DISTRIBUTION AND FREQUENCY OF OCCURRENCE OF KING AND CLAPPER RAILS IN MANAGED IMPOUNDMENTS AND TIDAL MARSHES

by

SEAN P. MCGREGOR

Under the Direction of SARA H. SCHWEITZER

ABSTRACT

Rails have been used as a bio-indicator of marsh health; however, little is known about rails' presence and distribution within the ACE Basin of South Carolina. We estimated frequency of occurrence of rails in managed impoundments and tidal marshes during summer 2005, and winter and summer 2006, using call broadcast surveys. We related occurrences to habitat structure during winter and summer 2006. One King and 3 Clapper Rails were radio-tracked from March to August 2006 to assess distribution during the breeding season. Rails occurred more frequently in tidal marshes during each season. Different habitat variables explained frequency of occurrence each season. All Clapper Rail radio-locations were in tidal marshes, but locations of the King Rail were in managed impoundments. Tidal marshes provided resources for Clapper Rails, while managed impoundments provided resources for King Rails. Further research is needed to improve management of impoundments to provide enhanced habitat for rails and their allies.

INDEX WORDS: Clapper Rail, King Rail, home range size, ACE Basin, frequency of occurrence, call broadcast survey, radio-telemetry, managed impoundment, and tidal marsh.

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DEDICATION

I would like to dedicate my thesis to my parents Agnes and Phil McGregor for their financial and emotional support during my graduate program. I would also like to dedicate my thesis to Jesus Christ for spiritual guidance.

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I would like to thank my advisor, Sara Schweitzer, for bringing me to Warnell School of Forestry and Natural Resources, as well as the guidance she provided throughout my graduate program. I would also like to thank Ernie Wiggers and Bob Cooper for their assistance and guidance throughout my graduate program. I would like to thank Ernie Wiggers and Eddie Mills for their advice, and help with setting up my project at Nemours Wildlife Foundation (Nemours), and Hollings ACE Basin National Wildlife Refuge (NWR). I would also like to thank Nemours supplemental funding, and for the use of their facilities, housing, marshes, trucks, and other equipment. I would to thank Larry Hartis and Jane Griess for their help with finding marshes to use for my study as well as other assistance. Nemours provided field technicians, and I would like to thank Sharon Vilitski, Jan Forrest, Adrian Campbell, and Daniel Barrineau for all of their assistance in the field. I would also like to thank all the staff at Nemours for providing help with work trucks, water manipulation, and most importantly lunch. For all of the help with statistics, I would like to thank Guo-Jing Weng and Jim Peterson. For trap design and radio attachment advice, I would like to thank Greg Kearns, and for call broadcast survey advice I would like to thank Courtney Conway and Chris Graves. For advice and assistance in other areas of my graduate program I would like to thank Natalie Hyslop, Scott Rush, and Cory Heaton. Finally, I would like to thank D.B. Warnell School of Forestry and Natural Resources, for the use of their facilities and the Graduate Recruitment Opportunities assistantship program for funding as well as the U.S. Fish and Wildlife Service and the National Fish and Wildlife Foundation for the funding of this project.

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CHAPTER 1

INTRODUCTION

King (*Rallus elegans*) and Clapper Rails (*R. longirostris*) are considered indicator species for estuarine marsh health due to their narrow ecological tolerance for tidal marshes, small home-range size during the breeding season, and their consistent diet of invertebrates (Gaines et al. 2003). King and Clapper rails may also be indicator species for estuarine marsh health in altered marshes. Research on King and Clapper Rails presents great challenges because of rails' elusive nature, secretive behavior, and remote wetland habitat. There have been unreliable estimates of Clapper Rails' population size in the Southeast due to the sporadic and inconsistent application of population estimation techniques (Eddleman and Conway 1994). Nest counts, track counts, and sightings have been used to estimate population size, but only at local levels and they are labor intensive and implausible in dense vegetation (Eddleman and Conway 1994). Conflicting information on King Rail distribution in published articles has created unreliable estimates of their population. Reid et al. (1994) claimed that no accurate estimates were available for the total population size of King Rails; however, Eddleman and Conway (1994) state that the King Rail population has been declining over the last 30 years. To clearly understand management needs for King and Clapper Rails, more accurate population estimates are needed.

Rail habitat along the southeastern United States includes tidal marshes; however, managed impoundments are also located within this area. Impoundments are marshes that are diked, and have their hydrology managed by water control structures (Williams et al. 2002).

Impoundments intensely managed for waterfowl provide hydrological cycles, vegetation, invertebrate food, and refugia for migratory and wintering waterfowl, yet they may not provide the resources that are important for marsh birds (Williams et al. 2002). Rails are secretive birds that select dense vegetation for refuge and nesting, and they feed in small openings and along tidal mudflats at the water-marsh interface (Eddleman and Conway 1998). Coastal marshes that are unmanaged may provide the vegetation rails require for nesting and protection, as well as open feeding sites.

Data on King and Clapper Rail abundance and habitat selection during winter and breeding seasons in the Southeast are limited. Further, little is known about rails' seasonal use of managed impoundments versus tidal marshes. This research addressed gaps in data concerning rail populations in the South Atlantic Coastal Zone (SACZ). The long-term goal of this research is to provide suggestions for multiple-species management of the numerous hectares of managed, impounded marshes in the SACZ.

Natural History of King and Clapper Rails

Both King and Clapper Rails are rusty in appearance with a slender decurved bill. King Rails have olive brown upper parts, while Clapper Rails have dull grayish upper parts. King Rails are slightly larger than Clapper Rails. King Rails are usually divided into two subspecies, *R. e. elegans* located in North America, and *R. e. rensdeni* located in Cuba (Meanley 1992, Reid et al. 1994). King Rails nest as early as February and clutch size range from 10 to 11 eggs (Reid et al. 1994). Both sexes incubate which last 21-23 days, afterwards young stay with their parents for 6 to 10 weeks in most southeastern regions (Reid et al. 1994). The breeding season may last up to seven months and re-nesting may occur if original nest is destroyed (Reid et al. 1994). King Rails are found in freshwater and brackish marshes, shrub swamps, and occasionally ricefield impoundments (Reid et al. 1994). They nest in portions of marshes with shallow water (0-25 cm) and forage in sites where depths are <10 cm, and when brooding young, they require sites with natural swales (Eddleman et al. 1988).

Concentrations of King Rails occur in floodplain wetlands of riverine systems along the Atlantic and Gulf Coasts, but little is known about exact wintering locations (Meanley 1992, Reid et al. 1994). Vegetation at selected habitat sites throughout the year includes grasses (Poaceae), sedges (Cyperaceae), and rushes (Juncaceae) that serve as cover (Eddleman et al. 1988, Meanley 1992).

There are at least 25 subspecies of Clapper Rails that occur from New England to Brazil (Meanley 1985). Eight subspecies are recognized in the United States. The Northern Clapper Rail (*R. l. crepitans*) ranges from Massachusetts to South Carolina, and overlaps with Wayne's Clapper Rail (*R. l. waynei*), that ranges from South Carolina to the southern tip of Florida. The Mangrove Clapper Rail (*R. l. insularum*) ranges from the southern tip of Florida to the Florida Keys, the Louisiana Clapper Rail (*R. l. saturatus*) ranges from the Florida panhandle to Mexico, and overlaps with the Florida Clapper Rail (*R. l. scottii*), found along the Florida coast (Eddleman and Conway 1994). The Florida Clapper Rail's range also overlaps with Wayne's Clapper Rail on the east coast of Florida. The Yuma Clapper Rail (*R. l. yumanesis*) is found in the lower Colorado River valley, and the Light-footed Clapper Rail (*R. l. levipes*) and California Clapper Rail (*R. l. obsoletus*) are found on the California coast but their ranges do not overlap (Lewis and Garrison 1983). Yuma, Light-footed, and California Clapper Rails are federally endangered in the U.S. (Conway and Gibbs 2005).

The Clapper Rail breeding season begins in late March and ends in late August (Lewis and Garrison 1983, Meanley 1985). Clapper Rails may produce more than one brood per year.

Average clutch size is 8.2 to 10.5 eggs and both sexes incubate the eggs (Lewis and Garrison 1983, Eddleman and Conway 1994). Clapper Rails select habitat that is characterized by low tidal salt marsh dominated by cordgrass (*Spartina* spp.) of moderate height and salinity levels that exceed 7,100 ppm at low tide and 5,600 ppm at high tide (Eddleman and Conway 1994). Because ranges of Clapper and King Rails overlap in brackish marsh, it is difficult to identify each species within this habitat and hybridization of the two species may occur (Meanley 1985, Graves 2001).

Ricefield impoundment management in South Carolina

In South Carolina, coastal wetlands are sometimes managed as impoundments. Natural impoundments comprise 15% of the total area of South Carolina and Georgia (Latham 1990). Natural impoundments are those that are created by wild animal, biological, and geological processes (Epstein 1995). Many man-made impoundments were created during the eighteenth and nineteenth centuries for rice and indigo production (Epstein and Joyner 1988). Wooden water control structures called ricefield trunks were used to manage these coastal impoundments (Morgan et al. 1975). Ricefield trunks control tidal water movement in and out of the impoundment (Morgan et al. 1975). South Carolina produced 70% of the United States' rice crop in the eighteenth century (Doar 1936). With the loss of slave labor, increased competition from Louisiana and Texas rice production, and a series of damaging hurricanes, South Carolina's rice production decreased significantly during the late 1800s (Morgan et al. 1975). Many rice plantations were purchased by wealthy northerners who used them for hunting and other objectives (Epstein and Joyner 1988).

The primary goal of most impoundment management practices on U.S. Fish and Wildlife Service (USFWS) National Wildlife Refuges (NWR) and other private and public lands in the

SACZ is to enhance the production of waterfowl (Williams et al. 2002). Management strategies are used to increase production of waterfowl foods and decrease production of unwanted vegetation such as cordgrasses (*Spartina* spp.), cattails (*Typha* spp.) and other nuisance species (Williams et al. 2002). Although these impoundment management strategies may be suitable for waterfowl and possibly shorebirds, they are not likely to produce useable habitat for rails. Unfortunately, few studies (Rundle and Fredrickson 1981, Epstein and Joyner 1988, Tori et al. 1988, Taft et al. 2002) have examined the effects of waterfowl management strategies on overall bird use of impoundments, and even less research has investigated rail use of these areas (Dodd et al. 1999). Use of marshes by rails is different from waterfowl use. Rails feed on open mud flats, and need dense vegetation for cover, but many managed impoundments are flooded seasonally and are not accessible to rails (Eddleman et al. 1988). In South Carolina, Epstein and Joyner (1988) found that Clapper Rails preferred tidal marshes over managed impoundments. Their study did not address reasons why Clapper Rails selected the tidal marshes, nor did the study assess habitat needs for rails in managed impoundments. Eddleman et al. (1998) found that rails responded best when partial drawdowns increased invertebrate prey, thus mimicking the tidal marshes by providing periods of flooding and open mudflats.

Multiple-Species Management

Human population growth, especially along the southeastern coast, conversion of land to housing developments, roads, and business structures, and increased public awareness of the use and importance of wetlands have increased the importance of multiple-species management objectives for wetlands (Epstein 1995). The waterbird community is diverse and consists of numerous families: Ardeidae, Charadriidae, Ciconiidae, Gruidae, Haematopodidae, Recurvirostridae, and Scolopacidae. Anatidae and Rallidae comprise the greatest numbers of waterbirds (Tori et al. 2002).

Multiple-species management is not a new concept. Public land use has been designated by state and federal agencies as single or multiple use property; for example, incorporating waterfowl management objectives with other objectives such as agriculture and fisheries has resulted in manipulations that accomplish different objectives (Epstein 1995). Little applied research has been done to aid managers in developing plans that would balance the needs of diverse waterbird groups that may be competing for wetland habitat (Parsons 2002).

To manage for multiple species, the needs of each species must be met. Different waterbirds have different requirements at different times during their life cycle. In Delaware Bay, Parsons (2002) found that wading birds and waterfowl used tidal sites less often relative to impoundments that were close to water control structures. Impoundments at Merritt Island NWR, Florida, have become important for maintaining the existing regional wading bird population (Breininger and Smith 1990).

Many conditions, such as hydrological alterations and current land use, should be evaluated (Tori et al. 2002). Water level manipulations that emulate the natural fluctuations in the water cycle can be used to achieve multiple-species management goals (Epstein 1995). By providing diverse water depths in managed impoundment complexes, managers can offer many wetland habitats that may be suitable for multiple species (Epstein 1995).

In this study we investigated rail species’ presence and absence, habitat selection, movement, and home range sizes within tidal marshes and managed impoundment complexes of the Ernest F. Hollings Ashepoo-Combahee-Edisto (ACE) Basin National Wildlife Refuge

(Refuge) and Nemours Wildlife Foundation (Nemours), Beaufort County, South Carolina. The specific objectives of this thesis were:

1. To estimate the frequency of occurrence of King Rails and Clapper Rails within managed impoundments and tidal marshes during breeding and winter seasons.

   Hypothesis: King and Clapper Rails will have greater presence within tidal marshes than managed impoundments during breeding and winter seasons.

2. To determine how habitat structure in managed impoundments and tidal marshes during breeding and winter seasons affects rail frequency of occurrence.

   Hypothesis: Tidal marshes will have more emergent perennial vegetation that rails use for nesting habitat, shallower water depths for foraging, and more vertical structure to provide cover during the breeding and winter seasons than managed impoundments; these habitat characteristics will explain greater rail frequency of occurrence in tidal marshes.

3. To determine breeding season habitat selection, home range sizes, and movement by King and Clapper Rails within managed impoundments and tidal marshes.

   Hypothesis: King and Clapper Rails' habitat selection and movement will be within tidal marshes because managed impoundments will have low vertical structure and a lower water level during early breeding season and a very high water level during late breeding season. Home range will be restricted to managed impoundments and tidal marshes that provide mudflats for foraging and nesting cover.

STUDY AREA

This study was conducted within two managed properties in Beaufort County, South Carolina: Ernest F. Hollings Ashepoo-Combahee-Edisto (ACE) Basin National Wildlife Refuge (Refuge) and Nemours Plantation Wildlife Foundation (Nemours). The Edisto, Ashepoo, and Combahee Rivers comprise the ACE Basin. This Basin is one of the largest undeveloped estuaries located on the east coast of the United States (U.S. Fish and Wildlife Service [USFWS] 2006). A diverse group of wildlife and plant species, including some that are federally endangered, are found within the ACE Basin.

The Refuge consists of approximately 4,781 ha of diverse habitats (USFWS 2006). In the mid-1700s tidal swamps bordering the rivers were cleared and diked for rice culture (USFWS 2006). There are 1,598 ha of tidal marsh and 1,214 ha of managed impoundments within the Refuge. The Refuge is divided into two units: Edisto River Unit and Combahee River Unit. I selected the Combahee River Unit (Fig. 1.1) for my study because it and the Nemours study sites are located along the Combahee River. The Combahee Unit is 1,847 ha and has two main subunits: Bonny Hall, south of the Combahee River; and Combahee Fields, north of the Combahee River. The Combahee Unit consists of 112 ha of tidal marsh and 1,063 ha of managed impoundments.

Nemours is located south of the Combahee Unit of the Refuge along the Combahee River (Fig 1.2). Nemours was established by Eugene DuPont, III and family in 1995, and is administered by a Board of Directors (Mills and Wiggers 2006). The long-term goal of Nemours is to be a leader in the scientific study and stewardship of our natural resources (Mills and Wiggers 2006). The 3,881-ha plantation contains diverse habitats, including 607 ha of remnant rice fields (managed impoundments), 115 ha of fresh and brackish tidal marshes, upland pine and hardwood forests, bottomland hardwoods, and cypress/tupelo forests (Mills and Wiggers 2006). Managed impoundments on Nemours are mainly brackish, while managed impoundments on the Refuge are mainly freshwater.

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Figure 1.1. Aerial photograph (1999) of Ernest F. Hollings ACE Basin National Wildlife Refuge, Beaufort and Colleton Counties, S.C. Study sites B5, B1, and C1 were managed impoundments and C8, C11, and C12 were tidal marshes. Call broadcast surveys were conducted in each of these areas to estimate frequency of occurrence of King and Clapper Rails during summers 2005, 2006 and winter 2006.

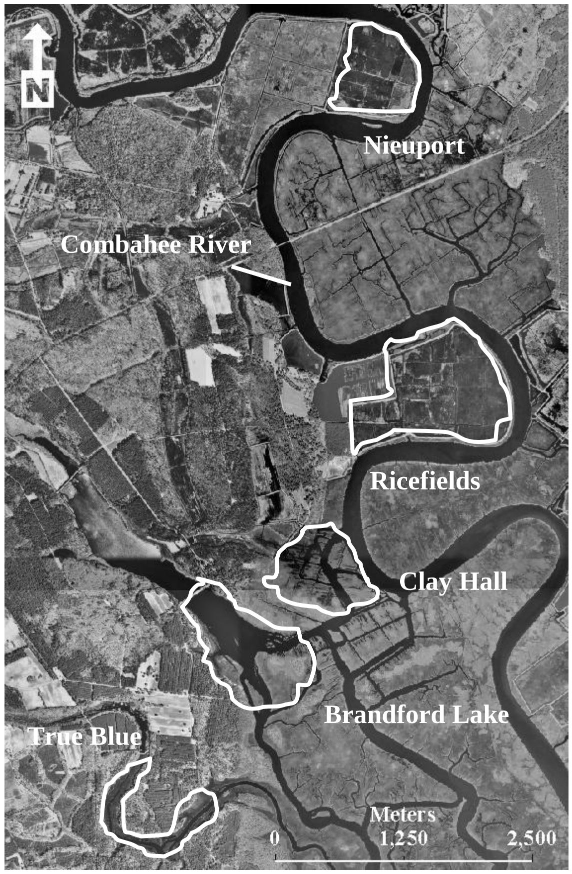

Figure 1.2. Aerial photograph (1999) of Nemours Wildlife Foundation, Beaufort County, S.C. Study sites, Ricefield 1 and 2, and Nieuport, were managed impoundments, and study sites, Branford Lake, True Blue, and Clay Hall, were tidal marshes. Call broadcast surveys were conducted in each study site to estimate frequency of occurrence of King and Clapper Rails during summers 2005, 2006, and winter 2006.

FREQUENCY OF OCCURRENCE OF KING (*Rallus elegans*) AND CLAPPER (*R. longirostris*) RAILS IN MANAGED IMPOUNDMENTS AND TIDAL MARSH[1]

[1] McGregor, S.P., S. H. Schweitzer, E. P. Wiggers, W. E. Mills, R. J. Cooper, and J. T. Peterson.
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INTRODUCTION

King Rails (*Rallus elegans*) occur in freshwater and brackish tidal marshes and Clapper Rails (*R. longirostris*) occur in brackish and saline tidal marshes. Their habitat needs include shallow water depths that provide foraging opportunities and relatively tall vegetation that protects young and provides nesting cover (Meanley 1985; Eddleman and Conway 1994). Tidal cycles in the coastal, southeastern U.S. provide rails with exposed mudflats during low tide, and tall marsh grasses such as cordgrass (*Spartina* spp.) and cattails (*Typha* spp.), for protection and nesting cover (Gaines et al. 2003).

Marshes along the Atlantic coast provide food, shelter, and cover for fish, shellfish, and wildlife (Gaines et al. 2003). Monitoring marsh ecosystem health is important because pollutants and other disturbances can destroy these fragile areas (Cumbee 2003). Rails have been used as indicators of marsh health because of their dependence on marsh habitats, strong site fidelity, small home range size during the breeding season, and their predictable diet of invertebrates (Gaines et al. 2003). Despite their potential as indicators of marsh health, the relative abundance and habitat selection of King and Clapper Rails in the South Atlantic Coastal Zone (SACZ) are poorly understood, likely because of their secretive, elusive nature (Eddleman and Conway 1998).

Many marshes in the SACZ are abandoned ricefield impoundments, now principally managed to provide migration and wintering habitat for waterfowl (Williams et al. 2002). Many of these impoundments could provide habitat for multiple waterbird species throughout the year. Human population growth along the southeastern coast has increased the importance of the remaining wetlands, including managed impoundments, and their protection and management as multi-species habitat (Epstein 1995). Little is known about the seasonal frequency of occurrence of rails in managed impoundments versus tidal marshes (Epstein and Joyner 1988). Unmanaged coastal marshes in the SACZ may provide the dense, emergent vegetation that rails require for nesting and protection, as well as open feeding sites (Lewis and Garrison 1983; Epstein and Joyner 1988). Basic information about the frequency of occurrence of rails as it relates to habitat structure in the tidal marshes versus managed impoundments in the SACZ is not known.

Because of inaccessibility of marsh interiors and the secretive nature of rails, accurate estimates of King and Clapper Rail population sizes are difficult to obtain, and existing estimates may be inaccurate (Eddleman and Conway 1994). Because rails stay concealed in dense vegetation, estimates of rail abundance rely on aural surveys rather than sightings. Rails call periodically and they respond to broadcast call recordings of conspecifics (Conway and Gibbs 2005). A standardized aural survey has been developed and provides a population index of abundance that could be compared among wetland habitat types (Conway 2005).

Call broadcast surveys are often used to elicit more responses from rails (Conway and Gibbs 2005) because rails' frequency of vocalization is inconsistent (Conway 2005). The call broadcast survey method assumes that the number of responses from rails increases in response to a recording, and some studies have supported this assumption (Conway and Gibbs 2005). The call broadcast survey method also obtains a more accurate index of rail abundance that will allow researchers to compare indices among other areas in the region to determine relative importance and quality of local habitat (Hinojosa-Huerta et al. 2002; Conway 2005). The call broadcast method (Conway 2005) is used for many current marshbird surveys (Conway and Gibbs 2005).

To better understand the frequency of occurrence of rails in managed impoundments and tidal marshes, we conducted call broadcast surveys of King and Clapper Rails and measured habitat characteristics in marsh complexes of the Ashepoo-Combahee-Edisto (ACE) Basin in

Beaufort County, South Carolina, one of the largest undeveloped coastal wetland systems (141,640 ha) in the U.S. Our specific objectives were to estimate the frequency of occurrence of rails in managed impoundments and tidal marshes during breeding and winter seasons, and to compare habitat characteristics associated with areas of greater frequencies of occurrence of rails with areas of low or no frequency of occurrence of rails. Further, we explored the habitat parameters that may explain patterns of occurrence of rails. We predicted that both rail species would have higher frequencies of occurrence in tidal marshes than in managed impoundments, because the tidal marshes were characterized by greater vertical plant structure, low individual plant species richness, shallower water, and horizontal cover containing high percentages of grass. We expected that these habitat parameters would explain presence of rails in different marsh sites. We also predicted that King Rails would be found in freshwater and brackish marshes, while Clapper Rails would be found in brackish to saline marshes.

STUDY AREA

This study was conducted within Ernest F. Hollings ACE Basin National Wildlife Refuge (Refuge) and Nemours Wildlife Plantation (Nemours), Beaufort and Colleton Counties, South Carolina. The Combahee River flows through the Refuge and Nemours, into St. Helena Sound, to the Atlantic Ocean. The Combahee River is influenced by twice-daily tides, with freshwater in the Refuge area, and brackish water farther downstream within the Nemours area. The Refuge consists of approximately 4781 ha of diverse habitats, including 1598 ha of tidal marshes and 1214 ha of managed impoundments. This study was conducted in the 1847-ha Combahee River Unit of the Refuge, consisting of two main subunits: Bonny Hall, south of the Combahee River; and Combahee Fields, north of the Combahee River. The Combahee River Unit consists of 112 ha of tidal marsh and 1063 ha of managed impoundments. Nemours is south of the Combahee Unit of the Refuge. The 3881-ha Nemours Wildlife Foundation contains diverse habitats, including 607 ha of remnant ricefields (managed impoundments), 115 ha of fresh and brackish tidal marshes, upland pine (*Pinus* spp.) and hardwood forests, bottomland hardwoods, and cypress (*Taxodium* spp.) - tupelo (*Nyssa* spp.) forests.

We selected three managed impoundments and three tidal marshes within the Refuge and Nemours, respectively; hence, our study sites were six managed impoundments and six tidal marshes (Figs. 1.1, 1.2). Sizes of study sites ranged from 23 to 170 ha. Management of impoundments focused on providing winter habitat for migratory waterfowl; thus, marshes were surrounded by a dike and interior canal, and the hydro-period was controlled by a ricefield trunk, water control structure (Williams et al. 2002). Access to impoundments and tidal marshes was by vehicle on dike roads or boat in rivers or canals. The first station from which call broadcast counts were taken was randomly established in each marsh, then additional stations were placed 200 m apart (Figs 2.1, 2.2). Each station had a 50-m radius. Because each study site was a different size, the number of stations placed in each was different, and the percentage of each study site surveyed was different. Overall, call broadcast survey stations covered 8% of managed impoundments and tidal marshes.

METHODS

Call Broadcast Survey. Surveys were conducted from May–June 2005 and 2006 (breeding season), and January–February 2006 (winter). Responses were recorded from each station once per season in each year. Boat access to all stations was limited to rising or high tide, so counts were performed relative to tidal cycle. Surveys began 30 min before sunrise and ended within 4 hr, or when one marsh was completed (Conway 2005). Each call broadcast sequence from each station was 12 min long. The first 6 min were passive (no rail call broadcast), followed by a 6-min call sequence: three 15-sec Clapper Rail call segments (*kik-kik-kik*) and three 15-sec King Rail call segments (*jupe-jupe-jupe*; Graves 2001). Between each 15-sec call segment, there were 45 sec of no broadcast. A portable CD player and speakers were used to broadcast calls from commercially available recordings (Walton and Lawson 1994). Rails were identified visually and aurally, and recorded within a 50-m radius (7854 m^2 plot). The azimuth to each detected rail was recorded to reduce the probability of double counting. For each season, we obtained the frequency of occurrence of rails – the number of King and Clapper Rails detected relative to the number of count stations in managed impoundments and tidal marshes.

Habitat Assessment. From each station, after each call broadcast count, we recorded water depth and salinity. Because surveys began during rising tides, water depths and salinity were recorded during rising or high tide. After all call broadcast surveys were completed each season, vegetation height was measured within randomly selected 7854 m^2 plots. The sum area of stations within which habitat variables were measured was 6% of tidal marshes and 5% of managed impoundments. Vegetation heights were recorded during all call broadcast seasons, using a 5-m cover pole, marked in 0.5-m increments (Griffith and Youtie 1988). An observer stood at the center of the survey station, a second person held the pole 4 m away in each cardinal direction, and the observer estimated vegetation height from the center (Griffith and Youtie 1988). The height of the tallest vegetation touching the pole was recorded (Dion et al. 2000, Davis 2004).

Horizontal cover (%) of plant species by category was recorded during winter and breeding seasons 2006. Categories of plant species were forbs, woody, grass, bare ground (soil), and debris (dead vegetation or dead floating vegetation). Two 0.5-m^2 rectangular frames were randomly placed within each selected 7854 m^2 plot and the percentage of horizontal cover in each frame provided by each species was estimated (Higgins et al. 1996). The total number of species within each frame was recorded and used to estimate species richness.

Data Analysis. We used a *t*-test (PROC *t*-TEST; SAS Institute, Inc. 1999) to detect differences in rail frequencies of occurrence between managed impoundments and tidal marshes, and to detect differences in each habitat variable between marsh types. For the 2005 breeding season, habitat variables were water depth, salinity, and vegetation height. For winter 2006 and the 2006 breeding season, habitat variables were water depth, salinity, vegetation height, horizontal cover of categories of vegetation, and plant species richness. Habitat data for each variable, except salinity, from Nemours and the Refuge were pooled, by marsh type (tidal or managed), each season. Salinity data were not pooled over Nemours and the Refuge because we wanted to test our expectation that salinity would differ between areas due to distance up river from the Atlantic Ocean, and our expectation that King Rail and Clapper Rail occurrence would be affected by salinity values (Meanley 1985, 1992; Graves 2001). Significance was set at $P \leq 0.05$ for all tests.

We used hierarchical linear models to explore the amount of variation in rail frequency of occurrence explained by habitat variables. We used a likelihood ratio test (Vuong 1989) to determine model selection. The likelihood ratio statistic was used to test the null hypothesis that competing models were equally close to the data processed, against the alternative hypothesis that one model was closer ($P \leq 0.05$; Vuong 1989). We tested two distribution models – Poisson and Zero-Inflated Poisson. Both Poisson models account for overdispersion in count data (Jansakul and Hinde 2002). We used general linear model procedures to identify habitat variables that explained the most variation in rail frequency of occurrence for winter 2006

(PROC GENMOD; SAS Institute, Inc. 1999). To explain the relative fit of each candidate model, we used Akaike's Information Criteria (AIC, Akaike 1973) with the small bias adjustment (AIC_c; Hurvich and Tsai 1989). The relative support for each candidate model was determined by calculating Akaike weights (*w*), where the highest value indicated the model with the most support (Burnham and Anderson 2002). We used the Akaike weights for two candidate models to assess the degree of evidence for one over the other (Anderson et al. 2000). Parameter estimates were used to assess the important confidence set of models (Rieman et al. 2006). We only used candidate models with Akaike weights that were within 10% of the highest weight (Thompson and Lee 2000).

Non-linear mixed model procedures were used to identify habitat variables that explained the most variation in rail frequency of occurrence for the 2006 breeding season (PROC NLMIXED; SAS Institute, Inc. 1999). We used a Zero-Inflated Poisson (ZIP) distribution because of the large number of zeros in the data. The ZIP distribution helps control for zero counts that are larger than expected (Jansakul and Hinde 2002). Non-linear mixed procedures with ZIP distribution produces two models – a presence model and abundance model (Hall 2000). The presence model determines the presence of at least one non-zero count in the data set. If there is an effect on the presence model, the abundance model determines what habitat variables affect the abundance of the nonzero count data (Hall 2000). We used AIC to select the highest supporting candidate models. We used parameter estimates to assess the important confidence set of models.

RESULTS

During all call playback surveys, we recorded 132 rail responses in tidal marshes and 12 rail responses in managed impoundments. During the 2005 and 2006 breeding seasons, and the

2006 winter season, frequency of occurrence of rails was greater in tidal marshes than in managed impoundments (Fig. 2.3). At Nemours, we detected no rails in managed impoundments during the 2005 or 2006 breeding season.

During the 2005 breeding season, salinity was higher (t = 9.8, P = 0.001, d.f. = 33) in managed impoundments than in tidal marshes at the Refuge (Fig. 2.4). At Nemours, salinity was not different (t = 0.60, P = 0.551, d.f. = 33) between managed impoundments and tidal marshes. Water depths were greater in tidal marshes (29 ± 7.6) than in managed impoundments (8.5 ± 2.5, t = -2.91, P = 0.004, D.F. = 68). Vegetation height was not different (t = 1.63, P = 0.112, D.F. = 34) between managed impoundments and tidal marshes (overall, 141.8 ± 6.3 cm).

During winter 2006, salinity was lower in tidal marshes than managed impoundments at the Refuge (t = 2.70, P = 0.011, D.F. = 33) and Nemours (t = 5.83, P = 0.0001, D.F. = 33; Fig. 2.4). Water depths were greater in tidal marshes than in managed impoundments (Table 2.1). Vegetation height was greater in tidal marshes than managed impoundments (Table 2.1). There was a greater percentage of grass cover and a lower percentage of bare ground (soil) in tidal marshes than in managed impoundments (Table 2.1). Species richness was not different between tidal marshes and managed impoundments (Table 2.1).

During the 2006 breeding season, salinity was higher in tidal marshes than in managed impoundments at the Refuge (t = -2.70, P = 0.011, D.F. = 33) and Nemours (t = -7.06, P = 0.0001, D.F. = 33; Fig 2.4). Water depths were greater in tidal marshes than in managed impoundments (Table 2.1). Vegetation height did not differ between tidal marshes and managed impoundments. Percentage of grass cover was greater and percentage of bare ground (soil) was lower in managed impoundments than in tidal marshes (Table 2.1). Plant species richness was lower in tidal marshes than in managed impoundments (Table 2.1).

Non-linear mixed models with ZIP and general linear models with Poisson were only developed for tidal marshes because of the low frequency of occurrence of rails in managed impoundments. During winter 2006, vegetation height, percentage of grass cover, and percentage of bare ground explained the most variation in rail frequency of occurrence in tidal marshes and had the greatest Akaike weight (w_i) (Table 2.2; 2.3). For the 2006 breeding season, the best model included water depth, vegetation height, and plant species richness (Table 2.4). Water depth had an effect on the presence model, while vegetation height and species richness had an effect on the abundance model (Table 2.5). Plant species richness did not contribute to the non-linear mixed model ($P = 0.1003$). Rails were detected more frequently in habitats with vegetation height between 100 and 200 cm, but we did not detect rails in habitats with vegetation heights >200 cm.

DISCUSSION

Tidal marshes within the Combahee River basin, in which the Refuge and Nemours are located, harbored more King and Clapper Rails than adjacent managed impoundments. Because previous studies found that rails selected areas with dense cover (Lewis and Garrison 1983; Gaines et al. 2003) and shallow water (Meanley 1985; Eddleman and Conway 1998), we expected that rails in our study area would also follow this pattern of habitat selection. We hypothesized that rails would not use managed impoundments because we predicted that water depths, vegetation structure, and horizontal cover in managed impoundments would not be ideal for rails. In fact, water depths were deeper in tidal marshes than in managed impoundments (Table 2.1). Determining water depth in tidal marshes was difficult because water depth measurements were taken while tide was rising, thus frequency of occurrence was not assessed at low tide in tidal marshes. We could not gain access to tidal marshes at low tide, but optimally, surveys should be conducted at different tidal cycles in tidal marshes.

Salinity measurements at the Refuge during breeding seasons 2005 and 2006, and winter 2006 supported others who concluded that King Rails are found within brackish to freshwater marshes (Meanley 1992; Graves 2001). Clapper rails typically use brackish to saline marshes (Eddleman and Conway 1998; Graves 2001), and were detected more frequently at Nemours.

During winter 2006, vertical structure was higher in tidal marshes than managed impoundments. King and Clapper Rails need high vertical structure during the winter for movement and cover (Reid et al. 1994; Eddleman and Conway 1998), and the tidal marshes in our study provided these needs. Tidal marshes had a greater percentage of grass and a lower percentage of bare ground cover than managed impoundments. Studies show that rails are associated with marsh habitats that are dominated by grass during the winter (Reid et. al. 1994; Eddleman and Conway 1998), but information on bare ground cover is lacking.

During breeding season 2006, widgeongrass (*Ruppia maritima*) dominated managed impoundments making mobility difficult for Clapper Rails. Tidal marshes had low species richness consisting of cordgrass at Nemours and cattails at the Refuge. Data on plant species richness effects upon rail frequency of occurrence is lacking. The percentage of grass and bare ground cover during 2006 breeding season was the same as winter 2006, suggesting that rails are more frequently in habitats that provide high percentages of grass and low percentages of bare cover in all seasons.

Vegetation height, percentage grass cover, and percentage bare ground were within the best supporting model in winter 2006 (Table 2.2). Rails had a greater frequency of occurrence in vegetation over 145 cm and in tidal marshes where the percentage of grass was ≥50% and bare ground cover was ≤50%. Relatively tall vegetation provides cover for rails (Reid et al. 1994; Eddleman and Conway 1998) and grass is an important species providing this cover in marsh habitats (Hinojosa et al. 2002; Gaines et al. 2003). These findings support our hypothesis that rail occurrences are greater in dense vegetation and horizontal cover comprised primarily of grass; however, bare ground cover may play a large role. Percentage of bare ground cover was a part of both confidence sets of models used for the parameter estimates (Table 2.3).

Water depth, plant species richness, and vegetation height were in the best supporting model in tidal marshes during breeding season 2006 (Table. 2.4). All responses were in areas with water depths ≤10 cm, which may suggest rails call during feeding periods at low tide. Studies show rails feed when mudflats are exposed in tidal marshes (Reid et al. 1994; Eddleman and Conway 1998). Studies also show uninterrupted tidal flow is important to maintain the habitat structures that are preferred by rails (Meanley 1992; Eddleman and Conway 1994). This result supports our hypothesis that King and Clapper Rail occurrence would be more frequent in shallower water.

Rail occurrences were associated with vegetation heights within 100-200 cm during breeding season 2006, providing the dense vegetation for nesting and cover needed by rails (Benoit and Askins 2002; Gaines et al. 2003). The relatively tall vegetation structure may provide protection from nest predators and high tide. These results supported our hypothesis that the occurrence of King and Clapper Rails would be greater in relatively tall, grassy vegetation.

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Table 2.1. Habitat variables measured in winter and breeding seasons 2006, in tidal marsh and managed impoundment study sites at Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort, S.C. Data from the Refuge and Nemours were pooled, and differences between tidal marsh and managed impoundment sites were detected with a Student's *t*-test ($P < 0.05$).

Season	Habitat variable	DF	*P*-value	Managed impoundment Mean ± SE	Tidal marsh Mean ± SE
Winter	Water depth (cm)	28, 40	0.0001	23 ± 2.7	54 ± 6.1
	Vegetation height (cm)	22, 27	0.0001	79 ± 10.3	173 ± 13
	Horizontal cover of grass (%)	22, 27	0.0001	28 ± 4.8	76 ± 3.5
	Bare ground (soil; %)	22, 27	0.0001	51 ± 6.7	14 ± 2.5
	Species richness (number of species)	22, 27	0.2261	1.8 ± 0.2	1.4 ± 0.1
Breeding	Water depth (cm)	28, 40	0.0001	8.5 ± 2.5	29 ± 7.6
	Vegetation height (cm)	22, 27	0.9811	154 ± 6.9	154 ± 8.9
	Horizontal cover of grass (%)	22, 27	0.0010	54 ± 7.1	86 ± 4.9
	Bare ground (soil; %)	22, 27	0.0316	15 ± 4.5	4 ± 1.8
	Species richness (number of species)	22, 27	0.0005	2.8 ± 0.2	1.6 ± 0.2

Table 2.2. Models estimating habitat variables' effect on frequency of occurrence of rails in tidal marshes during winter 2006 at Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, S.C. Included are number of parameters (K), Akaike Information Criterion values (AIC), small bias adjustment AIC (AIC_c), difference in AIC from the best fitting model (Δ_i), and AIC weights (w_i) for each candidate model. The best supporting candidate model has the highest Akaike weight.

Model candidate	K	AIC	AIC_c	Δ_i	w_i
Grass+Soil+Height[1,2]	4	20.4	22.6	0.0	0.590[3]
Soil+Height	3	22.8	24.1	1.5	0.279
Grass+Soil+Richness	4	25.2	27.4	4.8	0.054
Soil	2	26.8	27.4	4.8	0.054
Grass+Soil	3	28.6	29.9	7.3	0.015
Grass+Soil+WD	4	29.4	31.6	9.0	0.007
Grass+Height	3	32.6	33.9	11.3	0.002
Global	9	25.2	39.0	16.4	2E-04
Richness	2	42.2	42.8	20.2	2E-05
WD+Height+Richness	4	41.0	43.2	20.6	2E-05
WD+Height	3	43.0	44.3	21.7	1E-05
WD+Richness	3	43.4	44.7	22.1	9E-06
Height	2	44.4	45.0	22.4	8E-06
WD	2	46.2	46.8	24.2	3E-06
Grass	2	49.2	49.8	27.2	7E-07

[1]Grass = percentage of grass horizontal cover, Soil = percentage of bare ground, Height = vegetation height (cm), Richness = plant species richness, WD = water depth (cm)

[2]All models followed a Poisson distribution.

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

Table 2.3. Parameter estimates for the two best supporting models that show the important candidate models that affected the frequency of occurrence of rails in tidal marshes during winter 2006 at Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, S.C. Estimates and confidence intervals are standardized as number of rails detected per number of count stations. Estimates are relative to the baseline for each parameter. Parameters and baselines are described in Table 2.2.

Model candidate[1]	Parameter	Parameter estimate	SE	95% confidence interval Lower	Upper
Grass+Soil+Height					
	Intercept	-2.39	1.83	-5.98	1.19
	Grass	-0.77	0.37	-1.50	-0.05
	Soil	1.32	0.38	0.57	2.07
	Height	0.02	0.01	0.01	0.03
Soil + Height					
	Intercept	-5.70	1.54	-8.72	-2.67
	Soil	1.81	0.39	1.05	2.57
	Height	0.01	0.01	0.00	0.02

[1]General linear models with Poisson distribution were used

Table 2.4. Models estimating the habitat variables' effect on frequency of occurrence of rails in tidal marshes during the 2006 breeding season at Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, S.C. Included are number of parameters (K), Akaike Information Criterion values (AIC), small bias adjustment AIC (AIC_c), difference in AIC from the best fitting model (Δ_i), and AIC weights (w_i) for each candidate model. The candidate model with the highest Akaike weight is the best supporting model.

Model candidate	K	AIC	AICc	Δi	w_i
WD[1],Richness+VH[2]	5	77.8	81.3	0.0	0.42[3]
WD,VH	4	79.2	81.4	0.1	0.40
WD+Richness,VH	5	78.9	82.4	1.1	0.24
WD,Richness	4	84.1	86.3	5.0	0.03
Grass+Soil+WD,VH	6	82.3	87.5	6.2	0.02
WD,Richness+WD	5	86.1	89.6	8.3	0.01
Grass+Soil,VH	5	86.1	89.6	8.3	0.01
Grass+Soil+Richness+WD,VH	7	82.8	90.3	9.0	0.00
Grass,VH	4	88.2	90.4	9.1	0.00
Soil,VH	4	88.4	90.6	9.3	0.00
WD	4	89.6	91.8	10.5	0.00
WD+Richness	6	87.2	92.4	11.1	0.00
Richness	4	90.8	93.0	11.7	0.00
Grass+Soil+Richness,Grass+Soil+Richness	8	87.5	97.8	16.5	0.00
Soil	4	96.9	99.1	17.8	0.00
Grass	4	97.0	99.2	17.9	0.00
Grass+Soil,Grass+Soil	6	99.2	104.4	23.1	0.00
Global, Global	14	90.3	142.8	61.5	0.00

[1]WD = water depth, Richness = plant species richness, VH = vegetation height, Grass = percentage of grass horizontal cover, Soil = percentage of bare ground

[2]All models with commas contain ZIP and mean Poisson distributions, models without commas are ZIP only

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

Table 2.5. Parameter estimates for the three best supporting models, showing the important candidate models that affected the frequency of occurrence of rails in tidal marshes during the 2006 breeding season at Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort County, S.C. Estimates and confidence intervals are standardized as number of rails detected per number of count stations. Estimates are relative to the baseline for each parameter. Parameters and baselines are described in Table 2.4.

					95 % confidence interval	
Model candidates	Parameter sub-models	Parameters	Parameter estimate	SE	Lower	Upper
[1]WD,Richness+VH	[2]Presence sub-model	Intercept	-5.58	0.20	-6.09	-5.20
		WD	-2.06	0.20	-2.48	-1.64
	Abundance sub-model	Intercept	4.25	0.77	2.66	5.85
		Richness	-0.61	0.36	-1.34	0.13
		VH	-0.02	0.01	-0.03	-0.004
WD,VH	Presence sub-model	Intercept	-18.19	0.32	-18.85	-17.52
		WD	17.19	0.32	16.53	17.86
	Abundance sub-model	Intercept	3.81	0.75	2.25	5.37
		VH	-0.02	0.01	-0.03	-0.01
WD+Richness,VH	Presence sub-model	Intercept	-6.37	0.23	-6.85	-5.88
		WD	36.56	0.23	36.08	37.03
		Richness	-30.71	0.23	-31.19	-30.23
	Abundance sub-model	Intercept	4.01	0.69	2.58	5.45
		VH	-0.02	0.01	-0.03	0.03

[1]WD = water depth, Richness = plant species richness, VH = vegetation height

[2]Non-liner mixed models were used. The presence sub-model = ZIP, and abundance sub-model = mean Poisson.

Figure 2.1. Aerial photograph (1999) of Ernest F. Hollings ACE Basin National Wildlife Refuge, Beaufort County, S.C. Locations of call broadcast survey stations within each study site are shown. Surveys were conducted during the 2005 and 2006 breeding seasons, and winter 2006.

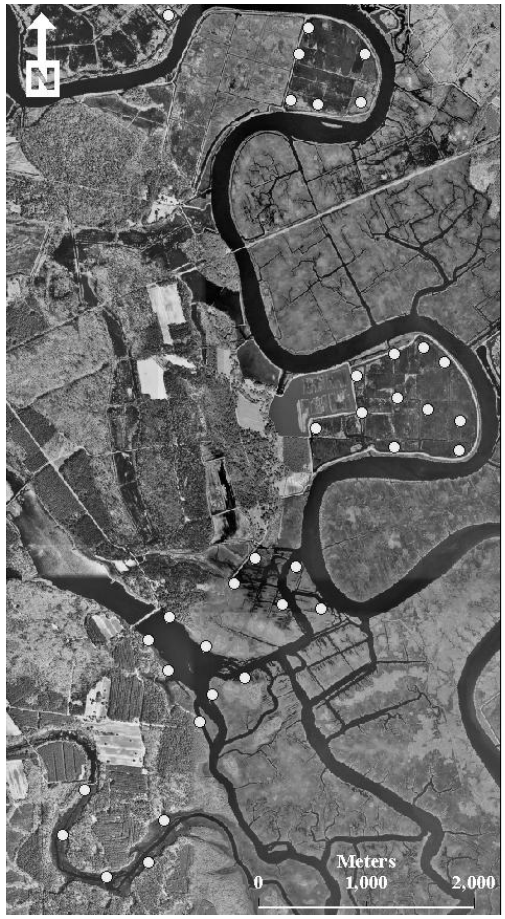

Figure 2.2. Aerial photograph (1999) of Nemours Wildlife Foundation, Beaufort County, S.C. Locations of call broadcast survey stations within each study site are shown. Surveys were conducted during the 2005 and 2006 breeding seasons, and winter 2006.

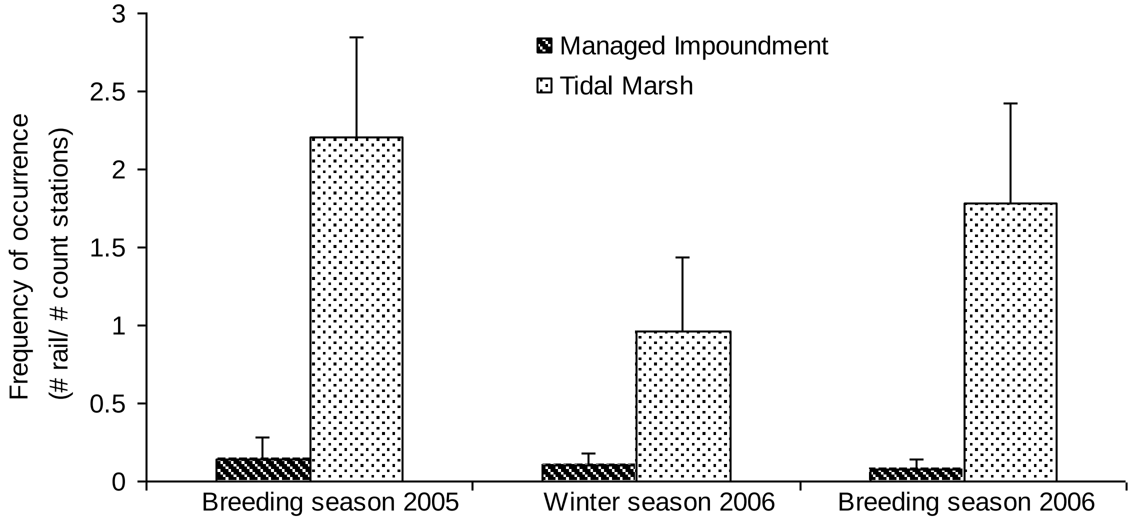

Figure 2.3. King and Clapper Rail frequency of occurrence from call broadcast surveys conducted in managed impoundments and tidal marshes at the Ernest F. Hollings ACE Basin National Wildlife Refuge and Nemours Wildlife Foundation, Beaufort, S.C., during May–June (breeding season) 2005 and 2006, and January–February (winter) 2006. Rails were detected more frequently in tidal marshes than in managed impoundments during each season (Student *t*-tests, $P < 0.05$). Error bars represent 95% confidence intervals.

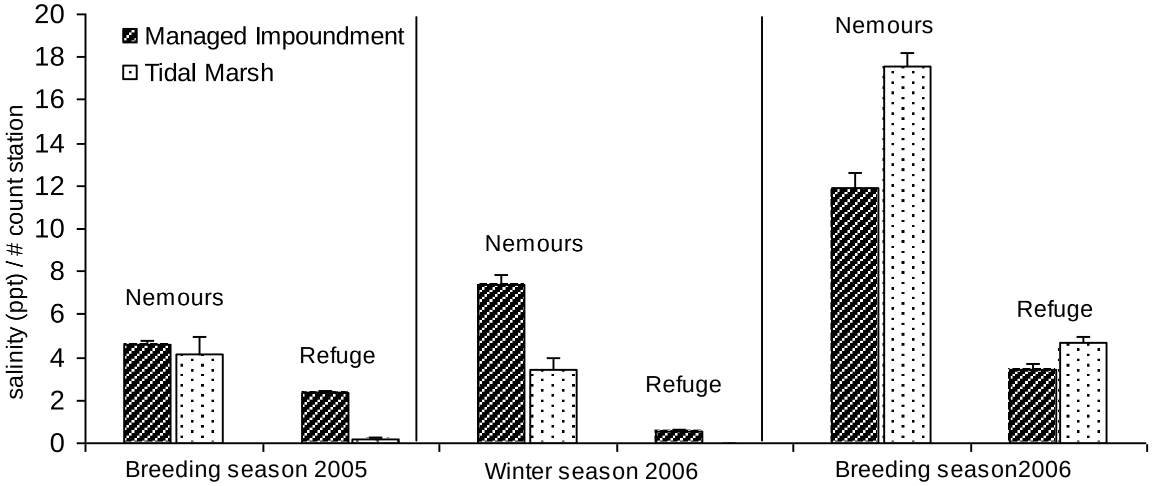

Figure 2.4. Salinity estimates within managed impoundments and tidal marshes of Ernest F. Hollings ACE Basin National Wildlife Refuge (Refuge) and Nemours Wildlife Foundation (Nemours) Beaufort County, South Carolina, during 2005 and 2006 breeding seasons and winter 2006. Salinity was taken during call broadcast surveys at each count station.

CHAPTER 3

DISTRIBUTION OF RAILS IN MANAGED IMPOUNDMENTS AND TIDAL MARSHES OF SOUTH CAROLINA[1]

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Introduction

King (*Rallus elegans*) and Clapper (*R. longirostris*) Rails are marsh-dwelling birds that exhibit strong site fidelity. Habitats selected by King Rails are freshwater and brackish marshes, and habitats selected by Clapper Rails are brackish and saline marshes (Meanley 1992, Eddleman and Conway 1998). They feed exclusively on invertebrates such as fiddler crabs (*Ulca* sp.), grasshoppers (Acridadae), crayfish (Cambaridae), and snails (Ampullariidae) (Eddleman and Conway 1994), and may help stabilize local invertebrate populations (Gaines et al. 2003). Because of their exclusive use of marshes and selection for invertebrate prey, rails are good indicators of marsh health (Gaines et al. 2003). Regrettably, the marsh habitat upon which rails rely is being lost rapidly. Only 12% of the area of the United States remains in wetlands (Zedler and Kercher 2005). The estimated wetland loss between 1986 and 1997 was 23,674 ha annually; 5,848 ha of this annual loss were estuarine, emergent wetlands (Dahl 2000). Rail populations appear to be suffering as a consequence of wetland loss and degradation.

Clapper Rails are found throughout North America, and consist of 8 subspecies (Eddleman and Conway 1994). The Yuma (*R. l. yumanensis*), Light-footed (*R. l. levipes*), and California (*R. l. obsoletus*) Clapper Rail subspecies are federally endangered in the United States (Conway and Gibbs 2005). All subspecies, except the Northern Clapper Rail (*R. l. crepitians*), are non-migratory (Eddleman and Conway 1994). King Rails in the South Atlantic Coastal Zone (SACZ) are considered the only non-migratory King Rails in the U.S. (Meanley 1992). Thirteen states, comprising most of the migratory range of the King Rail, list the King Rail as threatened or endangered (Cooper 2006).

Managed wetlands of the SACZ may provide important habitat for King and Clapper Rails; however, these marshes are intensely managed for migrating and wintering waterfowl.

Most management objectives focus on increasing waterfowl abundance during winter. It is not known to what extent rails use managed wetlands (Epstein and Joyner 1988) because tidal marshes are generally located adjacent to many managed impoundments. Movement of rails between the two marsh types is likely.

Little is known about non-migratory King Rail movement during the breeding season (Meanley 1992). Clapper Rail home range size may vary greatly among seasons and years at a given site if production of preferred foods is poor (Eddleman and Conway 1994). Movement of Clapper Rails is more restricted during the breeding season (Conway 1990). Little is known about habitat selection by rails, especially relative to managed and unmanaged coastal marshes of the SACZ.

Radio-telemetry is the most reliable method of determining rail movement patterns (Eddleman and Conway 1994); however, few radio telemetry studies have been conducted on King Rails, and many radio-telemetry studies on Clapper Rails have focused on the endangered subspecies (Conway 1990, Hinojosa et al. 2002) in the western United States. These studies were on Yuma Clapper Rails that use freshwater marshes, quite different from the coastal marshes used by eastern Clapper Rails. Cumbee (2003) radio-tracked Clapper Rails within marshes associated with Turtle Creek in Brunswick, Georgia. The average home range of Clapper Rails in this area was 0.28 ha, and ranged from 0.19 ha to 13.26 ha (Cumbee 2003).

We studied radio-tagged King and Clapper Rails to examine their habitat selection and movement relative to managed impoundments and tidal marshes. Our specific objectives were to estimate the home range size, habitat selection, and movement of rails between managed impoundments and tidal marshes during the breeding season. We suspected that habitat selection and movements of King and Clapper Rails would be restricted to tidal marshes where emergent vegetation provided cover and nesting sites. Further, we expected that King Rails would use fresh to brackish marshes and Clapper Rails would use brackish to saline marshes. This work addressed gaps in data concerning rail ecology and biology in the SACZ. The larger goal of this research was to provide suggestions for multi-species management of the numerous hectares of managed, impounded marshes in this region.

Study Area and Methods

We conducted our study within two managed properties, the Ernest F. Hollings Ashepoo-Combahee-Edisto (ACE) Basin National Wildlife Refuge (Refuge) and Nemours Plantation (Nemours), Beaufort and Colleton Counties, South Carolina. The Refuge consists of approximately 4781 ha that include 1598 ha of tidal marsh, 1214 ha of managed wetland impoundments, 486 ha bottomland hardwoods, 1133 ha of upland forests and 283 ha of grassland and shrub areas. The Refuge is divided into the Edisto River Unit and Combahee River Unit. We used the Combahee River Unit because of its proximity to Nemours and because both this unit and Nemours sites are on the Combahee River. The Combahee Unit includes 1847 ha and has two main subunits – Bonny Hall, south of the Combahee River, and Combahee Fields, north of the Combahee River. Nemours is located south of the Refuge and includes 3881 ha of diverse habitats, including 607 ha of remnant ricefields, now managed impoundments for waterfowl, 115 ha of tidal saline and brackish marshes, upland pine and hardwood forests, bottomland hardwoods, and cypress (*Taxodium* spp.) – tupelo (*Nyssa* spp.) forests. The Combahee River flows through both the Refuge and Nemours, to St. Helena Sound where all three rivers of the ACE Basin meet and converge with the Atlantic Ocean.

We trapped rails in three managed impoundments at the Refuge, and three tidal marshes each at the Refuge and Nemours. We selected trap sites in each marsh that were large enough for 20 m of trapping material. We chose non-flooded sites within marshes, and areas within each marsh where rails were heard or seen.

Trapping procedure

We used a cloverleaf trap design with drift fences to catch rails (Kearns et al. 1998). Rails that encountered the drift fence followed the fence into the funnel, and then a 15-cm ramp ensured the rails did not escape (Kearns et al. 1998). Once rails were in the cloverleaf trap, they found their way down a 10-cm ramp into a catch box (Kearns et al. 1998). A trap line consisted of two cloverleaf traps with a drift fence between them leading to each trap. We used three trap lines during the breeding season, rotating them among trap sites.

Trap lines were set from March through May 2006, and were placed in all tidal marshes at the Refuge and Nemours, and in three managed impoundments at the Refuge. We did not trap at all managed impoundments because they were not all accessible. Traps were set in the morning and checked twice a day for five days or until we caught two rails. A Johnny Stewart Mini Wildlife Caller with Long Range Speakers (Forestry Suppliers, Inc., Jackson, Mississippi) was placed at each trap line to increase capture probabilities (Kearns et al. 1998). This playback system broadcasted a 1-min recorded call of the King Rail and a 1-min recorded call of the clapper rail every 3 min for 6 hours each day.

Radio attachment and tracking

We fitted each rail with a uniquely numbered, size 5 aluminum band (USGS BBL, Laurel, Maryland), and a 6-g, 18-month radio-transmitter (Model R1-2C, Holohil Systems Ltd., Ontario, Canada) attached with a leg-loop harness (Rappole and Tipton 1991; Powell et al. 1998;

Haramis and Kearns 2000). To separate King from Clapper Rails, we recorded weight; bill length from nares to tip; tarsus length; middle toe length, not including the nail; tail length; and wing chord of each rail (Appendix B). We released each rail at the trap site after marking and measuring. We began recording radio-locations, 1 day after release. We used the homing technique (White and Garrott 1990) to locate each rail with an ATS radio receiver (Model R4000, Advanced Telemetry Systems, Inc., Isanti, Minnesota) and 3-element Yagi antenna (148-151.999 MHz). The tracking period was stratified to incorporate each period of the day (Conway 1990). We tracked and located rails three times per day – morning (9:00-11:00 hrs), midday (13:00-15:00 hrs), and evening periods (18:00-20:00 hrs). Each tracking period was 4 hrs apart and included a low tide and high tide period. We tracked each rail four days per week (every other day), except when severe thunderstorms occurred. Locations were recorded using a handheld Global Positioning System unit (Model Magellan Map 330, Magellan, Santa Clara, CA).

Home range and movement analysis

We considered each rail an experimental unit and each of its locations an observation or sample unit; hence, the number of locations for each rail was the sample size ($n \geq 30$; Garton et al. 2001). Sample sizes differed among rails due to weather or other events that precluded tracking for a day or more.

We used fixed kernel home range analysis (Hooge et al. 1997) to assess use of managed impoundments versus tidal marsh. To assess home range size for each rail, we estimated fixed kernel home range and minimum convex polygon using Animal Movement Extension of ArcView (Ver. 1.1, USGS, Anchorage, AK, MCP; Hooge et al. 1997). The MCP home range size was used in comparisons with previous home range studies on rails. We used the Animal

Movement Extension (Ver. 1.1, USGS, Anchorage, AK) to examine selection of habitat types (Hooge et al. 1997). Movement distances between each location identified for each rail from March–May 2006 was obtained with Hawths Analysis Tool in ArcGIS (Ver. 3.26; Beyer 2006). Average daily movement was estimated using a modified technique (Yoder et al. 2004). We used intervals to eliminate bias due to different sample sizes (number of locations) among rails (Conway 1990). We used 14-day intervals for each rail, and then calculated average movement (m) within each interval. These 14-day intervals consisted of days during which locations were recorded three times.

Results

We captured and radio-tagged five King and six Clapper Rails. Locations were obtained for 10 rails, but we obtained at least 30 locations for only one King and two Clapper Rails; thus, data from these rails were used in home range analyses. We did not estimate a home range size for rails with fewer than 30 locations (Garton et al. 2001).

Eight radio-tagged rails were lost during the study. One Clapper Rail was killed by a mink (*Mustela vision*) and two Clapper Rails slipped out of their radio-harness. One Clapper Rail and two King Rails left the study site or were not detected. One Clapper Rail used in the analyses left the study site or was not detected and the other Clapper Rail used in the analyses drowned. Overall the rail loss in this study was 73%. We lost all Clapper Rails and two King Rails.

Of the five captured King Rails on the Refuge, four moved from the Refuge to a complex of managed impoundments on private property. We obtained no additional locations from these rails because we did not have permission to work on the private property. The remaining King Rail was caught in tidal marsh and moved to managed impoundments. All locations (n = 67) were in four unflooded, managed impoundments within the Refuge, and were obtained from 26 April – 27 July 2006. Most locations (*n* = 55) were in one managed impoundment (kernel home range = 10 ha; Fig. 3.1). The overall kernel home range size of this rail was 31.3 ha, and its MCP was 90.5 ha.

All six Clapper Rails remained in tidal marshes at Nemours. Kernel home range sizes of two Clapper Rails were 3.6 ha (*n* = 34) and 0.7 ha (*n* = 37), respectively. The MCP home range for each Clapper Rail was 7.3 ha and 0.4 ha, respectively. Locations of the two Clapper Rails were within the edge of tidal marshes on the Combahee River (Figs. 3.2 and 3.3).

Five 14-day intervals were used for the King Rail (Fig. 3.4). Average daily movement for each Clapper Rail was determined using three 14-day intervals (Fig. 3.5.). The maximum distance traveled in one day by the King Rail was 238 m, and the minimum distance moved was 4.5 m. The average maximum distance traveled in one day by the Clapper Rails was 278.5 m (SE = 116 m), and the average minimum distance moved was 10.5 m (SE = 0.6).

Discussion

We were minimally successful at trapping rails within our study area. The traps and call broadcast device were effective, but our sampling effort should have been increased to capture more rails. We obtained enough radio-locations ($n \geq 30$) of one King Rail and two Clapper Rails to estimate three home range sizes. Hence, our results have limited application to the extensive SACZ area. On the other hand, our data are the first for rails in the region and provided insight into possible habitat selection behavior of King and Clapper Rails.

The large percentage of rails lost during this study may not be unusual in the SACZ. Cumbee (2003) lost 72% of Clapper Rails in Georgia due to predation and loss of transmitters. Raccoons (*Procyon lotor*) are probably the most dominant predator in the SACZ (Eddleman and

Conway 1998). Avian predators such as Bald Eagles (*Haliaeetus leucocephalus*), Red-Tailed Hawks (*Buteo jamaicensis*), and Barn Owls (*Tyto alba*) were present in the ACE Basin during this study, and may have preyed on rails.

The radio-tagged King Rail at the Refuge was located only in managed impoundments of the Combahee Fields Unit. These marshes were not under typical management for migratory and wintering waterfowl. They were characterized by brackish water in canals and ditches (4 to 5 ppt salinity; McGregor 2007), emergent, aquatic vegetation, and no water on the marshbed. An interspersion of mudflats and tall, emergent vegetation, typified the marsh used by the King Rail. Others have characterized marshes used by King Rails similarly (Reid et al. 1994). Non-migratory King Rails in the SACZ may select habitat that is similar to that selected by migratory King Rails in the Gulf Coast region which used inland freshwater wetlands during the breeding season (Meanley 1992). Managed impoundments in the SACZ may provide flood-free nesting habitat, especially during spring high tides.

Three King Rails survived to the end of the breeding season – one on the Refuge and two on private property. The MCP home range size of the King Rail on the Refuge was relatively large; thus, it may have been a male and/or a juvenile (Zembel et al. 1989; Legare and Eddleman 2000).

The average daily movement of the King Rail ranged from 65 to 140 m, and it used one managed impoundment for most of the breeding season. Long distance movement (1977 m) by the King Rail was associated with severe thunderstorms. Another study on nesting rails suggested that rails move long distances after nest failure (Cumbee 2003).

The radio-locations of the King Rail were in managed impoundments at the Refuge. Conversely, frequency of occurrence of King Rails from call playback surveys was higher in tidal marshes (McGregor 2007). Perhaps King Rails in managed impoundments do not call frequently, or they move away from the call playback recording and call from tidal marshes. These preliminary results do not support the hypothesis that King Rails are restricted to tidal marshes, especially when water is drained from the impoundment bed during spring (March – May).

All vegetation within tidal marshes used by Clapper Rails was smooth (*Spartina alterniflora*) and big (*S. cynosuroides*) cordgrass, typical habitat selected by eastern Clapper Rails (Eddleman and Conway 1994). Clapper Rails did not use managed impoundments, likely because the managed impoundments on Nemours did not provide the interspersion of mudflats for foraging and tall vertical structure for nesting that Clapper Rails prefer during the breeding season (Lewis and Garrison 1983; Gaines et al. 2003). At low tide, the Combahee River provided mudflats along its edge. Clapper Rail nests are generally within 15 m of tidal creeks or 1.7 m from open water (Eddleman and Conway 1994; Gaines et al. 2003). Tidal marshes in this area may provide optimal nesting habitat.

One of the two MCP home ranges of Clapper Rails in this study (7.3 ha) was larger than the average MCP home range reported in other studies (0.4 to 1.8 ha; Eddleman and Conway 1998; Cumbee 2003). Possibly, the larger home range resulted from the rail losing its nest during severe weather, then re-nesting at a second location (Cumbee 2003).

Clapper Rail daily movements were within narrow, tidal marsh bordering the Combahee River. None of the rails was located across the river (Figs. 3.2; 3.3). Average daily movement (n = 2 rails, 66.8 m, SE = 13 m) was less than that reported in other Clapper Rail studies (263 m; Zembal et al. 1989; Conway 1990); however, these studies were on western Clapper Rails.

Radio-locations, home range placement, and daily movement of Clapper Rails supported our hypothesis that Clapper Rails would use only tidal marshes.

Our preliminary data suggest that both managed impoundments and tidal marshes in the ACE Basin provide habitat for King Rails. It is likely that King Rails will use freshwater marshes and Clapper Rails will use brackish marshes, thus separating their ranges; however, as salinity varies, ranges of both rails may overlap within the intermediate brackish marsh (Graves 2001). Further assessments of larger numbers of rails will provide greater understanding of rail distribution, habitat use, and causes of mortality.

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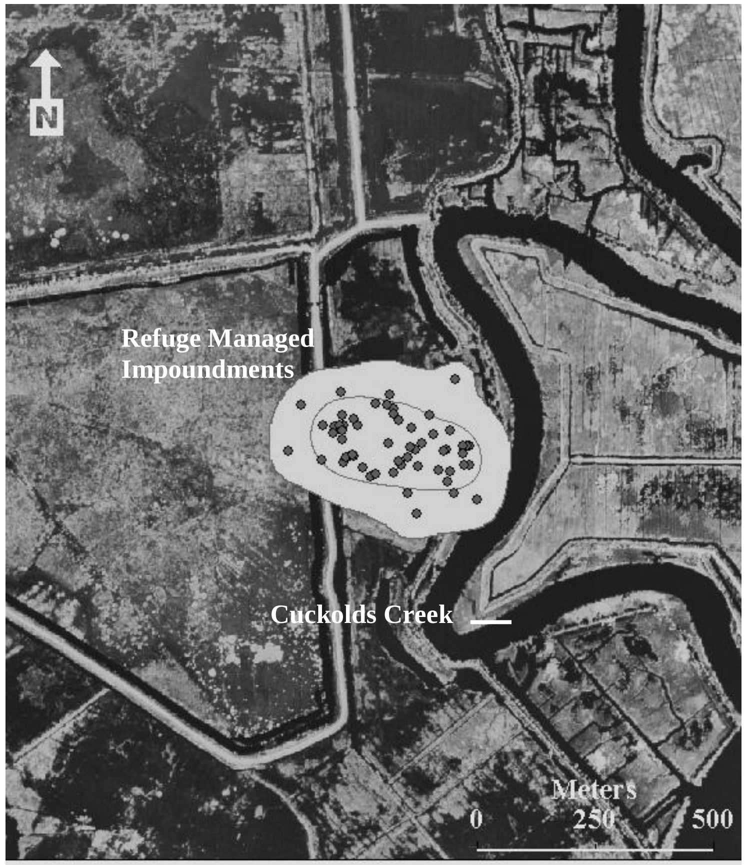

Figure 3.1. Aerial photograph (1999) of a 95% and 50% Kernel Home range size (10 ha) of a King Rail within two managed impoundments of the Ernest F. Hollings ACE Basin National Wildlife Refuge's managed impoundment complex, Beaufort County, S.C. The King Rail was radio-tracked from May- July 2007. This map does not include all King Rail locations or their entire home range size across the Refuge's managed impoundment complex.

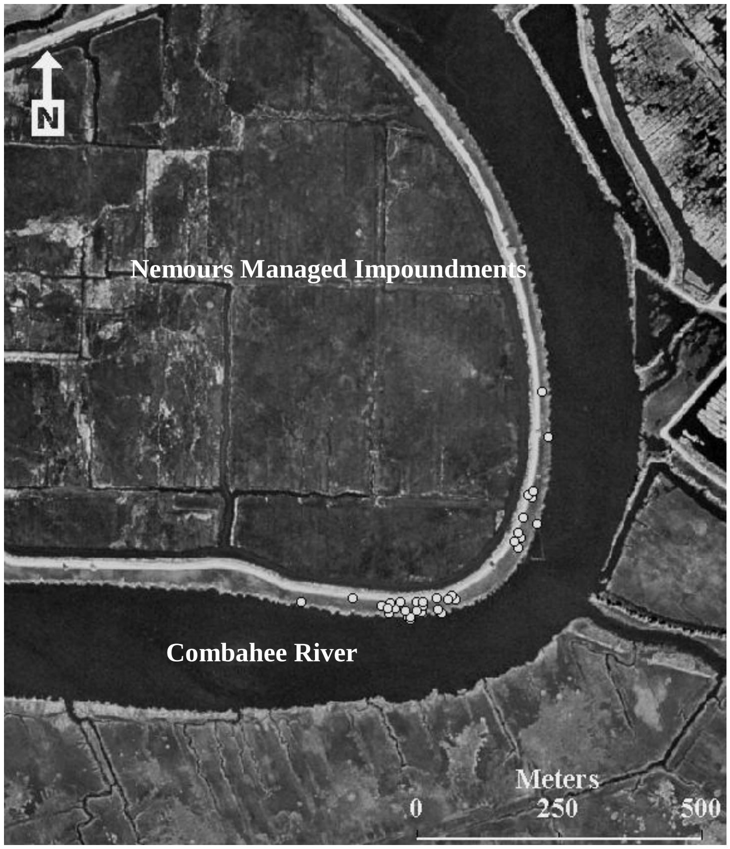

Figure 3.2. Aerial photograph (1999) of Clapper Rail locations (N = 34) located along a small edge of tidal marsh along the Combahee River and adjacent to Nemours Wildlife Foundation (Nemours) managed impoundments during April-June 2007, Beaufort County, S.C. No locations were located across the Combahee River or within Nemours managed impoundments.

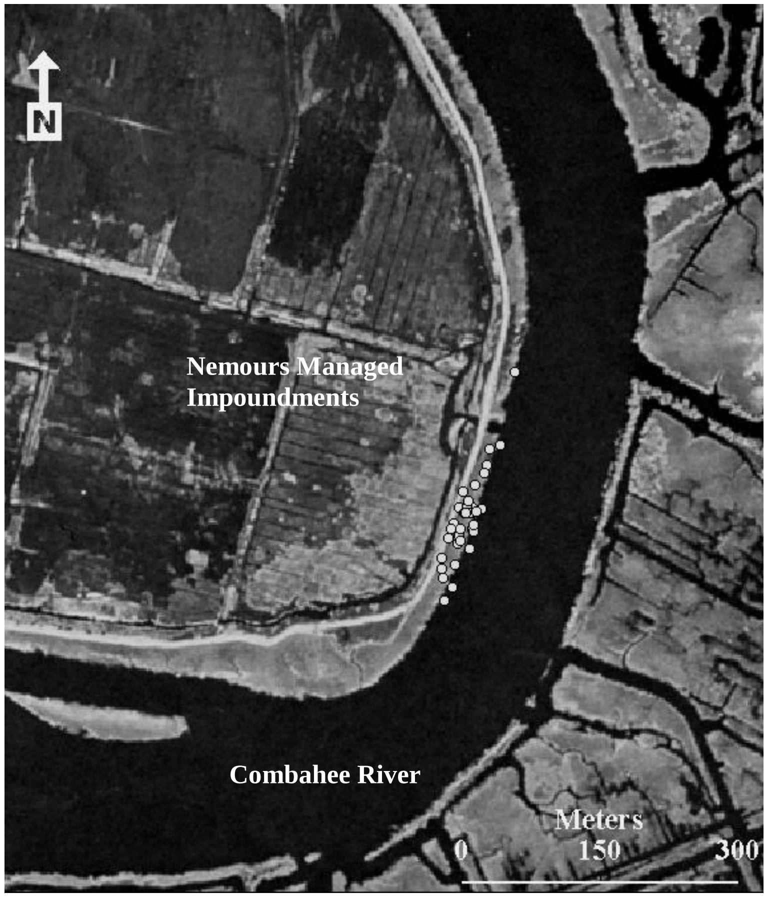

Figure 3.3. Aerial photograph (1999) of Clapper Rail locations (N = 37) in tidal marsh along the Combahee River and adjacent to Nemours Wildlife Foundation managed impoundments in Beaufort County, South Carolina. Locations were taken from April- June 2006. This Clapper Rail's locations are north of those in Figure 3.2.

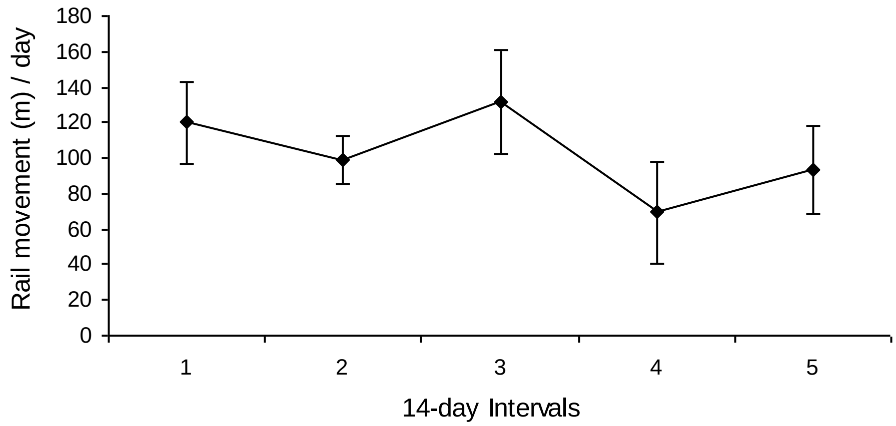

Figure 3.4. Daily average movements of a King Rail from May-July 2006 at Ernest F. Hollings ACE Basin National Wildlife Refuge, Beaufort County, South Carolina. Daily averages were taken in each 14-day interval. Error bars represent the 95% confidence limits of daily averages for each 14-day interval.

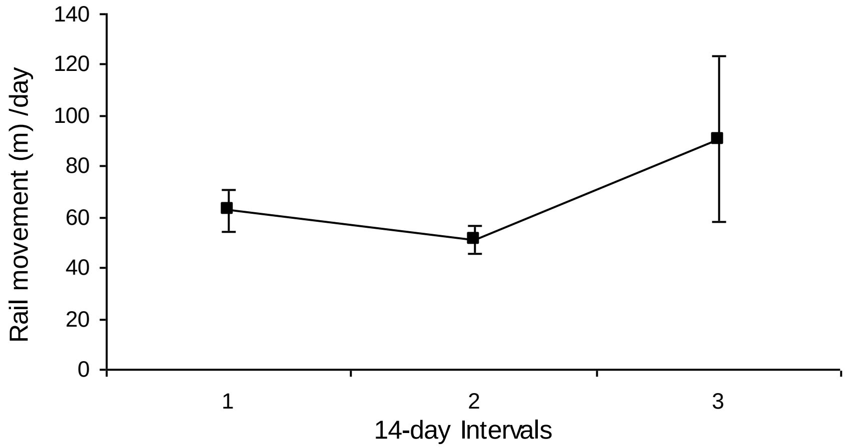

Figure 3.5. Daily average movements of two Clapper Rails from April-June 2006 at Nemours Wildlife Foundation, Beaufort County, South Carolina. Daily averages were taken for each 14-day interval for Clapper Rails. Error bars represent the 95% confidence limits of daily averages for each 14-day interval.

CHAPTER 4

CONCLUSION

Call broadcast surveys provide an index of abundance that can be used to compare presence and absence of rails between habitat types (Conway 2005). The frequency of rail responses in this study indicated a high probability of presence of rails in the tidal marshes and high probability of absence of rails in managed impoundments in ACE Basin, SC. These results corresponded with our hypothesis that rails would have higher frequencies of occurrence in tidal marshes. Tidal marshes meet the habitat requirements for King and Clapper rails in the South Atlantic Coastal Zone.

Rails need dense vegetation provided by tidal marshes for cover during the winter (Clack and Lewis 1983). We hypothesized that rails would not use managed impoundments because water depths, vegetation structure and horizontal cover in managed impoundments would not be ideal for rails. We found that managed impoundments had lower water depth in all seasons, but low frequency of occurrence of rails. This study compared water depth in two different marsh types. Tidal marshes have inconsistent water levels due to constant tidal cycles. Water depths in tidal marshes were taken after each call broadcast survey; therefore, tides were rising when water depths were taken. Hence, frequency of occurrence was not assessed at low tide in the tidal marshes when numbers of rails may increase. To better understand how water depth affects occurrence of rails between managed impoundments and tidal marshes, surveys should be conducted at high and low tide in tidal marshes. A large percentage of horizontal cover provided by grasses and low percentage of bare ground (soil) may provide dense horizontal cover for mobility by rails to from escape predators. High vertical structure provides cover for rails during the winter season.

During the breeding season, horizontal cover (%) was important in tidal marshes, and rails responded well in tidal marshes that had ≥145 cm of vertical structure. Low water depths provided mudflats for foraging. Tidal cycles provide periods of foraging, while horizontal cover in tidal marsh provides cover and nest protection.

Our survey techniques did not follow the procedures of the standardized marshbird monitoring protocol exactly (Conway 2005). Our surveys were conducted once each season and were within a 31-day period. Conway (2005) suggests conducting surveys at least twice a season to obtain the greatest response. Rehm and Baldassare (2007) found that rails call at different levels throughout the breeding season. By conducting surveys over a 70-day period, they were able to record responses throughout the breeding season, obtaining peak detection of each marshbird. More call broadcast surveys should be conducted within tidal marshes to accurately determine rails presence in marshes during breeding and non-breeding seasons, and how habitat variables affect their abundance. Our count stations encompassed a small percentage of total marsh available in our study area, but previous studies also had low percentages of total marsh covered by count stations (Hinojosa-Huerta 2002; Lor and Malecki 2002). To cover higher percentages of total marsh area, more count stations should be used in each marsh in the study.

All King Rail radio-locations were in managed impoundments, but during the call broadcast surveys we only detected King Rail responses in tidal marshes. Perhaps non-migratory King Rails will use non-tidal marshes as well as marshes affected by tides. However, it is difficult to determine why these results occurred because of our small sample size in this study.

The King Rail's home range was larger than the Clapper Rails' home range and it also traveled greater distances during the breeding season than Clapper Rails.

We only tracked one King Rail in this study. King Rails in this zone are believed to be non-migratory and no information is known about their movement and home range size during the winter and breeding season, so we could not compare our results to other studies. Further research should be conducted on home range size and movement for King Rails during breeding and non-breeding season in the SACZ. Further research should also be conducted to determine if all King Rails in ACE Basin are non-migratory. Managed impoundments may provide the necessary requirements for King Rails, but further research should be conducted to determine how these managed impoundments can provide habitat for King Rails and other waterbird species.

The average Clapper Rail home range for the study was much higher than other studies (Conway 1990; Cumbee 2003). Severe weather may have been an important factor for the large home range size. One Clapper Rail home range size was 7.3 ha, higher than the average home range size and the other was 0.4 ha, well within the average home range size described for Clapper Rails from other studies. Clapper Rails habitat selection and movement corresponded with the call broadcast surveys. High frequencies of occurrence, movement and habitat selection were within tidal marshes in the ACE Basin. These tidal marshes may provide better habitat conditions for Clapper Rails in the ACE Basin. Because we only tracked two Clapper Rails, more radio telemetry studies should be conducted to determine home range sizes and movement of Clapper Rails more accurately, as well as effects of weather on Clapper Rails in the ACE Basin.

Survival rate could not be determined from this study. Survival rate of rails is poorly known throughout their range. There are many mammalian, avian, reptilian, and fish predators that may feed on adult rails as well as eggs and chicks (Eddleman and Conway 1998; Gaines et al. 2003). Extreme high tides in the ACE Basin may cause significant damage to nests. Future research should be conducted to determine survival rate of nests and young in the ACE Basin and SACZ.

This study provides managers with information about basic habitat needs for Clapper and King Rails and ways to improve their managed impoundments to meet those needs. This study also addresses data gaps concerning King and Clapper Rails within the SACZ, and provides basic information about King and Clapper Rails in the ACE Basin.

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APPENDIX A

Nesting Habitat of King and Clapper Rails within the ACE Basin of South Carolina

King (*Rallus elegans*) and Clapper (*R. longirostris*) Rail nests are difficult to locate because of their unique design. King and Clapper Rails nest in coastal marshes of the Southeast. Both rails form nests in tall dense vegetation and nests are usually located a height above the ground. The height of the nest above the water depends on the water depth (Meanley 1992). Clapper Rails typically build nests above the high tide and close to a channel or tidal gut, the area that is being flushed and fertilized by the tides (Meanley 1985). King Rails have been known to nest away from tidal guts and channels (Reid 1989). Both rails use a platform that allows them to enter the nest (Meanley 1985). Clapper Rail nest are typically constructed from dried cordgrass and may have a roof or dome covering the nest (Lewis and Garrison 1983). Some suggest that this roof or dome is used as camouflage from aerial predators (Johnson 1973) others suggest that it protects eggs from tidal fluctuations (Andrews and Ohmart 1985). Clapper Rail nesting habitat and survival has been studied in Georgia (Gaines et al. 2003). Gaines et al. (2003) found that most Clapper Rails nest 1-4 m away from associated tidal pools.

King Rails in South Carolina are believed to be non-migratory species, but very little is known about their nesting activities. Surveys conducted in Louisiana show that King Rails have high nesting densities in ricefield impoundments (Cooper 2006). Tidal marshes in South Carolina are inundated by high tides twice each day. These extreme tidal cycles may cause significant nest destruction. It is important to understand where King and Clapper Rails nest to determine nest success and survival for rails in coastal marshes of South Carolina.

Locations of nests found during this study were in the Ashepoo-Combahee-Edisto (ACE) Basin of South Carolina. Nest searches were conducted from March to June 2006. Searches were conducted in areas that displayed nest habitat characteristics. Digital recordings of both rails' calls were used to determine best areas to conduct searches. Searches were conducted systematically and covered areas near and far from the tidal gut (Gaines et al. 2003). When nests were found, four measurements were taken: nest height (m), distance to open water (m), vegetation height around nest (m), and horizontal cover (%) around the nest.

We found four nests during the entire study, three Clapper Rail nests and one King Rail nest. The King Rail nest was an active nest with one egg. We found one Clapper Rail nest that was active with six eggs. All eggs were lost by the end of the survey. All nests were within 2 m of open water, and the average distance was 1.4 ± 0.2 m. Average nest height was 0.7 ± 0.2 m, but the King Rail nest height was 0.5 m. Horizontal cover (%) was a monoculture of grass species. The Clapper Rail nesting habitat was mostly cordgrasses (*Spartina* spp.). The King Rail nesting habitat was bulrushes (*Scripus* spp.) and cordgrass. The average plant height around the Clapper Rail nest was 1.8 ± 0.2 m. Plant height around the King Rail nest was 1.5 ± 0.03 m. All nests were found in tidal marshes. The King Rail nest had a partial dome covering the top of the nest.

These findings support other studies that found eastern Clapper Rail nests in habitats that are dominated by cordgrass (Eddleman and Conway 1998; Gaines et al. 2003). Clapper Rail nests were within 2 m of tidal gut, also found in other studies (Meanley 1985; Gaines et al. 2003). Ramps were found at each Clapper Rail nest site. Ramps are commonly used in habitats that have fluctuating water levels (Eddleman and Conway 1998). Average nest height in this study was higher than in other studies (Lewis and Garrison 1983; Gaines et al. 2003).

Vegetation height around nests was also higher than other studies (Meanley 1992; Gaines et al. 2003). Active nests were determined for only one Clapper Rail. Clapper Rails typically have two broods per season (Eddleman and Conway 1998). The active nest was found in June 2006, possibly a re-nesting attempt. This nest was destroyed by the end of June 2006. Alligators (*Alligator mississippiensis*) are abundant in coastal marshes of South Carolina. We determined that an alligator destroyed the nest because of the amount of damage at the nest site and vegetation around the site. These findings resemble other findings in the southern United States; however, it is difficult to determine why there was such a high amount of nest destruction.

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APPENDIX B
Measurements of Clapper and King Rails taken during 2006

Clapper Rails						
Age	Juvenile	Adult	Adult	Juvenile	Juvenile	Adult
Sex	Unknown	Male	Female	Unknown	Unknown	Male
*Leg band #	66301	66302	66309	66310	66403	66407
Bill length (mm)	50.2	60.3	61.7	62.5	57.7	69.3
Wing-cord length (mm)	130	155	145	140	140	150
Middle-toe length (mm)	40.2	46.8	40.8	38.5	42.2	45.2
Tail length (mm)	54.2	74.0	45.7	54.9	53.0	50.0
Tarsus length (mm)	46.5	49.6	47.3	45.5	40.5	58.8
Weight (g)	197	312	262	207	188	327
King Rails						
Age	Adult	Adult	Adult	Adult	Adult	
Sex	Unknown	Unknown	Unknown	Female	Male	
Leg band #	66401	66402	66404	66405	66406	
Bill length (mm)	56.4	59.6	57.0	61.3	55.1	
Wing-cord length (mm)	168	168	165	150	175	
Middle-toe length (mm)	49.9	52.4	47.6	47.3	55.4	
Tail length (mm)	64.4	66.1	53.4	51.9	59.0	
Tarsus length (mm)	62.5	66.3	65.2	53.7	62.9	
Weight (g)	372	312	347	347	397	

* All leg band numbers began with the same 4 digits: 0965