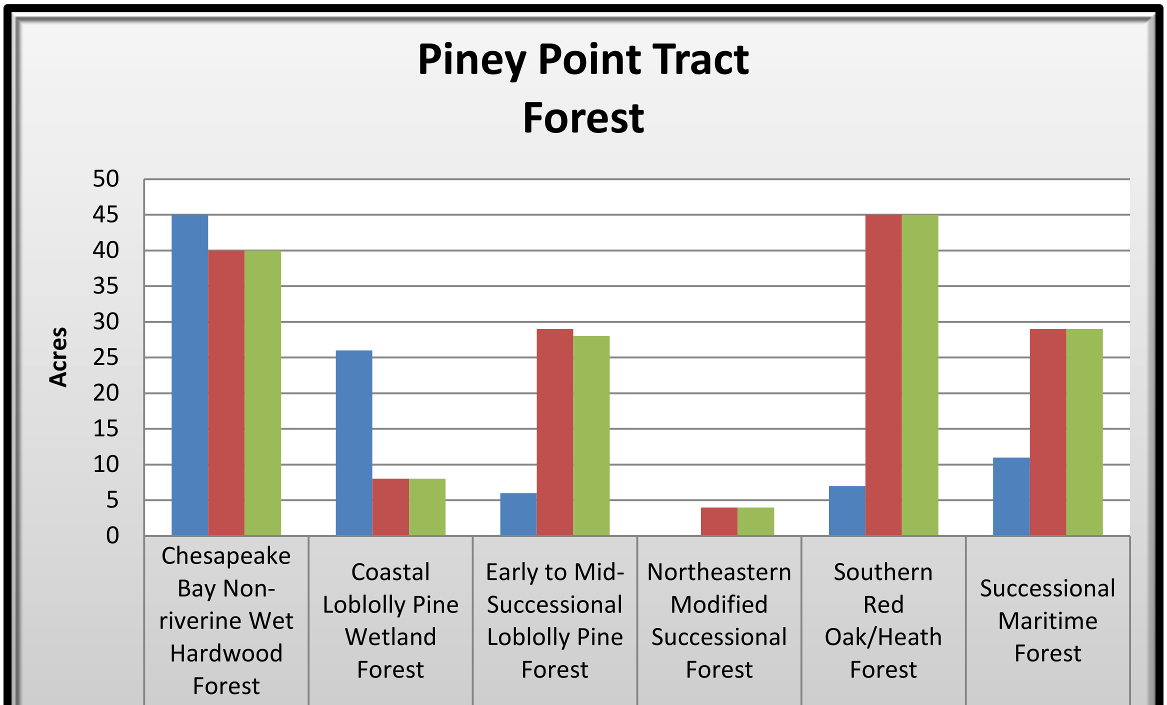
Rise	Acres
0.5 m	324 acres
1 m	383 acres
1.5 m	419 acres

Natural Capital (Table 4-3.2)

The Piney Point Tract has lower capitalization since it is smaller than the other landward tracts. Its capital value has increased over time through inundation from sea level rise.

Table 4-3.2. Natural Capital of Piney Point Tract

Year	Natural Capital (in 2012 dollars)
1937	$2,285,287/year
2002	$2,472,842/year
2007	$2,492,003/year



	Chesapeake Bay Non-riverine Wet Hardwood Forest	Coastal Loblolly Pine Wetland Forest	Early to Mid-Successional Loblolly Pine Forest	Northeastern Modified Successional Forest	Southern Red Oak/Heath Forest	Successional Maritime Forest
1937	45	26	6	0	7	11
2002	40	8	29	4	45	29
2007	40	8	28	4	45	29

Figure 4-3.5. Piney Point Tract Forest (1937, 2002, and 2007)

Piney Point Tract Forest (Figure 4-3.5): Forests at Piney Point have increased in the period from 1937 to 2007. Some forests have increased either through succession (Southern Red Oak/Heath Forest) or sea level rise and increased salinity exposure (Successional Maritime Forest). Chesapeake Bay Non-riverine Wet Hardwood Forest has likely decreased from conversion to marsh and Coastal Loblolly Pine Wetland Forest from impoundment development. Northeastern Modified Successional Forest has grown in some of the former agricultural fields as the more aggressive species have taken advantage of the disturbance and open conditions.

DNREC Sea Level Rise Analysis (Table 4-3.3)

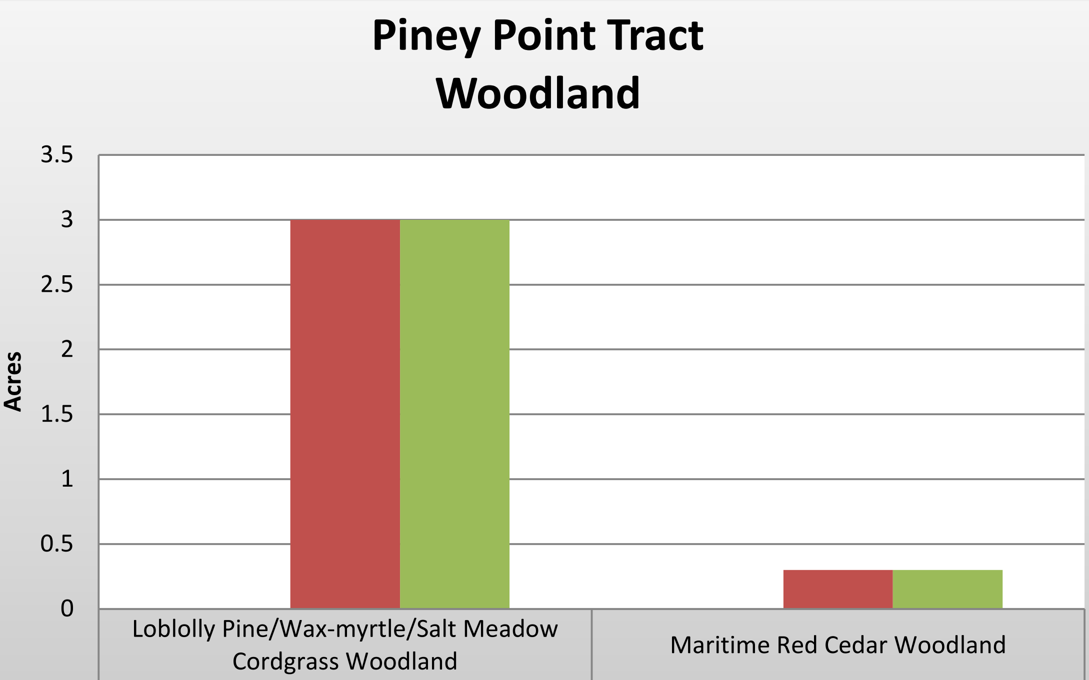
About 39 acres of forest will be inundated with 0.5 m of sea level rise in its current extent. At 1 m of rise another 51 acres will be inundated and at 1.5 m of rise 125 acres will be flooded.

Table 4-3.3. Projected acres of the Piney Point Tract Forest Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	39 acres
1 m	90 acres
1.5 m	125 acres

Natural Capital (Table 4-3.4)

The capital of forest was highest in 1937, but losses due to sea level rise and conversion of forest to marsh has transferred the capital to other communities.

Table 4-3.4. Natural Capital of Piney Point Tract Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$877,235/year
2002	$610,226/year
2007	$610,037/year



	Loblolly Pine/Wax-myrtle/Salt Meadow Cordgrass Woodland	Maritime Red Cedar Woodland
1937	0	0
2002	3	0.3
2007	3	0.3

Figure 4-3.6. Piney Point Tract Woodland (1937, 2002, and 2007)

Piney Point Tract Woodland (Figure 4-3.6): Two woodlands which were not present in 1937 have colonized the Piney Point Tract. One, Loblolly Pine/Wax-myrtle/Salt Meadow Cordgrass Woodland, has likely resulted from sea level rise causing increased salinity and converting adjacent Coastal Loblolly Pine Wetland Forest. Maritime Red Cedar Woodland has likely come about through regeneration from seed bank after logging in the 1920's and 1930's and further conversion of hardwood forests. Both of the communities were stable from 2002 to 2007.

DNREC Sea Level Rise Analysis (Table 4-3.5)

All of the woodland present on the Piney Point Tract will inundated with 0.5 m of sea level rise.

Table 4-3.5. Projected acres of the Piney Point Tract Woodland Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	3 acres
1 m	3 acres
1.5 m	3 acres

Natural Capital (Table 4-3.6)

Woodland was not present in 1937, so any amount represents a gain historically. In the recent period (2002-2007), the amount has stayed the same.

Table 4-3.6. Natural Capital of Piney Point Tract Woodland	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year (not present)
2002	$36,931/year
2007	$36,931/year

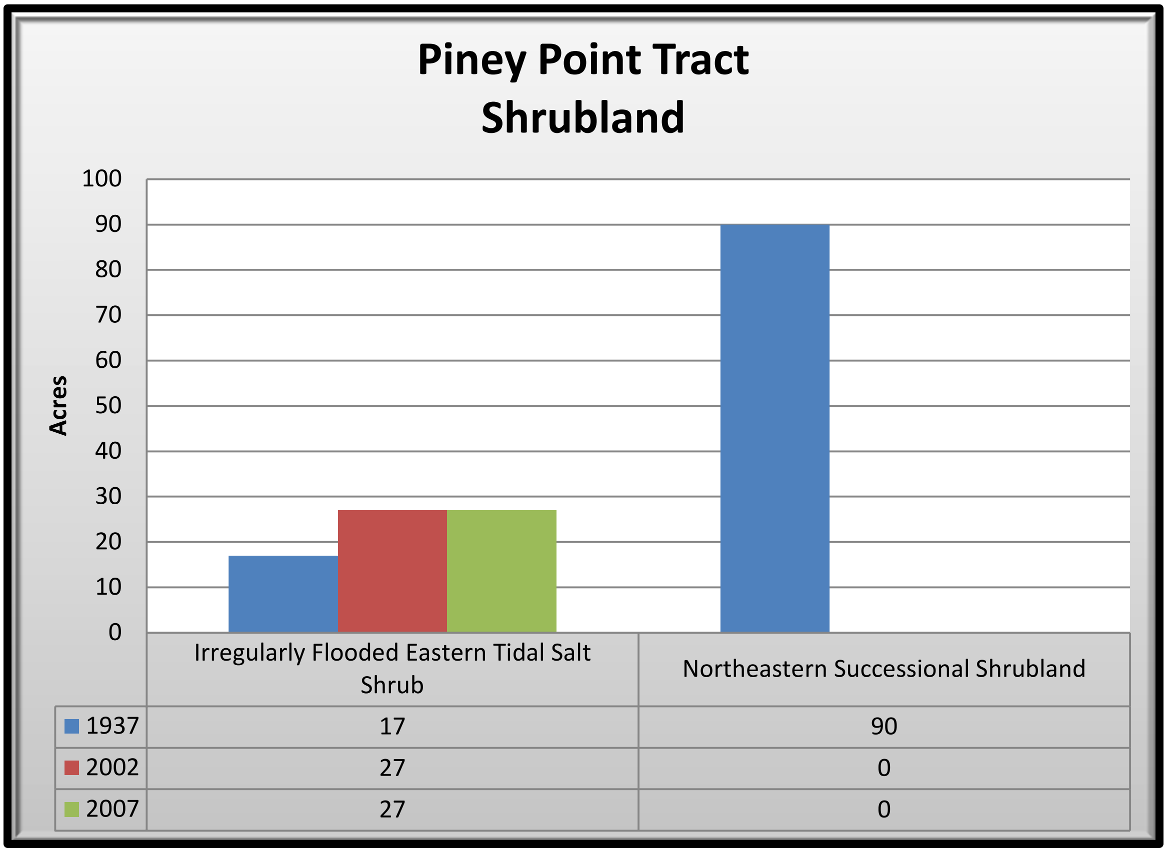


Figure 4-3.7. Piney Point Tract Shrubland (1937, 2002, and 2007)

Piney Point Tract Shrubland (Figure 4-3.7): Irregularly Flooded Eastern Tidal Salt Shrub is the only shrubland currently present in the Piney Point Tract since Northeastern Successional Shrubland has matured to forest. It has bucked the decreasing trend on the other tracts and has increased on this tract. This may be due to topographic highs which have reduced the overall inundation on this tract or tidal differences between the other tracts located on Little Assawoman Bay and Indian River Bay.

DNREC Sea Level Rise Analysis (Table 4-3.7)

At 0.5 m of sea level, the shrubland present on the Piney Point Tract is practically eliminated by flooding in its current extent.

Table 4-3.7. Projected acres of the Piney Point Tract Shrubland Inundated by Sea Level Rise

Rise	**Acres**
0.5 m	26 acres
1 m	26 acres
1.5 m	27 acres

Natural Capital (Table 4-3.8)

In spite of the maturation of Northeastern Successional Shrubland from 1937 into other communities, the capital of shrubland has gone up on gains from Irregularly Flooded Eastern Tidal Salt Shrub, which is a more valuable community. In the recent period (2002-2007) the acreage and capital have remained the same.

Table 4-3.8. Natural Capital of Piney Point Tract Shrubland

Year	Natural Capital (in 2012 dollars)
1937	$119,725/year
2002	$169,325/year
2007	$169,325/year

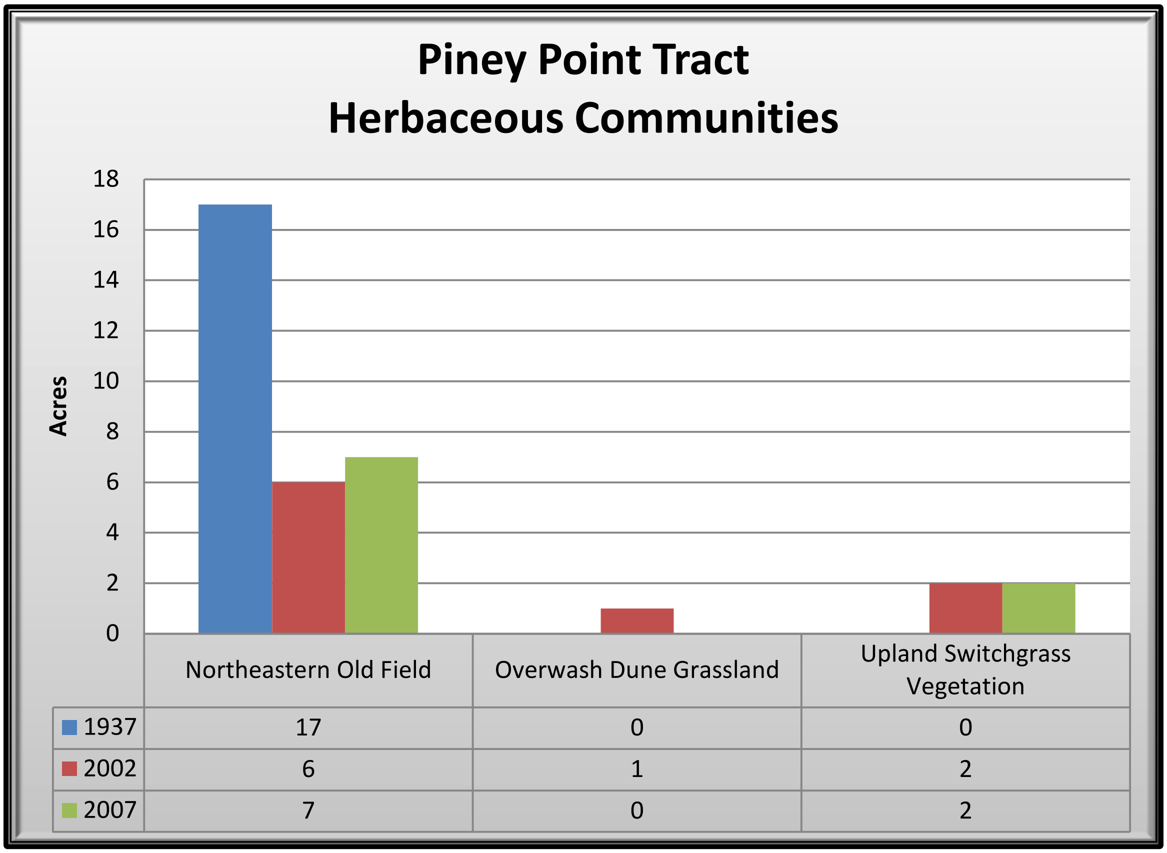


Figure 4-3.8. Piney Point Tract Herbaceous Communities (1937, 2002, and 2007)

Piney Point Tract Herbaceous Communities (Figure 4-3.8): Herbaceous communities have experienced a decrease overall in the 1937 to 2007 being led by Northeastern Old Field. Overwash Dune Grassland and Upland Switchgrass Vegetation have both developed since 1937 and are declining slightly or stable, respectively. Upland Switchgrass vegetation has been planted through efforts to provide a vegetated buffer around agricultural fields.

DNREC Sea Level Rise Analysis (Table 4-3.8)

Herbaceous communities are not affected too much by sea level rise at the Piney Point Tract as compared to the tract itself. At the highest amount of rise (1.5 m) only about half of the acreage will be inundated.

Table 4-3.9. Projected acres of the Piney Point Tract Herbaceous Communities Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	0.3 acres
1 m	3 acres
1.5 m	4 acres

Natural Capital (Table 4-3.10)

Natural capital of herbaceous communities has never been all that much compared with others and it has oscillated around the same amount over time.

Table 4-3.10. Natural Capital of Piney Point Tract Herbaceous Communities	
Year	**Natural Capital (in 2012 dollars)**
1937	$2,477/year
2002	$1,311/year
2007	$1,311/year

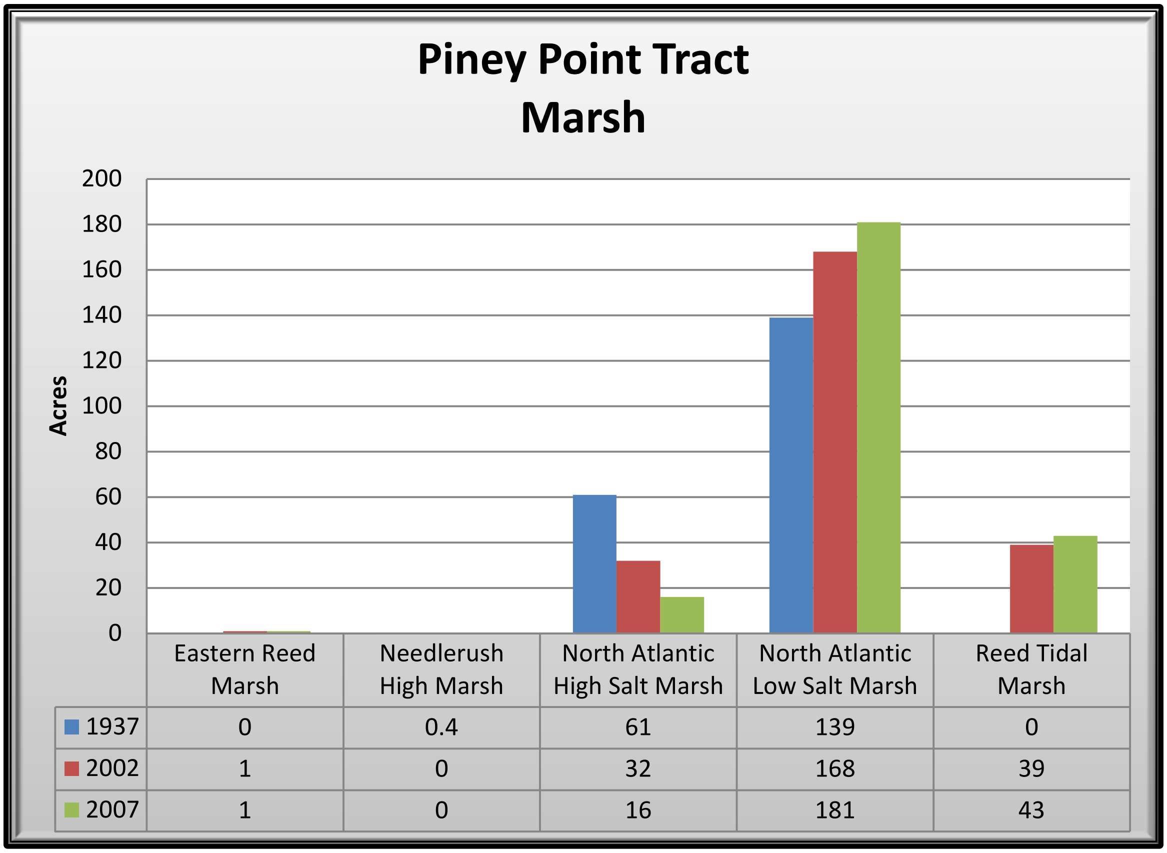


Figure 4-3.9. Piney Point Tract Marshes (1937, 2002, and 2007)

Piney Point Tract Marsh (Figure 4-3.9): Like the some of the other tracts, North Atlantic Low Salt Marsh and North Atlantic High Salt Marsh were the most prominent marsh types in 1937. Since 1937, North Atlantic High Marsh has decreased markedly while North Atlantic Low Salt Marsh has increased along with Reed Tidal Marsh, which has come about since 1937. It is likely that the area once covered by North Atlantic High Salt Marsh is now either North Atlantic Low Salt Marsh or Reed Tidal Marsh. Eastern Reed Marsh (a non-tidal *Phragmites* Marsh) has recently arrived and has populated two depression wetlands.

DNREC Sea Level Rise Analysis (Table 4-3.11)

At 0.5 m of sea level rise, essentially all of the current marsh area will be inundated.

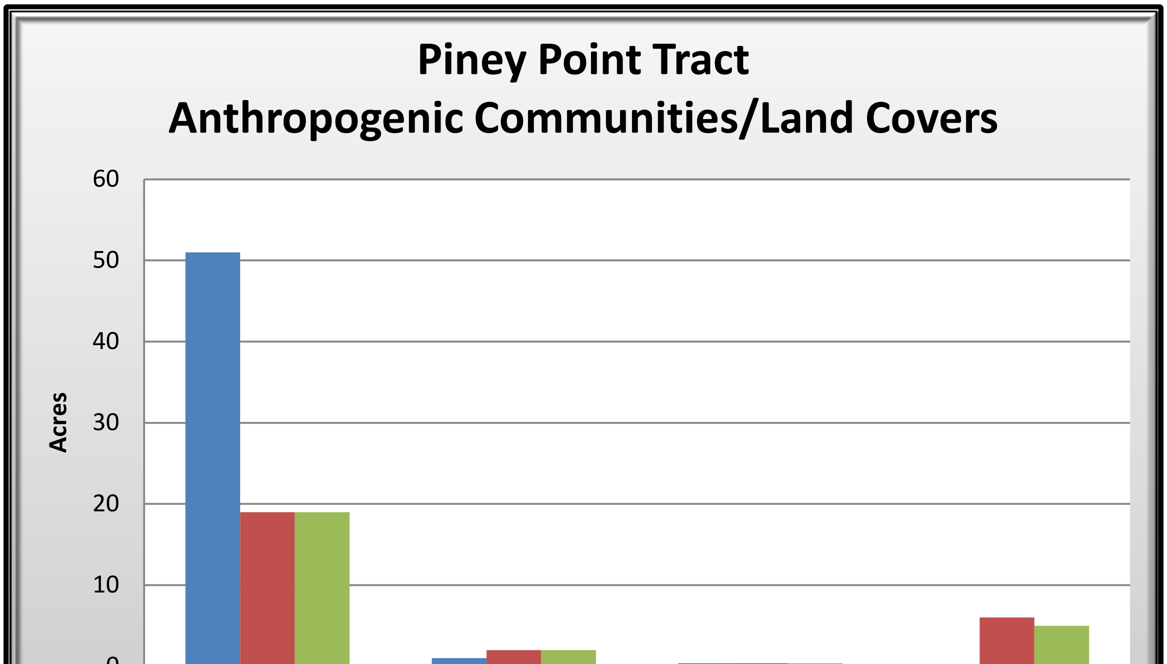
Table 4-3.11. Projected acres of the Piney Point Tract Marsh Inundated by Sea Level Rise

Rise	Acres
0.5 m	240 acres
1 m	241 acres
1.5 m	241 acres

Natural Capital (Table 4-3.12)

The capital value of marsh has continued an upward track mainly on increases in North Atlantic Low Salt Marsh. It is unknown how long this will continue before it starts to transfer more into water than it is bringing in.

Table 3-3.12. Natural Capital of Piney Point Tract Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$1,254,260/year
2002	$1,508,122/year
2007	$1,514,393/year



	Agricultural Field	Cultivated Lawn	Impervious Surface	Modified Land
1937	51	1	0.4	0
2002	19	2	0.4	6
2007	19	2	0.4	5

Figure 4-3.10. Piney Point Tract Anthropogenic Communities/Land Covers (1937, 2002, and 2007)

Piney Point Tract Anthropogenic Communities/Land Covers (Figure 4-3.10): Agricultural field was the most prominent anthropogenic community in 1937 but has decreased by more than half since then, as it succeeded to forest. All of the other anthropogenic communities have increased or decreased slightly.

DNREC Sea Level Rise Analysis (Table 4-3.13)

As a percentage of acreage, not many of the anthropogenic communities/land covers will be inundated even at the highest level (1.5 m). At the highest, 7 acres will be flooded.

Table 4-3.13. Projected acres of the Piney Point Tract Anthropogenic Communities/Land Covers Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	3 acres
1 m	6 acres
1.5 m	7 acres

Natural Capital (Table 4-3.14)

All of the natural capital for this category is coming from the agricultural fields, which is decreasing with the gradual elimination of the agricultural fields. This should result in a transfer and increase in the capital for the tract and wildlife area.

Table 4-3.14. Natural Capital of Piney Point Tract Anthropogenic Communities	
Year	**Natural Capital (in 2012 dollars)**
1937	$2,925/year
2002	$1,090/year
2007	$1,090/year

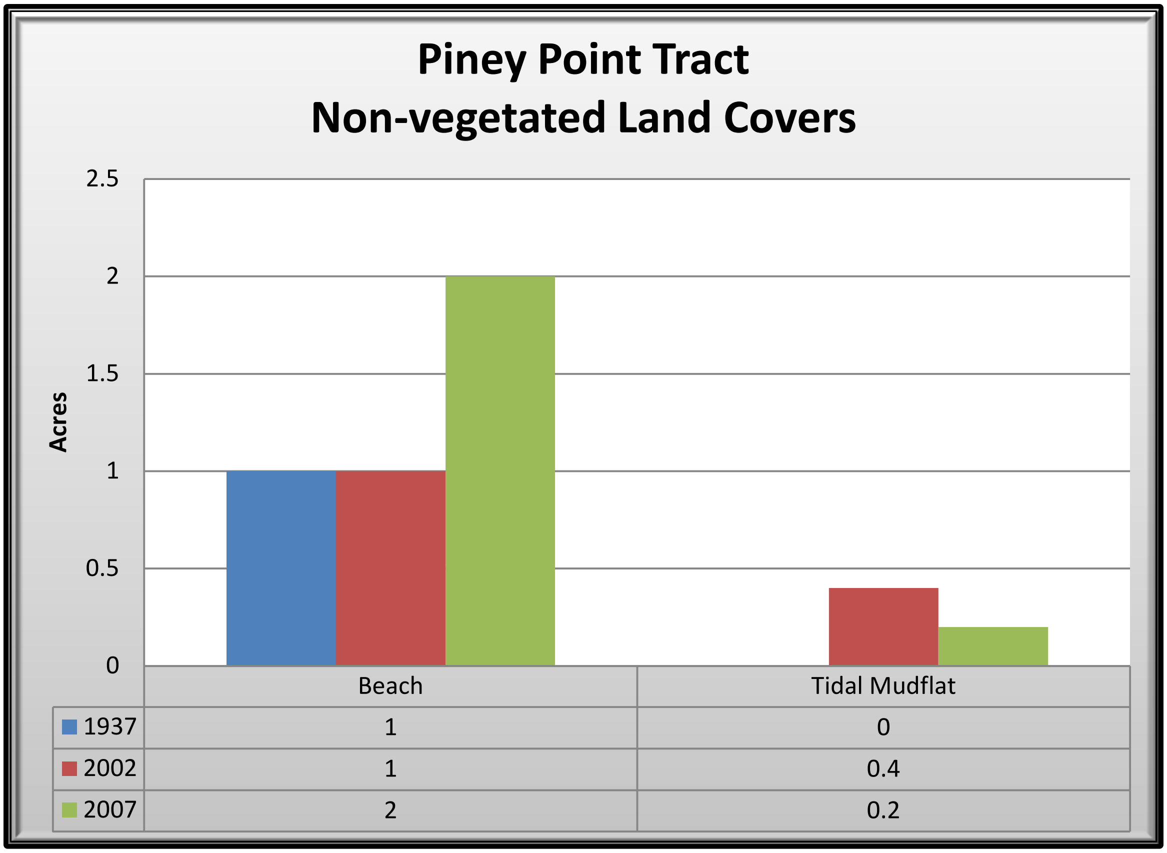


Figure 4-3.11. Piney Point Tract Non-vegetated Land Covers (1937, 2002, and 2007)

Piney Point Tract Non-vegetated Land Covers (Figure 4-3.11): Two non-vegetated land covers are located within the Piney Point Tract, one of which, tidal mudflat, was not present in 1937. Both of these types tend to be temporary in nature and oscillate in amount over time.

DNREC Sea Level Rise Analysis (Table 4-3.15)

Half of the acreage of Non-vegetated land covers will be inundated with 0.5 m of sea level rise. At 1 m and above all of the current acreage will be inundated.

Table 4-3.15. Projected acres of the Piney Point Tract Non-vegetated Land Covers Inundated by Sea Level Rise

Rise	Acres
0.5 m	1 acre
1 m	2 acres
1.5 m	2 acres

Natural Capital (Table 4-3.16)

This category did not have any capital in 1937, but gained capital from tidal mudflat since. It has been going down as tidal mudflats have been inundated.

Table 4-3.16. Natural Capital of Piney Point Tract Non-vegetated Land Covers	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year
2002	$2,509/year
2007	$1,254/year

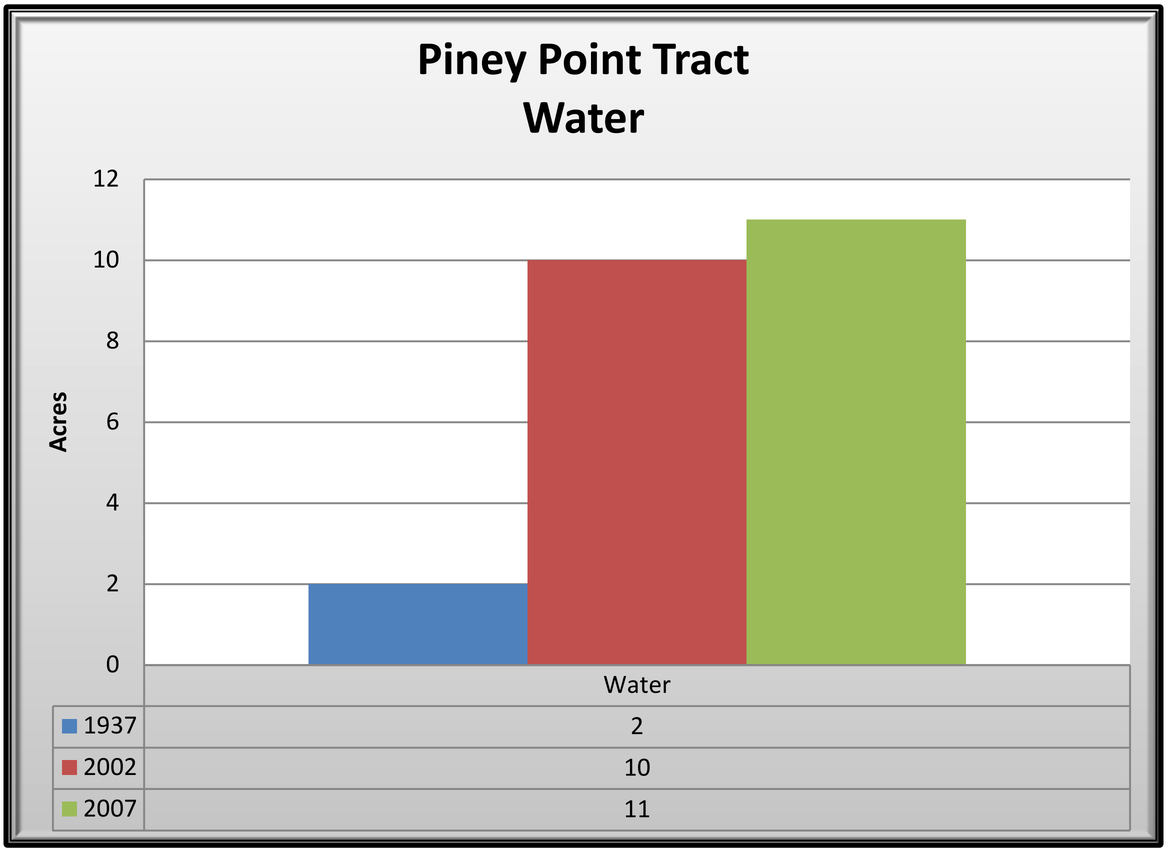


Figure 4-3.12. Piney Point Tract Water Coverage (1937, 2002, and 2007)

Piney Point Tract Water Coverage (Figure 4-3.12): Inundation by water, like the other tracts, has increased steadily and has increased in rate during the recent period. The historical average inundation rate at the Piney Point Tract is 0.13 acres/year (1937-2007). During the 2002-2007 period the rate was 0.2 acres/year. The rate during the 1937-2002 period was 0.12 acres/year showing a fairly stable rate until recently. Piney Point is not showing as much increase as the other tracts because its exposure to water is smaller and the topography is little bit higher than the other tracts.

Natural Capital (Table 4-3.17)

Like all of the other tracts, capitalization for water is going up with sea level rise.

Table 4-3.17. Natural Capital of Piney Point Tract Water Coverage

Year	Natural Capital (in 2012 dollars)
1937	$28,666/year
2002	$143,329/year
2007	$157,661/year

4. South Bethany Tract

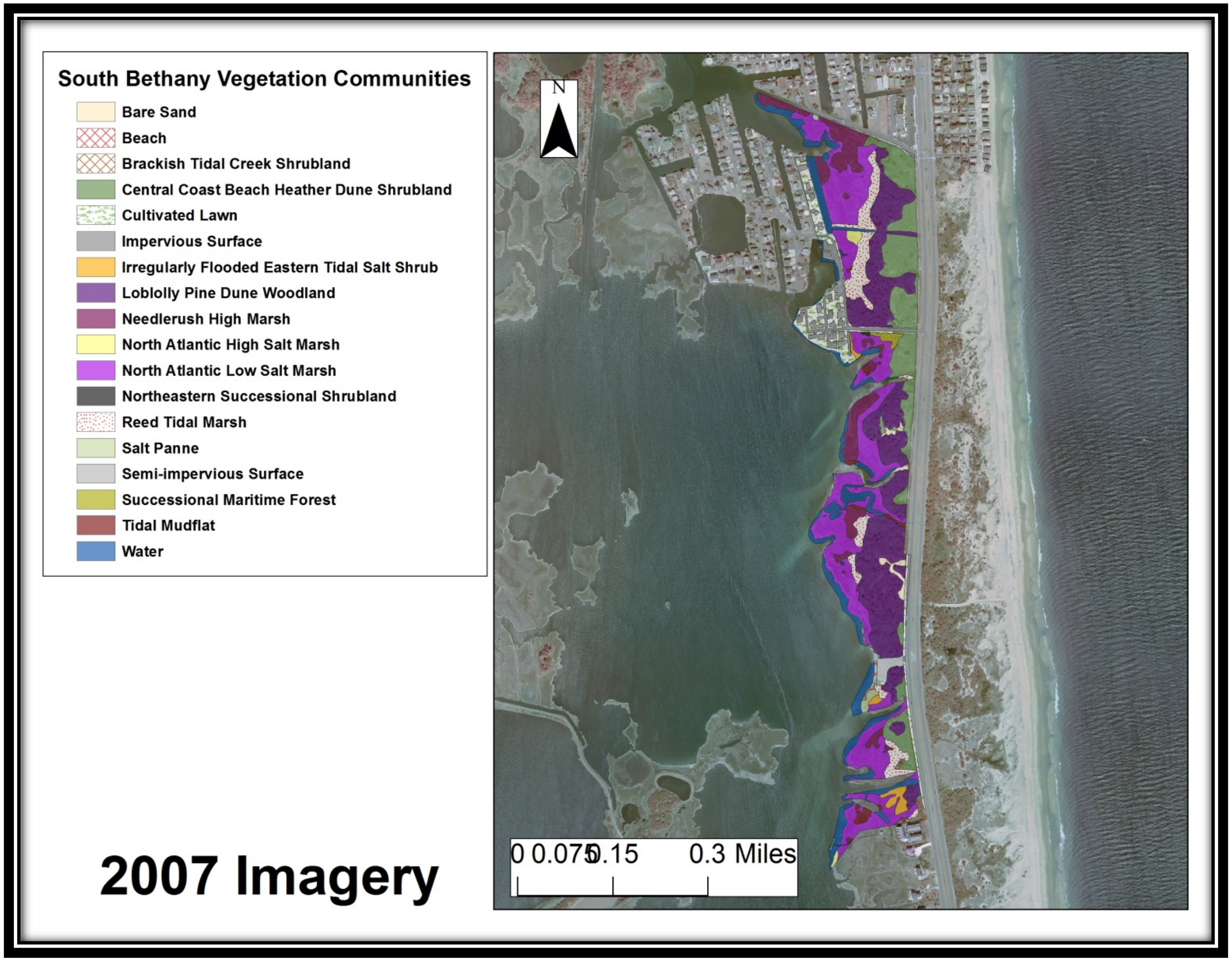


Figure 4-4.1. 2007 Vegetation Community map of the South Bethany Tract

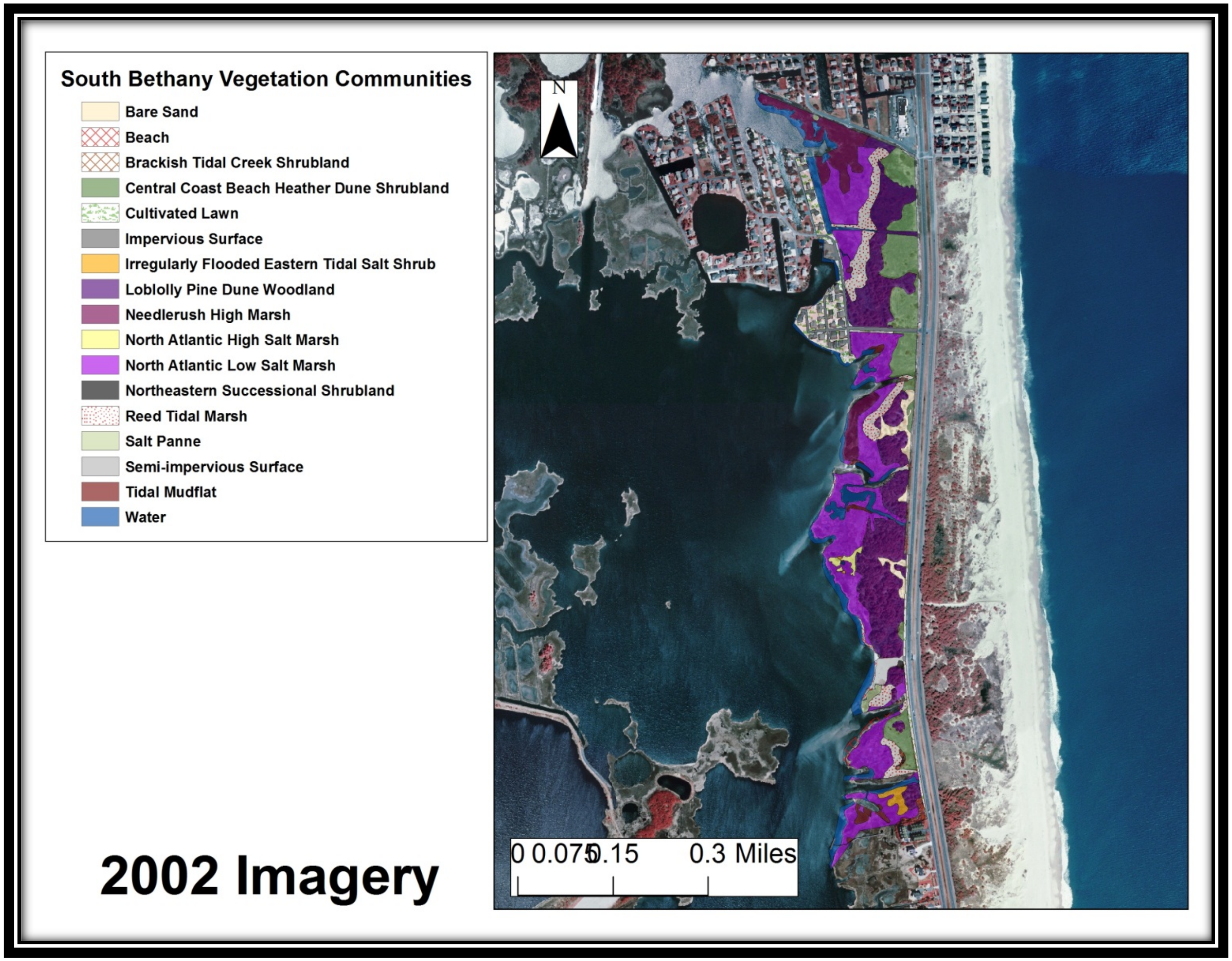


Figure 4-4.2. 2002 Vegetation Community map of the South Bethany Tract

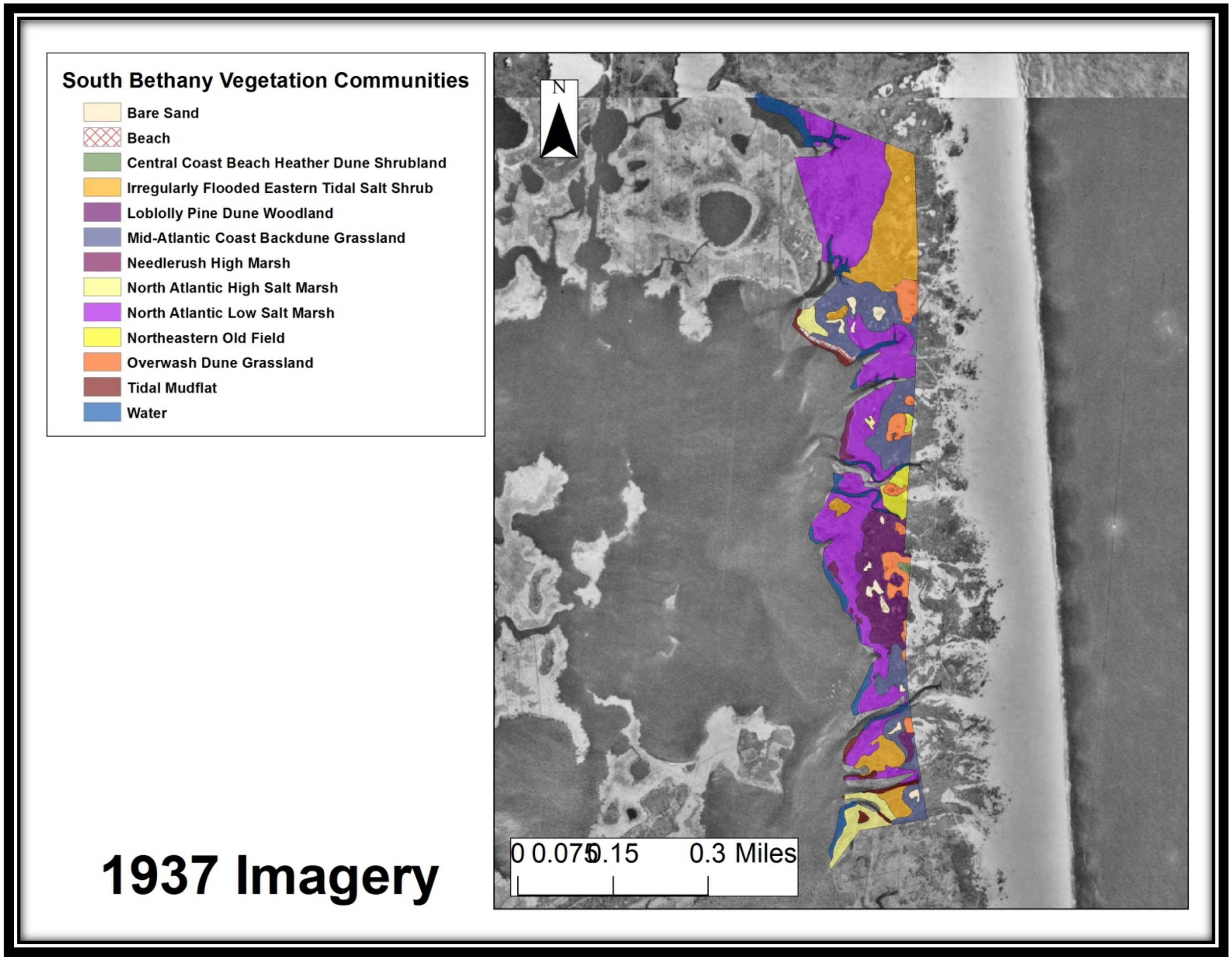
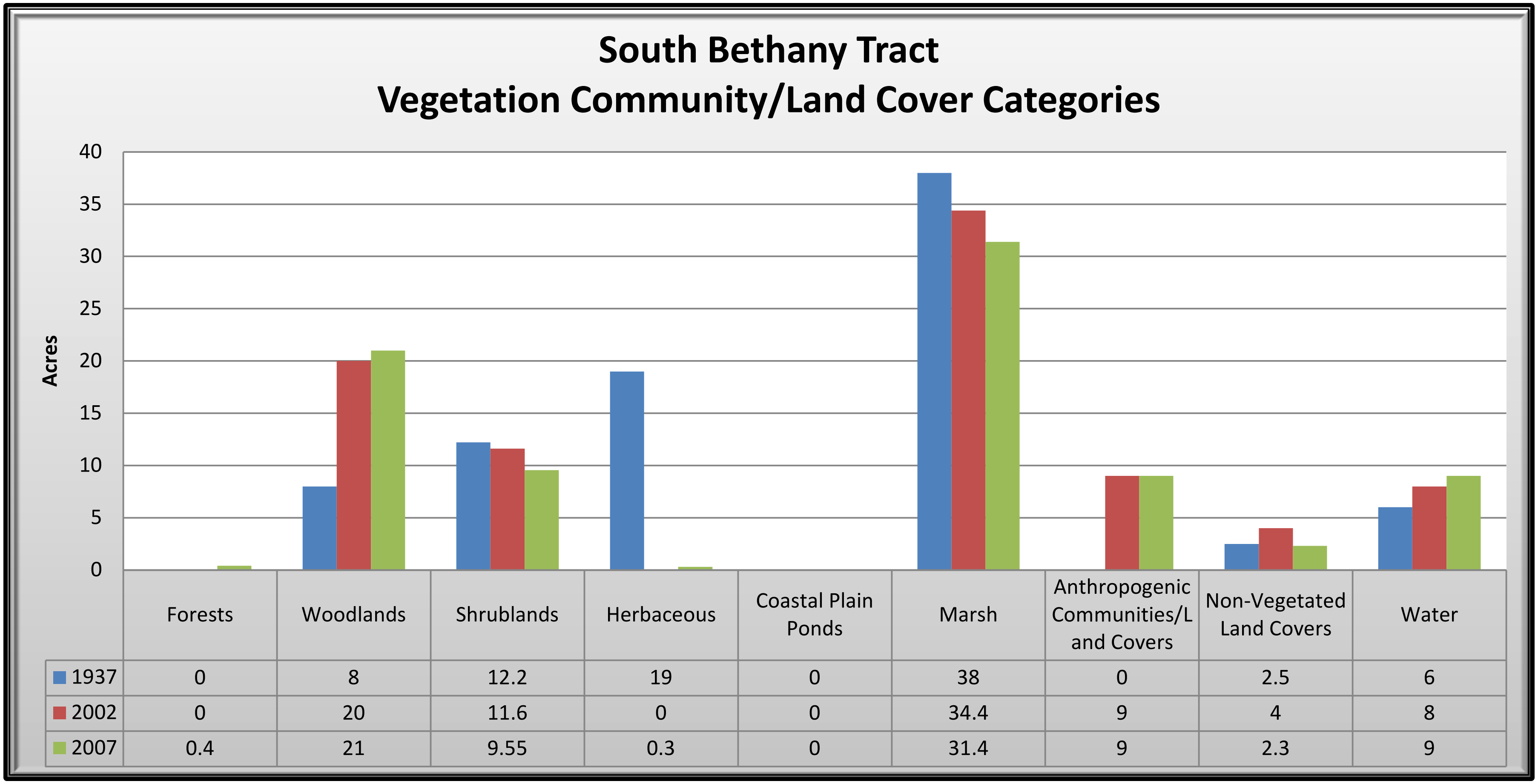


Figure 4-4.3. 1937 Vegetation Community map of the South Bethany Tract



	Forests	Woodlands	Shrublands	Herbaceous	Coastal Plain Ponds	Marsh	Anthropogenic Communities/Land Covers	Non-Vegetated Land Covers	Water
1937	0	8	12.2	19	0	38	0	2.5	6
2002	0	20	11.6	0	0	34.4	9	4	8
2007	0.4	21	9.55	0.3	0	31.4	9	2.3	9

Figure 4-4.4. South Bethany Tract Vegetation Communities/Land Covers (1937, 2002, and 2007)

South Bethany Tract Broad Trends (Figure 4-4.4): The South Bethany Tract is located on the Coastal Strand between the towns of South Bethany Beach and Fenwick Island. Because of the proximity to the ocean forests are few here and are expressed as woodlands with a more open canopy; a type which has increased over the study period. Shrublands have shown an overall decrease but a recent increase. Marsh in this tract has gradually decreased. Anthropogenic communities led by the impervious surface and cultivated lawn associated with DE 1, which was not present in 1937, have increased. Water coverage has gone up and down, likely due to the dynamics of dunes replacing sand to the marshes and rebuilding land, unlike the areas in the back bays where the other tracts are located.

DNREC Sea Level Rise Analysis (Table 4-4.1)

Most of the South Bethany Tract is inundated with 0.5 m of sea level rise, with an additional 14 acres being flooded with 0.5 m more rise. At 1.5 m this tract is completely flooded in its current extent.

Table 4-4.1. Projected acres of the South Bethany Tract Inundated by Sea Level Rise

Rise	Acres
0.5 m	70 acres
1 m	84 acres
1.5 m	86 acres

Natural Capital (Table 4-4.2)

The South Bethany tract has the least capital value due to its small size. Unlike so of the other tracts it has not benefitted from the water increases because of anthropogenic land covers being developed on it.

Table 4-4.2. Natural Capital of South Bethany Tract

Year	Natural Capital (in 2012 dollars)
1937	$410,144/year
2002	$351,516/year
2007	$349,087/year

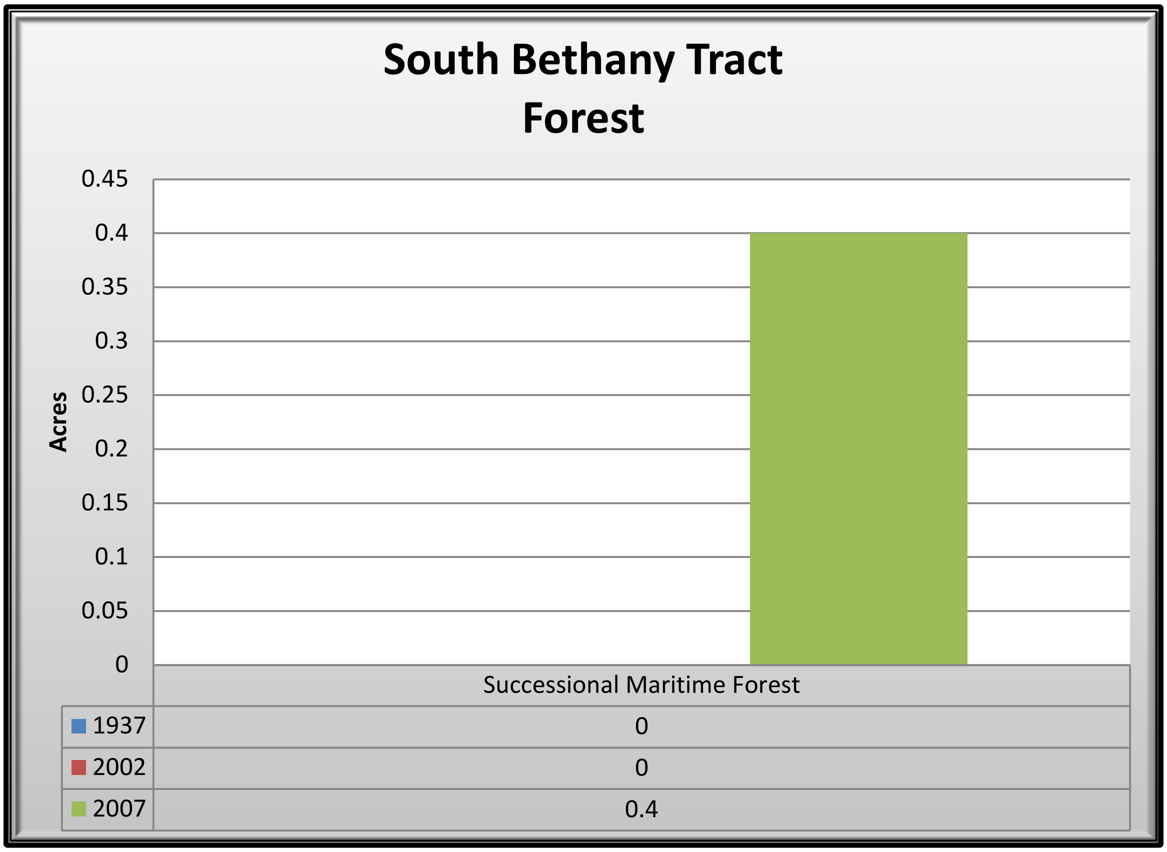


Figure 4-4.5. South Bethany Tract Forest (1937, 2002, and 2007)

South Bethany Tract Forest (Figure 3-4.5): Only one forest type is located on the Atlantic strand portion of Assawoman Wildlife Area. This type may have resulted from seed bank regeneration since there were no hardwood forests to convert.

DNREC Sea Level Rise Analysis (Table 4-4.3)

All of the forestland on the South Bethany Tract will be inundated with 0.5 m or more of sea level rise.

Table 4-4.3. Projected acres of the South Bethany Tract Forest Inundated by Sea Level Rise

Rise	Acres
0.5 m	0.4 acres
1 m	0.4 acres
1.5 m	0.4 acres

Natural Capital (Table 4-4.4)

The capital value of the forestland on the South Bethany Tract is extremely due to the small size of the forest. This forest may quickly transfer to marsh or to woodland in the short-term future.

Table 4-4.4. Natural Capital of South Bethany Tract Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year
2002	$0/year
2007	$76/year

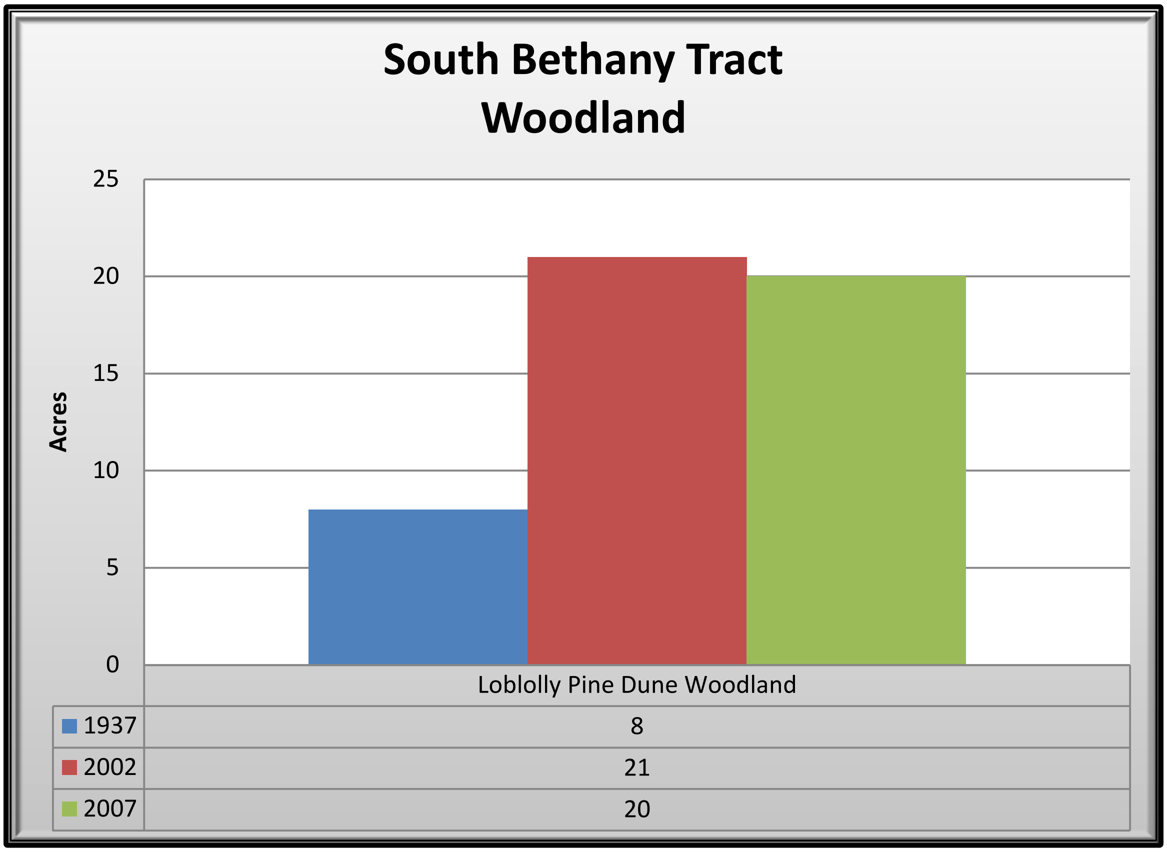


Figure 4-4.6. South Bethany Tract Woodland (1937, 2002, and 2007)

South Bethany Tract Woodland (Figure 4-4.6): Loblolly Pine Dune Woodland is the only woodland located on the South Bethany tract and is among the few wooded areas located on the Atlantic Strand, other than those located at Cape Henlopen State Park. The stand at the South Bethany Tract has increased since 1937 and is now relatively stable with slight conversion due to invasion by common reed (*Phragmites australis*).

DNREC Sea Level Rise Analysis (Table 4-4.5)

All of the woodland present on the South Bethany Tract will be inundated with 1 m or more of sea level rise.

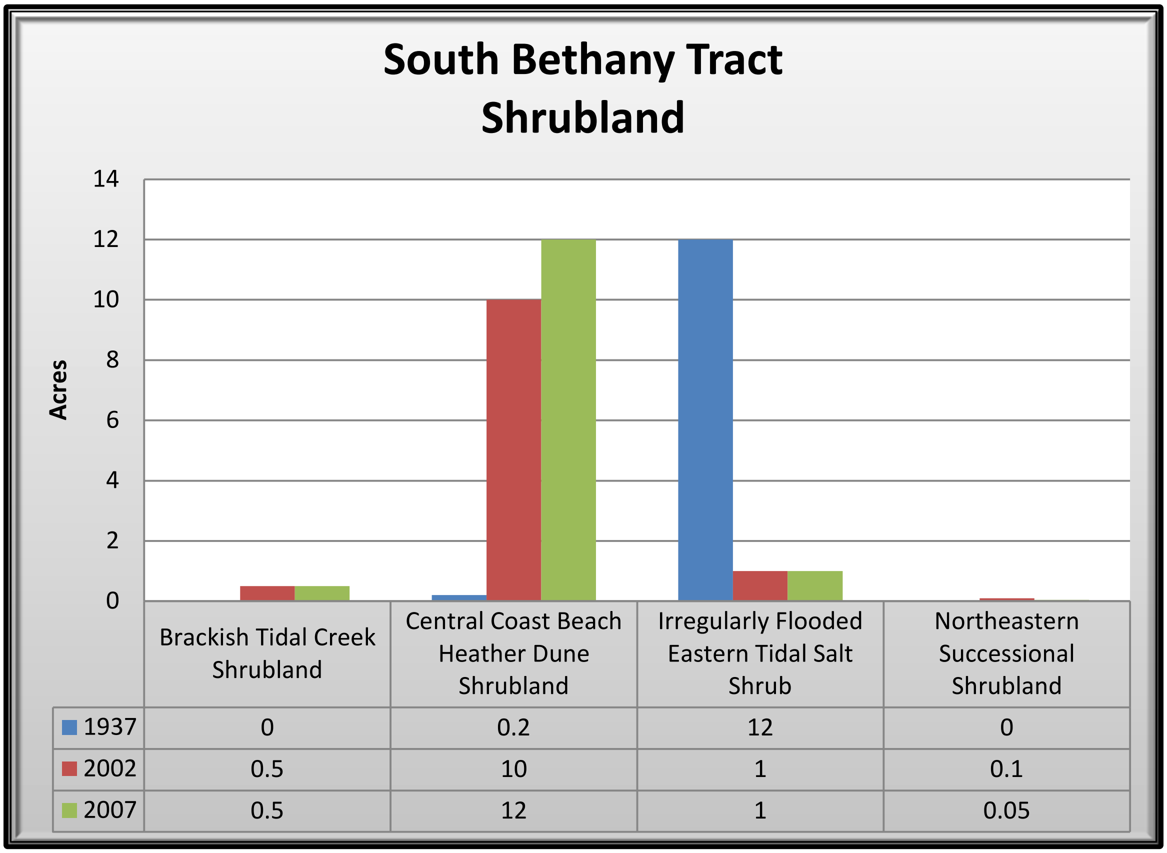
Table 4-4.5. Projected acres of the South Bethany Tract Woodland Inundated by Sea Level Rise

Rise	Acres
0.5 m	17 acres
1 m	20 acres
1.5 m	20 acres

Natural Capital (Table 4-4.6)

Natural capital of woodlands has been going down due to conversion to other habitats. This trend will likely continue in the future given the projections.

Table 4-4.6. Natural Capital of South Bethany Tract Woodland	
Year	**Natural Capital (in 2012 dollars)**
1937	$1,513/year
2002	$3,971/year
2007	$3,782/year



	Brackish Tidal Creek Shrubland	Central Coast Beach Heather Dune Shrubland	Irregularly Flooded Eastern Tidal Salt Shrub	Northeastern Successional Shrubland
1937	0	0.2	12	0
2002	0.5	10	1	0.1
2007	0.5	12	1	0.05

Figure 4-4.7. South Bethany Tract Shrubland (1937, 2002, and 2007)

South Bethany Tract Shrubland (Figure 4-4.7): Four shrublands are located on the South Bethany Tract. Irregularly Flooded Eastern Tidal Salt Shrub was prominent here in 1937 but has decreased to less than one acre, and may be victim of increasing sea level rise. Other shrublands have increased, such as Central Coast Beach Heather Dune Shrubland, which has colonized areas that were once bare sand. Two others, Brackish Tidal Creek Shrubland and Northeastern Successional Shrubland, have populated the tract since 1937, one of which, Northeastern Successional Shrubland, has shown a slight decline.

DNREC Sea Level Rise Analysis (Table 4-4.7)

Practically all of the shrubland present on the South Bethany Tract will be inundated with 1m or greater sea level rise.

Table 4-4.7. Projected acres of the South Bethany Tract Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	4 acres
1 m	12 acres
1.5 m	13 acres

Natural Capital (Table 4-4.8)

In 1937 shrubland had its highest capitalization but has since fallen with losses in Irregularly Flooded Eastern Tidal Salt Shrub. In the short-term (2002-2007), shrubland has made some gains from Central Coast Beach Heather Dune Shrubland.

Table 4-4.8. Natural Capital of South Bethany Tract Shrubland	
Year	**Natural Capital (in 2012 dollars)**
1937	$75,285/year
2002	$10,879/year
2007	$11,163/year

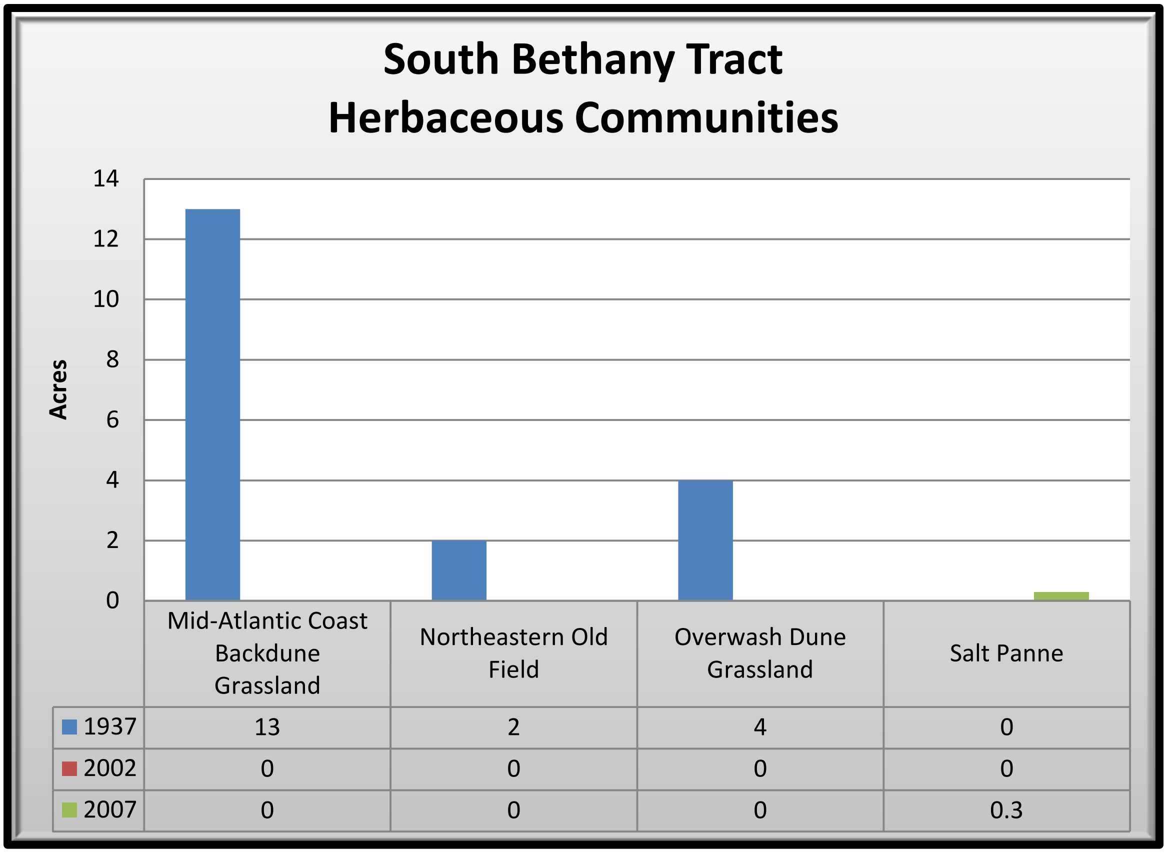


Figure 4-4.8. South Bethany Tract Herbaceous Communities (1937, 2002, and 2007)

South Bethany Tract Herbaceous Communities (Figure 4-4.8): Three herbaceous communities were once present in the South Bethany tract, but now only one remains and just barely.

DNREC Sea Level Rise Analysis (Table 4-4.9)

All of the remaining herbaceous communities will be inundated with just 0.5 m of sea level rise.

Table 4-4.9. Projected acres of South Bethany Tract Herbaceous Communities Inundated by Sea Level Rise

Rise	Acres
0.5 m	0.3 acres
1 m	0.3 acres
1.5 m	0.3 acres

Natural Capital (Table 4-4.10)

Natural capital for herbaceous communities was at its greatest in 1937 and declined to $0 in 2002 and has since rebounded. Given the fluctuating nature of these communities this may continue to happen in the future.

Table 4-4.10. Natural Capital of South Bethany Tract Herbaceous Communities	
Year	**Natural Capital (in 2012 dollars)**
1937	$2,768/year
2002	$0/year
2007	$1,881/year

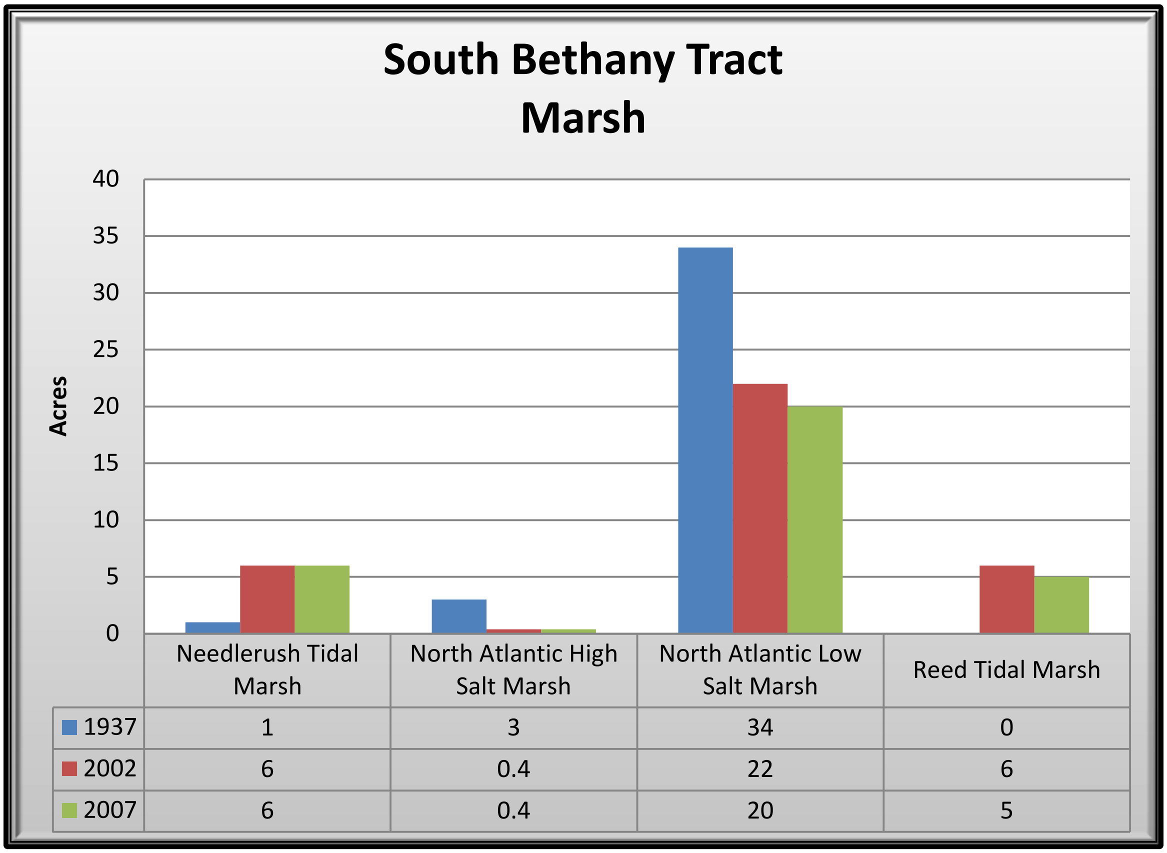


Figure 4-4.9. South Bethany Tract Marsh (1937, 2002, and 2007)

South Bethany Tract Marsh (Figure 4-4.9): Marshes overall have declined since 1937. North Atlantic High Salt Marsh has decreased to the point that it no longer exists on the tract (field visit in December 2010). North Atlantic Low Salt Marsh has also decreased but remains the most common marsh community. Needlerush High Marsh may be increasing from warmer temperatures from climate change and appears to be taking advantage of high areas in the marsh. Increases in Reed Tidal Marsh may be contributing to decreases in North Atlantic High Salt Marsh and Low Marsh along with sea level rise.

DNREC Sea Level Rise Analysis (Table 4-4.11)

All of the existing marshland in the South Bethany Tract will be inundated with 0.5 m of sea level rise.

Table 4-4.11. Projected acres of the South Bethany Tract Marsh Inundated by Sea Level Rise	
Rise	**Acres**
0.5 m	32 acres
1 m	32 acres
1.5 m	32 acres

Natural Capital (Table 4-4.12)

Marshland has suffered decreases and transfers of capital due to sea level rise gradually eating the marsh and having nowhere to migrate to.

Table 4-4.12. Natural Capital of South Bethany Tract Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$238,309/year
2002	$215,733/year
2007	$196,919/year

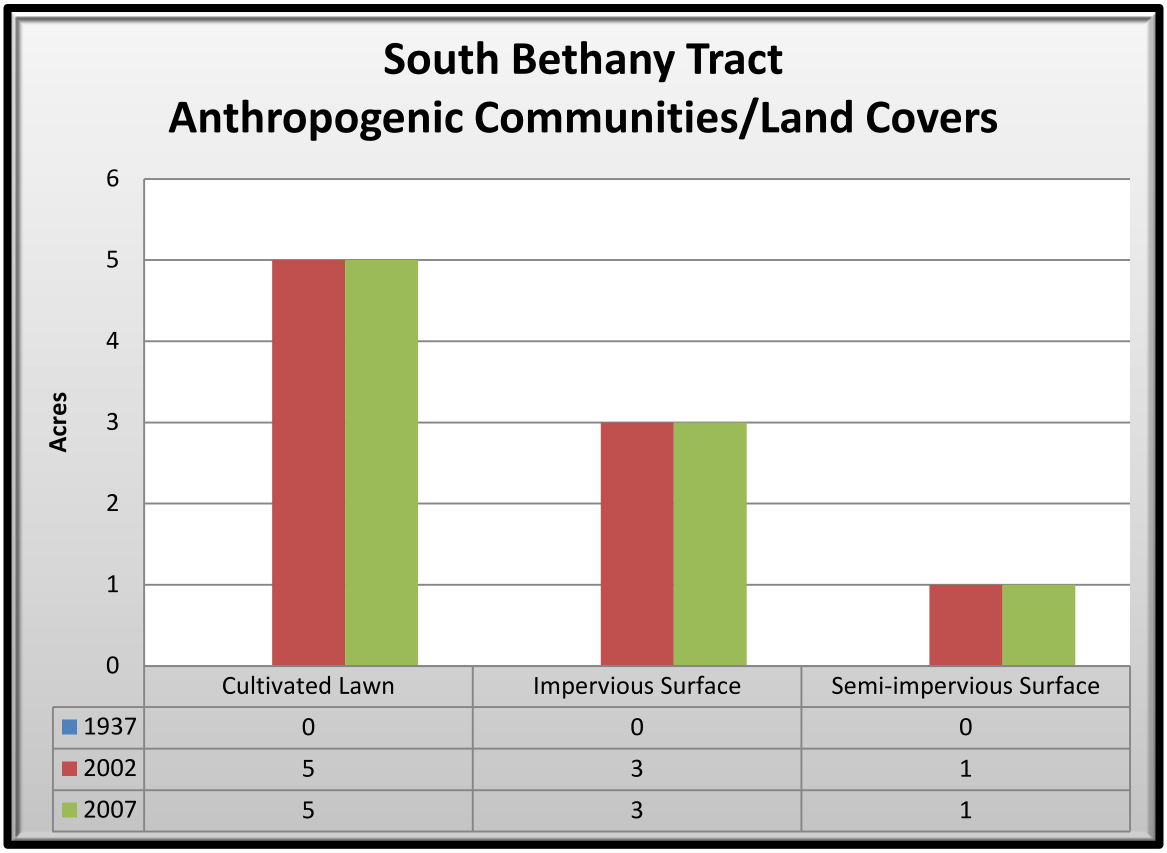


Figure 4-4.10. South Bethany Tract Anthropogenic Communities/Land Covers (1937, 2002, and 2007)

South Bethany Tract Anthropogenic Communities/Land Covers (Figure 4-4.10): In 1937 no anthropogenic communities were present in this tract or the Atlantic Strand. Since then, Cultivated Lawn and Impervious Surface associated with DE 1 and a state park access area have come into the tract.

DNREC Sea Level Rise Analysis (Table 4-4.13)

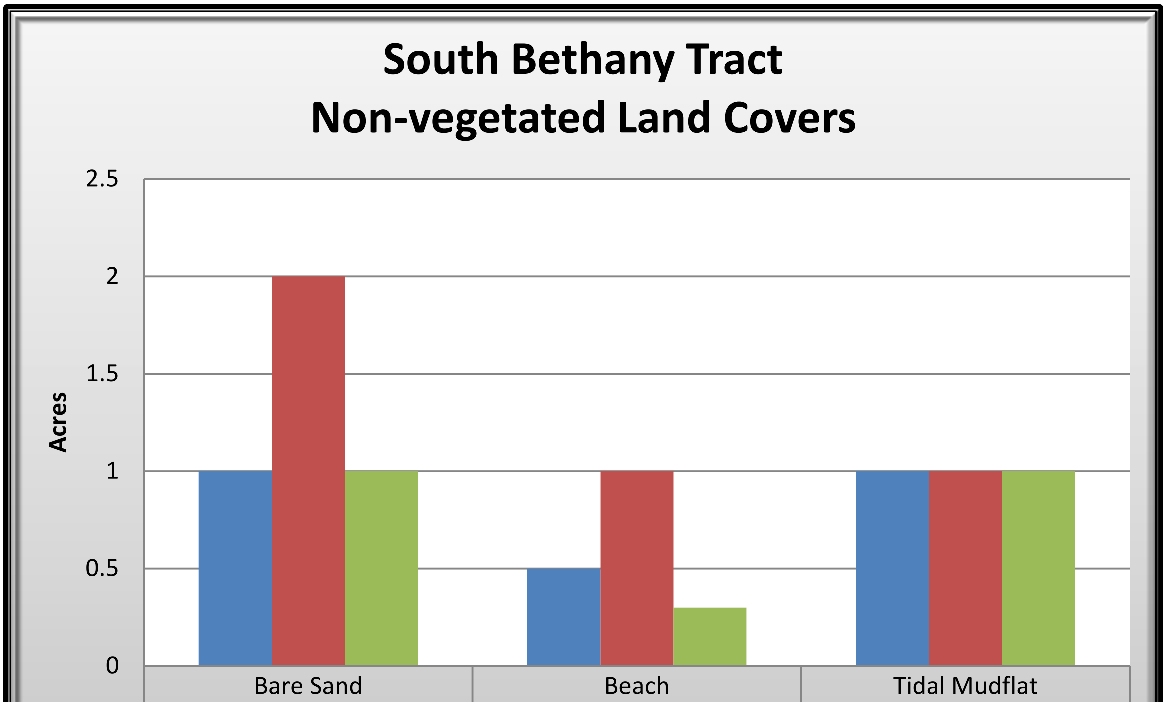
Most of the South Bethany Tract is inundated with 0.5 m of sea level rise, with an additional 14 acres being flooded with 0.5 m more rise. At 1.5 m this tract is completely flooded in its current extent.

Table 4-4.13. Projected acres of the South Bethany Tract Anthropogenic Communities/Land Covers Inundated by Sea Level Rise

Rise	Acres
0.5 m	7 acres
1 m	9 acres
1.5 m	9 acres

Natural Capital

Anthropogenic Communities/Land Covers do not have any capital value in the South Bethany Tract.



	Bare Sand	Beach	Tidal Mudflat
1937	1	0.5	1
2002	2	1	1
2007	1	0.3	1

Figure 4-4.11. South Bethany Tract Non-vegetated Land Covers (1937, 2002, and 2007)

South Bethany Tract Non-vegetated Land Covers (Figure 4-4.11): All of these land covers are ephemeral and vary over time. Due to the location of the tract, bare sand is brought over from the ocean beach and is deposited on dunes. Beach area on the Little Assawoman Bay side has increased and is likely being driven by erosion. Tidal mudflats come and go from marsh die off and sea level rise.

DNREC Sea Level Rise Analysis (Table 4-4.14)

All of the existing Non-vegetated Land Covers in the South Bethany Tract will be inundated with 0.5 m of sea level rise.

Table 4-4.14. Projected acres of the South Bethany Tract Non-vegetated Land Covers Inundated by Sea Level Rise

Rise	Acres
0.5 m	2 acres
1 m	2 acres
1.5 m	2 acres

Natural Capital (Table 4-4.15)

Non-vegetated Land Covers have remained at the same capitalization during the study period.

Table 4-4.15. Natural Capital of Piney Point Tract Non-vegetated Land Covers	
Year	**Natural Capital (in 2012 dollars)**
1937	$6,271/year
2002	$6,271/year
2007	$6,271/year

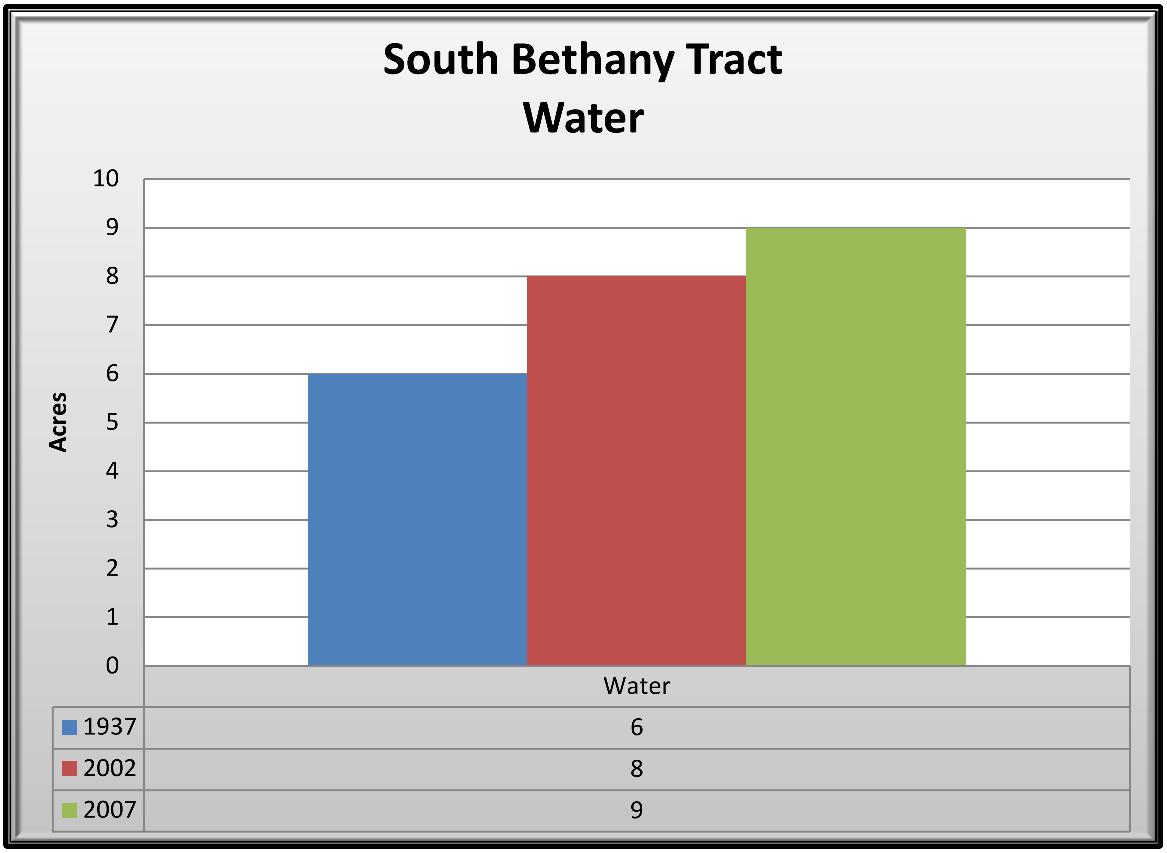


Figure 4-4.12. South Bethany Tract Water Coverage (1937, 2002, and 2007)

South Bethany Tract Water Coverage (Figure 4-4.12): Water coverage, unlike the other tracts, has decreased. Sand can rebuild land areas resulting in more or less water in a fits and starts pattern. Sea level rise may still be happening but the availability of sand loose helps the area rebuild from the rising water.

Natural Capital (Table 4-4.16)

Natural capital of water, like the other tracts, has been going up in the South Bethany Tract.

Table 4-4.16. Natural Capital of Piney Point Tract Water	
Year	**Natural Capital (in 2012 dollars)**
1937	$85,997/year
2002	$114,663/year
2007	$128,996/year

Chapter 5: Descriptions and Analysis of the Vegetation Communities

Twenty-seven vegetation communities and ten land covers were noted in the survey (Figures 8-19). Below are the descriptions of the vegetation communities. The National Vegetation Classification (NVC) Association number is given with the vegetation community and their approximate acreage in the project area. Names of communities correspond with the common names as given in the NVC and the Guide to Delaware Vegetation Communities.

An analysis of the change over time is provided for those communities that are considered to be affected most immediately by sea level rise. For Assawoman Wildlife Area these include the Brackish Tidal Creek Shrubland, Irregularly Flooded Eastern Tidal Salt Shrub, Loblolly Pine/Wax-myrtle/Salt Meadow Cordgrass Woodland, Needlerush High Marsh, North Atlantic Low Salt Marsh, North Atlantic High Salt Marsh, Successional Maritime Forest, and Water coverage.

The vegetation communities include:

1. Brackish Tidal Creek Shrubland (CEGL006846)—9 acres
2. Central Coast Beach Heather Dune Shrubland (CEGL003950)—8 acres
3. Chesapeake Bay Non-riverine Wet Hardwood Forest (CEGL004644)—171 acres
4. Coastal Loblolly Pine Wetland Forest (CEGL006137)—809 acres
5. Creeping Rush-Boltonia Coastal Plain Pond (CEGL006610)—3 acres
6. Cultivated Lawn (CEGL008462)—26 acres
7. Early to Mid-Successional Loblolly Pine Forest (CEGL006011)—72 acres
8. Eastern Reed Marsh (CEGL004141)—141 acres
9. Irregularly Flooded Eastern Tidal Salt Shrub (CEGL003921)—42 acres
10. Loblolly Pine Dune Woodland (CEGL006052)—21 acres
11. Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland (CEGL006849)—5 acres
12. Maritime Red Cedar Woodland (CEGL006212)—1 acre
13. Mid-Atlantic Coastal Maritime Forest (CEGL006040)—12 acres
14. Needlerush High Marsh (CEGL004186)—20 acres
15. North Atlantic High Salt Marsh (CEGL006006)—89 acres
16. North Atlantic Low Salt Marsh (CEGL004192)—518 acres
17. Northeastern Buttonbush Shrub Swamp (CEGL006069)—0.2 acres
18. Northeastern Modified Successional Forest (CEGL006599)—8 acres
19. Northeastern Old Field (CEGL006107)—73 acres
20. Northeastern Successional Shrubland (CEGL006451)—6 acres
21. Red Maple-Sweetgum Swamp (CEGL006110)—65 acres
22. Reed Tidal Marsh (CEGL004187)—73 acres
23. Salt Panne (CEGL004308)—1 acre
24. Southern Red Oak/Heath Forest (CEGL006269)—59 acres
25. Successional Maritime Forest (CEGL006154)—50 acres
26. Successional Sweetgum Forest (CEGL007216)—5 acres
27. Upland Switchgrass Vegetation (CEGL006616)—20 acres

***Brackish Tidal Creek Shrubland* [8 acres (Figures 5.1 and 5.2, Tables 5.1-5.3)] GNR S3**

DEWAP: Tidal High Marsh Habitat
NHC: Northern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh

Description

This shrubland community is dominated by wax-myrtle (*Morella cerifera*) with a scattering of salt meadow hay (*Spartina patens*) and eastern reed grass (*Phragmites australis*). In Assawoman Wildlife Area it is often found at the edges of brackish marshes, primarily in the Miller Neck Tract but with a small amount in the South Bethany Tract.

Analysis of Condition at Assawoman Wildlife Area

This shrubland community is located on high points in the marsh and is subject to inundation during storm tides. It was not present in the 1937 imagery but had arisen by 2002. Both the Miller Neck and South Bethany tracts have a lower topography overall allowing these communities to migrate easier. The community may have come from marsh regressing into the neighboring uplands changing the conditions nearby and making conducive to this community. The long term survival of this community is poor, but it is still uncertain as to whether this community will move upland with sea level rise. In the recent period the acreage has been stable with no gains or losses.

The overall condition of this community on the ground cannot be judged since it was not directly observed in the field and was determined from aerial imagery.

Table 5.2. Brackish Tidal Creek Shrubland has migrated into X or remained since 1937

X	Acreage
Early to Mid-Successional Loblolly Pine Forest	6 acres
Irregularly Flooded Eastern Tidal Salt Shrub	2 acres
Mid-Atlantic Coast Backdune Grassland	0.4 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	0.1 acres
North Atlantic Low Salt Marsh	0.1 acres
Other communities/land covers	0.2 acres

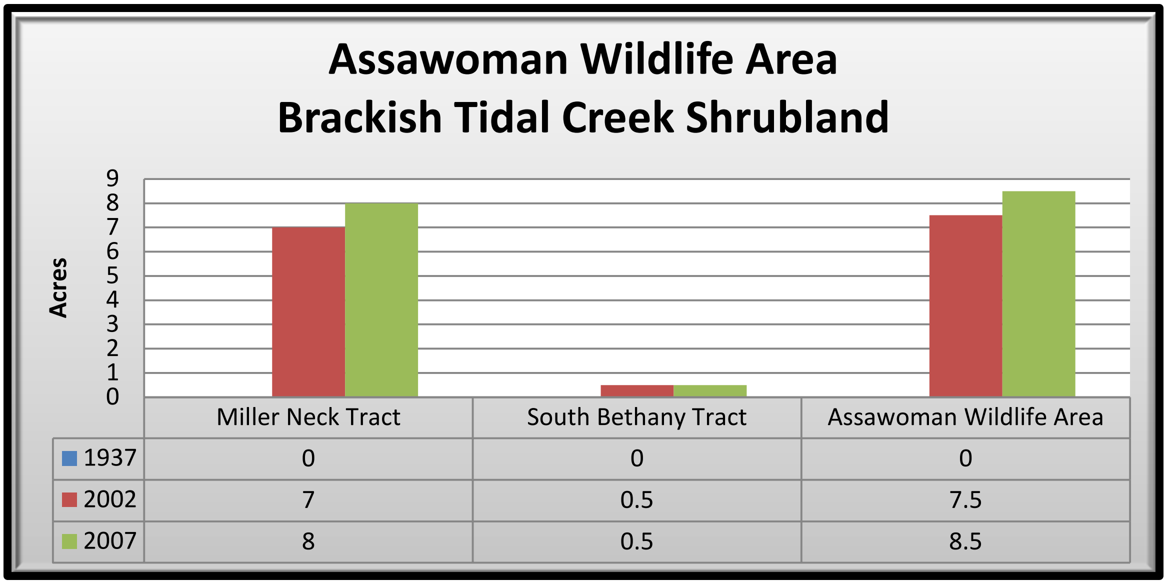


Figure 5.1. Brackish Tidal Creek Shrubland at Assawoman Wildlife Area (1937, 2002, and 2007)

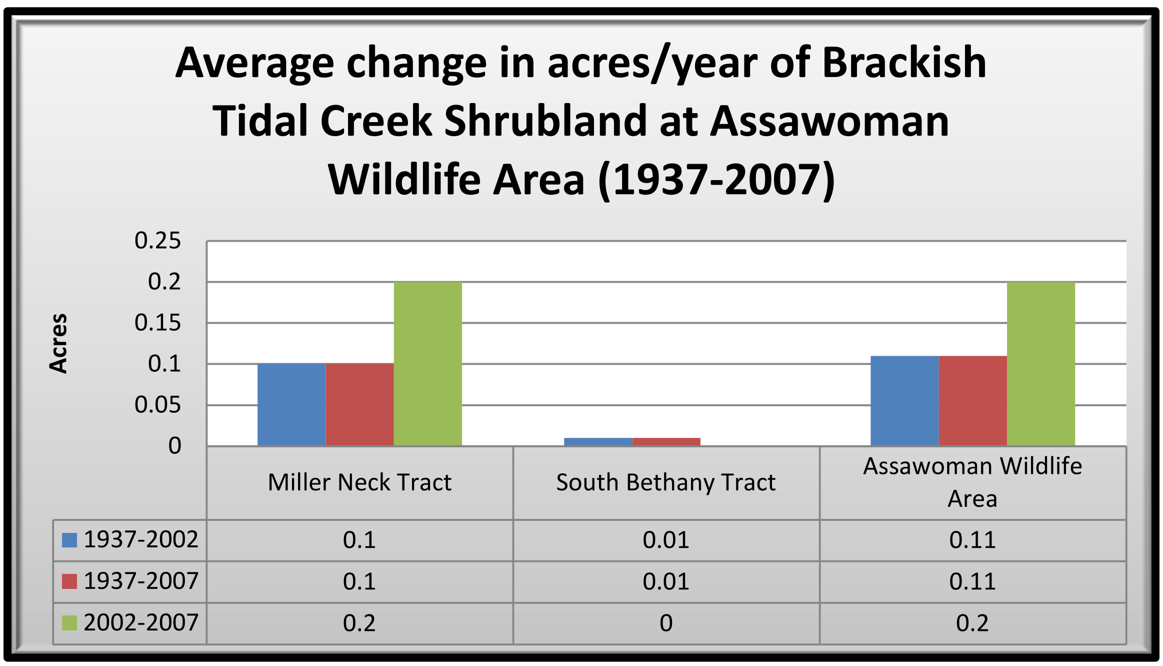


Figure 5.2. Average change in acres/year of Brackish Tidal Creek Shrubland at Assawoman Wildlife Area (1937-2007)

DNREC Sea Level Rise Analysis (Tables 5.1 and 5.2)

Almost all of the acreage of this community will be eliminated at 0.5 m of rise and will be eliminated with 1 m of rise (Table 5.1). This community has migrated into adjacent communities (Table 5.2) such as Early to Mid-Successional Loblolly Pine Forest and Irregularly Flooded Eastern Tidal Salt Shrub and has increased in the short term period so it may colonize new areas as sea level rises.

Table 5.1. Projected acres of Brackish Creek Tidal Shrubland Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	8 acres
1 m	8.5 acres
1.5 m	8.5 acres

Natural Capital (Table 5.3)

This community was not present in 1937 and therefore there is no value. By 2002 gained some capital and has increased since.

Table 5.3. Natural Capital of Brackish Tidal Creek Shrubland	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year
2002	$47,035/year
2007	$53,306/year

Central Coast Beach Heather Dune Shrubland **[11 acres (Figure 5.3, Tables 5.4-5.7)]**
G2 S2

DEWAP: Beach and Dune Habitat
NHC: North Atlantic Coastal Plain Dune and Swale

Description

This dwarf shrubland is totally dominated by beach heather (*Hudsonia tomentosa*). It is often found on patches of bare sand within reach of salt spray from the ocean or bay in the dunes of the South Bethany Tract.

Analysis of Condition at Assawoman Wildlife Area

This shrub community was present in small amount in 1937. Since the 1930's it has been steadily increasing on patches of bare sand and open areas in the South Bethany Tract. Most of the occurrences of this community appear to be in good condition but it is hard to judge because of the disturbance inherently present in the community. However, going by the acreage increase of the community, it appears to be thriving.

None of the Central Coast Beach Heather Dune Shrubland present in 1937 still existed in 2007. It had become 0.1 acres of Loblolly Pine Dune Woodland, 0.04 acres of Impervious Surface, 0.04 acres of bare sand, and 0.03 acres of cultivated lawn (Table 5.4). Since 1937, Central Coast Beach Heather Shrubland has increased its acreage by converting 5 acres of Irregularly Flooded Eastern Tidal Salt Shrub, 2 acres of Mid-Atlantic Coast Backdune Grassland, 2 acres of North Atlantic Low Salt Marsh, and 1 acre each of Overwash Dune Grassland, and Loblolly Pine Dune Woodland (Table 5.5).

Table 5.4. What was once Central Coast Beach Heather Dune Shrubland in 1937 has become X or remained in 2007

X	Acreage
Loblolly Pine Dune Woodland	0.1 acres
Impervious Surface	0.04 acres
Bare Sand	0.04 acres
Cultivated Lawn	0.03 acres

Table 5.5. Central Coast Beach Heather Dune Shrubland has migrated into X or remained since 1937	
X	**Acreage**
Irregularly Flooded Eastern Tidal Salt Shrub	5 acres
Mid-Atlantic Coast Backdune Grassland	2 acres
North Atlantic Low Salt Marsh	2 acres
Overwash Dune Grassland	1 acre
Loblolly Pine Dune Woodland	1 acre
Other communities/land covers	0.3 acres

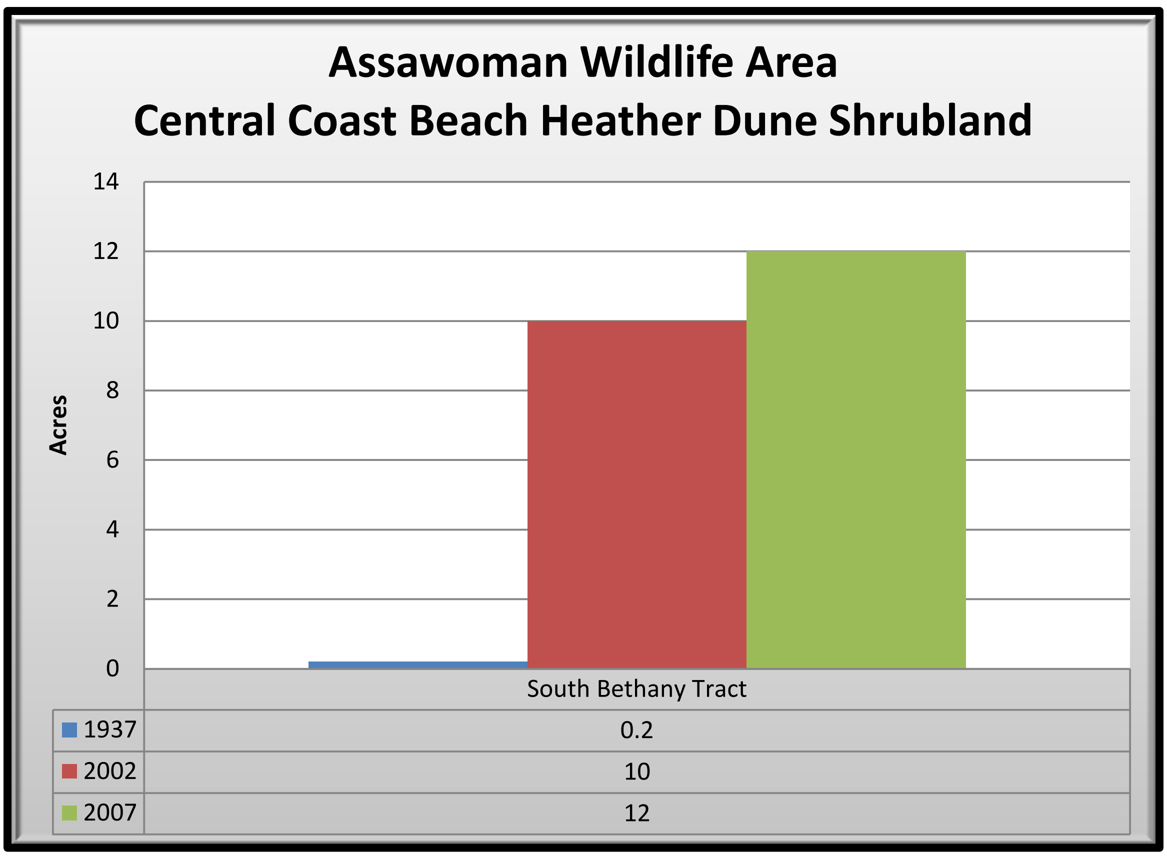


Figure 5.3. Central Coast Beach Heather Dune Shrubland at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.6)

Central Coast Beach Heather Dune Shrubland is often present in the ocean dunes and other places where there is mostly sand in the near coastal environment. About a fourth of the current community acreage will be impacted with 0.5 m of sea level rise. With 1 m of rise the community in its current form will be virtually eliminated and fully eliminated at 1.5 m of rise (Table 4.4).

Given that very little of this community has converted to other communities (Table 5.5), the migration of this community into other communities (Table 5.6), and the recent acreage increase (Figure 5.3), this community may persist even though the current acreage is projected to eliminated.

Table 5.6. Projected acres of Central Coast Beach Heather Shrubland Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	3 acres
1 m	10 acres
1.5 m	12 acres

Natural Capital (Table 5.7)

This community was not abundant in 1937 and therefore did not have a high capitalization. In 2002 this community was more common and with increases in acreage the capitalization is higher.

Table 5.7. Natural Capital of Central Coast Beach Heather Dune Shrubland	
Year	**Natural Capital (in 2012 dollars)**
1937	$29/year
2002	$1,311/year
2007	$1,603/year

***Chesapeake Bay Non-riverine Wet Hardwood Forest* [171 acres (Figures 5.4-5.5, Tables 5.8-5.11)]   G2   S5**

DEWAP: Coastal Plain Floodplain and Riparian Swamp Habitat
NHC: Central Appalachian River Floodplain

<u>*Description*</u>

This forested community is located to the south of Double Bridge Road in the Muddy Neck Tract and in various places in both the Miller Neck and Piney Neck Tracts. It is composed of a mixture of oaks (*Quercus* sp.) and few pines (*Pinus* sp.). Swamp white oak (*Quercus bicolor*), swamp chestnut oak (*Quercus michauxii*), willow oak (*Quercus phellos*), and southern red oak (*Quercus falcata*) are some of the oaks and are joined by red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and black gum (*Nyssa sylvatica*). The understory is composed of smaller members of the canopy plus American holly (*Ilex opaca*). Highbush blueberry (*Vaccinium corymbosum*) and common greenbrier (*Smilax rotundifolia*) compose the shrub and vine layer. Ground pine (*Lycopodium obscurum*) was the only herb noted.

Figure 5.4. Chesapeake Bay Non-riverine Wet Hardwood Forest

<u>*Analysis of Condition at Assawoman Wildlife Area*</u>

This forested community is located in the three landward tracts (Miller Neck, Muddy Neck, and Piney Point Tract). Its amount of acreage has gradually declined since 1937 with some of the decline continuing in the recent period (2002-2007) (Figure 5.5). In general the examples present at Assawoman Wildlife Area have thick understories showing a Mid-Successional age. Most stands are about 50-70 years of age with some a little younger.

In 2007, 78 acres of the original 1937 acreage was still present. The rest of the acreage has become 76 acres of Coastal Loblolly Pine Wetland Forest, 8 acres of Early to Mid-Successional Loblolly Pine Forest, 7 acres of Irregularly Flooded Eastern Tidal Salt Shrub, and 4 acres of Agricultural Field (Table 5.8). The progression of the Irregularly Flooded Eastern Tidal Salt Shrub shows that the brackish effects of the marsh are reaching somewhat into this community and closeness of it to the marsh.

This community has also migrated into other areas. Since 1937 it has converted 37 acres of Coastal Loblolly Pine Wetland Forest; 36 acres of Northeastern Successional Shrubland and 11 acres of Early to Mid-Successional Loblolly Pine Forest, 7 acres of agricultural field have matured to this community (Table 5.9).

Table 5.8. What was once Chesapeake Bay Non-riverine Wet Hardwood Forest in 1937 has become X or remained in 2007	
X	**Acreage**
Chesapeake Bay Non-riverine Wet Hardwood Forest	78 acres
Coastal Loblolly Pine Wetland Forest	76 acres
Early to Mid-Successional Loblolly Pine Forest	8 acres
Irregularly Flooded Eastern Tidal Salt Shrub	7 acres
Agricultural Field	4 acres
Other communities/land covers	24 acres

Table 5.9. Chesapeake Bay Non-riverine Wet Hardwood Forest has migrated into X or remained since 1937	
X	**Acreage**
Chesapeake Bay Non-riverine Wet Hardwood Forest	78 acres
Coastal Loblolly Pine Wetland Forest	37 acres
Northeastern Successional Shrubland	36 acres
Early to Mid-Successional Loblolly Pine Forest	11 acres
Agricultural Field	7 acres
Other communities/land covers	3 acres

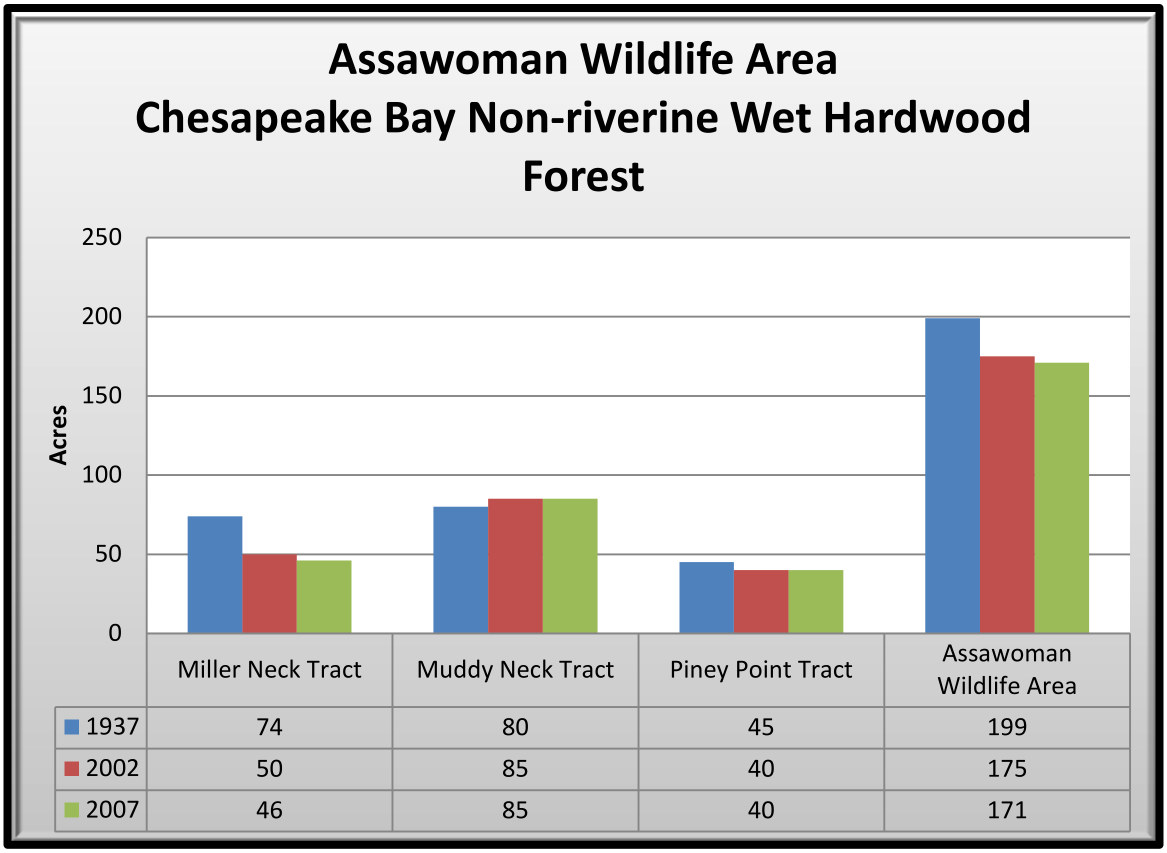


Figure 5.5. Chesapeake Bay Non-riverine Wet Hardwood Forest at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.10)

This community would lose 34 acres of current acreage with 0.5 m of sea level rise, an additional 13 acres with 1 m of rise, and 71 acres with 1.5 m of sea level rise. Even with 1.5 m of sea level rise this community will still be present in some amount.

Table 5.10. Projected acres of Chesapeake Bay Non-riverine Wet Hardwood Forest Impacted by Sea Level Rise

Rise	Acres
0.5 m	34 acres
1 m	47 acres
1.5 m	71 acres

Natural Capital (Table 5.11)

The decline in acreage of this community has also reduced the natural capital of this community with a loss of $344,162 from 1937 to 2007 and 49,166 from 2002 to 2007.

Table 5.11. Natural Capital of Chesapeake Bay Non-riverine Wet Hardwood Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$2,446,009/year
2002	$2,151,013/year
2007	$2,101,847/year

Coastal Loblolly Pine Wetland Forest **[810 acres (Figures 5.6-5.7, Tables 5.12-5.15)] G3 S3**

DEWAP: Coastal Plain Floodplain and Riparian Swamp Habitat
NHC: Northern Atlantic Coastal Plain Maritime Forest

Description

This is the most common forested community in Assawoman Wildlife Area. Loblolly pine (*Pinus taeda*) dominates the canopy and is associated by a few red maple (*Acer rubrum*). Sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), American holly (*Ilex opaca*), wild black cherry (*Prunus serotina*), southern red oak (*Quercus falcata*), black gum (*Nyssa sylvatica*) compose the understory along with a few sassafras (*Sassafras albidum*), flowering dogwood (*Cornus florida*), and sweetbay (*Magnolia virginiana*). Shrubs and vines include blackberry (*Rubus* sp.), common greenbrier (*Smilax rotundifolia*), highbush blueberry (*Vaccinium corymbosum*), and Japanese honeysuckle (*Lonicera japonica*). Herbs are few and include ground pine (*Lycopodium obscurum*), shaved sedge (*Carex tonsa*), putty-root orchid (*Aplectrum hyemale*), and partridge-berry (*Mitchella repens*).

Figure 5.6. Coastal Loblolly Pine Wetland Forest (Miller Neck)

Analysis of Condition at Assawoman Wildlife Area

This community spreads over a wide area and in some places fronts the salt shrub and marsh communities. This community is has shown a marked increase since 1937 as it has succeeded from Northeastern Old Field and Early to Mid-Successional Loblolly Pine that was present earlier. Some acreage was lost although at the Piney Point Tract likely due to conversion to Successional Maritime Forest, Irregularly Flooded Eastern Tidal Salt Shrub, and Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland. Observations in the field noted that this community is suffering the effects of increased salinity due to sea level rise and recent storms. This community is projected to remain stable for the short-term and may decline slightly in the long-term due to conversion to more brackish communities similar to what may be happening at the Piney Point Tract.

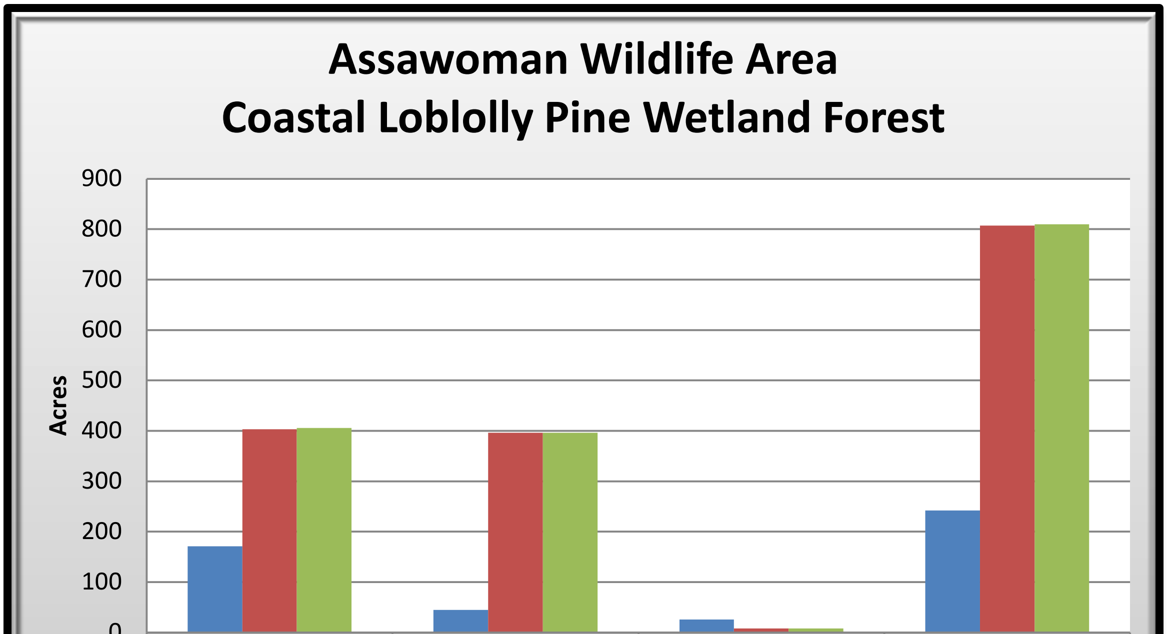
In 2007, 136 of the original 242 acres in 1937 still existed. The rest of the acreage became 37 acres of Chesapeake Bay Non-riverine Wet Hardwood Forest, 14 acres of Eastern Reed Marsh, 14 acres of Red Maple-Sweetgum Swamp, and 11 acres of North Atlantic Low Salt

Marsh (Table 5.12). The conversion to salt marsh reflects observations seen on the ground at the edges of this community where brackish effects have made their way into this community.

Since 1937, 343 acres of Early to Mid-Successional Loblolly Pine Forest, 103 acres of clear-cut, and 72 acres of agricultural field have matured to this community (Table 5.13). An additional 76 acres of Chesapeake Bay Non-riverine Wet Hardwood Forest have converted to this community. Most of the examples of this community are of young to mid-successional age and some of the younger ones have a thick understory. About a fourth of this community is older and is located on the Miller Neck Tract primarily. This older community may be about 80-100+ years old.

Table 5.12. What was once Coastal Loblolly Pine Wetland Forest in 1937 has become X or remained in 2007	
X	**Acreage**
Coastal Loblolly Pine Wetland Forest	136 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	37 acres
Eastern Reed Marsh	14 acres
Red Maple-Sweetgum Swamp	14 acres
North Atlantic Low Salt Marsh	11 acres
Other communities/land covers	31 acres

Table 5.13. Coastal Loblolly Pine Wetland Forest has migrated into X or remained since 1937	
X	**Acreage**
Early to Mid-Successional Loblolly Pine Forest	343 acres
Coastal Loblolly Pine Wetland Forest	136 acres
Clear-cut	103 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	76 acres
Agricultural Field	72 acres
Other communities/land covers	80 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	Assawoman Wildlife Area
1937	171	45	26	242
2002	403	396	8	807
2007	406	396	8	810

Figure 5.7. Coastal Loblolly Pine Wetland Forest at Asswoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.14)

Coastal Loblolly Pine Wetland Forest is vulnerable to sea level rise due to its low elevation and it being adjacent to the marsh. A little more than a third of the current acreage would be impacted with 0.5 m rise in sea level. More than half of the current acreage would be inundated with a 1 m rise and a 1.5 m rise would eliminate more than 2/3 of the current acreage. Since this is forest community, it tends to migrate slowly, and mostly through the maturation of younger communities such as Early to Mid-Successional Loblolly Pine Forest. Given sea level rise and the lack of more communities to mature to it, I would project that this community will lose quite a bit of acreage in the future and not regain them.

Table 5.14. Projected acres of Chesapeake Bay Non-riverine Wet Hardwood Forest Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	317 acres
1 m	454 acres
1.5 m	616 acres

Natural Capital (Table 5.15)

From a natural capital standpoint, Coastal Loblolly Pine Wetland Forest is the most valuable community in the wildlife area. The amount has been going up as more forest matures to this type. Eventually though it may decline as sea level rise bring more brackish water into the forest.

Table 5.15. Natural Capital of Coastal Loblolly Pine Wetland Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$2,974,543/year
2002	$9,919,241/year
2007	$9,956,115/year

***Creeping Rush-Boltonia Coastal Plain Pond* [3 acres (Figures 5.8-5.9, Tables 5.16-5.19)] GNR S1.1**

DEWAP: Coastal Plain Seasonal Pond Habitat
NHC: Northern Atlantic Coastal Plain Pond

<u>*Description*</u>

Assawoman Wildlife Area holds the only locations for this Coastal Plain Pond community in Delaware and is one of a handful of locations in the world for Hirst's panic grass (*Dichanthelium hirstii*). Like other Coastal Plain ponds this community fills with water in the late fall and winter and then becomes dry in the summer. Two variants of this community are located in Assawoman Wildlife Area. One is on Miller Neck and called Assawoman Pond and is the location of the Hirst's panic grass. Common species in Assawoman Pond include aster-like boltonia (*Boltonia asteroides*), one-flowered bog button (*Sclerolepis uniflora*), creeping rush (*Juncus repens*), bushy seedbox (*Ludwigia alterniflora*), Eaton's witchgrass (*Panicum spretum*), tall beakrush (*Rhynchospora macrostachya*), small's yellow eyed grass (*Xyris smalliana*), and stinking camphorweed (*Pluchea foetida*).

Figure 5.8. Creeping Rush Boltonia Coastal Plain Pond (Miller Neck)

The other variant is located on Muddy Neck and is called Muddy Neck Pond. Common species in Muddy Neck Pond include Walter's paspalum (*Paspalum dissectum*), Coastal Plain panicgrass (*Dichanthelium acuminatum* var. *lonigiligulatum*), creeping rush (*Juncus repens*), dog-fennel thoroughwort (*Eupatorium capillifolium*) that are associated by Virginia broom sedge (*Andropogon virginicus*), tall beakrush (*Rhynchospora macrostachya*), slender fimbry (*Fimbristylis autumnalis*), Canada rush (*Juncus canadensis*), Virginia meadowbeauty (*Rhexia virginica*), and clustered bluets (*Oldenlandia uniflora*), marsh seedbox (*Ludwigia palustris*), and combleaf mermaidweed (*Proserpinaca pectinata*).

These ponds have decreased dramatically since 1937 and the two examples that still remain are separated from the bay and therefore have not been captured by sea level rise yet. These two examples are at least 70 years old and are likely hundreds of years old.

Analysis of Condition at Assawoman Wildlife Area

Historically there were other examples located in the Miller Neck Tract and the Muddy Neck Tract. It is thought and appears in examination of aerial imagery that the lost examples of this community succumbed to intrusion of Reed Tidal Marsh or North Atlantic Low Salt Marsh as the sea level has risen or as exposure to higher salinities increased. The current examples are protected on all sides by topographic highs and are not in immediate danger of being intruded upon. In the long term this community may become wetter due to the water table rising though. It is unknown what the effects of this increased water may be on the community. Changes in moisture may exacerbate this condition.

In 2007, three acres of the original 14 acres in 1937 still existed. The rest of the acreage was converted into 8 acres of impoundment, 6 acres of water, 4 acres of Eastern Reed Marsh, and 2 acres of Coastal Loblolly Pine Wetland Forest (Table 5.16).

This community has not migrated since 1937 and only has three acres left in the wildlife area (Table 5.17).

Table 5.16. What was once Creeping Rush-Boltonia Coastal Plain Pond in 1937 has become X or remained in 2007	
X	**Acreage**
Impoundment	8 acres
Water	6 acres
Eastern Reed Marsh	4 acres
Creeping Rush Boltonia Coastal Plain Pond	3 acres
Coastal Loblolly Pine Wetland Forest	2 acres
Other communities/land covers	3 acres

Table 5.17. Creeping Rush-Boltonia Coastal Plain Pond has migrated into X or remained since 1937	
X	**Acreage**
Creeping Rush-Boltonia Coastal Plain Pond	3 acres

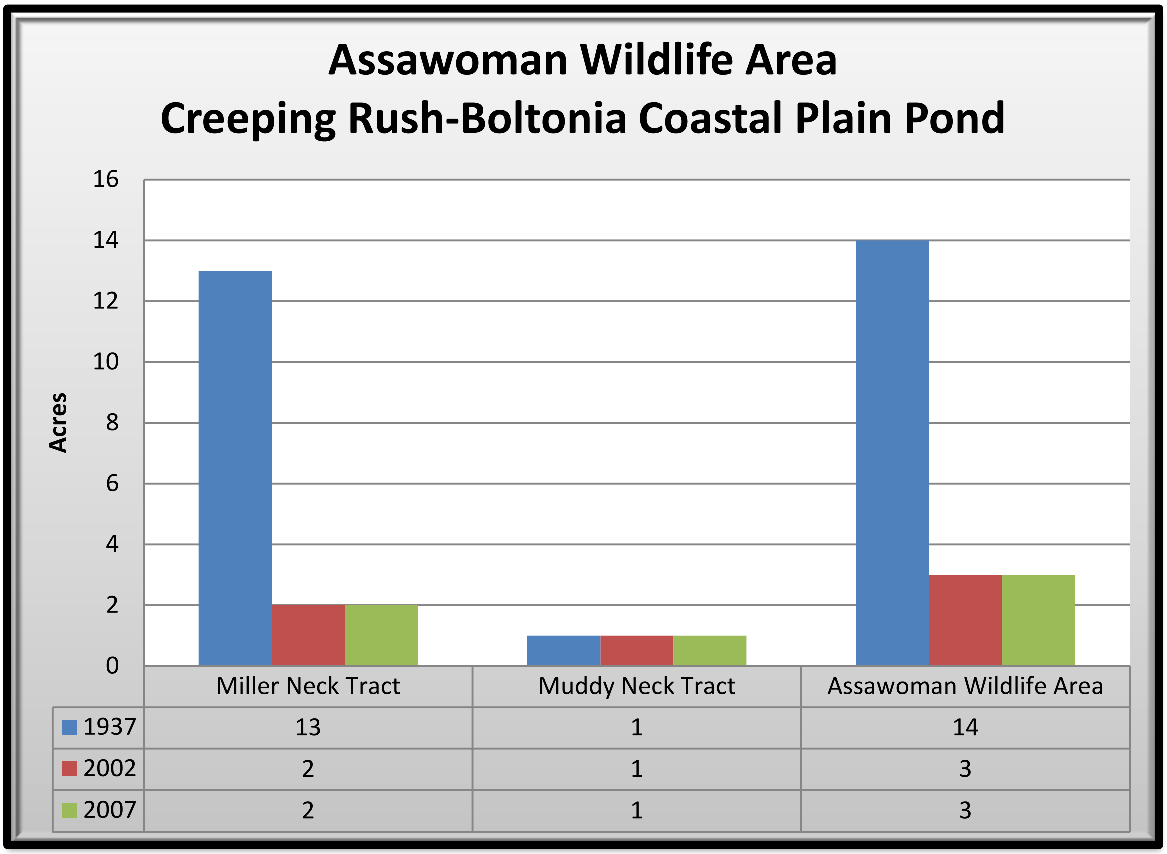


Figure 5.9. Creeping Rush-Boltonia Coastal Plain Pond at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.18)

Creeping Rush Boltonia Coastal Plain Pond communities would not be affected by 0.5 m of sea level rise at least not directly. One meter of rise would impact the community located on Muddy Neck and 1.5 m of rise would eliminate the community. It is unknown whether the Hirst's panic grass can be saved or placed in another habitat to continue its survival in Delaware. These ponds also include a lot of other plants unique to Delaware which would be lost with the current sea level rise scenarios.

Table 5.18. Projected acres of Creeping Rush Boltonia Coastal Plain Pond Impacted by Sea Level Rise

Rise	Acres
0.5 m	0 acres
1 m	1 acre
1.5 m	3 acres

Natural Capital (Table 5.19)

These coastal plain ponds have value as wetlands and help filter nutrients from the adjacent uplands. The reduction in the wetlands has resulted in a loss of the capital contributed by these communities. Of course, there is value is value in the rare species that are located in these habitats which the model does not account for. It would be hard to put a value on these species.

Table 5.19. Natural Capital of Creeping Rush Boltonia Coastal Plain Pond	
Year	**Natural Capital (in 2012 dollars)**
1937	$129,940/year
2002	$27,844/year
2007	$27,844/year

***Cultivated Lawn* [26 acres (Figure 5.10, Tables 5.20-5.22)]   GNA   SNA**

DEWAP: No Equivalent Classification
NHC: Semi-natural/Altered Vegetation and Conifer Plantations

Description

Cultivated lawn is located on residential areas and roadside on the edges of the wildlife area. These areas are characterized by planted ornamental grasses such tall fescue (*Festuca arundinacea*) that are mowed more than once per year and plantings of other ornamental plants.

Analysis of Condition at Assawoman Wildlife Area

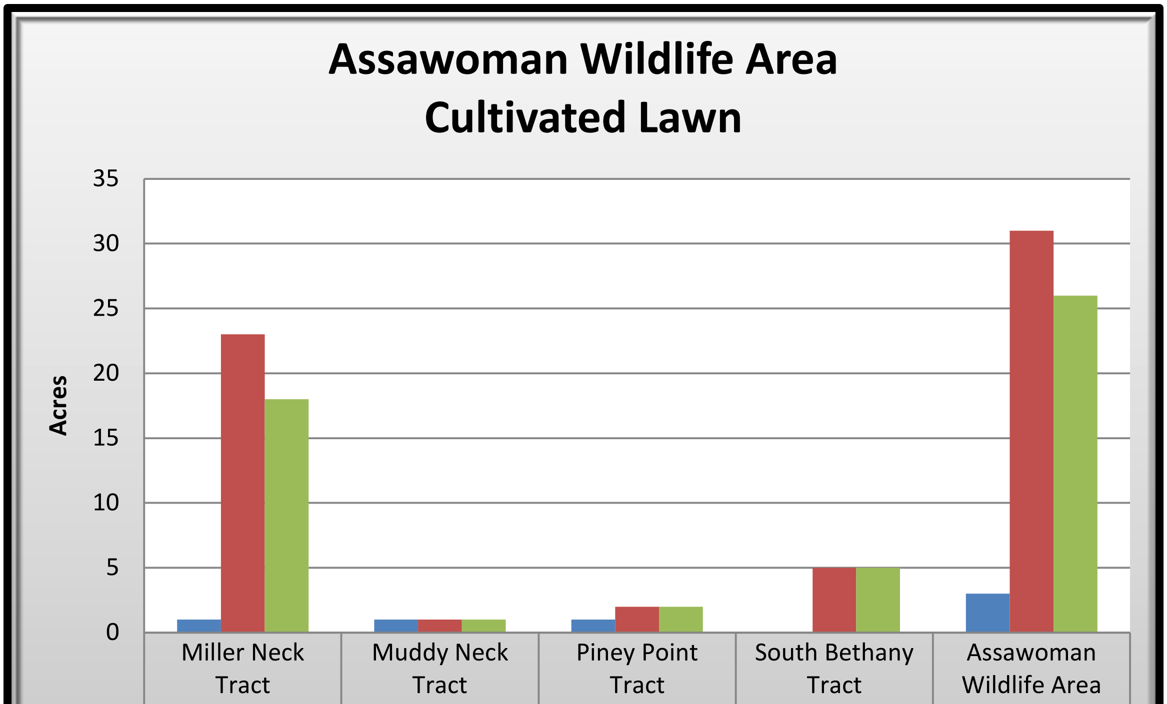
Cultivated lawn often moves in lock-step with the amount of impervious surface from roads, buildings, and parking lots. In 2007, only 0.4 acres of the original 3 acres of cultivated lawn from 1937 still existed (Table 5.20). The rest had become an acre each of Northeastern Old Field and Agricultural Field, 0.3 acres of Beach and 0.2 acres of Red Maple-Sweetgum Swamp.

Since 1937, cultivated lawns have been developed in 9 acres of Northeastern Old Field, 3 acres of North Atlantic Low Salt Marsh, 2 acres of Agricultural Field, 2 acres of Early to Mid-Successional Loblolly Pine Forest, and 2 acres of North Atlantic High Salt Marsh (Table 5.21). Some of this community was converted to impervious surface from 2002 to 2007 resulting in a loss of acreage.

Since this community is not a key wildlife habitat and has negligible value for wildlife it was not rated for quality.

Table 5.20. What was once Cultivated Lawn in 1937 has become X or remained in 2007	
X	**Acreage**
Northeastern Old Field	1 acre
Agricultural Field	1 acre
Cultivated Lawn	0.4 acres
Beach	0.3 acres
Red Maple-Sweetgum Swamp	0.2 acres
Other communities/land covers	1 acre

Table 5.21. Cultivated Lawn has migrated into X or remained since 1937	
X	**Acreage**
Northeastern Old Field	9 acres
North Atlantic Low Salt Marsh	3 acres
Agricultural Field	2 acres
Early to Mid-Successional Loblolly Pine Forest	2 acres
North Atlantic High Salt Marsh	2 acres
Other communities/land covers	7 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937	1	1	1	0	3
2002	23	1	2	5	31
2007	18	1	2	5	26

Figure 5.10. Cultivated Lawn at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.22)

In the sea level rise scenarios, 10 acres of cultivated lawn would be lost with 0.5 m of rise. At 1 m 14 acres would be lost and 15 acres with 1.5 m of rise.

Table 5.22. Projected acres of Cultivated Lawn Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	10 acres
1 m	14 acres
1.5 m	15 acres

Natural Capital

This habitat does not have any natural capital value.

***Early to Mid-Successional Loblolly Pine Forest* [71 acres (Figures 5.11-5.12, Tables 5.23-5.26)]**
GNA SNA

DEWAP: Early Successional Upland Habitat
NHC: Semi-natural/Altered Vegetation and Conifer Plantations

Description

Early to Mid-Successional Loblolly Pine Forest is located in the three landward tracts. Loblolly Pine (*Pinus taeda*) composes an overstory that overtops an understory of red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and American holly (*Ilex opaca*). The shrub and vine layer is dense in places and composed of common greenbrier (*Smilax rotundifolia*) and highbush blueberry (*Vaccinium corymbosum*). The herbaceous layer is non-existent, which is likely due to the high acidity of the needles from the pine. Most of the stands in Assawoman Wildlife Area appeared to be about 40-60 years old and showed good quality with an understory developing and few exotic invasive plants present.

Figure 5.11. Early to Mid-Successional Loblolly Pine Forest

Analysis of Condition at Assawoman Wildlife Area

This successional forested community came about with the abandonment of agriculture in the wildlife area back in the 1930's and 1940's. A lot of the Coastal Loblolly Pine Wetland Forest and Chesapeake Bay Non-riverine Wet Hardwood Forest, and Red Maple-Sweetgum Swamp in the wildlife area came from this community. This community is gradually decreasing as it matures.

In 2007, 10 acres of the original 468 acres of 1937 forest still remained. The rest had become 343 acres of Coastal Loblolly Pine Wetland Forest, 20 acres of agricultural field, 18 acres of Red Maple-Sweetgum Swamp, 13 acres of Eastern Reed Marsh, and 10 acres of Chesapeake Bay Non-riverine Wet Hardwood Forest (Table 5.23).

Since 1937, Early to Mid-Successional has populated 43 acres of abandoned agricultural field, 9 acres of Chesapeake Bay Non-riverine Wet Hardwood Forest, 5 acres of Northeastern Old Field, and 4 acres of Northeastern Successional Shrubland (Table 5.24).

Table 5.23. What was once Early to Mid-Successional Loblolly Pine Forest in 1937 has become X or remained in 2007	
X	**Acreage**
Coastal Loblolly Pine Wetland Forest	343 acres
Agricultural Field	20 acres
Red Maple-Sweetgum Swamp	18 acres
Eastern Reed Marsh	13 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	10 acres
Other communities/land covers	61 acres

Table 5.24. Early to Mid-Successional Loblolly Pine Forest has migrated into X or remained since 1937	
X	**Acreage**
Agricultural Field	43 acres
Early to Mid-Successional Loblolly Pine Forest	10 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	9 acres
Northeastern Old Field	5 acres
Northeastern Successional Shrubland	4 acres
Other communities/land covers	1 acre

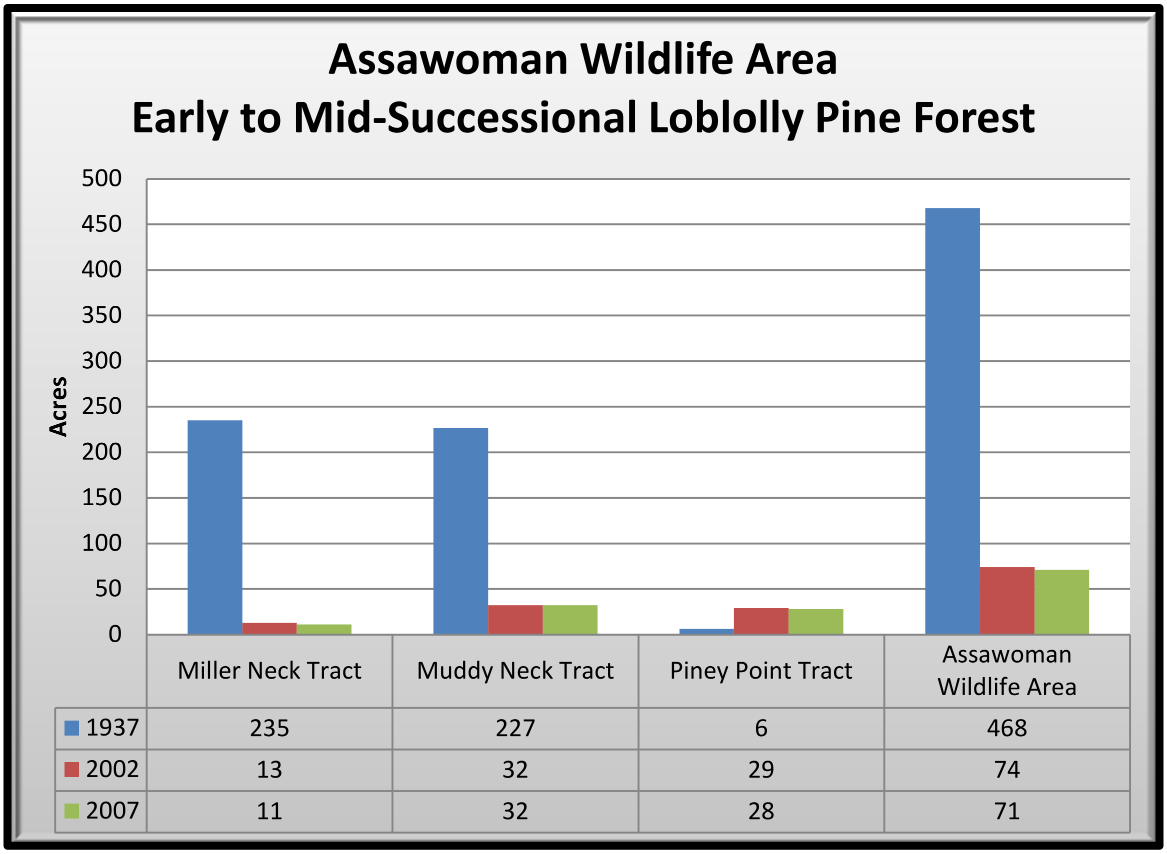


Figure 5.12. Early to Mid-Successional Loblolly Pine Forest at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.25)

Most of the impacts this community occur at 1 m of rise and above. 0.5 m of rise would inundate 11 acres of Early to Mid-Successional Loblolly Pine Forest. One meter of rise would inundate 42 acres and 1.5 m, 47 acres. A little less than half of this community would be left but it will likely mature to other communities by the time sea level rise affects it much.

Table 5.25. Projected acres of Early to Mid-Successional Loblolly Pine Forest Impacted by Sea Level Rise

Rise	Acres
0.5 m	11 acres
1 m	42 acres
1.5 m	47 acres

Natural Capital (Table 5.26)

Most of the natural capital of this community was transferred to other more mature communities as it grew.

Table 5.26. Natural Capital of Early to Mid-Successional Loblolly Pine Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$88,648/year
2002	$13,933/year
2007	$13,426/year

***Eastern Reed Marsh* [135 acres (Figures 5.13-5.14, Tables 5.27-5.30)] GNA SNA**

DEWAP: *Phragmites* Marsh
NHC: Semi-natural/Altered Vegetation and Conifer Plantations

Description

Figure 5.13. Eastern Reed Marsh (Zigzag Marsh, Miller Neck)

This community is located around freshwater impoundments in the wildlife area is characterized by a total or near total dominance of eastern reed grass (*Phragmites australis*) in a non-tidal area.

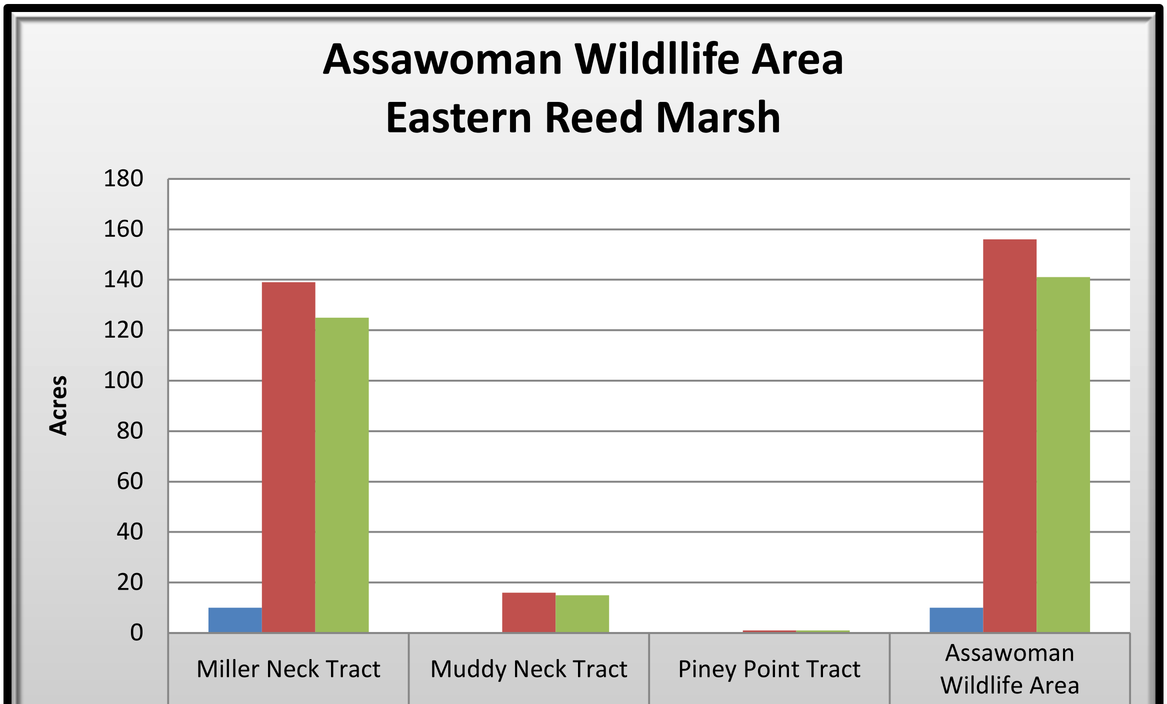
Analysis of Condition at Assawoman Wildlife Area

Eastern reed grass (*Phragmites australis*) was a relative newcomer to the wildlife area at the time of the 1937 imagery. Since this time it has grown to take over disturbed non-tidal wet areas and the edges of impoundments built in the 1950's.

In 2007, 7 acres of the original 10 acres from 1937 still existed. The rest of the acreage became 2 acres of water, 0.4 acres of impoundment, 0.2 acres of Coastal Loblolly Pine Wetland Forest, and 0.1 acres of Farm Pond/Artificial Pond (Table 5.27). Since 1937, this community has increased along with the impoundments and has spread into 42 acres of North Atlantic High Salt Marsh, 35 acres of North Atlantic Low Salt Marsh, 14 acres of Coastal Loblolly Pine Wetland Forest, 13 acres of Early to Mid-Successional Loblolly Pine Forest, and 7 acres of Eastern Reed Marsh (Table 5.28). The acreage from the salt marsh came from the edges of the impoundments which became non-tidal.

Table 5.27. What was once Eastern Reed Marsh in 1937 has become X or remained in 2007	
X	**Acreage**
Eastern Reed Marsh	7 acres
Water	2 acres
Impoundment	0.4 acres
Coastal Loblolly Pine Wetland Forest	0.2 acres
Farm Pond/Artificial Pond	0.1 acres
Other communities/land covers	0.1 acres

Table 5.28. Eastern Reed Marsh has migrated into X or remained since 1937	
X	**Acreage**
North Atlantic High Salt Marsh	42 acres
North Atlantic Low Salt Marsh	35 acres
Coastal Loblolly Pine Wetland Forest	14 acres
Early to Mid-Successional Loblolly Pine Forest	13 acres
Eastern Reed Marsh	7 acres
Other communities/land covers	30 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	Assawoman Wildlife Area
Series1	10	0	0	10
Series2	139	16	1	156
Series3	125	15	1	141

Figure 5.14. Eastern Reed Marsh at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.29)

Effectively all of this community would be inundated with 0.5 m of sea level rise. However, most of the occurrences of this community are on the edges of impoundments which may be built up as sea level rises.

Table 5.29. Projected acres of Eastern Reed Marsh Impacted by Sea Level Rise

Rise	**Acres**
0.5 m	139 acres
1 m	140 acres
1.5 m	140 acres

Natural Capital (Table 5.30)

Even though Eastern Reed Marsh is a community that is composed of an exotic invasive species it is still a wetland which filters nutrients and has natural value. The value of these wetland areas have gone up over time but have decreased recently with the rise of impoundment water.

Table 5.30. Natural Capital of Eastern Reed Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$92,814/year
2002	$1,447,898/year
2007	$1,308,677/year

***Irregularly Flooded Eastern Tidal Salt Shrub* [42 acres (Figures 5.15-5.17, Tables 5.31-5.34)]**
G5 S5

DEWAP: Tidal High Marsh Habitat
NHC: Northern Atlantic Coastal Plain Tidal Salt Marsh

Description

Figure 5.15. Irregularly Flooded Eastern Tidal Salt Shrub (Piney Point)

This shrub community is often located in areas that are slightly higher in elevation than either the North Atlantic High Salt Marsh or the Needlerush High Marsh. Marsh elder (*Iva frutescens*) and salt shrub (*Baccharis halimifolia*) are the dominant species. Other species intermixed amongst the shrubs include salt meadow hay (*Spartina patens*), saltgrass (*Distichlis spicata*), and salt marsh fleabane (*Pluchea odorata*).

Analysis of Condition at Assawoman Wildlife Area

The acreage of Irregularly Flooded Eastern Tidal Salt Shrub are reduced from their 1937 amounts with the exception of the Piney Point Tract which has increased, bucking a trend seen in other places in Delaware. It is unknown why salt shrub is increasing in one tract and not the others but Piney Point is located in another watershed.

In 2007, only 4 acres of the original 70 acres from 1937 remained, showing that this community has moved and changed over the years. The rest of the acreage has been changed to 19 acres each of North Atlantic Low Salt Marsh and Impoundment, 5 acres of Central Coast Beach Heather Dune Shrubland, and 4 acres each of Eastern Reed Marsh and North Atlantic High Salt Marsh (Table 5.31).

Since 1937, Irregularly Flooded Eastern Tidal Salt Shrub has not kept up with its losses, but has still managed to migrate some. It is has migrated into 8 acres of Coastal Loblolly Pine Wetland Forest (which is probably part of the dead pines seen around the wildlife area), 7 acres of Chesapeake Bay Non-riverine Wet Hardwood Forest, 6 acres of Northeastern Successional Shrubland, 4 acres each of North Atlantic Low Salt Marsh and North Atlantic High Salt Marsh (Table 5.32).

Localized increases in salinity could part of the reason. Research at Hog Island in Virginia showed that salt shrub (*Baccharis halimifolia*) was less tolerant of high salinities than marsh elder (*Iva frutescens*)[44] and other sources have shown that salt shrub and marsh elder can handle up to 15 ppt salinity[45] Fieldwork in the Inland Bays has revealed that marsh elders tends to be more dominant in the area than salt shrub and salinity distribution could be the factor leading this lending credence to the paper by Young, et al. Reductions in this community could very well reflect increases in salinity overall in the area above 15 ppt resulting in reductions of both species.

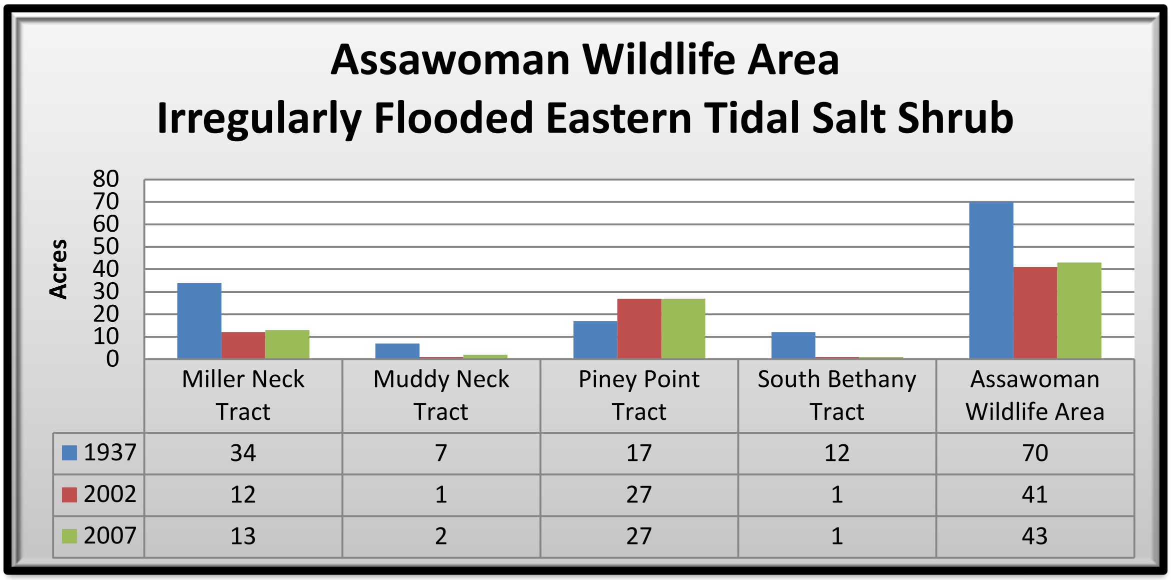
This community is often the "buffer" between the forests (Successional Maritime Forest and/or Coastal Loblolly Pine Wetland Forest) and the North Atlantic High Salt Marsh and/or North Atlantic Low Salt Marsh. From field observations it appears that this community be in the process of being skipped over due the high amount of rise. Also the Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland could be taking its place in those areas where a Coastal Loblolly Pine Wetland Forest is the edging forest.

The small uptick in occurrence in the past five years could be a just a slight bump up in an overall declining trend or it could be reforming from converting forest. If the long term (70 years) trend continues of losing 0.4 acres/year this community will be eliminated from three of the tracts in 105 years and sooner in the Miller Neck Tract (40 years), Muddy Neck Tract (20 years), stable and increasing in the Piney Point Tract, and South Bethany Tract (4 years). Hopefully new aerial imagery in 2012 will shed some light on the trends highlighted above.

[44] Young, D.R., D.L. Erickson, and S.W. Semones. 1994. Salinity and the small-scale distribution of three barrier island shrubs. Canadian Journal of Botany. 72 (9): 1,365-1,372.
[45] Slattery, Britt. E., Kathryn Reshetiloff, and Susan M. Zwicker. 2003. Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. 82 pp.

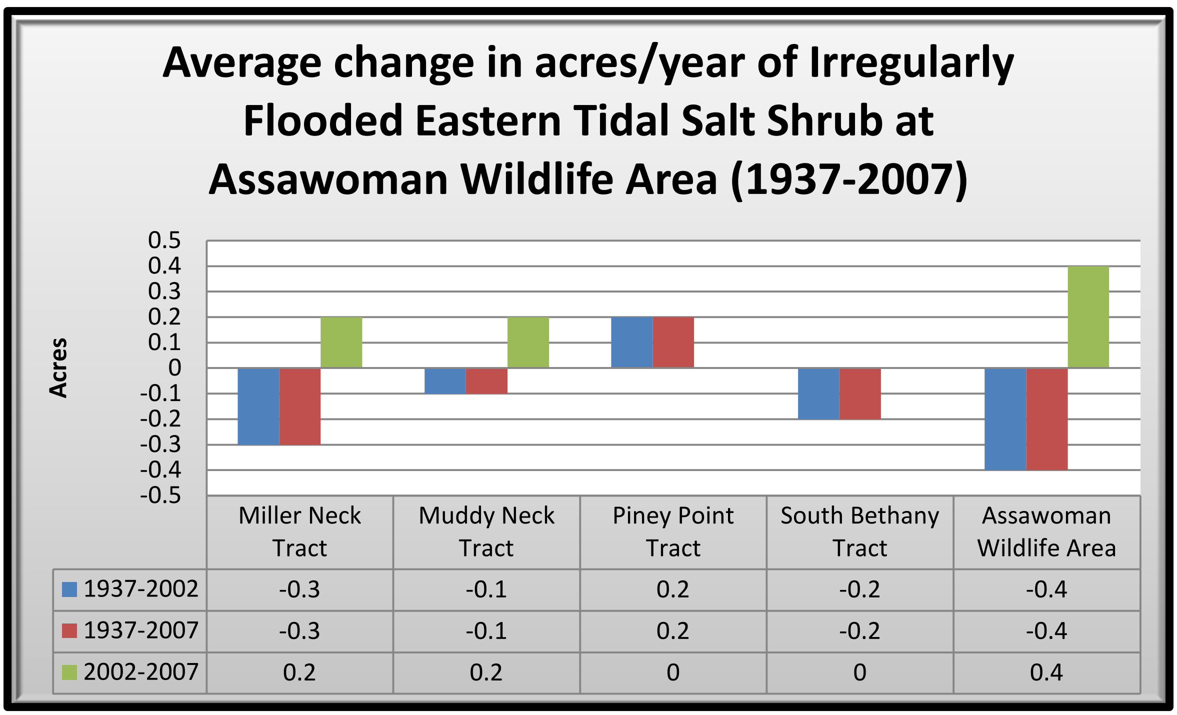
Table 5.31. What was once Irregularly Flooded Eastern Tidal Salt Shrub in 1937 has become X or remained in 2007	
X	**Acreage**
North Atlantic Low Salt Marsh	19 acres
Impoundment	19 acres
Central Coast Beach Heather Dune Shrubland	5 acres
Eastern Reed Marsh	4 acres
North Atlantic High Salt Marsh	4 acres
Other communities/land covers	20 acres

Table 5.32. Irregularly Flooded Eastern Tidal Salt Shrub has migrated into X or remained since 1937	
X	**Acreage**
Coastal Loblolly Pine Wetland Forest	8 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	7 acres
Northeastern Successional Shrubland	6 acres
North Atlantic Low Salt Marsh	4 acres
North Atlantic High Salt Marsh	4 acres
Other communities/land covers	12 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937	34	7	17	12	70
2002	12	1	27	1	41
2007	13	2	27	1	43

Figure 5.16. Irregularly Flooded Eastern Tidal Salt Shrub at Assawoman Wildlife Area (1937, 2002, and 2007)



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937-2002	-0.3	-0.1	0.2	-0.2	-0.4
1937-2007	-0.3	-0.1	0.2	-0.2	-0.4
2002-2007	0.2	0.2	0	0	0.4

Figure 5.17. Average change per year in amount of acres of Irregularly Flooded Eastern Tidal Salt Shrub at Assawoman Wildlife Area (1937-2007)

DNREC Sea Level Rise Analysis (Table 5.33)

Irregularly Flooded Eastern Tidal Salt Shrub is particularly vulnerable to sea level rise since it sits just above the mean tide level. Just a small amount of sea level rise, such 0.5 m, would practically eliminate the current extent of the community. An additional 0.5 m rise to 1 m would eliminate the community.

Table 5.33. Projected acres of Irregularly Flooded Eastern Tidal Salt Shrub Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	41 acres
1 m	42 acres
1.5 m	42 acres

Natural Capital (Table 5.34)

Irregularly Flooded Eastern Tidal Salt Shrub provided its greatest ecological service in 1937 when there was more acreage. It has since been reduced by almost half, but has had a slight increase with more acreage from the Piney Point Tract population.

Table 5.34. Natural Capital of Irregularly Flooded Eastern Tidal Salt Shrub	
Year	**Natural Capital (in 2012 dollars)**
1937	$438,991/year
2002	$257,233/year
2007	$269,666/year

Loblolly Pine Dune Woodland **[20 acres (Figures 5.18-5.19, Tables 5.35-5.38)] G1G2 S1**

DEWAP: Beach and Dune Habitats
NHC: North Atlantic Coastal Plain Maritime Forest

Description

This woodland community is confined to the immediate coast on the South Bethany Tract. Loblolly pine (*Pinus taeda*) associated by red maple (*Acer rubrum*) in a canopy overtopping sweetgum (*Liquidambar styraciflua*), southern red oak (*Quercus falcata*), serviceberry (*Amelanchier arborea*), and wild black cherry (*Prunus serotina*). Shrubs include inkberry (*Ilex glabra*), southern bayberry (*Morella cerifera*), highbush blueberry (*Vaccinium corymbosum*), lowbush blueberry (*Vaccinium stamineum*), and red chokeberry (*Aronia arbutifolia*) typify this community. Cinnamon fern (*Osmunda cinnamomea*) and roundleaf thoroughwort (*Eupatorium rotundifolium*) were only herbs noted.

The examples located on the South Bethany Tract are of good condition but are limited in area and suffer edge effects from nearby DE 1. This community may lose acreage in the future because of the constraints of the road and the lack of sand to produce land on the bayside.

Figure 5.18. Loblolly Pine Dune Woodland (South Bethany Tract)

Analysis of Condition at Assawoman Wildlife Area

This woodland community is only located on the South Bethany tract in the wildlife area. It is one of the rarer communities in the state and occurs only on the Atlantic Coastal Strand. These communities are likely flooded and receive salt spray during storm events. This particular occurrence is protected by the wildlife area and the prognosis is good for its survival in the short-term. In the long-term, its exposed condition may succumb to inundation from sea level rise.

In 2007, 6 acres of the original 8 acres from 1937 were still present. The rest of the acreage was changed to 1 acre of Central Coast Beach Heather Dune Shrubland, 0.4 acres of North Atlantic Low Salt Marsh, 0.2 acres of Reed Tidal Marsh, and 0.1 acres of Cultivated Lawn (Table 5.35).

Since 1937, this community has grown into 5 acres of Mid-Atlantic Coast Backdune Grassland, 4 acres of Irregularly Flooded Eastern Tidal Salt Shrub, 2 acres of Overwash Dune Grassland, and 2 acres of North Atlantic Low Salt Marsh (Table 5.36) with an increase of 13 acres. These areas likely had sand added to them from storm events allowing the pines to root. It is unknown whether the movement of sand may aid the migration of this community.

Table 5.35. What was once Loblolly Pine Dune Woodland in 1937 has become X or remained in 2007	
X	**Acreage**
Loblolly Pine Dune Woodland	6 acres
Central Coast Beach Heather Dune Shrubland	1 acre
North Atlantic Low Salt Marsh	0.4 acres
Reed Tidal Marsh	0.2 acres
Cultivated Lawn	0.1 acres
Other communities/land covers	0.3 acres

Table 5.36. Loblolly Pine Dune Woodland has migrated into X or remained since 1937	
X	**Acreage**
Loblolly Pine Dune Woodland	6 acres
Mid-Atlantic Coast Backdune Grassland	5 acres
Irregularly Flooded Eastern Tidal Salt Shrub	4 acres
Overwash Dune Grassland	2 acres
North Atlantic Low Salt Marsh	2 acres
Other communities/land covers	2 acres

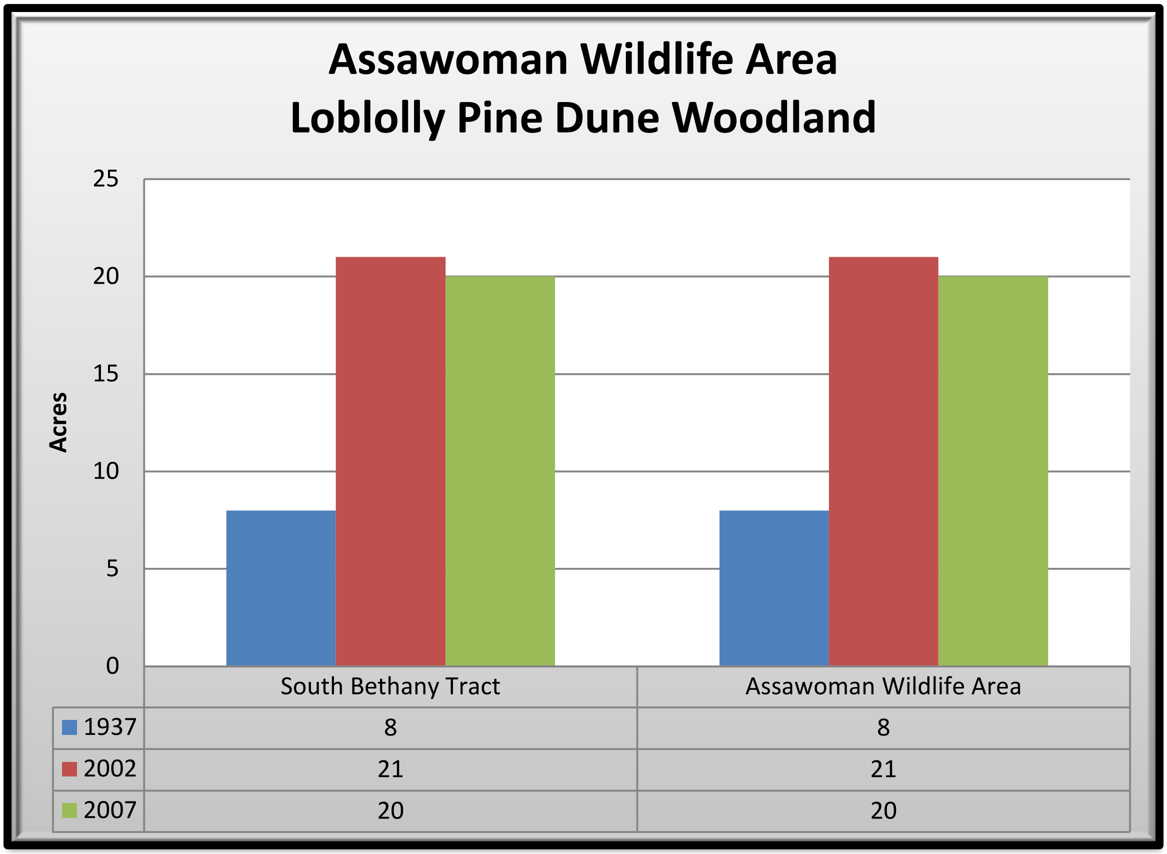


Figure 5.19. Loblolly Pine Dune Woodland at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.37)

Most of the current acreage of Loblolly Pine Dune Woodland would be lost with 0.5 m of sea level rise. An additional 0.5 m of rise would eliminate the current extent of the community. Since this community is long lived and takes time to establish and its position on the shore, it is unlikely that it will be able to migrate with the rise.

Table 5.37. Projected acres of Loblolly Pine Dune Woodland Impacted by Sea Level Rise

Rise	**Acres**
0.5 m	17 acres
1 m	21 acres
1.5 m	21 acres

Natural Capital (Table 5.38)

Loblolly Pine Dune Woodland has been increasing in acreage with a resulting increase in natural capital. The capital of this community will likely be transferred to other communities as sea level rise takes over.

Table 5.38. Natural Capital of Loblolly Pine Dune Woodland	
Year	**Natural Capital (in 2012 dollars)**
1937	$2,269/year
2002	$3,782/year
2007	$3,971/year

***Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland* [5.3 acres (Figures 5.20-5.21, Tables 5.39-5.41)] GNR S3**

DEWAP: Beach and Dune Habitats
NHC: Northern Atlantic Coastal Plain Maritime Forest

Description

This woodland community is located in places where the forest is converting to shrubland (Irregularly Flooded Eastern Tidal Salt Shrub) or more recently directly to North Atlantic High Salt Marsh. Loblolly pine (*Pinus taeda*) is dominant in the canopy and is often accompanied by some standing dead individuals. The understory is composed of salt shrub (*Baccharis halimifolia*) and marsh elder (*Iva frutescens*). Common herbs include salt meadow hay (*Spartina patens*) and saltgrass (*Distichlis spicata*).

Analysis of Condition at Assawoman Wildlife Area

This community is a newcomer to the wildlife area since the 1930's. This community is common in the Inland Bays region in places where there is a low area bordering a marsh. These communities likely eventually become part of the shrubland and marsh as the sea level rises with the overstory remaining as standing dead timber. The emergence of this community in the wildlife shows that there is some regression of the marsh into the upland areas. What is unknown but has been observed in the field is whether this community is developing in place of the Irregularly Flooded Eastern Tidal Salt Shrub due to the rate of sea level rise.

Since 1937 this community has converted 3 acres of Chesapeake Bay Non-riverine Wet Hardwood Forest, 2 acres of Early to Mid-Successional Loblolly Pine Forest, 0.3 acres of Northeastern Old Field, 0.2 acres of North Atlantic Low Salt Marsh, and 0.1 acres of Successional Maritime Forest (Table 5.39). With the exception of the North Atlantic Low Salt Marsh, this community appears able to convert other forested communities its constituent species.

Table 5.39. Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland has migrated into X or remained since 1937	
X	**Acreage**
Chesapeake Bay Non-riverine Wet Hardwood Forest	3 acres
Early to Mid-Successional Loblolly Pine Forest	2 acres
Northeastern Old Field	0.3 acres
North Atlantic Low Salt Marsh	0.2 acres
Successional Maritime Forest	0.1 acres

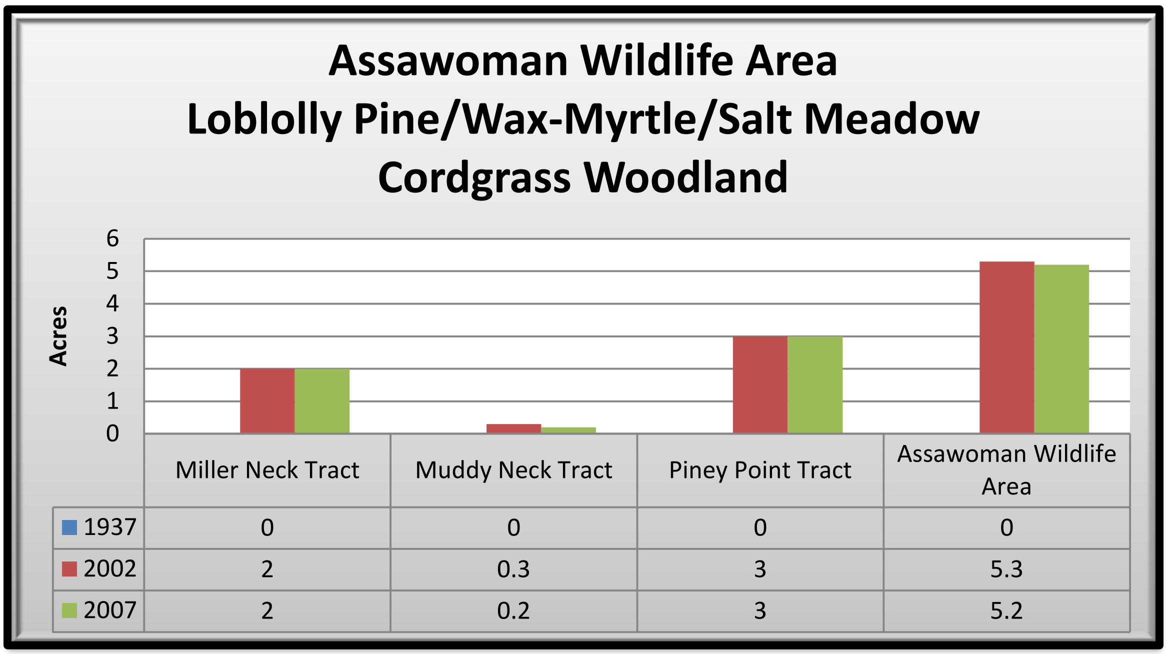


Figure 5.20. Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland at Assawoman Wildlife Area (1937, 2002, and 2007)

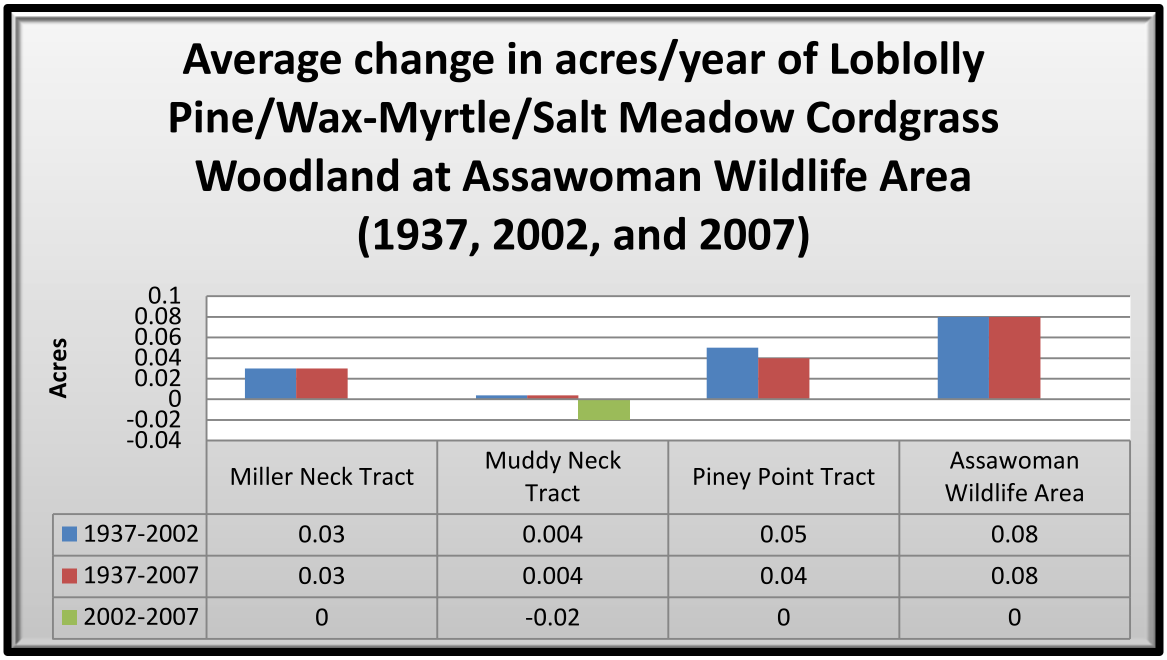


Figure 5.21. Average in acres/year of Loblolly Pine/Wax-Myrtle/Salt Meadow Cordgrass Woodland at Assawoman Wildlife Area (1937-2007)

DNREC Sea Level Rise Analysis (Table 5.40)

This community would be eliminated in its current extent with 0.5 m of sea level rise. This community appears able to convert other forested communities leaving its constituent species and therefore may have a chance to move landward with the sea level rise. In fact this community could be product of sea level rise since it was apparently not present in 1937.

Table 5.40. Projected acres of Loblolly Pine Wax-Myrtle Salt Meadow Cordgrass Woodland Impacted by Sea Level Rise

Rise	Acres
0.5 m	5 acres
1 m	5 acres
1.5 m	5 acres

Natural Capital (Table 5.41)

Because of its small acreage this community does not provide much natural capital but does provide more than it did in 1937.

Table 5.41. Natural Capital of Loblolly Pine Wax-Myrtle Salt Meadow Cordgrass Woodland	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year (not present)
2002	$946/year
2007	$946/year

***Maritime Red Cedar Woodland* [0.5 acres (Figure 5.22, Tables 5.42-5.45)] G2 S1**

DEWAP: Beach and Dune Habitats
NHC: Northern Atlantic Coastal Plain Maritime Forest

Description

This woodland community covers a small amount of the wildlife area but maybe once covered more area. In the early times of the wildlife area eastern red cedar (*Juniperus virginiana*) was logged from the wildlife area. This logging activity may have reduced the amount of this community in the wildlife area. The following description is general as this community was aerially interpreted and not visited in the field. This community is dominated by eastern red cedar in the canopy and is accompanied by wild black cherry (*Prunus serotina*), and persimmon (*Diospyros virginiana*). Prickly pear cactus (*Opuntia humifusa*) is often common in the herb layer.

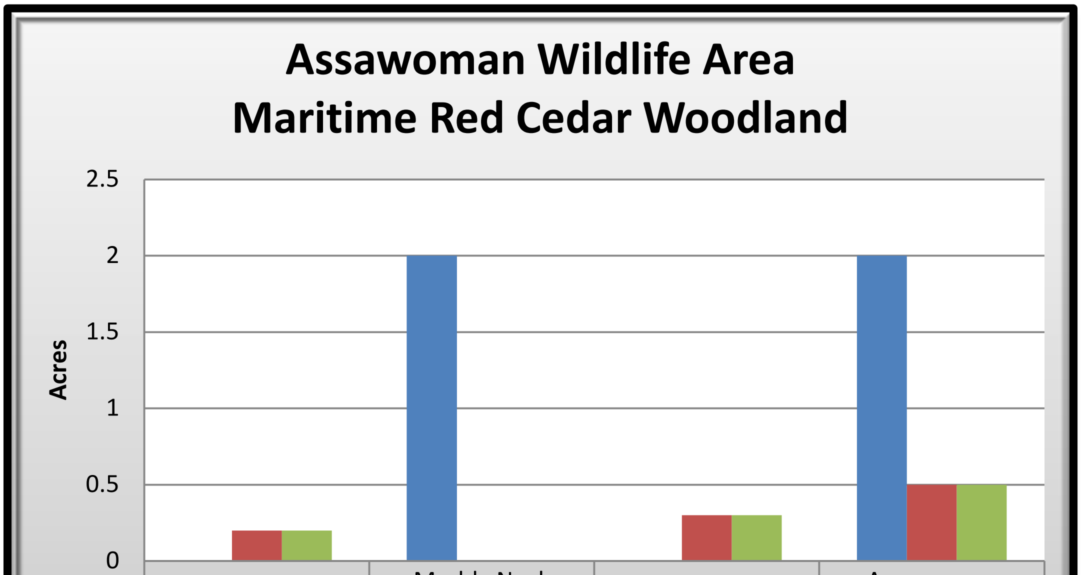
Analysis of Condition at Assawoman Wildlife Area

This woodland community may have once been much more prevalent in the wildlife area before the 1930's. Around the time of acquisition by the USDA, a lot of the cedar was logged in the wildlife area. This community appears to be gradually decreasing or changing over the Successional Maritime Forest, shrubland, or marsh as the sea level rises. Eastern red cedar (*Juniperus virginiana*) is a fast growing tree which makes this community rather short lived unless it spreads to other places. Most of the forests in the area are mature but it may move into areas that have been cleared from storm events.

None of the original acreage from 1937 was still present in 2007. All of the acreage was converted to 1 acre of Northeastern Old Field, 0.2 acres of Farm Pond/Artificial Pond, and 0.02 acres of Agricultural Field (Table 5.42). The small amount left of this community came from 0.3 acres of North Atlantic Low Salt Marsh and 0.2 acres of Mid-Atlantic Coastal Maritime Forest (Table 5.43).

Table 5.42. What was once Maritime Red Cedar Woodland in 1937 has become X or remained in 2007	
X	**Acreage**
Northeastern Old Field	1 acre
Farm Pond/Artificial Pond	0.2 acres
Agricultural Field	0.02 acres

Table 5.43. Maritime Red Cedar Woodland has migrated into X or remained since 1937	
X	**Acreage**
North Atlantic Low Salt Marsh	0.3 acres
Mid-Atlantic Coastal Maritime Forest	0.2 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	Assawoman Wildlife Area
1937	0	2	0	2
2002	0.2	0	0.3	0.5
2007	0.2	0	0.3	0.5

Figure 5.22. Maritime Red Cedar Woodland at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.44)

This community would be eliminated in its current extent with 0.5 m of sea level rise. It is unknown whether this community will move landward with sea level but Eastern Red Cedar (*Juniperus virginiana*) is a fairly fast growing tree and it may go in areas where Loblolly Pine Wax-Myrtle Salt Meadow Cordgrass Woodland has not.

Table 5.44. Projected acres of Maritime Red Cedar Woodland Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	0.5 acres
1 m	0.5 acres
1.5 m	0.5 acres

Natural Capital (Table 5.45)

Because of its small acreage this community does not provide much natural capital and this small amount has been declining.

Table 5.45. Natural Capital of Maritime Red Cedar Woodland	
Year	**Natural Capital (in 2012 dollars)**
1937	$378/year
2002	$95/year
2007	$95/year

***Mid-Atlantic Coastal Maritime Forest* [12 acres (Figures 5.23-5.24, Tables 5.46-5.49)]**
G2 S2

DEWAP: Coastal Plain Upland Forest Habitat
NHC: Northern Atlantic Coastal Plain Maritime Forest

Description

This forested community is located on a sandy swale that is drier than the surrounding area. Loblolly pine (*Pinus taeda*) is dominates a canopy that is associated by southern red oak (*Quercus falcata*). American holly (*Ilex opaca*), southern red oak (*Quercus falcata*), sweetgum (*Liquidambar styraciflua*), and sassafras (*Sassafras albidum*) compose the understory. The shrub layer is similar to the Southern Red Oak/Heath Forest with lowbush blueberry (*Vaccinium vacillans*), highbush blueberry (*Vaccinium corymbosum*), and common greenbrier (*Smilax rotundifolia*). Similar to the other pine forests, no herbs were noted in this community.

Figure 5.23. Mid-Atlantic Coastal Maritime Forest (Miller Neck)

The one example of this community in the wildlife area is of a good quality and has a well-developed understory. It is estimated to be mostly 60-70 years of age with a small part that is older.

Analysis of Condition at Assawoman Wildlife Area

This forested community was present in very small amount in 1937 and increased its coverage after the abandonment of agriculture. It is located on a rise above Miller Creek which is a little bit drier than the surrounding area. This community does not appear to be imminent danger of disappearing, though the recent loss may be due to maturation into Southern Red Oak/Heath Forest. Global climate change may possibly bring in pine beetles from the south as temperate rise which may negatively impact this community.

In 2007, 0.3 acres of the original 2 acres from 1937 was still present. The rest of the acreage had been converted to 0.4 acres of Reed Tidal Marsh, 0.4 acres of North Atlantic Low Salt Marsh, 0.4 acres of Coastal Loblolly Pine Wetland Forest, and 0.2 acres of Maritime Red Cedar Woodland (Table 5.46).

Since 1937, this community has increased acreage, spreading into 11 acres of clear-cut and 1 acre of Northeastern Old Field (Table 5.47). This community has some potential of increasing its size if it spreads into a nearby modified land area.

Table 5.46. What was once Mid-Atlantic Coastal Maritime Forest in 1937 has become X or remained in 2007

X	Acreage
Reed Tidal Marsh	0.4 acres
North Atlantic Low Salt Marsh	0.4 acres
Coastal Loblolly Pine Wetland Forest	0.4 acres
Mid-Atlantic Coastal Maritime Forest	0.3 acres
Maritime Red Cedar Woodland	0.2 acres
Other communities/land covers	0.1 acres

Table 5.47. Mid-Atlantic Coastal Maritime Forest has migrated into X or remained since 1937

X	Acreage
Clear-cut	11 acres
Northeastern Old Field	1 acre
Mid-Atlantic Coastal Maritime Forest	0.3 acres

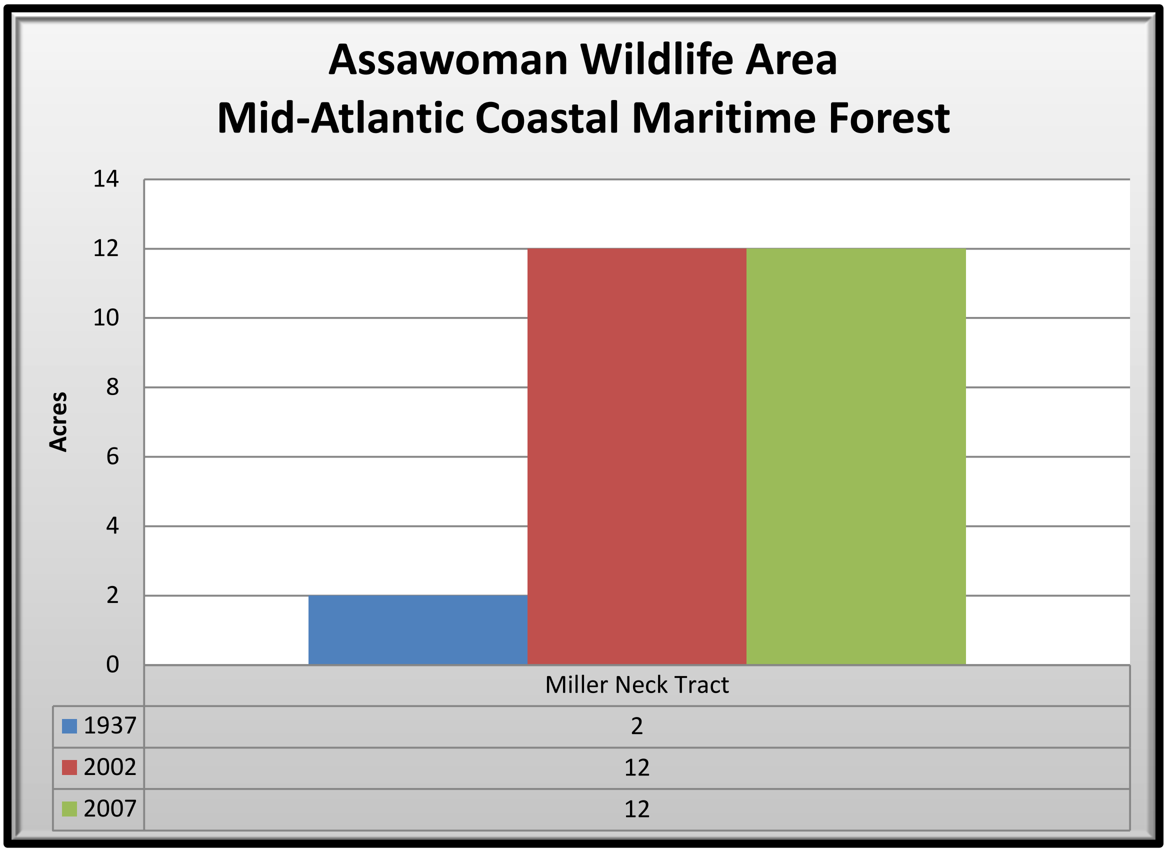


Figure 5.24. Mid-Atlantic Coastal Maritime Forest at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.48)

This community will still be present to some extent even with the highest amount of projected sea level rise (1.5 m). At 0.5 m of rise, one acre will be inundated and at 1 m 3 acres will be inundated. The highest level (1.5 m) will inundate about 2/3 (8 acres) of the current acreage. This forest takes a long time to establish and it is unknown whether it will migrate given that the main species, loblolly pine (*Pinus taeda*), needs an open area and a lot of light to regenerate.

Table 5.48. Projected acres of Mid-Atlantic Coastal Maritime Forest Impacted by Sea Level Rise

Rise	Acres
0.5 m	1 acre
1 m	3 acres
1.5 m	8 acres

Natural Capital (Table 5.49)

The capitalization of this forest has increased with gains in the acreage from growing into a clear-cut and Northeastern Old Field. It may possibly gain some capital it is grows into a modified land area that is adjacent.

Table 5.49. Natural Capital of Mid-Atlantic Coastal Maritime Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$378/year
2002	$2,269/year
2007	$2,269/year

***Needlerush High Marsh* [20 acres (Figures 5.25-5.27, Tables 5.50-5.53)] G5 S2**

DEWAP: Tidal High Marsh Habitat
NHC: Northern Atlantic Coastal Plain Tidal Salt Marsh

Description

Figure 5.25. Needlerush High Marsh (Muddy Neck Tract)

This marsh community is found on places of slightly higher elevation in the tidal marshes. It is dominated nearly entirely by needlerush (*Juncus roemerianus*) with a few bunches of salt meadow cordgrass (*Spartina patens*) mixed in.

Analysis of Condition at Assawoman Wildlife Area

Needlerush High Marsh is not as common as it apparently once was in the 1930's. Signatures from the 1937 imagery appear as Needlerush High Marsh but due to the inability to field check from this time it is impossible to be sure but they compare favorably to current existing marshes. Recently these marshes have experienced a slight increase overall in the 2002 to 2007 period. It has continued to decline although in the Miller Neck Tract. The regional manager at Assawoman Wildlife Area, Rob Gano, stated that he has noticed more Needlerush in the area.[46] These data appear to match that conclusion.

The species that dominates this marsh is one that reaches the southern limit of its range in Delaware and is poised to move northward with global climate change. But it can only move northward if the habitat is available. It appears that the new acreage is coming at the expense of the North Atlantic High Salt Marsh and the declines in the Miller Neck Tract and lack of increases in the South Bethany Tract are worrisome as they mirror the fate of the North Atlantic High Salt Marsh (Figure 5.26). However, there has been an increase in the Muddy Neck Tract. The prognosis for this community in the wildlife area overall can be considered fair-good. Overall the community is increasing in the wildlife area. Declines in the Miller Neck Tract and loss of high marsh habitat overall are worrisome though and may reflect an upcoming trend regardless of the species migration northward. If the current rate of loss is maintained in the

[46] Rob Gano, personal communication.

Miller Neck Tract this community could be extirpated from it in 15 years or 2022. Only time will tell what the ultimate fate will be.

Only 3 acres of original 26 acres from 1937 still existed in 2007. The rest of the acreage had converted to 7 acres of North Atlantic Low Salt Marsh, 6 acres of Impoundment, 3 acres of North Atlantic High Salt Marsh, and 2 acres of water (Table 5.50). Since 1937 this marsh has migrated into 10 acres of North Atlantic Low Salt Marsh, 3 acres of North Atlantic High Salt Marsh, 2 acres of water, and 1 acre of Northeastern Old Field (Table 5.51).

Table 5.50. What was Needlerush High Marsh in 1937 has become X or remained in 2007

X	Acreage
North Atlantic Low Salt Marsh	7 acres
Impoundment	6 acres
North Atlantic High Salt Marsh	3 acres
Needlerush High Marsh	3 acres
Water	2 acres
Other communities/land covers	6 acres

Table 5.51. Needlerush High Marsh has migrated into X or remained since 1937

X	Acreage
North Atlantic Low Salt Marsh	10 acres
North Atlantic High Salt Marsh	3 acres
Needlerush High Marsh	3 acres
Water	2 acres
Northeastern Old Field	1 acre
Other communities/land covers	1 acre

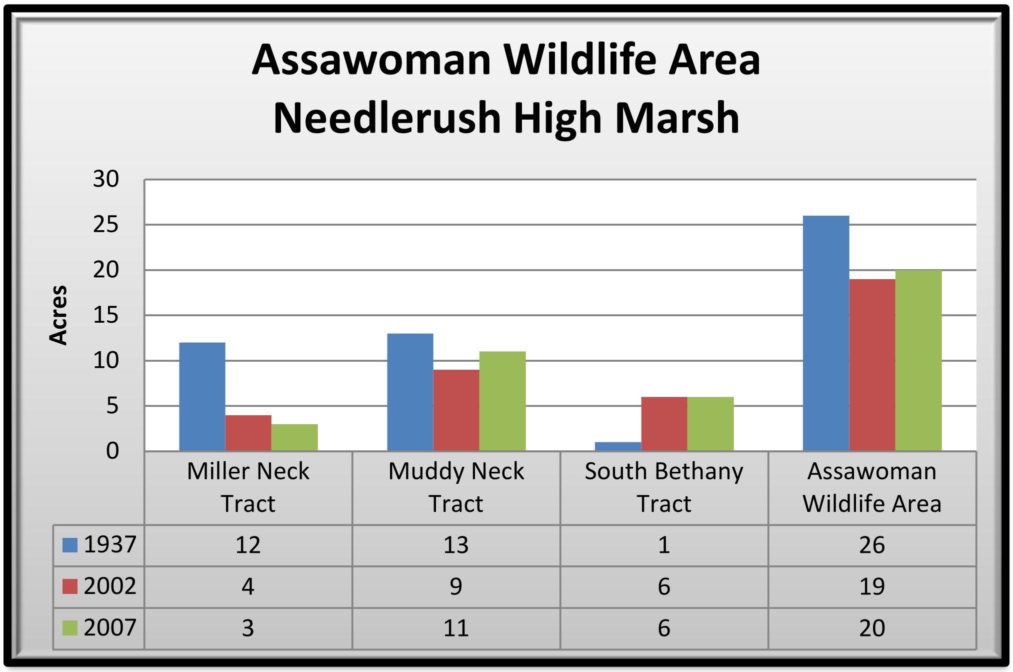


Figure 5.26. Needlerush High Marsh at Assawoman Wildlife Area (1937, 2002, and 2007)

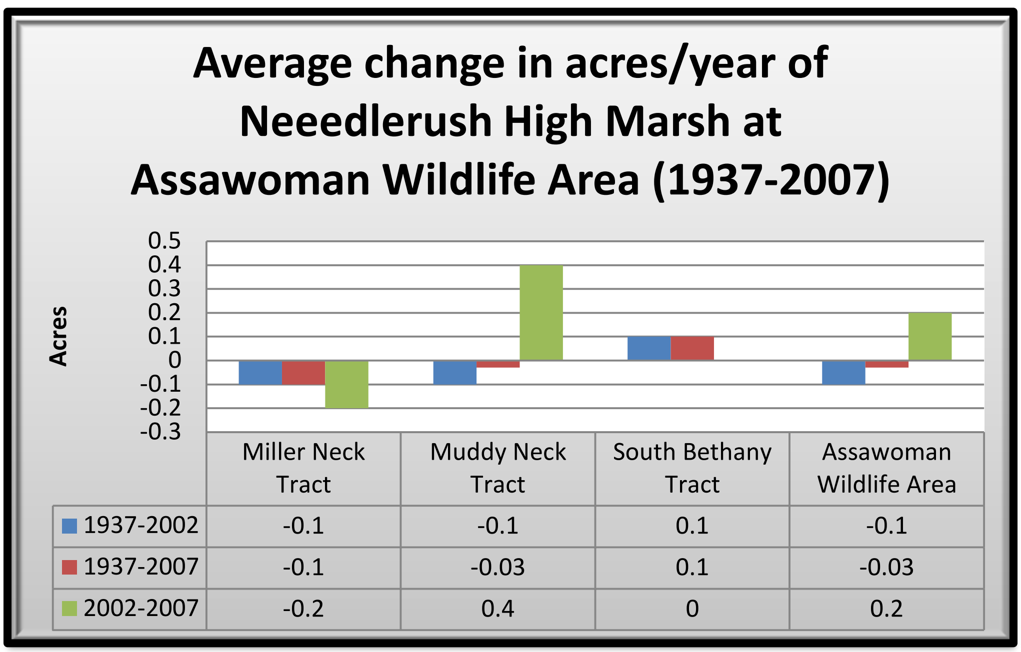


Figure 5.27. Average change per year in amount of acres of Needlerush High Marsh at Assawoman Wildlife Area (1937-2007)

DNREC Sea Level Rise Analysis (Table 5.52)

Needlerush High Marsh will be eliminated in its current extent with 0.5 m of sea level rise. Given the loss of high marsh habitat due to the rate of sea level rise, it is unlikely that this community will colonize other areas without help from restoration. Since this is community is composed of a southern species, Needlerush (*Juncus roemerianus*), it stands to move northward more into Delaware with climate change.

Table 5.52. Projected acres of Needlerush High Marsh Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	20 acres
1 m	20 acres
1.5 m	20 acres

Natural Capital (Table 5.53)

Needlerush High Marsh carries a higher capitalization rate than uplands because it is a wetland making these communities valuable for ecosystem services. The overall amount has decreased from the highs of 1937.

Table 5.53. Natural Capital of Needlerush High Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$163,053/year
2002	$119,155/year
2007	$125,426/year

***North Atlantic High Salt Marsh* [90.4 acres (Figures 5.28-5.30, Tables 5.54-5.57)] G5 S4**

DEWAP: Tidal High Marsh Habitat
NHC: Northern Atlantic Coastal Plain Tidal Salt Marsh

Description

Figure 5.28. North Atlantic High Salt Marsh (Muddy Neck)

This marsh community occurs at a slightly higher elevation than the North Atlantic Low Salt Marsh and is dominated by salt meadow cordgrass (*Spartina patens*). Other associates include saltgrass (*Distichlis spicata*), sea-lavender (*Limonium* sp.), and salt marsh fleabane (*Pluchea odorata*).

Analysis of Condition at Assawoman Wildlife Area

If North Atlantic High Salt Marsh is the canary in the coal mine then the high marshes at Assawoman Wildlife Area are in trouble. The canary is slowly dying. This community has experienced declines in all of the years mapped and has shrunk by almost 2/3 of its extent in 1937. The natural course would be for this community to retreat landward and colonize on places of higher elevation (through Irregularly Flooded Eastern Salt Shrub, Successional Maritime Forest, and Coastal Loblolly Pine Wetland) from the rising sea levels. From field observations and the analysis below (Table 5.54) North Atlantic High Salt Marsh is having a tough time migrating. Field observation would suggest that the shrub stage conversion (Irregularly Flooded Eastern Tidal Salt Shrub) is largely being skipped. *Spartina* patens is restricted is restricted to the high marsh zone by physiological constraints and cannot invade the low marsh on its own (Bertness 1991)[47]. Other research has shown that the accretion in the high marsh cannot keep up with sea level rise above 2.5 mm/yr [48] at rate which started in the middle 1800's. This accretion rate may further be hampered by the lack of organic mass from rising sea level [49]. My research shows that some of the high marsh has converted to North

[47] Bertness, M.D. 1991. Interspecific interactions among high marsh perennials in a New England salt marsh. Ecology 72 (1): pp. 125-137.
[48] Donnelly, Jeffrey P. and Mark D. Bertness. 2001. Rapid encroachment of salt marsh cordgrass in response to accelerated sea-level rise. Proc. Of the National Academy of Science 98 (25): 14,218-14,223.
[49] Miller, W.D., S.C. Neubauer, and I.C. Anderson. 2001. Effects of Sea Level Induced Disturbances on High Salt Marsh Metabolism. Estuaries 24 (3): 357-367.

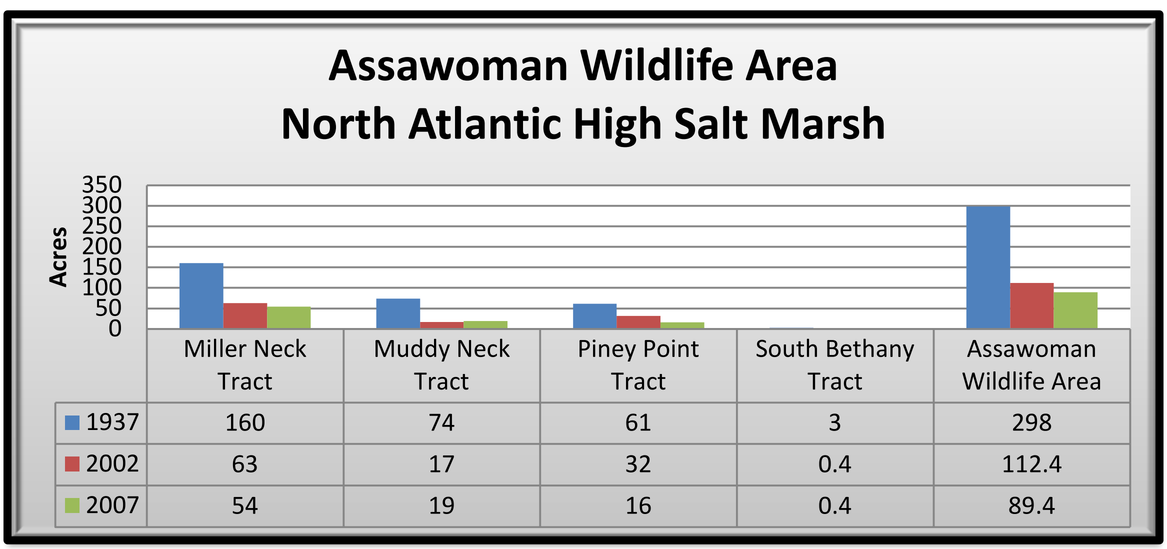
Atlantic Low Salt Marsh giving slight gains to the high marsh and shows that a high amount of the marsh is being inundated and converted to North Atlantic Low Salt Marsh. Also, observations in the field have noted that some of the marshes are changing into marshes that are purely dominated by salt grass (*Distichlis spicata*), especially in areas where salt marsh dieback was prevalent. It is unknown whether this is a trend or an aberration of the dieback.

Mosquito control activities and the building of impoundments is also responsible for some of the losses making projections difficult. Given that the losses continue even after the building of the impoundments makes the prognosis poor for this community. Using the short-term rate (5 years, 2002-2007) of loss to take out the effects of the impoundment losses, it is projected that this community will be gone from the Miller Neck Tract in 30 years (2032), Piney Point Tract in 5 years (2012) and a field observation in December 2010 has noted that it is now gone from the South Bethany Tract (Figure 5.30). Currently this community is increasing at the Muddy Neck Tract, but it is unknown whether trend will continue or will revert to losses like the others. This community is projected to be gone from the wildlife area in 16 years with the last point of refuge being the Miller Neck Tract, but may last a little while longer based on the individual tract rates of loss. All of these projections are based on the current rate of loss and only time will tell what actual rate will be or if they will disappear. All things considered it does not look hopeful for this community to remain in the wildlife area.

In 2007, 29 acres of the original 298 acres from 1937 still existed. The rest of the acreage converted to 125 acres of North Atlantic Low Salt Marsh, 43 acres of Impoundment, 42 acres of Eastern Reed Marsh, and 21 acres of water (Table 5.54). Since 1937, this community has suffered marked declines, but has still managed to migrate into 30 acres of North Atlantic Low Salt Marsh, 7 acres of Northeastern Old Field, 4 acres of Irregularly Flooded Eastern Tidal Salt Shrub, and Early to Mid-Successional Loblolly Pine Forest (Table 5.55).

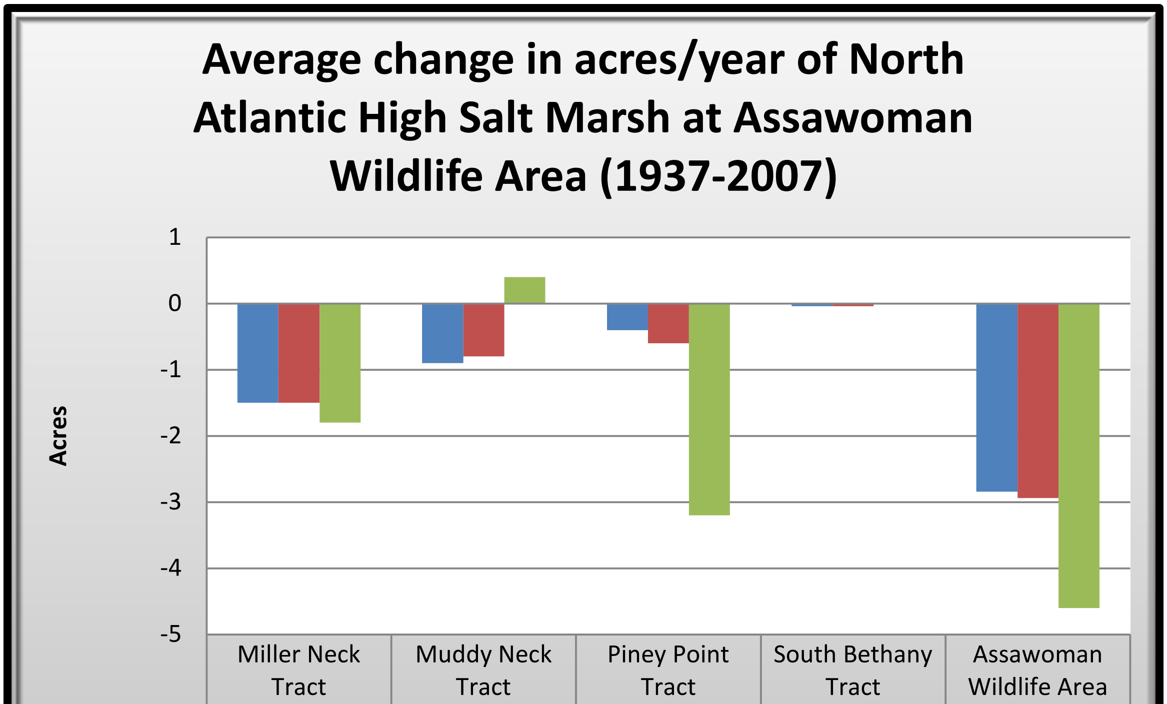
Table 5.54. What was once North Atlantic High Salt Marsh in 1937 has become X or remained in 2007	
X	**Acreage**
North Atlantic Low Salt Marsh	125 acres
Impoundment	43 acres
Eastern Reed Marsh	42 acres
North Atlantic High Salt Marsh	29 acres
Water	21 acres
Other communities/land covers	37 acres

Table 5.55. North Atlantic High Salt Marsh has migrated into X or remained since 1937	
X	**Acreage**
North Atlantic Low Salt Marsh	30 acres
North Atlantic High Salt Marsh	29 acres
Northeastern Old Field	7 acres
Irregularly Flooded Eastern Tidal Salt Shrub	4 acres
Early to Mid-Successional Loblolly Pine Forest	4 acres
Other communities/land covers	16 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937	160	74	61	3	298
2002	63	17	32	0.4	112.4
2007	54	19	16	0.4	89.4

Figure 5.29. North Atlantic High Salt Marsh at Assawoman Wildlife Area (1937, 2002, and 2007)



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937-2002	-1.5	-0.9	-0.4	-0.04	-2.84
1937-2007	-1.5	-0.8	-0.6	-0.04	-2.94
2002-2007	-1.8	0.4	-3.2	0	-4.6

Figure 5.30. Average change in acres/year of North Atlantic High Salt Marsh at Assawoman Wildlife Area (1937-2007)

DNREC Sea Level Rise Analysis (Table 5.56)

North Atlantic High Salt Marsh will be eliminated in its current extent with 0.5 m of sea level rise. However, given the transition of this community to North Atlantic Low Salt Marsh it may very likely happen before this point.

Table 5.56. Projected acres of North Atlantic High Salt Marsh Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	89 acres
1 m	89 acres
1.5 m	89 acres

Natural Capital (Table 5.57)

North Atlantic High Salt Marsh carries a higher capitalization rate than uplands because it is a wetland making these communities valuable for ecosystem services. A lot of the capitalization of this community is being transferred to North Atlantic Low Salt Marsh.

Table 5.57. Natural Capital of North Atlantic High Salt Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$1,868,847/year
2002	$702,386/year
2007	$558,146/year

***North Atlantic Low Salt Marsh* [514 acres (Figures 5.31 and 5.33, Tables 5.58-5.61)] G5 S5**

DEWAP: Tidal Low Marsh Habitat
NHC: Northern Atlantic Coastal Plain Tidal Salt Marsh

Description

Figure 5.31. North Atlantic Low Salt Marsh (Miller Neck Tract)

This is the most common marsh community in the wildlife area. It receives diurnal tides and is dominated nearly entirely by salt marsh cordgrass (*Spartina alterniflora*).

Analysis of Condition at Assawoman Wildlife Area

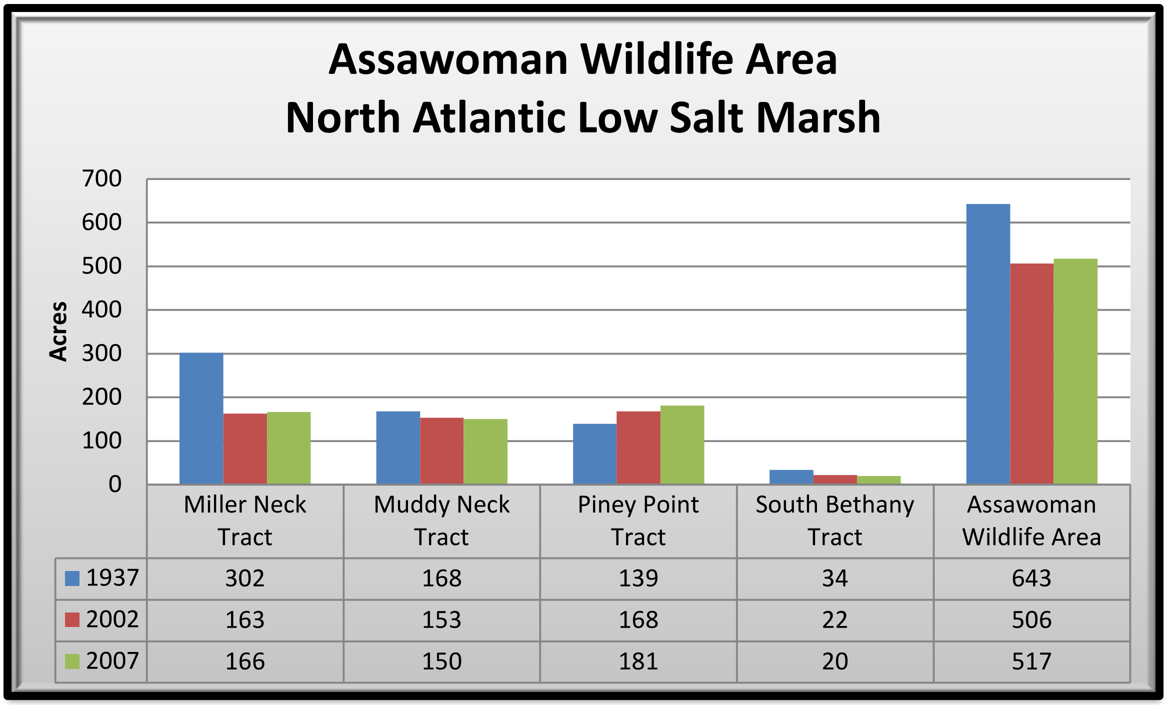
This community is directly impacted by sea level and is located on the interface between the land and open water in the bays. Like the North Atlantic High Salt Marsh it has lost acreage. While some of the lost has likely been to sea level rise, its losses have been mainly due to the construction of impoundments. Since the building of the impoundments it has gained acreage likely at the expense of the North Atlantic High Salt Marsh with sea level rise. Gains were seen in the Miller Neck and Piney Point Tracts and losses in the Muddy Neck and South Bethany Tracts.

The prognosis for this community is good for the current time in the Miller Neck Tract and appears to be good in the Piney Point Tract. Though the areas of salt grass noted in the North Atlantic High Salt Marsh discussion are mapped as North Atlantic Low Salt Marsh and they were noted in the Piney Point Tract. These areas could be giving this community an artificially high rate of increase (the bubble mentioned in the in the introduction). This community is decreasing in the Muddy Neck and South Bethany Tracts. Both of these tracts are constrained, either through topography with the Muddy Neck Tract or impervious surface (DE 1) on the South Bethany Tract, which may be driving the losses. Based on the short term (2002-2007) rate of loss in the South Bethany Tract, this community could be eliminated in 24 years (2031). Based on the short term (2002-2007) rate of loss at the Muddy Neck Tract, this community will persist for over 100 years. The community will persist in the wildlife area for at least the next 100 years based on current rates, but these rates are projected to increase.

In 2007, 320 acres of the original 643 acres from 1937 still existed. A lot of the acreage was lost in the development of the impoundments (129 acres), additional acreage has been lost to water (49 acres), Eastern Reed Marsh (41 acres), and Tidal Mudflat (37 acres) (Table 5.58). Despite losing acreage this community has been able to migrate into other areas mainly at the expense of North Atlantic High Salt Marsh (133 acres). Other communities converted include 15 acres of Irregularly Flooded Eastern Tidal Salt Shrub, 14 acres of Northeastern Old Field, and 11 acres of Coastal Loblolly Pine Wetland Forest (Table 5.59).

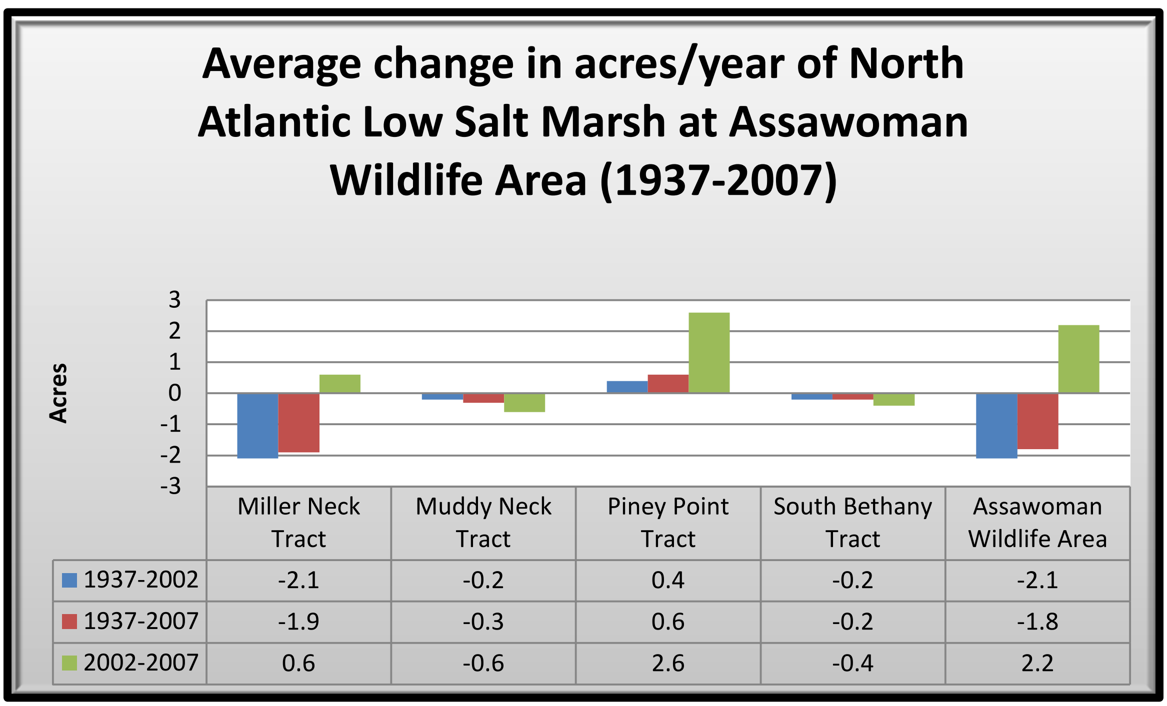
Table 5.58. What was once North Atlantic Low Salt Marsh in 1937 has become X or remained in 2007	
X	**Acreage**
North Atlantic Low Salt Marsh	320 acres
Impoundment	129 acres
Water	48 acres
Eastern Reed Marsh	41 acres
Tidal Mudflat	37 acres
Other communities/land covers	128 acres

Table 5.59. North Atlantic Low Salt Marsh has migrated into X or remained since 1937	
X	**Acreage**
North Atlantic Low Salt Marsh	320 acres
North Atlantic High Salt Marsh	133 acres
Irregularly Flooded Eastern Tidal Salt Shrub	15 acres
Northeastern Old Field	14 acres
Coastal Loblolly Pine Wetland Forest	11 acres
Other communities/land covers	30 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937	302	168	139	34	643
2002	163	153	168	22	506
2007	166	150	181	20	517

Figure 5.32. North Atlantic Low Salt Marsh at Assawoman Wildlife Area (1937, 2002, and 2007)



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937-2002	-2.1	-0.2	0.4	-0.2	-2.1
1937-2007	-1.9	-0.3	0.6	-0.2	-1.8
2002-2007	0.6	-0.6	2.6	-0.4	2.2

Figure 5.33. Average change per year in amount of acres of North Atlantic Low Salt Marsh at Assawoman Wildlife Area (1937-2007)

DNREC Sea Level Rise Analysis (Table 5.60)

North Atlantic Low Salt Marsh will be eliminated in its current extent with 0.5 m of sea level rise.

Table 5.60. Projected acres of North Atlantic Low Salt Marsh Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	518 acres
1 m	518 acres
1.5 m	518 acres

Natural Capital (Table 5.61)

North Atlantic Low Salt Marsh carries a higher capitalization rate than uplands because it is a wetland making these communities valuable for ecosystem services. A lot of the capitalization of this community was transferred initially to impoundment and but the capitalization is rising again in the short term (2002-2007).

Table 5.61. Natural Capital of North Atlantic Low Salt Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$4,032,446/year
2002	$3,173,278/year
2007	$3,242,262/year

***Northeastern Buttonbush Shrub Swamp* [0.2 acres (Figures 5.34-5.35, Tables 5.62-5.63)]**
G4G5 S1

DEWAP: Coastal Plain Seasonal Pond Habitat
NHC: Central Appalachian River Floodplain

Description

Figure 5.34. Northeastern Buttonbush Shrub Swamp

This shrub community was noted is a seasonally flooded swamp north of Millers Creek. A concentration of buttonbush (*Cephalanthus occidentalis*) was noted in an open water area in the swamp.

Analysis of Condition at Assawoman Wildlife Area

This community has arisen in a flooded depression since 1937. It has been stable in amount during the recent period and is projected to remain so in the near future, therefore and change analysis was not conducted for this community. Because of the small amount and possible rises in the ground water table the long-term prospects for this community are fair.

DNREC Sea Level Rise Analysis (Table 5.62)

The depression that this community is located in will "captured" with 1 m of sea level rise, at which point the effects of salinity will kill the buttonbush (*Cepahalanthus occidentalis*).

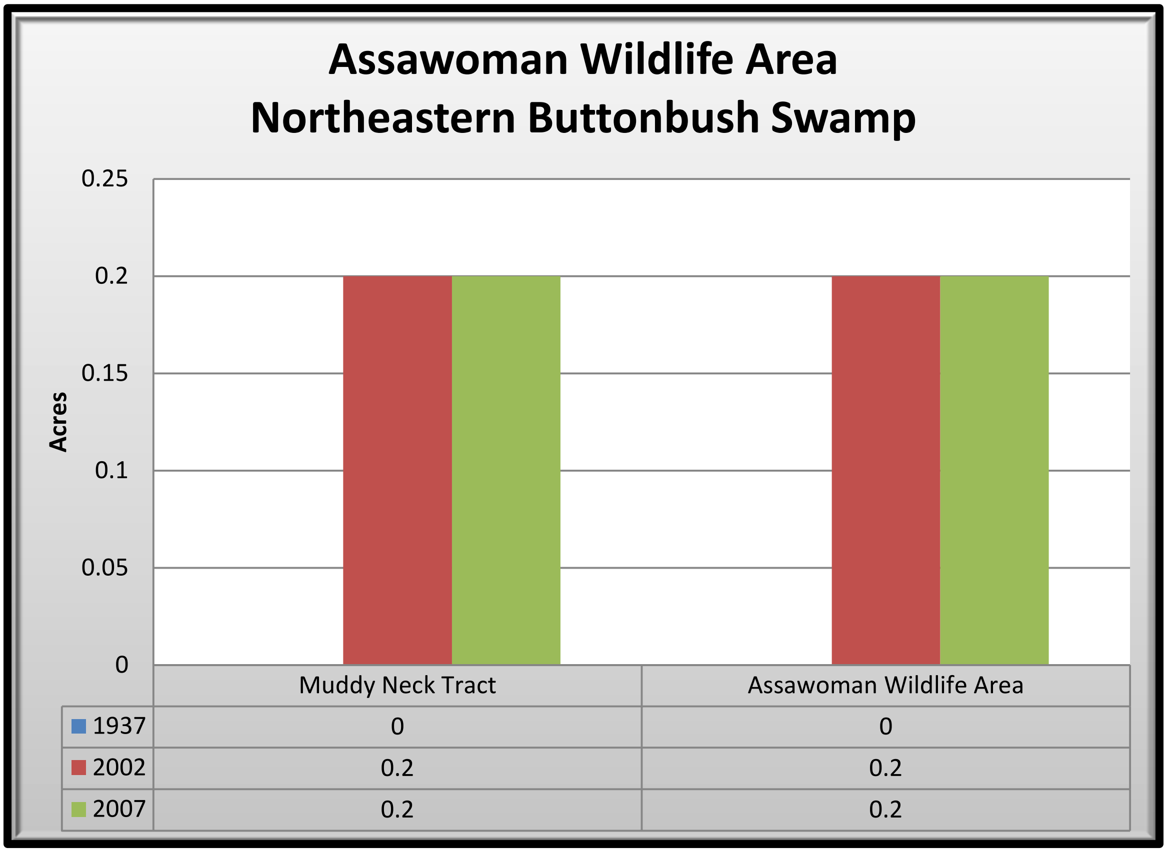
Table 5.62. Projected acres of Northeastern Buttonbush Shrub Swamp Impacted by Sea Level Rise

Rise	Acres
0.5 m	0 acres
1 m	0.1 acres
1.5 m	0.2 acres

Natural Capital (Table 5.63)

Northeastern Buttonbush Shrub Swamp was not present in 1937 and has since come into a depression that was once a Coastal Plain Pond. The capitalization from the pond was transferred to the buttonbush swamp.

Table 5.63. Natural Capital of Northeastern Buttonbush Shrub Swamp	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year
2002	$1,856/year
2007	$1,856/year



	Muddy Neck Tract	Assawoman Wildlife Area
1937	0	0
2002	0.2	0.2
2007	0.2	0.2

Figure 5.35. Buttonbush Shrub Swamp at Assawoman Wildlife Area (1937, 2002, and 2007)

***Northeastern Modified Successional Forest* [8 acres (Figures 5.36-5.37, Tables 5.64-5.66)]**
GNA SNA

DEWAP: Coastal Plain Upland Forest
NHC: Semi-natural/Altered Vegetation and Conifer Plantations

Description

This forested community is composed of an overstory of native trees with a shrub and vine understory dominated by invasive exotic species. Red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), wild black cherry (*Prunus serotina*), white oak (*Quercus alba*), southern red oak (*Quercus falcata*), and sassafras (*Sassafras albidum*) are common canopy species. The understory is composed of smaller members of the canopy plus Hercules club (*Aralia spinosa*), water oak (*Quercus nigra*), American holly (*Ilex opaca*), and mockernut oak (*Carya alba*). The shrub and vine layer is dense and composed of multiflora rose (*Rosa multiflora*), common greenbrier (*Smilax rotundifolia*), Japanese honeysuckle (*Lonicera japonica*), poison ivy (*Toxicodendron radicans*), Highbush blueberry (*Vaccinium corymbosum*), and wisteria (*Wisteria frutescens*). No herbs were noted in this community.

Figure 5.36. Northeastern Modified Succesional Forest (Muddy Neck Tract)

Analysis of Condition at Assawoman Wildlife Area

This community was not present in the wildlife area in 1937 (Figure 5.37). It arises from disturbance and infestation of invasive exotic and native plant species, which take over the understory and prevent regeneration of the canopy and native plant growth. In 1937, a lot of the potential invaders were not likely as well distributed. Since 1937 the exotics have become more established and this community spotlights where they have gained a foothold in the forest community. In Assawoman Wildlife Area it has located around dredge spoils in the Muddy Neck Tract and old agricultural fields in the Piney Point Tract. Careful management of exotic plant species can prevent this community from forming in regenerating areas.

Since 1937, this community has arisen from 4 acres of agricultural field, 2 acres Chesapeake Bay Non-riverine Wet Hardwood Forest, and 1 acre of Northeastern Successional Shrubland (Table 5.64).

Table 5.64. Northeastern Modified Successional Forest has migrated into X or remained since 1937	
X	**Acreage**
Agricultural Field	4 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	2 acres
Northeastern Successional Shrubland	1 acre

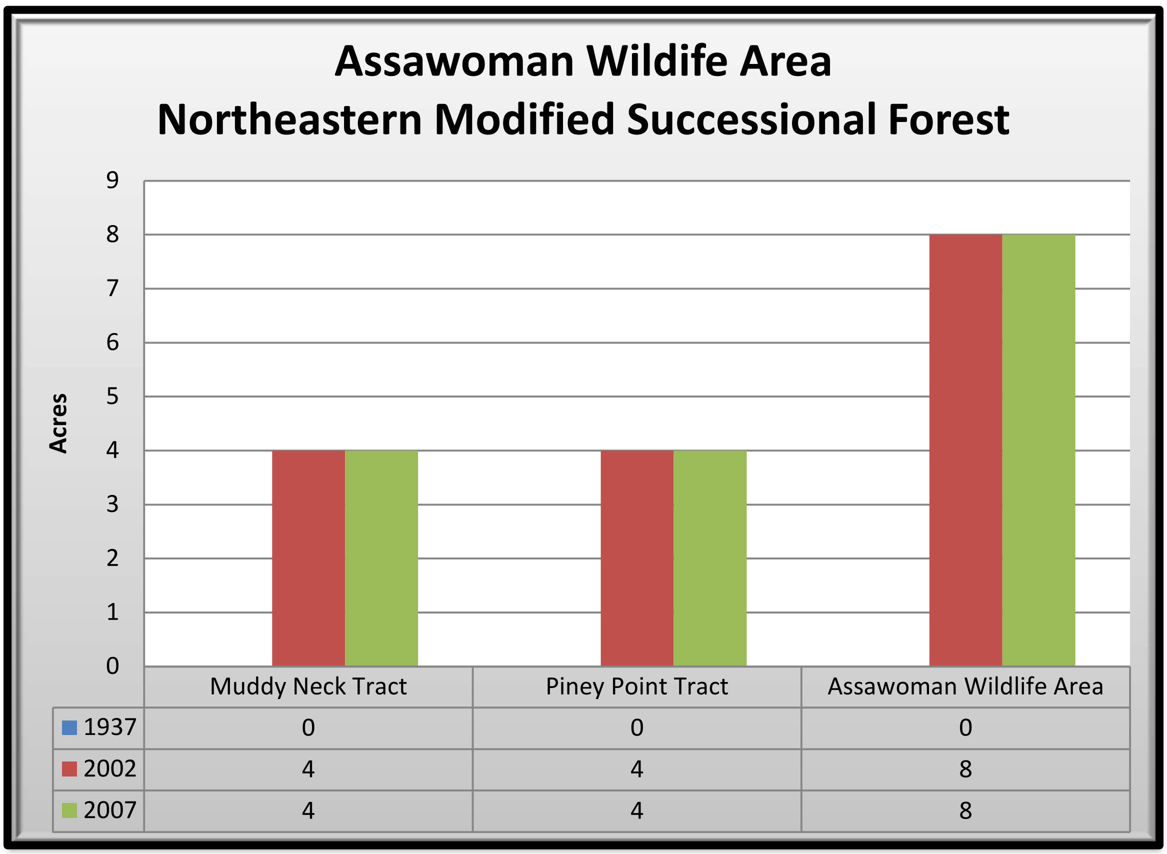


Figure 5.37. Northeastern Modified Successional Forest at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.65)

Very little of this community will be impacted by any of the current sea level rise scenarios. At the maximum about 1 acre will be lost to inundation.

Table 5.65. Projected acres of Northeastern Modified Successional Forest Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	0.01 acres
1 m	0.6 acres
1.5 m	0.7 acres

Natural Capital (Table 5.66)

Northeastern Modified Successional Forest has a small acreage and does not contribute much to the ecosystem budget for the wildlife area. The amount has been constant since 2002 and not much is projected to be lost in the future.

Table 5.66. Natural Capital of Northeastern Modified Successional Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year
2002	$1,513/year
2007	$1,513/year

***Northeastern Old Field* [71 acres (Figures 5.38-5.39, Tables 5.67-5.70)] GNR S5**

DEWAP: Early Successional Upland Habitat
NHC: Semi-natural/Altered Vegetation and Conifer Plantations

Description

Figure 5.38. Northeastern Old Field (Miller Neck Tract)

Northeastern old fields are fields that are mowed once or less per year or are abandoned from agriculture or both. Tall fescue (*Festuca arundinacea*) is often a dominant and is joined by horseweed (*Conyza canadensis*), broom-sedge (*Andropogon virginicus*), and Canada goldenrod (*Solidago canadensis*).

Analysis of Condition at Assawoman Wildlife Area

This community often arises from the abandonment of agricultural activities or other disturbances which clear the land. It has oscillated through time as more agricultural land is "retired" or lands are being opened for wildlife fields or buffers on existing agricultural fields. The community will likely be around for some time on the wildlife area in varying amounts as wildlife fields and abandoned agricultural fields.

Only 2 acres of the Northeastern Old Field from 1937 still remained in 2007. The rest had become 55 acres of Coastal Loblolly Pine Wetland Forest, 17 acres of North Atlantic Low Salt Marsh, 13 acres of Southern Red Oak/Heath Forest, 9 acres of cultivated lawn, and 7 acres of North Atlantic High Salt Marsh (Table 5.67). Since 1937, the acreage of Northeastern Old Field has decreased as these communities mature into shrublands and forests. New fields have come into 58 acres of agricultural field, 4 acres of Early to Mid-Successional Loblolly Pine Forest, 3 acres of Chesapeake Bay Non-riverine Wet Hardwood Forest, and 1 acre of Maritime Red Cedar Woodland (Table 5.68).

Table 5.67. What was once Northeastern Old Field in 1937 has become X or remained in 2007	
X	**Acreage**
Coastal Loblolly Pine Wetland Forest	55 acres
North Atlantic Low Salt Marsh	17 acres
Southern Red Oak/Heath Forest	13 acres
Cultivated Lawn	9 acres
North Atlantic High Salt Marsh	7 acres
Other communities/land covers	39 acres

Table 5.68. Northeastern Old Field has migrated into X or remained since 1937	
X	**Acreage**
Agricultural Field	58 acres
Early to Mid-Successional Loblolly Pine Forest	4 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	3 acres
Northeastern Old Field	2 acres
Maritime Red Cedar Woodland	1 acre
Other communities/land covers	2 acres

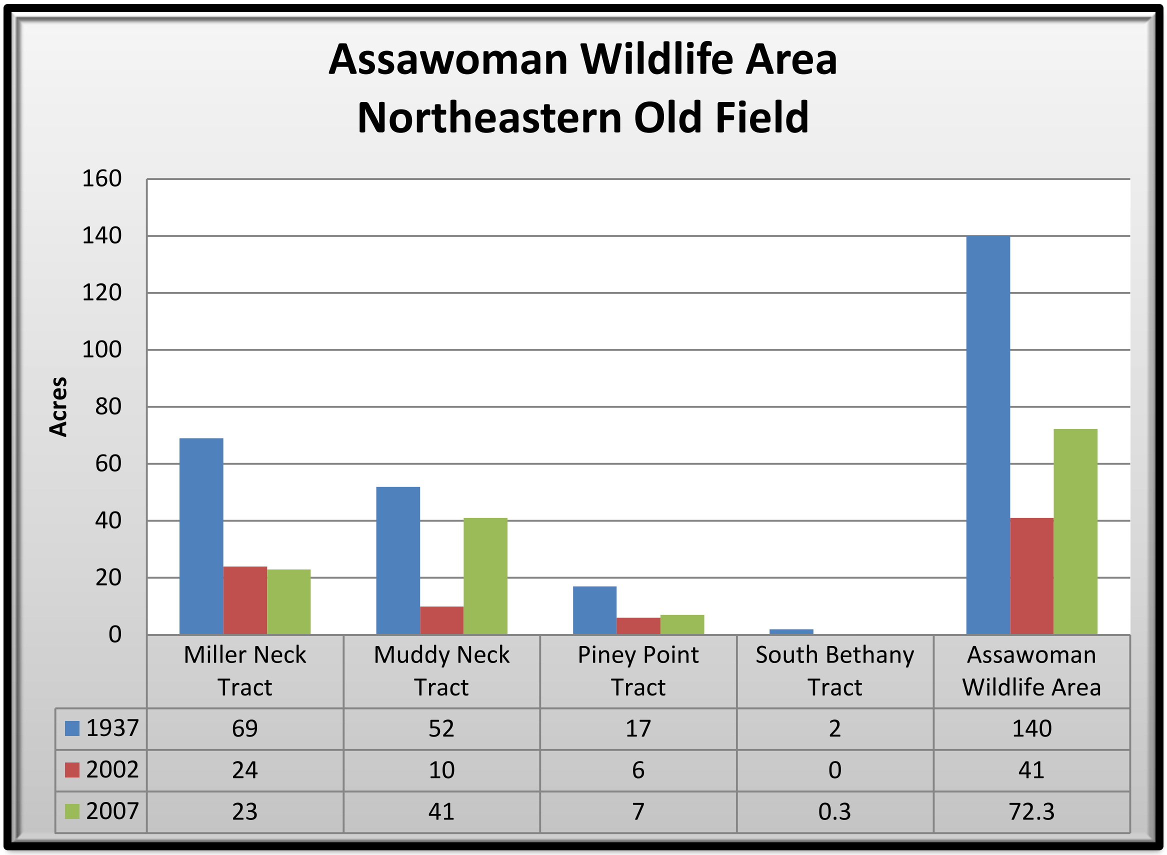


Figure 5.39. Northeastern Old Field at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.69)

A little more than half of the current Northeastern Old Field acreage will be affected by the highest sea level rise (1.5 m). At 0.5 m of rise 29 acres will inundation and at 1 m, 37 acres will be inundated. The highest scenario would flood 42 acres. This community often originates from abandoned agricultural fields and tends to oscillate in amount as fields are abandoned or put back to use.

Table 5.69. Projected acres of Northeastern Old Field Impacted by Sea Level Rise

Rise	Acres
0.5 m	29 acres
1 m	37 acres
1.5 m	42 acres

Natural Capital (Table 5.70)

Northeastern Old Field oscillates in amount depending on how many agricultural fields have been abandoned.

Table 5.70. Natural Capital of Northeastern Old Field	
Year	**Natural Capital (in 2012 dollars)**
1937	$20,398/year
2002	$5,974/year
2007	$10,490/year

Northeastern Successional Shrubland **[6.1 acres (Figure 5.40, Tables 5.71-5.74)] GNA SNA**

DEWAP: Early Successional Upland Habitat
NHC: Semi-natural/Altered Vegetation and Conifer Plantations

Description

This shrub community arises from Northeastern Old Fields and is composed of shrubs. In Delaware it is most often composed of exotic invasive shrubs but can be of natives as well in another successional step to forestland. They can also be found at the edges of agricultural fields and as hedgerows.

A typical shrubland of this type at Assawoman Wildlife Area is comprised of blackberry (*Rubus* sp.), multiflora rose (*Rosa multiflora*), Japanese honeysuckle (*Lonicera japonica*), Hercules club (*Aralia spinosa*), red maple (*Acer rubrum*), and sweetgum (*Liquidambar styraciflua*).

Analysis of Condition at Assawoman Wildlife Area

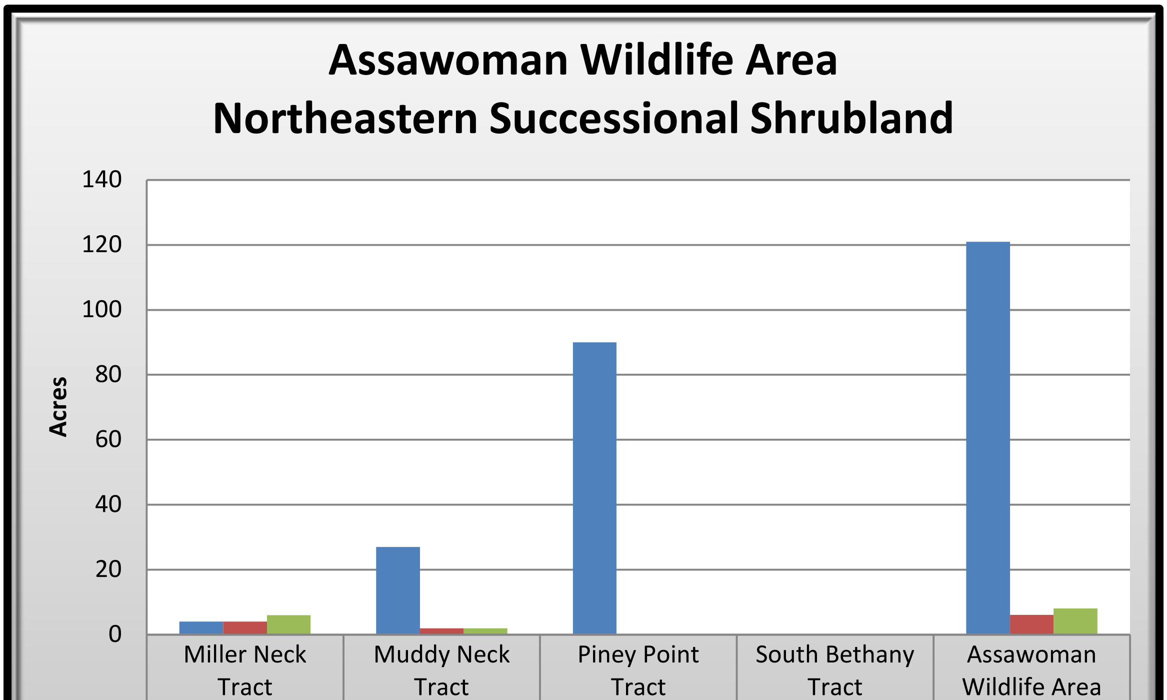
These shrublands have generally declined as they mature into forests. Muddy Neck tract contained the most acreage of this community historically but it has declined to about 3 acres now.

In 2007, none of the acreage from 1937 was still present showing the very successional nature of this community. All of the shrublands had gone on the become 36 acres of Chesapeake Bay Non-riverine Wet Hardwood Forest, 28 acres of Southern Red Oak/Heath Forest, 15 acres each of Reed Tidal Marsh and Successional Maritime Forest, and 6 acres of Irregularly Flooded Eastern Tidal Salt Shrub (Table 5.71). Since 1937 this community has populated 5 acres of agricultural field, 1 acre of Early to Mid-Successional Loblolly Pine Forest, 0.2 acres of Cultivated Lawn, and 0.1 acres of North Atlantic High Salt Marsh (Table 5.72).

Table 5.71. What was once Northeastern Successional Shrubland in 1937 has become X or remained in 2007

X	Acreage
Chesapeake Bay Non-riverine Wet Hardwood Forest	36 acres
Southern Red Oak/Heath Forest	28 acres
Reed Tidal Marsh	15 acres
Successional Maritime Forest	15 acres
Irregularly Flooded Eastern Tidal Salt Shrub	6 acres
Other communities/land covers	22 acres

Table 5.72. Northeastern Successional Shrubland has migrated into X or remained since 1937	
X	**Acreage**
Agricultural Field	5 acres
Early to Mid-Successional Loblolly Pine Forest	1 acre
Cultivated Lawn	0.2 acres
North Atlantic High Salt Marsh	0.1 acres
North Atlantic Low Salt Marsh	0.05 acres
Other vegetation communities/Land Covers	0.04 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937	4	27	90	0	121
2002	4	2	0	0.1	6.1
2007	6	2	0	0.05	8.05

Figure 5.40. Northeastern Successional Shrubland at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.73)

Northeastern Successional Shrubland will be lightly affected in its current extent, but the current shrubland will likely mature to another community by the time sea level rise affects it.

Table 5.73. Projected acres of Northeastern Successional Shrubland Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	1 acre
1 m	2 acres
1.5 m	3 acres

Natural Capital (Table 5.74)

Northeastern Successional Shrubland oscillates in amount depending on the amount of Northeastern Old Field and the abandoned agricultural fields.

Table 5.74. Natural Capital of Northeastern Successional Shrubland	
Year	**Natural Capital (in 2012 dollars)**
1937	$17,630/year
2002	$874/year
2007	$1,166/year

***Red Maple-Sweetgum Swamp* [221 acres (Figures 5.41-5.42, Tables 5.75-5.78)] G4G5 S2**

DEWAP: Coastal Plain Floodplain and Riverine Forest Habitat
NHC: Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest

Description

Red maple (*Acer rubrum*) and sweetgum (*Liquidambar styraciflua*) dominates the canopy in this forested community which occurs in seasonally flooded depressions. Other canopy associates include loblolly pine (*Pinus taeda*), pond pine (*Pinus serotina*), and blackgum (*Nyssa sylvatica*). The understory tends to be sparse, which is likely due to the water, and includes mostly American holly (*Ilex opaca*) and sweetbay (*Magnolia virginiana*). Highbush blueberry (*Vaccinium corymbosum*) was the only shrub noted. The herbaceous layer is composed of cinnamon fern (*Osmunda cinnamomea*), netted chain-fern (*Woodwardia areolata*), and partridgeberry (*Mitchella repens*).

Figure 5.41. Red Maple-Sweetgum Swamp (Muddy Neck Tract)

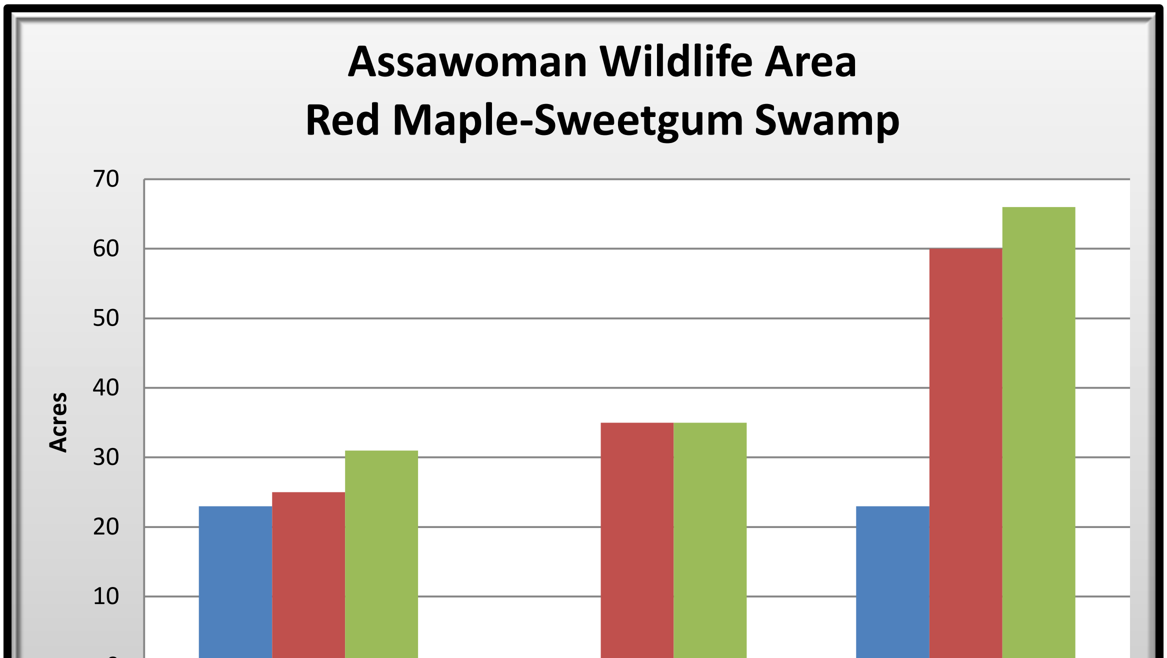
Analysis of Condition at Assawoman Wildlife Area

Most of this community has remained since 1937 with very little converting to other community types (Table 5.75). This community has been gaining with an increase in the hydrology of the area and maturation of younger forests such as Early to Mid-Successional Loblolly Pine Forest and Coastal Loblolly Pine Wetland Forest (Table 5.76).

Table 5.75. What was once Red Maple-Sweetgum Swamp in 1937 has become X or remained in 2007

X	Acreage
Red Maple-Sweetgum Swamp	22 acres
Cultivated Lawn	0.3 acres
Water	0.2 acres
Coastal Loblolly Pine Wetland Forest	0.2 acres

Table 5.76. Red Maple-Sweetgum Swamp has migrated into X or remained since 1937	
X	Acreage
Red Maple-Sweetgum Swamp	22 acres
Early to Mid-Successional Loblolly Pine Forest	18 acres
Coastal Loblolly Pine Wetland Forest	14 acres
Northeastern Old Field	4 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	3 acres
Other communities/land covers	4 acres



	Miller Neck Tract	Muddy Neck Tract	Assawoman Wildlife Area
1937	23	0	23
2002	25	35	60
2007	31	35	66

Figure 5.42. Red Maple-Sweetgum Swamp at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis(Table 5.77)

A lot of the impacts to Red Maple-Sweetgum Swamp from sea level rise will be due to "captures" from adjoining marsh and rising groundwater. About 13 acres will be impacted by 0.5 m of rise, 46 acres with 1 m of rise, and 61 acres with 1.5 m leading to virtual elimination of the community. Red Maple-Sweetgum Swamp is not likely to migrate due since it is found in depressions. Once the depressions are flooded it will have no other places to go unless new depressions form.

Table 5.77. Projected acres of Red Maple-Sweetgum Swamp Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	13 acres
1 m	46 acres
1.5 m	61 acres

Natural Capital (Table 5.78)

Red Maple-Sweetgum Swamp has been increasing in capitalization because of increases in acreage, though the additional flooding of existing depressions.

Table 5.78. Natural Capital of Red Maple-Sweetgum Swamp	
Year	**Natural Capital (in 2012 dollars)**
1937	$282,705/year
2002	$737,490/year
2007	$811,239/year

***Reed Tidal Marsh* [84 acres (Figures 5.43-5.44, Tables 5.79-5.82)]   GNA   SNA**

DEWAP: Tidal High Marsh Habitat
NHC: Northern Atlantic Coastal Plain Tidal Salt Marsh

Description

Figure 5.43. Reed Tidal Marsh (Miller Neck)

Reed Tidal Marsh is dominated completely by eastern reed grass (*Phragmites australis*) and is influenced by tide as compared to the Eastern Reed Marsh is which is not tidal.

Analysis of Condition at Assawoman Wildlife Area

This community is composed of an invasive exotic plant species, common reed (*Phragmites australis*), that was a relative newcomer to the marshes in 1937. Since this time though, it has made significant gains in acreage at the expense of three main communities, North Atlantic Low Salt Marsh, Northeastern Successional Shrubland, and North Atlantic High Salt Marsh.

Reed Tidal Marsh is very fluid as it dies off and then reappears in other areas. At Assawoman Wildlife Area, it has been helped in some respects with the building of the impoundments. In 2007, only 0.2 acres of the original 13 acres present in 1937 still remained. The rest of the acreage had become 4 acres of North Atlantic Low Salt Marsh, 3 acres each of impoundment and Eastern Reed Marsh (associated with the impoundments), 2 acres of North Atlantic High Salt Marsh (likely saved by eradication efforts), and 1 acre of water (Table 5.79). Since 1937, this marsh has migrated into many communities, resulting in large net gains. North Atlantic Low Salt Marsh has lost 30 acres, Northeastern Successional Shrubland has lost 15 acres, 9 acres of North Atlantic High Salt Marsh, 5 acres of Early to Mid-Successional Loblolly Pine Forest, and 3 acres of Irregularly Flooded Eastern Tidal Salt Shrub have all been converted (Table 5.80).

This community needs to be controlled and eliminated given the losses to the native marshland. Eradication of this marsh, may in the short-term, help to increase the acreage of the North Atlantic High Salt Marsh.

Table 5.79. What was once Reed Tidal Marsh in 1937 has become X or remained in 2007	
X	**Acreage**
North Atlantic Low Salt Marsh	4 acres
Impoundment	3 acres
Eastern Reed Marsh	3 acres
North Atlantic High Salt Marsh	2 acres
Water	1 acre
Other vegetation communities/land covers	1 acre

Table 5.80. Reed Tidal Marsh has migrated into X or remained since 1937	
X	**Acreage**
North Atlantic Low Salt Marsh	30 acres
Northeaster Successional Shrubland	15 acres
North Atlantic High Salt Marsh	9 acres
Early to Mid-Successional Loblolly Pine Forest	5 acres
Irregularly Flooded Eastern Tidal Salt Shrub	3 acres
Other communities/land covers	11 acres

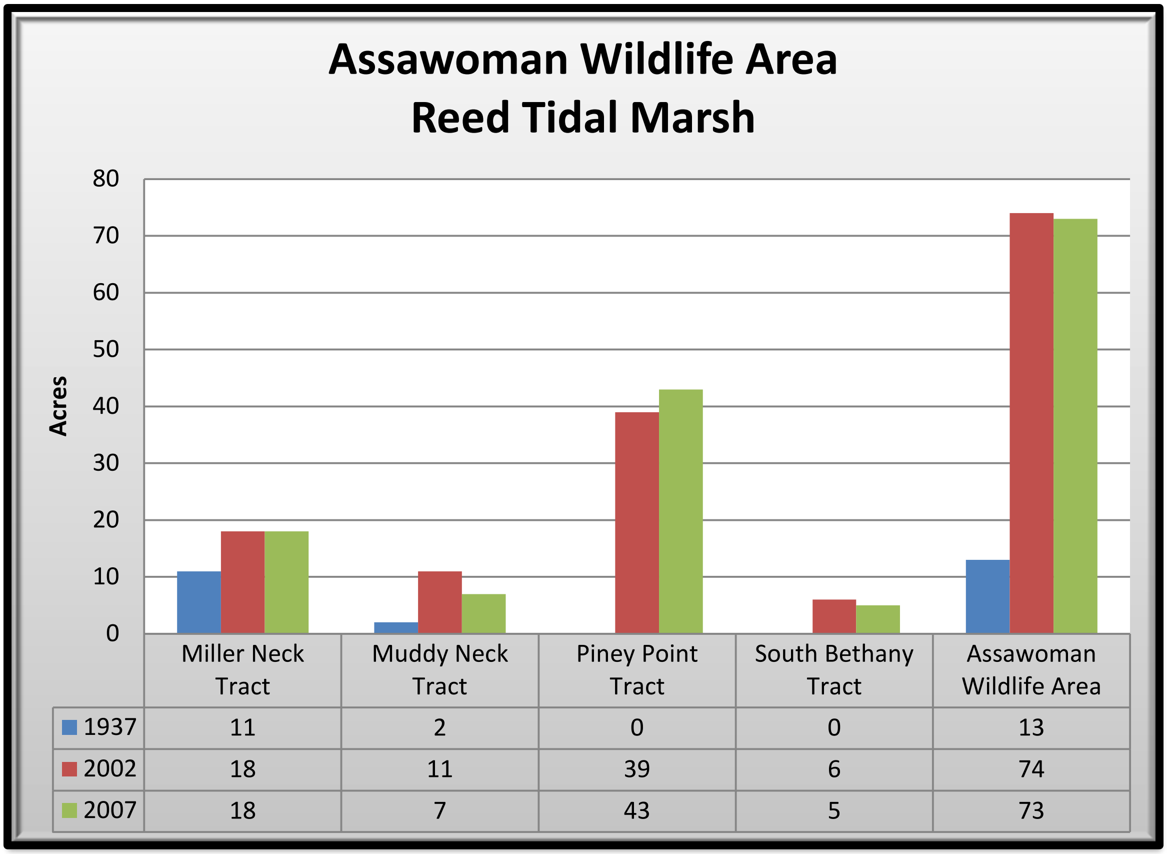


Figure 5.44. Reed Tidal Marsh at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.81)

Reed Tidal Marsh will practically be eliminated in its current extent with 0.5 m of sea level rise. However, given the invasive characteristics of the dominant species it will likely find new areas to colonize with the rise in sea level.

Table 5.81. Projected acres of Reed Tidal Marsh Impacted by Sea Level Rise

Rise	Acres
0.5 m	72 acres
1 m	73 acres
1.5 m	73 acres

Natural Capital (Table 5.82)

Despite being an invasive community, these areas are still wetlands and provide some filtering capacity and ecosystem value, though not as much as natural communities. The capitalization of this community has increased markedly since 1937 with increases in acreage, however, a slight transfer to North Atlantic Low Salt Marsh was seen in the recent period (2002-2007).

Table 5.82. Natural Capital of Reed Tidal Marsh	
Year	**Natural Capital (in 2012 dollars)**
1937	$81,527/year
2002	$464,076/year
2007	$457,805/year

Salt Panne **[1 acre, (Figure 5.45, Tables 5.83-5.85)] G5 S3**

DEWAP: Tidal Low Marsh Habitat
NHC: Northern Atlantic Coastal Plain Tidal Salt Marsh

Description

This herbaceous community is one of the most saline in the state. It arises from depressions in the salt marsh. Water in these depressions which left from the tide begins to evaporate resulting in saltier environment than the normal brackish water. A unique assemblage of plants is found in these depressions and is generally dominated by glasswort (*Salicornia virginica*) and dwarf glasswort (*Salicornia bigelovii*), which are associated by sea lavender (*Limonium carolinianum*) and halbeard-leaf orache (*Atriplex patula*). All of the occurrences of this community were obtained through aerial imagery analysis.

Analysis of Condition at Assawoman Wildlife Area

These communities tend to come and go and do not remain for a long period. As long as there is marsh present in the wildlife these areas will tend to remain.

This community was not present or discernible in the 1937 imagery. Since 1937 it has come into 1 acre of North Atlantic Low Salt Marsh and 0.3 acres of water (Table 5.83).

Table 5.83. Salt Panne has migrated into X or remained since 1937

X	Acreage
North Atlantic Low Salt Marsh	1 acre
Water	0.3 acres

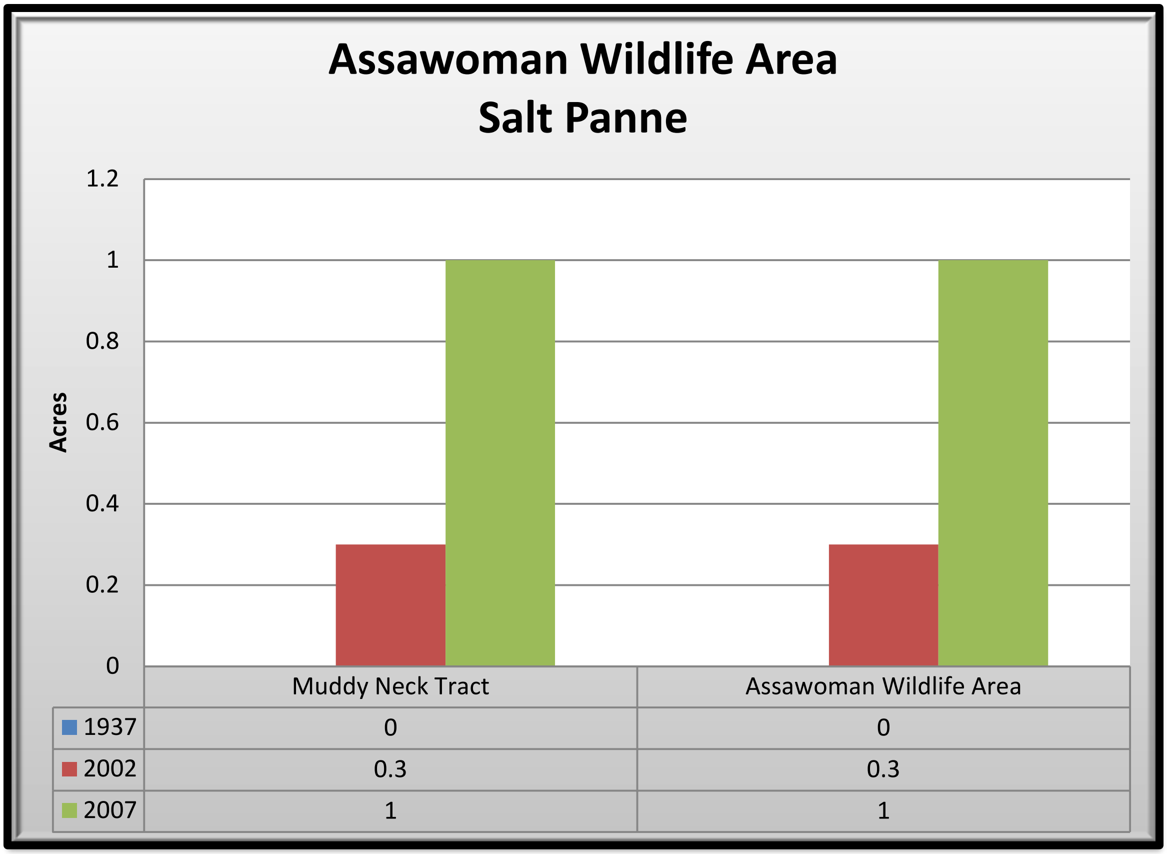


Figure 5.35. Salt Panne at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.84)

Salt Pannes will be eliminated in their current extent with 0.5 m of sea level rise. However, given the invasive characteristics of the dominant species it will likely find new areas to colonize with the rise in sea level.

Table 5.84. Projected acres of Salt Panne Impacted by Sea Level Rise

Rise	Acres
0.5 m	1 acre
1 m	1 acre
1.5 m	1 acre

Natural Capital (Table 5.85)

Salt Pannes contribute a very small amount of capitalization to the budget at Assawoman Wildlife Area. Sea level rise is expected to reduce this amount to $0.00.

Table 5.85. Natural Capital of Salt Panne	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year (not present)
2002	$1,881/year
2007	$6,271/year

***Southern Red Oak/Heath Forest* [59 acres (Figures 5.46-5.47, Tables 5.86-5.89)] G4G5 S5**

DEWAP: Coastal Plain Upland Forest Habitat
NHC: Northern Atlantic Coastal Plain Hardwood Forest

Description

This forested community is drier than most on the wildlife area is composed of southern red oak (*Quercus falcata*), sassafras (*Sassafras albidum*), and loblolly pine (*Pinus taeda*). Understory associates are primarily smaller members of the canopy plus American holly (*Ilex opaca*) and a few sweetbay (*Magnolia virginiana*) in some of the wetter areas. The shrub and vine layer is very similar to the other communities around it and includes lowbush blueberry (*Vaccinium vacillans*), highbush blueberry (*Vaccinium corymbosum*), and common greenbrier (*Smilax rotundifolia*). Partridge-berry (*Mitchella repens*) is the only herb documented from this community.

Figure 5.46. Southern Red Oak/Heath Forest (Miller Neck)

Analysis of Condition at Assawoman Wildlife Area

This forested community is generally located in the highest elevation places in the wildlife area and is one of the mature climax communities as evidenced by all of the 10 acres from 1937 still remaining in 2007 (Table 5.86). Since 1937, this community has increased in acreage mainly from maturation of Northeastern Successional Shrubland (28 acres), Northeastern Old Field (13 acres), and 2 acres each from North Atlantic Low Salt Marsh and Early to Mid-Successional Loblolly Pine Forest (Table 5.87).

Given the higher elevation of this community and the southern nature of a lot of the species in it, the prognosis for this community is good. Sea level rise will not likely affect it in the near future and it is unknown what affect climate change will have on it but it will likely be minimal for the near term.

Table 5.86. What was once Southern Red Oak/Heath Forest in 1937 has become X or remained in 2007	
X	**Acreage**
Southern Red Oak/Heath Forest	10 acres

Table 5.87. Southern Red Oak/Heath Forest has migrated into X or remained since 1937

X	Acreage
Northeastern Successional Shrubland	28 acres
Northeastern Old Field	13 acres
Southern Red Oak/Heath Forest	10 acres
North Atlantic Low Salt Marsh	2 acres
Early to Mid-Successional Loblolly Pine Forest	2 acres
Other communities/land covers	2 acres

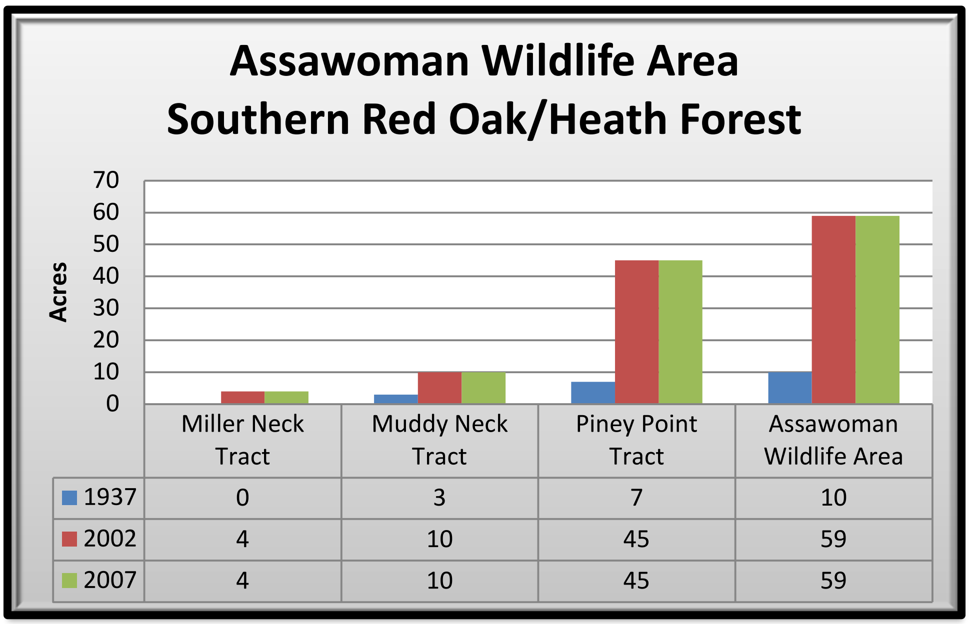


Figure 5.47. Southern Red Oak/Heath Forest at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.88)

About 15 acres of Southern Red Oak/Heath Forest will be inundated by 0.5 m of sea level rise, with an additional 15 acres at 1 m of rise, and 43 acres will be inundated with 1.5 m of rise. Since there are few high areas present in the wildlife area this community will likely migrate out of the wildlife area to higher ground or will be absorbed into places where it already is located.

Table 5.88. Projected acres of Southern Red Oak/Heath Forest Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	15 acres
1 m	30 acres
1.5 m	43 acres

Natural Capital (Table 5.89)

Maturation of early successional communities has transferred more to the capitalization of this community over time. Sea level rise, however, may in time reduce the amounts.

Table 5.89. Natural Capital of Southern Red Oak/Heath Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$1,891/year
2002	$11,157/year
2007	$11,157/year

***Successional Maritime Forest* [49 acres (Figures 5.48-5.50, Tables 5.90-5.93)] G2G3 S3**

DEWAP: Coastal Plain Upland Forest Habitat
NHC: Northern Atlantic Coastal Plain Maritime Forest

Description

This often stunted forested community is located on the edges of salt marshes. Common associates in the canopy include wild black cherry (*Prunus serotina*), persimmon (*Diospyros virginiana*), water oak (*Quercus nigra*), black willow (*Salix nigra*), and loblolly pine (*Pinus taeda*). American holly (*Ilex opaca*), eastern red cedar (*Juniperus virginiana*), and southern red oak (*Quercus falcata*) compose the understory. Highbush blueberry (*Vaccinium corymbosum*) composes the shrub layer and common greenbrier (*Smilax rotundifolia*) the vine layer. Reed grass (*Phragmites australis*) was the only herb noted in this community and was present only in occasional infestations.

Figure 5.48. Successional Maritime Forest (Piney Point Tract)

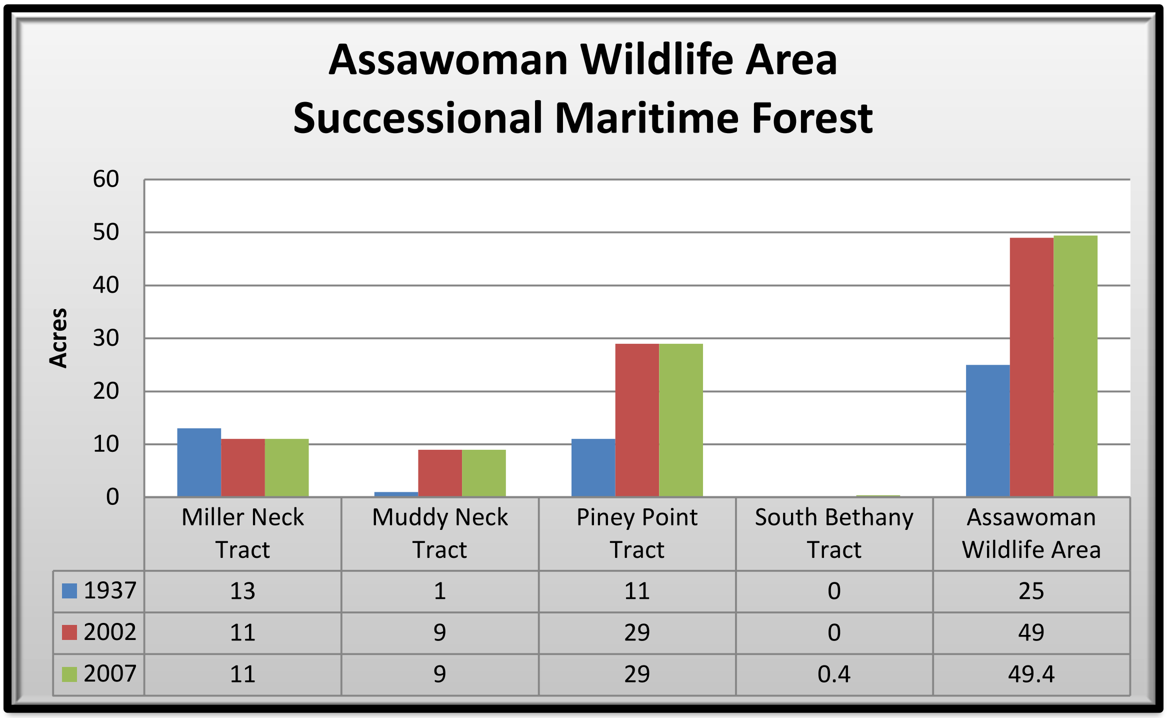
Analysis of Condition at Assawoman Wildlife Area

Successional Maritime Forest has overall increased at Assawoman Wildlife Area. A lot of the former Northeastern Successional Shrubland Sweetgum Forest matured to this community likely because of the proximity to saline influences. This community has been stable in the recent period. All of the occurrences of this community in the wildlife area are likely mature or at least in the late successional stage.

In 2007, 10 acres of the original 25 acres from 1937 still existed. The rest of the acreage converted to 3 acres of Reed Tidal Marsh, and 2 acres each of North Atlantic High Salt Marsh, North Atlantic Low Salt Marsh, and Irregularly Flooded Eastern Tidal Salt Shrub, showing the progression of the marsh into the adjacent uplands (Table 5.90). Since 1937, this community has increased its acreage from the maturation of 15 acres of Northeastern Successional Shrubland and 3 acres of Northeastern Old Field, and the conversion of 9 acres of North Atlantic Low Salt Marsh, and 8 acres of Coastal Loblolly Pine Wetland Forest (Table 5.91).

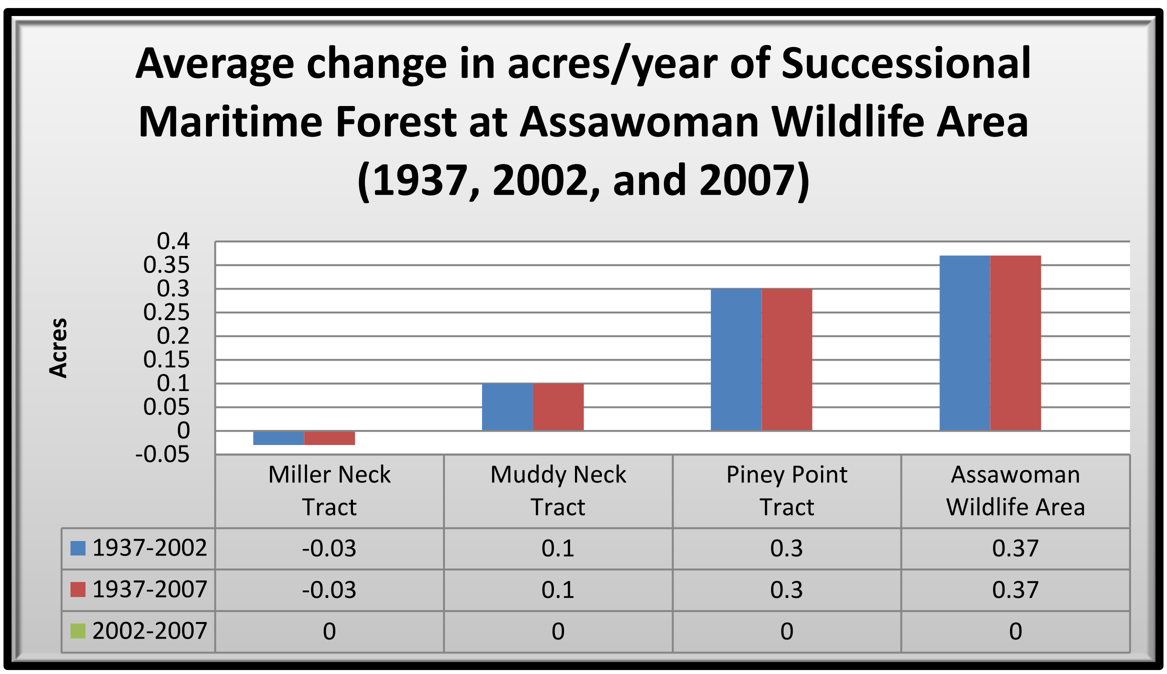
Table 5.90. What was once Successional Maritime Forest in 1937 has become X or remained in 2007	
X	**Acreage**
Successional Maritime Forest	10 acres
Reed Tidal Marsh	3 acres
North Atlantic High Salt Marsh	2 acres
North Atlantic Low Salt Marsh	2 acres
Irregularly Flooded Eastern Tidal Salt Shrub	2 acres
Other communities/land covers	6 acres

Table 5.91. Successional Maritime Forest has migrated into X or remained since 1937	
X	**Acreage**
Northeastern Successional Shrubland	15 acres
Successional Maritime Forest	10 acres
North Atlantic Low Salt Marsh	9 acres
Coastal Loblolly Pine Wetland Forest	8 acres
Northeastern Old Field	3 acres
Other communities/land covers	5 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937	13	1	11	0	25
2002	11	9	29	0	49
2007	11	9	29	0.4	49.4

Figure 5.49. Successional Maritime Forest at Assawoman Wildlife Area (1937, 2002, and 2007)



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	Assawoman Wildlife Area
1937-2002	-0.03	0.1	0.3	0.37
1937-2007	-0.03	0.1	0.3	0.37
2002-2007	0	0	0	0

Figure 5.50. Average change in acres/year of Successional Maritime Forest at Assawoman Wildlife (1937-2007)

DNREC Sea Level Rise Analysis (Table 5.92)

A little more than half of this community will be impacted by 0.5 m of sea level rise and will essentially be wiped out with 1 m and 1.5 m of sea level rise. It is unknown whether this community will convert others to maintain its acreage.

Table 5.92. Projected acres of Successional Maritime Forest Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	31 acres
1 m	42 acres
1.5 m	48 acres

Natural Capital (Table 5.93)

This community has increased in size and has had transfers of capitalization from other successional communities. Sea level rise, however, may in time reduce the capitalization.

Table 5.93. Natural Capital of Successional Maritime Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$4,728/year
2002	$9,266/year
2007	$9,342/year

***Successional Sweetgum Forest* [5 acres, (Figure 5.51, Tables 5.94-5.96)]**

DEWAP: Early Successional Upland Habitats
NHC: Semi-natural/Altered Vegetation and Conifer Plantations

Description

This successional forested community is dominated by sweetgum (*Liquidambar styraciflua*) with a few loblolly pine (*Pinus taeda*) mixed in. Underneath the low canopy, wax-myrtle (*Morella cerifera*), Japanese honeysuckle (*Lonicera japonica*), and blackberry (*Rubus* sp.) can be found.

Analysis of Condition at Assawoman Wildlife Area

Successional Sweetgum Forest is only present in the Miller Neck Tract and is a recently arrival to the wildlife area as it was not present in 1937. It has evolved from abandoned agricultural fields and a very small amount of Early to Mid-Successional Loblolly Pine Forest (Table 5.94). The occurrences in Assawoman Wildlife Area are in the early to mid-successional state and about 10-20 years old.

Table 5.94. Successional Sweetgum Forest has migrated into X or remained since 1937

X	Acreage
Agricultural Field	5 acres
Early to Mid-Successional Loblolly Pine Forest	0.4 acres

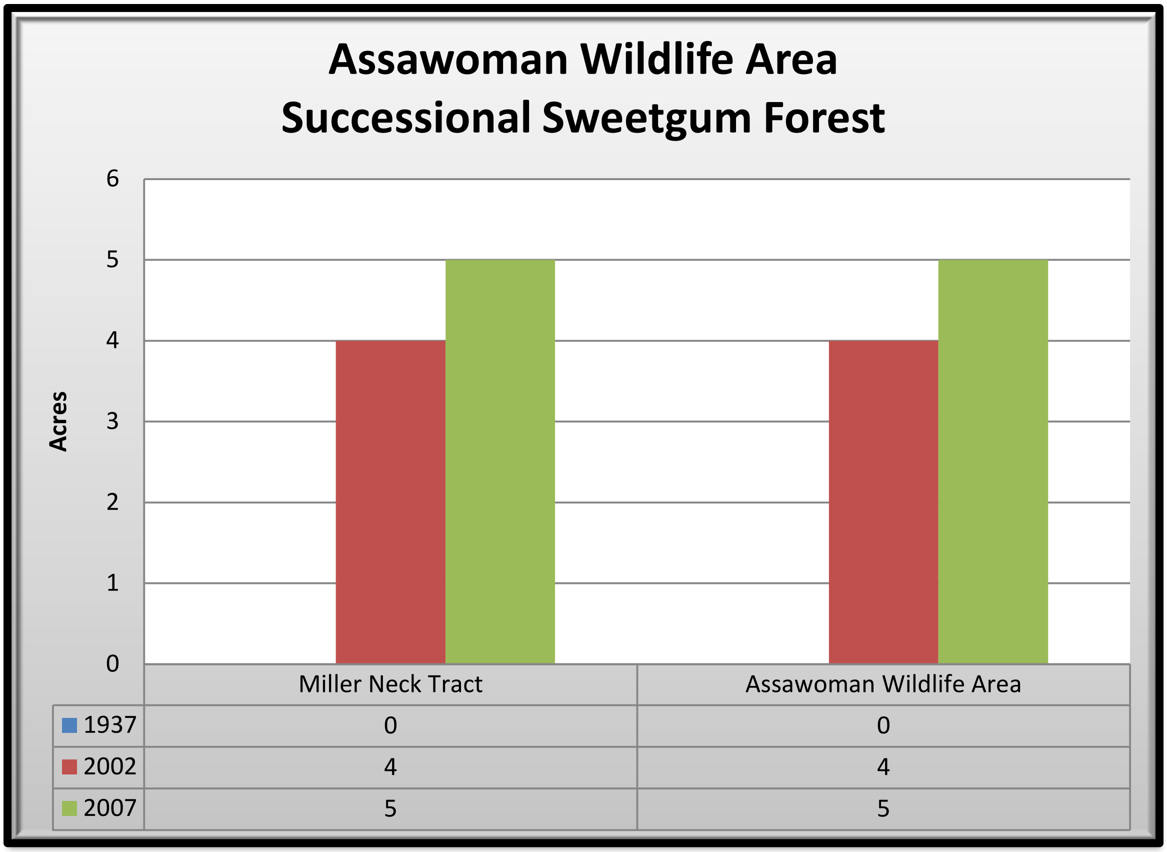


Figure 5.51. Successional Sweetgum Forest at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.95)

A small amount (1 acre) of this community will be inundated by 0.5 m of sea level rise. About half of the community will be impacted by 1 m of rise and it essentially be eliminated in its current extent with 1.5 m of rise. This community is a successional community by which other communities mature from. The inundation of this community means eliminates the possibility of this community maturing into other communities.

Table 5.95. Projected acres of Successional Sweetgum Forest Impacted by Sea Level Rise

Rise	Acres
0.5 m	1 acre
1 m	2 acres
1.5 m	4 acres

Natural Capital (Table 5.96)

This community has increased in size and has had transfers of capitalization from former agricultural fields. Sea level rise, however, may in time reduce the capitalization.

Table 5.96. Natural Capital of Successional Sweetgum Forest	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year
2002	$756/year
2007	$946/year

***Upland Switchgrass Vegetation* [20 acres (Figures 5.52-5.53, Tables 5.97-5.99)] GNR SNA**

DEWAP: Early Successional Upland Habitats
NHC: Semi-natural/Altered Vegetation and Conifer Plantations

<u>Description</u>

Figure 5.52. Upland Switchgrass Vegetation (Miller Neck Tract)

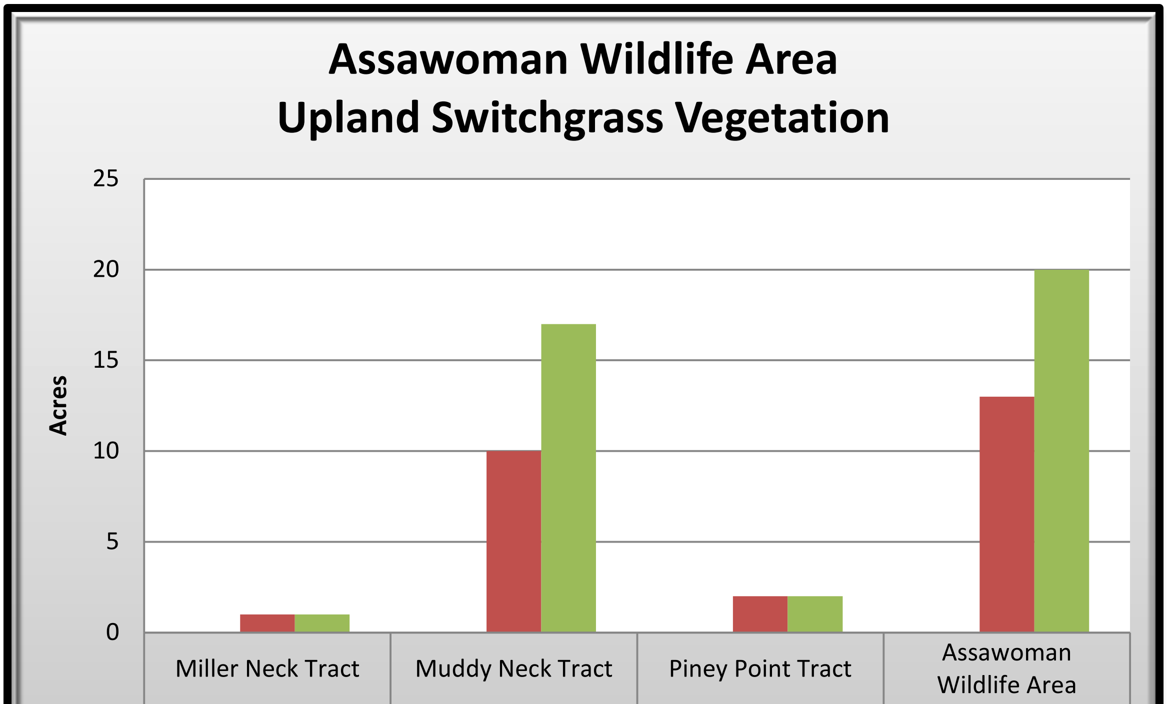
Upland Switchgrass Vegetation is located on the edges of fields that have been either reclaimed from agriculture or are partially reclaimed. Switchgrass (*Panicum virgatum*) is the dominant species and is joined by orchard grass (*Dactylis glomerata*) and tall fescue (*Festuca rubra*).

<u>Analysis of Condition at Assawoman Wildlife Area</u>

This community came about as the result of restoration efforts and as buffers in the agricultural fields (Table 5.97) in the wildlife area. It is being used for native grassland buffers of agricultural fields. The amounts are gradually increasing as this technique is used more and more.

Table 5.97. Upland Switchgrass Vegetation has migrated into X or remained since 1937

X	**Acreage**
Agricultural Field	17 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	2 acres
Early to Mid-Successional Loblolly Pine Forest	1 acre
Northeastern Old Field	0.4 acres
Cultivated Lawn	0.4 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	Assawoman Wildlife Area
1937	0	0	0	0
2002	1	10	2	13
2007	1	17	2	20

Figure 5.53. Upland Switchgrass Vegetation at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 5.98)

All of the sea level rise scenarios (0.5, 1, and 1.5 m) would inundate about 5 acres of this community.

Table 5.98. Projected acres of Upland Switchgrass Vegetation Impacted by Sea Level Rise

Rise	**Acres**
0.5 m	5 acres
1 m	5 acres
1.5 m	5 acres

Natural Capital (Table 5.99)

This community has increased in size and has had transfers of capitalization from former agricultural fields. Sea level rise, however, may in time reduce the capitalization.

Table 5.99. Natural Capital of Upland Switchgrass Vegetation	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year
2002	$1,894/year
2007	$2,914/year

CHAPTER 6: DESCRIPTIONS AND ANALYSIS OF THE LAND COVERS

Land covers are those areas such as agricultural fields or places that do not contain vegetation communities but still cover ground surface. In terms of sea-level rise, water is most important but it effects can also be seen in the impoundments.

The land covers include:

1. Agricultural Field—138 acres
2. Bare Sand—1 acre
3. Beach—3 acres
4. Farm Pond/Artificial Pond—6 acres
5. Impervious Surface—8 acres
6. Impoundment—233 acres
7. Modified Land—18 acres
8. Semi-impervious Surface—10 acres
9. Tidal Mudflat—41 acres
10. Water—135 acres

***Agricultural Field* [138 acres, (Figure 6.1, Tables 6.1-6.4)]**

DEWAP: No Equivalent Community
NHC: Agricultural

Description

Prior to becoming a wildlife area, a lot of the landscape was in agricultural use. In 1937 there were 341 acres that were planted in crops. The acreage has gradually decreased to 137 acres in 2007 with most of the previous lands converting back to forest. Most of the acreage today is used for corn crops.

Analysis of Condition at Assawoman Wildlife Area

Three of the tracts at Assawoman Wildlife Area have land that is used for agricultural purposes. Overall agriculture has been declining within the wildlife area and the abandoned fields have been converted to other uses such as Northeastern Old Field, Upland Switchgrass Vegetation and the older ones are now Coastal Loblolly Pine Wetland Forest or Early to Mid-Successional Loblolly Pine Forest. This mirrors the findings in a paper by Laura J. Shirley and Loretta L. Battaglia which found that agricultural areas in the Coastal Plain of the Gulf Coast were being replaced by forests[50].

Only 104 acres of the original 328 acres from 1937 still remain. The rest of the acreage has grown into 72 acres of Coastal Loblolly Pine Wetland Forest, 58 acres of Northeastern Old Field, 43 acres of Early to Mid-Successional Loblolly Pine Forest, and 17 acres of Upland Switchgrass that has been planted on the edges of the fields (Table 6.1). Very little agricultural fields have been developed since 1937, but 20 acres of Early to Mid-Successional Loblolly Pine Forest, and 4 acres each of Chesapeake Bay Non-riverine Wet Hardwood Forest and Coastal Loblolly Pine Forest have (Table 6.2).

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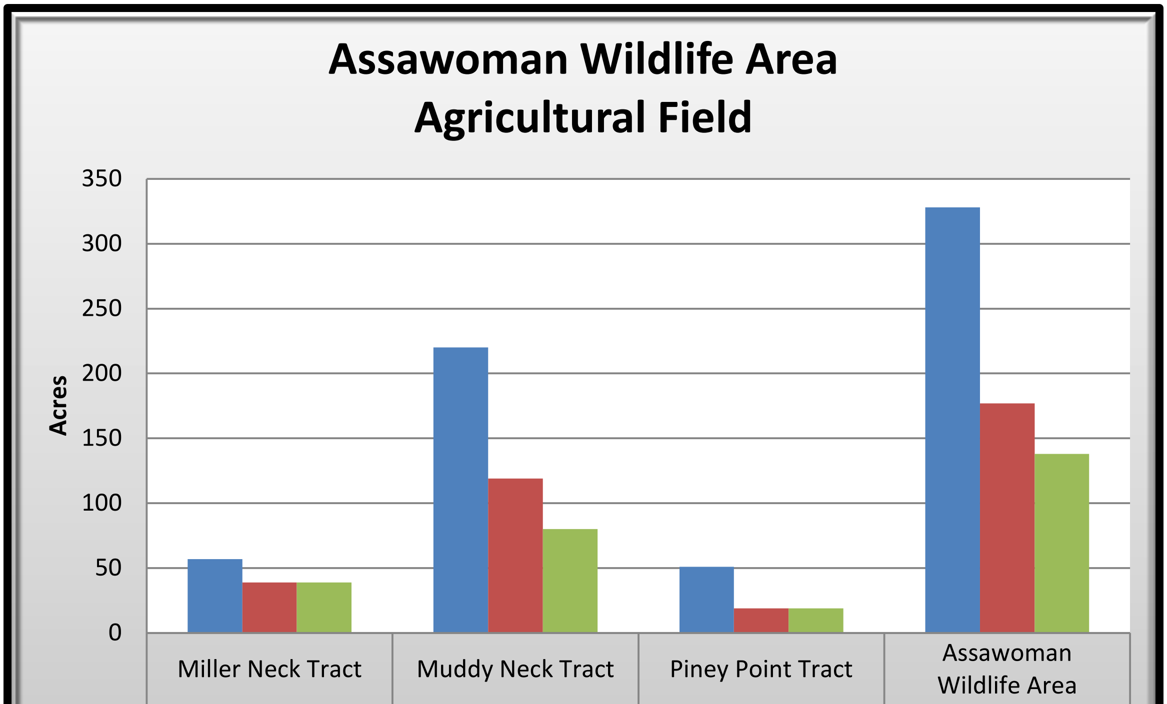
[50] Shirley, Laura J. and Loretta L. Battaglia. 2006. Assessing vegetation change in coastal landscapes of the northern Gulf of Mexico. Wetlands 26(4): 1057-1070.

Table 6.1. What was once Agricultural Field in 1937 has become X or remained in 2007	
X	**Acreage**
Agricultural Field	104 acres
Coastal Loblolly Pine Wetland Forest	72 acres
Northeastern Old Field	58 acres
Early to Mid-Successional Loblolly Pine	43 acres
Upland Switchgrass Vegetation	17 acres
Other communities/land covers	35 acres

Table 6.2. Agricultural Field has migrated into X or remained since 1937	
X	**Acreage**
Agricultural Field	104 acres
Early to Mid-Successional Loblolly Pine Forest	20 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	4 acres
Coastal Loblolly Pine Wetland Forest	4 acres
North Atlantic High Salt Marsh	1 acre
Other communities/land covers	5 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	Assawoman Wildlife Area
1937	57	220	51	328
2002	39	119	19	177
2007	39	80	19	138

Figure 6.1. Agriculture Fields at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 6.3)

About 19 acres of agricultural field would inundated with 0.5 m of sea level rise. Another 31 acres would be inundated with 1 m of rise and 79 acres would be inundated with 1.5 m of rise.

Table 6.3. Projected acres of Agricultural Field Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	19 acres
1 m	50 acres
1.5 m	79 acres

Natural Capital (Table 6.4)

The figures below do not count the value of the crops growing in the fields, only the value of the open space. Agricultural field value was at its greatest in 1937 and has been declining since. The capitalization has been transferred to other more mature communities.

Table 6.4. Natural Capital of Agricultural Field	
Year	**Natural Capital (in 2012 dollars)**
1937	$18,811/year
2002	$10,151/year
2007	$7,914/year

***Bare Sand* [1 acre, (Figure 6.2, Tables 6.5-6.8)]**

DEWAP: Nearshore Habitats
NHC: Intertidal Shore

Bare sand includes non-vegetated areas that are not in contact with water (non-beach areas). All of these areas in the wildlife area are located on the coastal strand in the South Bethany Tract.

Analysis of Condition at Assawoman Wildlife Area

The amount of bare sand has not changed in acreage during the study period except for a slight uptick in 2002, but it has moved a little and been replaced. None of the original 1937 one acre is present in 2007 with the former sand being replaced by 1 acre of Loblolly Pine Dune Woodland and 0.1 acre each of Impervious Surface and Cultivated Lawn (Table 6.5). Since 1937 this community has converted 0.4 acres of Overwash Dune Grassland and 0.1 acres of Loblolly Pine Dune Woodland (Table 6.6).

Table 6.5. What was once Bare Sand in 1937 has become X or remained in 2007	
X	**Acreage**
Loblolly Pine Dune Woodland	1 acre
Impervious Surface	0.1 acres
Cultivated Lawn	0.1 acres

Table 6.6. Bare Sand has migrated into X or remained since 1937	
X	**Acreage**
Overwash Dune Grassland	0.4 acres
Loblolly Pine Dune Woodland	0.1 acres

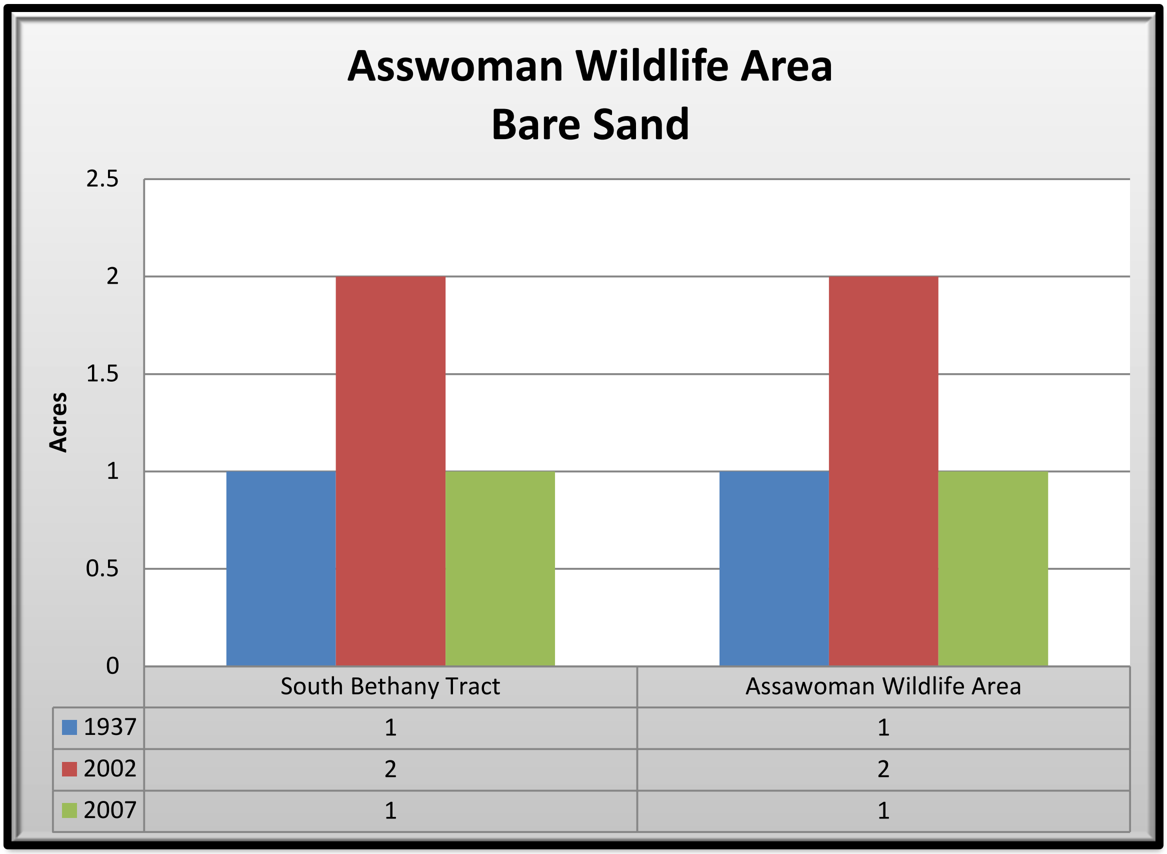


Figure 6.2. Bare Sand at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 6.7)

All of the bare sand areas in the wildlife area are located on the ocean strand of the South Bethany Tract. They tend to be on elevated dunes above the most of the sea level rise effects. However, 1.5 m of sea level rise would inundate this community completely in its current extent.

Table 6.7. Projected acres of Bare Sand Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	0.05 acres
1 m	0.4 acres
1.5 m	1 acre

Natural Capital (Table 6.8)

This land cover derives its value as undeveloped open space.

Table 6.8. Natural Capital of Bare Sand	
Year	**Natural Capital (in 2012 dollars)**
1937	$146/year
2002	$146/year
2007	$146/year

***Beach* [6 acres, (Figure 6.3, Tables 6.9-6.12)]**

DEWAP: Nearshore Habitats
NHC: Intertidal Shore

Areas of beach tend to be temporary and are at the mercy of storms and the sediment supply. Some of these areas are re-nourished on the South Bethany Tract.

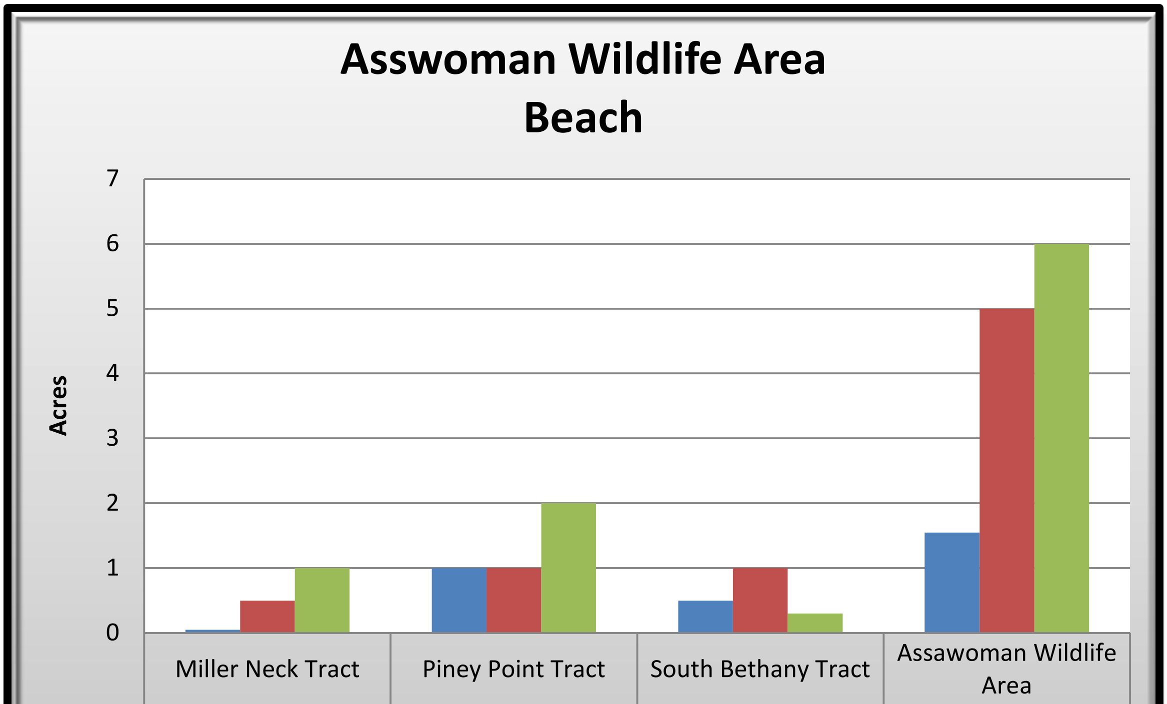
Analysis of Condition at Assawoman Wildlife Area

The amount of beach has overall increased over the study period, mostly in the South Bethany Tract where there is active beach renourishment.

In 2007, only 0.2 acres of the original 1.55 acres of beach from 1937 was still present. The rest became Irregularly Flooded Eastern Tidal Salt Shrub (0.4 acres), Cultivated Lawn (0.4 acres), Impervious Surface (0.1 acres), and Semi-impervious Surface (0.05 acres) (Table 6.9). Since 1937 beach has migrated into 1 acre each of North Atlantic Low Salt Marsh and Irregularly Flooded Eastern Tidal Salt Shrub, 0.3 acres of Cultivated Lawn, and 0.1 acres of North Atlantic High Salt Marsh (Table 6.10). These movements show the encroachment of the coast on the marsh.

Table 6.9. What was once Beach in 1937 has become X or remained in 2007	
X	**Acreage**
Irregularly Flooded Eastern Tidal Salt Shrub	0.4 acres
Cultivated Lawn	0.4 acres
Beach	0.2 acres
Impervious Surface	0.1 acres
Semi-impervious Surface	0.05 acres

Table 6.10. Beach has migrated into X or remained since 1937	
X	**Acreage**
North Atlantic Low Salt Marsh	1 acre
Irregularly Flooded Eastern Tidal Salt Shrub	1 acre
Cultivated Lawn	0.3 acres
Beach	0.2 acres
North Atlantic High Salt Marsh	0.1 acres
Other communities/land covers	0.2 acres



	Miller Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937	0.05	1	0.5	1.55
2002	0.5	1	1	5
2007	1	2	0.3	6

Figure 6.3. Beach at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 6.11)

About 2 acres of beach would be inundated with 0.5 m and 1 m of sea level rise. Another 1 acre would be added with 1.5 m of rise. A lot of the beach area is high in the dunes and above the influx of water.

Table 6.11. Projected acres of Beach Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	2 acres
1 m	2 acres
1.5 m	3 acres

Natural Capital (Table 6.12)

This land cover derives its value as undeveloped open space.

Table 6.12. Natural Capital of Beach	
Year	**Natural Capital (in 2012 dollars)**
1937	$226/year
2002	$729/year
2007	$874/year

***Farm Pond/Artificial Pond* [5 acres, (Figure 6.4, Tables 6.13-6.15)]**

DEWAP: Impoundment
NHC: No Equivalent Classification

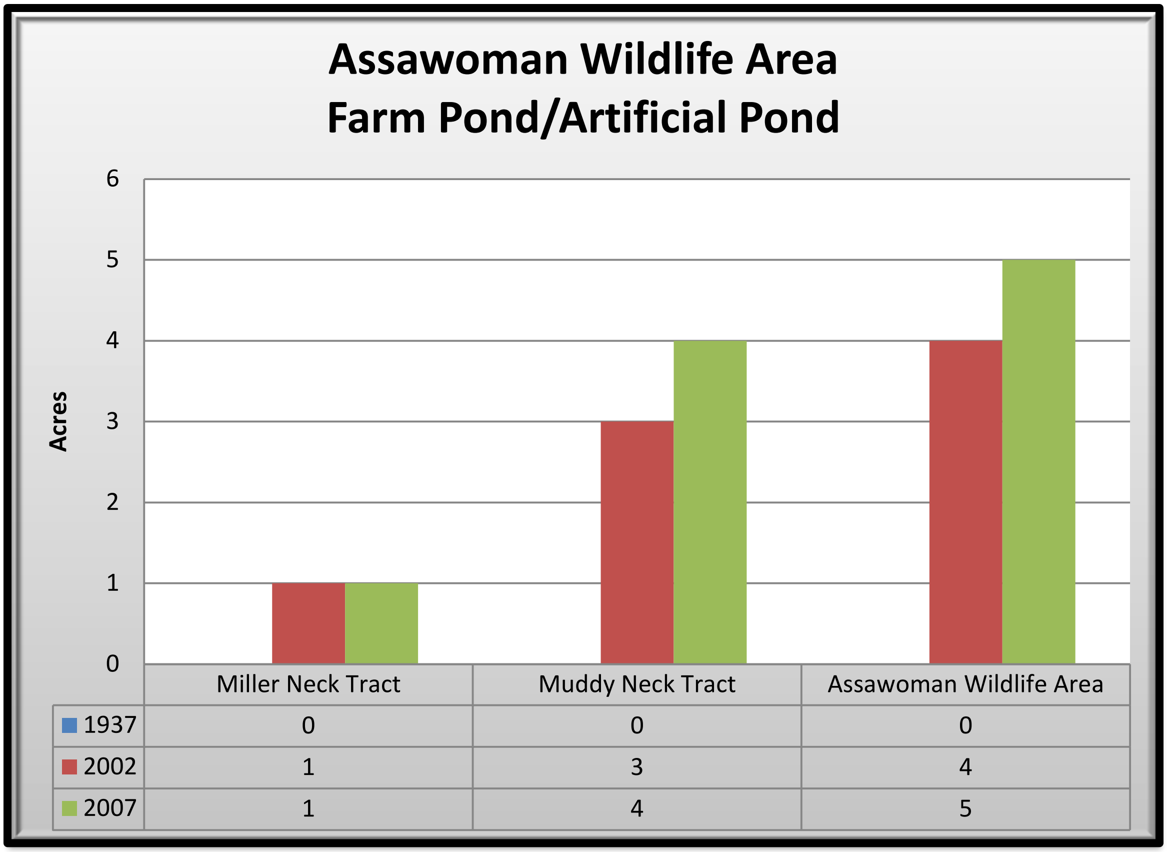
There were no farm ponds present in 1937 but in 2007 there are nine farm ponds totaling 5 acres. These ponds are located around a borrow pit in the Miller Neck Tract and around dredge spoils on the Muddy Neck Tract.

Analysis of Condition at Assawoman Wildlife Area

There has recently been an increase in ponds in the wildlife area on the Muddy Neck and Miller Neck Tracts. These ponds have been developed in 3 acres of Agricultural Field, 2 acres of Early to Mid-Successional Loblolly Pine Forest, 1 acre of Northeastern Old Field, 0.4 acres of Coastal Loblolly Pine Wetland Forest, and 0.2 acres of Maritime Red Cedar Woodland (Table 6.13). Due to the low elevation of the wildlife area some of these ponds will be "captured" by tidal water through sea level rise.

Table 6.13. Farm Pond/Artificial Pond has migrated into X or remained since 1937

X	**Acreage**
Agricultural Field	3 acres
Early to Mid-Successional Loblolly Pine Forest	2 acres
Northeastern Old Field	1 acre
Coastal Loblolly Pine Wetland Forest	0.4 acres
Maritime Red Cedar Woodland	0.2 acres
Other communities/land covers	0.3 acres



	Miller Neck Tract	Muddy Neck Tract	Assawoman Wildlife Area
1937	0	0	0
2002	1	3	4
2007	1	4	5

Figure 6.4. Farm Pond/Artificial Pond at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 6.14)

All of the current ponds at Assawoman Wildlife Area would be inundated or "captured" by sea level rise with 0.5 m of rise.

Table 6.14. Projected acres of Farm Pond/Artificial Pond Impacted by Sea Level Rise

Rise	Acres
0.5 m	5 acres
1 m	5 acres
1.5 m	5 acres

Natural Capital (Table 6.15)

This land cover derives its value as a filtering mechanism and groundwater recharge area.

Table 6.15. Natural Capital of Beach	
Year	**Natural Capital (in 2012 dollars)**
1937	$0/year
2002	$21,340/year
2007	$26,676/year

Impervious Surface **[8 acres, (Figure 6.5, Tables 6.16-6.18)]**

DEWAP: No Equivalent Classification
NHC: Commercial/Industrial

The amount of impervious surface has fluctuated with time. In 1937 there were 12 acres of impervious surface mostly as structures that have since fallen or have been removed. All of the tracts saw an increase in the 1937-2002 period with the South Bethany Tract going from none to almost 3.5 acres. An increase was seen in the 2002-2007 period in the Miller Neck Tract with new structures being built at Camp Barnes and the Wildlife Area.

Analysis of Condition at Assawoman Wildlife Area

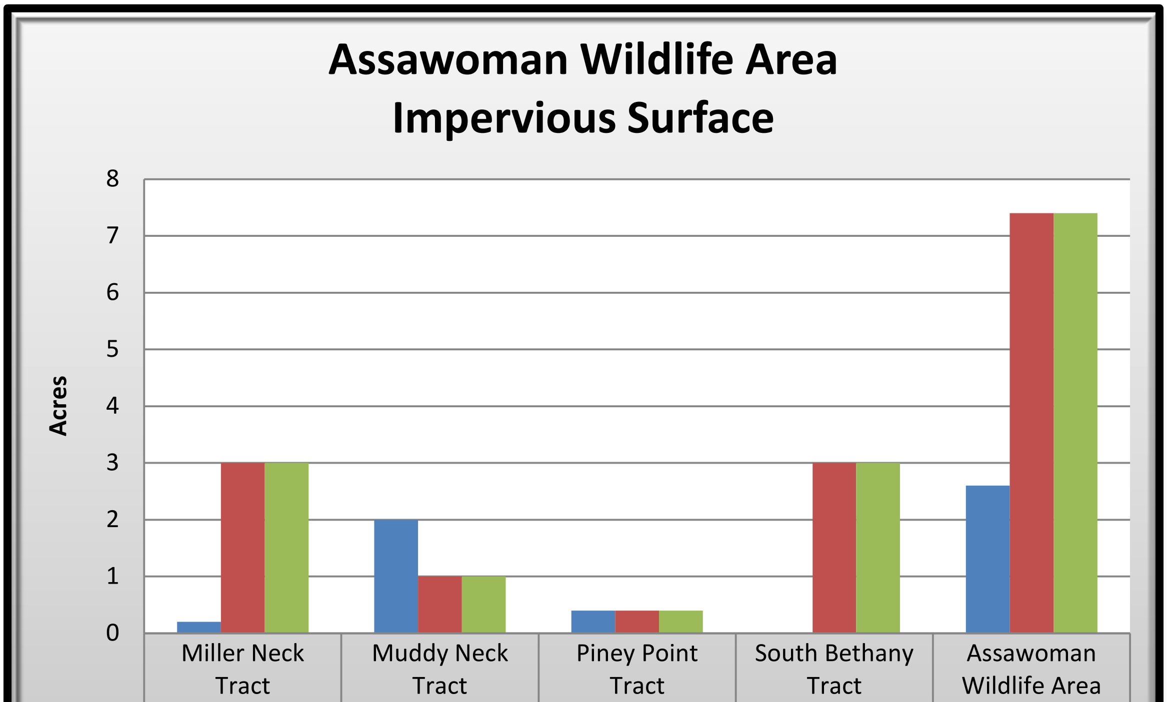
Impervious surface has greatly increased since 1937, but has been stable in the 2002 to 2007 period. In 2007, 1 acre of the original 2 acres from 1937 was still present. The other areas became 0.5 acres of Agricultural Field, 0.3 acres of Chesapeake Bay Non-riverine Wet Hardwood Forest, 0.2 acres of Semi-impervious Surface, and 0.1 acres of Upland Switchgrass Vegetation (Table 6.16). Since 1937, a lot of the increases have come from the paving of former dirt roads (2 acres), and development in Mid-Atlantic Coast Backdune Grassland (1 acre), Northeastern Old Field (1 acre), and North Atlantic Low Salt Marsh (1 acre) (Table 6.17).

Table 6.16. What was once Impervious Surface in 1937 has become X or remained in 2007

X	Acreage
Impervious Surface	1 acre
Agricultural Field	0.5 acres
Chesapeake Bay Non-riverine Wet Hardwood Forest	0.3 acres
Semi-impervious Surface	0.2 acres
Upland Switchgrass Vegetation	0.1 acres
Other communities/land covers	0.2 acres

Table 6.17. Impervious Surface has migrated into X or remained since 1937

X	Acreage
Semi-impervious Surface	2 acres
Impervious Surface	1 acre
Mid-Atlantic Coast Backdune Grassland	1 acre
Northeastern Old Field	1 acre
North Atlantic Low Salt Marsh	1 acre
Other communities/land covers	1 acre



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937	0.2	2	0.4	0	2.6
2002	3	1	0.4	3	7.4
2007	3	1	0.4	3	7.4

Figure 6.5. Impervious surface at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 6.18)

A little less than half of the impervious surface area in the wildlife area would be covered with water in a 0.5 m sea level rise. These areas would mainly be around beach access areas. In a 1 m and 1.5 m scenario, 4 acres would be inundated.

Table 6.18. Projected acres of Impervious Surface Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	3 acres
1 m	4 acres
1.5 m	4 acres

Natural Capital

This land cover does not have any natural capital value.

***Impoundment* [234 acres, (Figure 6.6, Tables 6.19-6.22)]**

DEWAP: Impoundment
NHC: No Equivalent Classification

Only one impoundment was present in 1937, which covered 29 acres and was still present in 2007 (Table 6.19). However some parts of the original impoundment were converted to cultivated lawn (0.2 acres) and water (0.1 acres). Since 1937 a lot more impoundments were developed in the 1950's and 1960's bringing the acreage to 223 acres in 2002. Since 2002, an additional 10 acres were added, mostly because of zigzag marsh being captured by tidal water through sea level rise and the indirect effects of groundwater rise. With 0.5 m of sea level rise almost all of the impoundments would be exposed to tidal water. However, efforts will likely be made to raise the tide gates to keep this from happening.

Analysis of Condition at Assawoman Wildlife Area

The addition of impoundments, inundated a lot marsh habitat accounting for 114 acres of lost North Atlantic Low Salt Marsh, 43 acres of North Atlantic High Salt Marsh, and 19 acres of Irregularly Flooded Eastern Tidal Salt Shrub (Table 6.20). In addition, one Creeping Rush-Boltonia Coastal Plain Pond was inundated in the impoundments.

Table 6.19. What was once Impoundment in 1937 has become X or remained in 2007	
X	**Acreage**
Impoundment	29 acres
Cultivated Lawn	0.2 acres
Water	0.1 acres

Table 6.20. Impoundment has migrated into X or remained since 1937	
X	**Acreage**
North Atlantic Low Salt Marsh	114 acres
North Atlantic High Salt Marsh	43 acres
Impoundment	29 acres
Irregularly Flooded Eastern Tidal Salt Shrub	19 acres
Creeping Rush-Boltonia Coastal Plain Pond	8 acres
Other communities/land covers	21 acres

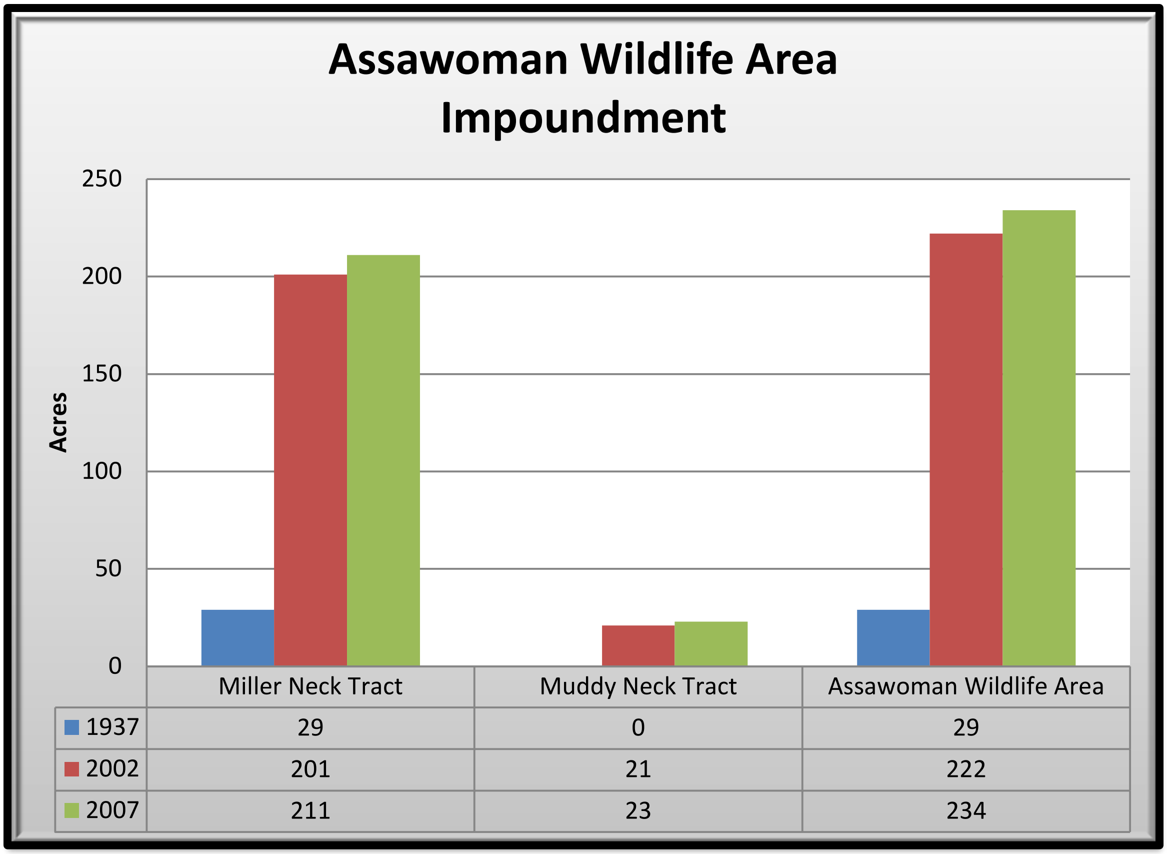


Figure 6.6. Impoundments at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 6.21)

All of the current impoundments at Assawoman Wildlife Area would be inundated or "captured" by sea level rise with 0.5 m of rise. However, it is likely that the gates holding back the impoundments will be built up to keep the impoundments.

Table 6.21. Projected acres of Farm Pond/Artificial Pond Impacted by Sea Level Rise

Rise	Acres
0.5 m	233 acres
1 m	233 acres
1.5 m	233 acres

Natural Capital (Table 6.22)

Impoundments are valuable for filtering capacity and habitat for waterfowl. This land cover is the most valuable in the wildlife area.

Table 6.22. Natural Capital of Beach	
Year	**Natural Capital (in 2012 dollars)**
1937	$154,718/year
2002	$1,184,392/year
2007	$1,248,413/year

***Modified Land* [19 acres, (Figure 6.7, Tables 6.23-6.25)]**

DEWAP: No Equivalent Classification
NHC: Quarries/Pits/Strip Mines?

Modified land denotes non-vegetated areas that have been disturbed. The largest of these is a dredge spoil that is located on the Muddy Neck Tract. Other areas include drained impoundments at the Piney Point Tract that have yet to vegetate.

Analysis of Condition at Assawoman Wildlife Area

Most of the modified land in the wildlife area is located in the Muddy Neck Tract in a dredge spoil deposition area, with smaller amounts in the Miller Neck and Piney Point Tracts. The acreage of this community has greatly increased since 1937 with one acre being gained in the Miller Neck Tract and one that has re-vegetated in the Piney Point Tract in the 2002 to 2007 period.

None of the modified land from 1937 has remained this way in 2007. Since 1 acre each has gone to Semi-impervious Surface and Impervious Surface (Table 6.23). Since 1937, modified land has been developed in 6 acres of Northeastern Old Field, 5 acres of Northeastern Successional Shrubland, and 2 acres each of Early to Mid-Successional Loblolly Pine Forest, Agricultural Field, and North Atlantic High Salt Marsh (Table 6.24).

Table 6.23. What was once Modified Land in 1937 has become X or remained in 2007

X	Acreage
Semi-impervious Surface	1 acre
Impervious Surface	1 acre

Table 6.24. Modified Land has migrated into X or remained since 1937

X	Acreage
Northeastern Old Field	6 acres
Northeastern Successional Shrubland	5 acres
Early to Mid-Successional Loblolly Pine Forest	2 acres
Agricultural Field	2 acres
North Atlantic High Salt Marsh	2 acres
Other communities/land covers	2 acres

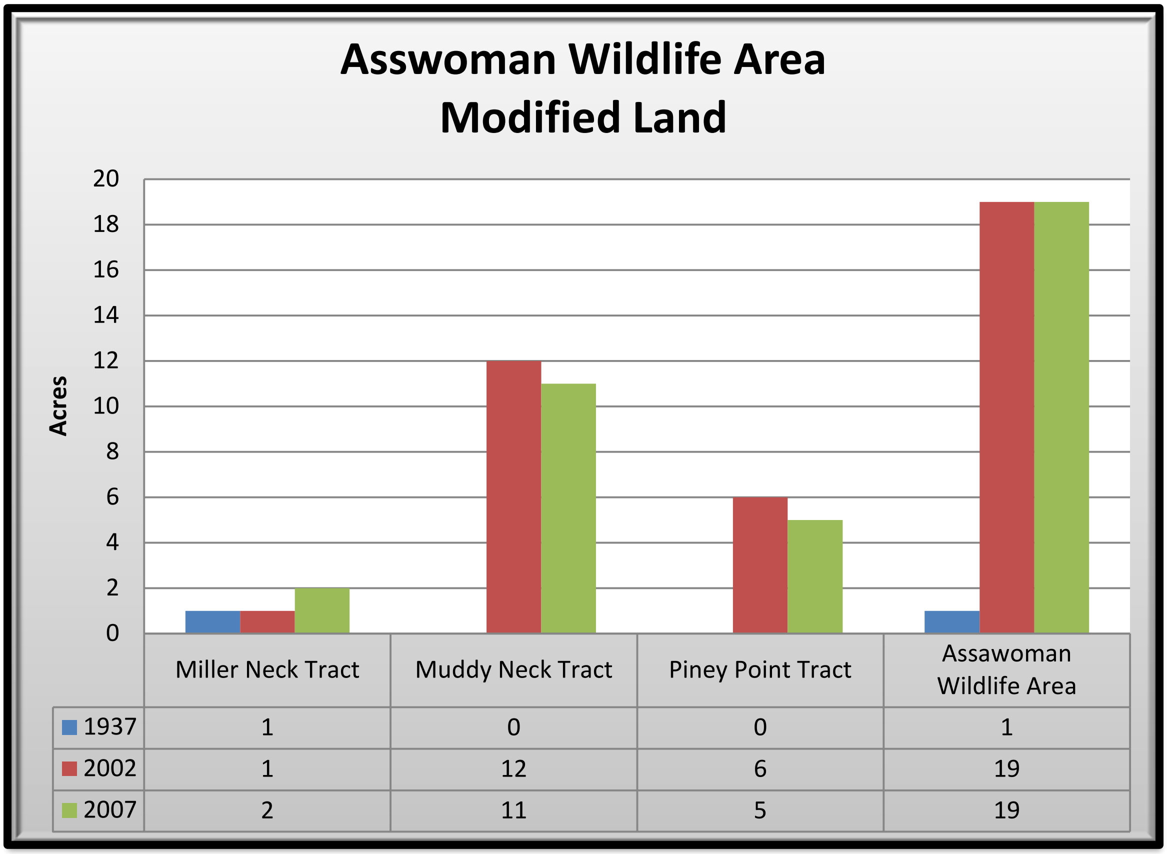


Figure 6.7. Modified Land at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 6.25)

Most of the modified land currently present will be inundated under all three scenarios.

Table 6.25. Projected acres of Modified Land Impacted by Sea Level Rise

Rise	**Acres**
0.5 m	14 acres
1 m	16 acres
1.5 m	16 acres

Natural Capital

Modified Land does not have any natural capital value.

Semi-impervious Surface **[8 acres, (Figure 5.8, Table 6.26-6.28)]**

DEWAP: No Equivalent Classification
NHC: Commercial/Industrial

This land cover includes the numerous dirt roads that go through the wildlife area. All of the roads are underlain by the sandy substrate that is common in the wildlife area. Some of these roads have been paved since 1937 resulting in a reduction of total area.

<u>*Analysis of Condition at Assawoman Wildlife Area*</u>

Semi-impervious surface in the form of dirt roads has decreased since 1937 with the paving of roads in the wildlife area and abandonment (Table 6.26). Some new dirt roads have been built on the edges of agricultural fields and former modified land (Table 6.27).

Table 6.26. What was once Semi-impervious Surface in 1937 has become X or remained in 2007

X	Acreage
Semi-impervious Surface	6 acres
Coastal Loblolly Pine Wetland Forest	4 acres
Impervious Surface	2 acres
Agricultural Field	1 acres
Cultivated Lawn	0.4 acres
Other communities/land covers	1 acre

Table 6.27. Semi-impervious Surface has migrated into X or remained since 1937

X	Acreage
Semi-impervious Surface	6 acres
Agricultural Field	1 acre
Modified Land	1 acre
Northeastern Old Field	0.5 acres
North Atlantic Low Salt Marsh	0.4 acre
Other communities/land covers	2 acres

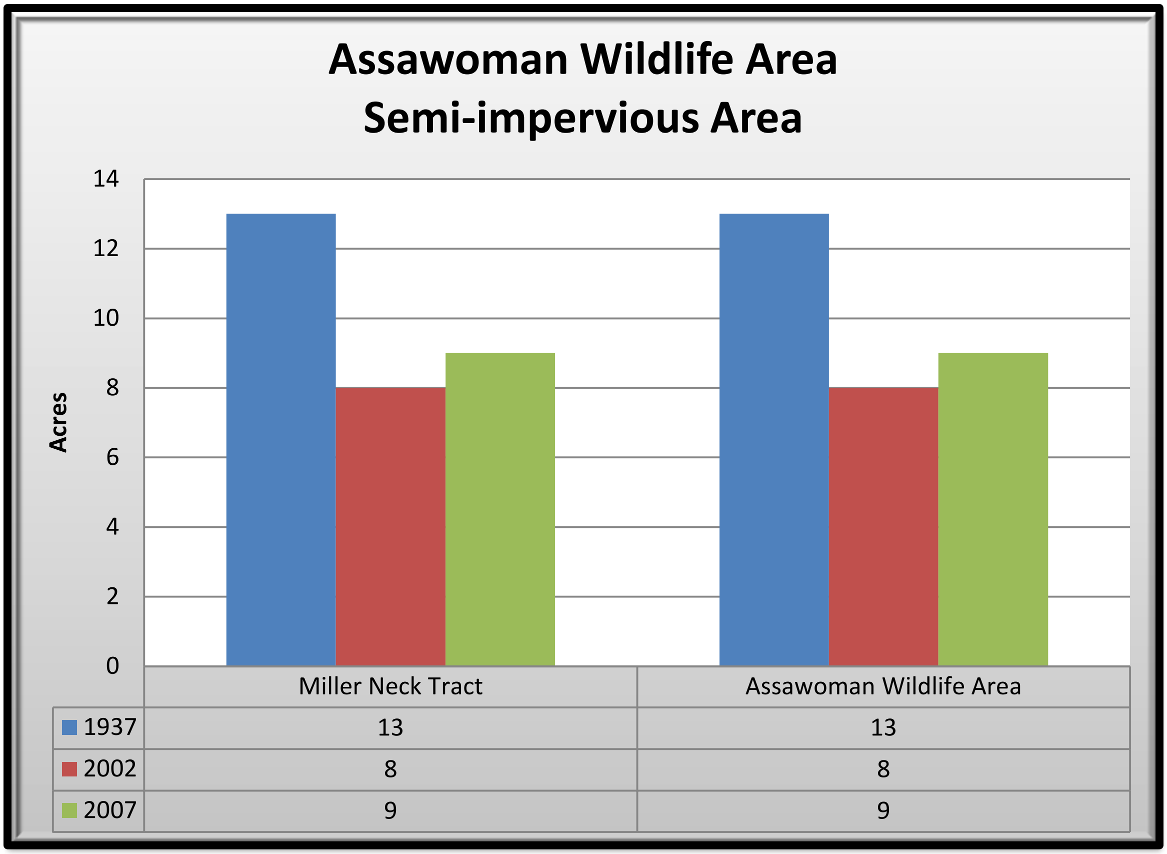


Figure 6.8. Semi-impervious Surface at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 6.28)

A little less than half of the Semi-impervious surface present today would be inundated by 0.5 m of sea level rise. Most of the current semi-impervious surface would be inundated by 1m (7 acres), and 1.5 m (8 acres).

Table 6.28. Projected acres of Semi-impervious Surface Impacted by Sea Level Rise

Rise	Acres
0.5 m	4 acres
1 m	7 acres
1.5 m	8 acres

Natural Capital

Semi-impervious surface has no natural capital value.

***Tidal Mudflat* [47.2 acres (Figure 6.9, Tables 6.29-6.32)]**

DEWAP: Nearshore Habitats
NHC: North Atlantic Intertidal Mudflat

Tidal mudflats come and go depending on the growth of salt marsh cordgrass and the movement of water. They have increased relative to 1937 but has shown a large decrease in the Muddy Neck Tract that is likely driven by topographical effects.

Analysis of Condition at Assawoman Wildlife Area

Tidal mudflats are more common in the wildlife since 1937 with oscillations in amount in any given year (Tables 6.29 and 6.30).

Table 6.29. What was once Tidal Mudflat in 1937 has become X or remained in 2007

X	Acreage
Water	5 acres
Impoundment	2 acres
North Atlantic Low Salt Marsh	0.4 acres
Tidal Mudflat	0.3 acres
Cultivated Lawn	0.2 acres

Table 6.30. Tidal Mudflat has migrated into X or remained since 1937

X	Acreage
North Atlantic Low Salt Marsh	28 acres
North Atlantic High Salt Marsh	9 acres
Needlerush High Marsh	1 acre
Northeastern Old Field	1 acre
Irregularly Flooded Eastern Tidal Salt Shrub	0.5 acres
Other communities/land covers	1 acre

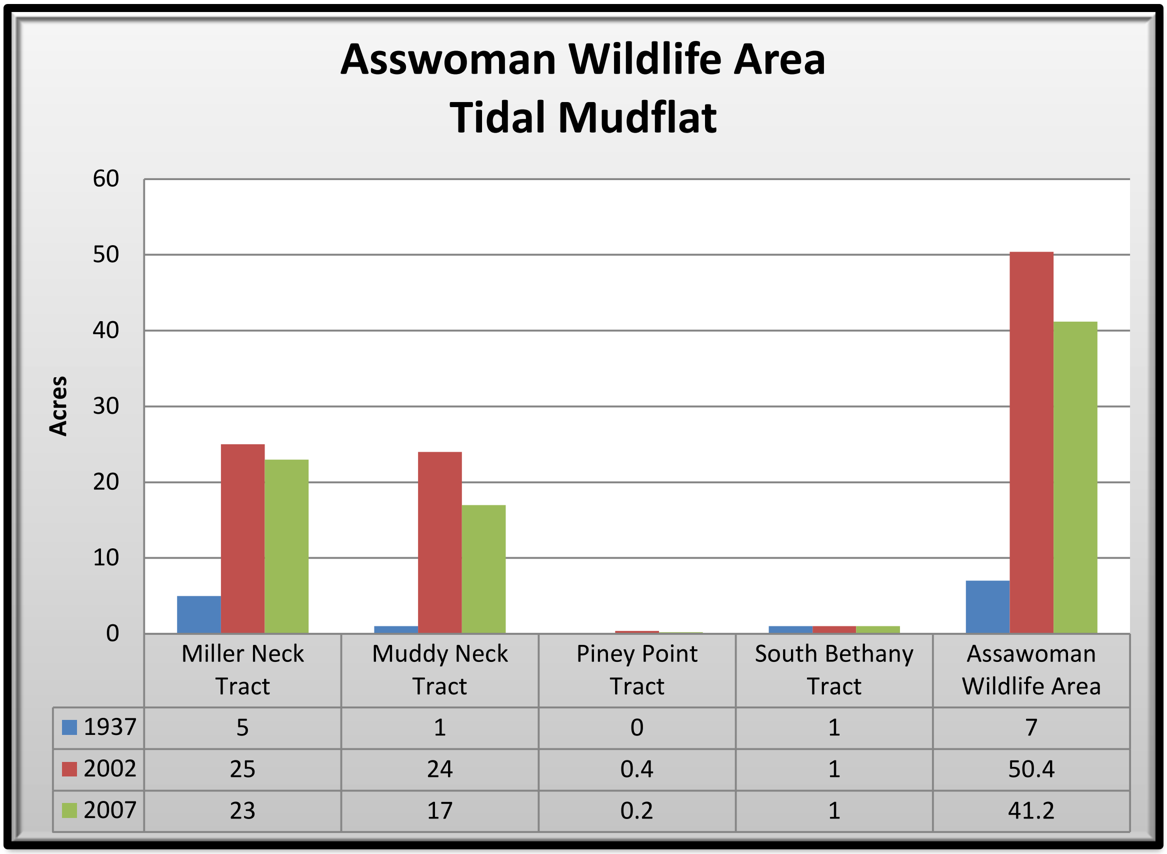


Figure 6.9. Tidal Mudflat at Assawoman Wildlife Area (1937, 2002, and 2007)

DNREC Sea Level Rise Analysis (Table 6.31)

All of the current tidal marsh at Assawoman Wildlife Area would be inundated with 0.5 m of rise.

Table 6.31. Projected acres of Tidal Mudflat Impacted by Sea Level Rise	
Rise	**Acres**
0.5 m	41 acres
1 m	41 acres
1.5 m	41 acres

Natural Capital (Table 6.32)

Tidal mudflats tend to go up and down in amount since they are a transitional land cover. They do have some filtering value in the marsh.

Table 6.32. Natural Capital of Tidal Mudflat	
Year	**Natural Capital (in 2012 dollars)**
1937	$43,889/year
2002	$316,074/year
2007	$258,378/year

Water **[125 acres, (Figures 5.10-5.11, Tables 6.33-6.35)]**

DEWAP: Nearshore Habitats
NHC: No Equivalent Community

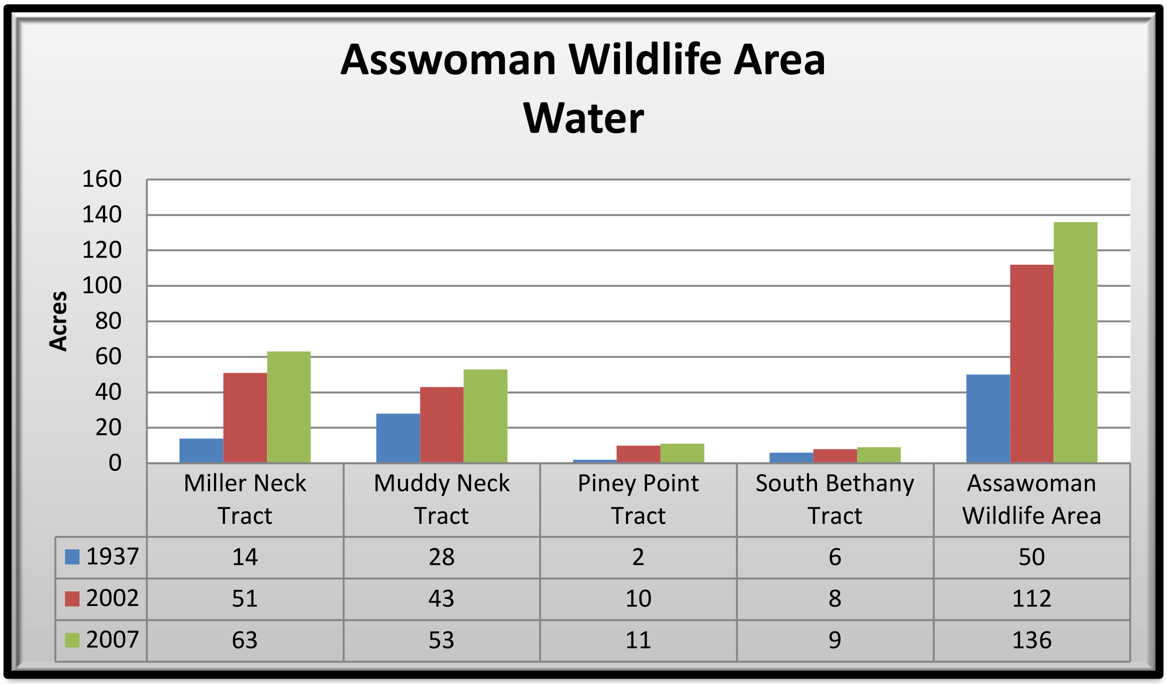
The amount of water present is often the bellwether of sea level rise along with the changes in the vegetation communities associated. In 2007 31 acres of the water present in 1937 still remained. The rest became 7 acres of North Atlantic Low Salt Marsh, 5 acres of impoundment, and 2 acres each of Needlerush High Marsh, and Successional Maritime Forest (Table 6.33). Since 1937, 56 acres of North Atlantic Low Salt Marsh has been inundated along with 21 acres of North Atlantic High Salt Marsh, 6 acres of Creeping Rush Boltonia Coastal Plain Pond that was "captured", and 5 acres of Tidal Mudflat (Table 6.34).

Table 6.33. What was once Water in 1937 has become X or remained in 2007

X	Acreage
Water	31 acres
North Atlantic Low Salt Marsh	7 acres
Impoundment	5 acres
Needlerush High Marsh	2 acres
Successional Maritime Forest	2 acres
Other communities/land covers	3 acres

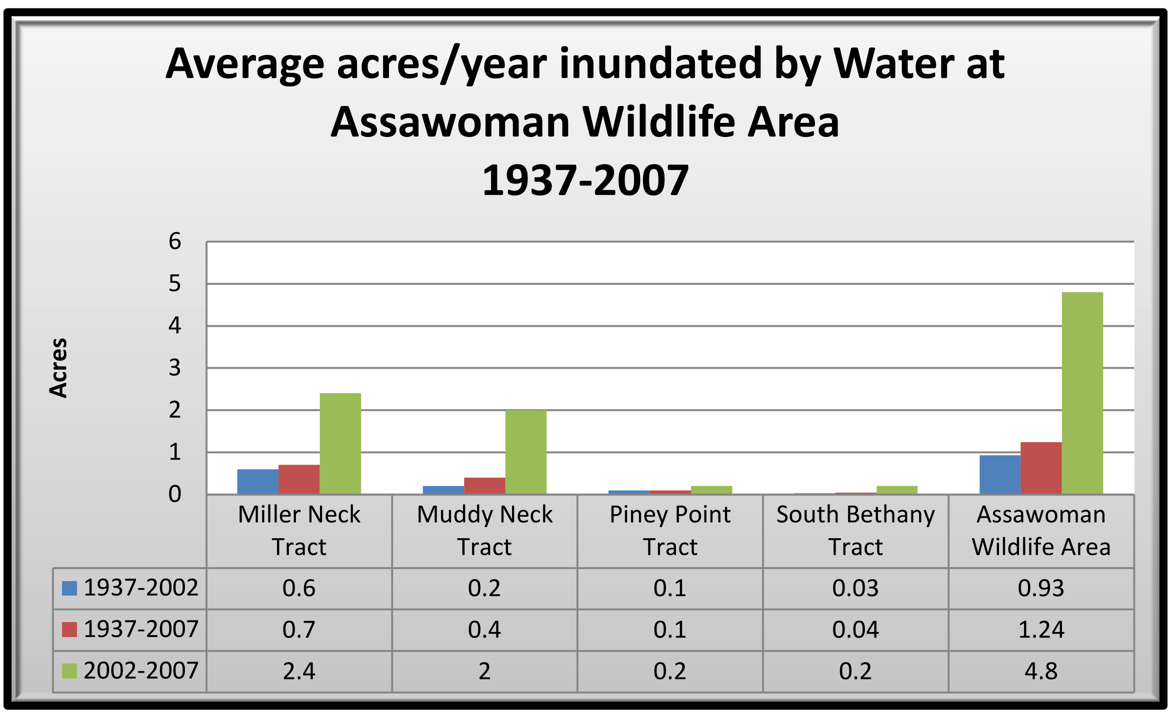
Table 6.34. Water has migrated into X or remained since 1937

X	Acreage
North Atlantic Low Salt Marsh	56 acres
Water	31 acres
North Atlantic High Salt Marsh	21 acres
Creeping Rush Boltonia Coastal Plain Pond	6 acres
Tidal Mudflat	5 acres
Other communities/land covers	17 acres



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937	14	28	2	6	50
2002	51	43	10	8	112
2007	63	53	11	9	136

Figure 6.10. Water at Assawoman Wildlife Area (1937, 2002, and 2007)



	Miller Neck Tract	Muddy Neck Tract	Piney Point Tract	South Bethany Tract	Assawoman Wildlife Area
1937-2002	0.6	0.2	0.1	0.03	0.93
1937-2007	0.7	0.4	0.1	0.04	1.24
2002-2007	2.4	2	0.2	0.2	4.8

Figure 6.11. Acres of land per year inundated by water at Assawoman Wildlife Area (1937-2007)

DNREC Sea Level Rise Analysis

Sea level rise does apply in this case since water is the one rising.

Natural Capital (Table 6.35)

Water is part of the estuary of the Inland Bays and as such is an important cycler of nutrients. The amount has steadily gone upward as sea level rises.

Table 6.35. Natural Capital of Water	
Year	**Natural Capital (in 2012 dollars)**
1937	$716,643/year
2002	$1,605,279/year
2007	$1,949,268/year

CHAPTER 7: DISCUSSION, CONCLUSION AND THE FUTURE OF ASSAWOMAN WILDLIFE AREA

Overall Summary and Conclusion

Assawoman Wildlife Area is probably the most vulnerable with respect to sea level rise because of the low elevation. The rate of sea level rise has recently risen when compared to the historic rate leading to salt exposure and death of trees adjacent to the marsh and changes in the vegetation communities most exposed to brackish effects and salt spray. While most impacts to the tidal marsh occurred during the building of the impoundments, there are still losses occurring within these marsh areas and in one case the elimination of North Atlantic High Salt Marsh in the South Bethany Tract.

Other changes noticed include the "capture" of non-tidal marshes in the Miller Neck Tract and the proliferation of tidal mudflats in the Miller Neck and Muddy Neck tracts.

Marsh Areas overall

Assawoman Wildlife Area is currently losing on average about 4.8 acres (Figure 6.11) of land a year to water inundation most likely through the combined effects of sea level rise and erosion of the edges of the marshland. Even more telling and pointing to sea level rise as the dominant factor is the loss of North Atlantic High Salt Marsh (Figure 5.30, Table 5.54). These losses show that more water is coming into the North Atlantic Low Salt Marsh, inundating the higher salt marsh areas and converting them. All of the tidal marsh areas will be inundated under the least of rise scenarios making them the most vulnerable of communities.

Impoundments

Currently the impoundments at Assawoman Wildlife Area are maintained by artificial floodgates that hold back tidal water. Eventually though, these gates will be overtopped and efforts will be made to raise them to account for the rise in sea level. However, there will come a point where the expense will exceed the benefits and these decisions need to be made now rather than later when money will have already been spent to no avail. At the current time the impoundments are exposed on one side to tidal water, but history shows that the impoundments can be "captured" on multiple sides. Are we willing to wall off the entire circumference of the impoundments to protect them?

Tract Vulnerability to Sea Level Rise

The South Bethany tract is the most vulnerable to sea level rise and will be totally lost with 1.5 m of sea level rise. The Piney Point Tract and Miller Neck Tracts are equally vulnerable and the Muddy Neck Tract will have the most land spared.

Appendix I: State rare vegetation ranking criteria

Ranks are based on a system developed by The Nature Conservancy and Natureserve to measure the relative rarity of vegetation communities within a given state. State rarity ranks are used to prioritize conservation and protection efforts so that the rarest of vegetation communities receive immediate attention. The primary criteria for ranking vegetation communities are the total number of documented occurrences with consideration given to the total number of occurrences and total amount of acreage in the state. Ranks for vegetation communities are updated annually and are based on current knowledge and mapping being done for the Guide to Delaware Vegetation Communities.

State Rank

S1 Extremely rare (i.e., typically 5 or fewer occurrences statewide), or may be susceptible to extirpation because of other threats to its existence.

S1.1 Only a single occurrence or population of the species is known to occur. (this rank is only applied to plants.)

S2 Very rare, (i.e., typically 6 to 20 occurrences statewide), or may be susceptible to extirpation because other threats to its existence.

S3 Rare to uncommon, not yet susceptible to extirpation but may be if additional populations are destroyed. Approximately 21 to 100 occurrences statewide.

S4 Common, apparently secure in the state under present conditions.

S5 Very common, secure in the state under present conditions.

SH Historically known, but not verified for an extended period (usually 15+ years); there are expectations that the species may be rediscovered.

SX Extirpated or presumed extirpated from the state. All historical locations and/or potential habitat have been surveyed.

SU Status uncertain within the state. Usually an uncommon species which is believed to be of conservation concern, but there is inadequate data to determine the degree of rarity.

SNR Unranked

SNA Not Applicable

SW Weedy vegetation or vegetation dominated by invasive alien species (this rank is only applied to natural communities).

SM Vegetation resulting from management or modification of natural vegetation. It is readily restorable by management or time and/or the restoration of original ecological processes (this rank is only applied to natural communities).

APPENDIX II: SGCN SPECIES EXPECTED FOR KEY WILDLIFE HABITATS

SGCN Species expected in Beach and Dune Habitats			
Species	**Common Name**	**Class**	**Tier**
Cincindela dorsalis media	white tiger beetle	Insect	1
Cincindela lepida	little white tiger beetle	Insect	1
Malaclemys terrapin terrapin	Northern diamondback terrapin	Reptile	1
Charadrius melodus	Piping plover	Bird	1
Haematopus palliatus	American Oystercatcher	Bird	1
Arenaria interpres	ruddy turnstone	Bird	1
Calidris canutus	Red knot	Bird	1
Calidrius alba	sanderling	Bird	1
Sterna hirundo	common tern	Bird	1
Sterna antillarum	least tern	Bird	1
Rynchops niger	black skimmer	Bird	1
Chordeiles minor	common nighthawk	Bird	1
Cincindela dorsalis	Eastern beach tiger beetle	Bird	2
Cincindela hirticolis	beach-dune tiger beetle	Bird	2
Melitara prodenialis	a snout-moth	Bird	2
Drasteria graphica atlantica	Atlantic graphic moth	Bird	2
Schinia spinosae	a noctuid moth	Bird	2
Falco peregrinus	peregrine falcon	Bird	2
Pluvialis squatarola	black-bellied plover	Bird	2
Catoptrophorus semipalmatus	willet	Bird	2
Calidris pusilla	semi-palmated sandpiper	Bird	2
Calidris maritima	purple sandpiper	Bird	2
Calidris alpina	dunlin	Bird	2
Larus marinus	great black-backed gull	Bird	2
Piplio erythrophthalmus	Eastern towhee	Bird	2
Passerculus sandwichensis	savannah sparrow	Bird	2

SGCN Species expected in Early Successional Upland Habitats			
Species	**Common Name**	**Class**	**Tier**
Nicrophorus americanus	American burying beetle	Insect	1
Callophrys irus	frosted elfin	Insect	1
Papaipema maritima	maritime sunflower borer moth	Insect	1
Terrapene carolina	Eastern box turtle	Reptile	1
Lampropeltis triangulum	milk snake	Reptile	1
Branta canadensis	Canada goose (migratory)	Bird	1
Circus cyaneus	Northern harrier	Bird	1
Bartramia longicauda	upland sandpiper	Bird	1
Scolopax minor	American woodcock	Bird	1
Asio flammeus	short-eared Owl	Bird	1
Chordeiles minor	common nighthawk	Bird	1
Lanius ludovicianus	loggerhead shrike	Bird	1
Dendroica discolor	prairie warbler	Bird	1

Ammodramus henslowii	Henslow's sparrow	Bird	1
Cincindela scutellaris	festive tiger beetle	Insect	2
Atrytonopsis hianna	dusted skipper	Insect	2
Satyrium liparops	striped hairstreak	Insect	2
Satyrium liparops strigosum	stiped hairstreak	Insect	2
Callophrys gryneus	juniper hairstreak	Insect	2
Speyeria aphrodite	aphrodite fritillary	Insect	2
Speyeria idalia	regal fritillary	Insect	2
Boloria bellona	meadow fritillary	Insect	2
Paratrea plebeja	trumpet vine sphinx	Insect	2
Calyptra canadensis	Canadian owlet	Insect	2
Acronicta rubricoma	a dagger moth	Insect	2
Papaipema rigida	rigid sunflower borer moth	Insect	2
Cirrhophanus triangulifer	a noctuid moth	Insect	2
Schina septentrionalis	a noctuid moth	Insect	2
Plegadis falcinellus	glossy ibis	Bird	2
Cygnus columbianus	tundra swan	Bird	2
Coragyps atratus	black vulture	Bird	2
Colinus virginianus	Northern bobwhite	Bird	2
Pluvialis squatarola	black-bellied plover	Bird	2
Coccyzus erythropthalmus	black-billed cuckoo	Bird	2
Chaetura pelagica	chimney swift	Bird	2
Colaptes auratus	Northern flicker	Bird	2
Empidonax minimus	least flycatcher	Bird	2
Tyrannus tyrannus	Eastern kingbird	Bird	2
Toxostoma rufum	Brown thrasher	Bird	2
Dendroica pensylvanica	Chestnut-sided warbler	Bird	2
Icteria virens	Yellow-breasted chat	Bird	2
Piplio erythrophthalmus	Eastern towhee	Bird	2
Spizella pusilla	field sparrow	Bird	2
Pooecetes gramineus	vesper sparrow	Bird	2
Passerculus sandwichensis	savannah sparrow	Bird	2
Ammodramus savannarum	grasshopper sparrow	Bird	2
Dolichonyx oryzivorus	bobolink	Bird	2
Cryptotis parva	least shrew	Bird	2

SGCN Species expected in Coastal Plain Upland Forest			
Species	**Common Name**	**Class**	**Tier**
Cicindela patruela consentanea	Northern barrens tiger beetle	Insect	1
Callophrys irus	frosted elfin	Insect	1
Catocala antinympha	sweetfern underwing	Insect	1
Catocala lacrymosa	tearful underwing	Insect	1
Terrapene carolina	Eastern box turtle	Reptile	1
Eumeces laticeps	broadhead skink	Reptile	1
Cemophora coccinea	scarlet snake	Reptile	1
Elaphe guttata	corn snake	Reptile	1
Lampropeltis triangulum	milk snake	Reptile	1

Haliaeetus leucocephalus	Bald eagle	Bird	1
Accipiter cooperii	Cooper's Hawk	Bird	1
Buteo platypterus	broad-winged hawk	Bird	1
Asio otus	long-eared owl	Bird	1
Melanerpes erythrocephalus	red-headed woodpecker	Bird	1
Certhia americana	brown creeper	Bird	1
SGCN Species expected in Coastal Plain Upland Forest			
Hylocichla mustelina	wood thrush	Bird	1
Wilsonia citrina	hooded warbler	Bird	1
Sciurus niger cinereus	Delmarva fox squirrel	Mammal	1
Discus catskillensis	angular disc	Gastropod	2
Cicindela patruela	Northern barrens tiger beetle	Insect	2
Cicindela unipunctata	one-spotted tiger beetle	Insect	2
Photuris frontalis	a firefly	Insect	2
Erynnis martialis	mottled duskywing	Insect	2
Erynnis baptisiae	wild indigo duskywing	Insect	2
Battus philenor	pipevine swallowtail	Insect	2
Polygonia progone	gray comma	Insect	2
Caripeta aretaria	a geometer moth	Insect	2
Tolype notialis	a lasiocampid moth	Insect	2
Hemileuca maia maia	the buckmoth	Insect	2
Cisthene kentuckiensis	Kentucky lichen moth	Insect	2
Cisthene tenuifascia	a lichen moth	Insect	2
Grammia phyllira	phyllira tiger moth	Insect	2
Zale metata	a noctuid moth	Insect	2
Catocala flebilis	mournful underwing	Insect	2
Catocala residua	residua underwing	Insect	2
Catocala cerogama	Yellow banded underwing	Insect	2
Acronicta exilis	Exiled dagger moth	Insect	2
Acronicta lithospila	Streaked dagger moth	Insect	2
Papaipema araliae	Aralia shoot borer moth	Insect	2
Papaipema baptisiae	Wild indigo borer moth	Insect	2
Lepipolys perscripta	A noctuid moth	Insect	2
Scincella lateralis	Ground skink	Reptile	2
Heterodon platirhinos	Eastern hognose snake	Reptile	2
Lampropeltis getula	Common kingsnake	Reptile	2
Storeria occipitomaculata	Redbelly snake	Reptile	2
Virginia valeriae	Smooth earth snake	Reptile	2
Agkistrodon contortix	Copperhead	Reptile	2
Coragyps atratus	Black vulture	Bird	2
Strix varia	Barred owl	Bird	2
Caprimulgus vociferus	whip-poor-will	Bird	2
Colaptes auratus	Northern flicker	Bird	2
Myiarchus crinitus	Great crested flycatcher	Bird	2
Sitta pusilla	Brown-headed nuthatch	Bird	2
Vireo flavifrons	Yellow-throated vireo	Bird	2
Dendroica dominca	Yellow-throated warbler	Bird	2
Mniotilta varia	Black-and-white warbler	Bird	2

Seiurus motacilla	Louisiana waterthrush	Bird	2
Oporornis formosus	Kentucky warbler	Bird	2
Piranga olivacea	Scarlet tanager	Bird	2
Piplio erythrophthalmus	Eastern towhee	Bird	2
Icterus galbula	Baltimora oriole	Bird	2
Lasionycteris noctivagans	Silver-haired bat	Mammal	2
Lasiurus borealis	Eastern red bat	Mammal	2
Lasiurus cinereus	Hoary bat	Mammal	2
Canis latrans	coyote	Mammal	2
SGCN Species expected in Forested Floodplains and Riparian Swamps			
Species	**Common Name**	**Class**	**Tier**
Satyrium kingi	King's hairstreak	Insect	1
Clemmys guttata	Spotted turtle	Reptile	1
Terrapene carolina	Eastern box turtle	Reptile	1
Nerodia erythrogaster	Plainbelly water snake	Reptile	1
Nycticorax nyticorax	Black crowned night-heron	Bird	1
Nyctanassa violacea	yellow-crowned night-heron	Bird	1
Buteo platypterus	Broad-winged hawk	Bird	1
Melanerpes erythrocephalus	Red-headed woodpecker	Bird	1
Hylocichla mustelina	Wood thrush	Bird	1
Parula americana	Northern parula	Bird	1
Setophaga ruticella	American redstart	Bird	1
Limnothlypis swainsonii	Swainson's warbler	Bird	1
Amblyscirtes aesculapius	Lace-winged roadside-skipper	Insect	2
Libytheana carinenta	American snout	Insect	2
Anacamptodes pergracilis	Cypress looper	Insect	2
Chloropteryx tepperaria	Angle winged emerald moth	Insect	2
Manduca jasminearum	Ash sphinx	Insect	2
Dolba hyloeus	Black alder or pawpaw sphinx	Insect	2
Haploa colona	A tiger moth	Insect	2
Orgyia detrita	A tussock moth	Insect	2
Catocala unijuga	Once-married underwing	Insect	2
Catocala praeclara	Praeclara underwing	Insect	2
Parapamea buffaloensis	A borer moth	Insect	2
Papaipema stenocelis	Chain fern borer moth	Insect	2
Gomphaeschna antilope	Taper-tailed darner	Insect	2
Gomphaeschna furcillata	Harlequin darner	Insect	2
Sympetrum ambiguum	Blue-faced meadowhawk	Insect	2
Enallagma weewa	Blackwater bluet	Insect	2
Hemidactylum scutatum	Four-toed salamander	Amphibian	2
Pseudotriton montanus montanus	Mud salamander	Amphibian	2
Hyla chrysoscelis	Cope's gray treefrog	Amphibian	2
Rana virgatipes	Carpenter frog	Amphibian	2
Opheodrys aestivus	Rough green snake	Reptile	2
Thamnophis sauritus	Eastern ribbon snake	Reptile	2
Agkistrodon contortix	copperhead	Reptile	2
Ardea herodias	Great blue heron	Bird	2

Casmerodius albus	Great egret	Bird	2
Egretta thula	Snowy egret	Bird	2
Egretta caerulea	Little blue heron	Bird	2
Egretta tricolor	Tricolored heron	Bird	2
Bubulcus ibis	Cattle egret	Bird	2
Plegadis falcinellus	Glossy ibis	Bird	2
Buteo lineatus	Red-shouldered hawk	Bird	2
Strix varia	Barred owl	Bird	2
Vireo flavifrons	Yellow-throated vireo	Bird	2
Protonotaria citrea	Prothonotary warbler	Bird	2
Helmitheros vermivorus	Worm-eating warbler	Bird	2
Oporornis formosus	Kentucky warbler	Bird	2
Piranga olivacea	Scarlet tanager	Bird	2
Icterus galbula	Baltimore oriole	Bird	2
Lasionycteris noctivagans	Silver-haired bat	Mammal	2
Nycticeius humeralis	Evening bat	Mammal	2

SGCN Species expected in Coastal Plain Seasonal Ponds			
Species	**Common Name**	**Class**	**Tier**
Poanes massasoit	Mulberry wing	Insect	1
Ambystoma tigrinum tigrinum	Tiger salamander	Amphibian	1
Hyla gratiosa	Barking treefrog	Amphibian	1
Clemmys guttata	Spotted turtle	Reptile	1
Euphyes dion	Dion skipper	Insect	2
Aeshna tubercullifera	Black-tipped darner	Insect	2
Aeshna verticalis	Green-striped darner	Insect	2
Anax longipes	Comet darner	Insect	2
Gomphaeschna antilope	Taper-tailed darner	Insect	2
Tetragoneuria costalis	Stripe-winged baskettail	Insect	2
Celithemis verna	Double-ringed pennant	Insect	2
Leucorrhinia intacta	Dot-tailed whiteface	Insect	2
Libellula axilena	Bar-winged skimmer	Insect	2
Libellula deplanata	Blue corporal	Insect	2
Botaurus lentiginosus	American bittern	Insect	2
Sympetrum ambiguum	Blue-faced meadowhawk	Insect	2
Sympetrum semicinctum	Band-winged meadowhawk	Insect	2
Lestes eurinus	Amber-winged sreadwing	Insect	2
Enallagma dubium	Burgundy bluet	Insect	2
Enallagma durium	Big bluet	Insect	2
Enallagma pallidum	Pale bluet	Insect	2
Enallagma vesperum	Vesper bluet	Insect	2
Nehalennia irene	Sedge sprite	Insect	2
Gomphus villosipes	Unicorn clubtail	Insect	2
Ambystoma maculatum	Spotted salamander	Amphibian	2
Hemidactylum scutatum	Four-toed salamander	Amphibian	2
Hyla chrysocelis	Cope’s gray treefrog	Amphibian	2
Scaphiopus holbrookii	Eastern spadefoot	Amphibian	2

Thamnophis sauritus	Eastern ribbon snake	Reptile	2

SGCN Species expected in Interdunal Wetlands			
Species	**Common Name**	**Class**	**Tier**
Photuris bethaniensis	Bethany Beach firefly	Insect	1
Cicindela hirticolis	Beach-dune tiger beetle	Insect	2

SGCN Species expected in Tidal High Marsh Habitats			
Species	**Common Name**	**Class**	**Tier**
Problema bulenta	rare skipper	Insect	1
Pero zalissaria	a geometer moth	Insect	2
Acontia delecta	a noctuid moth	Insect	2
Papaipema birdi	umbellifer borer moth	Insect	2
Brachymesia gravida	four-spotted pennant	Insect	2
Nycticorax nycticorax	black-crowned night-heron	Bird	1
Nyctanassa violacea	yellow-crowned night-heron	Bird	1
Anas rubripes	American black duck	Bird	1
Circus cyaneus	northern harrier	Bird	1
Laterallus jamaicensis	black rail	Bird	1
Asio flammeus	short-eared owl	Bird	1
Cistothorus platensis	sedge wren	Bird	1
Ammodramus caudacutus	saltmarsh sharp-tailed sparrow	Bird	1
Ammodramus maritimus	seaside sparrow	Bird	1
Botaurus lentiginosus	American bittern	Bird	2
Ixobrychus exilis	least bittern	Bird	2
Ardea herodias	great blue heron	Bird	2
Casmerodius albus	great egret	Bird	2
Egretta thula	snowy egret	Bird	2
Egretta caerulea	little blue heron	Bird	2
Egretta tricolor	tricolored heron	Bird	2
Bubulcus ibis	Cattle egret	Bird	2
Porzana carolina	sora	Bird	2
Fulica americana	American coot	Bird	2
Tyto alba	barn owl	Bird	2
Cistothorus palustris	marsh wren	Bird	2

SGCN Species expected in Tidal Low Marsh Habitats			
Species	**Common Name**	**Class**	**Tier**
Problema bulenta	rare skipper	Insect	1
Malaclemys terrapin terrapin	Northern diamondback terrapin	Reptile	1
Podilymbus podiceps	Pied-billed grebe	Bird	1
Nycticorax nycticorax	Black-crowned night-heron	Bird	1
Branta canadensis	Canada goose (migratory)	Bird	1
Anas rubripes	American black duck	Bird	1
Nyctanassa violacea	yellow-crowned night-heron	Bird	1
Circus cyaneus	northern harrier	Bird	1

Arenaria interpres	Ruddy turnstone	Bird	1
Asio flammeus	short-eared owl	Bird	1
Calidris canutus	Red knot	Bird	1
Sterna hirundo	Common tern	Bird	1
Sterna forsteri	Forster's tern	Bird	1
Rhnchops niger	Black skimmer	Bird	1
Ammodramus caudacutus	Saltmarsh sharp-tailed sparrow	Bird	1
Ammodramus maritimus	Seaside sparrow	Bird	1
Cicindela marginata	Margined tiger beetle	Insect	2
Pero zalissaria	A geometer moth	Insect	2
Acontia delecta	A noctuid moth	Insect	2
Brachymesia gravida	Four-spotted pennant	Insect	2
Pelecanus occidentalis	Brown pelican	Bird	2
Phalacrocorax carbo	Great cormorant	Bird	2
Phalacrocorax auritus	Double-crested cormorant	Bird	2
Ardea herodias	Great blue heron	Bird	2
Casmerodius albus	Great egret	Bird	2
Egretta thula	Snowy egret	Bird	2
Egretta caerulea	Little blue heron	Bird	2
Egretta tricolor	Tricolored heron	Bird	2
Bubulcus ibis	Cattle egret	Bird	2
Plegadis falcinellus	Glossy ibis	Bird	2
Anas platyrhynchos	mallard	Bird	2
Falco peregrinus	Peregrine falcon	Bird	2
Rallus elegans	King rail	Bird	2
Fulica americana	American coot	Bird	2
Pluvialis squatarola	Black-bellied plover	Bird	2
Himantopus mexicanus	Black-necked stilt	Bird	2
Catoptrophorus semipalmatus	Willet	Bird	2
Calidris pusilla	Semipalmated sandpiper	Bird	2
Calidris alpina	dunlin	Bird	2
Sterna nilotica	Gull-billed tern	Bird	2
Tyto alba	Barn owl	Bird	2
Cistothorus palustris	Marsh wren	Bird	2

SGCN Species expected in Impoundments			
Species	**Common Name**	**Class**	**Tier**
Podilymbus podiceps	Pied-billed grebe	Bird	1
Branta canadensis	Canada goose (migratory)	Bird	1
Anas rubripes	American black duck	Bird	1
Pandion haliaetus	osprey	Bird	1
Actitus macularia	Spotted sandpiper	Bird	1
Cygnus columbianus	Tundra swan	Bird	2
Anas platyrhynchos	mallard	Bird	2
Anas clypeata	Northern shoveler	Bird	2
Aythya valisneria	canvasback	Bird	2
Aythya marila	Greater scaup	Bird	2

Aythya affinis	Lesser scaup	Bird	2
Bucephala albeola	bufflehead	Bird	2
Lophodytes cucullatus	Hooded merganser	Bird	2
Pluvialis squatarola	Black-bellied plover	Bird	2
Himantopus mexicanus	Black-necked stilt	Bird	2
Catoptrophorus semipalmatus	willet	Bird	2
Calidris pusilla	Semipalmated sandpiper	Bird	2
Calidris alpina	dunlin	Bird	2