Chapter 5: Zeke's Island Component

5.1: Environmental Setting

The Zeke's Island component of the NCNERR is located in portions of both Brunswick and New Hanover counties, in south-eastern North Carolina just south of Kure Beach (Figure 5.1). The nearest population center is Wilmington, N.C. located 22 miles (35 km) to the north. Southport, N.C. is located across the Cape Fear River 10 miles (16 km) to the south-southwest. Zeke's Island is bounded to the north by Federal Point (encompasses Fort Fisher State Park and the North Carolina Aquarium at Fort Fisher), to the east by the Atlantic Ocean, the Cape Fear River to the west, and the Smith Island Complex to the south. Zeke's Island is located in the Cape Fear River basin and on a broader scale in the Carolinian biogeographic province (Figure 5.1).

Zeke's Island was one of the three original NERR components dedicated by NOAA and DCM in 1985 (Masonboro was added in 1991) and includes 1,165 acres (4.7 km^2). Zeke's Island is accessible by both foot traffic and boat. A boat ramp is present at the Northern end of the Reserve providing boat access to the basin area (Figure 5.1). Walking trails into the Reserve are provided through a partnership with the North Carolina Aquarium at Fort Fisher.

5.2: Historical Uses

A: Native American Usage

Prior to English settlement, the area around Zeke's Island was likely used as a hunting ground by Native American Indians. The Eastern Seaboard of the U.S. including North Carolina was inhabited by Algonkian speaking tribes. Midden evidence clearly demonstrates that coastal shellfish were an important food source for these peoples (Claassen 1986). Evidence for a native presence in the region is also provided by the accounts of early settlers (see below).

B: Colonial Uses

William Hilton, a New England explorer, sailed and explored the Cape Fear region during 1663-1666. His report enticed colonists from Massachusetts Bay Colony to try to settle in the area during the winter of 1663-1664. This settlement attempt failed as well as other attempts from 1664-1667. These settlement efforts did not succeed due to inadequate external support, internal dissention and hostile relations with Native Americans. A permanent European settlement known as Brunswick Town was founded in 1726 by Maurice Moore upstream of the Reserve sight on the western bank of the Cape Fear River (Watson, 1992). Brunswick Town became a vital port city specializing in naval-stores and rice produced by the nearby plantations which had been built in the region (Atkinson et al. 1998).

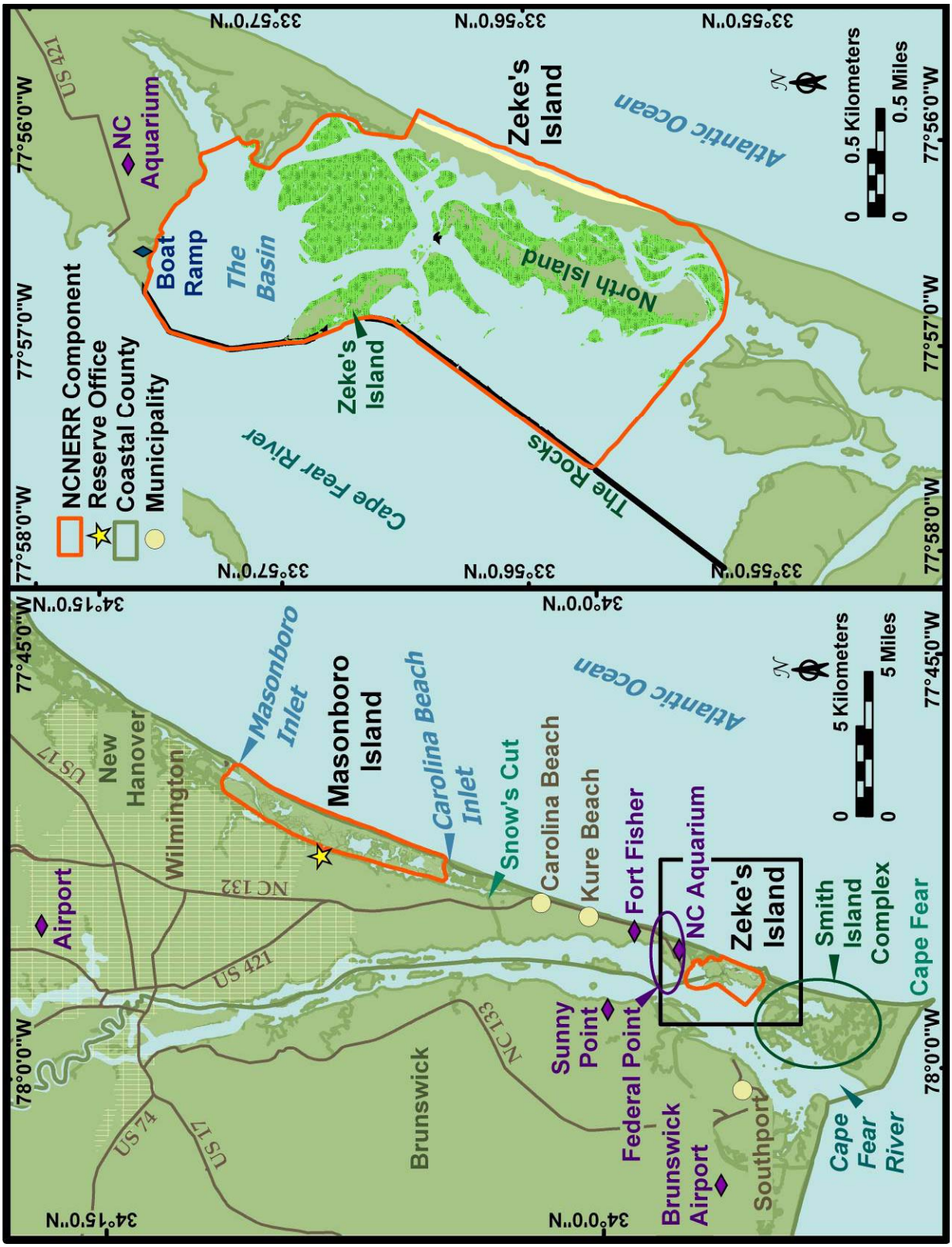

Figure 5.1: Zeke's Island location. The top panel shows a close up of Zeke's Island.

The importance of Brunswick Town waned after the rapid development and incorporation of Wilmington (Watson 1992). Wilmington grew into the primary port for the region largely due to the improvement in transportation infrastructure (ferries and roads) that occurred in the region during the 1770s (Watson 1992). In 1776 the last few people living in Brunswick Town were forced out when British troops burned the city during the Revolution and Brunswick Town lost representation in the General Assembly (Watson 1992). Today foundations of many of the town's buildings can be seen along with the exterior walls of the town's church.

C: Civil War Uses

When the civil war broke out, the port of Wilmington became critical to the success of the Confederacy. In an effort to keep the blockaders at bay and protect the runners when entering and leaving Wilmington, the Confederate Army constructed numerous earthern fortifications at the mouth of the Cape Fear River (Campbell 2005). During 1861-1862 the most prominent of these forts, Fort Fisher, was fortified and used as the main defense for Wilmington. Fort Fisher's guns were able to protect confederate blockade runners until late 1864 (Moorefield 1978). In January 1865, Fort Fisher fell to the Union army during a combined land and sea attack (Atkinson et al. 1998). Since 1865 the ocean has eroded much of the original fort. Only remnants of the western most edge of the original fort survive today.

D: Post Civil War Uses

Between 1875 and 1881, the U.S. Army Corps of Engineers constructed "The Rocks" – a massive breakwater running from Federal Point to Zeke's Island, and from Zeke's Island southward through the Smith Island Complex (Figure 5.1). Designed to reduce shoaling in the Cape Fear River, the Rocks drastically reduced the flow of water through New Inlet, which cut through the area now encompassed by the Reserve, and caused extensive changes in the landforms of the area. New Inlet migrated southward while Zeke's Island grew significantly in length. During the six years after the construction of the dam, New Inlet migrated from 580 meters per year to as much as 0.6 miles (1 km) per year before eventually closing (Cleary and Marden 2001). During the late 1800s Zeke's Island was home to a turpentine factory and a center for gill net fishing before these were destroyed during a hurricane in 1899 (Atkinson et al. 1998).

The Fort Fisher area was utilized for military purposes again during World War II. Equipment and usage included: a radar tower, artillery targets, ammunition bunkers, and an airstrip. After World War II and to present day, this area serves as a buffer zone to the Sunny Point Ammunition Loading Terminal located on the western side of the Cape Fear River (Figure 5.1) (Moorefield 1978). Sunny Point is the largest ammunition port in the nation, and the Army's primary east coast deep-water port (Figure 5.1). This use has restricted development in the area, and allowed the natural habitats to be preserved. The only permanent structures south of Kure Beach are a State Park centered on the remains of Fort Fisher, the southern facility of the North Carolina Aquariums, and a ferry terminal for the North Carolina Department of Transportation. This natural area provides public beach access and is used heavily as a recreational destination for swimming, kayaking, and fishing.

5.3: Climate

The nearest reliable weather station to the Zeke's Island area is located at the Brunswick County airport in Southport, N.C. (Figure 5.1). This weather station is maintained as part of the National Weather Service network of reporting stations. Annual mean temperature for the region from 1892 to 2004 was 62.9 °F (17.2 °C). The coolest temperatures occur in January, with average daily temperature of 45.4 °F (7.4 °C), and the warmest average daily temperature, 79.8 °F (26.5 °C) occur in July (Figure 5.2). Average annual rainfall for Southport is 61 in (155 cm). Historically, September has the highest rainfall amount with a monthly average of 9 in (23 cm), and April has the lowest rainfall with an average of 3 in (8 cm).

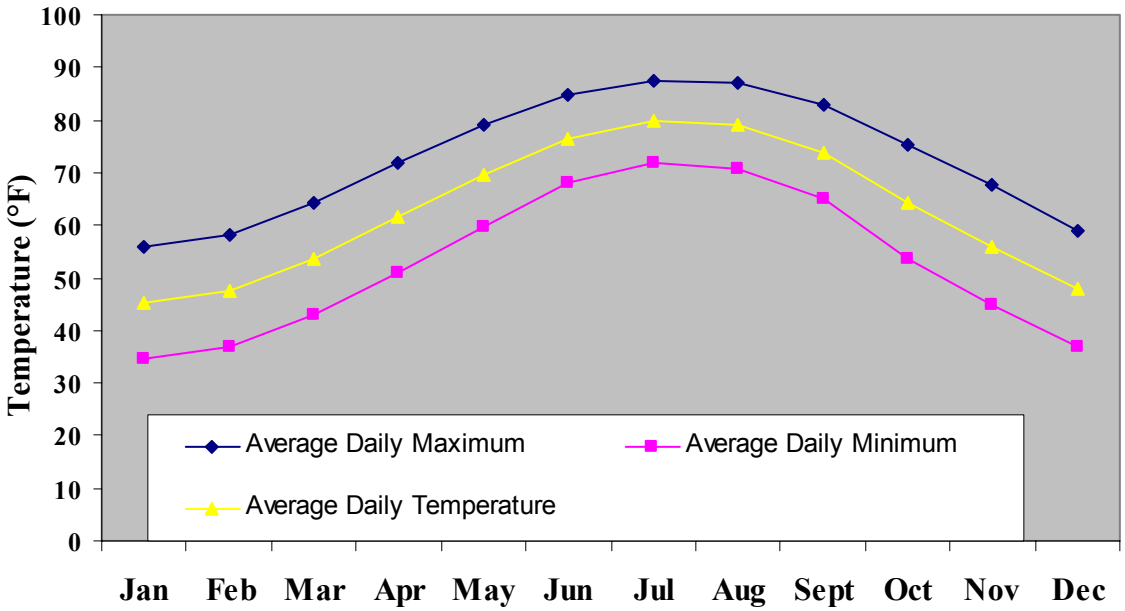

Figure 5.2: Average, minimum and maximum daily temperatures 1892 – 2004 by month for Southport, NC. *Figure from NOAA-National Climatic Data Center.*

The highest yearly rainfall recorded (70.47 in (27.7 cm) occurred in 1946. The driest year on record occurred in 1931 with an annual rainfall of only 27.99 in (11.0 cm) (Table 5.1). Snow and sleet are rare for this area due to the warming effect of the ocean in winter, but do occasionally occur.

Table 5.2 lists the named storms that have passed within 65 nm of Zeke's Island over the past 50 years. Notable storms include Bertha and Fran in 1996 which caused extensive damage to the Wilmington area. In 1999 Hurricane Floyd passed directly over Zeke's Island before moving north. The rainfall associated with Floyd led to extensive flood damage to southeastern North Carolina. More recently, hurricane Ophelia passed Zeke's Island just offshore in September of 2005 bringing large amounts of beach front erosion and large amounts of rainfall. The area has also experienced several Nor-Easter's during this time period, however these storms are not named and tracked as hurricanes are.

Table 5.1: Top ten highest and lowest annual precipitation amounts for Southport, N.C. recorded 1892 – 2004

Top 10 highest precipitation amounts 1892 – 2004		
Rank	Precipitation (in)	Date
1	70.47	1946
2	69.55	1947
3	69.00	1996
4	68.11	1987
5	67.21	1936
6	67.10	1922, 79
7	66.38	1969
8	66.29	1945
9	64.90	1971
10	64.82	1984
Top 10 lowest precipitation amounts 1892 – 2004		
Rank	Precipitation (in)	Date
1	27.99	1931
2	31.44	1923
3	34.79	1941
4	34.99	1940
5	35.72	1894
6	35.89	1903
7	36.56	1911
8	36.82	1926
9	36.91	1954
10	37.30	1902
Data from NOAA – National Climatic Data Center		

5.4: Geological Processes

The Zeke's Island component contains surface sediments representative of the coastal plain. These sediments are varying combinations of sand, silt and clay, from terrestrial and marine sources. Some of these deposits are considered Recent (less than ~11,550 years old) and some are of Pleistocene (~1.8 million to ~11,550 years before present) origin. The Pleistocene deposits are thin blankets of marine and estuarine sands and clays occurring in a series of terraces and scarps related to previous shoreline locations. These deposits overlay layers of Cretaceous (~140 to ~70 million years before present) and Tertiary (~70 to ~1.8 million years before present) terrigenous and carbonate deposits (Atkinson et al. 1998, Moorefield 1978).

The Cape Fear region is representative of coastal cape formations along North and South Carolina. Shoals often extend seaward from these cape areas. Frying Pan Shoals extends seaward from the Cape Fear estuary area outward to approximately 31 miles (50 km). Barrier island formations generally extend north and southwest off these cape regions. The accepted theory is that the capes have maintained their basic positions and morphologies throughout the Pleistocene and Holocene (~11,550 years ago to present) by migrating landward or seaward in response to sea level changes (Moorefield 1978).

Ocean inlets have historically formed, migrated, and closed within the barrier-spit area of Zeke's Island. The last oceanic inlet in this area, the New Inlet, closed in March 1999 (Cleary

and Marden 2001). Currently water exchange is dependent on the adjacent Cape Fear River (see below). Coastal processes continue to change and rework the beach environments that produce the barrier island and estuarine features found around Zeke's Island.

Table 5.2: Tropical storms passing within 65nm of Zeke's Island since 1956

Storm	Date	Name	Wind (kts)	Minimum Pressure (mb)	Classification
1	Sept 1956	Flossy	35		Extratropical
2	June 1957	Not Named	35		Tropical storm
3	Sept 1958	Helene	110	934	Category 3 hurricane
4	July 1960	Brenda	45		Tropical storm
5	Sept 1960	Donna	90	966	Category 2 hurricane
6	Sept 1961	Not Named	30		Tropical depression
7	Aug 1962	Alma	45	1002	Tropical storm
8	Oct 1963	Ginny	85		Category 2 hurricane
9	June 1964	Not Named	35		Tropical storm
10	Sept 1964	Dora	45		Tropical storm
11	June 1966	Alma	40	997	Tropical storm
12	June 1968	Abby	25		Tropical depression
13	Oct 1968	Gladys	75		Category 1 hurricane
14	Aug 1970	Not Named	30	1013	Tropical depression
15	Aug 1971	Doria	50	998	Tropical storm
16	Oct 1971	Ginger	60	991	Tropical storm
17	June 1972	Agnes	30	990	Tropical depression
18	June 1975	Amy	25	1012	Tropical depression
19	Oct 1975	Hallie	35	1003	Tropical storm
20	Sept 1977	Clara	20	1014	Tropical depression
21	Aug 1981	Dennis	45	1001	Tropical storm
22	June 1982	Subtropical 1	60	992	Subtropical storm
23	Sept 1984	Diana	100	960	Category 3 hurricane
24	Oct 1985	Isabel	25	1012	Tropical depression
25	Nov 1985	Kate	45	996	Tropical storm
26	Aug 1986	Charley	55	995	Tropical storm
27	Aug 1987	Arlene	10	1016	Tropical low
28	June 1995	Allison	35	995	Extratropical
29	June 1996	Arthur	35	1006	Tropical storm
30	July 1996	Bertha	85	975	Category 2 hurricane
31	Sept 1996	Fran	100	952	Category 3 hurricane
32	Oct 1996	Josephine	45	988	Extratropical
33	Aug 1998	Bonnie	100	965	Category 3 hurricane
34	Sept 1998	Earl	50	995	Extratropical
35	Sept 1999	Floyd	90	950	Category 2 hurricane
36	Oct 1999	Irene	70	978	Category 1 hurricane
37	June 2001	Allison	25	1006	Subtropical depression
38	Oct 2002	Kyle	35	1011	Tropical storm
39	Aug 2004	Alex	70	983	Category 1 hurricane
40	Aug 2004	Bonnie	25	1008	Tropical depression
41	Aug 2004	Charley	65	988	Category1 hurricane
42	Sept 2005	Ophelia	80	976	Category 1 hurricane
Data from the NOAA – Coastal Services Center					

A study into the sediment characteristics was conducted by Reserve staff in the mid 1990s. The sediments were analyzed for carbon and nitrogen content. These parameters are a good indicator of the amount of organic matter present. Organic matter tends to be very light and usually only settles in deeper areas with low energy conditions. Figure 5.3 shows the results of the sediment mapping efforts. The highest organic matter in the Reserve was located in the northwest portion of the basin (Figure 5.3). It should be noted that this work was conducted when an inlet opening to the ocean was present. Recently, as part of a nutrient flux study conducted in the Reserve, sediment samples were taken from the area in the basin that had the highest values and an adjacent area that originally showed very low values. The recent samples showed the same pattern for these regions. These depositional areas could also be a hotspot for contaminants. Many contaminants adhere to sediment particles and get deposited as the particles settle. Researchers from NOAA's Center for Coastal Environmental Health and Biomolecular Research in Charleston, SC recently completed a project at Zeke's Island 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). Unfortunately, the randomly chosen sample sites did not coincide with the area of high nitrogen. This gap in spatial coverage needs to be addressed with additional contaminant studies.

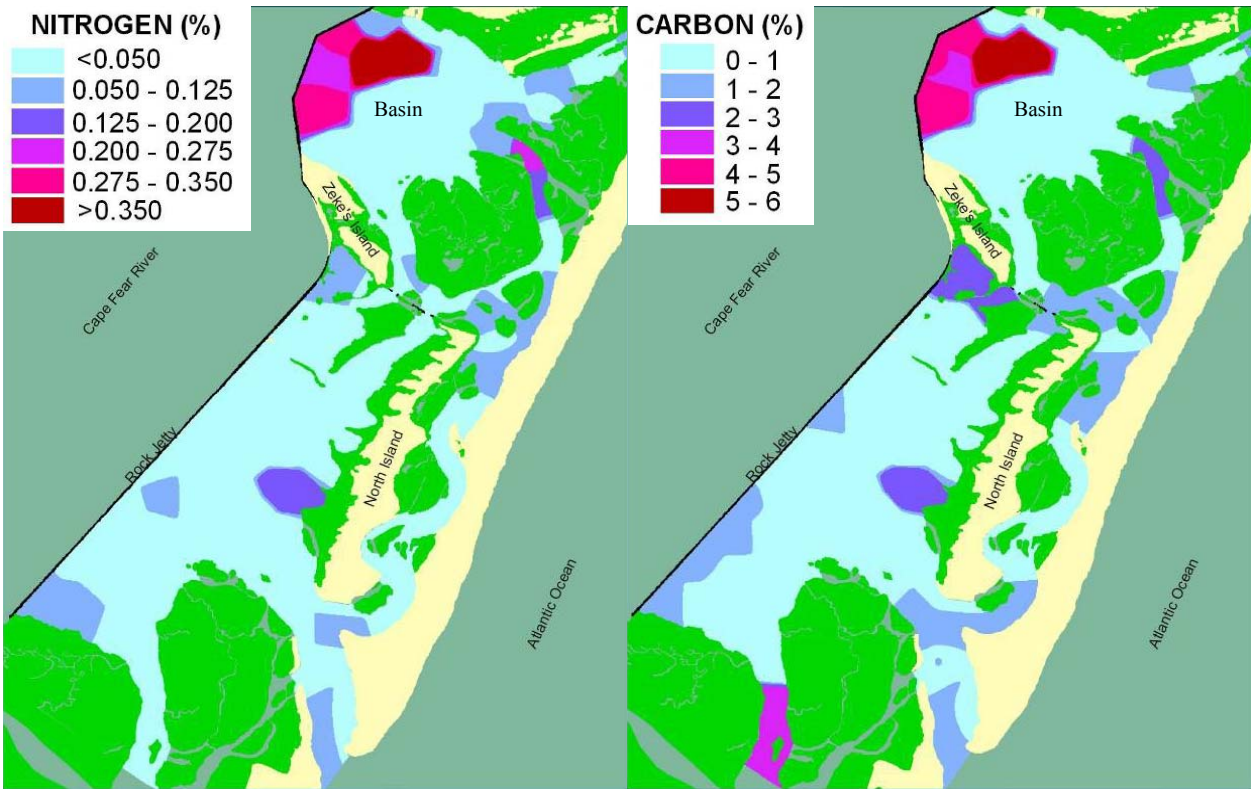

Figure 5.3: Subtidal sediment percent nitrogen (left frame) and carbon (right frame). Areas with the highest nitrogen and carbon are shown in red. The highest values are found in the northwest corner of the basin.

5.5: Hydrology and Water Quality

There are two bodies of water that contribute to water quality at Zeke's Island. Along the beach front, the Atlantic Ocean is the primary influence for water quality. Within the tidal creeks and Basin of Zeke's Island, the primary influence is the lower Cape Fear River Estuary (Figure 5.4). During periods when there is an open inlet at this Reserve component the two water sources mix and water quality is influenced by both. However, when there is not an active inlet, like currently exists today, these two water sources are separated and act independently on their respective spheres of influence.

A: Ocean-side

a: Hydrology

The tide range on the Ocean side of Zeke's Island is about 3.5 ft (1 m) during normal diurnal cycles and can reach almost 5 ft (1.5 m) during spring high tides (Ross and Bichy 2002). The offshore environment is influenced by warm core eddies that spin off the Gulf Stream and discharged water from the Cape Fear River. The near shore currents move sediment on and off the beach. This process is enhanced during coastal storms.

b: Water Quality

The beach front at Zeke's Island is a popular location for recreational activities. Consequently, the quality of the ocean water is extremely important for human health. Ocean water quality testing is conducted by the North Carolina Department of Environmental Health Shellfish Sanitation and Recreational Water Quality Section. 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. The Atlantic Ocean beach of Zeke's Island is defined as a Tier 1 area and thus is sampled once per week during swimming season, and monthly otherwise (Figure 5.5 site S-18). Based on the data available on the Recreational Water Quality section website (2003-present) the beach side of Zeke's Island has not had any swimming advisories. The average enterococcus bacteria concentration for Site S18 (Figure 5.5) from 2003-2005 was 10.4 enterococci per 100 ml water. This is not surprising given that the ocean currents along Zeke's Island move quite rapidly. Thus any pollutants in the area are rapidly flushed.

B: Lower Cape Fear River Estuary Water Quality

a: Hydrology

The major hydrological influence for the Basin and tidal creeks of Zeke's Island is the lower Cape Fear River Estuary. The Cape Fear River watershed is the largest within the State encompassing 9,324 square miles (24,149 km^2) from Greensboro, N.C. to the coast (Figure 5.4).

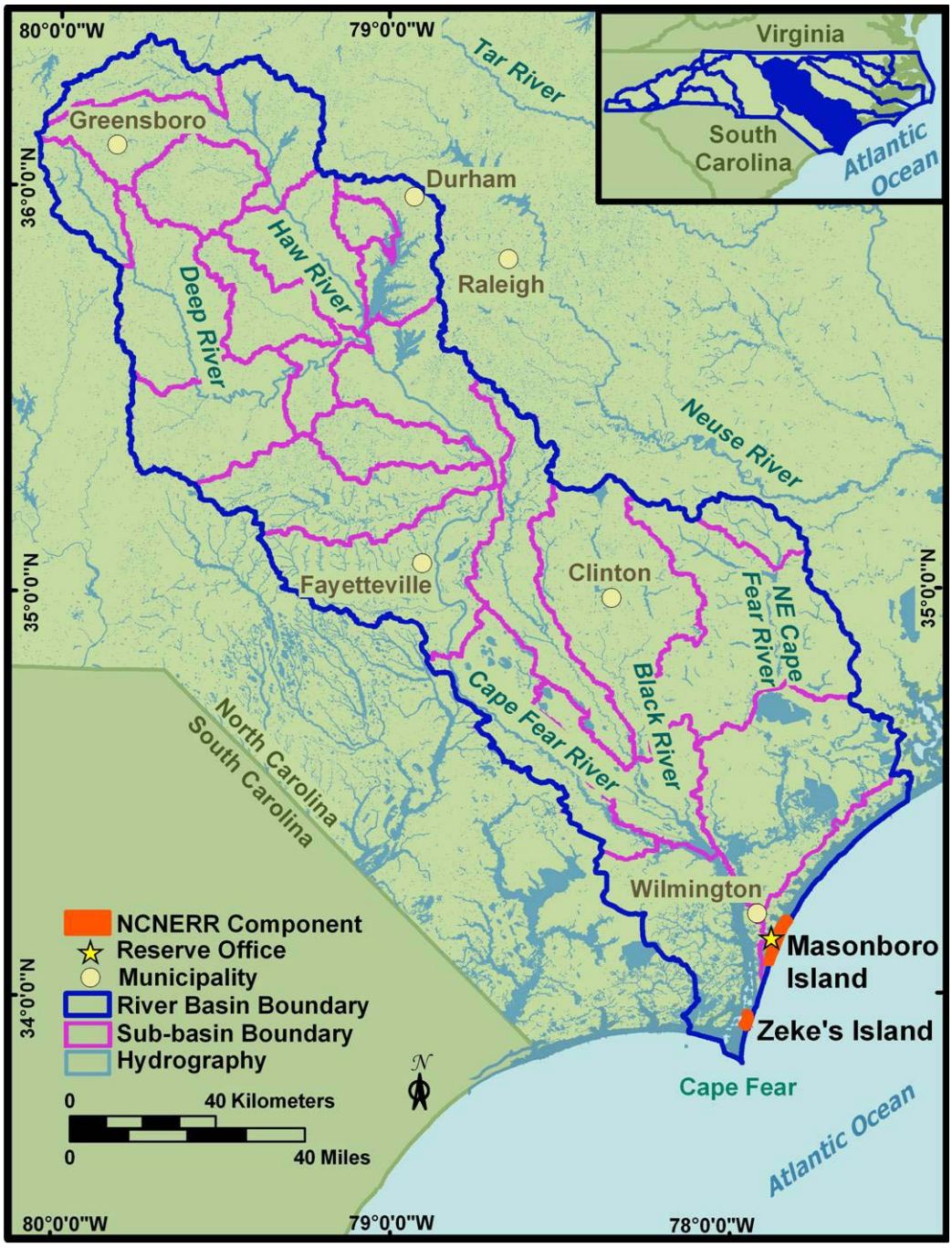

Figure 5.4: Cape Fear River Basin map.

The river supports a multitude of uses from agriculture, industry, power generation, and recreation. Since the last oceanic inlet closed in 1999, water within Zeke's Island has no direct exchange with the Atlantic Ocean. Thus, the water within Zeke's Island is directly dependent upon the water quality of the lower Cape Fear River Estuary. River water flows over the top of The Rocks during high tide. During extremely high tides and during periods of high river discharge, The Rocks are completely under water. Water exchange between the river and Zeke's Island also occurs through gaps where The Rocks have collapsed and no longer present a barrier to flow. The deepest water within Zeke's Island is only about 6 ft (1.8 m) and occurs in the tidal creeks. Tidal exchange in the Basin and tidal creeks is diurnal in nature and averages ~ 3.5 feet (1 m) in height. Strong winds from the south can enhance the water depths in the Reserve as they push water up the Cape Fear River.

b: Water Quality

The water quality of the Lower Cape Fear River Estuary is monitored by several entities working collaboratively within the Lower Cape Fear River Program. One of the stations monitored as part of this effort is located near Zeke's Island (Figure 5.5 site M23). Based on 2003-2004 findings, the water quality of the lower Cape Fear River Estuary near Zeke's Island was "good" in terms of dissolved oxygen concentrations, chlorophyll *a* concentrations, fecal coliform bacteria concentrations, and turbidity concentrations (Mallin et al. 2005) (Table 5.3). The criteria for a "good" rating are that N.C. State standards are not exceeded in more than 10% of all samples. A "fair" rating has samples exceeding North Carolina State standards in 11-25% of measurements, and a "poor" rating has samples exceeding the North Carolina State standard more than 25% of the time (North Carolina Division of Water Quality 2004). The North Carolina Division of Water Quality has designated the waters in Zeke's Island as shellfishing waters and high quality water. This means that shellfish can be harvested from the waters for human consumption. This is the most stringent water quality designation used by the North Carolina Division of Water Quality.

The four parameters mentioned above (dissolved oxygen, chlorophyll *a*, fecal coliform, and turbidity) are critically important because they serve as indicators of overall system health. Dissolved oxygen is needed by all estuarine organisms in order to survive. If there is not enough oxygen in the water, fish and other organisms may die. Chlorophyll *a* provides a measure of the amount of algae in a system which is an indicator for overall trophic status. Fecal coliform bacteria are indicators for other human illness causing organisms. Turbidity plays a big role in how much light passes through the water. When light does not penetrate very far in the water column, overall system productivity is hindered because the primary producers become light limited. This is not good for water quality because when estuarine primary producers are light limited they utilize less nutrients, increasing the nutrient load delivered downstream to the coastal ocean (see last paragraph in this section).

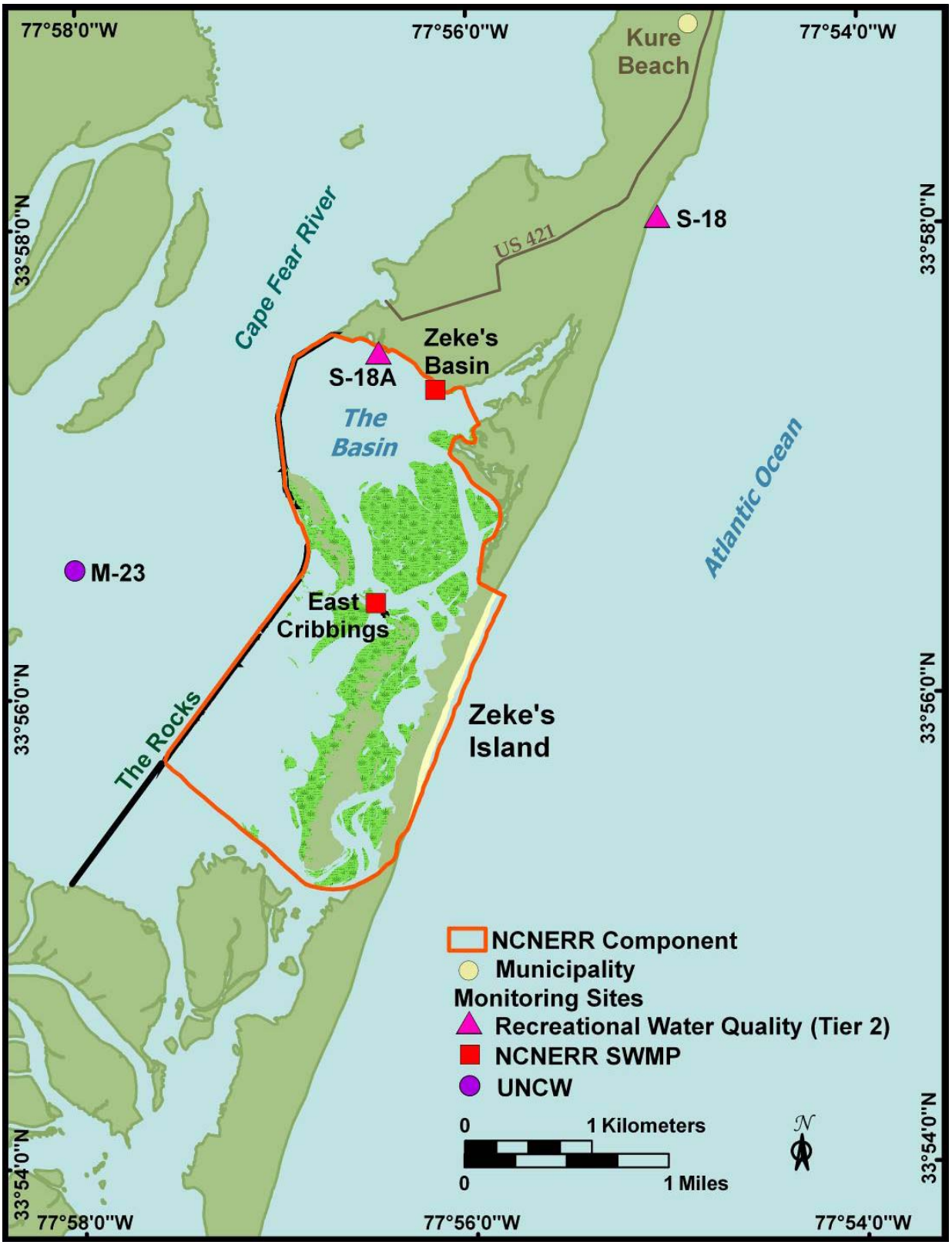

Figure 5.5: Water quality monitoring locations at Zeke's Island.

Table 5.3: Lower Cape Fear River water quality data averages from 2005

Parameter	Value
Temperature	19.7 °C
Salinity	21.7 psu
pH	7.9
Dissolved O_2	8.1 mg l^{-1}
Turbidity	7 NTU
Total Suspended Solids	12.8 mg l^{-1}
Light Attenuation	1.71 m^{-1}
Total Nitrogen	646 µg l^{-1}
Nitrate and Nitrite	133 µg l^{-1}
Ammonium	33 µg l^{-1}
Total Kjeldahl	506 µg l^{-1}
Total Phosphorus	28 µg l^{-1}
Othophosphate	15 µg l^{-1}
Chlorophyll a	3.4 µg l^{-1}
Fecal Coliform	6 CFU per 100ml
Aluminum	371 µg l^{-1}
Arsenic	4 µg l^{-1}
Cadmium	0 µg l^{-1}
Chromium	0 µg l^{-1}
Copper	9 µg l^{-1}
Iron	340 µg l^{-1}
Lead	0 µg l^{-1}
Mercury	0 µg l^{-1}
Nickel	11 µg l^{-1}
Zinc	4 µg l^{-1}
Data from Lower Cape Fear River Program Station M23	

The Recreational Water Quality section monitor at one Tier 2 location within the Zeke's Island basin (Figure 5.5 site 18A). Based on data from 2003 to present, there have not been any violations in this area and the average enterococci concentration was 24.4 enterococci per 100 ml water. However, during a period of high runoff associated with rainfall, a sample from this station in March 2003 had an enterococci reading of 324 enterococci per 100 ml water, demonstrating that the area is potentially susceptible to fecal contamination, and that all efforts to minimize runoff should be pursued.

Water quality within Zeke's Island has been monitored continuously by Reserve staff since 1994. Two SWMP water quality locations (Figure 5.5 site Zeke's Basin and East Cribbings) are equipped with continuously monitored water quality instruments made by Yellow Springs Instruments that measure: dissolved oxygen; pH; temperature; conductivity; salinity and turbidity. These locations have also been sampled monthly for nutrient (NH_4^+, NO_3^- and PO_4^{-3}) and chlorophyll *a* concentrations since 2002. The water quality within the basin is typically good. Table 5.4 provides the high, low and average for the measured water quality parameters at the SWMP stations at Zeke's Island.

Table 5.4: SWMP water quality data from Zeke's Island 2002-2006

	Zeke's Basin	East Cribbings
Parameter	**Range, Average**	**Range, Average**
Dissolved O_2 (%)	0 – 400, 93	10 – 300, 96
pH	6.6 – 9.3, 8	7 – 8.8, 8
Conductivity(mS/cm)	10 – 50, 34	8 – 50, 34
Salinity (psu)	5.5 – 34, 21	4 – 35, 21
Turbidity (NTU)	0 – 1000, 65	0 – 1000, 24
NH_4^+ (µg/l)	0 – 416, 116	0 – 415, 117
NO_3^- (µg/l)	0 – 444, 87	0 – 514, 105
PO_4^{-3} (µg/l)	0 – 136, 35	0 – 74, 21
Chlorophyll *a* (µg/l)	1 – 38, 6	1 – 21, 4

There are periods of high turbidity associated with wind and rain events, but the light scattering particles usually settle out quite rapidly once calmer conditions return. Salinity is variable, fluctuating based on runoff associated with rain events and tides. Strong tides push more saline water up the Cape Fear River making the salinity in the Zeke's Island Reserve higher. During drought periods, the salinity increases. During periods of heavy rain the salinity decreases. This was very evident during the passage of hurricane Ophelia in September 2005. Salinity after this storm decreased by about 4 ppt and remained depressed for the rest of September due to the influx of rain water associated with Ophelia (Figure 5.6).

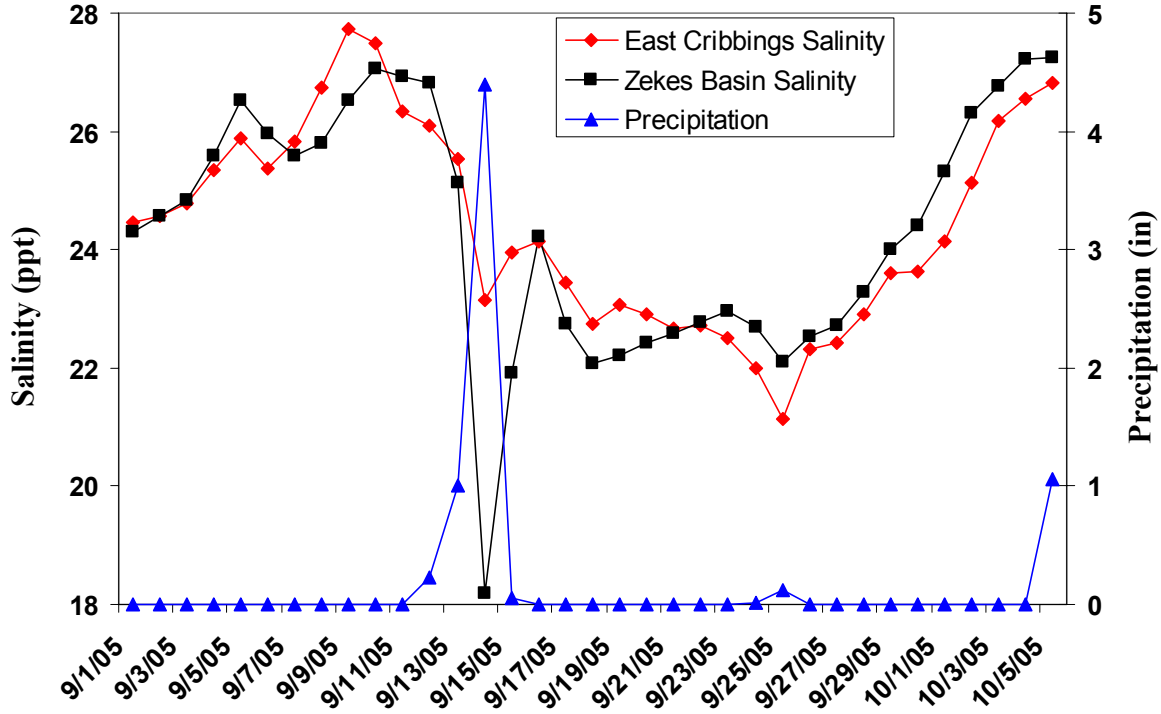

Figure 5.6: Daily averaged salinity and precipitation at Zeke's Basin and East Cribbings before, during (9-13-05 to 9-15-05), and after hurricane Ophelia. Precipitation data was measured at the weather station located on Masonboro Island.

Figure 5.7 shows the average annual temperature, salinity, dissolved oxygen, and turbidity measured at East Cribbings since 1994 and Zeke's Basin since 2002. Most of the parameters have remained fairly stable since 1994. This implies that the water quality within the Reserve has also been fairly stable and has been "good" since monitoring was initiated by Reserve staff. The low dissolved oxygen value from 1994 at East Cribbings is likely an artifact as data collection did not start that year until May. Typically the summer months have lower dissolved oxygen values due to the higher water temperatures. Oxygen values at both SWMP stations have remained pretty close to 8 mg l^{-1} throughout the dataset.

The two sites demonstrate some differences in overall turbidity values. The Zeke's Basin SWMP station generally had higher turbidity values compared to the East Cribbings SWMP station (Figure 5.7 and Table 5.4). The most probably cause for this is the differences in environmental conditions between the two stations. Zeke's Basin is a shallow sampling station that is impacted by a large wind fetch from the southwest. These two factors combine to make the sediments at the Zeke's Basin SWMP station easily resuspendable. These resuspended sediments cause high turbidity values. East Cribbings is a deeper more sheltered area. The highest annual turbidity average at East Cribbings (35 NTU) occurred in 1996. This is also the year the area was impacted by a series of fall hurricanes (Table 5.2). Turbidity values were elevated by these storms and their resultant runoff causing this high value. There also appears to be a general trend for increasing turbidity at East Cribbings since 2001 (Figure 5.7). This trend is unexplainable at this time, but staff has noticed that the site appears to be getting shallower. If this is what is going on, then increased turbidity would be expected because the shallower the bottom the more susceptible it is to sediment resuspension.

The yearly averaged salinity values at the East Cribbings SWMP station have been generally decreasing since 1994 at a rate of 0.5 ppt yr^{-1}. Like the turbidity trend above, it is hard to assign a direct cause for this change in salinity. One possibility is the closing of New Inlet. New Inlet was in the process of closing when the SWMP station at East Cribbings was installed in 1994. The inlet finally closed completely in 1999. This effectively cut the tidal creeks of Zeke's Island off from the Atlantic Ocean. As a result, salinity levels would be expected to decrease as the only water source would be the estuarine waters of the Cape Fear River. The slow pace of the decrease may be associated with residual salinity contained in the marshes and sediments of Zeke's that is slowly being leached. Another possibility would be a gradual increase in the amount of rain received by the Reserve, but this hypothesis is not supported by the precipitation data. The Cape Fear River has been deepened over this time period as well to support shipping activity at the State port in Wilmington, N.C. This could enhance the flow of freshwater downstream and be contributing to the salinity decrease as well. The Zeke's Basin dataset is not yet long enough to observe whether this decrease in salinity is occurring there as well. As years of data are accrued at this site, it is expected a similar trend will emerge.

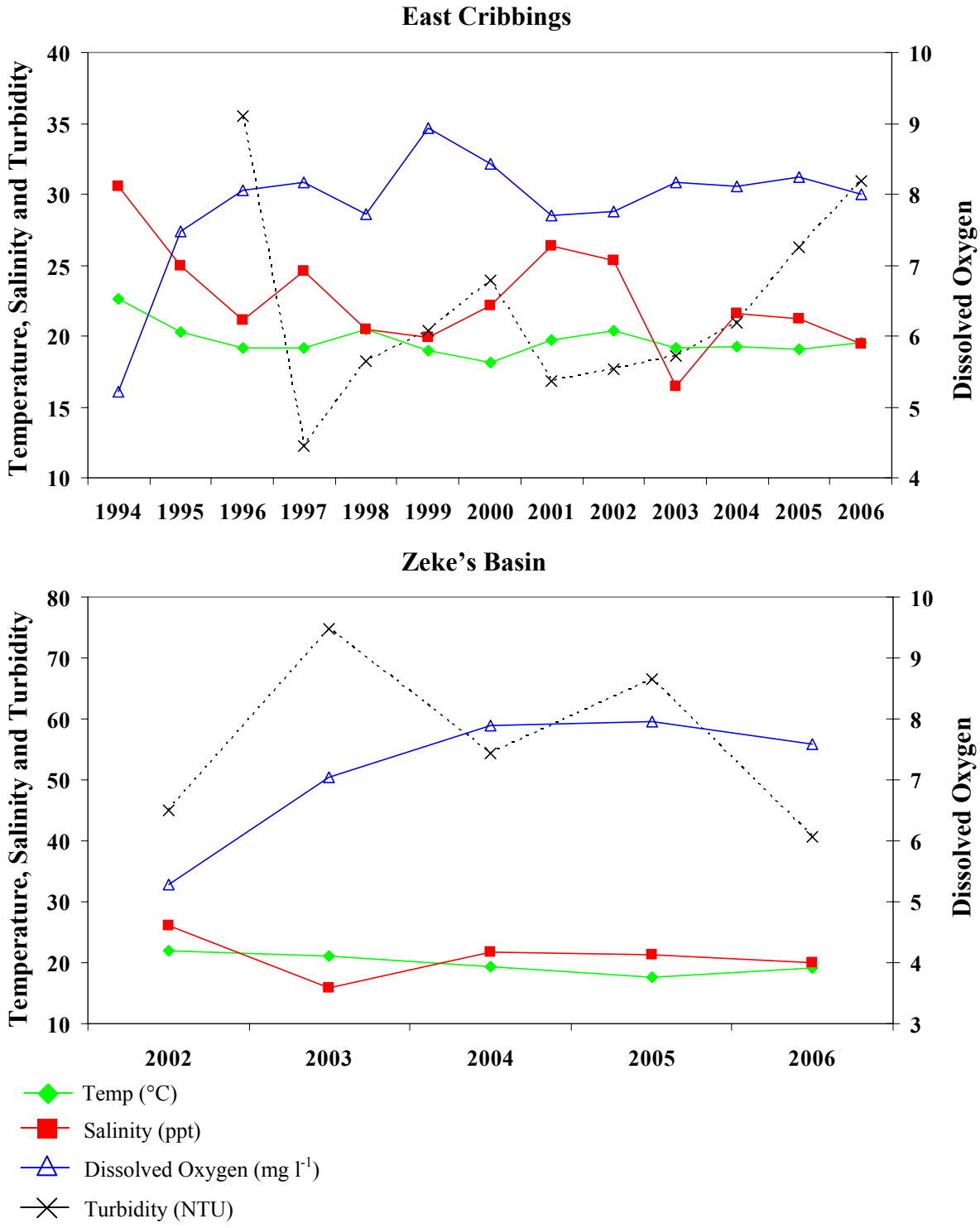

Figure 5.7: Yearly averaged physical-chemical SWMP data from Zeke's Island.

Figure 5.8 shows the nutrient (NO_3^-, NH_4^+, PO_4^{-3}) and Chlorophyll *a* concentrations in the Reserve since 2002 measured monthly as part of the SWMP. The range and average for the nutrient and Chlorophyll *a* values are included as part of Table 5.4. Nutrient pulses observed at Zeke's Basin were also observed at East Cribbings (Figure 5.8). This suggests that the pulses are associated with riverine input which affects both stations and not local runoff which would affect Zeke's Basin more than East Cribbings (since it is closer to land). NO_3^- and NH_4^+ tended to occur in similar concentrations at both stations (Figure 5.8 and Table 5.4). Pulses of both NH_4^+ and NO_3^- were frequently observed during all parts of the year. Similar pulses in PO_4^{-3} were not observed. PO_4^{-3} levels were usually quite low. Over the entire dataset, Zeke's Basin tended to have slightly higher PO_4^{-3} levels then East Cribbing (Table 5.4). Although the dataset is still quite limited in length, since 2002 there has not been any increase in the overall nutrient concentration at Zeke's Island. The average dissolved inorganic nitrogen (NH_4^+ and NO_3^-) to Phosphorus ratio is 13. Compared to Redfield ratios this means that Zeke's Island is nitrogen deficient (Redfield 1958). This suggests that the nutrient most limiting primary producer growth at Zeke's Island is nitrogen.

Chlorophyll *a* levels within the Reserve do not track the nutrient pulses (Figure 5.8). Chlorophyll levels tended to spike about 1 month after nutrient pulses (Figure 5.9). This lag time suggest that the phytoplankton at Zeke's Island may not be able to rapidly respond to nutrient pulses. This implies that something else besides nutrients may be limiting the growth of phytoplankton within Zeke's Island. The likely limiting factor is light availability. The water at Zeke's Island is often very cloudy, preventing light penetration. Since 2004, NCNERR staff has been measuring Secchi depths as part of routine SWMP activities. On average, the Secchi depth at Zeke's Island is 1.6 ft (0.5 m). This means that on average only the top 0.5 m of the water column receives enough light to sustain photosynthetic organisms. Chlorophyll *a* levels were negatively correlated with dissolved inorganic nitrogen ($p < 0.05$). This corroborates the hypothesis that the primary producers at Zeke's Island are light and not nutrient limited. These factors suggest that Zeke's Island is probably not serving as an efficient nutrient filter. Nutrients introduced into the Reserve, most likely pass through before being utilized. The interaction between nutrients versus light limitation for Zeke's Island primary producers is a knowledge gap that needs to be addressed by future research projects.

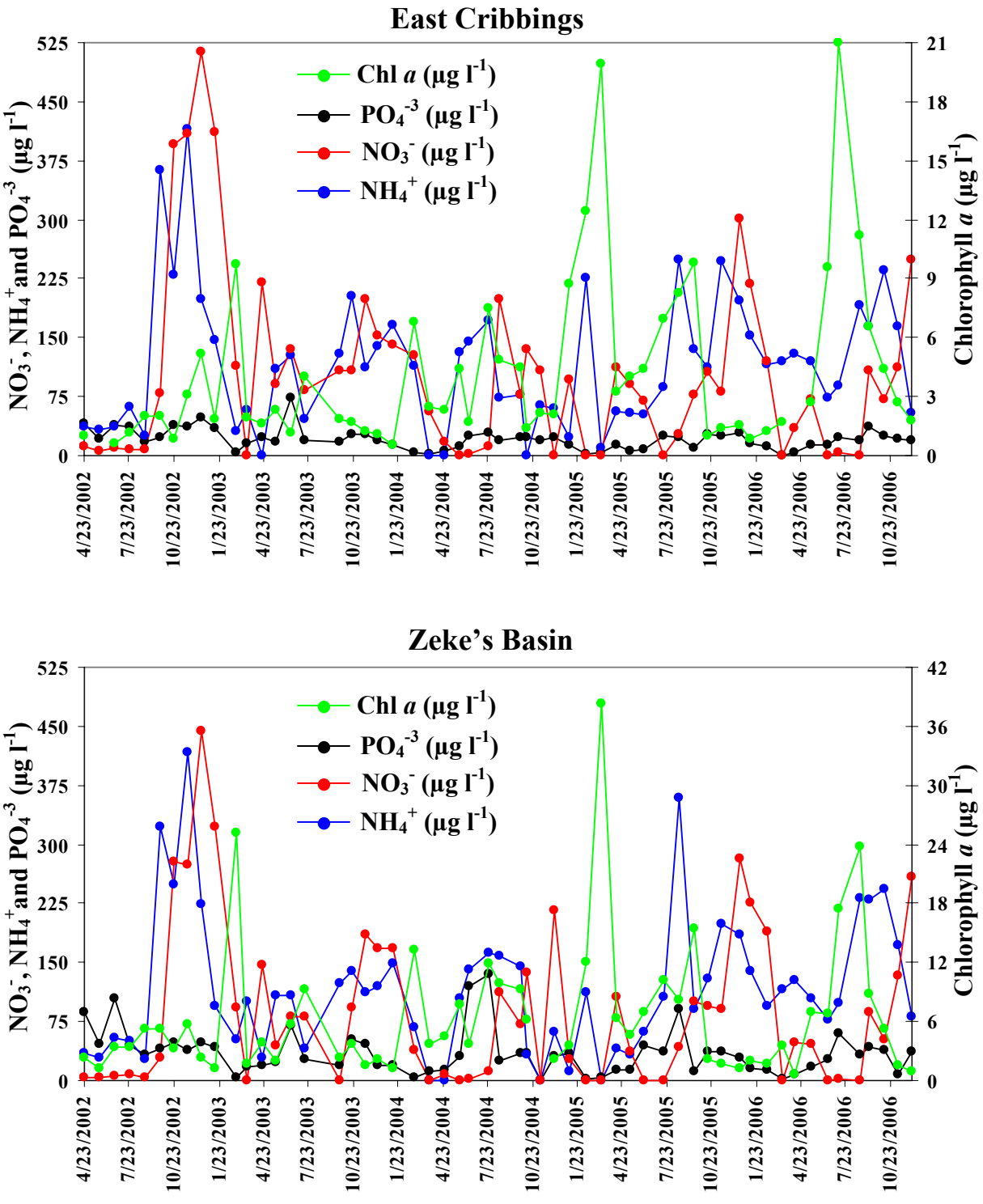

Figure 5.8: Monthly nutrient and Chlorophyll a data for East Cribbings and Zeke's Basin SWMP stations.

5.6: 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 Currituck Banks 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 softbottoms, tidal creeks, intertidal mud and sand flats, salt marshes, rock jetty, maritime forest, dunes and beaches (Table 5.5). Figure 5.9 shows the resultant map from this effort.

Table 5.5: Zeke's Island 1994 habitat classifications

Habitat	Description
Subtidal softbottoms	Open sand or mud flats that never get exposed at low tide.
Tidal creeks	Open water feeder creeks between the basin and historic inlets.
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.
The rocks	Remains of a rock jetty on the western boundary of Zeke's and in the area known as the Cribbings.
Evergreen maritime forest	Shrub forest areas on the upland islands.
Dunes	Area above the high tide line on the barrier spit along the eastern boundary of Zeke's.
Sandy beaches	Intertidal and supratidal areas of the barrier spit along the eastern boundary.

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 Zeke's Island habitat map based on this approach is presented at the Subclass level in Figure 5.10. 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 5.6). 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 Zeke's Island are described in the following paragraphs, with representative photographs presented in Appendix 4.

A point of clarification is required regarding the naming convention for the upland islands found within the Zeke's Island Reserve component. Two upland islands are present within the Reserve, North Island and Zeke's Island (Figure 5.1). To prevent confusion between the entire Zeke's Island Reserve and the upland island that shares the same name, the Reserve is always implied by the name Zeke's Island. The upland island within the Reserve will be called the upland Island Zeke's.

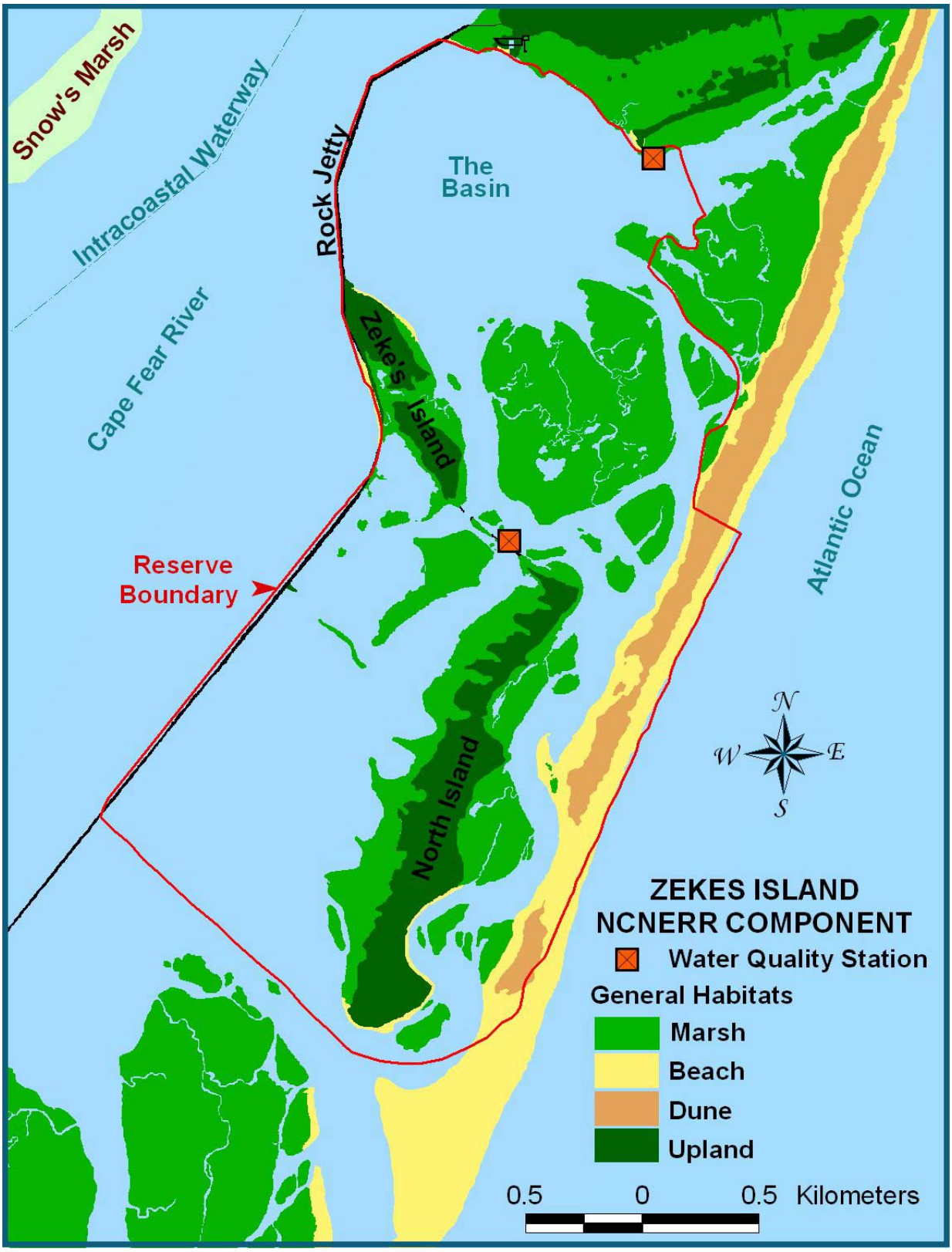

Figure 5.9: Habitat map from 1994 for Zeke's Island.

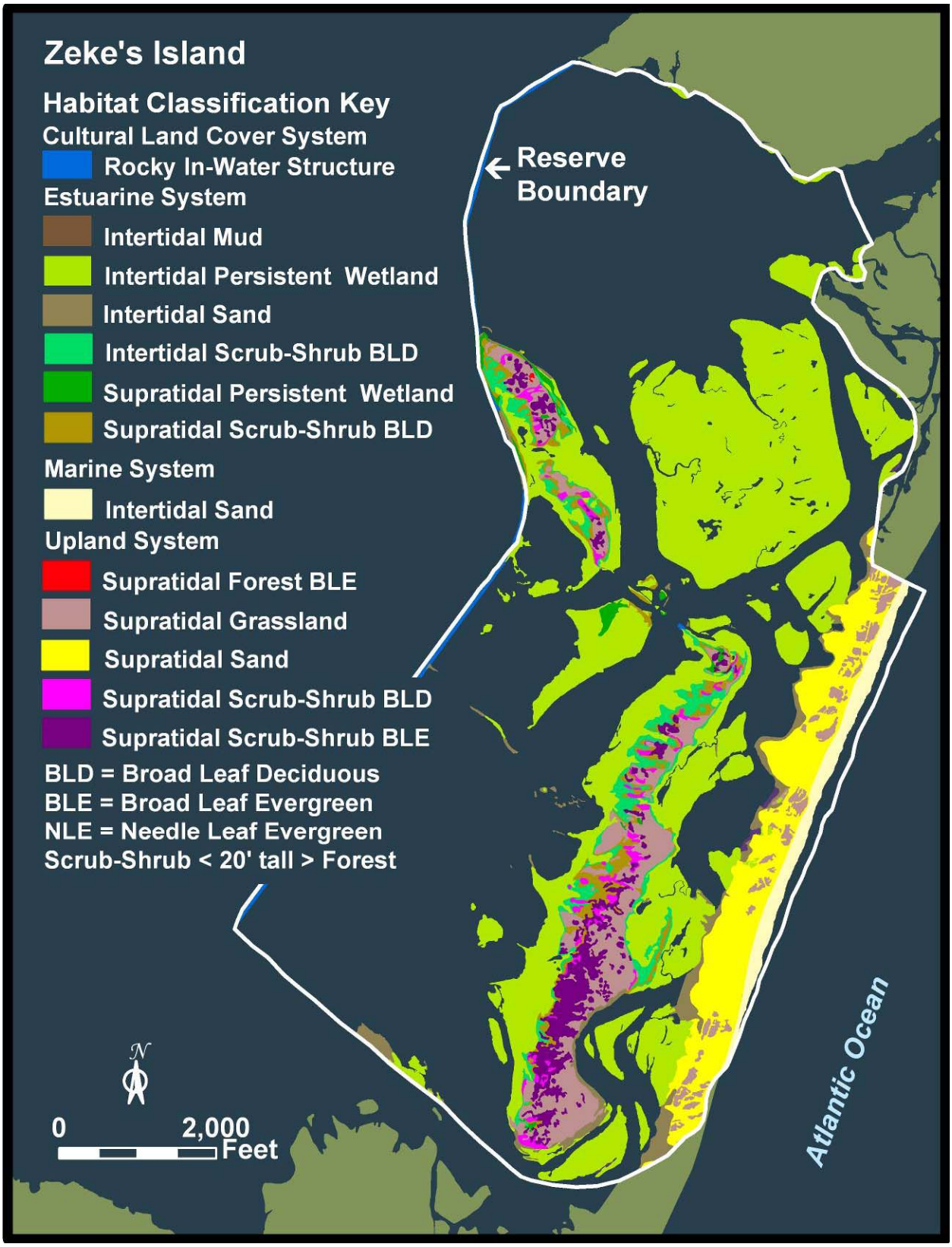

Figure 5.10: Zeke's Island 2004 habitat classification presented at the subclass level.

Table 5.6: Zeke's Island 2004 habitat classifications areal statistics

Habitat Subclass	Area (Acres)	% of Total
Estuarine Intertidal Persistant Wetland	365.81	56.13
Upland Supratidal Sand	77.93	11.96
Upland Supratidal Grassland	64.90	9.96
Upland Supratidal Scrub-Shrub Broad Leaf Evergreen	29.27	4.49
Estuarine Intertidal Scrub-Shrub Broad Leaf Deciduous	26.57	4.08
Estuarine Intertidal Sand	25.64	3.93
Marine Intertidal Sand	21.85	3.35
Estuarine Supratidal Scrub-Shrub Broad Leaf Deciduous	20.66	3.17
Upland Supratidal Scrub-Shrub Broad Leaf Deciduous	9.74	1.49
Estuarine Supratidal Persistant Wetland	5.04	0.77
CLC Rocky In-water Structures	2.89	0.44
Estuarine Intertidal Mud	1.35	0.21
Upland Supratidal Forest Broad Leaf Evergreen	0.14	0.02
Total Mapped Habitat Area	**657.49***	**100**
* Subtidal areas not mapped		

- The largest habitat subclass at the Zeke's Island Component was Estuarine Intertidal Persistant Wetland, with 365 acres and 56% of the total mapped area. This subclass is primarily expanses of Smooth Cordgrass (*Spartina alterniflora)* that are located in the center portion of the Reserve and along the fringes of both North Island and the upland Island Zeke's.

- The Upland Supratidal Sand subclass was second in coverage, with 78 acres for 12% of the total mapped habitat. These are open sandy areas, commonly known as "Sand Dunes", with $\leq$ 30% vegetative cover. They are adjacent to the Atlantic Ocean beach, along the eastern boundary of the Reserve.

- The third most prevalent subclass was Upland Supratidal Grassland, with 65 acres and 10% of the total mapped area. These areas have $\geq$ 30% vegetative cover with a mix of perennial beach grasses, including Salt Meadow Hay (*Spartina patens)*, Sea Oats (*Uniola paniculata*), Inland Saltgrass (*Distichlis spicata*) and various species of *Panicum.*

- The fourth largest subclass was Upland Supratidal Scrub-Shrub Broad Leaf Evergreen with 30 acres and 5% of the total habitat. This subclass occurred throughout the central corridors of North Island and the upland Island Zeke's. Species present include Yaupon (*Ilex vomitoria*), Wax Myrtle (*Morella cerifera* or *Myrica cerifera*), and Laurel Oak (*Quercus laurifolia*). A small amount of Eastern Red Cedar (*Juniperus virginiana*), a needle leaf evergreen, is also inhabits these areas.

- Estuarine Intertidal Scrub-Shrub Broad Leaf Deciduous subclass encompassed 27 acres (4% of total habitat) with Sea Ox-eye (*Borrichia frutescens*) the dominant species. This subclass bordered the inland edge of the Estuarine Intertidal Persistant Wetland, with extensive areas and smaller stands, respectively, in northern and southern North Island. Large swaths were also found along western and southern portions of the upland Island Zeke's.

- Three subclasses each represented 3 – 4% of the total mapped area. Estuarine Intertidal Sand (26 acres) consists of all sandy intertidal areas within the estuary, including the western edge of the barrier spit along the Atlantic Ocean. Marine Intertidal Sand (22 acres) was found along the ocean side of the Reserve. This subclass consists of the bare sand between the high and low tide lines. Stands of Estuarine Supratidal Scrub-Shrub Broad Leaf Deciduous (21 acres) were distributed across North Island and the upland Island Zeke's, as well as in the supratidal marsh between the two islands. Sea Ox-eye (*Borrichia frutescens*) is dominant, with a variety of companion species of grasses.

- Approximately 1% of the total habitat is covered by each of two subclasses. Upland Supratidal Scrub-Shrub Broad Leaf Deciduous (10 acres) was found in the upland areas of both North Island and the upland Island Zeke's. Vegetation consists of a mix of shrubs, especially Marsh Elder (*Iva frutescens*), and Grounsel Tree (*Baccharis halimifolia*). The Estuarine Supratidal Persistant Wetland (5 acres) subclass contains Salt Meadow Hay (*Spartina patens*), Inland Saltgrass (*Distichlis spicata*), and Black Needle Rush (*Juncus roemarianus*).

- Three subclasses each represented < 0.5% of the total habitat. Cultural Land Cover Rocky In-Water Structures (3 acres) refers to the rock wall jetty that defines the western boundary of the Reserve. Estuarine Intertidal Mud (1 acre) consists of two long muddy banks on the western edge of the barrier spit adjacent to the Atlantic Ocean. Upland Supratidal Forest Broad Leaf Evergreen (0.1 acres) characterizes a stand of mature Live Oak (*Quercus virginiana*) on the upland Island Zeke's that is approximately 75' in diameter.

5.7: Plants

The plant communities present within the Zeke's Island area are consistent with those of other barrier islands found in this part of the country. The dominant plant species for each habitat subclass are listed in the preceding section. The Natural Heritage Program has recognized two plant species within New Hanover County as significant (Table 5.7). Seabeach Amaranth (*Amaranthus pumilus*) (Figure 5.11) is listed as a threatened species on both the federal and state level and may be

Figure 5.11: Seabeach Amaranth

found in Zeke's Island on the foredune areas of the marine intertidal sand areas. Dune Bluecurls (*Trichostema sp*) (Figure 5.12) is considered a significantly rare species on the state level, with a range limited to North Carolina and adjacent states. Dune Bluecurls may be found at Zeke's within the marine intertidal sand areas and in the upland areas of the islands. However, neither of these plants was observed during the ground-truthing exercise as part of the field mapping exercises.

Figure 5.12: Dune Bluecurls

5.8: Animals

A: Invertebrates and Zooplankton

The depositional basin and tidal creeks of Zeke's Island are home to a vast array of invertebrate species. Crabs, shrimp, clams, tunicates, and oysters are commonly seen. The sediments support marine worms, snails and many other infauna species. All these organisms are extremely important because they are used as food items by many species of fish.

B: Fishes

Many fish species utilize the waters of Zeke's Island. Ross and Bichy (2002) published a thorough sampling of the ichthyofauna inhabiting Zeke's Island. This work identified 103 different species of fish utilizing Zeke's Island. The waters within Zeke's Island are an important nursery area for many species of fish including Flounder (*Paralichthys dentalus* and *Paralichthys lethostigma*), Mullet (*Mugil cephalus*), and Speckled Trout (*Cynoscion nebulosus*). Stingrays and small sharks have also been found in the Reserve.

C: Reptiles and Amphibians

Only a few reptile species have been documented at Zeke's Island. Sea turtles nest in the marine intertidal sand areas. The vast majority of these nests are from Loggerhead Sea Turtles (*Caretta caretta*). However, other marine turtle species including the Green Sea Turtle *(Chelonia mydas)* have been occasionally observed. Diamondback Terrapins (*Malaclemys terrapin centrata*) (Figure 5.13) are found within the marsh, and also nest near the primary dune line. The turtles and turtle eggs of all these species were prized for their meat in the 1700 and 1800's (McCauley 1945; Carr 1952).

Figure 5.13: Diamondback Terrapin on an estuarine intertidal mudflat.

Consequently, populations were decimated. Although they are all now protected from harvest (Table 5.7), populations have been slow to rebuild and the turtle numbers are still low. Other reptiles including Rat Snakes (*Elaphe obsolete*), Glass Lizards (*Ophisaurus ventralis*) and Six-liner Racerunners (*Cnemidophorus sexlineatus*) have been observed in the upland habitat areas at Zeke's Island (Atkinson et al 1998). It is likely that other snake and lizard species are occasionally transplanted to the Reserve from the mainland and just have not yet been documented. A full survey of upland fauna species is a gap that needs to be addressed.

Table 5.7: Species of special concern in and near Zeke's Island

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 Plants	*Amaranthus pumilus*	Seabeach Amaranth	T	T
Vascular Plants	*Trichostema sp*	Dune Bluecurls	SR-L	FSC
Bird	*Charadrius melodus*	Piping Plover	T	T
Bird	*Charadrius wilsonia*	Wilson's Plover	SR	-
Bird	*Egretta caerulea*	Little Blue Heron	SC	-
Bird	*Egretta thula*	Snowy Egret	SC	-
Bird	*Egretta tricolor*	Tricolored Heron	SC	-
Bird	*Pelecanus occidentalis*	Brown Pelican	SR	-
Bird	*Rynchops niger*	Black Skimmer	SC	-
Bird	*Sterna antillarum*	Least Tern	SC	-
Bird	*Sterna hirundo*	Common Tern	SC	-
Bird	*Haematopus palliatus*	American Oyster Catcher	SR	-
Bird	*Catoptrophorus semipalmatus*	Willet	SR	-
Reptile	*Caretta caretta*	Loggerhead	T	T
Reptile	*Chelonia mydas*	Green Turtle	T	T
Reptile	*Crotalus adamanteus*	Carolina Diamondback Terrapin	SC	-
Fish	*Evorthodus lyricus*	Lyre Goby	SR	-
Mammal	*Trichechus manatus*	West Indian Manatee	E	E

Data from the North Carolina Natural Heritage Program

D: Birds

Zeke's Island contains ideal bird habitat for many types of birds. Wading birds like Herons and Egrets and several duck species including Mallards, Pintails and Black, heavily utilize the tidal creeks and intertidal flats for feeding. The marine intertidal sand areas support many species of marine shore/wading birds. In addition, the uplands provide habitat for many species of songbird. Atkinson et al. (1998) documented over 260 species during their surveys at Zeke's Island. Several of these species are of special concern (Table 5.7).

E: Mammals

There is a wide array of mammals present within the Reserve area. The 1998 North Carolina National Estuarine Research Reserve Management Plan has listed the following mammals as being observed within Zeke's Island: Opossums (*Didelphis virginiana*), Raccoons (*Procyon lotor*), Grey Foxes (*Urocyon cinereogentus*), Marsh Rabbits (*Sylvilagus palustris*), River Otters (*Lontra Canadensis*), and Cotton Rats (*Sigmodon hispidus*). North Island has the

most upland habitat, and due to its size, and vegetative cover, it may provide the greatest opportunity for observing mammals. (Atkinson et al, 1998). The only mammal of special concern that occurs within Zeke's Island is an occasional visit by the West Indian Manatee (*Trichechus manatus*) (Table 5.7). Manatees are a rare visitor to the coastal waters of North Carolina, most frequently being seen in late summer. A full species list is included as Appendix 5.

5.9: Invasive Species

The only documented invasive species within the Zeke's Island at current time are the European Poplar (*Populus nigra L.*) and Beach Vitex (*Vitex rotundifolia*) (Figure 5.14). Beach Vitex is particularly detrimental because it does not provide the same level of habitat quality or defense against erosion compared to natural dune communities. Many other undiscovered invaders are likely present at Zeke's Island. Zeke's Island is susceptible to invasion by Nutria (*Myocaster coypus*), Tamarisk Tree (*Tamarix ramosissima*), Russian Olive (*Elaeagnus angustifolia*), etc. The shipping channel that passes through the Cape Fear River along Zeke's Island is a potential source for water borne invaders from around the world transported in the ballast water of ocean going vessels. Assessing the number and type of invasive flora and fauna is a priority for future research/stewardship activities at Zeke's Island.

Figure 5.14: Beach Vitex

5.10: Stressors

The Zeke's Island Reserve is exposed to a variety of stressors, both natural and anthropogenic (man-made). Natural stressors include hurricanes, inlet migration/closure, salinity fluctuations and sedimentation. Anthropogenic stressors include pollution, nutrient loading, habitat disruption and altered land use, and public use of the Reserve. A few of the major stressors are highlighted in the following sections.

A: Pollution/eutrophication

Eutrophication leads to excessive phytoplankton production. This can lead to a multitude of water quality problems including hypoxia, decreased light penetration, altered community composition, loss of seagrass beds, and decreased fish and shellfish populations. Recovery from eutrophication can take long periods of time even if the causes of the eutrophication are immediately halted (Mallin et al. 2000b, Mallin et al. 2001). Pollution can cause immediate effects if the pollutant is highly toxic, or its effect can occur over many years as pollutant loads gradually increase. At Zeke's increases in nutrients and pollutants are very likely possibilities given the large watershed of the Cape Fear River.

The North Carolina Department of Environment and Natural Resources - Division of Water Quality publishes a Basinwide Water Quality Plan for each of the major rivers in North Carolina every five years. This plan divides the river watershed into smaller subbasins for assessments. The Cape Fear River Subbasin 03-06-17 contains the lower Cape Fear estuary, including the portion of the river bordering the Reserve property. Within this subbasin there are 49 permitted dischargers; half of which discharge directly into the Cape Fear River. Ten of these are major dischargers (>1 million gallons (3,785,411 L) per day), with the largest including International Paper, and the City of Wilmington's North Side Waste Water Treatment Plant and South Side Waste Water Treatment Plant. (North Carolina Division of Water Quality 2005)

The Cape Fear River estuary was listed as partially supporting by the North Carolina Division of Water Quality due to low levels of dissolved oxygen. This means that the river was only partially capable of supporting the best uses suited to it. The impacts from waste water treatment plants discharges within the subbasin and non-point source pollution are suspected to be contributors to the impairment. Possible sources of non-point pollution include marinas, canal systems and septic systems (North Carolina Division of Water Quality 2005). Over the past year the more than 3,000,000 gallons (11,356,235 L) of untreated sewage were discharged by the City of Wilmington waste water treatment plants due to distribution system failure. Many other pollution impacts likely go undocumented. These increased discharges associated with the decrease in vegetated land cover noted above could dramatically lower the water quality within the Cape Fear River and Zeke's Island. Despite these issues, the SWMP monitoring has not yet picked up a declining water quality signal. This implies one of two things: 1) the Cape Fear River is still serving as an efficient filter for nutrients and pollution in which case the pollutant load is attenuated before it gets to Zeke's Island; or 2) the filtering capacity of the river has been overcome. In this scenario, the river is attenuating all the pollutants physically/biologically possible. This would explain the steady state conditions of the SWMP monitoring. In this case the river is no longer serving as a nutrient/pollution buffer but basically as a rapid one way waste pipeline to the coastal ocean. If the second option is indeed what is occurring, then the coastal Atlantic Ocean is where water quality changes would be first detected. Future research is needed on the coastal ocean within the Cape Fear River discharge zone to look for this. To try and address this NCNERR is seeking a partnership with NOAA's Coastal Ocean Research and Monitoring Program. This program has been looking at water quality within the coastal margin of N.C. since 2000. Together, we would place instrumentation at the mouth of the Cape Fear River to investigate the water quality at the river/ocean interface.

B: 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).

To assess the amount of change within the Zeke's Island watershed, land cover types were evaluated for the two most recent years that data were available, 1991 and 1997. Land cover information was obtained for coastal North Carolina from NOAA's Coastal Change Analysis Program. This analysis was conducted on the lower Cape Fear River watershed as designated by the United States Geologic Survey (Hydrologic Cataloguing Unit 03030005). See Appendix 4 for detailed methodology. Figure 5.15 shows the land cover maps for 1991 (panel a) and 1997 (panel b).

For clarity the changes that occurred between 1991 and 1997 have been grouped into three categories. The first category is a decrease in vegetation cover (of any type). The second is an increase in vegetation cover (of any type) and the third is 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 5.16 and Table 5.8 presents only these changed areas between 1991 and 1997.

Table 5.8: Change in land cover from 1991 to 1997 in the Zeke's Island watershed

Category	Acres	% of total
Total mapped area	672,098	n/a
Water area	37,530	5.6
Total land area	634,568	94.4
Decrease in vegetative cover	36,301	5.7
Increase in vegetative cover	28,690	4.5
Change from one unvegetative cover to another	297	0.05
Unchanged land cover	569,280	89.7
Net loss of vegetation = 1.2%		
Percent of land area with changed cover types = 10.3%		

Changes that occurred between 1991 and 1997 affected 10.3% of the watershed. The increase in vegetated conditions (4.5%) was mainly associated with succession of Grassland to Scrub/Shrub and Scrub/Shrub to Evergreen Forest, primarily in a band across the southern watershed, near the Green Swamp. Conversion of Evergreen Forest to Scrub/Shrub and Grassland (5.7%) in the southwestern portion of the watershed accounted for most of the decrease in vegetated conditions. The net loss in vegetative cover between 1991 and 1997 was 7,611 acres representing 1.2% of the watershed.

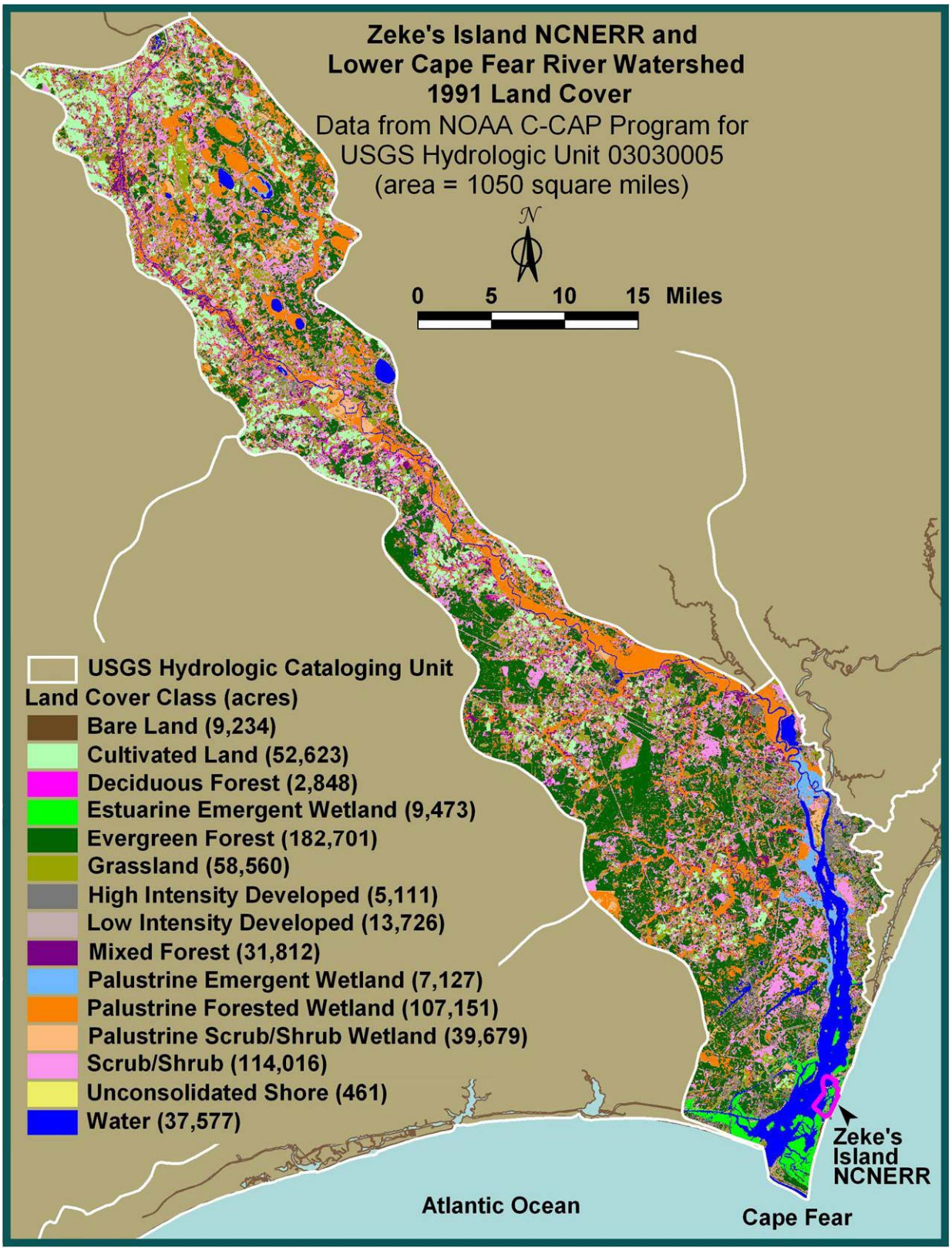

Figure 5.15a: Land use classification from 1991 in the Zeke's Island watershed.

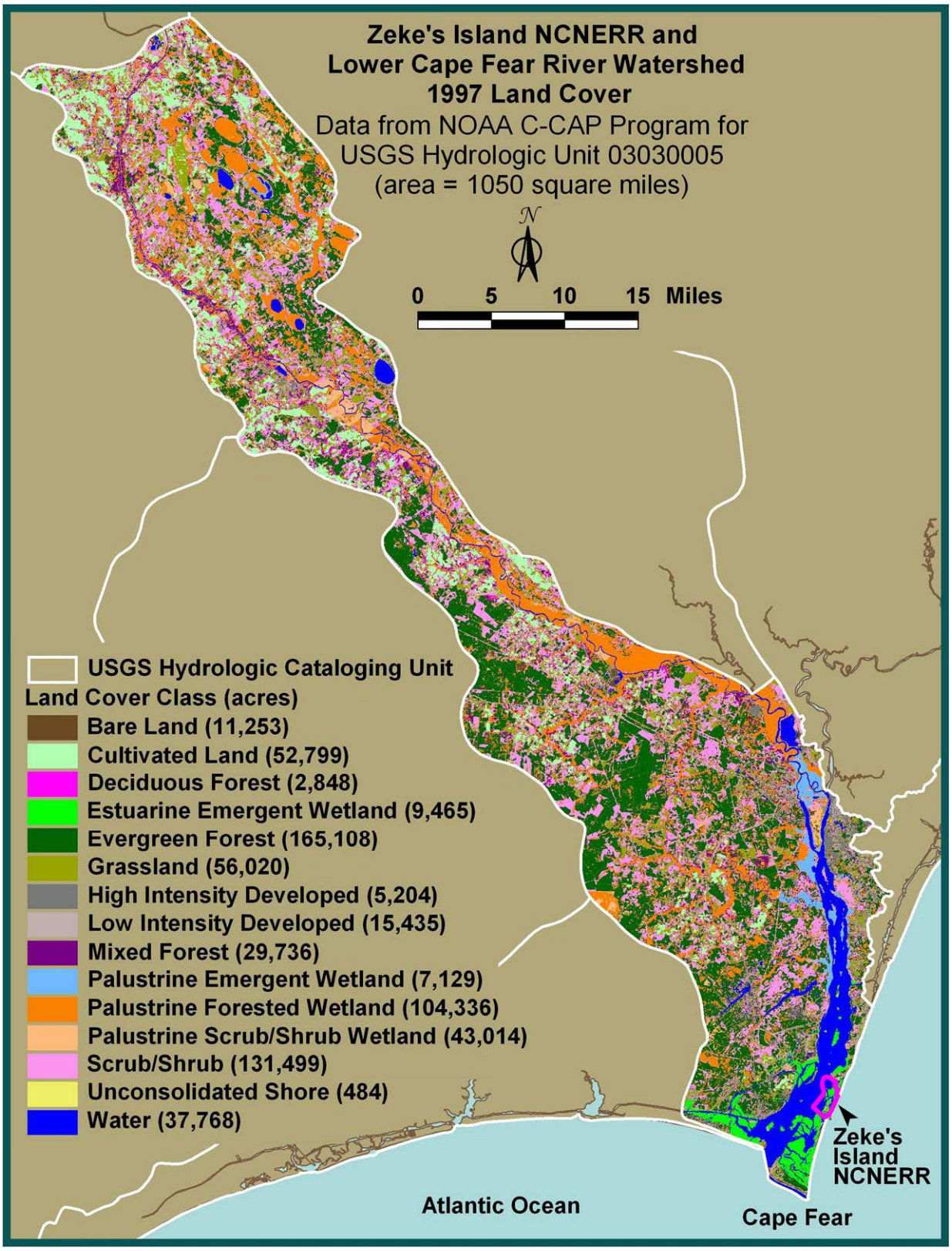

Figure 5.15b: Land use classification from 1997 in the Zeke's Island watershed.

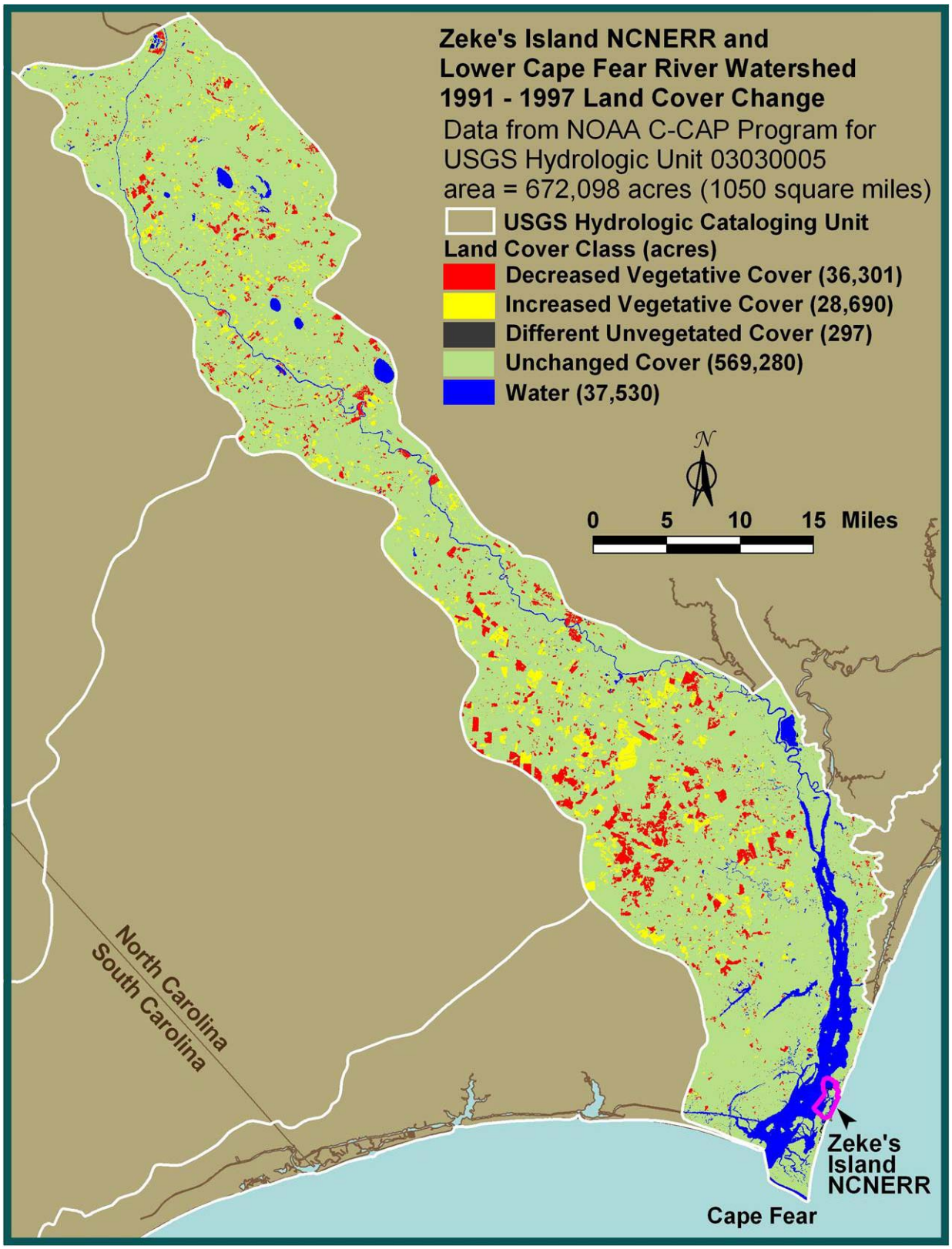

Figure 5.16: Changed land cover between 1991 and 1997 in the Zeke's Island watershed.

The loss of vegetation to Low and High Density Development between 1991 and 1997 for Zeke's watershed was 0.3%. This conversion mainly occurred in the southern extent of the watershed associated with development in the Wilmington region. It should be noted that the region has seen rapid development since 1997. Consequently, it is highly likely that the decrease in vegetative cover observed between 1991 and 1997 has only accelerated. 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. Although this trend has not shown up in the water quality data yet (see Section 5.5), as the vegetation loss continues in the Zeke's Island watershed, water quality within Zeke's Island may decrease.

C: Public Use

The Zeke's Island area is popular for fishing, kayak and boating activities, bird watchers and beachgoers. While one of the purposes of the NERRS program is that the public has access to the Reserve properties, not all public activities are harmless. The area of the Reserve managed by Fort Fisher State Recreation area is part of an approximately 4 mile (6.4 km) stretch of beach that allows off road vehicle use. This off road vehicle use can disrupt the dune community. Sea turtle and colonial bird nests can be destroyed and the beach area itself contaminated by leaking petroleums. Off road vehicle access to the beach is a controversial issue that managers at Fort Fisher are trying to deal with in a management plan update. Given the historical use of this area for off-road vehicle access, it is unlikely that all off-road vehicle use will be prohibited. Thus, this activity will continue to be a potential impact upon the Beach/Dune communities at Zeke's Island.

Boating activities within the Zeke's Island can also cause detrimental harm. Boat propellers can disrupt benthic communities, and boat wakes can increase shoreline erosion. Two cycle outboard engines also discharge large amounts of petroleum products into the water during operation. Given the hydrology at Zeke's Island, over time and with increased use, this could lead to hydrocarbon pollution. As the marine outboard industry continues its transition to four stroke technologies, this issue may become less of an issue in the future.

The Rocks at Zeke's Island are improperly used by people to access the Reserve for the purposes of fishing and walking. This is an extremely dangerous use given the condition of the jetty making up The Rocks. The concrete cap on the jetty is failing, and the top of the jetty in many areas is covered at high tide. Marine growth and the jagged rocks make the jetty extremely slippery (Figure 5.17). Many rescue operations have been required to assist visitors who are either stranded or injured on The Rocks. Assisting visitors with more appropriate Reserve access is a high priority issue for NCNERR. Plans to improve the boat ramp to Zeke's Basin are underway through a partnership involving all Federal Point management entities. This project will provide visitors improved boat, kayak, and fishing access to the Zeke's Island. This will hopefully decrease the use of the Rocks for Reserve access.

Figure 5.17: The Rocks at Zeke's Island.

5.11: 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

There are no research facilities on Zeke's Island. The NCNERR office is located at the University of North Carolina at Wilmington's Center for Marine Science approximately 15 miles (24 km) from Zeke's Island. The Center for Marine Science office covers 1,450 square feet, and provides offices for research staff as well as other staff, a common area/workspace, a storage area/mud room, and a large laboratory. The Center for Marine Science also affords NCNERR access to conference rooms, a machine shop, and boat parking for three NCNERR vessels that are used to support research and stewardship activities at Zeke's Island. Research activities at Zeke's Island can also be supported by the North Carolina Aquarium at Fort Fisher. This facility is located directly adjacent to the Reserve, and has space that staff of NCNERR can access for both research and education activities.

B: Historical Research Activities

Similar to the Currituck Banks component, the body of research available for Zeke's Island is small compared to Masonboro and Rachel Carson. Many of these historic research projects have been highlighted throughout the earlier parts of this chapter. Many others are contained in Appendix 6, the bibliography of work conducted within NCNERR. Most of the research projects that have been conducted at Zeke's Island were focused on the benthic infauna community, nutrients and contaminants and fish. General results from these projects indicate the there are healthy populations of benthic infauna at Zeke's Island, overall nutrient and pollutant loads at current time are low and Zeke's Island is heavily utilized by many fish species. These projects provide a great foundation to support future work.

C: Current Research Projects

There are currently two active studies going on within Zeke's Island. Reserve staff is conducting an investigation into the fluxes of oxygen and nutrients from the sediments within the Basin. This study was started in September of 2005 and will continue seasonally until June 2008. Benthic chambers are placed on the sediments within the basin and oxygen and nutrient concentrations within the chambers are monitored through time. The chambers are deployed at two end-member locations within the Reserve. The first location is in the high sediment nitrogen

area located in the northwestern corner of the Basin (Figure 5.5). The other is in a shallow area just to the left of the public boat ramp. Both opaque and translucent chambers are being utilized. The goals of this study are to quantify the amount of nutrients coming from the sediments within the Basin, determine the sediment oxygen demand of the sediments within the Basin, and to determine if there is a benthic autotrophic community in the Basin and if so how it impacts the above fluxes of oxygen and nutrients.

A study into the efficiency of Sea Oats (*Uniola paniculata*) seed production relative to nutrient and pollen limitation has also just started up. This study will determine if the Sea Oats at Zeke's Island are putting out a full seed set and if not, whether the decrease in seed production is a factor of nutrient limitation or pollen limitation. This study will provide valuable knowledge for beach renourishment and dune building projects. This is a high priority management issue for many U.S. East Coast Local and State governments.

One ongoing monitoring project is also occurring at Zeke's Island. Yearly surveys for the presence of Beach Vitex (*Vitex rotundifolia*) (see section 5.9) are being conducted by staff from Fort Fisher State Park. If large amounts of Vitex are found during the surveys, eradication efforts are initiated.

5.12: Future Research Needs

A study into the effects of breaching the rock wall needs to be conducted. The Basin area of Zeke's Island is filling in. Navigation within the Reserve is extremely difficult at low tide. Local fishermen as well have started complaining that since the last inlet closed in 1999, fishing within the Reserve has suffered. These stakeholders believe that putting some openings within the Rocks will alleviate these problems. A well designed study examining the hydrology and fish within the Reserve is needed to assess the changes that could be expected from breaching the rocks. This project would also provide partnership opportunity. The U.S. Army Corps of Engineers would be involved since the Rocks were originally an Army Corps project, and because of the ongoing dredging within the Cape Fear River shipping channel. The North Carolina Fort Fisher Aquarium would be an ideal partner given the location of their Fort Fisher facility and knowledge regarding area fauna. The North Carolina Department of Cultural Resources would also need to be involved since the Rocks are listed as a cultural heritage resource and are under their jurisdiction.

The fish survey conducted by Ross and Bichy (2002) needs to be repeated. The original survey was conducted during a time of open inlet activity at Zeke's Island. Given the anecdotal evidence from the local fishermen that the fishing at the Reserve has declined, this study is vitally needed. The North Carolina Division of Marine Fisheries would be an excellent partner for this study. They routinely conduct fish surveys within North Carolina waters. Since a baseline already exists, the new work would be much more meaningful.

Assessment of atmospheric deposition of nutrients and mercury is another critical need for Zeke's Island. Atmospheric sources can contribute upwards of 50% of the new nitrogen to coastal oceanic waters (Pearl and Fogel 1994), and is the one of the main sources of mercury delivery to the coastal ocean. North Carolina just recently updated its fish consumption advisory to include several Ocean dwelling fish. Because of this human health risk, quantifying this pollutant source is critical. The United States Department of Agriculture would be a prime partner to help with this project. They currently operate a network of atmospheric samplers to

quantify these parameters. Getting Zeke's Island into this network would be ideal given its location relative to population centers and prevailing wind patterns.

Studies into the health of the saltmarsh at Zeke's Island is needed. If the water areas of the Reserve are filling in, the saltmarsh in the region may be expanding in response. This activity would represent a fundamental shift from estuarine subtidal habitat to estuarine intertidal saltmarsh habitat. This shift would have implications for both flora and fauna within the Reserve. A detailed study investigating the marsh productivity, accretion and erosion rate, and overall health needs to be conducted. At the same time, the habitat mapping effort needs to be repeated so any change in marsh habitat can be assessed.