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Bird Use of Cumberland Island's Freshwater Wetlands

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BIRD USE OF CUMBERLAND ISLAND'S FRESHWATER WETLANDS

by

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(Under the Direction of C. Ray Chandler)

ABSTRACT

Cumberland Island is the southernmost barrier island off the coast of Georgia. Its freshwater wetlands are an important, rare habitat to have on a barrier island surrounded by saltmarsh and ocean. Many species of birds require freshwater wetlands as feeding, roosting and nesting grounds. However, the freshwater wetlands on Cumberland Island have been impacted by humans for centuries causing birds to abandon their historic nesting ground. Known land use histories of Cumberland Island's freshwater wetlands were gathered to try and determine how the wetlands changed over time. Wetlands were analyzed for presence of wetland-dependent birds and recorded.

Thirty-six species of birds from 10 orders and 15 families were identified using the freshwater wetland habitat. The highest bird abundance and species richness is seen, in order, at Plum Orchard, Lake Whitney, Hickory Hill Pond, and the North Swamp Fields. Wood Storks, Great Blue Herons, Great Egrets, Snowy Egrets and Black-crowned Night Herons were the species most frequently seen on the island. Rainfall was 24.7 cm below the 100 year average during the study, making water presence a determining factor in bird abundance. Habitat diversity, taken from the aerial maps also had an influence on bird abundance. Management recommendations should be made for restoration efforts of specific wetlands based on the species of birds that frequent the island.

INDEX WORDS: Wetlands, Birds, Cumberland Island, Freshwater

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CHAPTER 1: NATURAL AND CULTURAL HISTORY OF CUMBERLAND ISLAND

Cumberland Island has approximately 683.7 ha of freshwater wetlands, making up about 10% of the island's habitat (Figure 1). Anthropogenic changes have drastically altered the island's habitat resulting in a decline in the quality of freshwater wetlands and the total area of freshwater wetlands, with some wetlands disappearing completely (Carol Ruckdeschel, pers. comm., 2010). A history of Cumberland Island and how its freshwater wetlands have changed provide important context for understanding current management needs for freshwater wetlands on barrier islands.

Location of Cumberland Island

Cumberland Island is the largest and southernmost barrier island along the Georgia coast (Figure 2). Amelia Island, Florida borders the island to the south. Little Cumberland Island, a privately owned island just north of Cumberland Island, is separated from Cumberland Island by Christmas Creek and an extensive salt marsh. To the west of Cumberland Island is the town of St Mary's, the location of the National Park Service headquarters. The island is 28 km long and 0.8-9.7 km wide (Zomlefer et al. 2008). Excluding the tidal marshes, the island includes over 6,000 ha of land (Johnson et al. 1974). The shapes of the northern and southern coastlines are constantly changing due to shifting sands and tidal movements (Hillestad et al. 1975).

Geological History

The leading theory explaining the development of the barrier islands on the Georgia coast states that the islands were formed in two geologic epochs (Hoyt 1967). A dune ridge, known as the Silver Bluff Submergence, formed during the Pleistocene

(36,000-25,000 years ago) and characterizes the western portion of Georgia’s barrier islands (Hoyt 1967). Shells from the Silver Bluff Submergence have been carbon dated to the Pleistocene and support the leading theory that the majority of Cumberland Island was formed during this epoch when ocean levels were lower (Hoyt 1967). The Eastern portion of the barrier islands were formed during the Holocene (4000-5000 years ago) (Hoyt 1967). Dune ridges formed between the Pleistocene and Holocene portions of the island. The majority of the freshwater wetlands on Cumberland Island formed in the low areas between dune ridges (Johnson et al. 1974).

Climate and Weather

Cumberland Island’s climate is moderately subtropical with short, mild winters and hot, humid summers (Zomlefer et al. 2008). Fernandina Weather Station 082944 is located on Amelia Island, Florida, 1.5 km from Cumberland Island, the station has been collecting data since 1892. The average yearly high temperature over the last 100 years is 25°C (Table 1). The average annual rainfall over the last 100 years is 126 cm/year (Table 1). Rainfall is the main source of freshwater for most of the wetlands on Cumberland Island (Hillestad et al. 1975). Ground water maintains some of the wetlands on Cumberland Island; however, the aquifer responsible for providing freshwater to the wetlands is recharged by rain (Frick et al. 2002). Ground water is used by the National Park Service and island residents as their source of drinking water (Hillestad et al. 1975, Frick et al. 2002).

Heavy rainfall events help to maintain the ponds and sloughs on the island (Hillestad et al. 1975). Tropical storms are also an important source of freshwater, meeting rainwater needs in the ecosystem. Historically, the Georgia coast had a high level of hurricane activity; in the 1800s, six of the fourteen hurricanes that made landfall in Georgia were category three or higher (Georgia Emergency Management Agency 2012). Only four hurricanes made landfall on the Georgia coast in the twentieth century (1911, 1940, 1947, 1979; Georgia Emergency Management Agency 2012). Three additional hurricanes brought significant rain to the coast in 1994, 1995, and 2004 (Georgia Emergency Management Agency 2012). A major storm system has not directly hit Cumberland Island in over 30 years. Although direct impact by hurricanes are rare, without summer rain events wetlands dry up, affecting biological conditions for plants and breeding animals (Hillestad et al. 1975).

Cumberland Island's aquifers provide freshwater to the island and are used as municipal and industrial water sources (Hillestad et al. 1975). Rainfall naturally recharges the aquifers, but over the last 50 years, coastal development has increased demand on these water resources (Frick et al. 2002). Ground water withdrawals are occurring at a faster rate than rainfall is able to recharge the aquifer, causing saltwater intrusion into the deep Floridian aquifer and lower water outputs from the shallower aquifers (Frick et al. 2002). Weather, such as rainfall has an effect on the health of freshwater wetlands on Cumberland Island, but the presence of humans in the island's ecosystem also plays an important role.

Anthropogenic History

Humans have lived on or traveled to Cumberland Island for centuries prior to management by the National Park Service (Hillestad et al. 1975). Although direct impacts to the wetlands from historical human activity may not be known, the wetlands are a primary source of freshwater on the island and it is reasonable to assume that the earliest island inhabitants impacted wetlands (Dudgeon et al. 2006). The following is a brief history of historical impacts on the freshwater wetlands of Cumberland Island (Table 2).

Native Americans are thought to have arrived in the coastal region of Georgia 4,000 years ago. However, other than their obvious need for freshwater, there is little knowledge of their land use (Dilsaver 2004). On Cumberland Island, archeological evidence of ceramics, jewelry and burial mounds date back to 1,450 years ago and are attributed to the Tacatacuru Indians part of the Timucuan Indians of north Florida (Hillestad et.al. 1975, Dilsaver 2004). The Tacatacuru had settlements near present day Dungeness, Table Point and Brickhill Bluff (Figure 2) (Hillestad et al. 1975, Dilsaver 2004). Tacatacuru were known to have cleared fields for agriculture (maize) using fire, hunted small mammals, fished, and created expansive oyster shell mounds, which have been found near their known settlements on the island (Hillestad et al. 1975, Dilsaver 2004). There is no evidence that the Native Americans altered or diminished the freshwater wetlands on the island, but their use of agriculture and fire certainly could have impacted wetlands by opening up the landscape.

European contact on Cumberland Island began in the late 1500s with the arrival of the French who befriended the Tacatacuru (Dilsaver 2004). However, it was the Franciscan Spaniards in 1578 that created two missionary churches on the island (Dilsaver 2004). According to a priest in 1602, there were 792 Christian Indians living on the island who were sustained by agriculture (Dilsaver 2004). When the Spaniards came to the island they brought livestock. Cattle, horses and hogs have been roaming the island since 1597 (Bullard 2003, Dilsaver 2004). Freshwater wetlands provided water and grazing for free-ranging livestock. Grazing and defecating in wetlands negatively affects the soil, water quality, biodiversity and fauna (Reeves and Champion 2004). Cattle remove vegetation and open up wetland areas, which may be considered beneficial for wetland birds that prefer open areas, but their grazing changes the composition of the vegetation and reduces biomass, altering the habitat (Reeves and Champion 2004, Brown and Brown 2007). With a population of over 700 people living on the island and livestock roaming for food and water, freshwater wetlands would have been impacted.

With the arrival of the English into the region, the St. Mary's River became the boundary between Spanish territory to the south and English territory to the north, which caused the Spanish to abandon the island (Dilsaver 2004). After the Spanish missions were abandoned in 1686, Cumberland Island remained relatively uninhabited due to conflict between the Spanish and English (Dilsaver 2004). It is unknown exactly what happened to the Tacatacuru Indians, but European diseases probably thinned the population and the rest may have left with the Spanish missionaries (Hillestad et al. 1975, Dilsaver 2004). In the 1700s, English explorer James Oglethorpe built two forts on Cumberland Island to protect English claims from the Spanish. With the increasing conflict between the Spanish and English in the area, Cumberland Island was too dangerous for a constant settlement and the island became a no-man's land of outcasts and bandits during the 1750s (Dilsaver 2004). The island remained mostly uninhabited through the Revolutionary War, until General Nathaniel Green purchased the land to harvest live oaks for timber for the ship-building industry (Bullard 2003, Dilsaver 2004).

Between the Revolutionary War and the Civil War, much of Cumberland Island was converted to a plantation, causing a significant impact on the ecosystems of the island. Robert Stafford, a successful planter, purchased the majority of the island from residents who could not afford their land on the island (Bullard 2003, Dilsaver 2004). The first comprehensive change in land use dramatically transformed the island during this time period, from maritime forest to Sea Island cotton plantations. Rice, indigo, citrus, olives, corn, and sugar cane were also grown on the island (Hillestad et al. 1975, Dilsaver 2004). Over 400 slaves were needed to maintain the plantation (Bullard 2003, Dilsaver 2004). The forest was reduced to only patches of trees between the agricultural fields (Zomlefer et al. 2008). When the island was cleared for plantation agriculture, it was said that you could see all the way across the island from the Atlantic Ocean to the Cumberland Sound (Doug Hoffman, pers. comm., 2011). During the plantation era, the largest wetland on the island, the Swamp Fields were diked and drained for rice cultivation (Hillestad et al. 1975). Stafford owned the southern two-thirds of the island, and although not recorded, his agricultural techniques such as clearing the land, irrigation and draining wetlands for cultivation would have considerable negative effects on the freshwater wetlands.

After the Civil War, the island was again abandoned until Thomas Carnegie, brother of steel industrialist Andrew Carnegie, purchased the southern end of the island in 1881 (Hillestad et al. 1975, Bullard 2003, Dilsaver 2004). An elaborate mansion was built at Dungeness, and the island became a retreat for rich entrepreneurs. The Carnegie’s built three additional mansions, cultivated exotic plants and imported livestock (cows, hogs and horses), which were free to roam about the island (Hillestad et al. 1975, Dilsaver 2004). In 1886, Thomas Carnegie died and left his land to his wife Lucy. Over the next 40 years, Cumberland Island was used as a private hunting and recreation resort for the Carnegie family. Wetlands were maintained with fire for hunting waterfowl and by cattle grazing (Turner and Bratton 1987).

In 1916 Lucy Carnegie died and Dungeness mansion was abandoned due to the cost of upkeep, and in 1959 the mansion was destroyed by fire (Dilsaver 2004). Before Lucy Carnegie died, she set up a trust to protect the island from being divided into parcels and sold by her children (Hillestad et al. 1975, Dilsaver 2004). In 1962 the last of Lucy Carnegie's children died and ownership of the land was transferred to her grandchildren (Dilsaver 2004). Because of the expense of owning land on Cumberland Island, the grandchildren began to sell their properties. Charles Frasier, a noted land developer responsible for developing Hilton Head Island took an interest and purchased several lots of Cumberland Island (Seabrook 2004). Many island residents disliked Frasier's development ideas but could do nothing to stop him. Instead of seeing their home developed, island residents decided to sell their property, and in 1972 Cumberland Island became part of the National Park System (Hillestad et al. 1975). Island residents made a deal with the National Park Service to retain specified rights to their land and property while under the National Park Service ownership. Depending on specifics of the agreement, residents retained rights to their land for a certain period of time, most agreed on lifetime estates and several families agreed to lifetime of grandchildren estates (Seabrook 2004). In 2010 the first of the estate rights ended, the owners vacated and the land was given to the park (John Fry, pers. comm., 2011).

A National Park

In 1972 the National Park Service took over the island that had been impacted by hundreds of years of human history. Feral cows, horses and pigs roamed the island and grazed in the freshwater wetlands. Historic structures were abandoned and left in disrepair. Agricultural fields were allowed to grow over into live oak forest or had been planted with timber (Sprunt 1936). Uncapped artesian wells flowed freely into artificial and natural ponds. The wetlands as seen in Figure 1 were likely as extensive as ever. The National Park Service has limited resources and had to choose how to manage the island.

To return the island to its natural state, the National Park Service began removing feral livestock. Feral cows were penned and removed from the island by the early 1980s (Seabrook 2004). Woody vegetation that was once heavily browsed by cattle is now flourishing (Carol Ruckdeschel, pers. comm., 2010, Fred Whitehead, pers. comm., 2011). Many photographs of Cumberland island from the Carnegie era, show open wetland landscapes; these open areas were most likely maintained by cattle (Fred Whitehead, pers. comm., 2011). Feral pigs are harder to trap and remove than the cows. Although extensive hunting and trapping persists on the island, feral pigs are still found throughout the island (Doug Hoffman, pers. comm., 2010).

Feral horses have been a point of debate since the National Park Service took control of the island. Multiple researchers have come to Cumberland Island to study the horses and all believe that the herd needs to be reduced or completely moved off the island due to the damage the horses cause to the dunes and saltmarsh and freshwater wetlands (Turner 1988, Goodloe et al. 2000, Dolan 2002). Horses feed mainly on grasses and have been seen on multiple occasions submerged in Lake Whitney feeding on aquatic vegetation (Reeves and Champion 2004, personal observations 2011). On the other hand, feral horses are a substantial draw for tourists. In 1996, Congress passed a bill with a rider stating that the National Park Service cannot do anything to manage the horses on Cumberland Island (Seabrook 2004). Cumberland does not feed or manage their population of 250 feral horses which struggle to compete with white-tailed deer and feral hogs for food (Doug Hoffman, pers. comm., 2011). Although the rider expired in 1997, the National Park Service has not written a management plan to address the feral horses. Instead they are collecting as much information as possible about the impact of feral horses (Doug Hoffman, pers. comm., 2011). Cumberland Island is one of many east coast islands with wild horses. Chincoteague National Wildlife Refuge, Virginia, Assateague Island National Seashore, Maryland, as well as islands in the Outer Banks region of North Carolina are allowed to feed and manage (reduce by selling or culling) their horse herds (Zimmerman 2006).

In 1982 the northern half of Cumberland Island (3,561ha) was designated a wilderness area (Barringer 2005). This prevented a bridge or causeway from being built to the island, restricting the number of visitors to ferry transport, which set a limit of 300 visitors a day (Seabrook 2004). This upset many people who sought to profit from the tourists that would come to Cumberland Island (Seabrook 2004). It also upset Greyfield Inn managers, a privately owned and operated inn, which provided tours for their guest and were eventually ordered to cease their driving tours in the wilderness area (Barringer 2005). The wilderness prevents the use of heavy machinery that would be needed to dig fire lines and use prescribed fire. The majority of the freshwater wetlands fall within the wilderness area boundary. Although natural fires have ignited in the wilderness area they have been suppressed.

Many island residents who retained rights to their land, resided in the wilderness area. Although the National Park Service and Greyfield Inn were not allowed to drive or use machinery in the wilderness area, island residents could (Seasbrook 2004). Since some people were allowed to drive in the wilderness and others were not, in 2004 another rider was added to a bill that removed the main road along with several side roads from the wilderness (Barringer 2005). The rider also forced the National Park Service to start driving tours to the north end of the island (Barringer 2005). Tours began in August of 2011, their environmental impact is unknown (John Fry, pers. comm., 2011).

The National Park Service works hard to accommodate its mission statement:

> "...to promote and regulate the use of the...national parks...which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (National Park Service Organic Act 1916).

The National Park Service has to serve the public while simultaneously protecting the island from feral hogs, horses, and invasive plants. Archeologists, historians, and ecologists frequent the island for research purposes, while visitors come to see feral horses, undeveloped beaches and historic structures. With a diverse interest in Cumberland Island, many groups of conservationists have opinions on the welfare of Cumberland Island and the management of its resources. Multiple stakeholders such as Wild Cumberland (a Part of Wilderness Watch), Defenders of Wild Cumberland, and The Cumberland Island Conservancy criticize National Park Service management such as feral horse and hog problems along with the transportation management tours to the north end of the island, causing lawsuits and media attention (Associated Press 1997, Harlan 2007, Landers 2011).

With so many management issues currently facing the National Park Service, there is no plan to manage the freshwater wetlands on Cumberland Island. The majority of the resources go to protecting and monitoring sea turtle nests and historic structures. This is unfortunate because the presence of freshwater on a barrier island surrounded by salt marsh and ocean makes these wetlands a rare and potentially important habitat for a variety of plants and animals that depend on this ecosystem for survival. Lack of management is a problem because evidence suggests there is a decline the area and quality of habitat of Cumberland Island's freshwater wetlands. Normal ecological processes such as lightning-induced fires are suppressed to protect island residents (Laliberté 2007). Fire is an important perturbation on Cumberland Island that slows succession from wetland to forest by burning organic matter that would fill in the wetlands (Hillestad et al. 1975). Cattle have been removed, altering the vegetation structure around the wetlands (Fred Whitehead, pers. comm., 2011). There has been no restoration work done on any of the wetlands that were diked for hunting and agriculture. With alterations to the natural water flow, fire suppression, and removal of cattle, there has been nothing to keep woody vegetation from establishing and the wetlands appear to be decreasing in size altering valuable habitat.

The decline in suitable habitat has greatly affected wetland birds causing them to abandon historic nesting and roosting sites in search of better habitat (Frederick et al. 2009). This has happened on Sapelo Island, Georgia, where a rookery was abandoned because vegetation became too dense (Johnson et al. 1974). Due to the change in habitat features on Cumberland Island, many species of birds can no longer find suitable nesting, mating or feeding grounds (Ruckdeshel and Shoop 1987). Wood Ducks (*Aix sponsa*), Great Blue Herons (*Ardea herodias*), Great Egrets (*Ardea alba*), Snowy Egrets (*Egretta thula*), Tricolored Herons (*Egretta tricolor*), Little Blue Herons (*Egretta caerulea*), Green Herons (*Butorides virescens*), Black-crowned Night Herons (*Nycticorax nycticorax*), Yellow-crowned Night Herons (*Nyctanassa violacea*), and Osprey (*Pandion haliaetus*) were all recorded nesting in the freshwater wetlands on Cuberland Island in May of 1921 (Table 3). (Pearson 1922) White Ibis (*Eudocimus albus*) and Wood Stork rookeries (*Mycteria americana*) could be found throughout the island in the 1980s (Table 3) (Ruckdeschel and Shoop 1987). Currently these rookeries are no longer found on the island (Carol Ruckdeschel, pers. comm., 2010).

Freshwater habitats provide foraging grounds for breeding birds. Wood Storks and White Ibis rearing their young have been shown to prefer freshwater, because freshwater feeding grounds have higher quality food that provide for higher offspring survival (Gaines et al. 1998, Johnston and Bildstein 1990). During drought conditions, Wood Storks will move entire rookeries to more favorable habitats because salt marshes alone cannot support the breeding population (Gaines et al. 2000). Cumberland Island is used as foraging grounds throughout the year.

On Cumberland Island, during extended dry periods, vegetation establishes along wetland edges reducing the overall wetland area (Zomlefer et al. 2008). When vegetation established along the edges, the area of open water available for wading birds is too deep and prevents access to their foraging grounds (Coulter et al. 1987). Nesting is also affected by altered vegetation. Currently there are no records of nesting Wood Storks on

Cumberland Island, dry conditions coupled with increased vegetation allows predators to access nests that were once protected by water (Ruckdeschel and Shoop 1987, Pearson 1992).

Cumberland Island's freshwater wetlands have been historically used as foraging locations for wintering, migratory, and nesting birds (Pearson 1922, Sprunt 1936). During the winter months, Blackbeard Island's freshwater ponds, located 70 km north of Cumberland Island, support foraging habitat for a variety of waterfowl including Ring-necked Duck (*Aythya collaris*), Lesser Scaup (*Aythya affinis*), Mallard (*Anas platyrhynchos*), Gadwall (*Anas strepera*), American Wigeon (*Anas americana*), Canvasback (*Aythya valisineria*), Northern Pintail (*Anas acuta*), Green-winged Teal (*Anas carolinensis*), and Northern Shoveler (*Anas clypeata*) (Johnson et al. 1974). Wintering waterfowl numbers have decreased greatly over the years according to the naturalist at Greyfield Inn who has worked on Cumberland Island for over 30 years (Fred Whitehead, pers. comm., 2011).

The true loss of wetland bird inhabitants is unknown at this time and may never be known. A comprehensive survey of Cumberland Island's wetland birds has never been published. In the early 1900s, two lists were published by naturalists Thomas Pearson and Alexander Sprunt, who visited Cumberland Island and recorded the birds that they observed. Pearson listed 97 species, including notes about breeding activities that he saw over two days in May, 1922. Sprunt listed 149 species observed in April, 1932 and 1933. In 1973 researchers from the University of Georgia were contracted to complete an ecological survey of Cumberland Island for the National Park Service (Hillestad et al. 1975). With limited time and funding the survey was not comprehensive

(Carol Ruckdeschel, pers. comm., 2010). A list of 323 birds was published from the survey; however, the list contains "general observations" as "expected to occur" on the island and based their list on previous studies (Hillestad et al. 1975).

History and Description of Wetlands

To begin the assessment of wetland status and management needs on Cumberland Island, a detailed history of its wetlands is required. Cumberland Island has over 20 named wetlands defined as permanent, temporary or artificial ponds (Hillestad et al. 1975). There are many more small, un-named temporary ponds shown on maps, however, they were never a significant source of freshwater. Lake Whitney, South Whitney Pond, Lake Retta, Plum Orchard Pond, the Swamp Fields and Hickory Hill Pond are some of the largest and best known wetlands on the island (Figure 1).

Lake Whitney (30.8988,-81.41535) is the largest and only permanent body of freshwater on Cumberland Island (Figure 1and 3) (Hillestad et al. 1975, Frick et al. 2002). As of 2011, the current size of the Lake Whitney wetland is 36 ha. In 1973, the wetland was 33 ha (Hillestad et al. 1975). Lake Whitney currently has 2 ha of open water, in 1992 it had 4 ha and in 1973 it had 16 ha of open water (Hillestad et al. 1975, Lambert 1992). This is an 87.5% decrease in open water in 39 years. The only depth measurements of Lake Whitney were done by Hillestad et al., the deepest portion of the lake in 1975 was 1.8 m deep (Hillestad et al. 1975). Horses frequently cross the lake and the water does not cover their backs (personal observations, 2011). There is no documentation that Lake Whitney's hydrology has ever been altered by island residents. Several undated pictures show the lake as an open landscape, but over the years trees and dune movement have made the lake smaller and shallower, creating a concern that the lake is filling in with sediment (Hillestad et al. 1975). The open landscape around the lake is most likely due to the presence of feral cattle that frequented the dune area and the edge of the lake, prior to the National Park Service's management (Carol Ruckdeschel, pers. comm., 2010, Fred Whitehead, pers. comm., 2011). Other than duck hunting and fishing, Lake Whitney has remained mostly natural with the exception of possible fish stocking; Mosquitofish (*Gambusia affinis*), Bluegill (*Lepomis macrochirus*), Largemouth Bass (*Micropterus salmoides*) and Warmouth Sunfish (*Lepomis gulosus*) were collected in the lake (Hillestad et al. 1975, Lambert 1992). It is unknown when the lake may have been stocked, however at one time Lucy Carnegie prohibited fishing in the lake (Bullard 2003). An undated photograph from the Carnegie era shows an old-fashioned car ferry crossing Lake Whitney, but there are no photographs of any other structures around the lake (Figure 4).

South Lake Whitney Ponds (30.888673,-81.419985) makes up the southern portion of the Lake Whitney complex at 9 ha (6.5 ha in 1973) (Hillestad et al. 1975). The southern portion of the Lake Whitney Complex contains two natural grassy ponds that are ideal habitats for waterfowl (Figure 1) (Hilestad et al. 1975). The largest pond is South Whitney Pond, 8.4 ha (Figure 1). This pond is seasonal and water was never present in the pond during my surveys (Figure 3).

Willow Pond (30.829582,-81.443245) is the second largest body of freshwater on the island at 34 ha with seasonal depressions of open water. In 1973 the pond was 28 ha with 1.2 ha of open water (Figure 1) (Hillestad et al. 1975). Classified as a permanent pond, the water level in the pond varies greatly depending on rainfall (Hillestad et al. 1975, Frick et al. 2002). The pond was used for duck hunting and as a fishing area by the

Carnegie family who introduced Warmouth Sunfish into the pond. Currently, fish are no longer found in the now seasonal pond (Figure 3) (Hillestad et al. 1975, Frick et al. 2002, Carol Ruckdeschel, pers. comm., 2010).

Lake Retta (30.83627,-81.433951) is considered to be a freshwater lake with saltwater influence (Figure 1) (Hillestad et al. 1975). Lake Retta's current size is hard to determine. In 1973 the wetland was recorded to be 13 ha with 6 ha of open water (Hillestad et al. 1975). However, the USGS from the same time period delineates 66 ha as Lake Retta. Lake Retta was probably a complex of connected wetland areas and only the open water were recorded by Hillestad. Currently, Lake Retta's area is 2.06 ha. Lake Retta has always been a shallow lake averaging 61 cm deep in 1973 and 19.5 cm in 1992 (Hillestad et al. 1975, Frick 1992). The lake is on the eastern edge of the dune system, only 0.3 km from the high tide line, had an outflow to the ocean that backed up into the lake during extreme high tides and storm surges (Hillestad et al. 1975). The lake remained open because saltwater and tidal influence prevented the establishment of invading vegetation (Hillestad et al. 1975). Protecting the outflow was considered by Hillestad et al. necessary to maintain high levels of productivity (1975). Currently, the outflow is filled in by sand and water levels are completely dependent on rainfall (Doug Hoffman, pers. comm., 2011). Lake Retta remained dry for the majority of my study (Figure 4).

Plum Orchard Pond (30.856627,-81.465598) is a 0.19 ha man-made pond created as an aesthetic accessory to Plum Orchard Mansion (Figures 1 and 5). A well was dug in 1904 to create the pond; however it no longer receives a slow flow of water from the well (Frick et al. 2002, Doug Hoffman, pers. comm., 2010). There is no marsh associated with the pond, only open water. The pond's western edge is an earthen damn that protects the pond from the Cumberland Sound. Plum Orchard Pond is eutrophic as a result of bird guano and is completely covered with duck weed (*Lemna ssp*) (Hillestad et al. 1975). The pond is currently closed on the northern edge by oak and willow trees and is used regularly as a roosting site by a variety of herons (Figure 3) (Doug Hoffman, pers. comm., 2011).

The Old Swamp Fields (30.837615,-81.456721), once known as the Great Swamp, is a 132 ha tract of swamp land that was acquired by Robert Stafford, a plantation owner, and converted into rice fields in the 1840s (Figure 1) (Bullard 2003). Since the end of the civil war and the plantation era, the fields have no longer been cultivated and have reverted to wetlands. However, the diking and canals created during the agricultural periods are still present today and can be seen in aerial photographs (Figure 6). According to Hillestad (1975), 4 km of continuous canals were dug to drain the wetlands and create agricultural land. Because the canals connect to the intercostal waterway, the north end of the swamp fields has saltwater inundation during extreme high tides (29%) (Figure 3). The southern end of the swamp is fresh and drains to the north (Figure 3).

Hickory Hill Pond (30.823796,-81.450065) is a 1.35 ha pond fed by an artesian well. The wetland existed before the well was created, however the constant flow of water aids in keeping the land saturated and prevents vegetation from growing (Figure 1). The well is not inventoried in the 1981 geological survey; therefore it is not known when the well was dug or how long the well has been running. After the Durango Paper Company mill in St. Mary's, Georgia, shut down in the early 2000s, the strain on the aquifer eased and caused several uncapped or poorly capped wells to flow more frequently (Laliberté 2007). The pond is completely open with clear, sulfur-smelling water, compared to blackwater caused by tannic acid found elsewhere on the island (personal observation 2011) (Figure 3).

The freshwater wetlands on Cumberland Island are an important ecosystem that needs to be protected. The wetlands have been impacted by humans for years. The wetlands have been changed by agricultural practices, which permanently change the hydrology and vegetation composition (Table 2)(Kath et al. 2010). Feral livestock have been grazing in the freshwater wetlands for over 400 years. Fire has been used as tool to clear wetlands and then later suppressed to protect historic structures (Turner and Bratton 1987, Laliberté 2007). Although Cumberland Island has been protected since 1972, the freshwater wetlands have been ignored and many species of wetland birds no longer nest on the island (Table 3).

CHAPTER 2 BIRD USE OF CUMBERLAND ISLAND'S FRESHWATER WETLANDS

INTRODUCTION

Between 1780 and 1980, 53% of wetland habitat was lost in the lower 48 States (Dahl 1990). As of 2009 there were 44.6 million hectares of wetlands remaining in the contiguous United States (Dahl 2011). Freshwater ecosystems such as lakes, rivers and marshes are diverse, relatively rare habitats that make up about of 0.01% of the Earth's surface (Dudgeon et al. 2006). Even with increased public awareness of the importance of wetlands and efforts to restore them, freshwater ecosystems systems continue to decline (Dahl 2000, Sala 2000).

Wetlands perform a variety of important functions such as nutrient cycling, erosion control, water storage and provide habitat for many species of flora and fauna (Cronk et al. 2001). Scientists look at the condition of wetlands to determine overall ecosystem health and to study the effects of climate change. Freshwater wetlands resources are generally lost due to development (Dahl 2011). Reductions in wetland area have had a profound result. Habitat loss and degradation, fragmentation and development create circumstances where wetlands are no longer able to perform ecosystem services such as providing food, water, recreation, storm protection and irrigation for agriculture (Dahl 2011, USEPA 2012). Losing wetlands harms people as well as decreasing biodiversity.

Wetland habitats provide food and shelter for many animals. Birds are one of the better studied examples of the importance of wetlands habitat. Wetlands are used by birds for breeding, nesting and rearing young, as a source of drinking water, for feeding, loafing, roosting, shelter, and social interactions (Stewart 2007). With nearly one-third of North American birds classified as wetland-dependent, it is important to understand and conserve their habitat (Stewart 2007). Water level, vegetation composition, time of year, and wetland area are just a few key factors in determining wetland use by birds (Stewart 2007).

Wetland size is important, especially to wetland-dependent birds that are area-sensitive (Riffell et al. 2001). An increase in wetland size generally relates to an increase in bird abundance, species richness and species diversity (Gonzalez-Gajardo et al. 2009). However, in fragmented landscapes with available wetland habitat, species diversity will increase in any wetland as long the different species require different habitat (Venier and Fahrig 1996). Generally, bird diversity increases as habitat heterogeneity increases (Garay et al. 1991). Vegetation cover and structure of the wetland area is the key to bird use (Gonzalez-Gajardo et al. 2009).

Although the size of a particular wetland may be attractive to wetland-dependent birds, isolation from other wetland habitat can also play a role in bird abundance, species richness and species diversity (Brown and Dinsmore 1986). A large, isolated wetland may not offer the vegetation or structural differences many smaller wetlands could provide to birds. Depending on the species of bird and the time of year, different wetlands could provide different necessities, such as food and shelter (Brown and Dinsmore 1986).

Water depth preferences vary greatly across water bird species (Bolduc and Afton 2008). Seasonally, water levels fluctuate (Connor and Gabor 2006). Year-round water levels change and attract different species of birds at different times of the year (Powell

1987). Many migrating birds select wetlands based on water depth (White and James 1978). Water presence is related to food availability in wetlands and low water levels negatively affect feeding (Kahl 1964, Bildstein et al. 1990). Wetlands provide birds with food in the form of vegetation, invertebrates, fish, reptiles and small mammals (Kantrud and Stewart 1984, Hafner 1997). When wetlands are dry, food availability is limited and birds fly elsewhere to find food (Kahl 1964). When surveying wetland birds, the diversity of bird species makes identifying a single wetland trait responsible for their presence difficult to quantify.

Freshwater wetlands are an important habitat, especially in areas where wetlands are often smaller and more isolated. Barrier islands are surrounded by saltwater and contain extensive dry dune habitat. Freshwater wetlands on a barrier island, such as Cumberland Island are not only rare, but are an important habitat that needs to be managed. If Cumberland Island's freshwater wetlands are a rare, important habitat, then they should provide feeding and nesting ground to many species of birds. The objective of my thesis research was to (1) surveyed the wetland-dependent birds of the freshwater wetlands on Cumberland Island National Seashore to provide an inventory of birds known to currently occur in the wetlands, (2) used GIS to characterize the vegetation in and around the freshwater wetlands to understand current conditions and provide information for future comparisons.

METHODS

Study Site

Cumberland Island (30.851069, -81.4484275) is the southernmost island off the coast of Georgia. There are approximately 683.7 ha of freshwater wetlands delineated by the USGS on Cumberland Island (Figure 1). However due to dry conditions and plant succession, some of the areas defined as wetlands in Figure 1 either no longer exist, or have become too overgrown to be surveyed (See chapter 1 for history of sites). Because of these conditions, larger and more accessible wetlands were chosen for observational surveys. I surveyed a total of eight points (Figure 1). Several survey points fell within the wilderness area, where the vegetation around the wetlands can be very dense, making access limited. Due to these constraints, survey points were placed near or along trails in order to get into the wetland. Two of the wetland complexes had two survey points because of their large extent and the presence of two habitat types within the same complex. The following wetlands were surveyed: Lake Whitney (30.89983 -81.41537), South Whitney Pond (30.88840 -81.41848), Willow Pond (30.83278 -81.44078), Lake Retta (30.83622 -81.43361), Plum Orchard Pond (30.85649 -81.46596), North Swamp Field (30.84345 -81.45514), South Swamp Field (30.83379 -81.45713), and Hickory Hill Pond (30.82353 -81.45075) (Figure 1).

Weather

Weather data from December 2010 to November 2011 were collected from NOAA Weather Station GA Brunswick 23 S, located in Stafford Field (Figure 2) because Fernandina weather (see chapter 1) was only available from the Fernandina station through May 2010. The NOAA weather station in Stafford Field was installed December, 2004. The weather for Fernandina is considered to be representative for Cumberland Island (Stooksbury 2011).

Bird Surveys

To evaluate the avian community in the freshwater wetlands on Cumberland Island I conducted monthly surveys for one year, from December 2010 to November 2011, using broadcast calls and visual surveys. During each survey I recorded presence and number of any species that responded to the broadcast call, as well as any other species of bird that I saw in the freshwater wetlands. Surveys were done over the weekend around the 15th of each month.

Broadcast calls are a more way successful to detect marsh birds than other survey methods because many marsh birds are secretive, rarely observed, and some species do not call often (Conway 2009). I conducted the marsh bird surveys following the guidelines of The National Marsh Bird Monitoring Program (Conway 2009). Based on the protocol, I began surveys up to 30 min before sunrise and completed the surveys by 10 am (Conway 2009). When doing evening surveys, I began up to 2 hours before sunset and did surveys until dusk, which is the period of greatest marsh bird detection (Conway 2009). The surveys began with a 5 min passive period, to adjust for disturbance of walking into the wetland. For each species of bird surveyed, 30 seconds of calls are played, followed by 30 seconds of silence. Then another call is played. Each survey was 18 min long including the silent period.

The standardized surveys for breeding marsh birds were done 15 days apart during the peak breeding season. From the program recommendation for the southeastern United States, the dates for spring breeding surveys were done April 15-17, April 29-May 1, and May 14-16, 2011.

Although the methods for The National Marsh Bird Monitoring Program were created for breeding birds only, I used broadcast calls to elicit a response from migratory and wintering birds as well. I used broadcast calls for all the possible marsh birds that were noted to be winter, resident or transient birds on Cumberland Island by Hillestad et al. (1975). I used standardized digital recordings of vocalizations broadcast calls that I received from The National Marsh Bird Monitoring Program for the following marsh birds: Pied-Billed Grebe (*Podilymbus podiceps*), American Bittern (*Botaurus lentiginosus*), Least Bittern (*Ixobrychus exilis*), Yellow Rail (*Coturnicops noveboracensis*), Black Rail (*Laterallus jamaicensis*), Clapper Rail (*Rallus longirostris*), King Rail (*Rallus elegans*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), Purple Gallinule (*Porphyrio martinica*), Common Gallinule ((*Gallinula galeata*), American Coot (*Fulica americana*), and Limpkin (*Aramus guarauna*).

Vegetation

I used ArcGIS to analyze wetland habitat because physical access to all wetlands was not equal due to extensive marsh and deep water habitat. Many studies use aerial imagery in freshwater wetlands due to unstable soils and dense vegetation (Shima et al. 1976, Harvey and Hill 2001, ESRI 2007). I created habitat maps using ArcGIS 10.1. A 75 m aerial image of each wetland was taken from ArcGIS Explorer Desktop. The image was then geo-referenced in ArcGIS 10.1 using at least six known GPS coordinates (Harvey and Hill 2001). The image was then digitized using NAD1983 UTM Zone 17N projection. Different features were categorized into habitat classes. The new map was then overlaid onto two base maps to verify accuracy. The area of each map is 19 ha circular buffer. The buffer extends out 250 m from the survey point to account for the hearing range of birds surveyed. Ground truthing was used to verify the habitat classes (McConnell 2000, ESRI 2007). While ground truthing habitat classes, I identified the dominant vegetation on the ground for each habitat class by recording the most abundant vegetation types.

Statistical Analysis

The presence of birds in relation to water presence was analyzed using logistic regression (Sokal and Rohlf 2000) in JMP 9.0. High variation in bird presence through the year lead to data that was not normally distributed and non-parametric tests were chosen. The Friedman's Test was used to determine the importance of wetlands and variation by month (Sokal and Rohlf 2000). Nonparametric multiple comparisons by simultaneous test procedure was used to determine the wetlands of most importance (Sokal and Rohlf 2000). Average bird abundance, the number of birds seen per survey was calculated. Bird species richness was calculated monthly for each wetland. Bird species diversity was calculated using the Shannon-Wiener Index of diversity (H'), using the following formula (Krebs 1999).

$$H = -\sum_{i=1}^{S} p_i \ln(p_i)$$

A multiple regression was run using JMP 9.0 to relate bird abundance, bird species richness and bird diversity to monthly water presence, total wetland area and habitat diversity. The Shannon-Wiener Index of diversity was also used to define habitat diversity and was calculated using the number of habitat class in the 19 ha buffer.

RESULTS

Weather

During the study, average temperature was similar to the 100-year average (Table 1). The total rainfall was 24.7 cm lower than the 100-year average (Table 1).

Bird Surveys

At the eight survey sites, I observed a total of 36 species of birds from 10 orders and 15 families during 13 surveys (Appendix 1). Six of the 13 marsh birds responded to the broadcast calls. The marsh birds detected were the Pied-Billed Grebe, Yellow Rail, King Rail, Virginia Rail, Sora, and Common Gallinule.

Species richness, Shannon-Wiener Diversity Index and average abundance was used to classify the differences between each wetland. The average abundance, average species richness and average diversity for each wetland is shown in Figures 6-8, respectively. Plum Orchard and Lake Whitney had the highest average species richness, diversity and abundance.

Bird abundance and species richness was greater in Plum Orchard than Hickory Hill, Lake Retta, North Swamp Field, South Swamp Field, South Whitney Pond, and Willow Pond (Figures 6 and 7). Bird abundance and species richness was greater in Lake Whitney than South Swamp Field, South Whitney Pond, and Willow Pond (Figures 6 and 7). Bird abundance and species richness was greater in Hickory Hill than South Whitney Pond. Bird abundance and species richness is greater in North Swamp Field than South Whitney Pond (Figures 6 and 7). Species diversity was greater in Plum Orchard than Lake Retta, North Swamp Field, South Swamp Field, South Whitney Pond, and Willow Pond (Figure 8). Species diversity was greater in Lake Whitney than South Whitney

Pond (Figure 8). There was no variation in bird abundance by month (χ^2=4.788, df =12, p=0.9647). There was no variation in species richness by month (χ^2=10.267, df =12, p=0.5927).

Logistic regression was used to predict the effect water presence had on wetland-dependent birds. Wood Storks, Great Blue Herons, Great Egrets, Snowy Egrets and Black-crowned Night Herons had a greater presence when water was available (Table 4). Wood Storks were 9.5 times more likely to be present with water. Great Blue Herons were 11.9 times more likely to be present with water Great Egrets were 6.8 times more likely to be present with water. Snowy Egrets were 8.2 times more likely to be present with water. Black-crowned Night Herons were 9.5 times more likely to be present with water. Little Blue Herons and White Ibis were more likely to be present, however there were too few data to calculate their odds ratio.

Vegetation

Digitized maps of each wetland's habitat diversity are seen in the following figures: Lake Whitney (Figure 9), South Whitney Pond (Figure 10), Willow Pond (Figure 11), Lake Retta (Figure 12), Plum Orchard Pond (Figure 13), North Swamp Field (Figure 14), South Swamp Field (Figure 15), and Hickory Hill Pond (Figure 16). The dominant vegetation for each class was identified in the field for each pond as above. (Tables 5-12). Live Oak (*Quercus virginiana*) is the dominant tree found in the forests surrounding the wetlands. Vegetation varied greatly between wetlands, saw palmetto (*Serenoa repens*), dog fennel (*Eupatorium serotinum)*, sand cordgrass (*Spartina bakeri*) and wax myrtle (*Morella cerifera*) were common vegetation around the edges of the wetlands.

Birds and Vegetation

Water presence, wetland area and habitat diversity were all important factors for higher bird abundance (Table 13). Water presence was the only important factor to increase bird diversity (Table 13). Although r^2=.7 094 for species richness, there was likely a high variance within the data and the effect of water presence, wetland area or habitat diversity could not be determined (Table 13).

DISCUSSION

Cumberland Island's has a long and diverse history of human presence. Prior to the plantation era there is little to no knowledge of how the land looked. It was not until the Carnegie era that pictures of the landscape were taken and wildlife presence was recorded. Without records, impossible to know how the island's freshwater wetlands have transformed over the different human eras, but what is known is how they have diminished in size and bird use over the last 50 years.

Bird species richness and diversity was low, especially compared to historical data. Thirteen species of wetland-dependent birds were recorded nesting on Cumberland Island in the last 75 years (Pearson 1922, Ruckdeschel and Shoop 1987). Of those 13 species only two were recorded nesting on the island during my study. More than 20 species of birds belonging to family Anseriformes, the waterfowl, have been recorded in the freshwater wetlands of Cumberland Island in the past. The Carnegie family was known to be avid duck hunters and even burned wetlands to enhance habitat. However, only four species from Anseriformes were seen during my study. The changes in freshwater habitat has likely caused a decline in bird use.

Size of wetlands did not seem to matter, contrary to recent studies. According to most studies, higher bird abundance and species richness is strongly correlated with an increase in wetland area (Gonzalez-Gajardo et al. 2009). However in my study, wetland area was not a strong predictor of bird abundance, richness and diversity. Plum Orchard Pond and Hickory Hill Pond are both small bodies of water, but because they have constant water flow, they provide habitat not found elsewhere on the island and attract birds. Plum Orchard Pond is near the intracoastal waterway and salt marsh. Factoring in the area of these features that also provide wetland habitat into the regression did not increase the significance of area in the model.

Wetland size was not related to higher bird abundance; however, presence of water was a factor and is likely due to drought. Plum Orchard Pond, Lake Whitney, Hickory Hill Pond, and the North Swamp Field all had water present throughout the study, which probably lead to a significantly higher bird abundance and species richness. Rainfall was 24.7 cm lower than the 100 year average causing many of the freshwater wetlands on the island that in the past had water year round to now completely dry up in the summer. However, drought may not be the only reason for low bird abundance and is just another factor driving the freshwater wetlands succession to shrubs and trees.

There are longer term changes at work on Cumberland Island. The open water area in Lake Whitney, the largest wetland on the island, has decreased 87.5% over in 39 years. That is typical to most freshwater wetlands on the island; historical data shows more water than today. There are many factors that could attribute to why Cumberland Island is losing its freshwater wetlands. Since the National Park Service has taken over, there have been changes in the way the island is managed. Fire regime and grazing changes may be some of the most influential changes.

Of the eight study sites, all but Hickory Hill Pond and Plum Orchard Pond have burned in the last 20 years (John Fry pers. comm. 2010). Lightning often ignites wildfires on the island and are confined and allowed to burn out as long as they do not endanger historic structures or island residences (Laliberté 2007). Fire is important to remove woody vegetation and thick grasses from wetlands (Vogl 1973). The wetlands on Cumberland Island do burn and vegetation returns to pre-burn levels within two years (Davison and Bratton 1988). If natural fires are dependent on lightning and fires have burned in most of the wetlands, then natural fire suppression does not seem to be the problem. However, before the National Park Service took over, island residents used to burn the ponds and sloughs from Willow Pond to Lake Whitney to enhance waterfowl habitat (Turner and Bratton 1987). Since fire was used to enhance waterfowl habitat, the fact that wetlands are no longer burned regularly has caused vegetation to regrow and birds may no longer find it desirable nesting habitat.

Feral cows have been completely removed from the island. The effect they had on the vegetation was not known until they were removed from the island and woody plants were allowed to grow naturally (Fred Whitehead pers. comm. 2011). Cattle grazing alter wetland habitat greatly. Grazing reduces plant biomass and species richness and can alter vegetation composition (Reeves and Champion 2004). Looking at the vegetation changes in the aerial imagery of Lake Whitney over a 40 year period, there were no net change in vegetation in 1942, 1953,1962 and 1971 (Lambert 1992). However, after the National Park Service took over in 1972 and feral cows were contained and removed from the island, areal imagery from 1981 and 1988 showed vegetation growing along the eastern shore of the lake (Lambert 1992). Comparing current aerial imagery from 2011 to Lambert's imagery, there has been an even greater vegetation increase in the dunes that was previously believed to be filling in Lake Whitney (Figures 8 and 17). Removing cattle from wetland areas greatly affects habitat and vegetation structure (Brown 2007). With the removal of cattle, the dunes have likely stabilized and the woody vegetation that was unable to establish due to grazing has caused vegetation to flourish and may be responsible for the diminishing open water habitat (Brown and Brown 2007).

Grazing also affects birds. Cattle and horses will feed in wetlands (Reeves and Champion 2004). Grazing animals have been known to trample bird nest (Reeves and Champion 2004). Although removing vegetation around wetland edges can increase open water habitat for some species of birds, it can also degrade nesting and feeding habitat for others (Reeves and Champion 2004). The freshwater wetlands on Cumberland Island were grazed for nearly 400 years; the removal of cattle has changes the vegetation structure which in turn can affect bird preference.

Habitat preference varies for wetland associated birds. According to the Cornell species accounts for the 13 marsh birds surveyed for, the birds nest on the ground or in vegetation in the water (Eddleman 1994, Bookhout 1995, Conoway 1995, Melvin and Gibbs 1996, Muller and Storter 1999, Bannor and Kiviat 2002, Brisbin and Mowbray 2002, Bryan 2002, West 2005, Poole and Bevier 2005, Gibbs et al. 2009, Lowther et al. 2009). The marsh birds also spend the majority of their time on the ground or near the ground while feeding (Eddleman 1994, Bookhout 1995, Conoway 1995, Melvin and

Gibbs 1996, Muller and Storter 1999, Bannor and Kiviat 2002, Brisbin and Mowbray 2002, Bryan 2002, West 2005, Poole and Bevier 2005, Gibbs et al. 2009, Lowther et al. 2009). Herons, egrets and storks generally nest in colonies in trees that are surrounded by water (Ruckdeschel and Shoop 1987). Cumberland Island has lost its nesting rookeries, likely due to predation. Rookeries are abandoned when water levels drop too low to protect against invading predators (Ruckdeschel and Shoop 1987).

There are many avian predators on Cumberland Island. Coyotes, opossums, armadillos, raccoons, feral hogs and bobcats are all found on the island and are known to eat ground birds and their eggs (Sooter 1946, Wiseman and Hendrickson 1950, Fitch et al 1952, Dorney 1954, Hanson and Karstad 1959, Baker et al. 2001). Coyotes are newly establish the island with a population possibly as high as two dozen individuals; their impact on the island is unknown at this point. (Doug Hoffman, pers. comm., 2012). Opossums and armadillos diets are mainly insects and vegetation, if they predate eggs or small birds on Cumberland Island it is probably just opportunistic predation (Wiseman and Hendrickson 1950, Fitch et al. 1952). Raccoons have been recorded eating shorebird nests, so any ground nests could be a target; they are only controlled when they predate seaturtle nests (Sabine et al. 2006). Feral hogs were frequently seen rooting in the wetlands during the survey. With the population of feral hogs on Cumberland Island between 200-300 and their frequent use of the wetlands as a foraging habitat, depredation of ground birds and their eggs is likely (Doug Hoffman, pers. comm, 2012). Bobcats were reintroduced to on the island in the 1980’s. The released bobcats were radio-tracked and their diet recorded; they are known to eat birds (Baker et al. 2001). With the lack of space that an island has and the variety of predators, nesting and foraging birds face predation easily on Cumberland Island (Figure 16).

Harris Neck National Wildlife Refuge is 80 km north of Cumberland Island. Harris Neck has six man-made ponds managed for feeding and nesting birds (USFWS 2012). The wildlife refuge also constructed over 100 nesting platforms that have successfully encouraged Wood Stork nesting (USFWS 2012). The water levels are managed by the refuge to attract wading birds during the nesting season and for waterfowl in the winter (USFWS 2012). One possibility for lack of birds on Cumberland Island is the ample nesting and feeding area protected and managed for at Harris Neck National Wildlife Refuge

There are many factors attributing to the loss of freshwater wetlands on Cumberland Island and the loss of bird biodiversity. However active management can save some of the wetlands. Plum Orchard Pond is maintained by a well and an earthen dam. It also has the highest bird abundance, species richness and species diversity of any other freshwater wetland on the island. Dams are considered bad because they alter the habitat, but the loss of Plum Orchard Pond's dam would mean the loss of Plum Orchard Pond. Without the pond the island would lose a valuable roosting site that would lower the biodiversity on the island. Hickory Hill Pond is also maintained by an artesian well. Turning off the well will likely result in woody vegetation encroachment into the wetland; similar to the condition of Ashley and Johnson Ponds on the northwest portion of the island.

A dry climate period, coupled with fire regime changes and the removal of feral cows has created different habitats on Cumberland Island that may not be desirable for nesting.

Predation adds to the problem. Future studies should look at the predator densities on the island. Baseline vegetation maps have been made for all the wetland study sites and could be compared to future work done on the island. If equipment becomes available, aerial imagery for the entire island, such as the imagery that Lambert used for Lake Whitney should be digitized to better understand the changes that have occurred on Cumberland Island since the National Park Service took over. Habitat requirements for wetlands birds include open water feeding area and shrubs or trees surrounded by water for nesting. However, most of the freshwater wetlands no longer have these requirements.

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Table 1. Average Monthly Temperature and Rainfall.

	Period of Record : 1/ 1/1892 to 5/31/2009		Period of Study 2010/2011		Period of Record : 1/ 1/1892 to 5/31/2009	Period of Study 2011/2010
	Average Min Temperature Celsius	Average Max Temperature Celsius	Average Min Temperature Celsius	Average Max Temperature Celsius	Total Rainfall cm	Total Rainfall cm
December	15.67	25.28	0.95	13.91	7.21	1.19
January	7.06	17.56	3.28	14.09	7.65	12.67
February	8.11	18.83	8.35	18.93	8.23	9.88
March	11.11	21.94	11.31	22.38	9.07	10.59
April	14.61	25.22	15.06	26.17	7.09	2.29
May	18.61	28.50	18.23	28.39	8.08	4.32
June	21.89	30.94	21.89	31.81	13.84	9.75
July	22.94	32.06	23.19	32.10	14.81	6.99
August	23.06	31.78	23.41	33.58	14.96	11.43
September	22.11	29.89	20.61	29.83	19.02	16.81
October	17.67	26.11	14.14	25.09	11.13	11.56
November	12.17	21.89	11.65	21.89	5.77	4.67

Average monthly temperature and rainfall readings were taken from NOAA weather station GA Brunswick 23 S located in Stafford field on Cumberland Island. The period record from 1892 to 2010 is from the Fernandina Beach, Florida weather station on Amelia Island.

Table 2. The impact to Cumberland Island's freshwater wetlands by historical era.

Time Period	Positive	Negative
Native American	-	Minimum agriculture
European settlement	Cattle grazing opens up wetlands Hogs and horses roam island	Cattle grazing reduces biomass Increases nutrients Tramples habitat
Plantation era	Dikes create ponded areas Agriculture opens up wetlands	Wetlands drained for agriculture Habitat fragmentation
Carnegie era	Burned wetlands Created artificial ponds	Allowed livestock to roam island Livestock feeds in wetlands
Modern era	Removed cattle Reduce feral hog population	Ground water withdrawal Remove cattle grazing Suppressed wildfire

Table 3. Nesting history of Cumberland Island's wetland birds

Common Name	Recorded nesting between 1922 - 1987	Currently nesting 2011
Wood Duck	*	*
Wood Stork	*	
Great Blue Heron	*	
Great Egret	*	
Snowy Egret	*	
Little Blue Heron	*	
Tricolored Heron	*	
Cattle Egret	*	
Green Heron	*	
Black-crowned Night-Heron	*	
Yellow-crowned Night-Heron	*	
White Ibis	*	
Osprey	*	*

Table 4. Logistic regression for presence/absence of birds – Significant species are more likely to be present in the presence of water.

	Effect Likelihood Ratio Tests			Odds Ratio	
Common Name	χ^2	df	p	Odds Ratio	Reciprocal
Wood Duck	3.2927	1	0.0696		
Blue-winged Teal	2.1869	1	0.1392		
Hooded Merganser	3.0124	1	0.0826		
Ruddy Duck	1.4883	1	0.2225		
Wild Turkey	2.3792	1	0.1230		
Pied-billed Grebe	1.4883	1	0.2225		
Wood Stork	8.2283	1	0.0041*	0.1044	9.5818
Anhinga	0.7398	1	0.3897		
American Bittern	0.7398	1	0.3897		
Great Blue Heron	10.6547	1	0.0011*	0.0839	11.9231
Great Egret	5.2723	1	0.0217*	0.1464	6.8305
Snowy Egret	6.7087	1	0.0096*	0.1226	8.1579
Little Blue Heron	8.6565	1	0.0033*	.	.
Tricolored Heron	2.2457	1	0.1340		
Cattle Egret	0.7398	1	0.3897		
Green Heron	3.0124	1	0.0826		
Black-crowned Night-Heron	8.2283	1	0.0041*	0.1044	9.5818
Yellow-crowned Night-Heron	2.1869	1	0.1392		
White Ibis	10.3664	1	0.0013*	.	.
Glossy Ibis	1.4883	1	0.2225		
Roseate Spoonbill	2.2457	1	0.1340		
Black Vulture	2.6874	1	0.1011		
Turkey Vulture	2.2457	1	0.1340		
Osprey	0.6619	1	0.4159		
Northern Harrier	0.7398	1	0.3897		
Red-shouldered Hawk	3.7885	1	0.0516		
Yellow Rail	0.3270	1	0.5674		
King Rail	0.7398	1	0.3897		
Virginia Rail	0.7398	1	0.3897		
Sora	1.4883	1	0.2225		
Common Gallinule	0.7398	1	0.3897		
Killdeer	0.0093	1	0.9228		
Spotted Sandpiper	1.4883	1	0.2225		
Greater Yellowlegs	0.7398	1	0.3897		
Sandwich Tern	0.7398	1	0.3897		
Belted Kingfisher	2.2457	1	0.1340		

Table 5. Lake Whitney vegetation by habitat class.

Area	Ha	% Area	Dominant Species	% Cover
Submerged vegetation	0.55	2.82	*Hydrocotyle umbellata*	80
			Lemna ssp	2
			Typha latifolia	2
			Poaceae	16
Open water	1.79	9.17	Open Water	95
			Mudflat	1
Marsh	4.29	21.9	*Spartina bakeri*	98
			Morella cerifera	1
			Typha latifolia	1
Interdune	2.29	11.71	*Morella cerifera*	<1
			Persea borbonia	<1
			Quercus virginiana	<1
			Bare Sand	99
Pine/Scrub	5.76	29.4	*Pinus elliottii*	60
			Morella cerifera	4
			Quercus virginiana	3
			Persea borbonia	1
			Bare Sand	32
Forest	4.89	24.99	*Quercus virginiana*	98
			Serenoa repens	2

Table 6. South Whitney Pond vegetation by habitat class.

Area	Ha	% Area	Dominant Species	% Cover
Marsh	4.68	24.03	*Spartina bakeri*	50
			Andropogon Spp	45
			Eupatorium serotinum	5
Edge	0.913	4.68	*Serenoa repens*	85
			Ilex vomitoria	1
			Quercus virginiana	5
			Morella cerifera	5
			Persea borbonia	2
			Acer rubrum	2
Forest	12.13	62.23	*Quercus virginiana*	100
Slough	1.78	9.14	*Spartina bakeri*	90
			Mudflat	10

Table 7. Willow Pond vegetation by habitat class.

Area	Ha	% Area	Dominant Species	% Cover
Open water	0.39	2.03	*Typha latifolia*	5
			Pluchea foetida	2
			Eupatorium serotinum	15
			Water/mud	30
			Eleocharis flavescens	48
Marsh	3.94	20.24	*Eupatorium serotinum*	95
			Spartina bakeri	5
Forest	14.31	73.41	*Serenoa repens*	10
			Spartina bakeri	15
			Eupatorium serotinum	5
			Quercus virginiana	69
			Morella cerifera	<1
			Ilex vomitoria	<1
			Persea borbonia	<1
Interdune	0.85	4.39	Dune	100

Table 8. Lake Retta vegetation by habitat class.

Area	Ha	% Area	Dominant Species	% Cover
Marsh	1.66	8.55	*Pluchea foetida*	26
			Panicum ssp	70
			Typha latifolia	1
			Cephalanthus occidentalis	1
			Kosteletzkya virginica	2
Edge	0.54	2.81	*Salix caroliniana*	50
			Morella cerifera	24
			Pinus taeda	24
			Quercus virginiana	1
			Ilex vomitoria	<1
			Sabal palmetto	<1
Forest	11.89	61.00	*Pinus taeda*	5
			Quercus virginiana	94
			Morella cerifera	<1
			Sabal palmetto	<1
Interdune	5.401	27.72	*Morella cerifera*	9
			Pinus taeda	10
			Ilex vomitoria	1
			Bare Sand	80

Table 9. Plum Orchard Pond vegetation by habitat class.

Area	Ha	% Area	Dominant Species	% Cover
Salt marsh	1.52	7.81	*Spartina alterniflora*	100
Intracoastal waterway	5.15	26.44	River	100
Tidal mudflat	1.11	5.72	Tidal Mudflat	99
			Spartina bakeri	1
Open water	0.19	1.01	*Lemna ssp*	100
Historic landscape	2.67	13.69	*Quercus virginiana*	1
			Ornamental	3
			Houses/Lawn	94
Forest	8.85	45.40	Quercus virginiana	92
			Sabal palmetto	1
			Persea borbonia	1
			Morella cerifera	1
			Juniperus virginiana	5
Edge	0.17	0.88	*bambusa multiplex*	8
			Quercus virginiana	91
			Sabal palmetto	<1
			Juniperus virginiana	<1
			Morella cerifera	<1

Table 10. North Swamp Fields vegetation by habitat class.

Area	Ha	% Area	Dominant Species	% Cover
Marsh	8.25	42.28	*Distichlis spicata*	59
			Juncus ssp	1
			Baccharis angustifolia	30
			Poaceae	10
Berm	0.20	1.02	*Borrichia frutescens*	10
			Baccharis angustifolia	10
			Pinus taeda	10
			Sabal palmetto	1
			Spartina bakeri	69
Forest	10.62	54.43	*Pinus taeda*	75
			Quercus virginiana	20
			Sabal palmetto	2
			Morella cerifera	3
Open water	0.43	2.25	Tidal Mudflat	90
			Canal	10

Table 11. South Swamp Fields vegetation by habitat class.

Area	Ha	% Area	Dominant Species	% Cover
Berm	0.40	2.08	*Sabal palmetto*	1
			Morella cerifera	2
			Spartina bakeri	97
Marsh	12.14	62.27	*Sabal palmetto*	65
			Morella cerifera	30
			Juniperus virginiana	1
			Pinus taeda	1
			Kosteletzkya virginica	1
			Spartina bakeri	2
Forest	11.18	57.38	*Pinus taeda*	94
			Acer rubrum	1
			Quercus virginiana	4
			Morella cerifera	1

Table 12. Hickory Hill Pond vegetation by habitat class.

Area	Ha	% Area	Dominant Species	% Cover
Open water	0.72	3.71	Open Water	100
Edge	0.09	0.50	*Eupatorium serotinum*	70
			Bare Ground	20
			Spartina bakeri	9
			Typha latifolia	1
Forest	18.69	95.77	*Quercus virginiana*	68
			Pinus taeda	30
			Morella cerifera	1
			Persea borbonia	<1
			Sabal palmetto	<1

Table 13. Multiple Regression Analysis – Average Abundance, Diversity and Species Richness compared to water presence, wetland area, and habitat diversity.

Dependent	Independent	r^2	F	p
Average Abundance		0.9682	40.5418	0.0019*
	Water Presence			0.0036*
	Wetland Area			0.0087*
	Habitat Diversity			0.0018*

Dependent	Independent	r^2	F	p
Diversity		0.8980	11.7428	0.0188*
	Water Presence			0.0110*
	Wetland Area			0.1150
	Habitat Diversity			0.0504

Dependent	Independent	r^2	F	p
Species Richness		0.7094	3.2555	0.1420
	Water Presence			0.1026
	Wetland Area			0.2817
	Habitat Diversity			0.1621

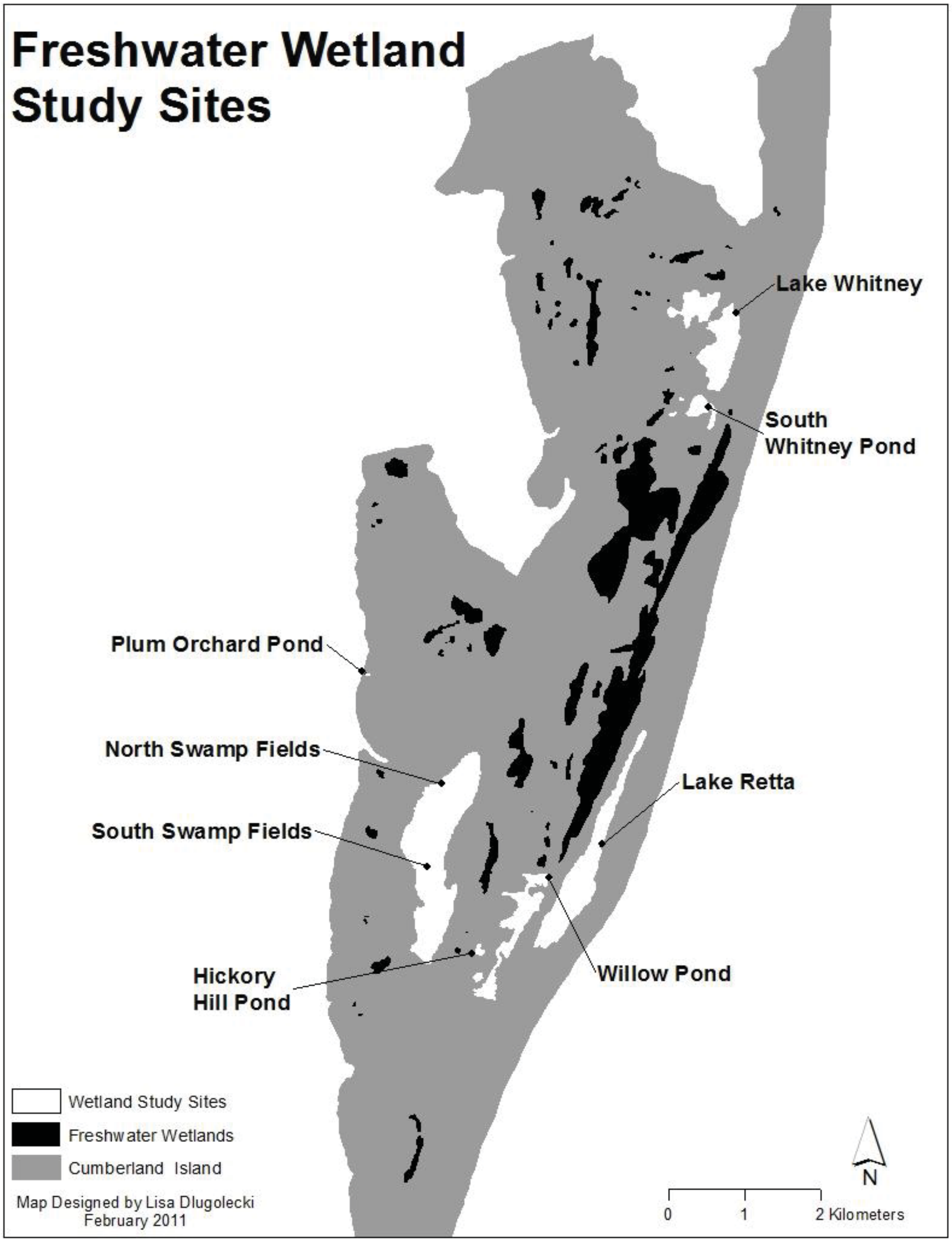


Figure 1. Freshwater Wetlands Study Site Location. Wetlands were digitized from USGS base map but do not represent current size of wetland. Points are location of survey points.

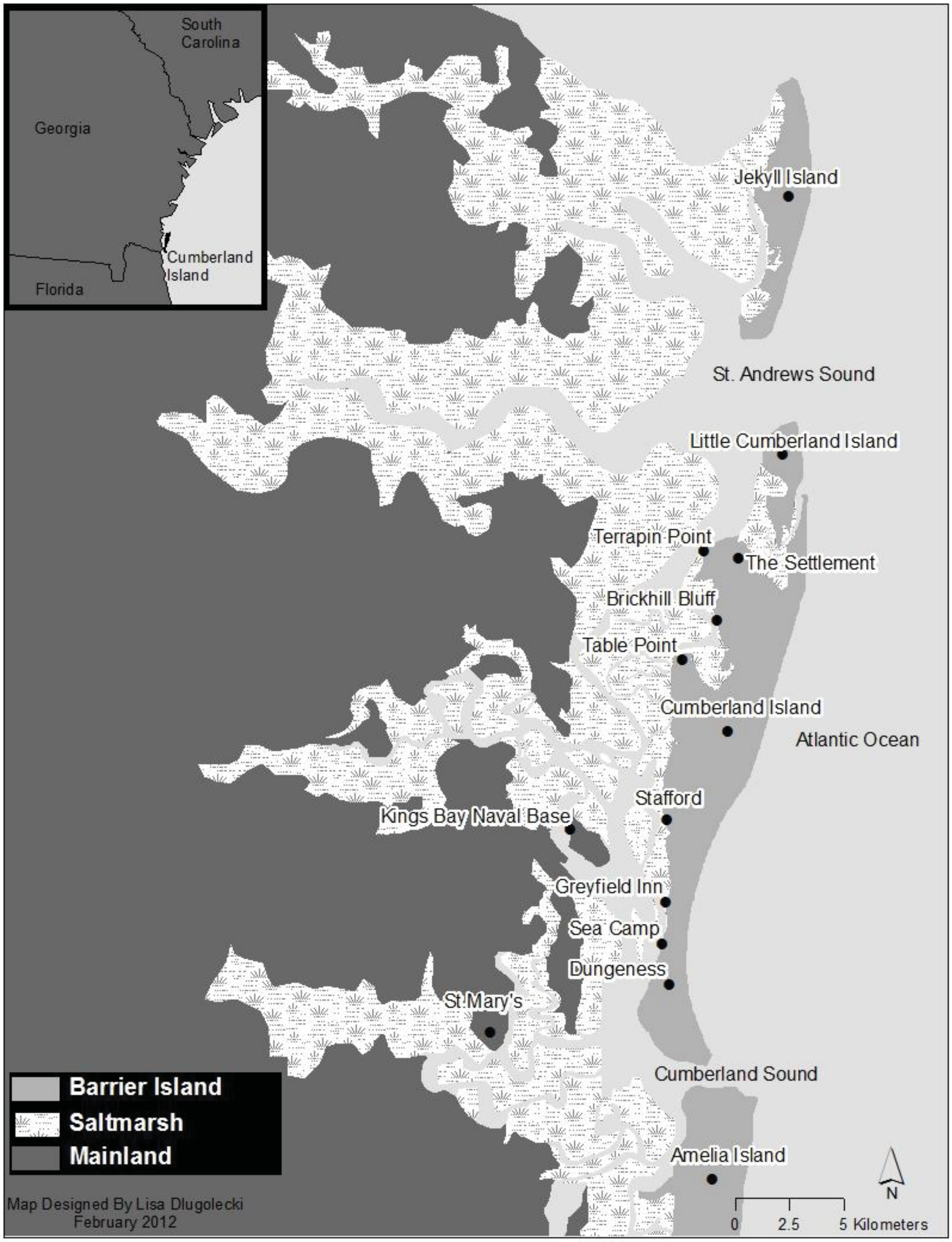


Figure 2. Cumberland Island Locator Map. Cumberland Island point marker is at -81.441 30.852.

Figure 3. Photographs of wetlands used in this study. a. Lake Whitney, b. South Whitney Pond, c. Willow Pond, d. Lake Retta, e. Plum Orchard Pond, f. North Swamp Field, g. South Swamp Field, h. Hickory Hill Pond. Photos Taken in 2011.

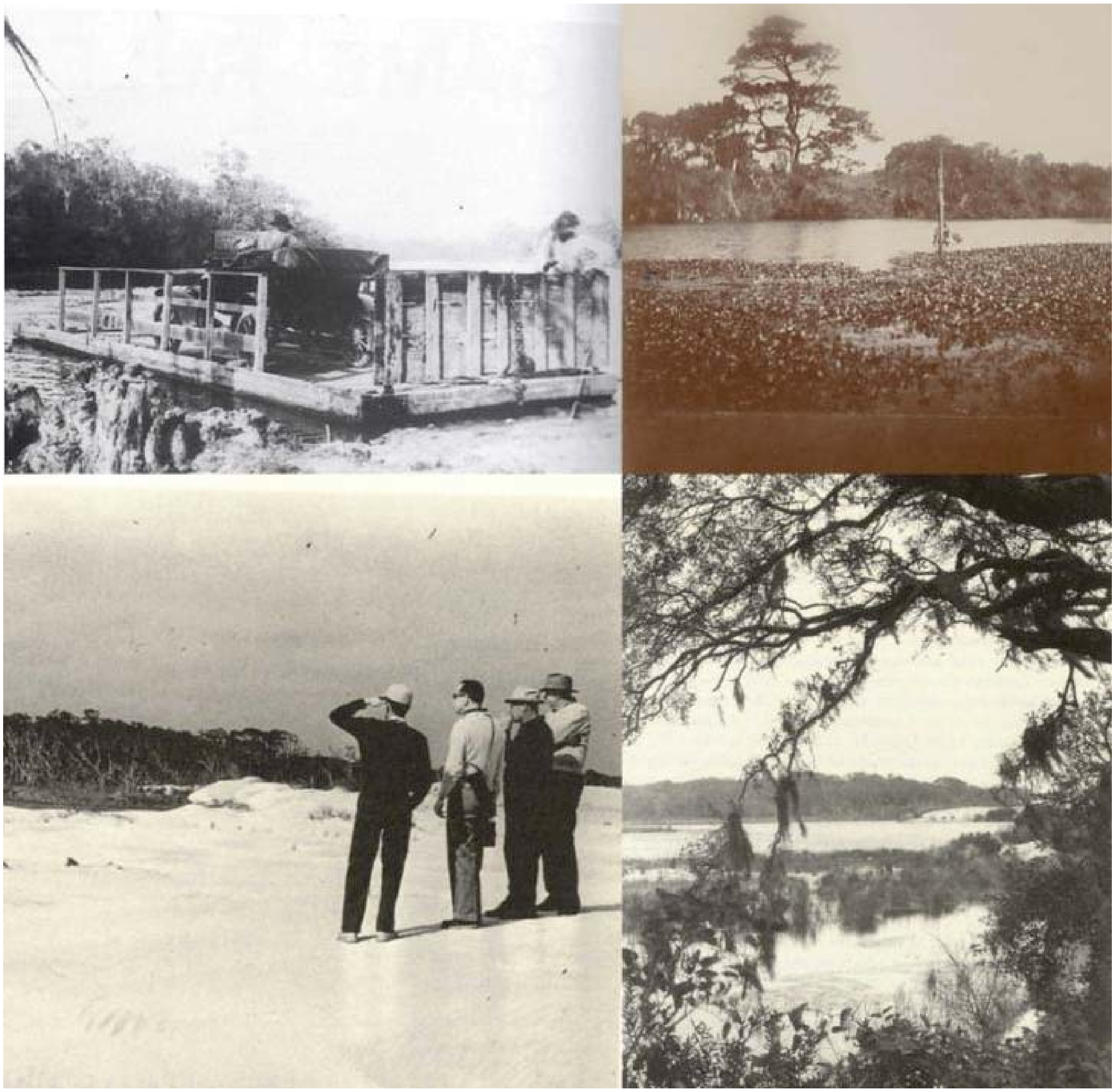


Figure 4. Historical Photographs of Lake Whitney, undated.
Top left – Old ferry thought to of been used on Lake Whitney.
Top right – View from north end of Lake Whitney.
Bottom left – Dune encroachment on the northeast corner of Lake Whitney.
Bottom right – View of Lake Whitney looking from the south to the north.

Figure 5. Aerial imagery of Swamp Field canals. Photo taken from ArcGIS Desktop Explorer. From aerial image, dikes and canals dug in the late 1800s are still visible.

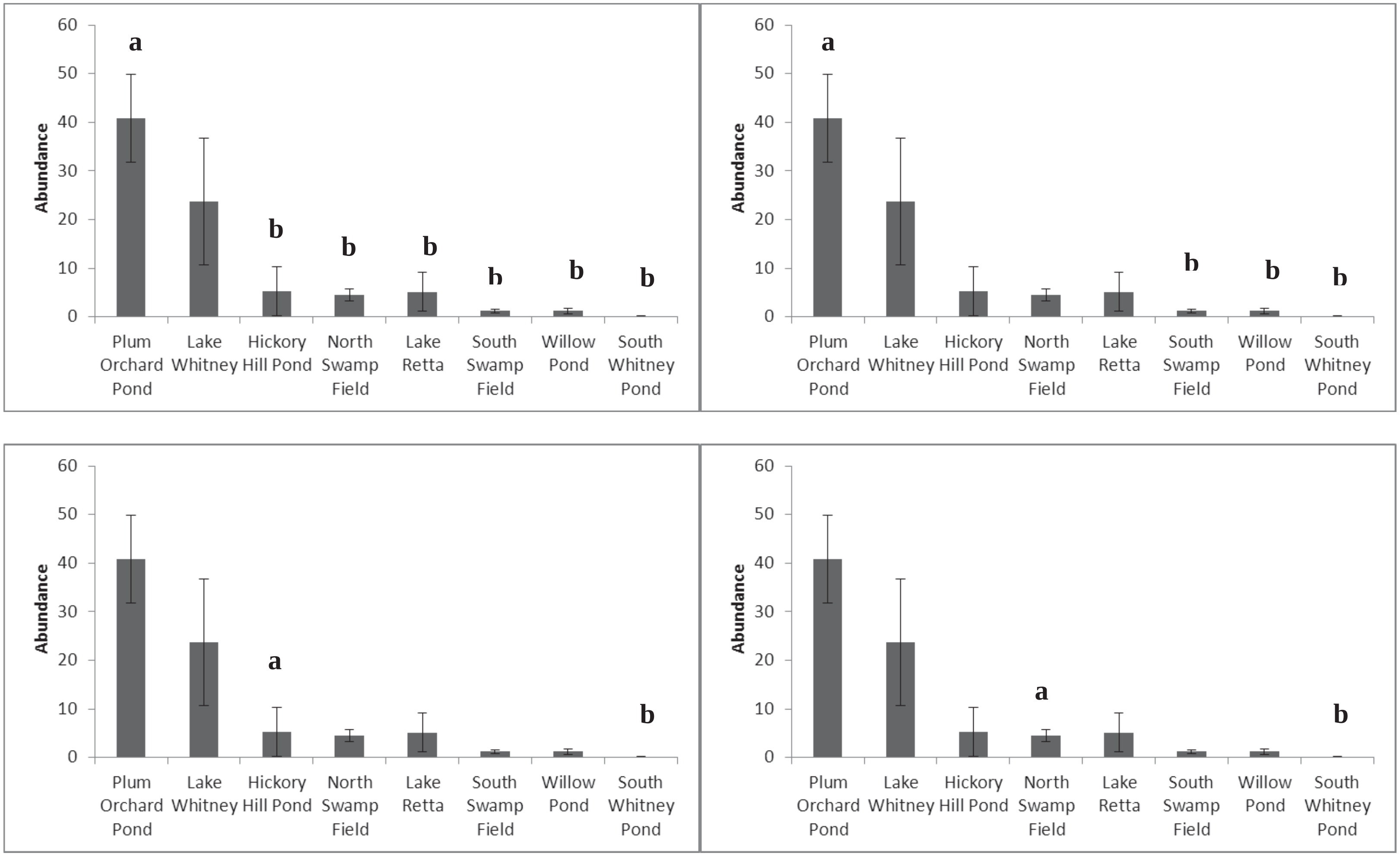


Figure 6. Friedman's Test for bird abundance. $\chi 2 = 46.564$, df=7, $\alpha_{0.05}=14.0671$ $p>0.0001^{*}$. Multiple comparisons by simultaneous test procedure were used to determine the difference in bird abundance between wetlands. Wetlands with letter 'a' have significantly higher bird abundance in relation to the wetlands with letter 'b'.

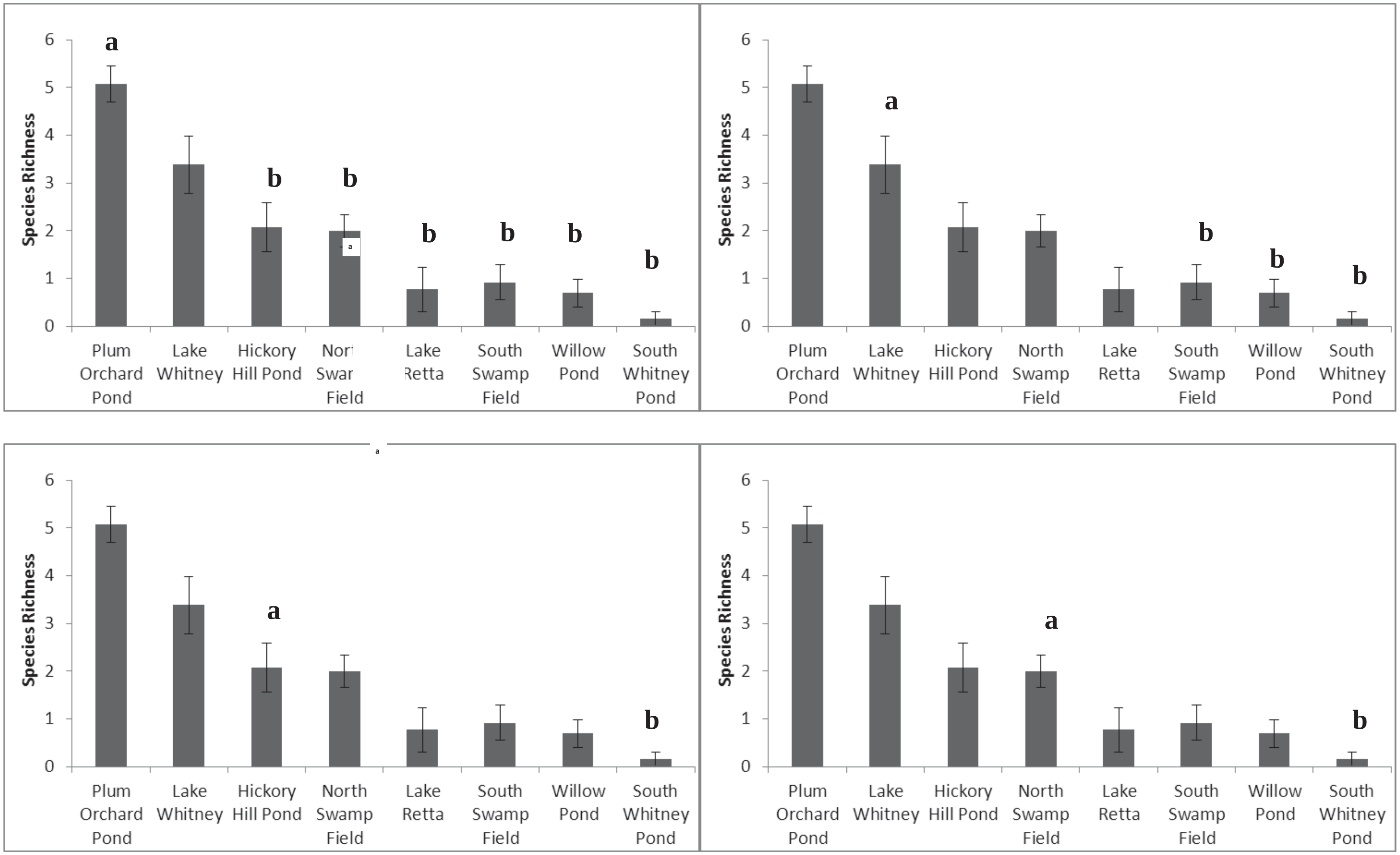
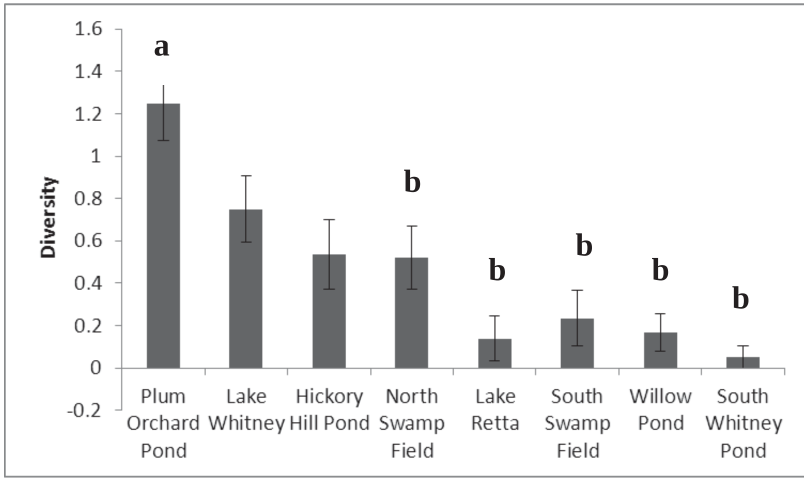


Figure 7. Friedman's Test for bird species richness. $\chi 2 = 47.256$ df=7, $\alpha.05=14.0671$, $p<0.0001^*$. Multiple comparisons by simultaneous test procedure were used to determine the difference in bird species richness between wetlands. Wetlands with letter 'a' have significantly higher bird species richness in relation to the wetlands with letter 'b'.



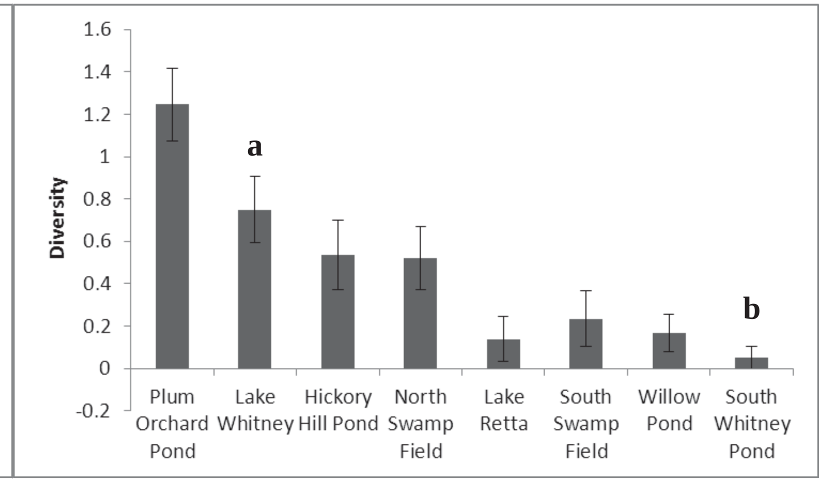


Figure 8. Friedman's Test for bird species diversity(H). $\chi 2 = 35.01467$ df=7, $\alpha_{.05}=14.0671$, $p<0.0001^{*}$. Multiple comparisons by simultaneous test procedure were used to determine the difference in bird species diversity between wetlands. Wetlands with letter 'a' have significantly higher bird species diversity in relation to the wetlands with letter 'b'.

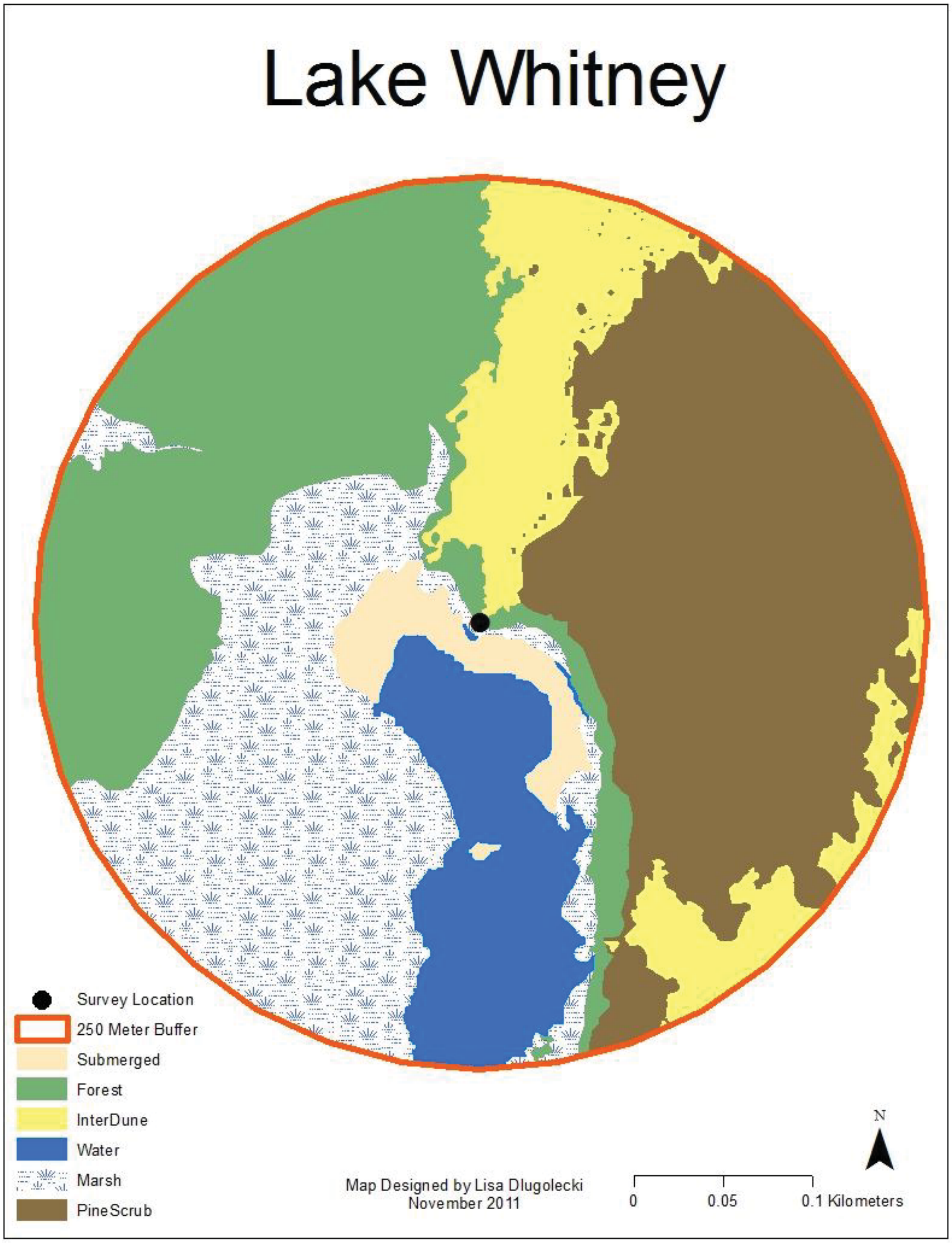


Figure 9. Lake Whitney habitat diversity map.

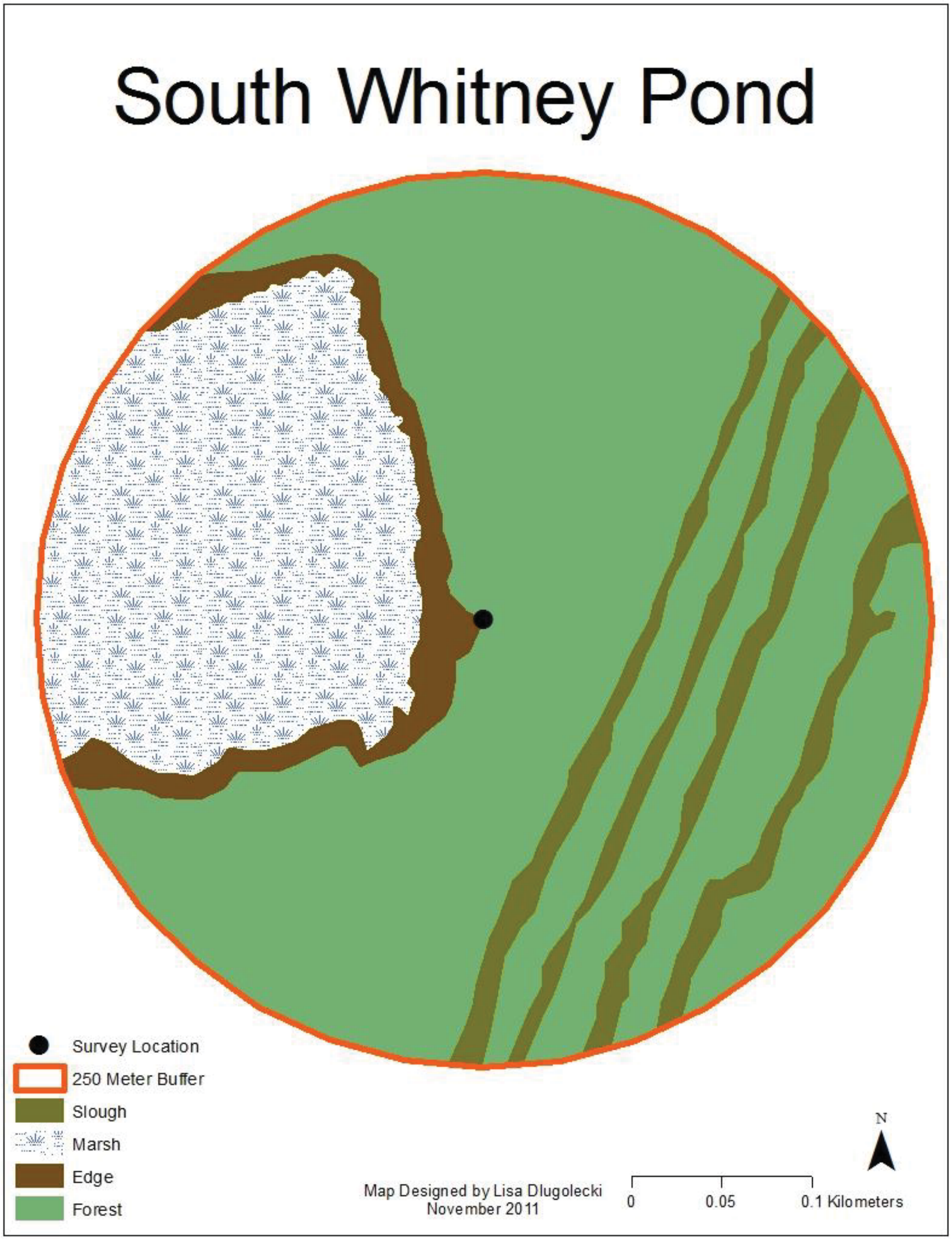


Figure 10. South Whitney Pond habitat diversity map.

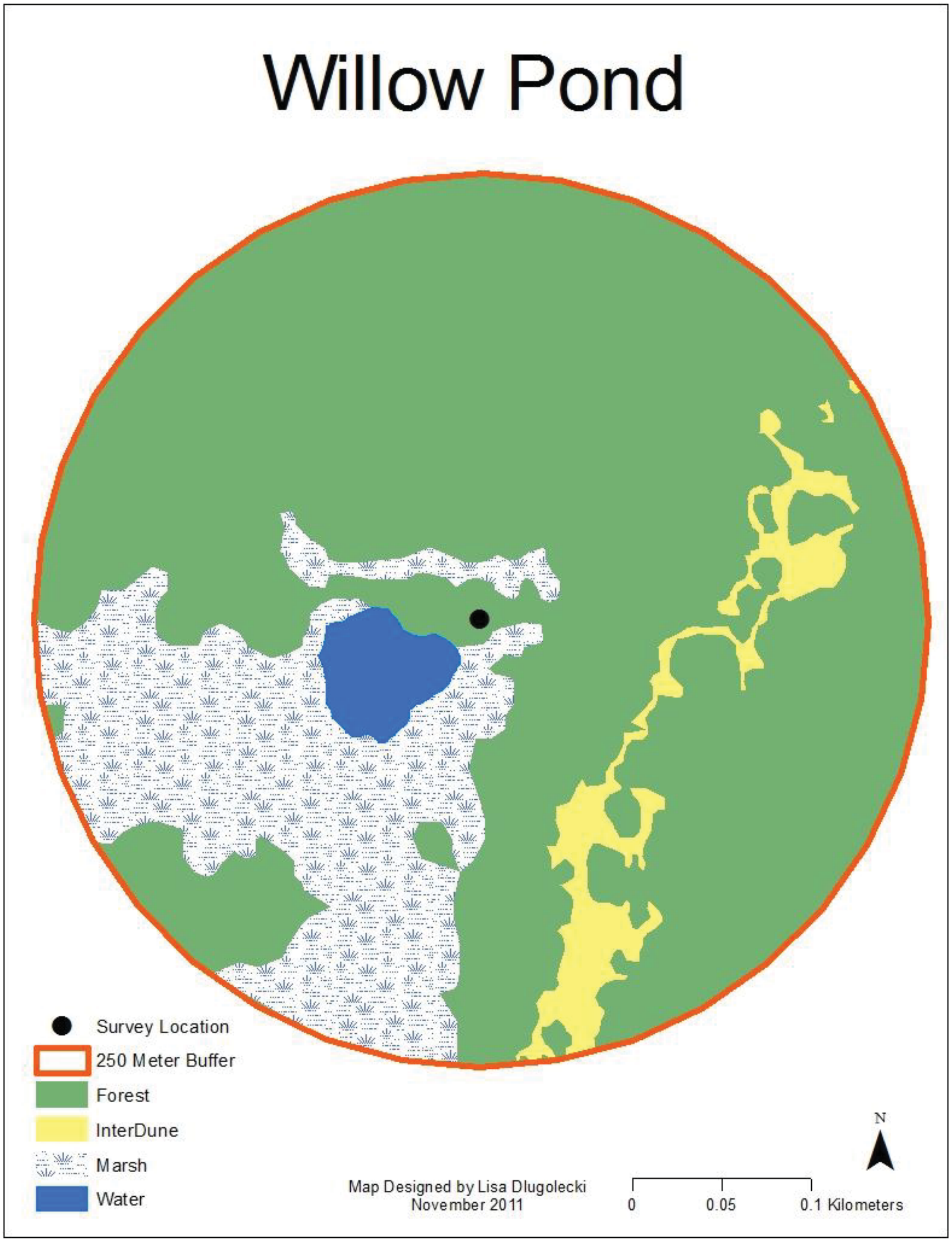


Figure 11. Willow Pond habitat diversity map.

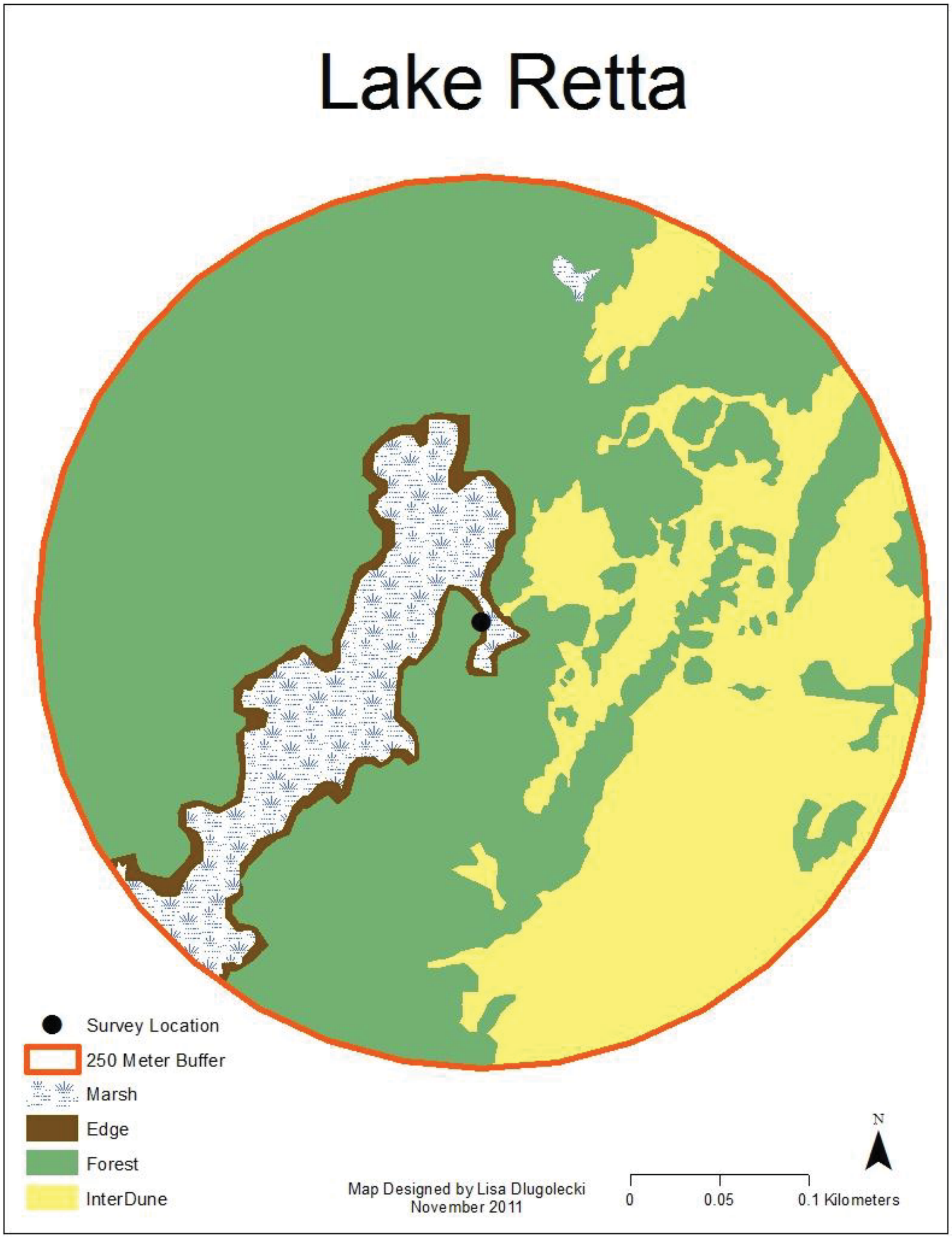


Figure 12. Lake Retta habitat diversity map.

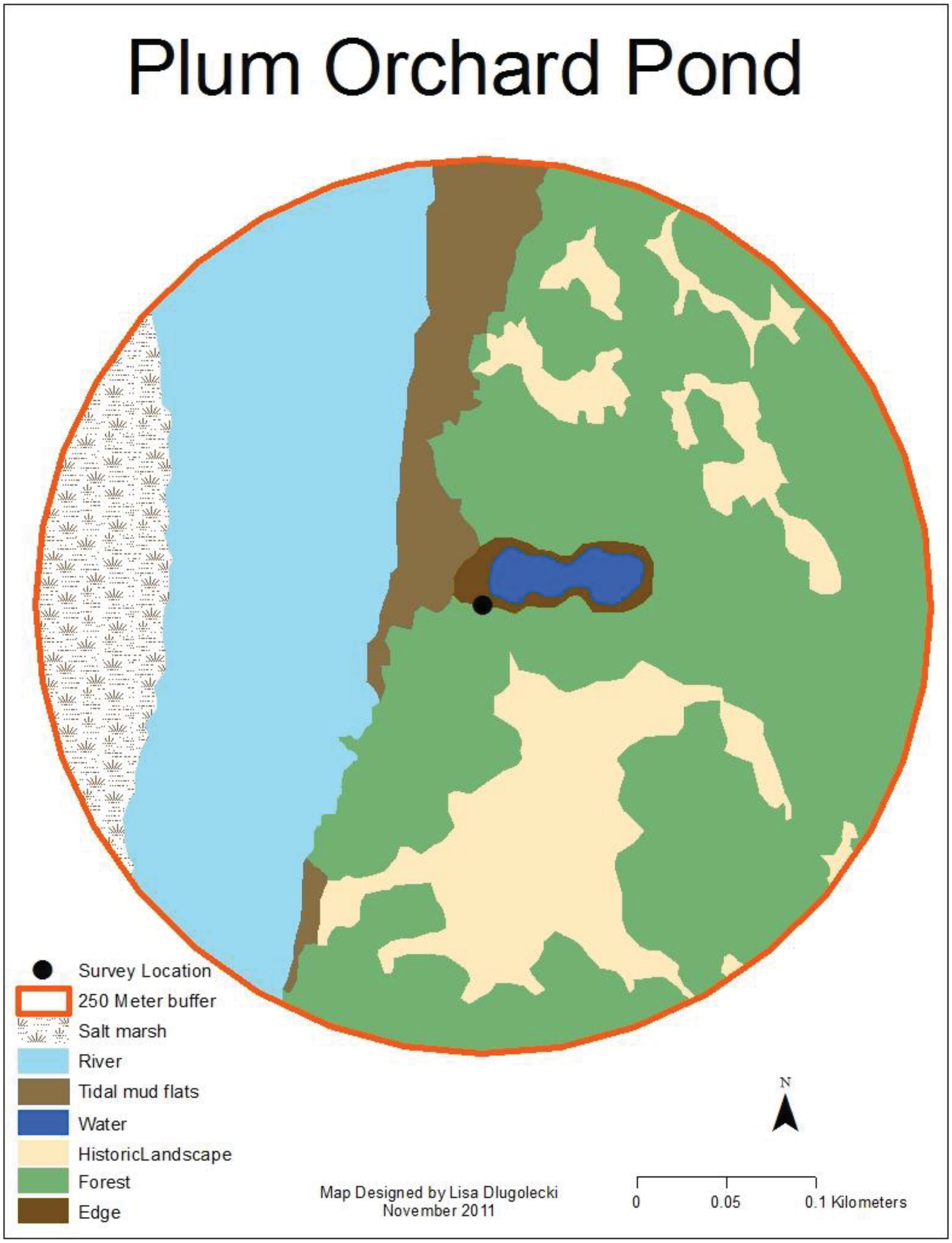


Figure 13. Plum Orchard Pond habitat diversity map.

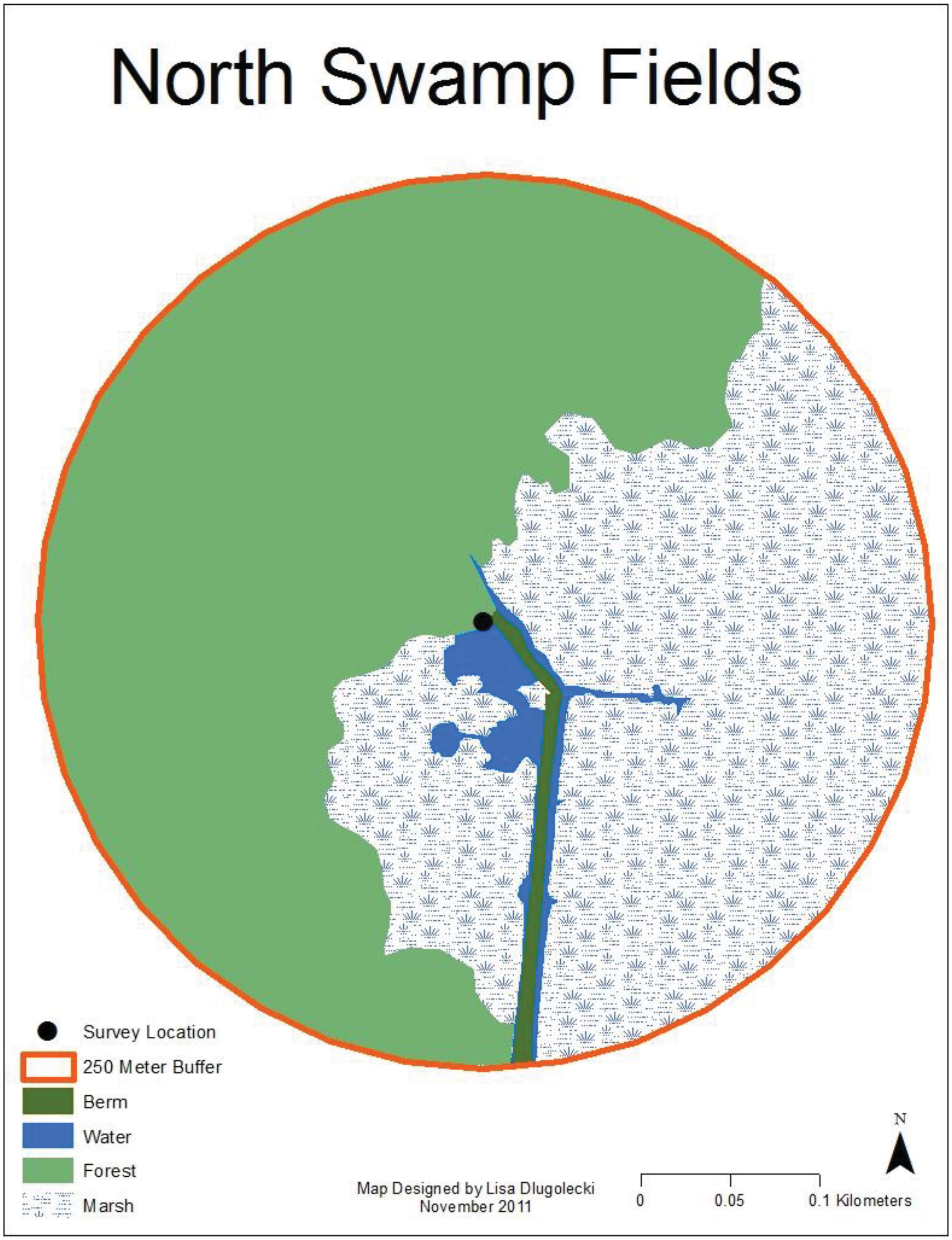


Figure 14. North Swamp Field habitat diversity map.

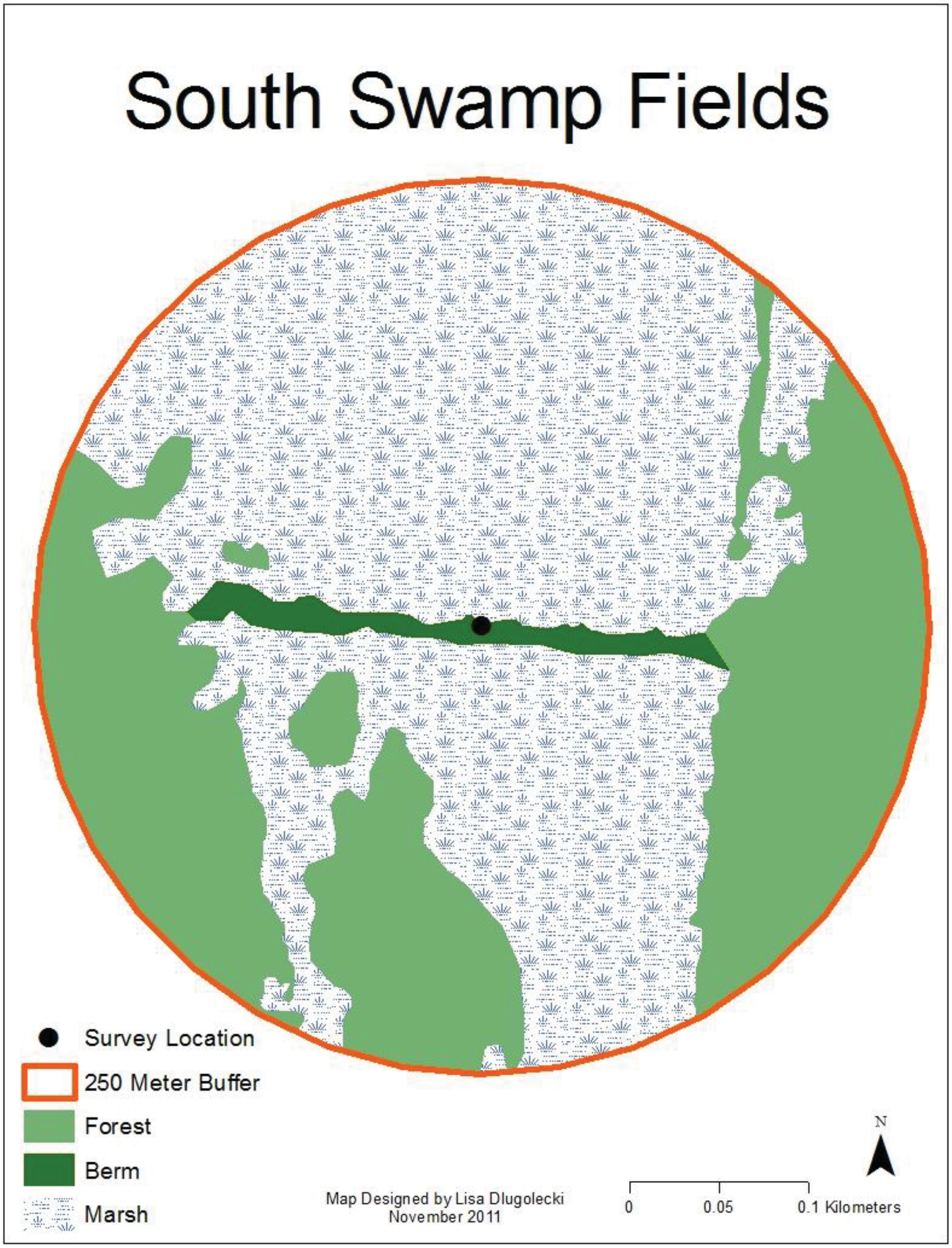


Figure 15. South Swamp Fields habitat diversity map.

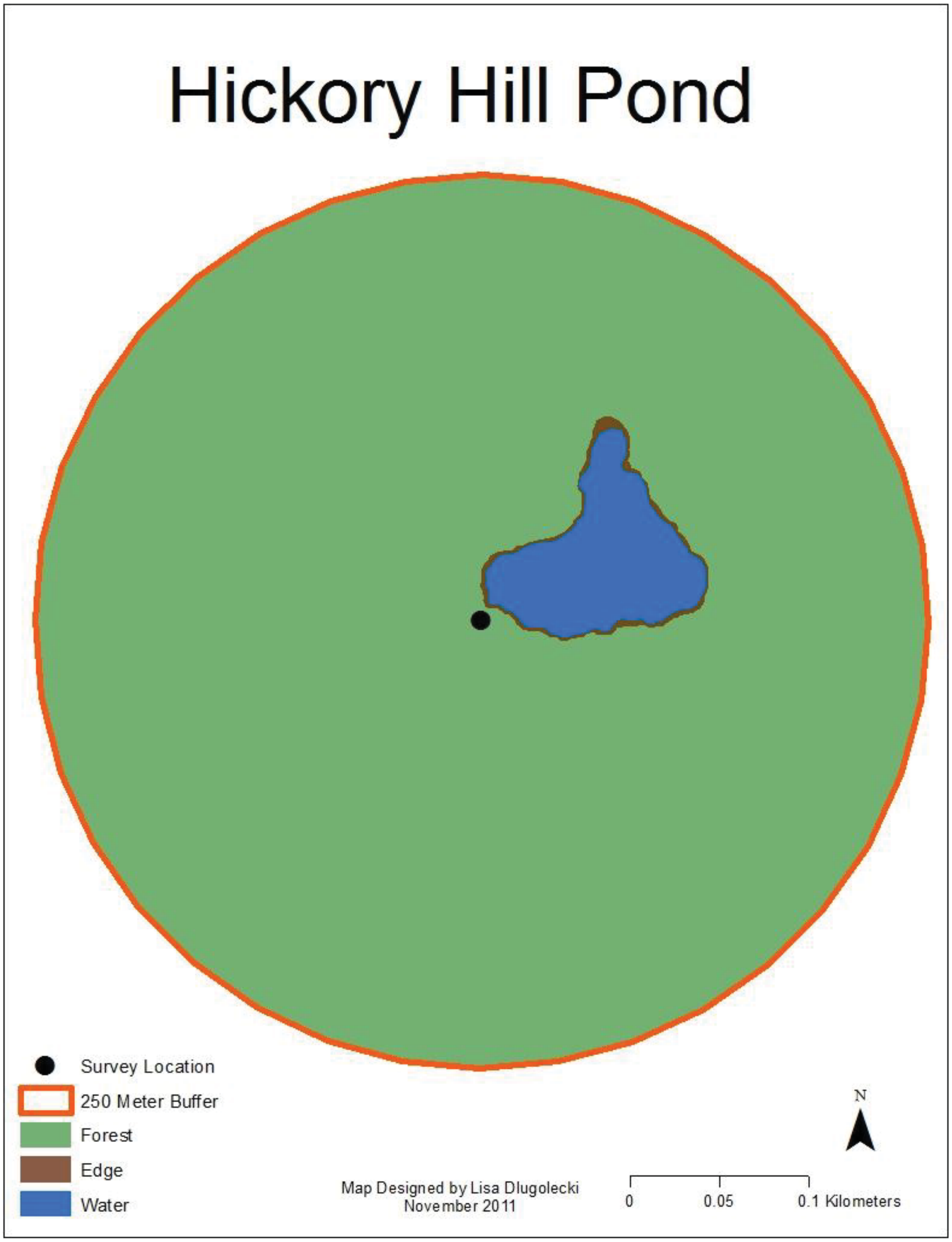


Figure 16. Hickory Hill Pond habitat diversity map.

Figure 17. Great Egret predation in the Swamp Fields.

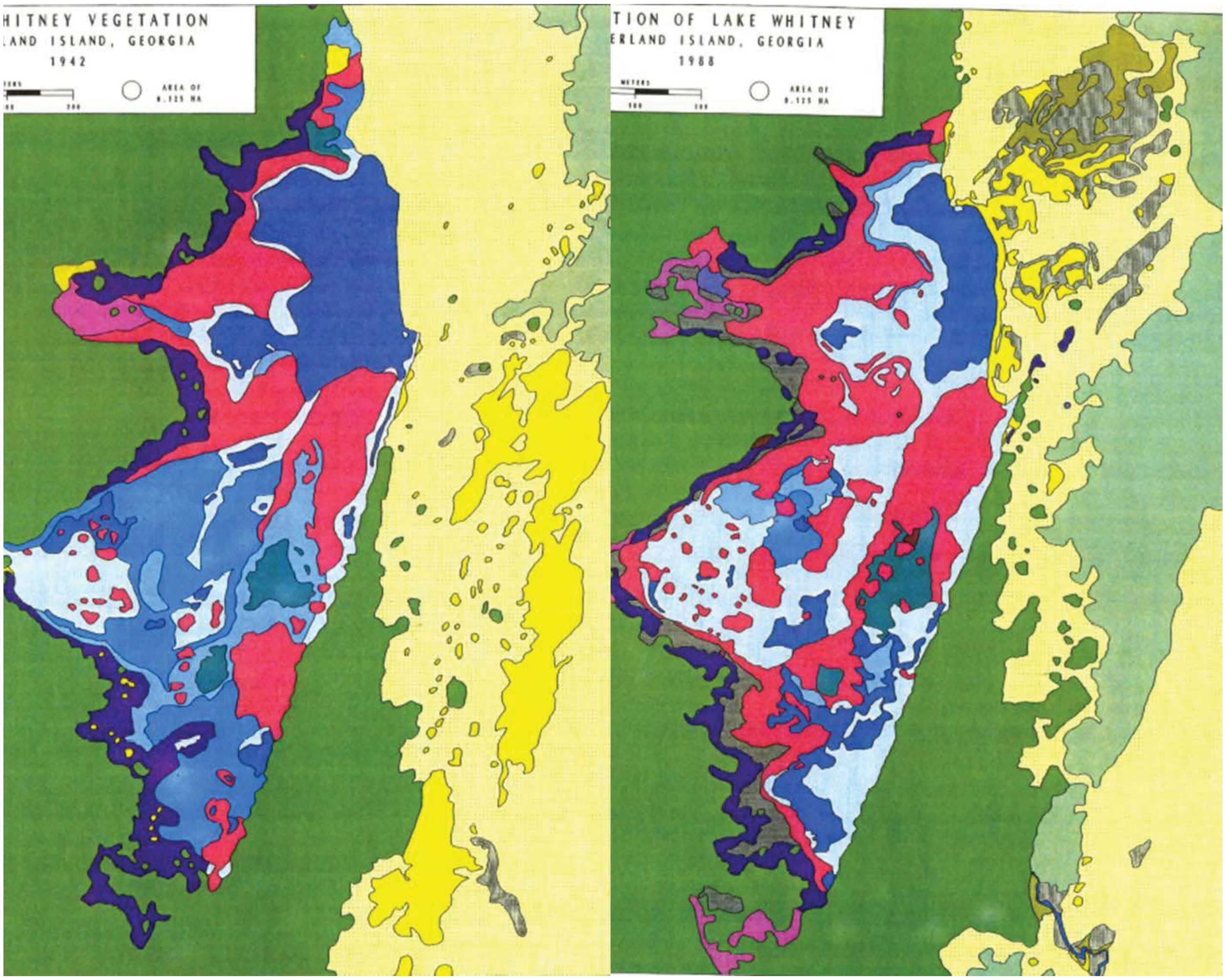


Figure 18. Vegetation Changes from 1942 to 1988. From Lambert 1992.

APPENDIX 1- LIST OF WETLAND BIRDS DETECTED ON CUMBERLAND ISLAND

Common Name	Order	Family	Scientific Name
Wood Duck	Anseriformes	Anatidae	*Aix sponsa*
Blue-winged Teal			*Anas discors*
Hooded Merganser			*Lophodytes cucullatus*
Ruddy Duck			*Oxyura jamaicensis*
Wild Turkey	Galliformes	Phasianidae	*Meleagris gallopavo*
Pied-billed Grebe	Podicipediformes	Podicipedidae	*Podilymbus podiceps*
Wood Stork	Ciconiiformes	Ciconiidae	*Mycteria americana*
Anhinga	Suliformes	Anhingidae	*Anhinga anhinga*
American Bittern	Pelecaniformes	Ardeidae	*Botaurus lentiginosus*
Great Blue Heron			*Ardea herodias*
Great Egret			*Ardea alba*
Snowy Egret			*Egretta thula*
Little Blue Heron			*Egretta caerulea*
Tricolored Heron			*Egretta tricolor*
Cattle Egret			*Bubulcus ibis*
Green Heron			*Butorides virescens*
Black-crowned Night-Heron			*Nycticorax nycticorax*
Yellow-crowned Night-Heron			*Nyctanassa violacea*
White Ibis		Threskiornithidae	*Eudocimus albus*
Glossy Ibis			*Plegadis falcinellus*
Roseate Spoonbill			*Platalea ajaja*
Black Vulture	Accipitriformes	Cathartidae	*Coragyps atratus*
Turkey Vulture			*Cathartes aura*
Osprey		Pandionidae	*Pandion haliaetus*
Northern Harrier		Accipitridae	*Circus cyaneus*
Red-shouldered Hawk			*Buteo lineatus*
Yellow Rail	Gruiformes	Rallidae	*Coturnicops noveboracensis*
King Rail			*Rallus elegans*
Virginia Rail			*Rallus limicola*
Sora			*Porzana carolina*
Common Gallinule			*Gallinula galeata*
Killdeer	Charadriiformes	Charadriidae	*Charadrius vociferus*
Spotted Sandpiper		Scolopacidae	*Actitis macularius*
Greater Yellowlegs			*Tringa melanoleuca*
Sandwich Tern		Laridae	*Thalasseus sandvicensis*
Belted Kingfisher	Coraciiformes	Alcedinidae	*Megaceryle alcyon*