Chapter 3: Rachel Carson Component

3.1: Environmental Setting

The Rachel Carson component of the NCNERR is located in the central part of North Carolina's coast. It is located near the mouth of the Newport River in southern Carteret County, directly across Taylor's Creek from the historic town of Beaufort. One of the two State ports, Morehead City, is located three miles to the west. Rachel Carson is bounded to the north by Taylor's Creek and the city of Beaufort, to the east by Back Sound, to the south by the Cape Lookout National Seashore, and to the west by Piver's and Radio Islands (Figure 3.1). The Rachel Carson Reserve is located in the White Oak River Basin and on a broader scale in the Carolinian biogeographical province. Acquisition of the area was completed in 1985, with the addition of Middle Marshes later in 1989. The site is accessible only by boat. The state Wildlife Resources Commission operates a public boat ramp and parking lot along Taylor's Creek, while the Duke University Marine Laboratory and NOAA's Center for Coastal Fisheries and Habitat Research Laboratory have boat-launching facilities on nearby Pivers Island. Several private ferry companies offer access to the Reserve from Beaufort. The 2,625-acre (10.6 km^2) site consists of several small islands (Carrot, Town Marsh, Bird Shoal, Horse Island, and Middle Marshes) and extensive salt marshes and intertidal/subtidal flats (Taggart and Henderson 1988) (Figure 3.1).

3.2: Historical Uses

A: Native American Uses

Prior to European colonization of North Carolina, the Carrot Island-Middle Marshes area may have seen intermittent use by the Coree tribe of Native Americans. The Corees are thought to have spent considerable time on the nearby Outer Banks especially in the vicinity of Cape Lookout (Taggart and Henderson 1988)

B: Colonial Uses

European settlement of the Beaufort area began in the first two decades of the eighteenth century. In 1723 the commissioners of Beaufort began to sell lots as the town developed as a port. The early settlers used the waters in and near the Rachel Carson site for shipping lumber, naval stores, and farm commodities (Taggart and Henderson 1988).

During the early 1700s, several pirates were active along the North Carolina coast. One in particular, Edward Teach (Blackbeard) sailed the waters of the Caribbean and eastern U.S. Coast. (Lee 1974; Hill et al. 1975). In 1718 Blackbeard's flagship the Queen Anne's Revenge, struck a shoal just off Beaufort Inlet and was lost. The suspected remains of his ship were found less than 4 miles (6.4 km) from the Rachel Carson Reserve in 1996 by Intersail, Inc. Since 1996, several marine archeological expeditions have been conducted on the wreck to scientifically document the wreck and recover and preserve artifacts (North Carolina Department of Cultural Resources 2006).

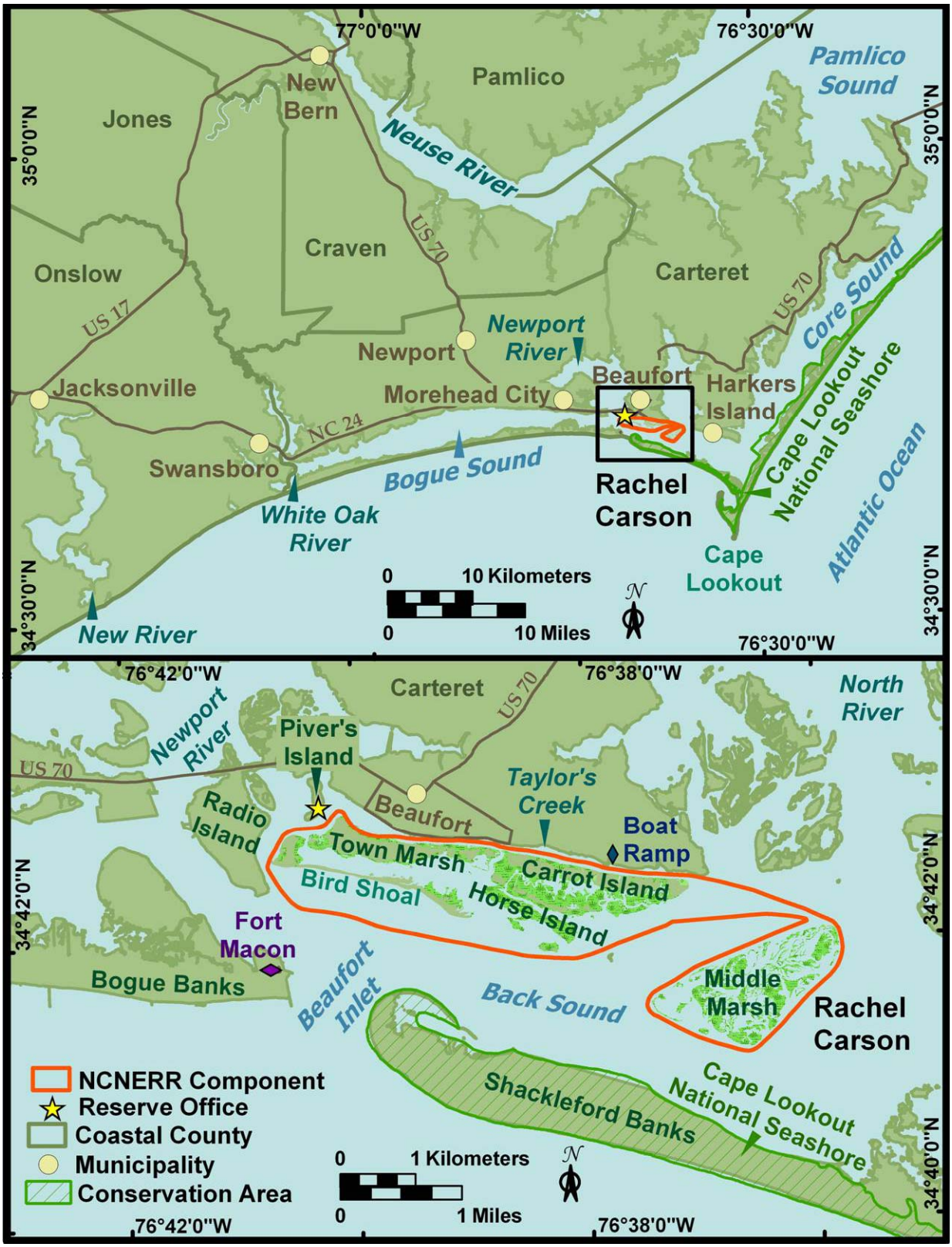

Figure 3.1: Rachel Carson location. The bottom panel shows a close up of the Rachel Carson Reserve component including local names for areas of the Reserve.

C: War Uses

In 1782, a Revolutionary War skirmish near the mouth of Taylor's Creek involved townsmen and a small British-landing party. Following an initial exchange of fire, the British moved about one-half mile (0.8 km) eastward and landed on Carrot Island, spending the night there. At sunrise, the British crossed Taylor's Creek to the mainland, overcame the local troops, and swept into Beaufort to begin a short-lived occupation of the town (Taggart and Henderson 1988).

Although not directly occurring on the Reserve, there was significant Civil War activity within 5 miles of the present day Reserve. At the start of the Civil War, Union forces were driven from Fort Macon. Fort Macon was an earthen and brick walled coastal defense built after the war of 1812 to protect Beaufort inlet (Figure 3.1). Confederate forces used the guns of Fort Macon to protect the deep water port of Beaufort so that supplies needed to sustain the confederate war effort could be brought in. In 1862, Union forces laid siege to the fort in an effort to retake it. After a full day of shelling from land and sea, the fort fell and the Union army re-took control of the fort and Beaufort inlet. The Union army used the fort for the rest of the war to prevent Confederate blockade runners from entering Beaufort harbor and as a coaling station for Union ships. Fort Macon was again used during World War II as a base for an Army coastal defense detachment. The Fort is now part of the Fort Macon State Park and is heavily visited during the warm summer months.

D: Other Historical Uses

As early as 1806, it was reported that mullet were being caught by a fishery on Carrot Island, then dressed, salted and taken to Beaufort to be sold. Other fisheries also developed in the region including menhaden, oysters, clams, flounder, and sea turtles. The first processing plant in the state for menhaden, still a valuable commercial species, was established on nearby Harker's Island in 1865. The first factory in Beaufort was built in 1881. Beaufort began to decline as a port following the establishment of Morehead City in the 1850s. Improvements in the channel from Beaufort Inlet to the Terminal facilities at Morehead City, especially those that have taken place during the twentieth century, completed this eclipse (Taggart and Henderson 1988).

In 1854, Town Marsh (then called Bird Shoal) was three-eighths of a mile long. By 1885, Town Marsh had more than doubled in length and its northern shoreline moved even closer to the Beaufort waterfront. The growth of Town Marsh had made the Taylor's Creek channel almost unusable, so in 1893 the citizens of Beaufort asked the federal government to build a breakwater on Town Marsh to protect the channel along the town's waterfront. Although that request was denied, in the early 1900s the U.S. Army Corp of Engineers began dredging the mouth of Taylor's Creek, using Carrot Island as a dredge material deposition area. Before the dredging, Carrot Island was essentially all tidal marsh with some elevated hammock land.

By the 1930s, the islands had been built up by the dredge material deposition to the point that they provided protection for the town of Beaufort from high winds, flooding and storm waves. In fact, the great hurricane of 1933 caused relatively little damage to the town. The Corps of Engineers continued to utilize the islands as deposition sites for local dredging projects and maintain rights for this purpose even today.

Horses were placed on the island during the 1940s by a Beaufort resident. It was practice then to bring livestock over to the islands to graze. With the resident's passing, the horses remained and became feral. The horses became the property of the State of North Carolina when the land was purchased in the 1980s and are managed as a wild population. The population is currently around 42.

The calm waters of Taylor's Creek behind the Reserve have been a safe harbor for boats since the Army Corp of Engineers finished the first dredging projects in the 1930s. As a result, boaters visiting the Beaufort area utilize the area on the back side of the Reserve as an anchorage.

3.3: Climate

The National Weather Service in Newport, North Carolina provides the most up to date, reliable weather data for the region. The annual maximum temperature for the area is 72.2 °F (22.3 °C), and the minimum is 54.3 °F (12.39 °C). Average total precipitation is 55.56 inches (141.1 cm), with an average snowfall of 1.3 inches (3.3 cm).

Table 3.1: Climate data for Morehead City, N.C. 5/2/1948 to 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Maximum	55.4/ 13.0	57.4/ 14.1	63.0/ 17.2	70.8/ 21.5	77.8/ 25.4	83.8/ 28.8	87.0/ 30.5	86.7/ 30.4	83.1/ 28.4	75.3/ 24.1	67.0/ 19.4	58.5/ 14.7	72.2/ 22.3
Average Minimum	36.2/ 2.4	37.7/ 3.2	43.3/ 6.3	51.8/ 10.9	60.8/ 16.0	68.6/ 20.4	72.7/ 22.6	71.8/ 22.1	66.9/ 19.4	56.4/ 13.6	46.6/ 8.1	38.8/ 3.7	54.3/ 12.4
Average Precipitation	4.3/ 11.0	3.9/ 9.9	4.0/ 10.3	3.0/ 7.7	4.4/ 11.3	4.5/ 11.5	6.4/ 16.2	6.9/ 17.6	6.1/ 15.5	4.2/ 10.6	3.7/ 9.5	4.0/ 10.1	55.6/ 141.1
Average Snowfall	0.3/ 0.8	0.6/ 1.5	0.4/ 1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1/ 0.3	1.3/ 3.3
Data from NOAA - National Climatic Data Center.													

The Rachel Carson area is especially susceptible to tropical storm/hurricane impacts because of the geography of the region. This part of the coast juts out into the Atlantic Ocean in an east-west orientation (Figure 3.1). Thus, the area is very prone to impact by northward moving storms. Table 3.2 lists all tropical activity that has passed within 65 nautical miles of the Rachel Carson Reserve since 1960. Recently, several significant storms have impacted the area causing heavy damage and flooding including: Hurricanes Bertha and Fran during the summer of 1996, Bonnie in 1998, Floyd in 1999, Isabel in 2003 and Ophelia in 2005.

Table 3.2: Tropical storms passing within 65 nautical miles of Rachel Carson since 1960

Storm	Date	Name	Wind (kts)	Minimum Pressure (mb)	Classification
1	July 1960	Brenda	50	-	Tropical storm
2	September 1960	Donna	95	958	Category 2 hurricane
3	August 1962	Alma	45	1002	Tropical storm
4	September 1964	Dora	45	-	Tropical storm
5	October 1964	Isbell	65	994	Category 1 hurricane
6	October 1964	Isbell	40	1000	Extratropical
7	June 1966	Alma	40	-	Tropical storm
8	June 1966	Alma	40	990	Tropical storm
9	September 1967	Doria	45	-	Tropical storm
10	June 1968	Abby	25	-	Tropical depression
11	October 1968	Gladys	75	-	Category 1 hurricane
12	August 1970	Not named	30	-	Tropical depression
13	August 1971	Doria	50	998	Tropical storm
14	September 1971	Ginger	80	985	Category 1 hurricane
15	October 1971	Ginger	60	991	Tropical storm
16	June 1972	Agnes	30	990	Tropical depression
17	June 1975	Amy	25	1011	Tropical depression
18	October 1975	Hallie	45	1002	Tropical storm
19	September 1977	Clara	25	1012	Tropical depression
20	July 1979	Bob	20	1012	Tropical depression
21	August 1981	Dennis	50	999	Tropical storm
22	June 1982	Subtop 1	60	992	Subtropical storm
23	September 1984	Diana	115	949	Category 4 hurricane
24	September 1985	Gloria	90	942	Category 2 hurricane
25	November 1985	Kate	45	996	Tropical storm
26	August 1986	Charley	55	995	Tropical storm
27	August 1987	Arlene	10	1016	Tropical low
28	June 1995	Allison	40	995	Extratropical
29	June 1996	Arthur	40	1005	Tropical storm
30	July 1996	Bertha	90	974	Category 2 hurricane
31	September 1996	Fran	100	985	Category 3 hurricane
32	October 1996	Josephine	45	988	Extratropical
33	August 1998	Bonnie	95	963	Category 2 hurricane
34	September 1999	Dennis	55	986	Tropical storm
35	September 1999	Floyd	90	956	Category 2 hurricane
36	October 1999	Irene	80	976	Category 1 hurricane
37	June 2001	Allison	25	1006	Subtropical depression
38	July 2002	Arthur	30	1009	Tropical depression
39	October 2002	Kyle	30	1012	Tropical depression
40	September 2003	Isabel	90	956	Category 2 hurricane
41	August 2004	Alex	70	983	Category 1 hurricane
42	August 2004	Bonnie	25	1008	Tropical depression
43	August 2004	Charley	60	1000	Tropical storm
44	September 2005	Ophelia	75	979	Category 1 hurricane

Data from the NOAA – Coastal Services Center.

3.4: Geological Processes

Carteret County is located in the south-central part of the North Carolina coastal plain. In general, the county's land surface is a plain representing a former sea floor that has been elevated above sea level in the relatively recent geologic past. The existing plain slopes toward the Atlantic Ocean at an overall rate of less than three feet per mile, and the topography is flat and largely swampy. The sea has gradually returned to cover much of the low ground in the coastal bays and extends up the streams to form broad estuaries. Wave and tidal action have built up a chain of offshore bars or banks which border the ocean and are separated from the remainder of the county by Bogue, Back, and Core Sounds. The main estuaries with influence on the Rachel Carson component are the Newport and North River estuaries. (N.C. Division of Water Quality 2007)

The islands and tidal flats comprising Rachel Carson consist of Recent and Pleistocene (1.8 million to 10,000 years ago) sediments of the Pamlico Terrace. Soils found within the component generally consist of sandy profiles with little to no horizon development (i.e., Entisol order). This is indicative of soils having a relatively recent origin (Buol et al. 1980). Unlike the other components that make up NCNERR, Rachel Carson is not a true barrier island. The Reserve is located behind the line of primary barrier islands (Figure 3.1).

During the early 1930's the U.S. Army Corps of Engineers began dredging Taylor's Creek. The spoil from this deepening project was placed on top of the shoals and marshes adjacent to the creek. These activities raised the elevation of the marshes several feet and are the basis for the present day Town Marsh (which is in actuality an upland island) and Carrot Island. Thus, the upland areas of Rachel Carson are made from sediment dredged up out of Taylor's Creek. These areas are mostly sand with occasional areas of shell debris. The Army Corps still uses portions of the Reserve as a deposition site for spoils from maintenance dredging activities of Taylor's Creek.

3.5: Hydrology and Water Quality

A: Hydrology

The waters around Rachel Carson are generally less than six ft (1.8 m) in depth except for Taylor's Creek that is periodically dredged by the U.S. Army Corps of Engineers to a depth of 14 ft (4 m). Tides in the Rachel Carson area average 1.5 ft (0.5 m) and are semidiurnal in nature. The Rachel Carson Reserve is located in the White Oak River Basin (Figure 3.2).
The Reserve is located in the convergence zone of several bodies of water: the Newport River, North River, Back Sound, and Bogue Sound (Figure 3.1). Currents in the region are highly influenced by the adjacent Beaufort Inlet. Beaufort Inlet is dredged in support of the State Port

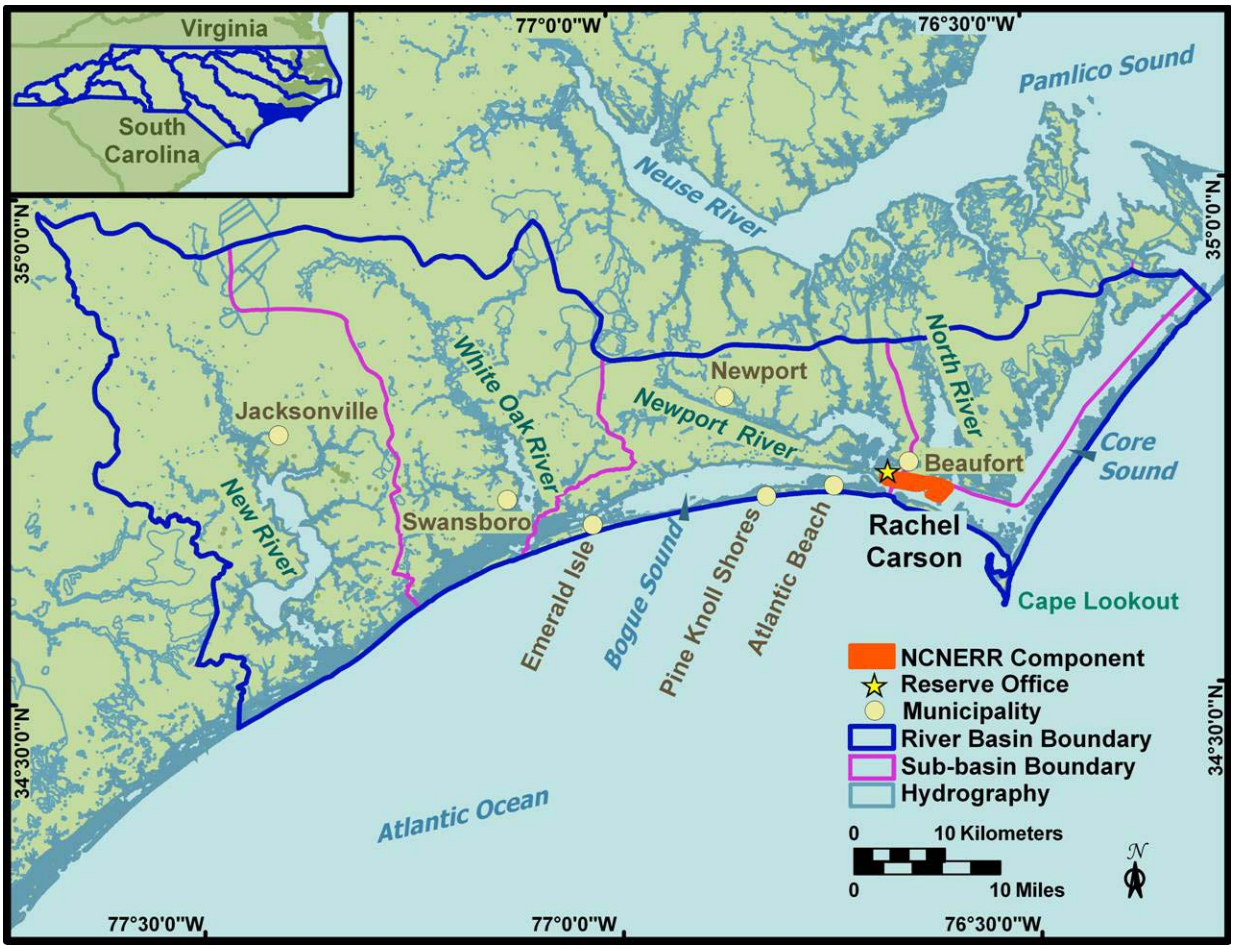

Figure 3.2: White Oak River Basin map.

Facility located in Morehead City to a depth greater than 40 ft (~12 m). This alteration enhances ocean-estuary exchange compared to what would occur if the inlet were not modified. The enhanced exchange increases the pollution capacity of the area waters as pollutants can rapidly dilute into the coastal ocean. The enhanced exchange also means salinity values in the Rachel Carson Reserve are near ocean concentration, ~35 ppt. Figure 3.3 shows yearly averaged water quality data from SWMP-like instrumentation that was deployed by NCNERR from 1998-2003 in the Reserve at Middle Marsh and from Deep Creek from 1999-2003. The salinity values at both sampling locations were very stable and remained near 30 ppt in all years.

The Newport and North Rivers account for most of the riverine influence to the Reserve. The Newport River widens into the Newport River estuary, which separates Bogue Sound from Back Sound. The head of the estuary, near Newport, has periodic, naturally low dissolved oxygen concentrations and low pH values due to swamp water inflow (North Carolina Division of Water Quality 2007). The swamp stream headwaters of the Newport River are relatively pristine and drain portions of Croatan National Forest. The North River is east of the Newport River and drains into Back Sound. The North River drains primarily agricultural land and low development residential areas (North Carolina Division of Water Quality 2007).

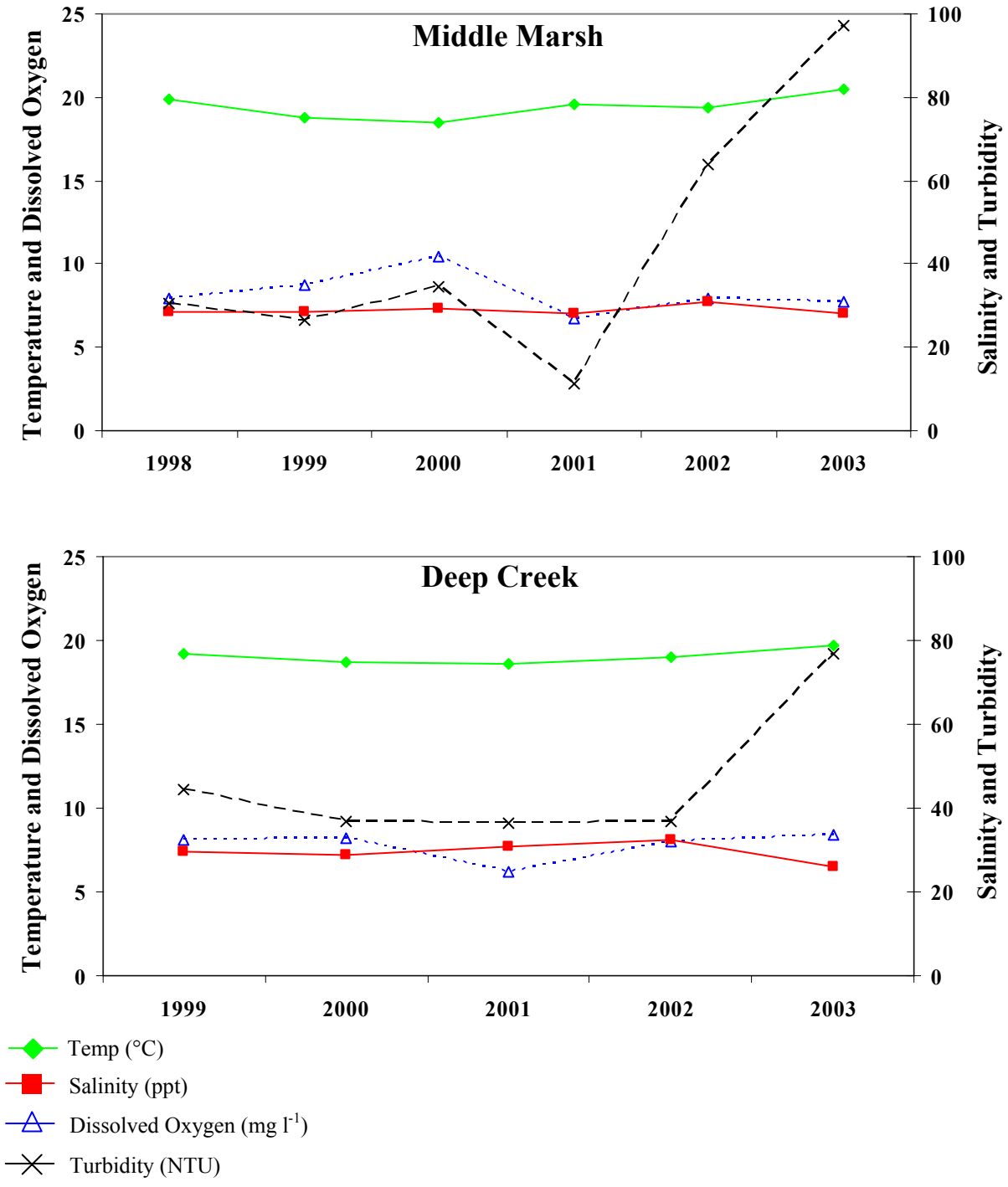

Figure 3.3: Yearly averaged data from the SWMP-like monitoring stations at Rachel Carson.

B: Water Quality

Water quality around Rachel Carson is generally high, with low nutrients and bacteria concentrations and with ample dissolved oxygen (N.C. Division of Water Quality 2007). The yearly data from the NCNERR SWMP-like water quality monitoring stations corroborate this assessment. Yearly oxygen concentrations remained above 6 mg l^{-1} which is well above the level of oxygen required by most estuarine organisms (Diaz and Rosenberg 1995; Sagasti et al. 2001) (Figure 3.3). The low dissolved oxygen signal from the swamp headwaters of the Newport River is completely muted by the time the water gets to the Rachel Carson Reserve.

The largest point source discharge impact to the Rachel Carson Reserve is the Beaufort waste water treatment plant (1.5 million gallons (5,678,117 L) per day) (North Carolina Division of Water Quality 2007). The outfall pipe discharges into Taylor's Creek near the former NCNERR Deep Creek sampling location (Figure 3.4). Because of this outfall, the waters of Taylor's Creek are permanently closed to shellfishing. Water quality of Taylor's Creek and the tidal creeks that enter the Reserve from Taylor's Creek are classified as "SC" (no taking of shellfish and no swimming allowed) by the Division of Water Quality, all other areas in the Reserve are classified as "SA" (safe for shellfish gathering and swimming) waters.

The waters around Rachel Carson are heavily utilized for boating, fishing, swimming, and shellfishing. Consequently, there is a large amount of effort put into quantifying the water quality in the region. The N.C. Recreational Water Quality Program began testing coastal waters in 1997. The mission is to protect the public health by monitoring the quality of coastal recreational waters and notifying the public when bacteriological standards for safe bodily contact are exceeded. They test for enterococcus bacteria (an indicator organism whose presence is correlated with that of others that can cause illness in humans) to determine if swimming advisories should be posted. Limits for enterococcus are based on the level of use a particular beach receives. A Tier 1 area is defined as receiving daily use during swimming season (April – September). Tier 1 beaches shall not exceed either: (1) A geometric mean of 35 enterococci per 100 ml of water, that includes a minimum of at least five samples collected within 30 days; or (2) A single sample of 104 enterococci per 100 ml of water. A Tier 2 area is defined as receiving on average three days of use per week during swimming season. The enterococcus level in a Tier 2 swimming area shall not exceed a single sample of 276 enterococci per 100 ml of water. A Tier 3 area is defined as receiving four days of use per month during swimming season. The enterococcus level in a Tier 3 swimming area shall not exceed two consecutive samples of 500 enterococci per 100 ml of water. There are several Tier 1, 2, and 3 water quality stations located near the Rachel Carson Reserve (Figure 3.4). The data from these sampling locations is presented in Table 3.3 and Figure 3.5.

Table 3.3: Enterococci data for the sampling stations near Rachel Carson 2003-2006

Station	C-2	C-57	C-59A	C-58	C-60A	C-56	C-55B	C-56A
Tier	Tier 1	Tier 1	Tier 2	Tier 2	Tier 2	Tier 2	Tier 2	Tier 3
Minimum	9	9	9	9	9	9	9	9
Maximum	104.4	2006	20	20	20	2006	164	2005
Average	11.6	55.5	9.3	9.3	9.3	72.5	15.0	80.1
Data from: http://www.deh.enr.state.nc.us/shellfish/Water_Monitoring/RWQweb/data.htm								

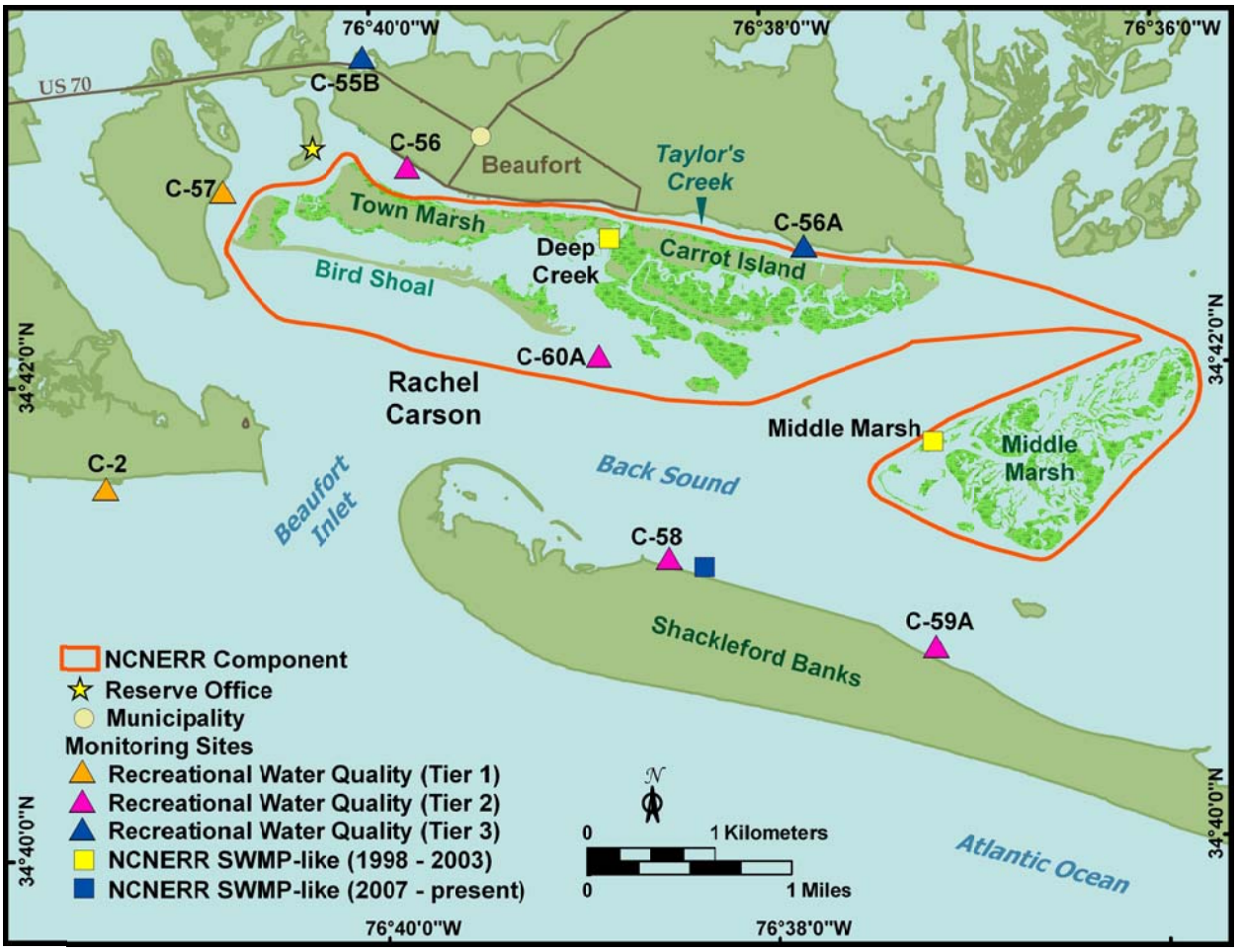

Figure 3.4: Water quality monitoring locations at Rachel Carson.

From these data it can be seen that quite a large variation in the enterococci concentrations exist among the various sampling locations. The sampling sites in Back Sound adjacent to Shackleford Banks (C-58 and C-59A) and the ocean-side boundary of Rachel Carson (C-60A) consistently had the lowest enterococci values. The sampling locations in Taylor's Creek C-56 and C-56A had the highest enterococci values. This contamination could be coming from several sources. The first is the Beaufort wastewater treatment outfall, the second is the public boat anchorage and marinas in the area, and the third is from runoff from adjacent land areas. Regardless of the source, the data show that Taylor's Creek is susceptible to bacteria contamination, and that the shellfish closure in the area is justified.

Unlike the other Reserve components, there has not been any historical nutrient sampling conducted by NCNERR within the Rachel Carson component. This is a data gap for this Reserve component. To address this need and to fill the void in water quality sampling that has existed since 2003, NCNERR has entered into a partnership with the National Park Service. This partnership, codified with a Memorandum of Understanding, provides for two SWMP-like water quality monitoring locations including nutrient sampling. The first of these stations, located within the Cape Lookout National Seashore boundary at the Shackleford Banks boat dock, was installed in October 2007 (Figure 3.4). The second is planned for installation in

February 2008 within the NCNERR boundary at the original NCNERR Middle Marsh SWMP-like sampling location that occurred from 1998-2003 (Figure 3.4).

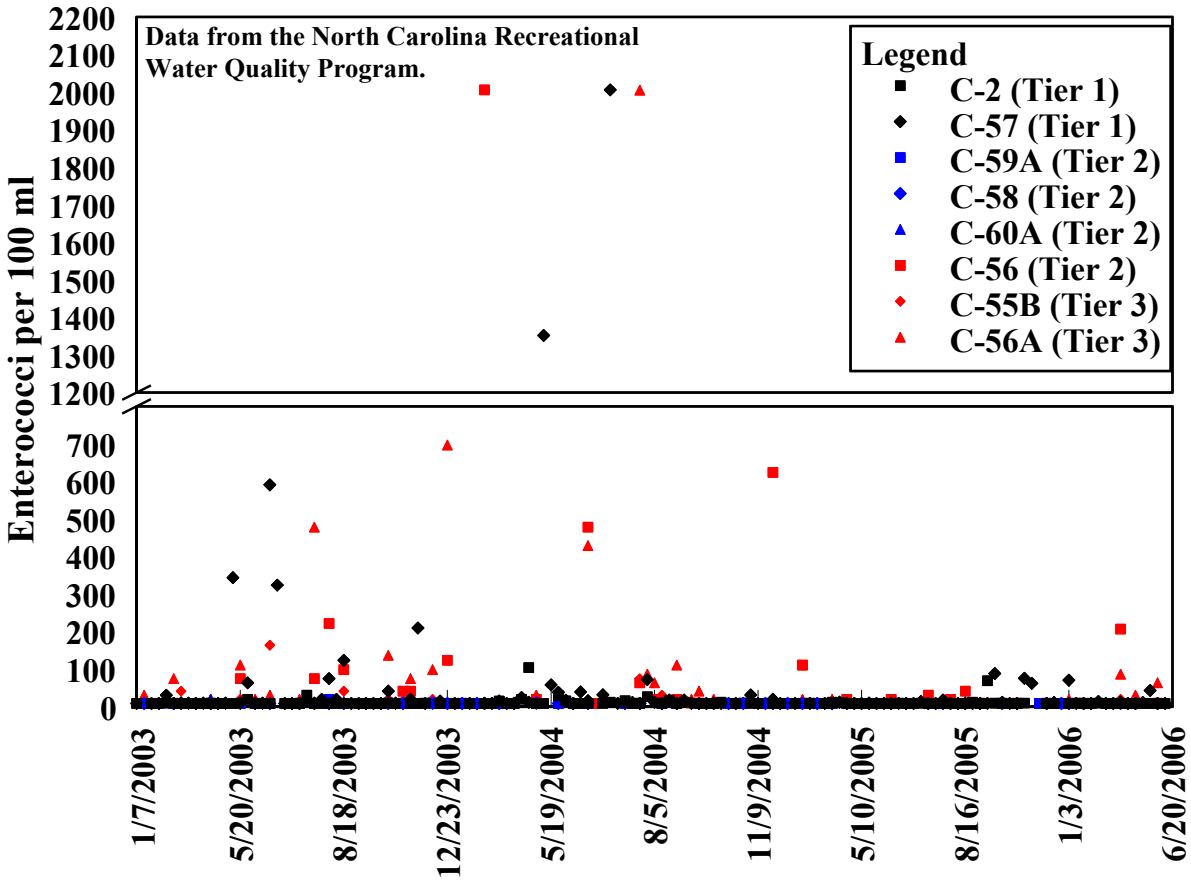

Figure 3.5: Enteroccoci data from the recreational water quality sampling stations near Rachel Carson.

3.6: Habitat Types

A primary objective of SWMP Phase 3 is to evaluate changes over time in estuarine habitats and coastal land cover. To accomplish this, the types and locations of habitats within the Reserve must be periodically quantified. The habitat types of Rachel Carson were initially characterized in 1994. This effort used a very general classification system that only broke habitats down into very broad categories. These habitat types included subtidal flats, tidal creeks, submerged aquatic vegetation beds, salt marshes, dredge spoil areas, Maritime shrub thicket and forest, dunes and beaches (Table 3.4). Figure 3.6 shows the resultant map from this effort.

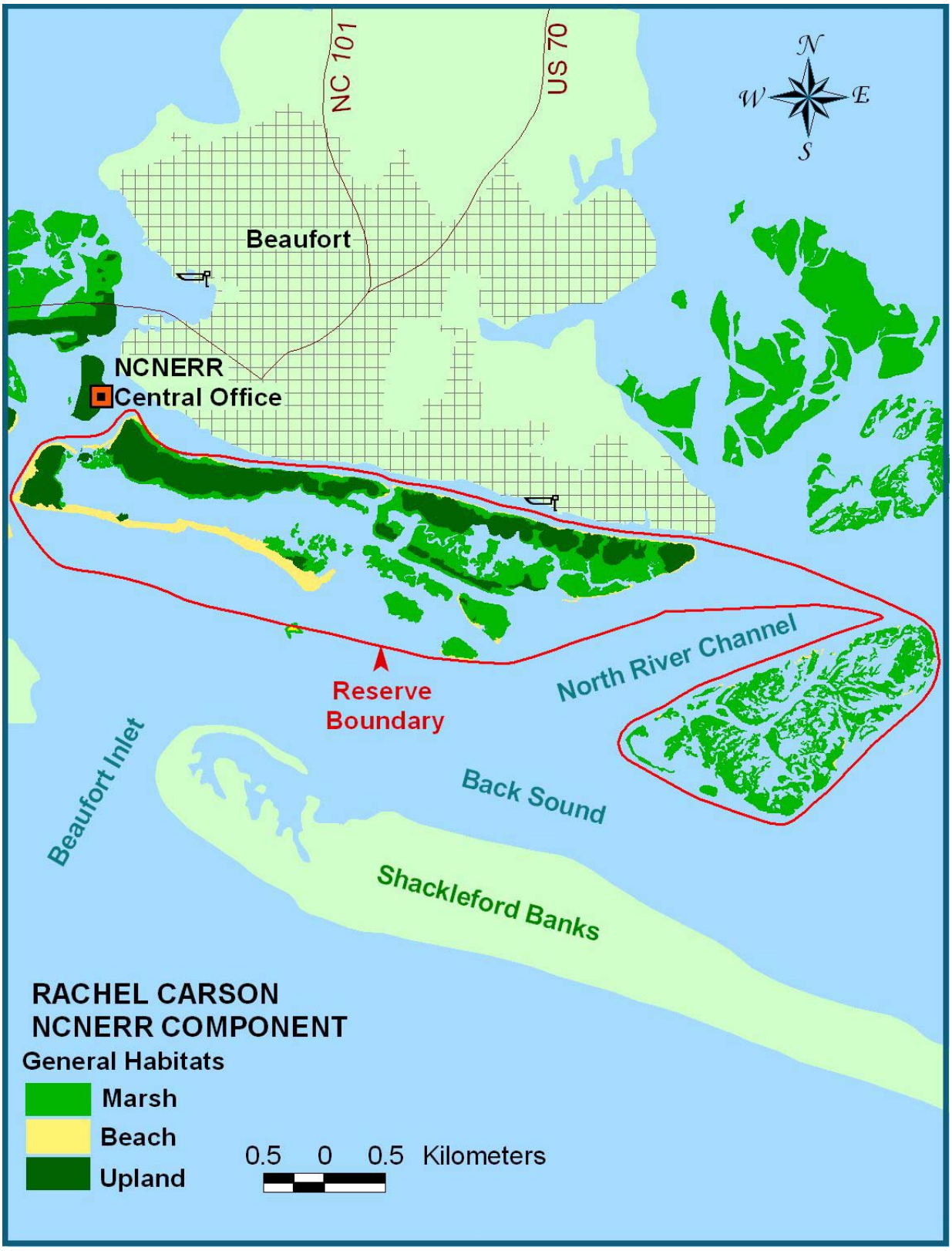

Figure 3.6: Habitat map from 1994 for Rachel Carson.

Table 3.4: Rachel Carson 1994 habitat classifications

Habitat	Description
Subtidal flats	Open sand or mud flats that never get exposed at low tide.
Tidal creeks	Open water feeder creeks through the marshes and across tidal flats.
Eelgrass and other submerged aquatic plant beds	Subtidal areas that are primary habitat for bay scallops and associated species.
Intertidal mud and sand flats	Open sand or mud flats that are submerged at high tide and exposed at low tide.
Salt marshes	Low and high fringing areas that are persistently wet.
Dredge material areas	Dredged materials become vegetated by pennywort and grasses and if left undisturbed undergo successional invasion by shrubs.
Shrub thicket/Maritime forest	Shrub forest areas on the upland island areas.
Dunes	Upland areas stabilized by grasses.
Sandy beaches	Intertidal areas of sandy beach and boat landing areas.

However, this assessment provided only minimal information regarding habitat types and function. To more accurately and methodologically account for the various habitat types within the Reserve components, in 2005 NCNERR participated as a pilot Reserve for the NERRS habitat and land use classification system. This effort categorized the habitats within the Reserves using a much improved classification system (Appendix 4).

The updated habitat map for Rachel Carson is presented at the subclass level in Figure 3.7. Areal statistics for habitat occurrence were calculated from the digital classification data and are provided as acreage and the percentage of total acres mapped for each habitat subclass (Table 3.5). Subtidal areas were not included in this assessment. Visual observations were made during field surveys to document predominant plant species for each habitat subclass. These data provide a framework for conducting more in-depth inventories of vegetation composition and conditions. Habitat subclasses at Rachel Carson are described in the following paragraphs, with representative photographs presented in Appendix 4.

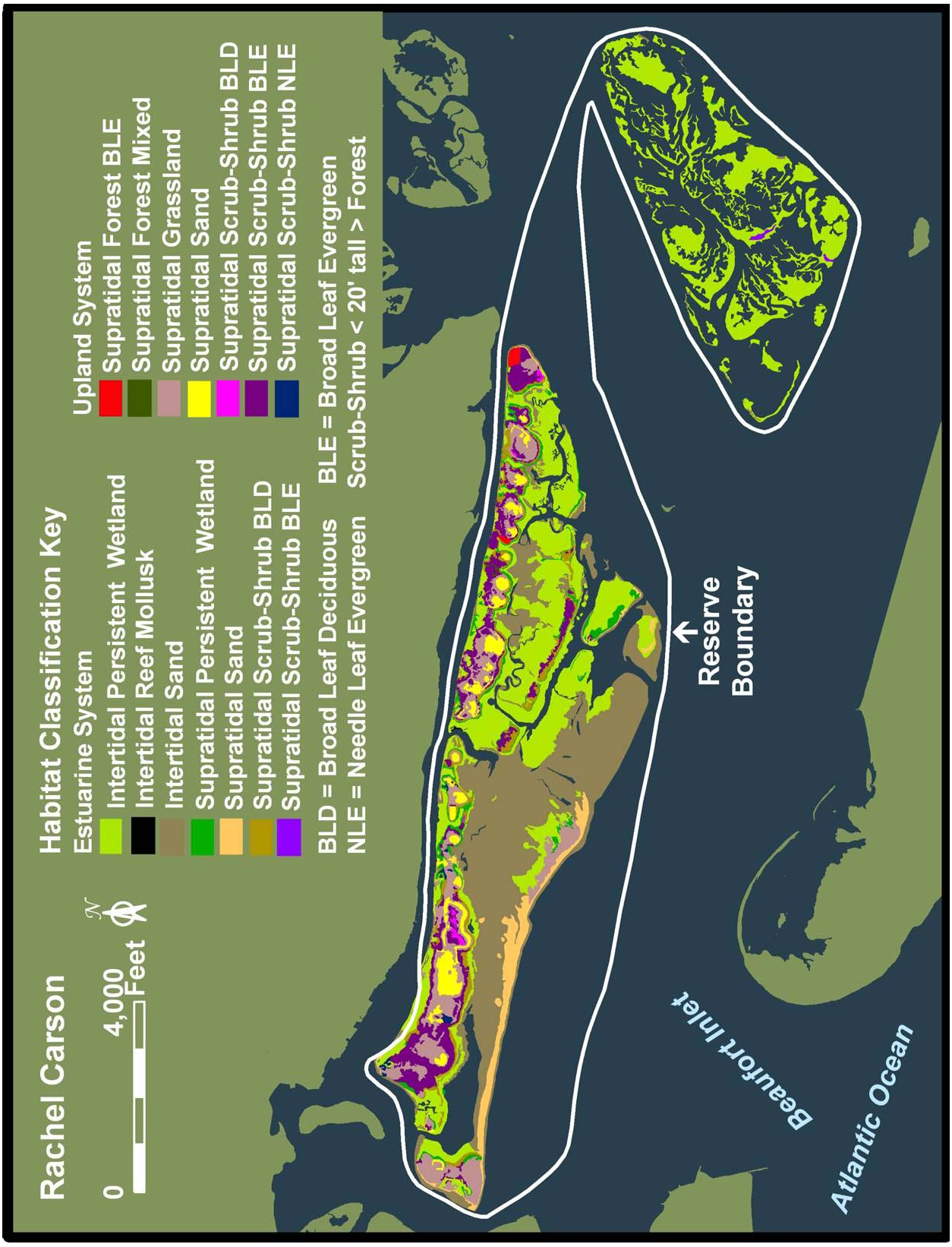

Figure 3.7: Rachel Carson 2004 habitat classification presented at the subclass level.

Table 3.5: Rachel Carson 2004 habitat classification areal statistics

Habitat Subclass	Area (Acres)	% of Total
Estuarine Intertidal Persistant Wetland	433.97	40.44
Estuarine Intertidal Sand	323.56	30.15
Upland Supratidal Grassland	90.48	8.43
Upland Supratidal Scrub-Shrub Broad Leaf Evergreen	75.59	7.04
Estuarine Supratidal Sand	38.88	3.62
Estuarine Supratidal Scrub-Shrub Broad Leaf Deciduous	37.92	3.53
Upland Supratidal Sand	33.61	3.13
Estuarine Supratidal Persistant Wetland	29.10	2.71
Upland Supratidal Scrub-Shrub Needle Leaf Evergreen	2.94	0.27
Upland Supratidal Forest Broad Leaf Evergreen	2.58	0.24
Upland Supratidal Scrub-Shrub Broad Leaf Deciduous	2.34	0.22
Estuarine Supratidal Scrub-Shrub Broad Leaf Evergreen	1.42	0.13
Upland Supratidal Forest Mixed	0.45	0.04
Estuarine Intertidal Reef Mollusc	0.16	0.01
Total Mapped Habitat Area	**1,073.00***	**100.00**
* Subtidal areas not included		

- The most dominant habitat type within the Rachel Carson component was Estuarine Intertidal Persistant Wetland, comprising over 40% of total habitat. This subclass is commonly known as the salt marsh. Areas of this subclass were found along the exterior edges of Carrot Island as well as nearly 100% coverage of the Middle Marsh area. At Rachel Carson this habitat type was dominated by Smooth Cordgrass (*Spartina alterniflora)*.

- Next in area coverage was the Estuarine Intertidal Sand subclass, making up 30% of total habitat. The majority of this subclass area was represented in the large tidal flats, but intertidal sand was also found around the perimeter of Carrot Island.

- The third most dominant class was Upland Supratidal Grassland, with 90 acres representing 8% of the total habitat. These areas were found in the interior portions of Carrot Island, interspersed with various scrub-shrub habitats and bare sand. This habitat subclass contained barrier island grass species such as Salt Meadow Hay (*Spartina patens)*, Sea Oats (*Uniola paniculata*), as well as cultivated lawn species such as Centipede (*Eremochloa ophiuroidesand*). These landscape grasses may have come from the manicured lawns across Taylor's Creek (Figure 3.1).

- Upland Supratidal Scrub-Shrub Broad Leaf Evergreen was located mostly in the interior portions of Carrot Island, bordering grasslands and marshes. The species found within this subclass are a mix of Yaupon (*Ilex vomitoria*), Wax Myrtle (*Morella cerifera* or *Myrica cerifera*), Laurel Oak (*Quercus laurifolia*), and Live Oak

(*Quercus virginiana)*. The Eastern Red Cedar (*Juniperus virginiana*), a needle leaf evergreen, is also found among the broad leaf evergreens, though is not dominant.

- The following subclasses comprised between 2-4 % of total habitat area and covered between 25-40 acres each (listed in decreasing order): Estuarine Supratidal Sand, Estuarine Supratidal Scrub-Shrub Broad Leaf Deciduous containing mostly Sea Ox-eye (*Borrichia frutescens*), and Glasswort (*Salicornia spp.*); Upland Supratidal Sand with $\leq$30% vegetative cover and Estuarine Supratidal Persistant Wetland, inhabited by a variety of grass species.

- The following habitats each covered less than 3 acres and 1% of total habit (listed in decreasing order): Upland Supratidal Scrub-Shrub Needle Leaf Evergreen dominated by Eastern Red Cedar (*Juniperus virginiana*); Upland Forested Broad Leaf Evergreen dominated by Live Oak (*Quercus virginiana)* and Upland Supratidal Scrub-Shrub Broad Leaf Deciduous, containing a mix of Marsh Elder (*Iva frutescens*), and Grounsel Tree (*Baccharis halimifolia*).

- Two habitats each included less than 0.05 acres and 1% of total: Upland Forested Mixed (containing a mix of pines and oaks) and Estuarine Intertidal Reef Mollusc consisting of live oysters and oyster shells.

3.7: Plants

The plant communities present within the Rachel Carson area are consistent with those of other barrier islands and marsh islands found in this part of the country. The dominant terrestrial plant species for each habitat subclass are listed in the preceding section. For a full species list refer to Appendix 5. The Natural Heritage Program has recognized several plant species found within the Rachel Carson community as threatened or significantly rare (Table 3.6). The Reserve is an important haven for these rare plants because it provides an area protected from development.

Large beds of marine seagrass are also found at the Rachel Carson Reserve. The seagrasses that have been documented within Rachel Carson include Eelgrass (*Zostera marina*), Shoalgrass (*Halodule wrightii*), and Wigeon Grass (*Ruppia maritime*) (Denault 2007). These SAV species provide habitat, food and refuge; produce oxygen; absorb nutrients; and reduce erosion by wave activity. Seagrass beds are currently being mapped by both NOAA staff and NCNERR staff. These efforts are highlighted under the current research activities in section 3.11.

Table 3.6: Species of special concern in and near Rachel Carson

State Status Codes: E = Endangered, T = Threatened, SC = Special Concern, SR = Significantly Rare, L = range limited to North Carolina and adjacent states.

Federal Status Codes: E = Endangered, T = Threatened, FSC = Federal Special Concern.

Major Group	Scientific Name	Common Name	State Status	Federal Status
Vascular Plant	*Amaranthus pumilus*	Seabeach Amaranth	T	T
Vascular Plant	*Dichanthelium caerulescens*	Blue Witch Grass	E	None
Vascular Plant	*Ipomoea imperati*	Beach Morning-glory	SR	None
Vascular Plant	*Lysimachia asperulifolia*	Rough-leaf Loosestrife	E	E
Vascular Plant	*Polygonum glaucum*	Seabeach Knotweed	SR	None
Vascular Plant	*Solidago verna*	Spring-flowering Goldenrod	T	FSC
Vascular Plant	*Trichostema sp. 1*	Dune Bluecurls	SR	FSC
Invertebrate Animal	*Busycon canaliculatum*	Channeled Whelk	SC	None
Invertebrate Animal	*Busycon carica*	Knobbed Whelk	SC	None
Invertebrate Animal	*Busycon contrarium*	Lightning Whelk	SC	None
Invertebrate Animal	*Chaetopterus variopedatus*	Parchment Tubeworm	SC	None
Bird	*Aimophila aestivalis*	Bachman's Sparrow	SC	FSC
Bird	*Ammodramus henslowii susurrans*	Eastern Henslow's Sparrow	SR	FSC
Bird	*Anhinga anhinga*	Anhinga	SR	None
Bird	*Botaurus lentiginosus*	American Bittern	SR	None
Bird	*Charadrius melodus*	Piping Plover	T	T
Bird	*Charadrius wilsonia*	Wilson's Plover	SR	None
Bird	*Coturnicops noveboracensis*	Yellow Rail	SR	None
Bird	*Dendroica virens waynei*	Black-throated Green Warbler - Coastal Plain Population	SR	FSC
Bird	*Egretta caerulea*	Little Blue Heron	SC	None
Bird	*Egretta thula*	Snowy Egret	SC	None
Bird	*Egretta tricolor*	Tricolored Heron	SC	None
Bird	*Gelochelidon nilotica*	Gull-billed Tern	T	None
Bird	*Passerina ciris ciris*	Eastern Painted Bunting	SR	FSC
Bird	*Pelecanus occidentalis*	Brown Pelican	SR	None
Bird	*Plegadis falcinellus*	Glossy Ibis	SC	None
Bird	*Rynchops niger*	Black Skimmer	SC	None
Bird	*Sterna hirundo*	Common Tern	SC	None
Bird	*Sternula antillarum*	Least Tern	SC	None
Amphibian	*Bufo quercicus*	Oak Toad	SR	None
Reptile	*Caretta caretta*	Loggerhead Turtle	T	T
Reptile	*Chelonia mydas*	Green Sea Turtle	T	T
Reptile	*Heterodon simus*	Southern Hognose Snake	SC	FSC
Reptile	*Lampropeltis getula sticticeps*	Outer Banks Kingsnake	SC	None
Reptile	*Lepidochelys kempii*	Atlantic Kemps Ridley	E	E
Reptile	*Malaclemys terrapin centrata*	Carolina Diamondback Terrapin	SC	None
Reptile	*Nerodia sipedon williamengelsi*	Carolina Water Snake	SC	None
Reptile	*Seminatrix pygaea*	Black Swamp Snake	SR	None
Reptile	*Sistrurus miliarius*	Pigmy Rattlesnake	SC	None
Mammal	*Neotoma floridana floridana*	Eastern Woodrat - Coastal Plain Population	T	None
Mammal	*Trichechus manatus*	West Indian Manatee	E	E

Data from the North Carolina Natural Heritage Program

3.8: Animals

Animal presence within the Reserve is high compared to other coastal areas of comparable size due to the diverstiy of habitats within the Rachel Carson Reserve. Within the Reserve, there is a variety of upland and supratidal habitats which offer foraging habitats for birds, mammals, and crustaceans. The estuarine waters and subtidal habitats surrounding Carrot Island and Middle Marsh are important nursery grounds for many fish species. The Rachel Carson Reserve also provides valuable habitat for mollusks, invertebrates and insects (See Appendix 5 for a full species list).

A: Invertebrates and Zooplankton

Crustaceans inhabit the intertidal and supratidal areas within Rachel Carson. Common crustaceans for this area include: Ghost Crab (*Ocypode sp.*), Fiddler Crab (*Uca sp.*), Mole Crab (*Emerita talpoida*), Beach Flea (*Orchestia sp.*), Sand Shrimp (*Crangon septemspinosa*), Horseshoe Crab (*Limulus polyphemus*), Blue Crab (*Callinectes sapidus*), and other crab and shrimp species (Taggart and Henderson, 1998). Research by an NCNERR Graduate Research Fellow examined the way female Blue Crabs use tidal currents to move. Results indicated that by timing vertically movements with tidal cycles, female crabs could control the direction they moved relative to the Ocean. This research also showed that the Rachel Carson Reserve was an important stopover for migrating female Blue Crabs (Carr et. al. 2004)

The soft substrates within the Rachel Carson Reserve provide habitat for forty-seven species of invertebrates (Taggart and Henderson, 1998), including the Eastern Oyster (*Crassostrea virginica*), several species of clams, Atlantic Bay Scallop (*Argopecten irradians*), Ribbed Mussel (*Modiolus demissus (Dillwyn)*), many gastropods and a wide variety of benthic species. Four invertebrates found within the boundaries of the Rachel Carson Reserve, the Channeled Whelk (*Busycon canaliculatum*), the Knobbed Whelk (*Busycon carica*), the Lightening Whelk (*Busycon contrarium*), and the Parchment Tubeworm (*Chaetopterus variopedatus*), have been given special concern status by the North Carolina Natural Heritage Program (Table 3.6) (Taggart and Henderson, 1998).

Several studies regarding oysters and scallops have been conducted in the Reserve. Scallop numbers have been declining in recent years. Studies have found that the area is starved for larvae recruitment (Peterson and Summerson 1992). The reasons behind this larvae recruitment issue are still being investigated. It is also believed that the scallop population is suffering from heavy predation by sting rays. A NCNERR GRF fellow conducted research into oysters in Middle Marsh. He examined how habitat setting influenced restored oyster communities. He observed that restored oyster reefs enhanced the abundance of resident invertebrates (Grabowski et al. 2005).

B: Fishes

The waters around Rachel Carson serve as nursery and habitat areas for many commercially important fisheries. Over 50 species of fish have been documented as present around Rachel Carson (Taggart and Henderson, 1998). NOAA's Fisheries Service has conducted a sampling program since 1985 to document the fish larvae present in the waters passing under the bridge between Piver's island and the mainland (Figure 3.1). This program

called "bridgenet" provides a long term quantification of the nekton using the Rachel Carson area as a nursery. Table 3.7 shows the most abundant species that have been documented by this sampling program from 1985-2002. Sampling has continued since 2002, although larvae identification has not been completed. Preserved samples will be analyzed as resources allow. Information regarding this sampling program can be obtained from Dr. Gretchen Beth Martin at the NOAA Beaufort Laboratory.

Table 3.7: Species collected by NOAA Fisheries Service Bridgenet sampling program 1985-2002.

Scientific Name	Common Name	Number collected
Leiostomus xanthurus	Spot	215054
Lagodon rhomboids	Pinfish	154973
Micropogonias undulates	Atlantic Croaker	74242
Brevoortia tyrannus	Atlantic Menhaden	48973
Myrophis puctatus	Speckled Wormeel	26967
Myrophis puctatus (leptocephalus)	Speckled Wormeel Lepto	23451
Engraulidae	Anchovy	18652
Paralichthys albigutta	Gulf Flounder	9852
Orthopristis chrysoptera	Pigfish	8613
Gobiidae	Goby	6260
Paralichthys lethostigma	Southern Flounder	6254
Mugil cephalus	Striped Mullet	4824
Paralichthys dentatus	Summer Flounder	2173

NCNERR GRF work has also examined the habitat selection, foraging effort, and schooling behavior of Red Drum, (*Sciaenops ocellatus*) within Rachel Carson. Red Drum showed strongest preference for sand and second strongest preference for oyster reef. Sandy habitats were selected most often for both active foraging and sedentary activity. While reefs were often the second choice of red drum, they were used most for sedentary activity. Red Drum used grassbeds infrequently and almost exclusively for foraging. Red Drum occurred mostly in schools or groups in all three habitats and were seen isolated from each other rarely (Powers 2005).

In addition to Red Drum, the Reserve is home to many other commercially important finfish. Middle Marsh is heavily utilized for foraging by Speckled Trout (*Cynoscion nebulosus*) and Flounder (*Paralichthys dentalus* and *Paralichthys lethostigma*). Juvenile members of the Snapper-Grouper complex are often observed feeding in Middle Marsh along seagrass beds and oyster reefs. Spot (*Leiostomus xanthurus*), Croaker (*Micropogonias undulates*), Menhaden (*Brevoortia tyrannus*) and Striped Mullet (*Mugil cephalus*) are also frequently observed in the Reserve, especially in later summer early fall. The deep channels running through the Reserve attract Bluefish (*Pomatomus saltatrix*) and Spanish Mackerel (*Scomberomorus maculates*). Many species of sharks and rays are also found within the Reserve boundaries.

C: Reptiles and Amphibians

Most reptile and amphibian sightings occur in the upland habitats and include several species of lizards, snakes, frogs and toads. The Eastern Box Turtle (*Terrapene carolina*) is the

most frequently observed terrestrial turtle on the Reserve. The Loggerhead Sea Turtle (*Caretta caretta*), a federally threatened species (Table 3.6), may be found on or around the Rachel Carson Reserve. Also present within the area are the Green Sea Turtle (*Chelonia mydas*), Atlantic Kemps Ridley (*Lepidochelys kempii*) and the Carolina Diamondback Terrapin (*Malaclemys terrapin centrata*). On rare occasions the ocean side boundary of the Rachel Carson Reserve is used by these marine turtles for nesting.

D: Birds

Over 200 species of birds have been documented on the Rachel Carson Reserve. This site is within the primary fall migration route for many species of birds (Atkinson, et al. 1998). The Rachel Carson component is commonly utilized by the following bird species: Snowy Egret (*Egretta thula*), Little Blue Heron (*Egretta caerulea*), Tricolored Heron (*Egretta tricolor*), Glossy Ibis (*Plegadis falcinellus*), Gull-billed Tern (*Sterna nilotica*), and Black Skimmer (*Rynchops niger*) (Atkinson, et al. 1998). Seasonal nesting occurs within the Reserve by: gulls, terns, and skimmers on the dunes of Bird Shoal, while herons and egrets have a rookery within the Middle Marshes shrub thicket (Atkinson, et al. 1998). Federally threatened Piping Plovers (*Charadrius melodus*) and state listed significantly rare Wilson's Plovers (*Charadrius wilsonia*) have been observed feeding within the Reserve component (Table 3.6). Two species of Raptor have been observed by staff on the Rachel Carson Reserve, the Osprey (*Pandion haliaetus*) and Red-tailed Hawk (*Buteo jamaicensis*).

E: Mammals

Mammals found within the Reserve include Raccoon (*Procyon lotor*), Gray Foxes (*Urocyon cinereogentus*), Marsh Rabbits (*Sylvilagus palustris*), and feral horses (Atkinson, et al. 1998). As of January 2007, the feral horse population was up to 42 individuals (see section 3.9). Marine mammals are also found in the waters surrounding the Reserve. The Atlantic Bottlenose Dolphin (*Tursiops truncatus*) is the most common marine mammal sighted. Occasionally a stray West Indian Manatee (*Trichechus manatus*) will visit the Reserve, although sightings are rare.

3.9: Invasive Species

There are several documented invasive species present on the Rachel Carson Reserve. These include the Tamarisk Tree (*Tamarix ramosissima*), Russian Olive (*Elaeagnus angustifolia*), Nutria (*Myocaster coypus*) and feral horses. The Tamarisk Tree or Saltcedar is a native species found in Eurasia and Africa. It was imported as an ornamental shade tree and for its erosion control and wood production potential (Figure 3.8) (Graetz 1973). A mature tree can produce up to 600,000 seeds each year and can

Figure 3.8: Tamarisk Tree at Rachel Carson.

consume up to 300 gallons (1,135 L) of water per day. This tree spreads rapidly by seed and root propagation. The trees can grow up to one foot (0.3 m) per month and range from 5-20 ft (1.5-6 m) tall when mature. Monitoring of this tree began on the Rachel Carson Reserve in June of 2001 and has continued every summer since then with using hand-held GPS units to plot the location of the trees. Figure 3.9 shows the locations of the Tamarisk trees on Rachel Carson from the mapping effort that was completed during the summer of 2006. Tamarisk out-competes native vegetation by consuming vast amounts of water and by exuding salt from its leaves. These processes increase the Chloride concentration of the soil beyond the tolerance of most native species (Stein and Flack 1996). Another problem specific to the Rachel Carson Reserve is that the trees' water usage could dry up the watering holes that the feral horses use. Efforts to monitor the spread of the trees will continue as will efforts to remove them using cut stump herbicide application. A pilot removal effort using this method was conducted in 1999. This effort showed promise as an effective management strategy. The primary lesson learned from this pilot study was that repeat herbicide applications are required to quell sprouts that emerge from the original tree's cut stump. One herbicide application was not enough to achieve effective control.

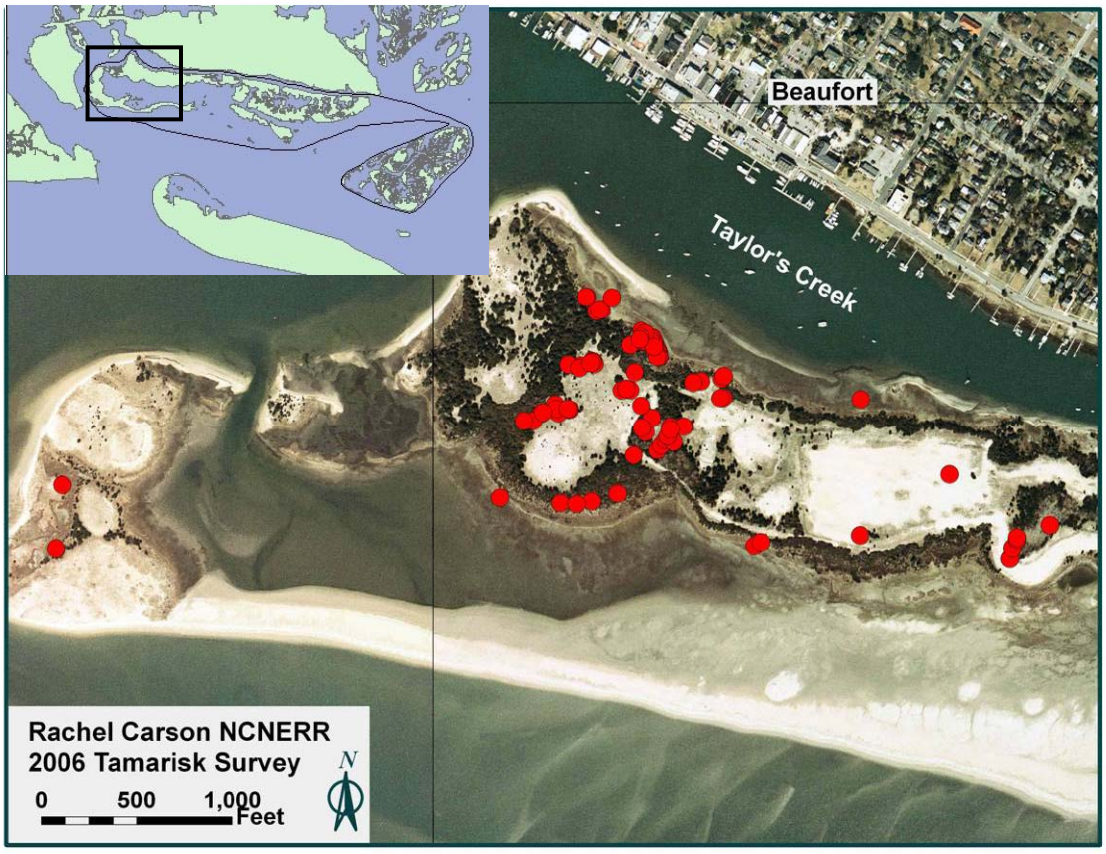

Figure 3.9: Tamarisk locations (red dots) at Rachel Carson from the 2006 mapping effort. Map shows location of aerial photo on reserve.

The upland areas that are now part of the Rachel Carson Reserve were used as grazing areas for livestock, by local residents starting in the 1940s. As a result of this practice, a feral population of horses is now present on the Reserve (Figure 3.10). These horses are not part of the natural biota for the island and their presence has caused problems and interference with the native communities of the Reserve. The main food supply of the feral horse is Smooth Cordgrass (*Spartina alternaflora*). Studies have shown feral horse populations may adversely affect biomass, percent cover, height, density and surface cover of *Spartina* and more importantly decrease seed production (Hay and Wells, 1988). Thus, horse activity decreases the marshes' ability to provide wave dampening; fish habitat and erosion protection; and may eventually lead to marsh loss. The action of the horses' hooves can also hasten erosion of island sediments, and can cause damage to colonial bird and sea turtle nests.

Figure 3.10: Horse and foal at Rachel Carson

Despite the harsh conditions the horses thrived on the Reserve and during the late 1980s and early 1990s causing the population to exceed the Reserve's carrying capacity. This led to massive malnutrition and several deaths. The horses are considered a cultural resource so management action was required to alleviate the over crowding. A birth control program was initiated to stem new births. This coupled with natural morality has helped the horse population get near the target number of 40 horses. This method was chosen because it has been proven effective in wild horse populations located on Cape Lookout National Seashore (Figure 3.1) and Assateague Island National Seashore on the Maryland – Virginia border. Since the darting process started, there have been 8 births at Rachel Carson.

To properly implement the birth control program, an accurate record of the horse population must be maintained. Individual horses are identified, photographed, and maintained in a notebook. Each horse is tracked in the notebook for births, general health, social habits and eventually death. Beyond the birth control program, the horse population is treated as a wild herd. The Reserve's staff from the Beaufort office oversees the horse management for Rachel Carson.

Figure 3.11: Picture of a Nutria (Myocastor coypus).

Table 3.8 lists other invasive species that are currently known to exist on the Rachel Carson Reserve. To date, no investigations have been done on these species other than to

confirm that they are present. Future work will need to examine the impact of these species. The nutria or *Myocastor coypus* in particular are potentially very problematic because their feeding habits cause damage to vegetation and destruction of wetland habitats (Figure 3.11).

Table 3.8: Other invasive species found on Rachel Carson

Scientific Name	Common Name
Ambrosia artemisiifolia	Ragweed
Commelina communis	Dayflower
Conyza Canadensis	Horseweed
Eupatorium capillofolium	Dog fennel
Melilotus alba	White sweet clover
Salsola kali	Russian thistle
Xanthium stumarium	Cocklebur
Cortaderia selloana	Pampas grass
Codium fragil	Dead man's fingers
Myocastor coypus	Nutria
Eremochloa ophiuroidesand	Centipede grass
Data from NCNERR staff observations.	

3.10: Stressors

The Rachel Carson Reserve component is exposed to a variety of stressors, both natural and anthropogenic (man-made). Natural stressors include hurricanes and Nor'Easters, sea level rise, and drought. Anthropogenic stressors include altered land use, pollution, nutrient loading, and habitat disruption. Some of the key stressors are discussed in detail below.

A: Pollution/eutrophication

The primary concern in this category for the Rachel Carson Reserve is fecal contamination of shellfish beds. Fecal contamination enters surface waters from a variety of sources: failing septic tanks, spills and leaks from municipal sewer systems, illegal pump outs from vessels and defecation by resident fauna. There has been a large body of work regarding fecal contamination within the Rachel Carson Reserve. Three NCNERR GRF fellows have examined the waters around Rachel Carson for fecal contamination. They have found that the waters are susceptible to episodic loading associated with runoff events (Gregory et al. 2006; Coulliette 2007; Love 2007). This coupled with the increased development that has occurred in the region (see below) suggest that more acres of shellfish beds may be closed in the future.

B: Sea Level Rise and Erosion

Sea level rise and erosion is a serious concern in coastal areas worldwide (Pilkey and Cooper 2004). North Carolina is especially susceptible because a large portion of the Coastal Plain has very low relief. The Intergovernmental Panel on Climate Change predicts increased rates of global sea-level rise over the next century in direct response to known global climate

warming (IPCC 2001). Increased rates of sea-level rise will adversely impact coastlines of North Carolina in the following ways:

- Accelerated rates of coastal erosion and land loss;
- Increased economic losses due to flooding and storm damage;
- Increased loss of urban infrastructure;
- Collapse of some barrier island segments; and
- Increased loss of estuarine wetlands and other coastal habitats (Riggs 2003).

Most of the estuarine shorelines in North Carolina are eroding in response to the ongoing long-term rise in sea level. The weighted average for the recession of all shoreline types within the highly variable regional setting is -2.7 ft yr^{-1} (0.8 m yr^{-1}) (Riggs 2003). Many areas within the Rachel Carson Reserve are less than 1ft (0.3 m) above present sea level. Consequently, large areas of the Reserve will be converted to subtidal habitat if accretion rates can not keep up with sea level rise (see Section 3.11 C).

Erosion, largely driven by storm processes, results in the systematic loss of both uplands and wetlands through time (Riggs 2003). Erosion can also be accelerated by man-made activities such as boating (Rogers and Skrabal 2003). Recreational and commercial boats can generate closely spaced, steep waves that are particularly prone to cause erosion. The Rachel Carson Reserve has experienced this type of erosion on the east end of Carrot Island where Taylor's Creek enters Back Sound. At this location, the no wake zone of Taylor's Creek ends and mariners power up just as they are rounding the end of Carrot Island. During power up the largest wakes tend to be produced because the boat is displacing the most water. Aerial photography was used to calculate the erosive loss on the east end of Carrot Island from 1994-2004 (Figure 3.12). This work, conducted by Jacquie Ott (NCNERR GIS specialist), clearly shows the loss of Reserve property due to erosion. Of the nine transects investigated, between 12 and 45 ft (3.6 and 13.7 m) have been lost. This erosion has undercut the high bluff that is present on this end of the Reserve resulting in the loss of several upland forest trees. This study clearly shows the impact boat wakes can have. A rise in sea level will only exacerbate this problem. Management options to alleviate this issue are currently being considered. Some of the options include extending the no wake zone, installing a natural breakwater (oyster reef) and conducting programs to educate local boaters.

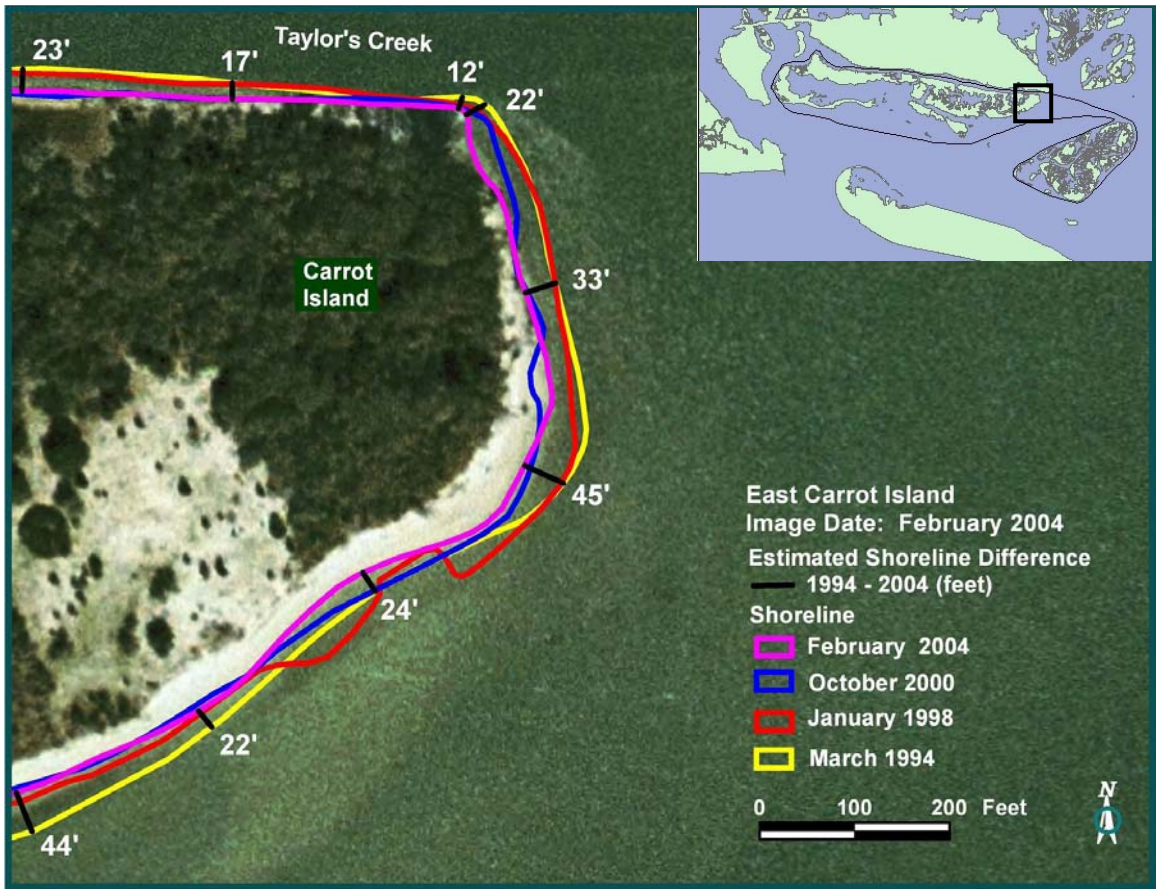

Figure 3.12: Historical shorelines on the east end of Rachel Carson (Carrot Island) since 1994, showing significant erosion.

C: Altered Land Use

The type of land cover present is a critical issue because how the land is used and the type of cover on it has large impacts on its ability to sequester nutrients and pollution rather than convey them to surface waters. Natural land covers with vegetative cover such as forest and marsh have large buffering capacities. They tend to trap nutrients and sediment prior to them entering surface waters. Developed land tends to have very little capacity to absorb nutrients and pollution. This is because developed land has increased impervious surfaces such as roofs, roads, and parking lots. These surfaces do not let water infiltrate the ground and high percentages of impervious surfaces have been correlated with degraded water and sediment quality (Holland et al. 2004, Mallin et al. 2000b). Consequently stormwater runs off these surfaces, picking up whatever contaminants and nutrients are on them and rapidly moves these materials to surface waters (Mallin et al. 2000b, Mallin et al. 2001).

Carteret County's population had an estimated increase in percent population growth of 11.7 % from 1990-2000, and a projected increase of 13.9% for 2000-2020 (N.C. Department of Environment and Natural Resources 2007). Most of this population increase has occurred in the western part of the county where the Rachel Carson Reserve is located. In addition to residential development, scattered commercial and industrial development continues to occur throughout the county. To accurately account for this development, the land use of the county was mapped

using land cover data from NOAA's Coastal Change Analysis Program using the protocol presented in Appendix 4. The two most recent years that data is available for are 1991 and 1997. Figure 3.13 shows the land cover maps for 1991 (panel a) and 1997 (panel b) for the Rachel Carson watershed (United States Geological Survey - Hydrologic Cataloging Unit 03020106). See Appendix 4 for detailed methodology. This delineation covers all the areas of the White Oak River Basin as shown in Figure 3.2 except for the New River sub-basin. The major land cover types were water (38%), Evergreen Forest (19% in 1991, 16% in 1997) and Palustrine Forested Wetland (11% both years) associated with the Croatan National Forest in the Western region of the watershed. Low and High Density Developed (2%) was concentrated in the barrier island communities of Bogue Banks as well as Beaufort and Morehead City.

For clarity the changes that occurred between 1991 and 1997 have been grouped into three categories: 1) decreased vegetation cover (of any type), 2) increased vegetation cover (of any type), and 3) a change from one type of non-vegetated cover to another (neither an increase of decrease of vegetation). The decrease in vegetation cover category includes all areas where the Land Cover changed between 1991 and 1997 to a class that characterizes conditions with generally less plant cover or biomass. Examples of this category are a transition from Forested to Grassland or Scrub-shrub to Low Density Development. The increase in vegetation cover category was assigned to all areas where the Land Cover changed to a class that represents generally greater plant cover or biomass. Examples of this category are succession of grassland to Scrub-Shrub and Scrub-Shrub to Forested. The change in non-vegetated cover category designates all areas that had different non-vegetated land cover classes in 1991 and 1997. Examples included water to unconsolidated shore, unconsolidated shore to bare land and bare land to low-density developed. Figure 3.14 and Table 3.9 show the changes between 1991 and 1997 associated with these three groups.

Table 3.9: Change in land cover from 1991 to 1997 in the Rachel Carson watershed

Category	Acres	% of total
Total mapped area	752,337	n/a
Water area	285,941	38.0
Total land area	466,396	62.0
Decrease in vegetative cover	36,033	7.7
Increase in vegetative cover	21,953	4.7
Change from one unvegetative cover to another	1,041	0.22
Unchanged land cover	407,369	87.3
Net loss of vegetation = 3.0%		
Percent of land area with changed cover types = 13%		

Changes that occurred between 1991 and 1997 affected 13% of the watershed. The increase in vegetated conditions (5%) was due primarily to succession of Grassland to Scrub/Shrub and Palustrine Scrub/Shrub Wetland to Palustrine Forested Wetland along the western and northern edges of the watershed. These areas are primarily located in protected natural areas. The 8% decrease in vegetative cover consisted primarily of conversion of Evergreen Forest to Scrub/Shrub and Grassland.

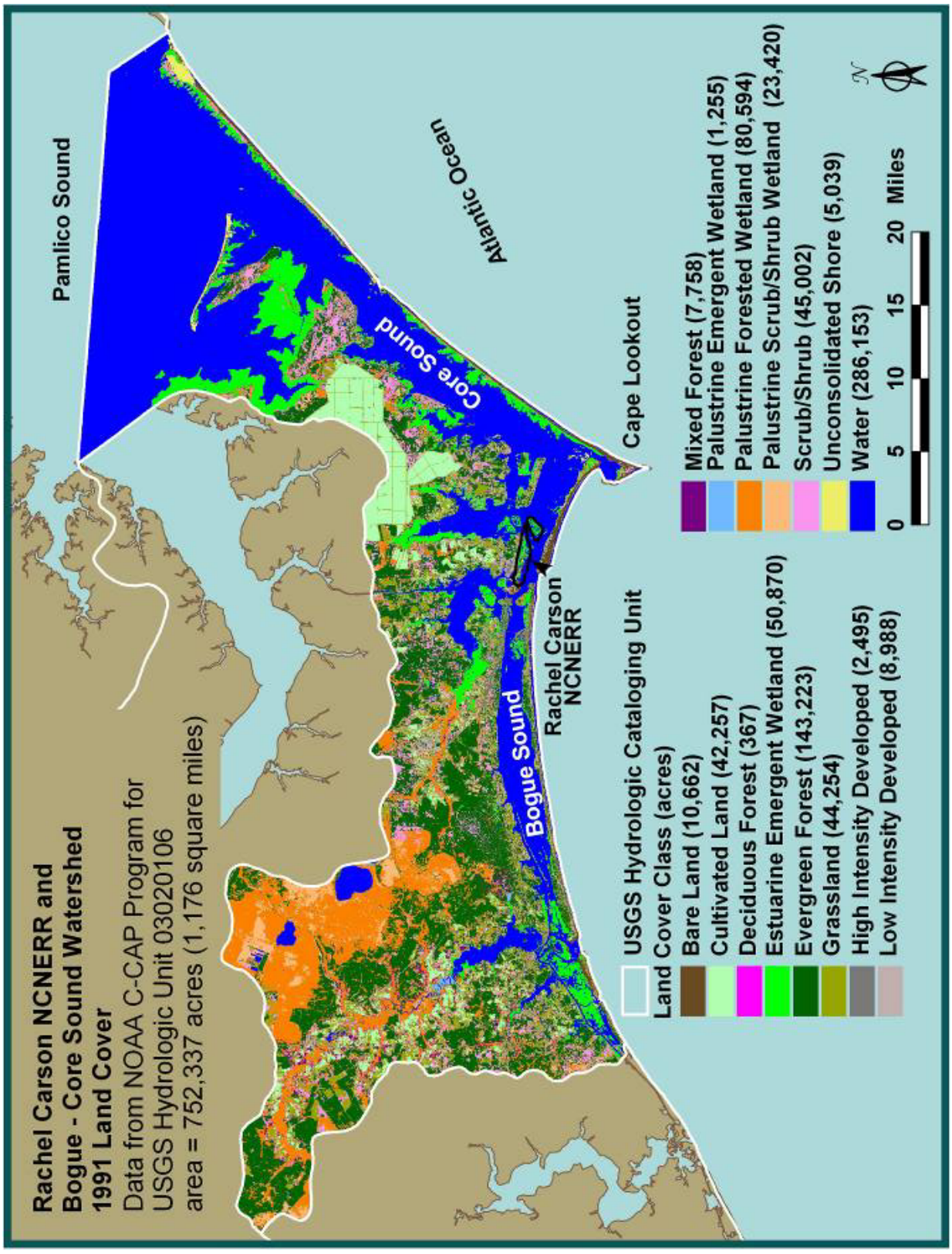

Figure 3.13a: Land use classification from 1991 in the Rachel Carson watershed.

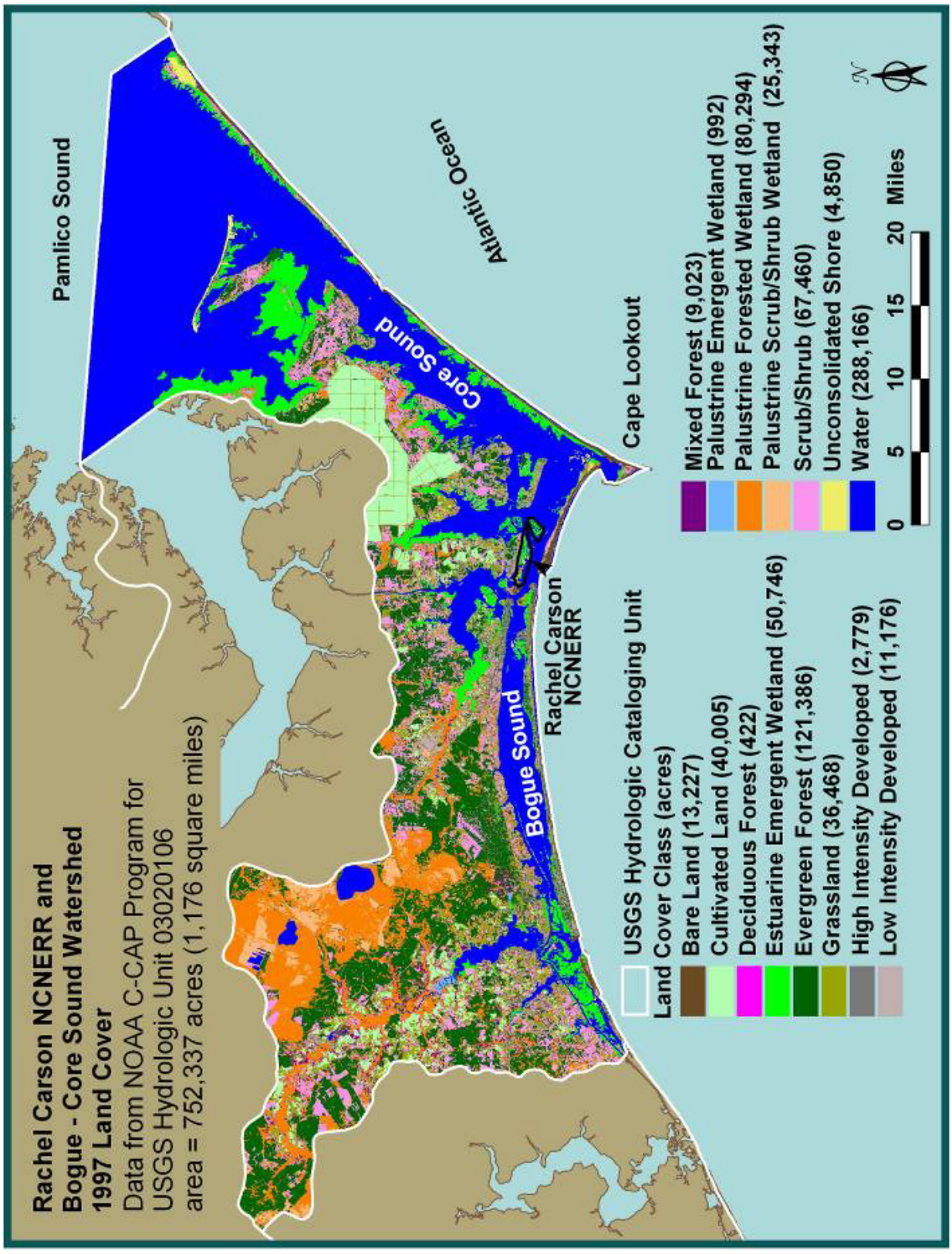

Figure 3.13b: Land use classification from 1997 in the Rachel Carson watershed.

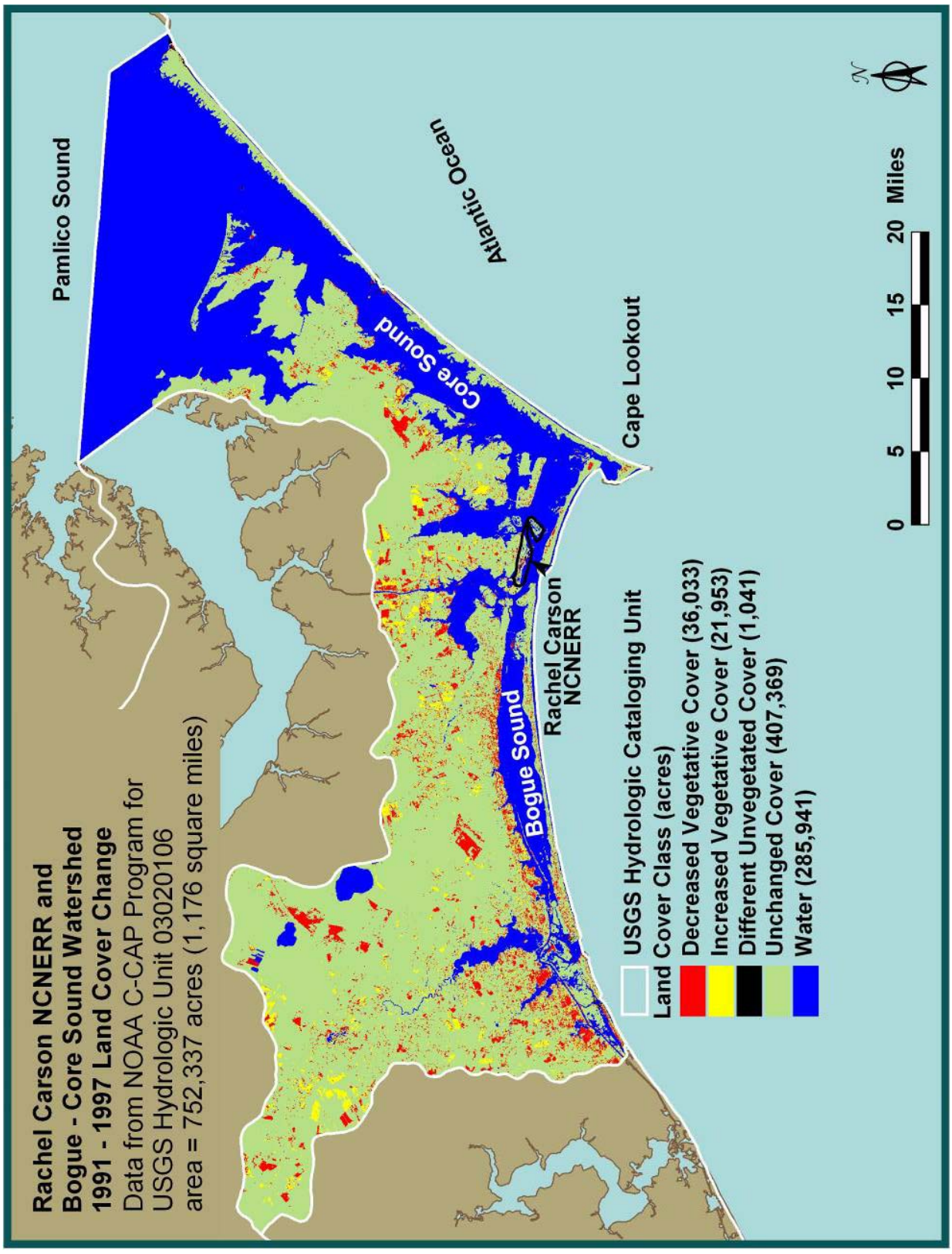

Figure 3.14: Changed land cover from 1991 to 1997 in the Rachel Carson watershed.

The net loss of vegetated land cover between 1991 and 1997 was 3%, principally surrounding Bogue Sound. While 3% seems like a low value, as noted above, this represents only the initial pulse of increased development within the area. Since 1997, development pressure has increased. In 2006 alone three major condominium projects occurred on the grounds of former low density developments. Decreased vegetative cover has been unequivocally linked to declines in water quality (Mallin et al. 2000b, Mallin et al. 2001). Less vegetation leads to increased runoff and less filtering capacity within the watershed. This is particular troubling for the Rachel Carson area given the susceptibility to eutrophication that the region has exhibited (see above section). It is expected that a much greater loss of vegetation cover will be detected in the time period since 1997.

D: Public Use

The Rachel Carson Reserve is open to the public for enjoyment. Fishing, boating, sailing, kayaking, shellfishing and shelling are all common recreational activities on and around the site. The island of Town Marsh has a marked self-guided trail that leads participants through the different estuarine habitats. Areas of the Reserve are heavily utilized as a destination by individuals with private boats. These activities lead to a substantial litter problem on the Reserve. Clean Sweeps are conducted at least twice annually by Reserve staff and volunteers. During these activities many (10+) bags of trash are removed from the Reserve. Unleashed dogs are also a constant problem on the Reserve. Dogs tend to chase colonial nesting birds disrupting feeding, breeding, and nesting.

3.11: Research Activities

The information in this section is in a rapid state of flux. Research projects are constantly being initiated, executed and completed. As a result, this section will rapidly become dated. Despite this complication, it is still beneficial to describe the current body of research in this manner. The past projects represent a large foundation which future projects can utilize as planning guides. The projects currently being worked on are designed to address current high priority coastal management issues. Thus, in addition to the actual research results, these projects will provide future interested parties with awareness into what the high priority issues were for the Reserve at this time. The needed research represents current knowledge gaps that need to be addressed. While future projects may address some of these, the underlying issues such as eutrophication and sea level rise will still be valid.

A: Research Facilities

The NCNERR office in Beaufort, N.C. is located at the NOAA Center for Coastal Fisheries and Habitat Research. NCNERR and the administrative branch of the NOAA lab share a building. This building provides office space for the research coordinator as well as for Reserve management and education staff. The co-location of staff provides great opportunity for cross sector collaboration. The building was not designed to provide support for research activities. There is a common room with counters and a sink that can be used for small clean

research related activities. There are two boats available for research activities in the Beaufort office, and access to the site is ideal.

To make up for the lack of research facilities within the NCNERR-NOAA building, agreements have been made between NCNERR and several of the local marine laboratories in the region. The research coordinator has access to laboratory space at the University of North Carolina – Institute of Marine Science and at the NOAA Beaufort laboratory. Additional research facilities are potentially available through the Duke Marine Lab and North Carolina State's Center for Marine Science and Technology, although formal agreements have not been pursued at this point. The space available from these local marine research facilities provides the research coordinator with space and equipment to conduct most Reserve related research activities.

B: Historical Research Activities

There has been a large body of research conducted at the Rachel Carson Reserve since its dedication. These are documented in Appendix 6 the bibliography of work conducted within NCNERR. Carteret County has marine labs from NOAA, Duke University, North Carolina State University, The University of North Carolina at Chapel Hill, and also the headquarters for the N.C. Division of Marine Fisheries. All of these groups have conducted extensive research in and near the Rachel Carson Reserve. Historically, most of the NCNERR's GRF's have been based in Carteret County and used the Rachel Carson Reserve as their field site.

The research that has been conducted at the Reserve covers a broad range of topics. Projects mentioned previously in this chapter will not be relisted here. There have been numerous studies examining shellfish including the Eastern Oyster (*Crassostrea virginica*) and Scallop (*Argopecten irradians*). These projects have provided knowledge regarding the habitat value of oyster reefs, larvae recruitment, predator interaction, and restoration methods (Peterson and Summerson. 1992; Grabowski et al. 2005). There has also been a large body of work examining the spatial coverage of seagrass beds and their interaction with ecosystem components (Ferguson et al. 1993; Fonseca et al. 2001; Biber et al. 2005; Denault 2007). Several projects including one funded by NOAA's Cooperative Institute for Coastal and Estuarine Environmental Technology (Sobsy et al. 2006) have examined the amounts, source, and fate for fecal contamination found within the waters of the Reserve (Gregory et al. 2006; Coulliette 2007; Love 2007). Researchers from NOAA's Center for Coastal Environmental Health and Biomolecular Research in Charleston, SC recently completed a project at Rachel Carson examining the sediments in the Reserve using an EPA-Environmental Monitoring and Assessment Program style sampling design. The results of this project showed that the overall condition of the sediments within the Reserve was good and contaminant loads were relatively low (Cooksey and Hyland 2007). All of these and the many others listed in the bibliography help create a great base of knowledge for the Rachel Carson Reserve.

C: Current Research Activities

There are many research and monitoring activities currently being conducted at the Rachel Carson Reserve. Some of these projects are being conducted by Reserve staff while others are being done by outside researchers. NCNERR staff from all sectors is engaged in tracking the invasive Tamarisk tree on the Reserve. Information about this project is located in

section 3.9. The Bridgenet sampling program discussed in section 3.8 is also still being conducted. The NCNERR-National Park Service water quality monitoring discussed in section 3.4 is also ongoing.

Two separate efforts are engaged in examining the geographic location, species makeup and density of SAV within the Reserve. NCNERR staff and interns are using on the ground methods to identify seagrass beds and map their size and species make up. The most recent efforts from this found previously unknown beds of grass on the front of Town Marsh and Carrot Island. The NOAA lab in Beaufort is using aerial photography and GIS methods to identify sea grass beds within the Reserve. Coordination between these two projects is underway and will continue into the future. The end result of these projects is to identify all areas within the Reserve that currently has seagrass beds. This will provide an ideal baseline to track future changes. This is an important issue because declines in SAV coverage can be used as an indicator of declining water quality.

A program to document the number and species of birds using the Reserve in winter as part of the Audubon Christmas Bird Count is also ongoing. The annual Christmas bird counts are conducted by a local volunteer and bird expert John Fussell. He has been doing the Christmas bird counts for several years. The information from these counts is available from the Audubon Society at (http://www.audubon.org/bird/cbc/history.html). He also conducts census data for nesting Piping Plovers, a species of special concern during the breeding season.

Dr. Dan Rittschoff a faculty member from the Duke University Marine Lab continues several research projects that partially utilize the Rachel Carson Reserve. Dr. Rittschoff's work includes: 1) the ecology and behavioral biology of local macroinvertebrates such as blue crabs and mud snails; 2) barnacle models as they relate to fouling and the prevention of fouling and bioadhesives; and 3) impacts of xenobiotics on behavior and reproduction. Dr. Rittschoff has also been an avid participant in the Reserve Estuary Live program that uses the internet to bring estuarine programming into the classroom.

A project examining sea level rise and marsh accretion is also being conducted within the Reserve by staff from NOAA's Center for Fisheries and Habitat Research in Beaufort, N.C. and the University of North Carolina – Institute of Marine Science. This work aims to determine if the marshes in Rachel Carson and adjacent coastal waters will keep up with projected sea level rise, and what functional changes may occur in the marsh ecosystem. This work is being headed by Drs Carolyn Currin and Michael Piehler.

A project examining the impact on the Bay Scallop (*Argopecten irradians*) by Cownose Stingray (*Rhinoptera bonasus*) predation is currently occurring within Middle Marsh. This project by University of North Carolina – Institute of Marine Science researchers will provide valuable data needed to managers trying to understand why Bay Scallop numbers have dramatically declined over the past decade.

3.12: Future Research Needs

A large amount of work still remains to be completed at Rachel Carson. This section will detail a few of these projects and potential partners that could assist in making the projects attainable. This is not meant to be an exhaustive list, rather a guide to known knowledge gaps that need to be filled.

A project examining the before and after effects of the management strategy enacted to combat the erosion problem on the east end of Carrot Island is needed. Shoreline stabilization is a high priority for coastal resource managers in the State. This project could provide some valuable data regarding the ecological implications of shoreline stabilization. Partners that could assist in this effort include the N.C. Divisions of Coastal Management and Marine Fisheries, the N.C. Coastal Federation, and the NOAA Beaufort lab.

Horse exclosure experiments need to be conducted on Rachel Carson to quantify the effect the horse population has on native vegetation. This could be done in the upland areas as well as the marshes. This information could help management decide the appropriate number of horses that should be in the herd. This study would also be suitable to include in Reserve education programs. Groups could be taken to the enclosures and visually observe the vegetation in the enclosure compared to that outside. The National Park Service maintains a distinct population of horses on Shackleford Banks. They would be ideal partners to assist in this project.

As noted before, there are several invasive species currently on Rachel Carson that have not been investigated relative to their ecological impacts. This works needs to be done so that management strategies can be developed. The Nature Conservancy and the local marine labs would be ideal candidates for partners in this project.

Results from a research market analysis revealed much interest in continuing the fecal contamination and source tracking work relative to shellfish beds. At current time, shellfish beds are closed anytime total fecal numbers break the established threshold. This policy is slightly problematic as beds are closed at times when the fecal contamination is caused by non-human sources. If rapid source tracking methods can be developed, shellfish beds could be better managed. Closings could only be implemented when the fecal contamination is caused by human sources.