ECOLOGICAL VALUE AND BIRD USE OF MANAGED IMPOUNDMENTS AND TIDAL MARSHES OF COASTAL SOUTH CAROLINA

by

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(Under the Direction of Sara H. Schweitzer)

ABSTRACT

Currently, managed wetlands (impoundments) are manipulated to provide wintering habitat for waterfowl (Anseriformes) and hunting opportunities. Impoundments may be used as supplemental habitat by migrating shorebirds (Charadriiformes) that are facing declines in the quality and quantity of stopover sites. We quantified the species and number of birds present in managed impoundments and tidal marshes during migration and winter seasons with scan sample surveys, documented behavior (e.g., feeding, breeding, roosting) of target bird species with time-activity budgets, and estimated birds' selection of food items through collection and esophageal dissection. Target bird species were Blue-winged Teal (*Anas discors*), Green-winged Teal (*A. crecca*), Greater Yellowlegs (*Tringa melanoleuca*), and Lesser Yellowlegs (*T. flavipes*). These data provided information on when and how the birds were using managed impoundments and tidal marshes. Our results suggest that management for multi-species use of impoundments is effective.

INDEX WORDS: ACE Basin, *Anas crecca*, *Anas discors*, Food items, Impoundment, Managed wetland, Multi-species use, Scan sample, Shorebirds, South Carolina, Teal, Tidal marsh, Time-activity budget, *Tringa flavipes*, *Tringa melanoleuca*, Yellowlegs

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B.S., University of Vermont, 2002

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2009

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May 2009

DEDICATION

This work is dedicated to my parents for their love and support. Also to D.D., E.M., J.M., C.R., A.B., H.M., M.B., T.J., and all of my other friends who spent time with me laughing, complaining, and stressing, but mostly for loving me through it all. I extend a special thank you to B.W., B.S., C.R., and A.H. for showing me how to "walk down another street."

ACKNOWLEDGEMENTS

First, I would like to thank Sara Schweitzer for trusting the folks at the Nemours Wildlife Foundation and taking a chance on someone whom she had never met. This project will no doubt influence the remainder of my career as it sparked in me a love for wetlands and wetland-dependent birds. Your encouragement, guidance, and time will never be forgotten.

I must give a special thank you to Ernie Wiggers and Eddie Mills at the Nemours Wildlife Foundation for hiring me as an intern in 2003, fresh out of undergraduate college, with no field experience. Without that opportunity I never would have found my way to the University of Georgia, which has provided me with much more than an education. You both were more than supervisors to me and I will always be grateful for that. Eddie and Juli Mills, you have stuck by me through it all, providing me with love and guidance in life. I am leaving graduate school with a confidence instilled by you both.

To Cecil Jennings, Jim Peterson, and Susan Ellis-Felege, I thank you for you assistance with statistical analysis and patience with me through it. My interns and technicians, Ryan, Klimstra, Joseph Hollis, and Daniel Barrineau, my data collection would be incomplete without your work. I thank the Nemours Wildlife Foundation and National Fish and Wildlife Foundation for funding, and Nemours, the USFWS and Hobonny plantation, for field sites, unlimited access, and guidance. Thank you to the Warnell School of Forestry and Natural Resources for this amazing educational and life experience.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

During the Eighteenth and Nineteenth centuries, culture and economics in coastal South Carolina led to the clearing and diking of tidal swamps and hardwood bottomland forests for rice production (DeVoe and Baughman 1986). Extensive dike and canal systems were constructed by hand to create tidal impoundments necessary for growing rice and building an economy. Water levels and salinities could be manipulated relatively easily with dikes, canals, manmade water control structures, and the influence of the natural tides (Tompkins 1987). During this time, rice plantations flourished along all major fresh tidal rivers in South Carolina as thousands of hectares were put into rice cultivation (Williams 1987).

Because of the end of slavery after the Civil War, several devastating storms in the late Nineteenth and early Twentieth centuries, and competition from rice producers in Texas, Louisiana, and Arkansas, large-scale rice production came to an end in coastal South Carolina (DeVoe and Baughman 1986; Williams 1987). Planting rice within the Combahee River basin, the site of this study, ended in 1927 (DeVoe and Baughman 1986). The rice culture generated a philosophy that embraces private land ownership and use of wetlands (Gordon *et al.* 1989). As a result, the trend that followed the demise of southern rice production included the purchase of plantations by wealthy northern sportsmen to develop them into hunting preserves. The earthen dikes and manmade water control structures were maintained or repaired, and these impoundments have since been managed primarily for wintering waterfowl and hunting opportunities through a

combination of water level control and vegetation management, know collectively as moist-soil management.

Coastal wetlands are among the most productive and ecologically valuable natural ecosystems on earth; however, they are also some of the most disturbed ecosystems (Bildstein *et al.* 1991). By the 1970s, almost half the wetlands in the lower 48 states had been filled or drained for the increasing human population (Tiner 1984) and about 23,700 ha are lost annually (Dahl 2005). Taylor *et al*. (1993) reported that wetland area in the U.S. had decreased by 54% since pre-settlement days and according to the USFWS, urban and rural development accounted for 61% of net loss of freshwater wetlands between 1998 and 2004 (Dahl 2006). In the South Atlantic, approximately 40% of the wetland area existing in the 1700s has been altered or lost (Williams *et al.* 1998). On the coast of South Carolina, residential and commercial development surrounds the more than 40,468 ha (Tufford 2005) of protected land and water of the ACE Basin, a watershed created by the Ashepoo, Combahee, and Edisto Rivers and their convergence into St. Helena Sound. Replacing wetlands and adjacent uplands with buildings and pavement influences water quality and erosion in and around estuaries (Gordon *et al.* 1989). Not only are wildlife species affected by the loss and degradation of wetlands, but economic, ethical, and aesthetic values may also be affected (Williams *et al.* 1998). Wetlands provide hunting, recreational, and ecotourism opportunities, improved aesthetics in a developed landscape, flooding mitigation and improved water quality, and increased property values. There are 28,328 ha of managed wetlands in coastal South Carolina (Williams 1987) and opportunities for habitat restoration and enhancement exist. The inherent manageability of impoundments makes them unique and adds to their

importance among coastal ecosystems (Williams 1987), particularly for some wetland bird species. Additionally, the tradition of managing wetlands to benefit waterfowl offers "conservation umbrella" opportunities to develop integrative management schemes encompassing a diverse suite of waterbird taxa (Parsons *et al.* 2002). However, our knowledge of basic functional processes (i.e., nutrient cycling, effects on fish populations, water quality) of impoundment systems along coastal South Carolina is lacking (Tufford 2005). Knowledge of the role this habitat plays on a regional scale (i.e., refugia, stopover sites, wintering sites) is insufficient to suggest how to change current management protocols (Tufford 2005). With a better understanding of the role this habitat plays on a regional scale, especially in comparison with natural areas, I will be able to suggest new management schemes to increase abundance and diversity of wetland-dependent birds. Managing impoundments for multiple species is an increasing trend and more data are needed to devise and implement successful management strategies (Bolen 2000). As early as the 1930s, Aldo Leopold recognized the need for taxonomic integration within management. He encouraged people to consider a diverse group of birds such as shorebirds, bitterns (*Botaurus* sp.), and colonial wading birds, in addition to waterfowl, as natural habitat was degraded and lost (Erwin 2002).

IMPOUNDMENT MANAGEMENT

The most important tasks in managing an impoundment for wildlife are manipulating water levels and salinity (Tompkins 1987; Williams *et al.* 1998), and water control structures, called ricefield trunks (hereafter trunks), are essential for this management. Trunks are relatively simple structures; their design and function have changed very little over the centuries (R. D. Porcher, The Citadel, pers. comm.). Each

trunk has a wooden box that acts as a pipe, connecting the impoundment and the tidal river through the dike (Fig. 1.1). On either end of the box is a flap gate that opens or seals shut, depending on the direction of water flow. There is also a flashboard riser on the impoundment side of the trunk. Riser boards can be removed to manipulate water levels while maintaining water in the impoundment. To drain an impoundment (Fig. 1.2), the inside flap gate (impoundment side) would be raised and the outside flap gate (natural water source) set to open and close freely with the tide. During an outgoing tide, water would be pulled from the impoundment. During an incoming tide, the water flow would seal the outside gate shut, keeping water from re-flooding the impoundment. Depending on the size of the impoundment and the force of tides in a particular area, several tide cycles may be required to fill or drain an impoundment.

When managers can control water levels and salinity, they can influence the plants within the impoundment and specifically the successional stage within the impoundment. Early succession is a stage in which preferred waterfowl food plants grow well (Tufford 2005). Early successional plant species tend to produce abundant seed resources and are associated with a diverse group of invertebrates, the primary foods of dabbling ducks (Williams *et al.* 1998). Further, compared to cereal grains often planted for waterfowl, naturally occurring, early successional plant communities are less costly to produce, provide a buffer to the effects of lead poisoning, are more nutritious, almost always productive, and host more diverse populations of invertebrates, amphibians, reptiles, and mammals (Williams *et al.* 1998). Because impoundments lack influence from daily tides, they tend to be rich in detritus and thus high in invertebrate and fish abundance (Montague *et al.* 1987; Weber 1994). Common target plants in freshwater

impoundments are: smartweeds (*Polygonum* spp.), panicgrasses (*Panicum* spp.), flatsedges (*Cyperus* spp.), and Giant Foxtail (*Setaria magna*). Common target plant species in brackish impoundments are Saltmarsh Bulrush (*Schoenoplectus robustus*), Dwarf Spikerush (*Eleocharis parvula*), and Widgeongrass (*Ruppia maritima*).

For a typical moist-soil management scenario for waterfowl, managers quickly drain water out of impoundments (a drawdown) in February when waterfowl begin to migrate north. Water is left just below the bed through the summer for target food plant germination (Wilkinson 1987, Williams *et al.* 1998). Sometimes a manager will slowly raise the water during the growing season to promote emergent and submerged aquatic vegetation (e.g., Widgeongrass; Wilkinson 1987). In early fall, water is drawn off the bed to dry the surface, expedite senescence and decomposition of plants, and conduct prescribed fires or spot burns, creating open areas for waterfowl, reducing unwanted buildup of vegetation, and simulating food plant growth (Mitchell *et al.* 2006). Impoundments are usually flooded between 22 and 45 cm (Weber and Haig 1997b; Williams *et al.* 1998) in late fall and water remains on the impoundments through winter until the cycle starts again in February. Adjustments are made within each impoundment and salinity gradient if necessary. For instance, to eliminate Giant Cordgrass (*Spartina cynosuroides*), managers may need to leave an impoundment flooded through the summer, sacrificing waterfowl plants for a season (Williams *et al.* 1998).

If management objectives include providing shorebird and wading bird habitat in the spring, drawdowns will be slow and staggered to concentrate invertebrate and fish populations and open new areas as spring progresses (Weber and Haig 1997a; Williams *et al.* 1998; Hunter 2000; Isola *et al.* 2000). Creating an interspersion of depths through

slow and staggered drawdowns is important for late migrants (Weber 1994) and also because shorebird predation can reduce prey abundance or biomass, reduce mean prey size, and alter invertebrate recruitment (Weber and Haig 1997a). Extended spring drawdowns for shorebirds and waders may promote growth of undesirable plants around edges of the impoundment but this can be controlled in the fall with prescribed burning and flooding (Weber and Haig 1996).

Shorebirds in particular may benefit from impoundments if management focuses on heterogeneity of habitat features and multi-purpose use rather than viewing waterfowl as a priority over other bird groups (Erwin 1986). Coastal South Carolina is recognized as an important stopover site on the Atlantic Flyway for migratory shorebirds (Weber and Haig 1996). Coastal South Carolina also harbors numerous birds listed as species of concern, threatened, or endangered within the U.S. Fish and Wildlife Service's South Atlantic Migratory Bird Initiative (SAMBI), the U.S. Shorebird Conservation Plan (Brown *et al*. 2001), and the Western Hemisphere Shorebird Reserve Network Conservation Plan (Fernandez *et al*. 2006), evidence that management may have large-scale, inter-continental significance. Habitat loss is a significant factor in population declines of birds (Tufford 2005). To protect and increase these populations, managing remaining, requisite habitat to benefit diverse groups of birds with varying needs is critical. To manage impounded wetlands for multiple species, we must first know the birds' requirements for survival and maintenance.

In addition to habitat loss, birds are threatened by pollution, storms, direct competition with humans on remaining habitat, new and introduced predators, and global climate change, which may change availability of habitat and food resources (O'Brien *et*

al. 2006). Shorebirds are particularly at risk because they tend to concentrate at few sites at specific times (Skagen and Knopf 1993; Weber and Haig 1996). Because shorebirds migrate incredible distances and cover much of the globe, they are difficult to track and monitor. Therefore, the best opportunities to study and census shorebirds may be in staging areas during migration, when they congregate in large numbers in open areas (Weber 1994). These research efforts add to the basic knowledge of shorebirds and help determine which species are at risk because of declining populations and habitat. Gaining a better understanding of shorebird populations and habitat needs is important because their affinity for particular staging areas puts them at great risk from ecological (i.e., catastrophic storms) and human-caused disasters (i.e., oil spills) as well as significant habitat loss. The U.S. Shorebird Conservation Plan calls for allocating sufficient foraging habitat for an estimated 2 million migrant shorebirds using inland and managed wetlands in the southeastern U.S. during spring (Hunter *et al*. 2000; Oring *et al*. 2000; Brown *et al.* 2001).

Because impoundments are managed specifically for waterfowl, there are many opportunities to study them in this habitat. Tufford (2005), who compiled an extensive review of impoundment research, suggests that substantial information on migrating and wintering waterfowl such as habitat requirements, structure, and function across scales is needed. Additional information is also needed on the relative importance of various food items that migrating and wintering waterfowl consume. There are guidelines for managing impoundments for wintering waterfowl but following these does not guarantee that ducks will be present; land managers and scientists in South Carolina have reported decreasing numbers of wintering waterfowl and impoundments without wintering birds

(Tufford 2005). Tufford (2005) concludes that winter habitat selection by ducks is not well understood and recommends scientific studies such as mine to answer these questions and to revise management strategies. Comparative studies between managed and unmanaged wetlands in the same location across a range of species and impoundment types (e.g., salinity, management objectives) would be particularly beneficial (Tufford 2005).

This study is particularly important because of the abundance of managed impoundments in the Combahee River Basin and my choice of focal birds. Because of the similarity of these habitat types along the South Atlantic Coast, my results and management recommendations can be applied from North Carolina to Florida. My research also may have effects on an international scale, as I studied long-distance migrants who depend on quality wetlands as stopover sites (Kushlan 1986; Tufford 2005). Isola *et al.* (2000) claim that their study is the first to simultaneously examine habitat for waterfowl and shorebirds. Our focal species use the same habitat simultaneously and because of niche partitioning, they should use these areas differently. They are particularly appropriate for studying community processes within these habitats because they are epibenthic, relatively large organisms, and prefer open areas (Weber 1994). My study provides new information on niche partitioning and interspecific interactions within habitats. My study also provides new information about effects of a salinity gradient on migratory, wetland-dependent birds. My research addresses questions and needs proposed by the U.S. Shorebird Conservation Plan, such as determining factors that influence or inhibit effective management of impoundments for shorebirds, and development of local and regional monitoring protocols that may improve

upon the International Shorebird Survey (Hunter 2000). Weber and Haig (1997b) suggest more studies are needed on shorebird diets in coastal, diked wetlands, and my data on selection of food items by wintering shorebird and waterfowl species will meet these needs.

STUDY OVERVIEW

This study had three overall objectives that are addressed in the following three chapters. The first objective was to compare abundance and diversity of dabbling ducks and shorebirds in managed impoundments and tidal marshes during two parts of their annual cycle — winter and migration. To accomplish this, surveys for dabbling ducks and shorebirds were conducted from January to mid-May of 2007 and 2008 on four managed impoundments and four tidal marshes. In doing so, presence and abundance of dabbling ducks and shorebirds on the two habitat types were quantified and compared to determine if there was a difference in habitat preference. The potential effects of season (e.g., winter and migration), tide level (e.g., high and low) and habitat (e.g., managed and natural) were analyzed. Based on opportunistic foraging behavior of waterfowl and shorebirds, I expected birds to be present on my study site during winter and/or migration seasons, foraging to build lipid reserves and improve body condition so they could survive migration and have a productive breeding season. I expected dabbling ducks to be more abundant on managed impoundments in winter, regardless of tidal stage, based on current management plans and previous studies (e.g., Burger *et al.* 1982; Breininger and Smith 1990; Gordon *et al.* 1998; Mitchell *et al.* 2006). I expected that shorebirds would not be on managed impoundments until spring draw down, because in winter, water levels range from 20-45 cm to meet the needs of waterfowl, but which exclude

shorebirds. After draw down, shorebirds should be on managed impoundments, regardless of tide level, but especially during high tide, when water levels on tidal marshes would be too high for them. They should take advantage of any opportunity to forage before migration and breeding. I expected to find shorebirds on tidal marshes only during low tide, as high water levels during high tide would push the birds out.

My second objective was to classify behaviors of birds at study sites to determine how dabbling ducks and shorebirds were using them. I assumed the birds were using the study sites for foraging primarily, and loafing (rest sites) secondarily. I achieved this objective by conducting time-activity budgets on four focal species: Blue-winged Teal (*Anas discors*), Green-winged Teal (*A. crecca*), Greater Yellowlegs (*Tringa melanoleuca*), and Lesser Yellowlegs (*T. flavipes*). These species are dependent on shallow water wetlands and are common wintering and migratory species in coastal South Carolina. I felt they were representative of similar species using the same habitat. And because all four species will use the same habitat simultaneously, I was interested in how they use the habitat differently so there is no niche overlap. I expected the types and diversity of behaviors by each species to differ within each habitat depending on the season and tidal stage.

My third objective was to determine food habits of these four focal species on managed impoundments to better understand niche relationships and appropriate habitat management. I expected diets to differ among the four species, allowing them to use the same habitat simultaneously. Diets would also differ based on physiology of the species (e.g., gizzards of teal are designed to digest seeds, while gizzards of yellowlegs are better suited for digesting soft-bodied prey). I performed necropsies on harvested teal and

yellowlegs from managed impoundments and analyzed esophageal and gizzard contents. A project summary, management recommendations, and further research suggestions follow in the fifth chapter.

LIFE HISTORIES

Blue- and Green-winged Teal are common residents of North America. Blue-winged Teal have a widespread North American nesting distribution, from southeastern Alaska, through Canada and the Prairie Pothole Region of the U.S., to the Gulf Coast of Texas and Louisiana as well as Nova Scotia south through New Jersey (Rohwer *et al.* 2002). They winter along the coast of California through the Baja Peninsula, from North Carolina through the southeastern U.S., into the West Indies and throughout most of Middle and South America (Rohwer *et al.* 2002). Blue-winged Teal are among the earliest fall migrants and latest spring migrants. They can be found on wetlands of coastal South Carolina from August into May (Rohwer *et al.* 2002). Green-winged Teal have a more northerly nesting distribution than Blue-winged Teal. They breed throughout Alaska and the Aleutian Islands and throughout almost all of Canada. In the U.S., they breed in the northwestern states, parts of the northern Midwest, and may breed in Massachusetts and Maine (Johnson 1995). Green-winged Teal also have a more northerly winter range than Blue-winged Teal. They winter as far north as Alaska, British Columbia, and Connecticut, south throughout the U.S., Mexico, and the West Indies (Johnson 1995). They can be found on wetlands throughout South Carolina from late September into April.

Blue- and Green-winged Teal forage on seeds, vegetation, and invertebrates by dabbling with only the bill submerged, dabbling with the head submerged, gleaning from vegetation, or tipping up (Johnson 1995; Rohwer *et al.* 2002). Teal rarely dive for food but will dive to escape predators or forced copulations (Johnson 1995; Rohwer *et al.* 2002). Green-winged Teal also probe for invertebrates on mudflats and plow through mud with bills open (pers. observ.). Both teal prefer shallow water, but only the Green-winged Teal is common on mudflats and more apt to loaf on dry land (Johnson 1995). Teal in flight are very fast and move together in tight flocks, similar to shorebirds (Dunne 2006). They ascend straight off land or water when taking flight. Both teal exhibit typical preening behaviors and sleep with their bills tucked. Green-winged Teal usually sleep standing on dry land (Johnson 1995) and are more vocal than Blue-winged Teal (Dunne 2006).

Greater and Lesser Yellowlegs are common migrant shorebirds throughout North America, the lesser with an estimated population five times greater than that of the Greater Yellowlegs (O'Brien *et al.* 2006). Greater Yellowlegs nest from southern Alaska, across central Canada to eastern Nova Scotia, forming a band across the arctic (Elphick and Tibbits 1998). They winter from southern New York through the southeastern U.S., into the West Indies, Central America, and throughout South America to Tierra del Fuego, and from northern and interior California through the Baja Peninsula (Elphick and Tibbits 1998; O'Brien *et al.* 2006). Lesser Yellowlegs nest throughout most of Alaska and northwestern Canada, but not northeastern Canada (Tibbits and Moskoff 1999). Their winter population is less abundant than Greater Yellowlegs on the west coast of the U.S.; they are found from central California south and do not winter in the

northern part of Texas or Mexico (Tibbits and Moskoff 1999; Elphick and Tibbits 1998). On the east coast, they can be found from southern New Jersey, through the Southeast, West Indies, Central and South America, to Tierra del Fuego. Locally, both species can be found along the entire coast of South Carolina (Chan 2008) from July through April (Tibbits and Moskoff 1999; Elphick and Tibbits 1998), although Smith *et al.* (1991) reported migrating Lesser Yellowlegs in northwestern Arkansas in June. Fall migration dates vary, especially for Lesser Yellowlegs, and they may not arrive on winter grounds until September or October, but yellowlegs breed and migrate south earlier than most other shorebird species (Tibbits and Moskoff 1999; Elphick and Tibbits 1998).

Greater and Lesser Yellowlegs forage on flooded fields, coastal marshes, mud flats, pond edges, vernal ponds, lakeshores, river bottoms, and tidal creeks (Paulson 2005; Dunne 2006; O'Brien *et al.* 2006); both are highly alert, active foragers. They have good diurnal vision (Rojas De Azuaje *et al.* 1993) and forage visually during daylight. Both species forage in shallow water, typically between 2 and 15 cm (Rundle and Frederickson 1981; Weber and Haig 1996; Elphick and Oring 1998; Isola *et al.* 2002). Greater Yellowlegs are often seen plowing forward with bill or head under water, presumably chasing fish (pers. observ.). They also chase and stab aggressively at items on the surface of mud or water. Lesser Yellowlegs can also be aggressive, but less so than Greater Yellowlegs. They are often seen picking at the surface of mud or water, rather than stabbing and jabbing (Dunne 2006). Both species use a side-sweeping ("scything") bill motion attributed with tactile feeding (Elphick and Tibbits 1998; Tibbits and Moskoff 1999; Paulson 2005), with Greater Yellowlegs often forming lines of conspecifics while doing this (Dunne 2006). Greater Yellowlegs are more apt to swim

while foraging than the smaller Lesser Yellowlegs; however, both species will forage while chest deep.

Lesser Yellowlegs are more gregarious than greater yellowlegs and often found in large flocks of conspecifics and various other shorebird species, especially dowitchers (*Limnodromus* spp.; pers. observ.). Both yellowlegs are very vocal; they combine vocalizations with a head-bobbing display when they feel threatened. Both yellowlegs commonly perch in trees (Dunne 2006) and may use these perches for preening (Elphick and Tibbits 1998; Tibbits and Moskoff 1999). They both sleep with their heads turned and bills tucked into their scapulars. Yellowlegs use typical preening behaviors and often stretch a wing and leg on one side simultaneously (Elphick and Tibbits 1998; Tibbits and Moskoff 1999).

STUDY AREA

Research was conducted on the Ernest F. Hollings ACE Basin National Wildlife Refuge (NWR) and the Nemours Wildlife Foundation (Nemours; Fig. 1.3) in Seabrook and Yemassee, Beaufort County, South Carolina (32°40'N, 80°43'W). The ACE Basin (141,640 ha), which encompasses the NWR and Nemours, and includes the Ashepoo, Combahee, and Edisto rivers, is one of the largest, relatively undeveloped estuaries on the East Coast and exceeds 40,468 ha of protected land (Tufford 2005). The ACE Basin was the flagship project of the Atlantic Coast Joint Venture of the North American Waterfowl Management Plan and is part of the "Lowcountry Initiative," a nationally important wetlands conservation and perpetual management effort (Williams *et al.* 1998). Established in 1990, the NWR encompasses 4,781 ha of diverse habitat, including 1,599

ha of tidal marsh and 1,214 ha of managed wetland impoundments. The remaining area is composed of upland forests, grasslands, and shrublands (USFWS 2005). The NWR is divided into 2 units – the Edisto Unit and Combahee Unit. I worked within the Bonny Hall subunit of the Combahee Unit. Bonny Hall (688 ha) is located south of the Combahee River and is north of the fresh water line, but the water is typically brackish to fresh (B. Woodward, USFWS, pers. comm.). Salinities within the impoundments and tidal marshes range from 0-5 ppt, except during drought. The American Bird Conservancy recognizes the NWR as a Globally Important Bird Area and the NWR has met the habitat protection goals of the North American Waterfowl Management Plan (Harrigal 2007).

Nemours is south of the Combahee Unit of the NWR and water is brackish to saline (5-30 ppt). Nemours, which is in private ownership, was established in 1995 by Eugene duPont III. A Board of Directors governs Nemours, with missions of land stewardship, scientific studies, and education. Nemours is 3,986 ha of diverse habitat including 748 ha of remnant ricefield impoundments, 124 ha of brackish and (artificial) freshwater marshes, upland pine and hardwood forests, bottomland hardwoods, and cypress (*Taxodium* sp.)/tupelo (*Nyssa* sp.) swamps.

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Figure 1.1. The flapgate and flashboards of a water control structure (ricefield trunk) used in impoundments managed for waterfowl. The trunk connects a managed impoundment to a natural water source such as a tidal river, or connects two impoundment compartment as shown here.

Figure 1.2. A water control structure (ricefield trunk) used in impoundments managed for waterfowl. To drain a managed impoundment, a manager opens the inside flap gate on the trunk to draw water out of the impoundment and into the natural water source, or between impoundment compartments as shown here.

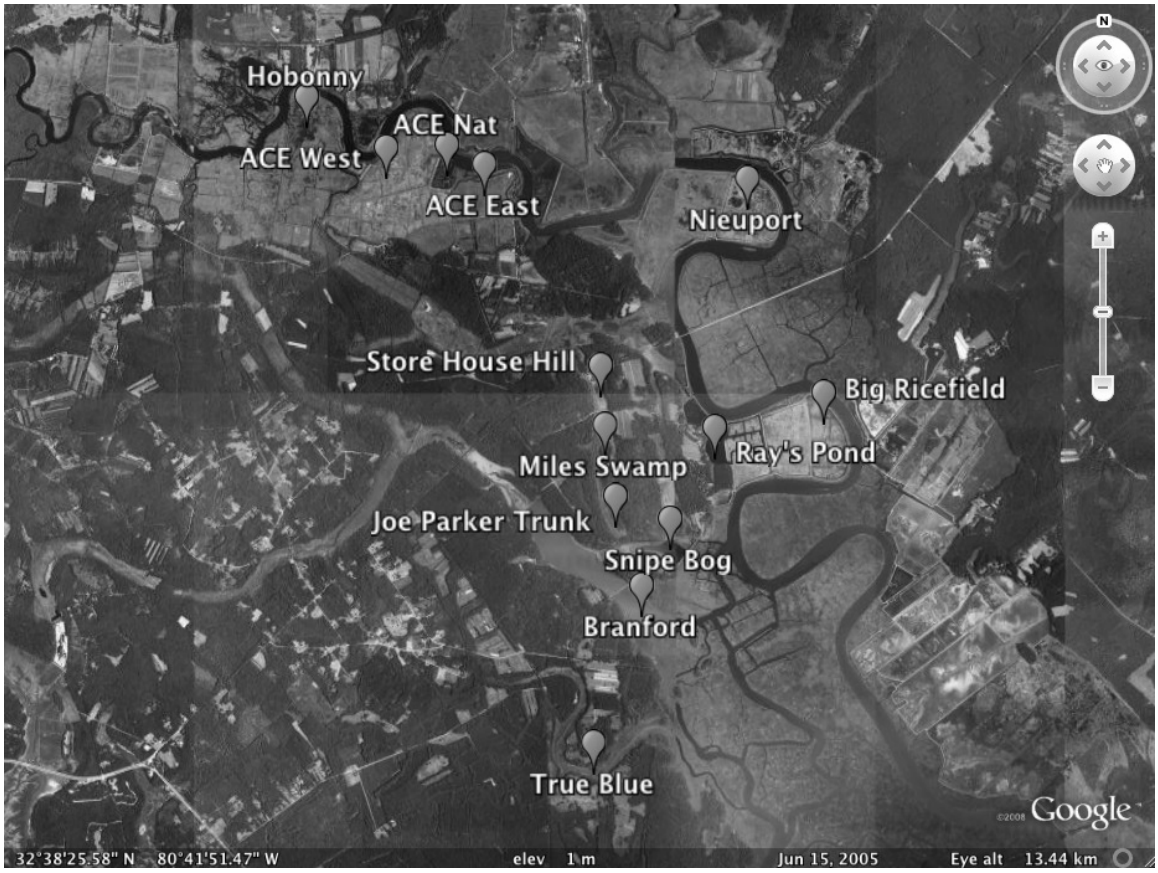

Figure 1.3. Satellite view (Google Earth 2008) of 13 experimental units used to investigate difference in abundance, time-activity budgets, and food habits of dabbling ducks and shorebirds in managed impoundments and tidal marshes. Units were located on the Ernest F. Hollings ACE Basin NWR and the Nemours Wildlife Foundation, Beaufort County, SC. Clockwise from top left corner, the NWR units are Hobonny to ACE East and Nemours units are Nieuport to True Blue.

CHAPTER 2

ABUNDANCE OF DABBLING DUCKS AND SHOREBIRDS IN MANAGED IMPOUNDMENTS AND TIDAL MARSHES OF COASTAL SOUTH CAROLINA[1]

[1] Nareff, G. E., S. H. Schweitzer, E. P. Wiggers, and W. E. Mills. 2009. To be submitted to *Southeastern Naturalist.*

ABSTRACT

As wetlands have declined in quality and quantity, wetland-dependent birds have faced loss of habitat attributes necessary for meeting their basic biological needs. We examined the contribution managed impoundments provided within a larger ecosystem and their provision of additional habitat for migratory shorebirds relative to declining natural, tidal wetlands. We surveyed birds within managed impoundments and tidal marshes adjacent to the Combahee River in the Ashepoo-Combahee-Edisto (ACE) Basin in southeastern South Carolina from January to mid-May in 2007 and 2008. Scan samples were used to estimate abundance of birds and to quantify bird use of the two habitat types. Specifically, our objectives were to: 1) compare abundance of dabbling ducks and shorebirds in managed impoundments and tidal marshes during winter and migration seasons, and 2) compare species composition of birds in managed impoundments during winter and migration seasons, during comparable tidal stages. We used Mann-Whitney U tests to detect differences in abundance of dabbling ducks or shorebirds between years, seasons, or within specific units between years. Dabbling ducks were always more abundant in managed impoundments than tidal marshes. Shorebirds were always more abundant in tidal marshes than managed impoundments. However, within impoundments, shorebird abundance during migration was greater in 2008 (17.30 ± 6.08) than in 2007 (1.18 ± 0.47; $P = 0.0004$).

Key Words

ACE Basin, *Anas crecca*, *Anas discors*, Dabbling ducks, Impoundment, Multi-species use, Shorebirds, South Carolina, Tidal marsh, Yellowlegs, Zero-inflated Poisson

INTRODUCTION

Coastal South Carolina is recognized as an important wintering and stopover site on the Atlantic Flyway for migratory waterfowl and shorebirds (Landers et al. 1976; Weber and Haig 1996). Coastal South Carolina also harbors numerous birds listed as species of concern, threatened, or endangered within the U.S. Fish and Wildlife Service's (USFWS) South Atlantic Migratory Bird Initiative (SAMBI), the U.S. Shorebird Conservation Plan (Brown et al. 2001), and the Western Hemisphere Shorebird Reserve Network Conservation Plan (Fernandez et al. 2006). To protect and increase these populations, managing all remaining requisite habitat to benefit diverse groups of birds with varying needs is critical. To manage impounded wetlands for multiple species, we must first know the birds' requirements for survival and maintenance.

There are 28,328 ha of managed impoundments in South Carolina, most left over from the rice culture of the Eighteenth and Nineteenth centuries (Williams 1987). Traditionally, remnant ricefield impoundments are managed for wintering waterfowl. Shorebirds may also benefit from impoundments if management focused on heterogeneity of habitat features and multi-purpose use rather than viewing waterfowl as a priority over other bird groups (Erwin 1986). Shorebirds are particularly at risk to habitat loss because they tend to concentrate at few sites at specific times and exhibit strong site fidelity (Weber and Haig 1996).

Our knowledge of basic functional processes (e.g., aquatic invertebrate community parameters, fish community composition and survival, water quality) in impoundments along coastal South Carolina is lacking (Tufford 2005). Knowledge of the role this habitat plays on a regional scale (e.g., refugia, stopover sites, wintering sites)

is insufficient to suggest how to change current management protocols (Tufford 2005). However, impoundments probably could provide additional habitat to numerous bird species, not only waterfowl. Prior research along the Atlantic Coast found that numerous shorebird species (e.g., Semipalmated Sandpiper [*Calidris pusilla*], Western Sandpiper [*C. mauri*], Long-billed Dowitcher [*Limnodromus scolopaceus*]) used impoundments more frequently than natural wetlands between January and July (Burger et al. 1982; Boettcher et al. 1995; Weber and Haig 1996). When waders, waterfowl, other water birds (e.g., Rallidae), shorebirds, larids, sparrows, swallows, and other species (i.e., hawks, corvids, passerines) were accounted for, Burger et al. (1982) determined that natural marshes in Barnegat Bay, New Jersey had less than half the number of species as impoundments; passerines were the only birds more abundant in natural marshes.

With a greater understanding of how and why these managed areas attract birds, especially relative to natural areas, we will be able to suggest new management schemes to increase abundance and diversity of wintering waterfowl and migrating shorebirds. An integrative shorebird-waterfowl management technique manipulates water levels, plant species composition, and percentage of cover provided by plants in impoundments for wintering waterfowl, and for shorebirds during spring migration, after wintering waterfowl leave for their breeding habitats (Joyner 1987; Weber 1994; Weber and Haig 1997b). The integrative technique can be used to increase biodiversity within one habitat type over a period of time and is possible in this situation because dabbling ducks and shorebirds have different peak migration periods.

We compared abundance of dabbling ducks and shorebirds between habitats, tides, and seasons to estimate the significance of managed impoundments to each bird

group. We expected dabbling ducks to be more abundant in managed impoundments than tidal marshes during winter when water levels were ≥20 cm. We expected shorebirds to be more abundant in tidal marshes than managed impoundments in winter, when water in impoundments would be too deep to accommodate them. Shorebirds would only be in tidal marshes during low tide because water during high tide would push them out of the habitat. In spring, water is drained from managed impoundments and we expected shorebird abundance to increase, especially during high tide when tidal marshes were inaccessible to them.

STUDY AREA

Research was conducted on the Ernest F. Hollings Ashepoo-Combahee-Edisto (ACE) Basin National Wildlife Refuge (NWR) and the Nemours Wildlife Foundation (Nemours; Fig. 2.1) in Yemassee and Seabrook, Beaufort County, South Carolina (32°40'N, 80°43'W). Both the NWR and Nemours are in the ACE Basin (141,640 ha), composed of the Ashepoo, Combahee, and Edisto River basins, one of the largest, relatively undeveloped estuaries on the East Coast with >40,468 ha of protected land (Tufford 2005). The ACE Basin was the flagship project of the Atlantic Coast Joint Venture of the North American Waterfowl Management Plan and is part of the "Lowcountry Initiative," a nationally important wetlands conservation and perpetual management effort (Williams et al.1998). Established in 1990, the NWR encompasses 4,781 ha of diverse habitat, including 1,599 ha of tidal marsh and 1,214 ha of managed wetland impoundments. The remaining area is composed of upland forests, grasslands, and shrublands (USFWS 2005). The NWR is divided into 2 units – the Edisto and Combahee Units. We worked within the Bonny Hall subunit of the Combahee Unit.

Bonny Hall (688 ha) is located south of the Combahee River and is north of the freshwater line, but the water is typically fresh to brackish (Woodward, USFWS, pers. comm.). Salinities within the impoundments and tidal marshes range from 0-5 ppt, except during drought. The American Bird Conservancy recognizes the NWR as a Globally Important Bird Area and the NWR has met the habitat protection goals of the North American Waterfowl Management Plan (Harrigal 2007).

Nemours is south of the Combahee Unit of the NWR and water is brackish to saline (5-30 ppt). Nemours, which is in private ownership, was established in 1995 by Eugene duPont III. A Board of Directors governs Nemours, with missions of land stewardship, scientific studies, and education. Nemours is 3,986 ha of diverse habitat including 748 ha of remnant ricefield impoundments, 124 ha of brackish and (artificial) freshwater marshes, upland pine and hardwood forests, bottomland hardwoods, and cypress (*Taxodium* sp.)-tupelo (*Nyssa* sp.) swamps (Nemours 2007).

Typical impoundment management involves rapidly decreasing water levels after ducks leave in late February by removing flashboard risers and opening ricefield trunks. The soil remains moist through the summer for germination of target food plants. The impoundments are burned in the fall to remove unwanted plants, release nutrients into the soil, make plant seeds available to birds, and create openings in the vegetation. The impoundments are flooded in October to prepare for the return of southbound ducks. Historically, management objectives are to make the habitat suitable for wintering duck populations without regard for other bird species.

Our study sites (experimental units) included managed impoundments and tidal marshes within the NWR and Nemours. Two impoundments were selected at the NWR

and two at Nemours; and two tidal marsh sites were selected at the NWR (one surveyed in 2007; two surveyed in 2008), and two at Nemours. Study sites were selected based on size (intending to select similarly-sized sites; Table 2.1), salinity (intending to select sites that represented fresh, brackish, and saline marsh), ease of access, vegetation structure, and presence of waterfowl and shorebirds. Numbers of sampling plots within each experimental unit differed because of each unit's size (Table 2.2).

The percentage of horizontal cover from vegetation within impoundments varied during the study because of prescribed burning, water level management, and weather. The approximate percentages of vegetation cover within impoundments in 2007 and 2008 (estimated from 2006 aerial photos, quality of recent prescribed burns, and our ability to see the plots while surveying) were: Nieuport, 60%; Big Ricefield, 70%; ACE West, 60%; and ACE East, 90% (70% in 2007). The two impoundments at the NWR were not burned in 2008 because of a moratorium on prescribed burning at NWRs (B. Woodward, USFWS, pers. comm.); therefore, the percentage of vegetative cover was high.

METHODS

Surveys. We used a modified form of scan sampling (Altmann 1974) to record birds present within the boundaries of each fixed-radius sampling plot. Centers of sampling plots were marked with bamboo poles, reflective tape, and orange flagging. Whenever possible, plot boundaries were natural and/or permanent boundaries (e.g., dikes, canals). For plots without permanent boundaries, plot lines were marked with flagging so birds outside the boundaries were not counted. The two larger impoundments (Table 2.1) contained plots with a 100-m radius and the two smaller impoundments contained plots with a 50-m radius. Three of the four tidal marshes were surveyed with

one plot each and sizes varied (Table 2.2); the fourth tidal marsh was divided equally into two sampling plots.

Surveys were conducted within 2 hours of dead low and peak high tides (i.e., from 1 hour before until 1 hour after), when shorebirds forage most actively (Weber 1994; Weber and Haig 1996; Burger et al. 1977; Weber and Haig 1997a). We did not conduct surveys before sunrise, after dusk, during rain, or on days with high wind to increase the probability of accurately detecting birds. Surveys were from blinds, dikes, or kayaks, depending on locations of sampling plots. A surveyor quietly approached a sampling plot and waited for 10 min before the survey began to allow birds to settle after potentially being disturbed and flushed by the approach of the surveyor. The surveyor used Swarovski 8x32 EL binoculars (Tyrol, Austria) and a Pentax 65-mm ED spotting scope with a 20-60x zoom lens (Tokyo, Japan) to scan the plot. Each bird seen or heard was counted once. Birds were identified to species level when possible (Burger et al. 1977; Bildstein et al. 1982; Breininger and Smith 1990; Page et al. 1999); otherwise they were sorted into pre-determined groups (e.g., dabbling ducks, yellowlegs, peeps, dowitchers). Scans were completed as quickly as possible to avoid double counting or under-counting birds that may have been moving. Time required per scan sample (1-10 min) varied with flock size. Once all birds in a plot were counted, the survey was considered complete. If birds were not present or there were very few birds present, the surveyor remained in the blind or kayak for a minimum 10 min to wait for birds that may have left during the pre-survey acclimation period. Surveys took place during winter (1 January-28 February [29 February 2008]) and migration (1 March-10 May). Each season, we surveyed each plot three times per high and low tides, for a total of six

surveys per plot in each season. We estimated the index of abundance by totaling all dabbling ducks and all shorebirds for each season and calculated the mean number of birds per year or season by managed impoundments and tidal marshes. We recorded distance from surveyor to each bird or flock of birds detected in 2008 but not 2007; hence, we report an index of abundance rather than an estimate. For each survey, we recorded temperature, estimated percentage of cloud cover, and wind speed using the Beaufort scale.

Statistical Analysis. Data were pooled over years and a binary code was used to differentiate between seasons, tides, habitats, presence or absence of avian predators, salinities, and categories of temperature, cloud cover, wind speed, and vegetation coverage (%). Avian predators observed and included in analyses were the Bald Eagle (*Haliaeetus leucocephalus*), Northern Harrier (*Circus cyaneus*), Red-tailed Hawk (*Buteo jamaicensis*), Great Horned Owl (*Bubo virginianus*), Merlin (*Falco columbarius*), Sharp-shinned Hawk (*Accipiter striatus*), and Cooper's Hawk (*Accipiter cooperii*). We evaluated a zero-inflated Poisson regression approach (ZIP; PROC NLMIXED; SAS Institute, Inc. 2002-2003) to detect differences in abundance (number of dabbling ducks or shorebirds) between impoundments and tidal marshes, based on season, tide, and habitat. We chose the ZIP because of its ability to account for the high number of zeros within our data. The Vuong test (Vuong 1989) suggested that our zero-inflated model was a significant improvement over a standard Poisson model. We used Akaike's Information Criteria with the small sample size bias adjustment (AIC_c) to explain the relative fit of each model candidate. We found these models were not predictive because of high delta (Δi) values (Tables 2.3 and 2.4). We formed new models with different

variables: temperature, cloud cover, wind speed, vegetation cover, salinity, and presence or absence of avian predators; however, these models were also not predictive because of high Δi values (Tables 2.5 and 2.6). Instead, we used Mann-Whitney U tests (PROC NPAR1WAY; SAS Institute, Inc. 2002-2003) to detect differences in indices of abundance of dabbling ducks or shorebirds between years, seasons, or within specific plots between years. The a priori level of significance was set to $\alpha = 0.05$ for all tests.

RESULTS

We detected 100 species during the course of the study. We counted 19,963 birds in 2007 and 28,936 birds in 2008 within our sample plots. Birds flying over plots were recorded but not included in the total species count or analysis. In 2007, dabbling ducks (ducks) accounted for 47%, shorebirds 17%, Rallidae 5.3%, and Ardeidae/Ciconiidae 1.3% of all individuals detected. In 2008, ducks accounted for 20%, shorebirds 25%, Rallidae 13%, and Ardeidae/Ciconiidae 8.9% of all individuals detected. Birds in the Family Rallidae were: Clapper Rail (*Rallus longirostris*), King Rail (*R. elegans*), sora (*Porzana carolina*), Common Moorhen (*Gallinula chloropus*), and American Coot (*Fulica americana*). Birds in the Families Ardeidae and Ciconiidae were: American Bittern (*Botaurus lentiginosus*), Great Blue Heron (*Ardea herodias*), Great Egret (*Ardea alba*), Snowy Egret (*Egretta thula*), Little Blue Heron (*E. caerulea*), Tricolored Heron (*E. tricolor*), Green Heron (*Butorides virescens*), Black-crowned Night-heron (*Nycticorax nycticorax*) and Wood Stork (*Mycteria americana*).

Dabbling ducks. We recorded 10 species of dabbling ducks over the two years. The index of abundance (abundance) for ducks during winter did not differ between years ($df = 1$, $P = 0.5093$; Table 2.7). During winter, abundance of ducks in impoundments did

not differ between years, and abundance in tidal marshes did not differ between years (Table 2.8). Fewer ducks were detected in plots during migration in 2007 (2.18 ± 1.11) than in 2008 (26.31 ± 12.66; df = 1, $P = 0.0006$; Table 2.7). During migration, ducks were more abundant within impoundments in 2008 (35.04 ± 17.10) than in 2007 (0.45 ± 0.12; df = 1, $P < 0.0001$; Table 2.9).

Shorebirds. We recorded 18 shorebird species, including one Ruff (*Philomachus pugnax*), a Eurasian species, and one nesting species, the Black-necked Stilt (*Himantopus mexicanus*). During winter, shorebird abundance in impoundments did not differ between years, and abundance in tidal marshes did not differ between years (Table 2.8). Fewer shorebirds were detected in plots during migration in 2007 (17.29 ± 7.43) than 2008 (31.46 ± 14.19; df = 1, $P = 0.0095$; Table 2.7). Shorebird abundance within impoundments during migration was greater in 2008 (17.30 ± 6.08) than in 2007 (1.18 ± 0.47; df = 1, $P = 0.0004$; Table 2.9). Specifically, shorebirds were more abundant on ACE West and Nieuport impoundments during migration in 2008 (29.96 ± 10.31) than 2007 (0.54 ± 0.259; df = 1, $P < 0.0001$).

DISCUSSION

A study in South Carolina (Gordon et al. 1989) found that the occurrence of Mallard (*Anas platyrhynchos*), Green-winged Teal, and Northern Pintail (*Anas acuta*) was greater than expected in managed impoundments and lower than expected in natural marshes. Further, they found that the abundance of Northern Pintail, Green-winged Teal, American Wigeon (*Anas americana*), Northern Shoveler (*Anas clypeata*), Mallard, and American Black Duck (*Anas rubripes*) were positively correlated with habitats that were managed for Smooth Cordgrass (*Spartina alterniflora*) and Black Needlerush (*Juncus*

roemerianus). At the Edwin B. Forsythe NWR in Atlantic County, New Jersey, ducks used managed impoundments rather than tidal marshes for staging, feeding, or loafing (Burger et al. 1982). Our data for dabbling ducks are consistent with these results and support our hypotheses. Impoundments within our study sites were managed specifically for wintering waterfowl and successfully attracted these birds; hence, we assume impoundments provided food, cover, and loafing sites needed by waterfowl for overwinter survival.

Management schemes were different among managed impoundments and between years, likely affecting the abundance of ducks detected. In 2007, the dike around ACE East was failing and the water was drawn down immediately to facilitate repair. It was not re-flooded and did not provide any habitat for ducks or shorebirds, except for the canal surrounding the impoundment bed. Prescribed burning, an important component of managing these wetlands for waterfowl, was not possible within two experimental units (ACE West and ACE East) in 2008 because of a burn ban at all NWRs (B. Woodward, USFWS, pers. comm.). Although not statistically significant ($df = 1$, $P = 0.7486$), there was a noticeable decrease in the abundance of ducks wintering on ACE West in 2008 (112.45 ± 28.21 birds per survey) from 2007 (359.83 ± 175.35 birds per survey), but what caused the decrease, aside from an increase in vegetation cover was not clear. ACE West did not have problems with the dike and had less vegetation than ACE East in 2007, so the lack of fire in 2008 was likely not as detrimental to ACE West. Additional explanations for the decrease in abundance of wintering ducks, include a difference in species using the plot (see below), hence differences in what the managed impoundment offered for food and cover, disturbance from an increase in road

construction in the area, or a normal shift in the wintering population. Tufford (2005) suggested short-stopping during migration might be one reason for a decrease in wintering ducks in coastal South Carolina over the last 15-20 years. However, the lack of fire in 2008, and the subsequent increase in vegetation on this unit caused a decrease in available open water and may have influenced the choice in managed impoundments.

Teal were the most abundant dabbling ducks within our plots in 2008; in 2007, the most abundant duck species was Northern Pintail. Although some studies have concluded that Northern Pintails exhibit high fidelity to wintering sites (Cox Jr. 1998; Hestbeck 1993), we did not see a single Northern Pintail in 2008. Northern Pintails start to leave wintering grounds in January and northward migration is heaviest in February (Austin and Miller 1995). Green-winged Teal may linger on their wintering grounds until April (Johnson 1995) and Blue-winged Teal are among the latest migrants in the spring (Rohwer et al. 2002). The abundance of teal in 2008 was likely the reason dabbling duck abundance during migration was greater than in 2007.

As expected, shorebirds were more abundant on tidal marshes than impoundments during winter. Water in impoundments during winter may be ≥45 cm, depending on the target species within Anseriformes (Williams et al. 1998). Most shorebird species require water levels between sheet water and 15 cm (Elphick and Oring 1998; Isola et al. 2000; Rundle and Frederickson 1981; Weber and Haig 1996). Our results are consistent with Weber (1994), who found that shorebird numbers on tidal marshes peaked in February.

When water levels in managed impoundments are drawn down in early spring, shorebirds can forage independent of tidal cycles. We expected shorebirds to use managed impoundments more abundantly during high tide than low tide, but there was no

difference in abundances between tides (df = 1, $P = 0.8510$). Shorebird abundance in managed impoundments during migration increased from 2007 (1.18 ± 0.47) to 2008 (17.30 ± 6.08; Table 2.9). Although shorebird abundance in managed impoundments was not greater than abundance in tidal marshes, we believe their use of impoundments and the increase in abundance in this habitat between 2007 and 2008 are biologically important. With improved management of impoundments, we expect shorebirds numbers to continue to increase, especially during high tide. Prior research found that several shorebird species prefer managed impoundments to natural wetlands (Boettcher et al. 1995; Burger et al. 1982; Weber and Haig 1996). Researchers concluded that shorebirds selected managed impoundments because of reliable prey availability and consistent water levels (Boettcher et al. 1995; Tufford 2005). Because managed impoundments are not open to twice-daily tides, water is not circulated regularly and they likely accumulate sediments and organic content (Weber and Haig 1996). Weber (1994) and Weber and Haig (1996) found that detritus-rich managed impoundments attracted more prey (i.e., macroinvertebrates) and thus more shorebirds than natural marsh areas. Further, Boettcher et al. (1995) suggested that a lack of daily tides reduced competition between large and small shorebirds because the two groups will forage in appropriate water depths within an impoundment and not overlap. Hence, shorebird density and absolute numbers were significantly higher on managed impoundments than tidal marshes, even at low tide (Weber 1994), which is consistent with our results of a greater abundance of shorebirds on managed impoundments during low tide.

As with the dabbling ducks, each managed impoundment did not attract shorebirds equally. Three of four impoundments were managed appropriately for

shorebirds in spring 2008 (Big Ricefield, ACE West, and Nieuport). The problems associated with management at ACE East have been described above. Although the percent vegetation cover in Big Ricefield was not substantially greater than ACE West and Nieuport (approximately 70% vs. 60%), it was more evenly distributed in Big Ricefield, which left fewer openings available to foraging or roosting shorebirds than ACE West and Nieuport. Patchy distribution of vegetation (and hence spots burns) is important in creating habitat that meets the needs of wintering or migrating shorebirds.

We detected that shorebirds were more abundant within ACE West and Nieuport impoundments during migration in 2008 (29.96 ± 10.31) than in 2007 (0.54 ± 0.259). These two managed impoundments were drawn down slowly in 2008 instead of a rapid, relatively uncontrolled draw down, which was conducted in 2007 on both plots. Even though ACE West was not burned in 2008, vegetation cover remained near 60% and there were pockets of open sheet water and mud available to foraging shorebirds. Gradual drawdowns are more effective than rapid ones because new mudflats are continuously exposed and the availability of prey to shorebirds is extended (Rundle and Fredrickson 1981). Intensive feeding by shorebirds rapidly reduces prey abundance or biomass (Weber and Haig 1997a) so, slow draw downs that gradually expose more of the bed and leave sheet water to ensure invertebrate persistence should be beneficial to and attract more shorebirds.

An interspersion of water depths also accommodates a diversity of bird species with differing bill and leg lengths (Isola et al. 2000; Taft et al. 2002; Weber and Haig 1996; Weber and Haig 1997a); access to foraging habitat by shorebirds is positively related to the length of their tarsometatarsus (Collazo et al. 2002). Most of the shorebirds

on ACE West were yellowlegs while Nieuport supported a variety of shorebirds from the smallest peeps, Least Sandpipers (*Calidris minutilla*), to yellowlegs and dowitchers, and the long-legged Black-necked Stilts, which also nested at Nieuport.

Nocturnal surveys were not possible without the proper equipment (i.e., night vision scopes), but would have been beneficial for a clearer understanding of abundance of birds on managed impoundments and tidal marshes after dark. We witnessed hundreds of ducks flying into the plots at sunset, apparently to roost for the night. We were not able to count these birds and did not survey after dark. We know that shorebirds are active at night (Andrei et al. 2007), perhaps even more active at night than during the day (Robert et al. 1989). Shorebirds may exhibit a habitat shift at night in reaction to nocturnal prey items (Erwin et al. 1994). We witnessed feeding bouts on Branford on nights with a full or nearly full moon (i.e., when night vision scopes were not needed). These were casual observations, not surveys and other plots were not observed after dark.

Impoundments in coastal South Carolina are currently managed primarily for wintering waterfowl and hunting opportunities. If managed to meet the water depth and foraging needs of shorebirds, these impoundments can be additional habitat in areas where natural habitat is decreasing in quality and quantity or during high tide when shorebirds are pushed out of tidal marshes. In general, dabbling ducks and shorebirds have different peak migration times hence impoundments can be managed appropriately for both groups at different times. Shorebirds were more abundant on our plots during winter than migration. If a manager has flexibility and is not pressured to maximize waterfowl hunting opportunities, setting aside some impoundments for wintering shorebirds may be appropriate. We are confident that with more consistent prescribed

burns, slower drawdowns, and holding water on impoundments through mid-May, shorebird abundance on impoundments will increase.

ACKNOWLEDGEMENTS

This study was made possible by funds from the National Fish and Wildlife Foundation and the Nemours Wildlife Foundation. Nemours provided housing and equipment. The USFWS and Hobonny Plantation provided access to field sites. R. Klimstra, J. Hollis, and D. Barrineau provided field assistance, and J. T. Peterson, C. A. Jennings, and S. Ellis-Felege assisted with statistical analysis.

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Figure 2.1. Satellite view (Google Earth 2008) of eight experimental units used to investigate differences in abundance of dabbling ducks and shorebirds between managed impoundments and tidal marshes. Units were located on the Ernest F. Hollings ACE Basin NWR and the Nemours Wildlife Foundation, Beaufort County, SC. Clockwise from top left corner, the NWR units are Hobonny to ACE East and Nemours units are Nieuport to True Blue.

Table 2.1. Experimental design of investigation into the value to birds of managed impoundments and tidal marsh, Combahee River basin, Beaufort County, South Carolina, 2007-2008. The number in parentheses is the size in hectares of each experimental unit.

Experimental Units			
Managed impoundments		Tidal marshes	
NWR[1]	Nemours[2]	NWR	Nemours
ACE West (174.46 ha)	Nieuport (119.83 ha)	ACE Natural (<1 ha)	True Blue (8.66 ha)
ACE East (55.93 ha)	Big Ricefield (48.16 ha)	Hobonny (50 ha)	Branford (34.88 ha)

[1]NWR = Ernest F. Hollings ACE Basin National Wildlife Refuge

[2]Nemours = Nemours Wildlife Foundation

Table 2.2. Experimental design of investigation into the value to birds of managed impoundments and tidal marsh, Combahee River basin, Beaufort County, South Carolina, 2007-2008. The number in parentheses is the number of sampling plots in each experimental unit.

Experimental Units			
Managed impoundments		Tidal marshes	
NWR[1]	Nemours[2]	NWR	Nemours
ACE West (4)	Nieuport (4)	ACE Natural (1)	True Blue (1)
ACE East (3)	Big Ricefield (3)	Hobonny (1)	Branford (2)

[1]NWR = Ernest F. Hollings ACE Basin National Wildlife Refuge

[2]Nemours = Nemours Wildlife Foundation

Table 2.3. Model candidates estimating dabbling duck abundance in managed impoundments and tidal marshes during winter and migration in 2007 and 2008 at the Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, SC. Included are number of parameters (K), Akaike Information Criterion values (AIC), small sample size bias adjustment AIC (AICc), difference in AIC from the best fitting model (Δi), and AIC weights for each candidate model (Wi). The best supporting candidate model has the highest Akaike weight.

Model Candidate	K	AIC	AICc	Δi	Wi[3]
MGMT + WIN + TIDE + MGMT*WIN + MGMT*WIN*TIDE + YEAR[1,2]	7	48598	48599	0.00	1.00
MGMT + WIN + TIDE + MGMT*WIN + MGMT*WIN*TIDE	6	50064	50065	1486	0.00
MGMT + WIN + TIDE + MGMT*WIN + YEAR	6	50421	50241	1642	0.00
MGMT + WIN + TIDE + MGMT*TIDE + YEAR	6	50685	50686	2087	0.00

[1]MGMT = managed impoundment or tidal marsh; WIN = winter or migration season; TIDE = high tide or low tide; YEAR = 2007 or 2008

[2]All models follow a zero-inflated Poisson distribution

[3]Akaike weights are interpreted as relative plausibility of candidate models

Table 2.4. Model candidates estimating shorebird abundance in managed impoundments and tidal marshes during winter and migration in 2007 and 2008 at the Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, SC. Included are number of parameters (K), Akaike Information Criterion values (AIC), small sample size bias adjustment AIC (AICc), difference in AIC from the best fitting model (Δi), and AIC weights for each candidate model (Wi). The best supporting candidate model has the highest Akaike weight.

Model Candidate	K	AIC	AICc	Δi	Wi[3]
MGMT + WIN + TIDE + MGMT*WIN + MGMT*WIN*TIDE + YEAR[1,2]	7	18022	18023	0.00	1.00
MGMT + WIN + TIDE + MGMT*WIN + YEAR	6	18042	18043	20	0.00
MGMT + WIN + TIDE + MGMT*TIDE + YEAR	6	18241	18242	219	0.00
MGMT + WIN + TIDE + MGMT*WIN + MGMT*WIN*TIDE	6	18929	18930	907	0.00

[1]MGMT = managed impoundment or tidal marsh; WIN = winter or migration season; TIDE = high tide or low tide; YEAR = 2007 or 2008

[2]All models follow a zero-inflated Poisson distribution

[3]Akaike weights are interpreted as relative plausibility of candidate models

Table 2.5. Model candidates estimating dabbling duck abundance in managed impoundments and tidal marshes during winter and migration in 2007 and 2008 at the Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, SC. Included are number of parameters (K), Akaike Information Criterion values (AIC), small sample size bias adjustment AIC (AICc), difference in AIC from the best fitting model (Δi), and AIC weights for each candidate model (Wi). The best supporting candidate model has the highest Akaike weight.

Model Candidate	K	AIC	AICc	Δi	Wi[3]
VEG + TEMP + CLOUD + WIND + SAL + HAWK[1,2]	7	42537	42538	0.00	1.00
VEG + TEMP + CLOUD + WIND + SAL	6	43400	43400	862	0.00
VEG + TEMP*CLOUD*WIND + SAL	4	50220	50220	7682	0.00
VEG + SAL	3	50659	50660	8122	0.00
VEG + TEMP*CLOUD*WIND + SAL + HAWK	5	51719	51719	9181	0.00

[1]VEG = vegetation cover estimated to be 0-19%, 20-39%, 40-59%, or 60-100%; TEMP = <-1.1, -1.1-3.9, 4.4-9.4, 10-20.6, ≥21.1 C; CLOUD = 0-24%, 25-49%, 5-74%, 75-100%; WIND = 0, 1, 2, 3, 4 on the Beaufort scale; SAL = above the freshwater line or below the freshwater line; HAWK = presence or absence of avian predator

[2]All models follow a zero-inflated Poisson distribution

[3]Akaike weights are interpreted as relative plausibility of candidate models

Table 2.6. Model candidates estimating shorebird abundance in managed impoundments and tidal marshes during winter and migration in 2007 and 2008 at the Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, SC. Included are number of parameters (K), Akaike Information Criterion values (AIC), small sample size bias adjustment AIC (AICc), difference in AIC from the best fitting model (Δi), and AIC weights for each candidate model (Wi). The best supporting candidate model has the highest Akaike weight.

Model Candidate	K	AIC	AICc	Δi	Wi
VEG + TEMP + CLOUD + WIND + SAL + HAWK	7	14416	14417	0.00	0.92
VEG + TEMP + CLOUD + WIND + SAL	6	14421	14422	5.00	0.08
VEG + TEMP*CLOUD*WIND + SAL + HAWK	5	14570	14570	153	0.00
VEG + TEMP*CLOUD*WIND + SAL	4	14582	14582	165	0.00
VEG + SAL	3	14582	14582	165	0.00

[1]VEG = vegetation cover estimated to be 0-19%, 20-39%, 40-59%, or 60-100%; TEMP = <-1.1, -1.1-3.9, 4.4-9.4, 10-20.6, ≥21.1 C; CLOUD = 0-24%, 25-49%, 5-74%, 75-100%; WIND = 0, 1, 2, 3, 4 on the Beaufort scale; SAL = above the freshwater line or below the freshwater line; HAWK = presence or absence of avian predator

[2]All models follow a zero-inflated Poisson distribution

[3]Akaike weights are interpreted as relative plausibility of candidate models

Table 2.7. Indices of abundance for dabbling ducks and shorebirds sorted by season (winter and migration) and year (2007 and 2008) within managed impoundments and natural marshes at the Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, SC. Each sampling plot was surveyed six times per season.

Bird group	Season	Year	Mean # of birds/survey	Standard error	*P*-value[1]
Dabbling ducks	Winter	2007	84.04	41.06	
		2008	24.10	7.25	0.5093
	Migration	2007	2.18	1.11	
		2008	26.31	12.66	0.0006
Shorebirds	Winter	2007	14.17	7.10	
		2008	31.46	14.19	0.8116
	Migration	2007	17.29	7.43	
		2008	30.89	13.77	0.0095

[1]If $P \leq 0.05$, then indices of abundance were different between years for either dabbling ducks or shorebirds, within season. A Mann-Whitney U test (PROC NPAR1WAY; SAS Institute, Inc. 2002-2003) was used to detect differences.

Table 2.8. Dabbling duck and shorebird abundance in managed impoundments and tidal marshes during winter 2007 and 2008 at the Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, SC. Each sampling plot was surveyed six times during winter.

Bird group	Year	Habitat	Mean # of birds/survey	Standard error	*P*-value[1]
Dabbling ducks	2007	Impoundment	107.93	52.56	
	2008	Impoundment	32.67	9.68	0.8604
	2007	Tidal marsh	0.42	0.24	
	2008	Tidal marsh	0.07	0.07	0.1990
Shorebirds	2007	Impoundment	0.44	0.25	
	2008	Impoundment	0.24	0.13	0.7852
	2007	Tidal marsh	62.21	30.44	
	2008	Tidal marsh	118.87	51.20	0.8295

[1]If $P \leq 0.05$, then indices of abundance were different between years for either dabbling ducks or shorebirds, within habitat. A Mann-Whitney U test (PROC NPAR1WAY; SAS Institute, Inc. 2002-2003) was used to detect differences.

Table 2.9. Dabbling duck and shorebird abundance in managed impoundments and tidal marshes during migration 2007 and 2008 at the Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, SC. Each sampling plot was surveyed six times during migration.

Bird group	Year	Habitat	Mean # of birds/survey	Standard error	*P*-value[1]
Dabbling ducks	2007	Impoundment	0.45	0.12	
	2008	Impoundment	35.04	17.10	<0.0001
	2007	Tidal marsh	8.21	4.85	
	2008	Tidal marsh	1.87	1.67	0.4361
Shorebirds	2007	Impoundment	1.18	0.47	
	2008	Impoundment	17.30	6.08	0.0004
	2007	Tidal marsh	73.67	31.22	
	2008	Tidal marsh	68.93	49.42	0.4805

[1]If $P \leq 0.05$, then indices of abundance were different between years for either dabbling ducks or shorebirds, within habitat. A Mann-Whitney U test (PROC NPAR1WAY; SAS Institute, Inc. 2002-2003) was used to detect differences.

CHAPTER 3

TIME-ACTIVITY BUDGETS OF TEAL AND YELLOWLEGS IN MANAGED IMPOUNDMENTS AND ADJACENT TIDAL MARSHES[1]

[1] Nareff, G. E., S. H. Schweitzer, E. P. Wiggers, and W. E. Mills. 2009. To be submitted to *Waterbirds.*

ABSTRACT

Managed impoundments may provide additional habitat to wintering and migrating waterfowl (Anseriformes) and shorebirds (Charadriiformes) in areas where natural habitat has been degraded or lost. Classifying how these birds allocate their time on managed impoundments can provide information necessary for appropriate modifications to make impoundments available as quality habitat. Diurnal time-activity budget data were used to understand the habitat requirements of wintering and migrating Blue-winged Teal (*Anas discors*), Green-winged Teal (*A. crecca*), Greater Yellowlegs (*Tringa melanoleuca*), and Lesser Yellowlegs (*T. flavipes*) in coastal South Carolina and to determine if focal species used managed impoundments differently than tidal marshes. Data were collected on five managed impoundments and two tidal marshes during winter and spring, 2007 and 2008. When birds were present in managed impoundments and tidal marshes, we expected them to forage and loaf most frequently. To detect differences among proportions of observations in behavior categories among species or between habitats, teal species, yellowlegs species, or sexes, we used a Kruskal-Wallis test or Mann-Whitney U tests, respectively. In both habitats, the most frequent behavior of all four species was foraging (41-87%). Loafing ($df = 1$, $P = 0.0146$), alert ($df = 1$, $P = 0.0035$), and agonistic behaviors ($df = 1$, $P = 0.0165$) were more frequent on managed impoundments; foraging was more frequent on tidal marshes ($df = 1$, $P < 0.0001$).

Key Words

ACE Basin, *Anas crecca*, *Anas discors*, Dabbling ducks, Impoundment, Shorebirds, South Carolina, Tidal marsh, Time-activity budget, *Tringa flavipes*, *Tringa melanoleuca*, Yellowlegs

INTRODUCTION

From the mid-1950s to the 1970s, the United States lost 185,000 ha of wetlands annually (Frayer *et al.* 1983). By 1997, the annual loss was reduced to 23,700 ha (Dahl 2005). Although wetland loss has slowed, the quality of remaining wetlands may be poor. Migratory birds face challenging conditions within a changing landscape; wetland habitat they may have used in previous years may no longer be available. Wildlife biologists and land managers have responsibilities as land stewards to mitigate wetland loss by managing remaining habitat to meet the needs of these birds. Eleven percent of the remaining 500,000 ha of marshes along the Atlantic Coast of the southeastern U.S. is diked and managed, and 60% of these marshes are in South Carolina (Montague *et al.* 1987). Most of these impoundments are managed for wintering waterfowl with moist-soil management techniques that keep impoundments in an early successional stage, a stage in which plants preferred by wintering waterfowl grow well (Montague *et al*. 1987; Tufford 2005). Early successional plant species tend to produce abundant seed resources and support a diverse group of invertebrates (Williams *et al.* 1998), the primary foods of dabbling ducks. The primary goals of managing impoundments for wintering waterfowl are to increase food, cover, and open areas (Williams *et al*. 1998); managers typically aim for 50:50 vegetation-to-open water ratio.

However, impoundments also may provide breeding, foraging, and roosting habitat for shorebirds (Hunter 2000). When water levels in impoundments are drawn down in the spring to a constant shallow depth, shorebirds may forage within them without heed to tidal cycles. Weber and Haig (1996) found that shorebirds were more concentrated in managed impoundments at high tide than in tidal marshes at low tide. If

water levels in impoundments are amenable to seasonal needs of shorebirds, impoundments could supplement tidal wetlands, thereby increasing the quality and quantity of wetlands available to shorebirds in areas where much wetland area has been filled or degraded significantly (Weber 1994; Boettcher *et al*. 1995; Weber and Haig 1997).

Time-activity budgets provide information on how birds allot time to different behaviors in their daily cycle. They are useful in assessments of ecological, behavioral, and physiological adaptations of bird species to external factors (Quinlan and Baldassarre 1984). These data also provide information used to guide management decisions. Specifically, if we manage wintering and stopover habitats optimally, birds will improve their body condition at these sites, and increase the probability of higher reproductive rates on breeding grounds. Improving management of habitat considered supplemental to natural habitat, such as providing good winter and stopover habitat on impoundments, could reduce or reverse declining trends in shorebird populations.

The four focal species in our study were the Blue-winged Teal (*Anas discors*), Geen-winged Teal (*A. crecca*), Greater Yellowlegs (*Tringa melanoleuca*), and Lesser Yellowlegs (*T. flavipes*). These species are dependent on shallow water wetlands and are common wintering and migratory species in coastal South Carolina. They are representative of similar species using similar habitat, and they use an array of foraging behaviors (Elphick 2000). These four species frequently use the same habitat simultaneously; hence, we could learn how and when they use the habitat while avoiding direct competition for resources, and how management activities affect use of the habitat. Previous research in other areas suggests that species will select different food items,

different sizes of the same food items, or forage at different times to avoid direct conflict, or engage in defense of resources thereby engaging in direct competition (e.g., Baker and Baker 1973; Rave and Baldassarre 1989; Hepworth and Hamilton 1991). We conducted TABs to understand how these four species use managed impoundments in comparison to tidal marshes so we can implement appropriate impoundment management and make them accessible and useable by a variety of wetland-dependent bird species. We expected all four species to use managed impoundments and tidal marshes most frequently for foraging and loafing.

STUDY AREA

Research was conducted on the Ernest F. Hollings Ashepoo-Combahee-Edisto (ACE) Basin National Wildlife Refuge (NWR) and the Nemours Wildlife Foundation (Nemours; Fig. 3.1) in Yemassee and Seabrook, Beaufort County, South Carolina (32°40'N, 80°43'W). Both the NWR and Nemours are in the ACE Basin (141,640 ha), composed of the Ashepoo, Combahee, and Edisto River basins, one of the largest, relatively undeveloped estuaries on the East Coast with >40,468 ha of protected land (Tufford 2005). The ACE Basin was the flagship project of the Atlantic Coast Joint Venture of the North American Waterfowl Management Plan and is part of the "Lowcountry Initiative," a nationally important wetlands conservation and perpetual management effort (Williams *et al.* 1998). Established in 1990, the NWR encompasses 4,781 ha of diverse habitat, including 1,599 ha of tidal marsh and 1,214 ha of managed wetland impoundments. The remaining area is composed of upland forests, grasslands, and shrublands (USFWS 2005). The NWR is divided into 2 units – the Edisto and Combahee Units. We worked within the Bonny Hall subunit of the Combahee Unit.

Bonny Hall (688 ha) is located south of the Combahee River and is north of the freshwater line, but the water is typically fresh to brackish (Woodward, USFWS, pers. comm.). Salinities within the impoundments and tidal marshes range from 0-5 ppt, except during drought. The American Bird Conservancy recognizes the NWR as a Globally Important Bird Area and the NWR has met the habitat protection goals of the North American Waterfowl Management Plan (Harrigal 2007).

Nemours is south of the Combahee Unit of the NWR and water is brackish to saline (5-30 ppt). Nemours, which is in private ownership, was established in 1995 by Eugene duPont III. A Board of Directors governs Nemours, with missions of land stewardship, scientific studies, and education. Nemours is 3,986 ha of diverse habitat including 748 ha of remnant ricefield impoundments, 124 ha of brackish and (artificial) freshwater marshes, upland pine and hardwood forests, bottomland hardwoods, and cypress (*Taxodium* sp.)/tupelo (*Nyssa* sp.) swamps. We collected time-activity budget data on two freshwater impoundments, three brackish impoundments, and two brackish tidal marshes, all on Nemours property.

METHODS

Data for diurnal time-activity budgets (TAB) were collected using instantaneous sampling methodology (Altmann 1974) during winter and spring. Winter was from 1 January -28 February (29 February in 2008) and spring was from 1 March - 10 May, based on wintering and migration chronology (Johnson 1995; Elphick and Tibbits 1998; Tibbits and Moskoff 1999; Rohwer *et al*. 2002; O'Brien *et al*. 2006). Categories of behavioral activities were based on Hohman and Rave (1990): *loaf* — inactive or

sleeping; *alert* — vigilant with head off shoulders; *locomotion* — walking, swimming (not in pursuit of food), or flying; *agonistic* — threats or aggressive interactions with other birds; *preen* — behavior associated with body maintenance; and *foraging* — behavior associated with food search, capture, and handling. Data for TABs were collected on the four focal species within managed impoundments and tidal marshes within our experimental units from one hour before peak high or dead low tides to one hour after (Bellrose 1976; Burger *et al*. 1977; Weber 1994; Weber and Haig 1996; Weber and Haig 1997). Our data collection was timed relative to tidal cycles because wildlife activities on tidally influenced habitat revolve around the tides, not necessarily relative to time of day.

If there were ≤5 focal birds on a plot, we obtained a time-activity budget on all birds. If >5 birds were present, we started with the bird farthest to the left and recorded data on as many birds' TABs within a flock as possible without repeating individual birds. Shorebirds tended to be spread out and not in tight flocks; TAB were possible on most yellowlegs on a plot at one time. When ≥50 teal were in a flock, we started at the left and recorded TABs on as many birds as possible without repeating individuals, and then moved to the right and randomly chose sub-groups to sample within the larger flock. If there was any uncertainty whether a bird had already been sampled, the sampling concluded within that flock. A focal bird was observed for 5 min or until it was out of view, whichever came first. Using a clock on a digital recorder, focal birds' behaviors were noted every 20 sec during the 5-min sampling period (Paulus 1984; Morton *et al.* 1989; Johnson and Rohwer 2000; Adams *et al.* 2000). Hence, there were 15 instantaneous observations of behavior of a focal bird in each 5-min sampling period.

Activities were recorded on a Sony ICD-8300 handheld digital recorder (Tokyo, Japan) and later downloaded to MS Excel (Microsoft Corporation, Redmond, WA).

We divided the number of instantaneous observations for each behavior category by the total number of observations to get proportion of observations allocated to each behavior category. These data were pooled over species and sorted by species within managed impoundments and tidal marshes. The proportion of observations allocated to each behavior was arcsine square root transformed before analysis (Rave and Baldassarre 1989; Hepworth and Hamilton 2001; McKinney and McWilliams 2005). To detect differences among proportions of observations in behavior categories among species, we used a Kruskal-Wallis test (PROC NPARIWAY; SAS Institute, Inc. 2002-2003). To detect differences among proportions of observations in behavior categories between habitats, teal species, yellowlegs species, or sexes, we used a Mann-Whitney U test (PROC NPARIWAY; SAS Institute, Inc. 2002-2003). The a priori level of significance was set to $\alpha = 0.05$ for all tests. Behavior categories (loaf, alert, locomotion, agonistic, feed, and preen) were the dependent variables because time spent in one behavior affected time spent in other behaviors (Davis and Smith 1998; De Leon and Smith 1999).

RESULTS

We estimated 164 TABs from all species from five managed impoundments and two tidal marshes, but 143 TABs were analyzed statistically. The 21 TABs not analyzed lasted <5 min and therefore, did not provide adequate numbers of observations for our model. After data were pooled over focal species and habitat, we detected that within managed impoundments (n = 46 birds' TABs), foraging (43%) and loafing (20%)

behaviors were most frequent, followed by alert (13%), locomotion (15%), preening (8%), and agonistic (<1%) behaviors. Loafing (df = 1, $P = 0.0146$), alert (df = 1, $P = 0.0035$), and agonistic behaviors (df = 1, $P = 0.0165$) were more frequent on managed impoundments. Within tidal marshes (n = 97 birds's TABs), foraging (72%) was the most common behavior, followed by locomotion (17%), alert (6%), preening (3%), loafing (<1%), and agonistic (<1%) behaviors. Feeding was more frequent on tidal marshes (df = 1, $P < 0.0001$). Blue-winged Teal were more frequently alert than other species (df = 3, $P < 0.0001$). Greater Yellowlegs walked, swam, or flew more frequently than other species (df = 3, $P < 0.0001$). Green-winged Teal foraged more frequently than other species (df = 3, $P < 0.0001$).

Blue-winged Teal (n = 9) were only detected within managed impoundments and during high tide. The behavior detected most frequently was foraging (44%), followed by alert (22%), loafing (14%), preening (10%), locomotion (9%), and agonistic (<1%) behaviors (Fig. 3.2). Six males and three females were observed; a Mann-Whitney U test determined frequencies of behaviors did not differ between sexes.

Green-winged Teal TABs were examined almost exclusively within tidal marshes (n = 54 vs. n = 1 within managed impoundments) and during low tide (the one detection of Green-winged Teal within managed impoundments was during low tide). Within tidal marshes, the most frequent behavior of Green-winged Teal was foraging (87%) followed by locomotion (8%), alert (3%), preening (2%), and loafing (<1%) behaviors (Fig. 3.3). Nineteen females and 37 males were observed; a Mann-Whitney U test determined frequencies of behaviors did not differ between sexes.

Greater Yellowlegs were observed within managed impoundments (n = 11) and tidal marshes (n = 22). The most frequently recorded behavior of Greater Yellowlegs within managed impoundments was foraging (49%); other behaviors were loafing (27%), locomotion (14%), alert (5%), preening (4%), and agonistic (1%) behaviors (Fig. 3.4). Greater Yellowlegs within tidal marshes were foraging (42%) and locomotion (40%) most frequently; otherwise they were alert (10%), preening (7%), or in agonistic (<1%) behaviors (Fig. 3.5). Locomotion (df = 1, $P = 0.0018$) and loafing (df = 1, $P = 0.0127$) were more frequent within managed impoundments; other behaviors were not different between habitats.

Lesser Yellowlegs were detected within managed impoundments (n = 25) and tidal marshes (n = 21). Within managed impoundments, the most frequently observed behavior was foraging (41%), followed by loafing (19%), locomotion (14%), alert (14%), preening (1%), and agonistic (1%) behaviors (Fig. 3.6). Lesser Yellowlegs within tidal marshes were most frequently observed foraging (65%), followed by locomotion (19%), alert (10%), loafing (3%), and preening (3%) behaviors (Fig. 3.7). Lesser Yellowlegs foraged more frequently within tidal marshes (df = 1, $P = 0.0018$); other behaviors were not different between habitats.

DISCUSSION

Understanding how birds use a particular habitat is important to manage it appropriately. Our objective was to understand how teal and yellowlegs used managed impoundments and tidal marshes and if the two groups used the habitats differently. We expected all birds to use managed impoundments and tidal marshes most frequently for

foraging and loafing. Data for Green-winged Teal (Fig. 3.3) and yellowlegs on managed impoundments (Fig. 3.4 and 3.6) supported this hypothesis. Wintering and migrating birds used these sites; their primary needs were to survive the winter and prepare for migration and nesting by improving body condition. Using their time for foraging and loafing would be an efficient way to conserve energy, survive the winter, and prepare for migration and nesting.

Blue-winged Teal were most frequently alert (22%) when not foraging (Fig. 3.2). Nemours and the Combahee River are hunted and the Blue-winged Teal may have felt the need to stay alert. Time spent alert most likely is related to flock size. Two and five of the Blue-winged Teal were in flocks of 13 and 31 birds, respectively. We do not have flock-size data for the remaining two birds but they were located on a small impoundment (Snipe Bog) that rarely had large flocks of waterfowl (pers. observ.). Flocks of 13 and 31 birds are not particularly large; and not surprisingly birds within them were frequently alert – presumably watching for predators or paired males looking out for unpaired males that would attempt to copulate with their females. Although alert was a common behavior and may have been because of males protecting females, frequency of occurrence of alert behavior did not between sexes ($df = 1$, $P = 0.2311$).

Both yellowlegs species most frequently walked, flew, or swam on tidal marshes when not foraging (Fig. 3.5 and 3.7). TAB categories differentiate between locomotion associated with foraging and locomotion to change location or escape a threat. Because tidal marshes are influenced by fluctuating water levels, prey may be spread out across a large area, whereas in managed impoundments with constant water depths, prey may be concentrated within microhabitats. Although a bird chasing prey would not be

categorized as walking, a bird walking or flying between feeding bouts would be recorded under the locomotion category. Our tidal marsh plots had ≤20% vegetation cover and hence less cover to escape from predators. Yellowlegs may have had to move around more frequently in the open areas to feel safe. Bald Eagles (*Haliaeetus leucocephalus*) were the only avian predators detected on the tidal marsh plots and these birds are not likely predators of yellowlegs. A more likely explanation for the frequency of locomotion on tidal marshes is competition between shorebirds for space and feeding locations. There were often ≥200 shorebirds on Branford at one time and these birds were likely competing for similar food resources or at least feeding spots. Shorebirds can deplete prey (Weber 1997; Weber and Haig 1997) and will move from spot to spot to avoid competitive exclusion and depleting a resource (Burger 1977).

Although loafing was not different by species (df = 3, $P = 0.1933$), it was more frequent on impoundments (df = 1, $P = 0.0146$) and yellowlegs were frequently encountered sleeping on Nieuport. Dowitchers (*Limnodromus* sp.) were also frequently observed sleeping (pers. observ.). We believe impoundments during migration season provided a safe habitat for shorebirds to forage in open areas, but also loaf among the vegetation, which provides safety through horizontal structure. The presence of nesting Black-necked Stilts (*Himantopus mexicanus*) within impoundments is also evidence of the protective capacity of these habitat structures.

Analyses were limited by sample size, vegetation density (i.e., ability to see the birds in impoundments), and the birds' fear of surveyors. Nemours and the Combahee River are hunted and we found that the birds were sensitive to human disturbance. Observations of birds within impoundments were often >100 m and observing them

through vegetation or without mixing up one individual with another was difficult. We could not compare Blue-winged Teal activities between managed impoundments and tidal marshes because they were rarely found in the latter. Green-winged Teal were found in managed impoundments but observing them for the above reasons was very difficult. We were able to get numerous time-activity budgets for Green-winged Teal on the Branford Unit (Fig. 3.1) because it is an open mudflat at low tide. Mudflats are very important to Green-winged Teal (Rave and Baldassarre 1989) and they may have used these plots preferentially. Larger sample sizes and further analysis would be beneficial to determine if teal use managed impoundments and tidal marshes differently. Taller and more secretive blinds than those used in the current project, arriving on the plots prior to sunrise, and more productive prescribed burns would have aided in refraining from flushing birds, decreasing vegetation, and thus conducting more TABs.

Nocturnal time-activity budgets were not possible without the proper equipment (i.e., night vision scopes), but would have been appropriate for a better understanding of how these birds apportion behaviors throughout their 24-hour daily cycle. Behaviors during daylight hours are not independent of what the birds are doing after dark. Any activities at night will affect the amount of time spent in subsequent activities during the day (Davis and Smith 1998) and diurnal time-activity budgets should not be extrapolated to the entire daily cycle of the bird (Andrei *et al.* 2007). We observed hundreds of ducks flying into the plots at sunset, apparently to roost for the night, although ducks actively feed at night when predation pressure is lessened and thermoregulation requirements may be greater than during daylight hours (Paulus 1984; Robert *et al.* 1989). We were not able to count these birds and did not survey after dark.

We know that shorebirds are active at night (Andrei *et al.* 2007), perhaps even more active at night than during the day (Robert *et al.* 1989). Feeding at night may be related to a decrease in active predators, lower temperatures and thus higher energy requirements, and taking advantage of nocturnal prey (Robert *et al.* 1989; Erwin *et al.* 1994). Robert *et al.* (1989) proposed that nocturnal feeding may also be related to limited space and time as tides restrict foraging times. If this were true, shorebirds would be expected to forage at night during low tide. We witnessed feeding bouts on Branford on nights with a full or nearly full moon (i.e., when night vision scopes were not needed). These were not surveys, but casual observations and other plots were not observed after dark. Without knowing what the shorebirds are foraging on in both habitats, we cannot predict a habitat shift in response to nocturnal prey.

Wintering and stopover habitat should be managed to satisfy the dietary needs of a diverse group of birds and should consist of areas appropriate for loafing safely. Water levels within impoundments should be drawn down to between sheet water and 15 cm during migration to concentrate prey and provide foraging habitat for shorebirds. Staggering drawdowns throughout the migration season would open new foraging sites late in the season to compensate for possible prey depletion. Waterfowl and shorebirds benefit from an interspersion of vegetation and open water or mudflats, which provide areas for foraging and loafing simultaneously.

ACKNOWLEDGEMENTS

This study was made possible by funds from the National Fish and Wildlife Foundation and the Nemours Wildlife Foundation. Nemours provided housing and

equipment. The USFWS and Hobonny Plantation provided access to field sites. R. Klimstra, J. Hollis, and D. Barrineau provided field assistance.

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Figure 3.1. Satellite view (Google Earth 2008) of seven experimental units from which we collected time-activity budget data of dabbling ducks and shorebirds. Units were located on the Ernest F. Hollings ACE Basin NWR and Nemours Wildlife Foundation, Beaufort County, SC. Clockwise from top left corner, the NWR unit is ACE West and Nemours units are Nieuport to True Blue. Branford and True Blue are tidal marshes, other units are managed impoundments.

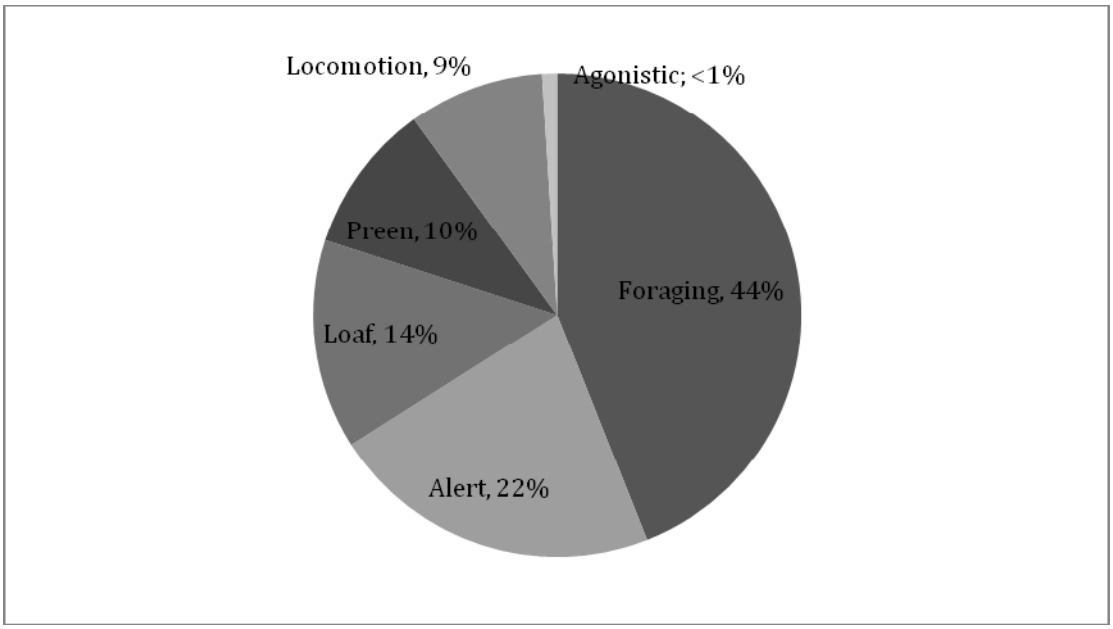

Figure 3.2. Frequency of occurrence of behaviors by Blue-winged Teal (n = 9) within managed impoundments at the Ernest F. Hollings ACE Basin NWR and Nemours Wildlife Foundation, Beaufort County, SC. Blue-winged Teal foraged more frequently than any other behavior and when not foraging, were most frequently alert.

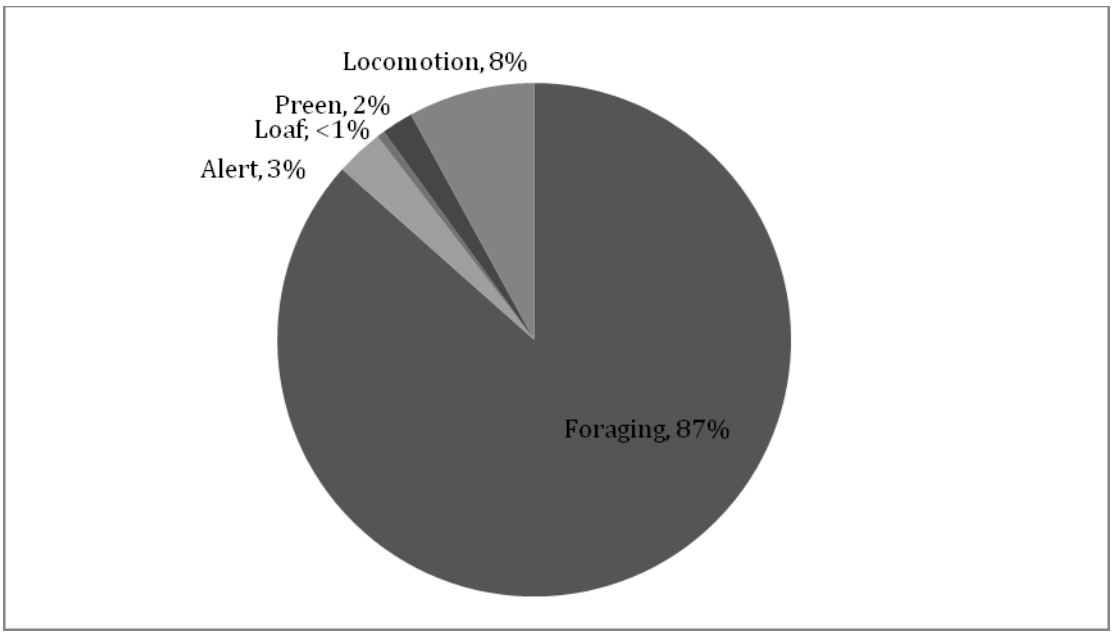

Figure 3.3. Frequency of occurrence of each behavior by Green-winged Teal (n = 54) within tidal marshes at the Nemours Wildlife Foundation, Seabrook, Beaufort County, SC. Green-winged Teal foraged more frequently than any other behavior and when not foraging, were most frequently loafing.

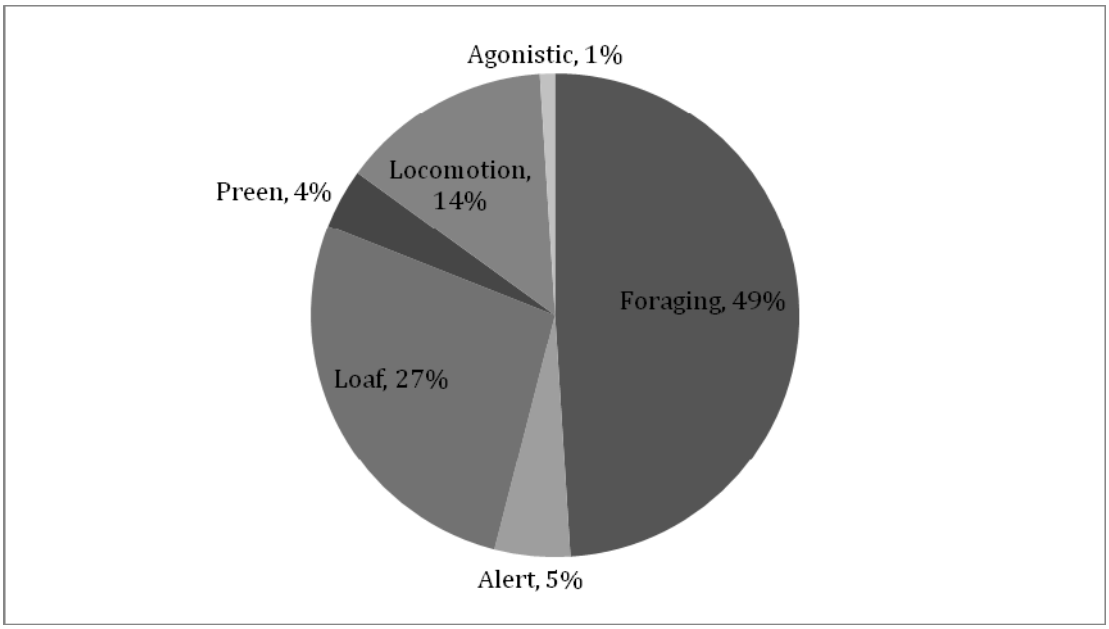

Figure 3.4. Frequency of occurrence of behaviors by Greater Yellowlegs (n = 11) within managed impoundments at the Ernest F. Hollings ACE Basin NWR and Nemours Wildlife Foundation, Beaufort County, SC. Greater Yellowlegs foraged more frequently than any other behavior and when not foraging, were most frequently loafing.

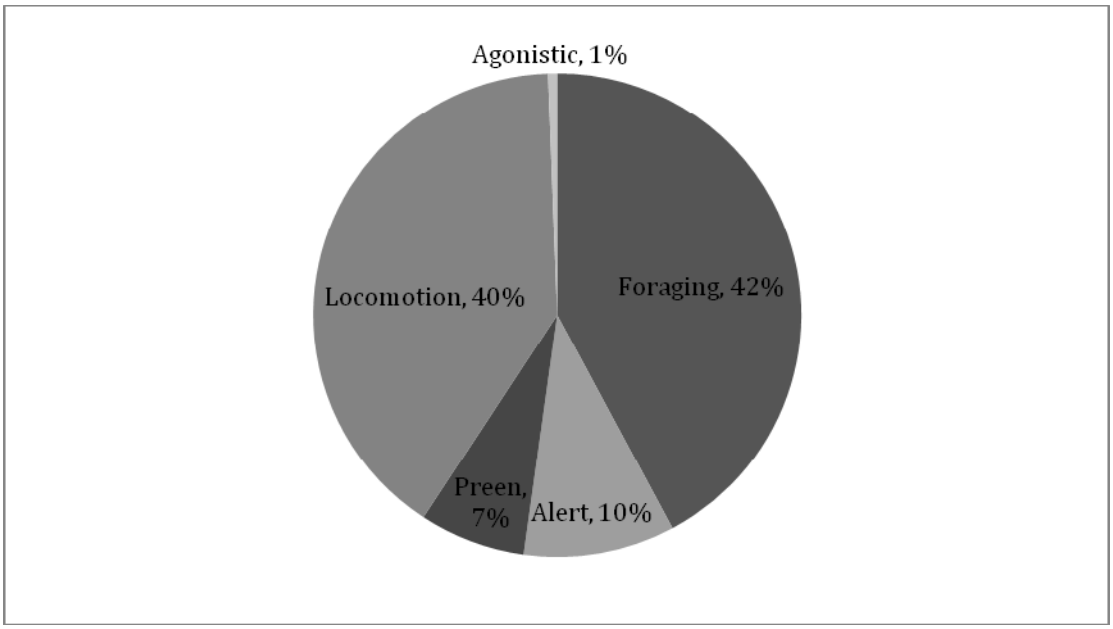

Figure 3.5. Frequency of occurrence of behaviors by Greater Yellowlegs (n = 22) within tidal marshes at the Nemours Wildlife Foundation, Seabrook, Beaufort County, SC. Greater Yellowlegs foraged more frequently than any other behavior and when not foraging, were most frequently walking, flying, or swimming.

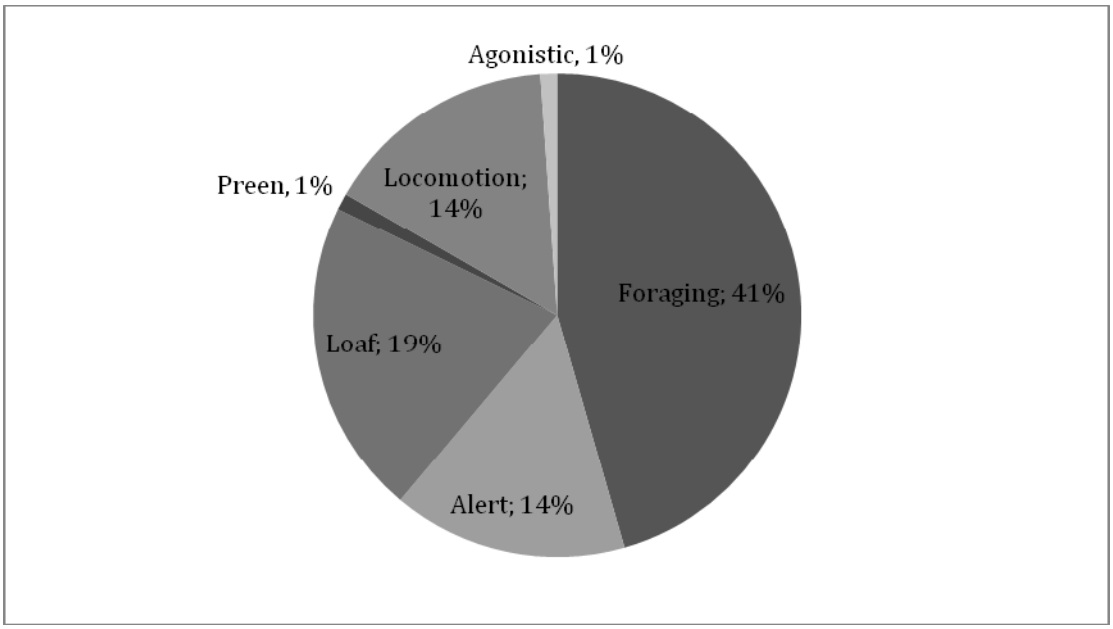

Figure 3.6. Frequency of occurrence of behaviors by Lesser Yellowlegs (n = 25) within managed impoundments at the Ernest F. Hollings ACE Basin NWR and Nemours Wildlife Foundation, Beaufort County, SC. Lesser Yellowlegs foraged more frequently than any other behavior and when not foraging, were most frequently loafing.

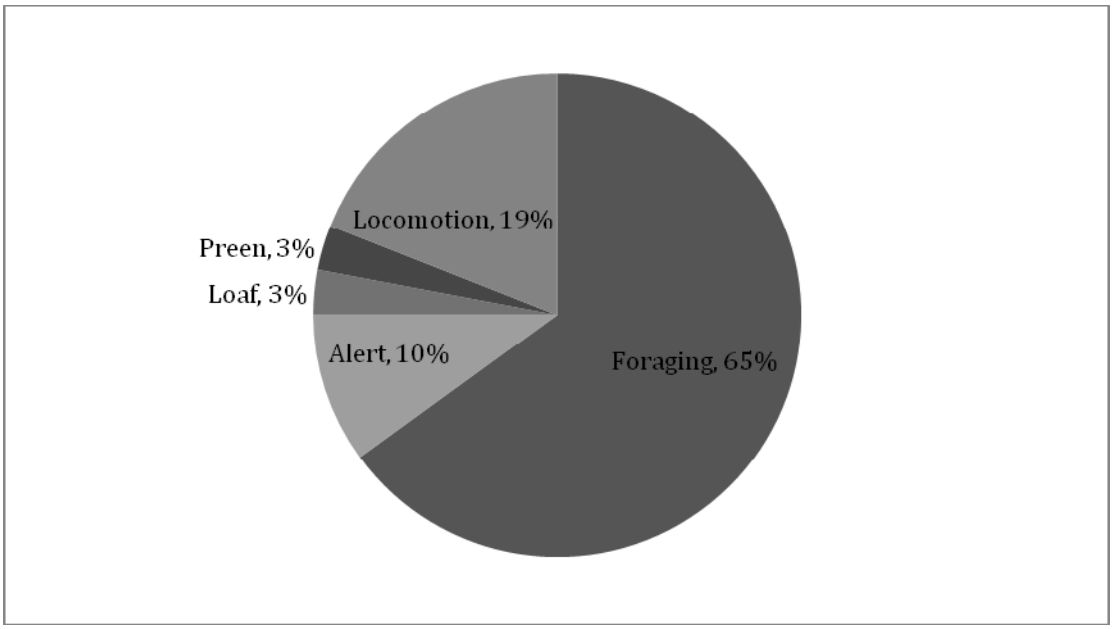

Figure 3.7. Frequency of occurrence of behaviors by Lesser Yellowlegs (n = 21) within tidal marshes at the Nemours Wildlife Foundation, Beaufort County, SC. Lesser Yellowlegs foraged more frequently than any other behavior and when not foraging, were most frequently walking, flying, or swimming.

CHAPTER 4

FOOD HABITS OF TEAL AND YELLOWLEGS IN MANAGED COASTAL IMPOUNDMENTS OF THE SOUTH ATLANTIC[1]

[1] Nareff, G. E., S. H. Schweitzer, J. Pike, E. P. Wiggers, and W. E. Mills. 2009. To be submitted to *Waterbirds.*

ABSTRACT

Understanding wildlife diets enables land managers to manipulate habitat and provide seasonal necessities for target species, thereby attracting and maintaining wildlife on managed land. We examined diets of Blue-winged Teal (*Anas discors*), Green-winged Teal (*A. crecca*), Greater Yellowlegs (*Tringa melanoleuca*), and Lesser Yellowlegs (*T. flavipes*) that were feeding in managed impoundments within the Ashepoo-Combahee-Edisto (ACE) Basin of South Carolina. Foraging sites used by teal and yellowlegs are similar, thus we hypothesized that they avoid foraging competition by selecting different food items. We expected that seeds and invertebrates would be the primary food items for teal and yellowlegs, respectively. We collected a sample of teal and yellowlegs and examined the esophagus, gizzard, and their contents from each bird. We obtained aggregate percentages of numbers of invertebrates and seeds consumed by teal, yellowlegs, and individual species. We used Mann-Whitney U tests to detect differences between percentages of food items selected by teal and yellowlegs, between food contents of esophagi and gizzards, and between food selected by Blue-winged and Green-winged Teal. Teal consumed more seeds ($df = 1$, $P = 0.0097$) than yellowlegs. Percentages of food contents did not differ between esophagi and gizzards from teal and yellowlegs ($df = 1$, $P = 0.4593$).

Key Words

ACE Basin, *Anas crecca*, *Anas discors*, Dabbling ducks, Food habits, Impoundment, Shorebirds, South Carolina, Tidal marsh, *Tringa flavipes*, *Tringa melanoleuca*, Yellowlegs

INTRODUCTION

The loss and modification of wetlands have changed seasonal habitats used by many bird species; thus, foraging opportunities for wetland-dependent birds have changed significantly (Gruenhagen and Fredrickson 1990). To manage remaining natural wetlands and human-made impoundments as habitats for birds, information is needed on how birds use these areas throughout their annual cycle, including use of, and competition for food resources (Gruenhagen and Fredrickson 1990).

Impoundments are recognized as important to shorebirds for breeding, foraging, and roosting (Hunter 2000). Prior research found that some shorebirds prefer impoundments to natural wetlands (Burger *et al.* 1982; Boettcher *et al.* 1995; Weber and Haig 1996). Researchers concluded that shorebirds selected impoundments because of reliable prey availability and consistent water levels (Boettcher *et al.* 1995; Tufford 2005). When impoundments are drawn down in the spring, shorebirds are able to forage independent of tidal cycles. If managed appropriately, impoundments can be supplemental habitat for shorebirds in areas where natural habitat is decreasing in quality and quantity (Weber 1994; Boettcher *et al.* 1995; Weber and Haig 1997b).

Because impoundments are not open to natural tidal flow, water is not circulated regularly so they are likely to have more accumulation of sediments and organic content than natural marshes (Weber and Haig 1996). Further, Weber (1994) and Weber and Haig (1996) found that detritus-rich impoundments attracted more prey and thus more shorebirds than natural marsh areas. Hence, shorebird abundance and density were significantly higher in impoundments (Weber 1994). At the Savannah National Wildlife

Refuge, Savannah, Georgia, avian abundance was lowest in natural wetlands when compared to impoundments (Graves 2001).

We selected four focal species for our study: Blue-winged Teal (*Anas discors*), Green-winged Teal (*A. crecca*), Greater Yellowlegs (*Tringa melanoleuca*), and Lesser Yellowlegs (*T. flavipes*). These species are dependent on shallow water wetlands and are common wintering and migratory species in coastal South Carolina.

Greater and Lesser Yellowlegs forage on flooded fields, coastal marshes, mud flats, pond edges, vernal ponds, lakeshores, river bottoms, and tidal creeks (Dunne 2006; O'Brien *et al.* 2006); both are highly active foragers. They have good diurnal vision (Rojas De Azuaje *et al.* 1993) and forage visually during daylight. Both species forage in shallow water, typically between 2 and 15 cm (Rundle and Frederickson 1981; Weber and Haig 1996; Elphick and Oring 1998). Greater Yellowlegs are often seen plowing forward with their bill or head under water, presumably chasing fish (pers. observ.). They also chase and stab aggressively at items on the surface of mud or water. Lesser Yellowlegs can also be aggressive, but less so than Greater Yellowlegs. Lesser Yellowlegs are often seen picking at the surface of mud or water, rather than stabbing and jabbing (Dunne 2006). Both species use a side-sweeping bill motion attributed to tactile feeding (Elphick and Tibbits 1998; Tibbits and Moskoff 1999), and Greater Yellowlegs often form lines of conspecifics while tactile feeding (Dunne 2006). Lesser Yellowlegs are more gregarious while foraging than are Greater Yellowlegs. In addition, Greater Yellowlegs are more apt to swim while foraging than the smaller Lesser Yellowlegs, however both species will forage while chest deep.

Informative and complete diet studies require collection and necropsy of birds, in addition to observations of feeding birds (Rundle 1982). Identifying prey items of shorebirds, particularly smaller shorebirds, simply by observing them forage is nearly impossible. Stomach pumps (Duffy and Jackson 1986) and other forms of stomach flushing (Tsipoura and Burger 1999) are available, but we chose collection of entire birds and necropsy for this study. We presumed collection by shooting would be more efficient than live capture and examination. Our study sites were characterized by soft soil sediments (pluff mud) and homogeneous or hemi-marsh grasses, making the use of common trapping techniques (e.g., mist nets, cannon nets) impractical. Teal were particularly weary of humans because of hunting pressure, thus very difficult to capture. Because the four focal species were abundant, we concluded that collecting a small number of them would not affect their local or global populations; however, every effort was made to maximize information collected from them and minimize number of kills (Duffy and Jackson 1986).

Gizzards of teal are almost entirely muscle, whereas those of yellowlegs have a larger cavity, with less muscle (Fig. 4.1), and this difference reflects the species' diet. A small gizzard is related to diets composed of relatively soft items (e.g., fly larvae, midge larvae); large, muscular gizzards are related to tough-skinned prey, fibrous plant material, and seeds that require a lot of grinding (Piersma *et al.* 1993). Shorebird and waterfowl gizzards change size and mass throughout the year, depending on migratory and reproductive status and seasonal changes in diet (Paulus 1982; Drobney 1984; Whyte and Bolen 1985; Piersma *et al.* 1993).

Waterfowl food habits studies began in the early Twentieth century (Baldassarre and Bolen 2006) and examined food contents in gizzards and esophagi combined. They took place almost exclusively during fall and winter (Baldassarre and Bolen 2006), so foods selected at other times of the year were not known. Because 95% of 125 food habit studies conducted from 1901 through 1965 were based entirely or partially on food materials from the gizzard or stomach, they likely were biased toward hard-to-digest food items such as seeds (Bartonek 1968); hence, the importance of invertebrates in the diet of waterfowl was missed in early studies. In addition, immediate use of preservatives was not a common practice in early food habits studies; rather, freezing birds, without using preservatives was common (Paulus 1982; Whyte and Bolen 1985; Brennen *et al.* 1990). Without the use of a preservative, post-mortem digestion occurred and further biased food content data (Swanson and Bartonek 1970; Rundle 1892; Duffy and Jackson 1986). To properly manage for a species and understand its feeding ecology, we must understand their basic biological needs throughout their annual cycle (i.e., migration, nesting, wintering) using unbiased methods.

The purposes of this study were to (1) identify food items selected by focal bird species; (2) estimate percentages of categories of food items selected by teal and yellowlegs; (3) compare diet selection of teal and yellowlegs; and (4) provide suggestions for future management and research to provide better understanding of the ecology of this impoundment–tidal marsh system. Based on previous studies elsewhere on these bird species (Brooks 1967; Swanson and Bartonek 1970; Swanson *et al.* 1974; Landers *et al.* 1976; Baker 1977; Rundle 1982), we expected that the diet of teal would be mostly seeds and some invertebrates and that the diet of yellowlegs would be composed primarily of

invertebrates. Because these species share similar foraging habitat without expressing aggression towards one another, they seem to have partitioned the habitat by selecting different food items, different sizes of the same items, or different life stages of the same invertebrate species. Alternatively, food items may be so abundant and accessible in the managed impoundments that there is no need for competition and aggressive behavior.

STUDY AREA

Birds were collected from the Nemours Wildlife Foundation (Nemours), Seabrook, Beaufort County, South Carolina (32°40'N, 80°43'W). Nemours is 3,986-ha of diverse habitat including 748 ha of remnant ricefield impoundments, 124 ha of brackish and freshwater marshes, upland pine and hardwood forests, bottomland hardwoods, and cypress (*Taxodium* sp.)-tupelo (*Nyssa* sp.) swamps (Nemours 2007). The Combahee River borders the impoundment complex, providing the natural water source when floodgates are open. Nemours is approximately 13 km from the mouth of the River and the water ranges from fresh to saline (0-30 ppt). Impoundments at Nemours were managed for wintering waterfowl through moist-soil management (see Williams *et al.* 1998 for detailed descriptions). Impoundments were typically managed to provide a 50:50 vegetation-to-open-water ratio and target plant species included Widgeongrass (*Ruppia maritima*) and Saltmarsh Bulrush (*Scirpus robustus*).

METHODS

We collected 21 teal and 31 yellowlegs on five managed impoundments from January to May 2007 and 2008 (Fig. 4.2; Federal Permit # MB139730-0; South Carolina Permit # 65-2006; UGA IACUC Permit # A2006-10162-0). To ensure birds had food in their upper digestive tracts, and that food was from the habitat of interest, we observed

feeding birds for ≥10 min before collection (Swanson and Bartonek 1970; Rundle 1982; Jorde *et al.* 1983; Duffy and Jackson 1986; Brennan *et al*. 1990; Gruenhagen and Fredrickson 1990). Birds were shot with steel shot and either a Remington 870 Express 12-gauge shotgun or a Mossberg 500 12-gauge shotgun. Care was taken to aim at the birds in a way to cause immediate death, but to leave the digestive tract intact. Birds were not collected from tidal marshes because of our inability to access them while following protocol (i.e., because of the soft substrate, we could not observe birds for ≥10 minutes, shoot them, and then get to them quickly to inject preservative). Also, Blue-winged Teal were rarely observed within tidal marshes.

All of the following methods required use of medical latex gloves and were done in a well-ventilated area. To preserve the contents of the esophagus, immediately after dispatch, a disposable medical syringe was used to inject 3-6 ml of 10% formalin solution into the esophagus (Baker 1977). In 2008, 80% ethanol was used as the preservative (Swanson and Bartonek 1970; Fritzell *et al*. 1979). Ethanol, although flammable, is safer, less offensive, and easier to obtain than formalin (Pike, Clemson University, pers. comm.). The preservative was injected slowly to avoid overflowing the esophagus and spilling the food contents. The amount of preservative forced into the esophagus depended on the size of the bird and the amount of food in it. Before any dissection, whole birds were frozen until they could be processed to remove the digestive tracts.

Once the sample was complete, birds were thawed and the esophagus and gizzard were removed but kept intact and placed in glass jars filled with the preservative used in the field. Jars were refrigerated until processing to identify contents.

Contents of the esophagus and gizzard were kept separate. Each esophagus and gizzard was removed from the jar of preservative and rinsed with tap water over a 500-micron sieve. Contents from each esophagus and gizzard were placed in a white photo tray with 2.5-cm sides and tap water. We used a fluorescent illuminated magnifier with a 1.25x, 13-cm circular viewing area, and straight forceps with 0.1-mm x 0.06-mm tips to sort items. Plant seeds and invertebrates (whole or pieces) were placed in vials of 80% ethanol labeled with waterproof paper and an alcohol pen; labels were inserted into each vial. Identifications were to the lowest taxonomic level possible using up to 75x magnification on a dissecting scope, or up to 1000x magnification on a compound microscope. Early instar larvae and damaged organisms were identified to the lowest taxonomic level possible and noted on the bench data sheet (Moulton *et al*. 2000). Organisms that could not be identified to a species level were assigned a "sp." designation. Organisms within the phylum Arthropoda concluded at the Class level, and those within the phylum Gastropoda concluded at the Family level.

Food items were sorted by plant and animal material, and by taxon; data were summed for all birds, by teal and yellowlegs, and by teal species. We calculated aggregate percentages of food items by summing the number of items for all birds, groups of birds, or species, and dividing each by the total number of food items consumed within each category. Data did not meet the assumptions of normality, even after percentages were arcsine square root transformed. A Mann-Whitney U test (PROC NPAR1WAY; SAS Institute, Inc. 2002-2003) was used to detect differences in percentages of invertebrates and seeds between teal and yellowlegs, between teal species, and

between esophagus and gizzard contents. The a priori level of significance was set to $\alpha = 0.05$ for all tests.

RESULTS

We collected 21 teal and 31 yellowlegs over the 2 years of the study. The birds represented four species – 7 Blue-winged Teal, 14 Green-winged Teal, 3 Greater Yellowlegs, and 28 Lesser Yellowlegs. Two Greater Yellowlegs and one Lesser Yellowlegs could not be used because the steel shot punctured their digestive tracts. Both teal and yellowlegs consumed invertebrates and seeds. Sixteen food items were identified in the esophagi of teal and yellowlegs: 10 types of invertebrates, and seeds from six plants; teal and yellowlegs both consumed five of the same invertebrates and one of the same seeds (Table 4.1). Gizzards contained four types of invertebrates and one seed that were not found in the esophagi (Table 4.2), but percentages of food items did not differ between the esophagi and gizzards of teal and yellowlegs combined ($df = 1$, $P = 0.4593$).

One Blue-winged Teal had 2435 items in its esophagus (Fig. 4.3), which was 2191 items more than all other birds combined. When including this bird in analysis, there was not a significant difference ($df = 1$, $P = 0.9749$) between percentages of invertebrates consumed by teal and yellowlegs; however, teal consumed a greater percentage of seeds ($df = 1$, $P = 0.0088$) than yellowlegs. There was no significant difference between the percentage of invertebrates ($df = 1$, $P = 0.1858$) or seeds ($df = 1$, $P = 0.5738$) consumed by Blue-winged and Green-winged Teal. We believed the Blue-winged Teal with 2435 items in its esophagus was a highly unusual situation and this bird was removed for the following statistical analyses; by removing this bird, the number of

different invertebrates encountered in esophagi decreased to nine and plants decreased to five.

Teal consumed 10 types of invertebrates (20%) and six types of seeds (80%). Teal consumed a greater percentage of seeds (df = 1, $P = 0.0097$) than yellowlegs, but there was not a significant difference (df = 1, $P = 0.8118$) between percentages of invertebrates consumed by teal and yellowlegs. Green-winged Teal consumed more invertebrates (df = 1, $P = 0.0112$) than Blue-winged Teal but percentages of seeds consumed by the two species did not differ (df = 1, $P = 0.4673$). The most common invertebrate selected by teal was *Chironomus* sp. and the most common seed was *Ruppia maritima* (Table 4.3). Six teal (30%) did not have any food items in their esophagus and were not included in statistical analysis.

Yellowlegs consumed seven types of invertebrates (98%) and only one individual consumed a seed (2%). The most common invertebrate selected by yellowlegs was *Chironomus* sp. and the only seed consumed by yellowlegs was *Ruppia maritima* (Table 4.4). Ten yellowlegs (36%) did not have any food items in their esophagus and were not included in statistical analysis.

DISCUSSION

Understanding how birds partition resources and knowing what they consume enhance our management of habitat. We were able to improve our understanding of how four species of wetland-obligate birds use managed impoundments to satisfy food requirements and why they can use habitats simultaneously. Teal consumed mostly seeds and some invertebrates, while yellowlegs consumed invertebrates almost exclusively – only one yellowlegs consumed seeds and it only had one seed in its esophagus. Both teal

and yellowlegs consumed Chironomids most frequently, in both larval and pupae stages. To partition resources and avoid competitive exclusion, birds can consume the same species of invertebrate but in different life stages or sizes. Chironomids were not categorized into larvae and pupae in 2007, so we could not determine if the birds consumed the forms differently; however, all focal birds consumed both life stages.

Analyses of water samples from Nieuport found Hydrophilidae, Scirtidae, and Corixidae to be the most abundant invertebrates (English and Pike, Clemson University, unpubl. data). Without exact abundance data for all plots from which we collected birds, we cannot predict preference for food items. However, existing data indicate that yellowlegs may preferentially select Chironomids over the more abundant beetle species available in impoundments.

Frequency of occurrence studies (presence/absence) may be biased towards prey that preserve better or persist longer in digestive tracts such as seeds or invertebrates with hard exoskeletons (Duffy and Jackson 1986). Swanson and Bartonek (1970) and Rundle (1982) found that food items in esophagi of Blue-winged Teal and four shorebird species, respectively, were markedly different than food items in the gizzards. Further, Rundle (1982) found that invertebrate diversity was greater in gizzards than esophagi and attributed the differences to differential rates of passage of different foods. We found four invertebrates and one seed in gizzards that were not found in esophagi (Table 4.2). If these items had been included, most would not have been substantial additions to the number of food items consumed by birds, except *Trichocorixa kanza*, which would have been 47% of the digestive tract contents from one yellowlegs and *Solanum* sp., which would have been 16% of one Blue-winged Teal's digestive tract contents. We observed

birds foraging for ≥10 min prior to collection so the food items in the gizzard may have been consumed at other locations, but we cannot know that without comparing what was available at our sites to sites within a bird's daily range. If the difference in diversity between esophagi and gizzards was because of birds consuming foods in different areas, digestion rate would be a factor. Digestion rates in the wild are unknown (Brennan *et al.* 1990) so digestion rate data come from captive birds. Tuck (in Fritzell *et al*. 1979) fed a known amount of earthworms (Oligochaeta), isopods (Isopoda), and beetles (Coleoptera) to Common Snipe (*Gallinago delicata*). Within 10 min of ingestion, the prey items within the gizzard were reduced by 40%, and after 1 h, only 4% of the items could be identified microscopically. In an experiment with captive, force-fed Blue-winged Teal, 100% of amphipods and 82% of snails within the gizzard were digested beyond recognition within 10 min and invertebrates were never found in the gizzard after 20 min (Swanson and Bartonek 1970).

The percentage of combined food items in esophagi and gizzards of teal and yellowlegs was not different ($df = 1$, $P = 0.4593$); however, the percentage of invertebrates was nearly greater in gizzards than esophagi ($df = 1$, $P = 0.0662$) for both teal and yellowlegs and the percentage of invertebrates in gizzards of yellowlegs was greater than the percentage in esophagi ($df = 1$, $P < 0.0001$). Based on previous studies, we expected seeds but not invertebrates to persist in the gizzard. Birds MS9 and MS10 (both lesser yellowlegs) contained six and 12 Chironomids in their esophagus, respectively, but 125 and 189 Chironomids in their gizzard, respectively. Chironomids are soft-bodied invertebrates and probably do not persist long in the gizzard. These items probably were consumed within the 10-min observation period before collection. Bird

JPT17 (lesser yellowlegs) did not contain snails in the esophagus but 89 in the gizzard, which is not unusual considering the hard shell of the snail. Only using the esophagus for waterfowl food habits studies because of the morphology (i.e., strong musculature) of the gizzard seems appropriate. However, investigating digestive rates and differential rates of passage of food items within birds that consume soft-bodied prey would be beneficial. Further, using both the gizzard and esophagus for food habits studies of shorebirds may be appropriate.

Although great care was taken to follow methodology and collect birds that were actively foraging, two Blue-winged Teal, four Green-winged Teal, one Greater Yellowlegs, and nine Lesser Yellowlegs did not have food items in their esophagus. Of the birds with empty esophagi, the two Blue-winged Teal had 34 and 158 food items in their gizzards; we did not examine the gizzards of the four Green-winged Teal, one Greater Yellowlegs, and four of the ten Lesser Yellowlegs because doing so was not necessary for our objectives. The remaining six Lesser Yellowlegs with empty esophagi had 5, 14, 35, 54, 59, and 90 food items in their gizzard. Empty esophagi are consistent with data from Swanson and Bartonek (1970) and Fritzell *et al*. (1979) who found "some" birds and 50% of collected birds, respectively, had empty digestive tracts, though they were observed feeding before collection. Regurgitation following death and amount of available food should be considered in birds without food items in their esophagus (Swanson and Bartonek 1970). One female Blue-winged Teal had a conspicuous mass of seeds and invertebrates in its esophagus or proventriculus (Fig. 4.3). We do not know if forcing preservative into the esophagus moved items within the digestive tract.

Transportation of samples (i.e., by car, by boat) may further agitate prey items within the preservative solution, breaking up soft-bodied prey and making them harder to identify or count (Duffy and Jackson 1986).

Teal and yellowlegs can forage in similar habitat by consuming different food items or different life stages of the same food item. Teal are morphologically designed to have a diet rich in seeds whereas yellowlegs are designed to consume and digest invertebrates. Managed impoundments should be drained slowly in the spring to provide foraging habitat for shorebirds and to prevent invertebrate prey items from perishing (i.e., due to desiccation of impoundment substrates). Typical moist-soil management (as described in Tufford 2005) should provide an adequate seed source for waterfowl consumption. We recommend looking at available prey compared to what the birds are actually eating by taking core samples from the areas where birds were collected.

ACKNOWLEDGEMENTS

This study was made possible by funds from the National Fish and Wildlife Foundation and the Nemours Wildlife Foundation. Nemours provided housing and equipment. The USFWS provided access to field sites. R. Klimstra, J. Hollis, and D. Barrineau provided field assistance. Clemson University provided lab space and equipment.

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Figure 4.1. A bisected teal gizzard (left) compared to a bisected gizzard of a yellowlegs (right). The teal gizzard is mostly muscle with a very small cavity (dark area), an adaptation for crushing and grinding seeds, while the yellowlegs gizzard has a larger cavity (dark area) and is adapted to digest soft-bodied prey items such as fly and midge larvae.

Figure 4.2. Satellite view (Google Earth 2008) of five experimental units used to investigate food habits of teal and yellowlegs within managed impoundments in 2007 and 2008. Units were located on the Nemours Wildlife Foundation, Beaufort County, SC.

Table 4.1. Food items found in the esophagi of Blue-winged and Green-winged Teal and Greater and Lesser yellowlegs collected in 2007 and 2008 from managed impoundments at the Nemours Wildlife Foundation, Beaufort County, SC to investigate food habits. Numbers represent the number of birds that consumed the item.

Food Item	Teal	Yellowlegs
Coleoptera Curculionidae	0	1
Coleoptera Hydrophilidae *Berosus* sp. (L)[1]	3	2
Coleoptera Hydrophilidae *Enochrus* sp. (L)	0	1
Coleoptera Dytiscidae *Liodessus noviaffinis* (A)[2,3]	1	0
Diptera Chironomidae *Apedilum* sp. (L)	1	0
Diptera Chironomidae *Chironomus* sp.	8	9
Diptera Ephydridae *Ephydra* sp.[3]	1	0
Hemiptera Corixidae	3	5
Hymenoptera Formicidae	1	0
Ostracoda	3	2
Sorbeoconcha Hydrobiidae	6	3
Trichoptera Leptoceridae (case only)	2	0
Najadales Ruppiaceae *Ruppia maritima*	6	1
Cyperales Cyperaceae	4	0
Cyperales Poaceae[4]	5	0
Cyperales Poaceae *Oryza* sp.[3]	1	0
Polygonales Polygonaceae	5	0
Unknown seed	1	0

[1]L = larvae
[2]A = adult
[3]Item only consumed by a Blue-winged Teal that was not used for statistical analysis
[4]Grasses excluding rice species

Table 4.2. Food items found in the gizzards of teal and yellowlegs collected on managed impoundments at the Nemours Wildlife Foundation, Beaufort County, SC in 2007 and 2008. These items were not found in the esophagi of either group and hence were not used in analysis. Numbers represent the number of birds that consumed the item. Blue-winged Teal was the only species to consume *Solanum* sp.

Food Item	Teal	Yellowlegs
Coleoptera Hydrophilidae *Tropisternus* sp.	0	1
Diptera Ceratopogonidae *Dasyhelea* sp.	0	1
Diptera Dolichopodidae	0	1
Diptera Empididae *Clinocera* sp.	0	1
Hemiptera Corixidae *Trichocorixa kanza*	0	2
Solanales Solanaceae *Solanum* sp.	3	0

Table 4.3. Percentage of teal collected (n = 21) in 2007 and 2008 from managed impoundments at the Nemours Wildlife Foundation, Beaufort County, SC that consumed each of the food items. Only food items in esophagi were considered. Six teal collected did not contain any food items.

Food Item	Percentage
Coleoptera Curculionidae	0.0
Coleoptera Hydrophilidae *Berosus* sp. (L)[1]	14
Coleoptera Hydrophilidae *Enochrus* sp. (L)	0.0
Coleoptera Dytiscidae *Liodessus noviaffinis* (A)[2,3]	5.0
Diptera Chironomidae *Apedilum* sp. (L)	5.0
Diptera Chironomidae *Chironomus* sp.	38
Diptera Ephydridae *Ephydra* sp.[3]	5.0
Hemiptera Corixidae	14
Hymenoptera Formicidae	5.0
Ostracoda	10
Sorbeoconcha Hydrobiidae	29
Trichoptera Leptoceridae (case only)	5.0
Najadales Ruppiaceae *Ruppia maritima*	29
Cyperales Cyperaceae	19
Cyperales Poaceae[4]	24
Cyperales Poaceae *Oryza* sp.[3]	5.0
Polygonales Polygonaceae	24
Unknown seed	5.0

[1]L = larvae
[2]A = adult
[3]Item only consumed by the Blue-winged Teal that was not used for statistical analysis
[4]Grasses excluding rice species

Table 4.4. Percentage of yellowlegs collected (n = 28) in 2007 and 2008 from managed impoundments at the Nemours Wildlife Foundation, Beaufort County, SC that consumed each of the food items. Only food items in esophagi were considered. Ten yellowlegs collected did not contain any food items.

Food Item	Percentage
Coleoptera Curculionidae	4.0
Coleoptera Hydrophilidae *Berosus* sp. (L)[1]	7.0
Coleoptera Hydrophilidae *Enochrus* sp. (L)	4.0
Coleoptera Dytiscidae *Liodessus noviaffinis* (A)[2]	0.0
Diptera Chironomidae *Apedilum* sp. (L)	0.0
Diptera Chironomidae *Chironomus* sp.	32
Diptera Ephydridae *Ephydra* sp.	0.0
Hemiptera Corixidae	18
Hymenoptera Formicidae	0.0
Ostracoda	7.0
Sorbeoconcha Hydrobiidae	11
Trichoptera Leptoceridae (case only)	0.0
Najadales Ruppiaceae *Ruppia maritima*	4.0
Cyperales Cyperaceae	0.0
Cyperales Poaceae[3]	0.0
Cyperales Poaceae *Oryza* sp.	0.0
Polygonales Polygonaceae	0.0
Unknown seed	0.0

[1]L = larvae
[2]A = adult
[3]Grasses excluding rice species

Figure 4.3. Arrow points to a large mass of seeds in either the esophagus or proventriculus of a Blue-winged Teal collected from a managed impoundment at the Nemours Wildlife Foundation, Beaufort County, SC to investigate food habits.

CHAPTER 5

CONCLUSIONS

Waterbird use of managed impoundments depends on the season, management strategy, unit area, and resource availability (Joyner 1987). I determined that managed impoundments within the Ashepoo-Combahee-Edisto (ACE) Basin are suitable for use by wintering waterfowl. These same impoundments can provide habitat for migrating shorebirds if managed appropriately. A multi-species management scheme is possible and recommended.

As expected, dabbling ducks were more abundant in managed impoundments regardless of season or tide stage. Data also confirmed that shorebirds were more abundant in tidal marshes at low tide, during the winter season; however, shorebirds were always more abundant in tidal marshes than managed impoundments, regardless of season. During migration, when water levels within impoundments were lowered, shorebirds increased in abundance and use of this habitat. I expected shorebirds to be more abundant in impoundments during high tide when they were pushed out of tidal marshes by high water. However, I concluded that there was no difference in shorebird abundance between high and low tides. According to my time-activity budget data, loafing occurred more frequently in managed impoundments and foraging occurred more frequently in tidal marshes. This indicates that all of the birds' needs are not being met within one habitat and they may need a diversity of habitats to satisfy their daily requirements. My food habits data supported my hypothesis that teal and shorebirds would consume different food items, which may also confirm the need for a complex of

habitats. Food availability and food content data from tidal marshes is necessary for further conclusions.

FUTURE RESEARCH

Impoundment management. Several shorebird species winter along the coast of South Carolina and other states in the Southeast. My study area harbored an equal number of shorebirds during winter (23.05 ± 8.07) and migration (24.27 ± 7.94) seasons. Land managers who are not pressured to manage for waterfowl hunting opportunities should consider managing a complex of impoundments available to wintering waterfowl and shorebirds, to determine if impoundments can provide additional habitat to shorebirds through the winter. Boettcher *et al.* (1995) claim that wintering shorebirds seek out habitat where resources are adequate, stable, and predictable and they look for areas that provide alternative habitats for foraging, roosting, and protection from severe weather. Impoundments are closed to daily tides, thus making food resources and habitat structure within them stable and predictable. My data show that resources within them were also adequate to support a diversity of birds.

Continued monitoring of impoundments as additional habitat for migrating shorebirds is essential. Research that includes larger and more diverse (i.e., percent vegetation cover, salinity) tidal marshes for comparison would be beneficial. I was limited by availability of tidal marshes and only had one that was comparable in size to my managed impoundments. The size of individual wetlands will affect the abundance of birds using them. Although ACE Natural (<1 ha) appeared to be available to a diversity of shorebirds, birds other than passerines or Wilson's snipe (*Gallinago delicata*)

rarely used it. Branford Unit (34.88 ha), which was much larger than ACE Natural, attracted a great diversity and abundance of shorebirds and wading birds.

Wading birds (Ciconiiformes and possibly Gruiformes) including the endangered South Carolina resident Wood Stork (*Mycteria americana*) may also benefit from an integrative shorebird-waterfowl management because late drawdowns will concentrate fish populations within impoundments (Breininger and Smith 1990; Tufford 2005). On the Delaware Bay in New Jersey, wading birds were most abundant at impoundments undergoing a mid-season drawdown (Parsons 2002). Burger *et al.* (1982) correlated a high biomass in impoundments in Barnegat Bay, New Jersey to an abundance of large birds and Woodward (USFWS, pers. comm.) described the impoundments at the ACE Basin NWR during a typical spring as "covered in white," referring to the great abundance of herons, egrets and Wood Storks. There were 189 waders on my plots during migration in 2007 (including 118 on ACE West) and 398 (including 188 on ACE West and 130 on Nieuport) in 2008. I am interested in how wading birds use managed impoundments and tidal marshes and if their abundance is different between the two habitats.

Current impoundment management methods may be detrimental to benthic invertebrates, fish, and coastal marsh endemic bird species (Burger *et al.* 1982; DeVoe and Baughman 1986; Weber 1994; Bolduc and Afton 2003; Mitchell *et al*. 2006). Comprehensive research on impoundments as a functioning ecosystem would be beneficial. I have data on macroinvertebrates, water quality, and fish from my plots and will be able to tie everything together temporally.

Time-activity budgets. I have a better understanding of how dabbling ducks and shorebirds use managed impoundments in comparison to tidal marshes. Taller, more secretive blinds and more effective prescribed burns than those used currently would have aided our data collection and I recommend continued research on behaviors and time allotment.

Food habits. A study comparing what birds consume on managed impoundments and what is available would be particularly beneficial to understanding the role managed impoundments play in satisfying dietary needs and also birds' preferences for food.

MANAGEMENT RECOMMENDATIONS

Although managed wetlands benefit a diversity of birds, conservation of natural marshes is necessary for coastal marsh endemics (i.e., Clapper Rail [*Rallus longirostris*], Seaside Sparrow [*Ammodramus maritimus*], Nelson's Sharp-tailed Sparrow [*Ammodramus nelsoni*]) that benefit from grassland-like conditions and daily tides (Burger *et al.* 1982; Weber 1994; Mitchell *et al*. 2006). A diversity and balance of habitats within the wetland complex should result in a greater diversity of wildlife. More research is needed on shorebird use of impoundments before I can recommend increasing the amount of managed impoundments for shorebirds. However, if the primary goal of a landowner is to maximize waterfowl abundance and hunting opportunities, I do recommend increasing the number of managed impoundments.

I recommend managers maintain a diverse wetland complex based on differing needs of dabbling ducks and shorebirds. A complex of privately owned, state, and federal management areas provides a diverse area for wetland-dependant species and thus decreases competition for resources by spreading wildlife out among a large area

(Williams *et al.* 1998). There is a need for a large-scale, coordinated regional management effort (Skagen and Knopf 1993) with strong connections between research, management, and monitoring to provide an evaluative and adaptive framework (Parsons *et al.* 2002).

Within the wetland complex, impoundments should follow an integrative shorebird-waterfowl management technique (Weber 1994). Water control structures are the most important part of moist-soil management, which relies on water level manipulation (Williams 1987). Ricefield trunks and dikes should be maintained and repaired as soon as possible, when necessary.

I recommend slow, staggered drawdowns beginning at the end of February, that allow differing water depths for a diversity of birds and new areas of exposed mud and invertebrate concentrations to become available over time (Weber 1994; Weber and Haig 1996; Hunter 2000; Isola *et al.* 2000; Collazo *et al.* 2002). Sheet water should remain at least through May for later migrant shorebirds, and soil should remain moist through the summer for waterfowl food plant germination. In fall, water should be removed so prescribed fire and other vegetation control methods (i.e., disking) can be implemented to encourage waterfowl food plants and invertebrate communities, remove undesirable plant species, and create a patchy distribution of vegetation (Tompkins 1987; Scrimgeour *et al.* 2001; Tufford 2005). Disturbance to the vegetation provides an interspersion of open water or mud for foraging and vegetation for loafing and escape from predators. Because foraging and loafing were the most common behaviors on my plots, wintering and stopover habitat should be managed primarily to satisfy the dietary needs of a diverse

group of birds and to provide safe areas for loafing (i.e., horizontal vegetation structure). Providing birds with adequate space to reduce competitive exclusion is also important.

Impoundments, if managed appropriately, do provide adequate habitat for migrating shorebirds and can serve as additional habitat to adjacent tidal marshes. However, improved management is necessary to significantly influence shorebird use of impoundments. With an evaluative, adaptive management strategy, we can continue to increase the amount of available habitat for shorebirds and possibly offset the affects of decreasing quality and amount of natural habitat.

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APPENDIX A

LIST OF ALL AVIAN SPECIES DETECTED IN 2007 AND 2008 ON EXPERIMENTAL UNITS AT THE ERNEST F. HOLLINGS ASHEPOO-COMBAHEE-EDISTO BASIN NATIONAL WILDLIFE REFUGE AND NEMOURS WILDLIFE FOUNDATION, BEAUFORT COUNTY, SC

Table A.1. List of all avian species detected during surveys in 2007 and 2008 on the Ashepoo-Combahee-Edisto Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, SC.

Family	Common Name	Scientific Name
Podicipedidae	Pied-billed Grebe	*Podilymbus podiceps*
	Horned Grebe	*Podiceps auritus*
Pelecanidae	American White Pelican	*Pelecanus erythrorhynchos*
Anhingidae	Anhinga	*Anhinga anhinga*
Phalacrocoracidae	Double-crested Cormorant	*Phalacrocorax auritus*
Ardeidae	American Bittern	*Botaurus lentiginosus*
	Great Blue Heron	*Ardea herodias*
	Great Egret	*Ardea alba*
	Snowy Egret	*Egretta thula*
	Little Blue Heron	*Egretta caerulea*
	Tricolored Heron	*Egretta tricolor*
	Green Heron	*Butorides virescens*
	Black-crowned Night-heron	*Nycticorax nycticorax*
Threskiornithidae	Glossy Ibis	*Plegadis falcinellus*
	White Ibis	*Eudocimus albus*
Ciconiidae	Wood Stork	*Mycteria americana*
Anatidae	Wood Duck	*Aix sponsa*
	Mallard	*Anas platyrhynchos*
	American Black Duck	*Anas rubripes*
	Mottled Duck	*Anas fulvigula*
	Gadwall	*Anas strepera*
	Northern Pintail	*Anas acuta*
	American Wigeon	*Anas americana*
	Northern Shoveler	*Anas clypeata*
	Blue-winged Teal	*Anas discors*
	Green-winged Teal	*Anas crecca*
	Canvasback	*Aythya valisineria*
	Lesser Scaup	*Aythya affinis*
	Ring-necked Duck	*Aythya collaris*
	Bufflehead	*Bucephala albeola*
	Hooded Merganser	*Lophodytes cucullatus*
	Red-breasted Merganser	*Mergus serrator*
Cathartidae	Turkey Vulture	*Cathartes aura*
Accipitridae	Osprey	*Pandion haliaetus*
	Sharp-shinned Hawk	*Accipiter striatus*
	Cooper’s Hawk	*Accipiter cooperii*
	Northern Harrier	*Circus cyaneus*
	Red-tailed Hawk	*Buteo jamaicensis*
	Bald Eagle	*Haliaeetus leucocephalus*
Falconidae	Merlin	*Falco columbarius*

Family	Common Name	Scientific Name
Rallidae	Clapper Rail	*Rallus longirostris*
	King Rail	*Rallus elegans*
	Sora	*Porzana carolina*
	Common Moorhen	*Gallinula chloropus*
	American Coot	*Fulica americana*
Charadriidae	Black-bellied Plover	*Pluvialis squatarola*
	Killdeer	*Charadrius vociferus*
	Semipalmated Plover	*Charadrius semipalmatus*
Recurvirostridae	Black-necked Stilt	*Himantopus mexicanus*
	American Avocet	*Recurvirostra americana*
Scolopacidae	Greater Yellowlegs	*Tringa melanoleuca*
	Lesser Yellowlegs	*Tringa flavipes*
	Solitary Sandpiper	*Tringa solitaria*
	Willet	*Catoptrophorus semipalmatus*
	Dunlin	*Calidris alpina*
	Pectoral Sandpiper	*Calidris melanotos*
	White-rumped Sandpiper	*Calidris fuscicollis*
	Western Sandpiper	*Calidris mauri*
	Least Sandpiper	*Calidris minutilla*
	Long-billed Dowitcher	*Limnodromus scolopaceus*
	Short-billed Dowitcher	*Limnodromus griseus*
	Ruff	*Philomachus pugnax*
	Wilson's Snipe	*Gallinago delicata*
Laridae	Bonaparte's Gull	*Larus philadelphia*
	Laughing Gull	*Leucophaeus atricilla*
	Ring-billed Gull	*Larus delawarensis*
	Caspian Tern	*Sterna caspia*
	Royal Tern	*Sterna maxima*
	Forster's Tern	*Sterna forsteri*
Columbidae	Mourning Dove	*Zenaida macroura*
Strigidae	Great Horned Owl	*Bubo virginianus*
Alcedinidae	Belted Kingfisher	*Ceryle alcyon*
Picidae	Downy Woodpecker	*Picoides pubescens*
	Northern Flicker	*Colaptes auratus*
Tyrannidae	Eastern Phoebe	*Sayornis phoebe*
Corvidae	American Crow	*Corvus brachyrhynchos*
	Fish Crow	*Corvus ossifragus*
Hirundinidae	Barn Swallow	*Hirundo rustica*
	Tree Swallow	*Tachycineta bicolor*
Paridae	Eastern Tufted Titmouse	*Baeolophous bicolor*
Tryglodytidae	Marsh Wren	*Cistothorus palustris*
	Sedge Wren	*Cistothorus palustris*
	Carolina Wren	*Thryothorus ludovicianus*

Family	Common Name	Scientific Name
Regulidae	Ruby-crowned Kinglet	*Regulus calendula*
Sylviidae	Blue-gray Gnatcatcher	*Polioptila caerulea*
Turdidae	American Robin	*Turdus migratorius*
Mimidae	Northern Mockingbird	*Mimus polyglottos*
Parulidae	Yellow-rumped Warbler	*Dendroica coronata*
	Palm Warbler	*Dendroica palmarum*
	Common Yellowthroat	*Geothlypis trichas*
Cardinalidae	Painted Bunting	*Passerina ciris*
	Northern Cardinal	*Cardinalis cardinalis*
Emberizidae	Savannah Sparrow	*Passerculus sandwichensis*
	Song Sparrow	*Melospiza melodia*
	Swamp Sparrow	*Melospiza georgiana*
Icteridae	Bobolink	*Dolichonyx oryzivorus*
	Red-winged Blackbird	*Agelaius phoeniceus*
	Common Grackle	*Quiscalus quiscula*
	Boat-tailed Grackle	*Quiscalus major*
Fringillidae	American Goldfinch	*Carduelis tristis*

APPENDIX B

PERMITS REQUIRED FOR COLLECTION OF TEAL AND YELLOWLEGS FOR FOOD HABITS DATA

1. Dr. Ernie P. Wiggers of the Nemours Wildlife Foundation holds a Scientific Collecting Permit though the USFWS that permits the shooting and collection of 40 Blue- and/or Green-winged Teal and 40 Greater and/or Lesser Yellowlegs (Permit # MB139730-0). William E. Mills and Gretchen E. Nareff are authorized subpermittees.

2. Dr. Ernie P. Wiggers and William E. Mills hold a SCDNR permit that allow the shooting and collection of 40 Blue- and/or Green-winged Teal and 40 Greater and/or Lesser Yellowlegs (Permit # 65-2006).

3. Dr. Sara H. Schweitzer holds a University of Georgia Institutional Animal Care and Use Permit # A2006-10162-0 and UGA Animal Welfare Assurance # A3437-01