SPATIAL ECOLOGY AND SEASONAL HABITAT USE OF THE KING RAIL (*RALLUS ELEGANS*) ALONG THE ATLANTIC COAST

by

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Abstract: The King Rail (*Rallus elegans*) continues to experience population declines throughout its range. Due to its secretive nature and occupancy of densely vegetated marshes, little is known about the behavior and ecology of the King Rail. Moreover, conservation efforts lack essential information about King Rail habitat use to make informed decisions, especially along the Atlantic coast and during the non-breeding period. To address this, radio-telemetry was used to elucidate the spatiotemporal patterns of movement and habitat preferences of King Rails throughout the year. The microhabitat characteristics were quantified at nest locations and where adults were located during the breeding and non-breeding periods, including the poorly understood brood-rearing period. Nest densities were greatest in areas with high interspersion of emergent vegetation and open water, and most rails selected nest sites in *Juncus roemerianus* patches, the predominant species of emergent vegetation. Adults traveled with their broods substantial distances from nest locations, as much as 1 kilometer within the first week post-hatching, to areas with less *Juncus roemerianus* and with shallower water than where they nested. During the non-breeding and brood-rearing periods, adults were found closer to edges of open water and emergent vegetation than during the nesting period, areas thought to provide increased foraging opportunities. Empirically, it was determined for the first time that adults use wooded and shrubby marsh during the brood-rearing and non-breeding periods. This habitat type has not been considered under current King Rail management plans.

Observations spanning the entire year documented the movements of King Rails and revealed that at least part of the population is resident. Mean home range size was 19.8±2.5 ha (95% kernel density). Individual home range sizes did not differ significantly between seasons. There was evidence of sexual segregation in habitat use during the non-breeding period. Females had significantly larger home ranges than males and tended to travel greater distances. During the non-breeding season, all birds captured in emergent marsh were male, and radio-tagged females were found using adjacent wooded marsh. Adults used both managed impoundments and emergent natural marsh at all times of the year, but increased their use of impoundments immediately following drawdown, and while brood-rearing, especially when water levels rose abruptly in natural marsh. In coastal habitats prone to variation in water level, provision of impoundments with sluice control adjacent to natural marsh appears to be of benefit to brood-rearing King Rails. Where populations are present year-round, habitat management should emphasize interspersion of patches of emergent vegetation with pockets of open water providing a mosaic of cover and appropriate nest sites in proximity to foraging areas. Scrub-shrub and wooded wetland habitat at the perimeter of emergent marsh may favor residency of overwintering King Rails of both sexes. These findings highlight the need for conservation efforts to consider the habitat preferences and spatial distribution of King Rails throughout the year and at all life stages.

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King Rail microhabitat preferences vary among breeding, brood-rearing, and non-breeding periods

1.1 ABSTRACT

The King Rail (*Rallus elegans*) is a secretive marsh bird that inhabits emergent wetlands across the Eastern half of the U.S. and is experiencing population declines throughout its range. Recently designated as a focal species by the U.S. Fish and Wildlife Service, information on habitat requirements are lacking, especially along the Atlantic coast. From 2012-2014, I quantified microhabitat preferences for King Rails during the breeding, brood-rearing, and non-breeding periods. King Rail nests were mostly found in *Juncus roemerianus*, the predominant vegetation species at the study site, and nest densities were greatest (up to 48.0±5.1 nests/km^2) in areas with a high degree of heterogeneity between open water and emergent vegetation. Within the first couple of weeks of hatching, King Rails preferred to take their offspring to areas with significantly less *Juncus roemerianus* and shallower water than where they nested. Kings Rails were observed using wooded marsh during the brood-rearing and non-breeding periods. During the non-breeding period, adults were more often found closer to open water and edge than during the breeding period, signaling a change in microhabitat preference. My findings support the use of management strategies that provide a mosaic of emergent vegetation and open water, with wooded or shrubby margins for King Rails. King Rail habitat preferences change across seasons and conservation efforts should consider year-round needs as well as seasonal variability of habitat use throughout its range.

1.2 INTRODUCTION

Since the 1700s, over 50% of North America's wetlands have been lost or significantly degraded due to human impacts (Wilen and Frayer 1990, Dahl 2006). While the rate of wetland loss has generally decreased since the 1970s in the United States, in the mid-1980s 89% of wetland loss in the United States occurred in the Southeast (Hefner et al. 1994), while emergent wetlands decreased nationally by 57,720 ha between 1998-2004 (Dahl 2006). Birds can be useful bioindicators for investigating environmental quality (Paillisson et al. 2002, Padoa-Schioppa et al. 2006). Specifically, the presence of wetland obligates such as wading birds can be positive indicators of ecosystem health (Kushlan 1993).

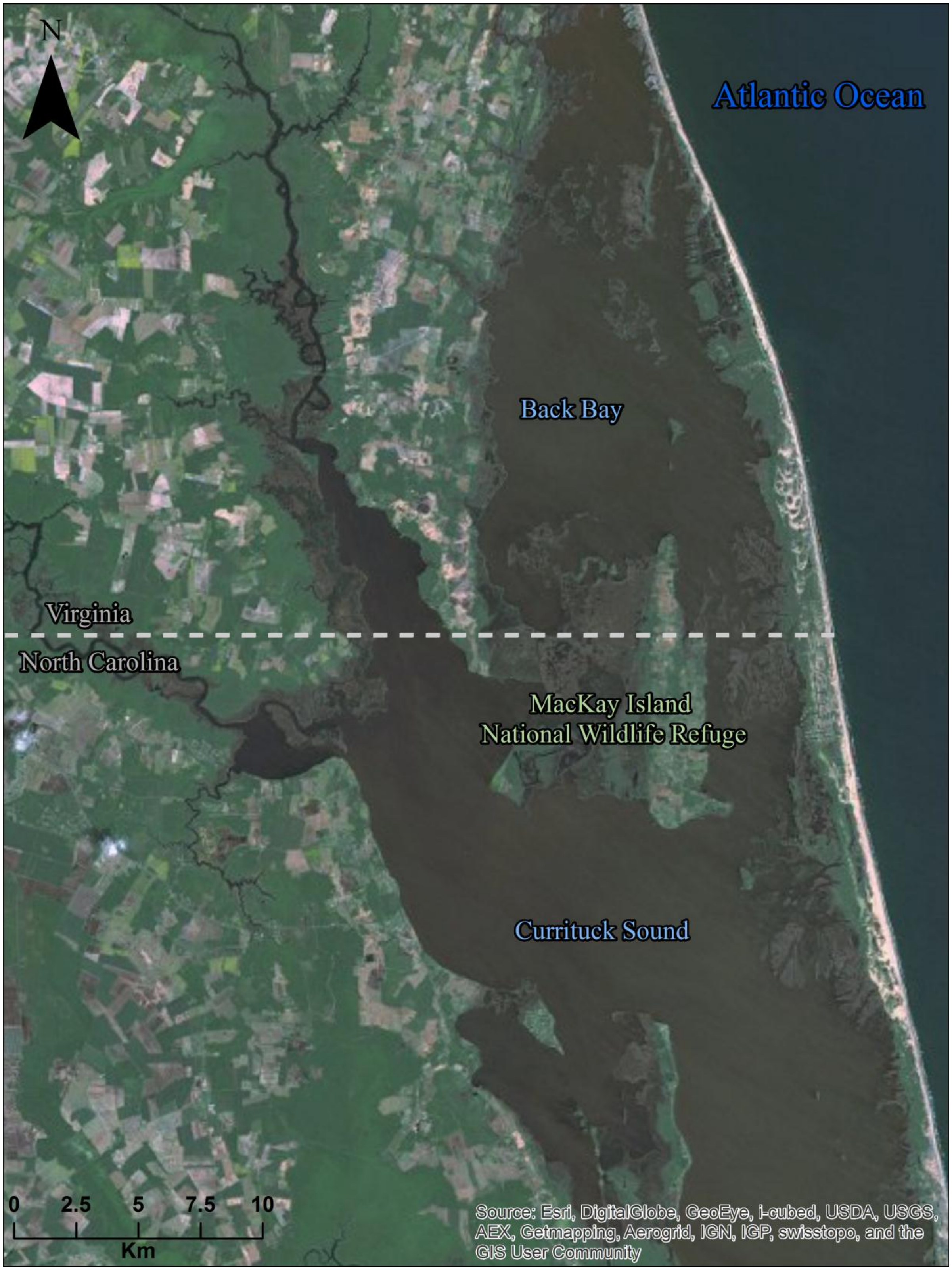
Nine species of rails (Family: Rallidae) breed throughout North America, occupying a variety of wetland types, and all are threatened by habitat loss (Eddleman et al. 1988). The King Rail (*Rallus elegans*) inhabits emergent wetlands across the eastern half of the United States, but has experienced long-term population decline resulting from habitat loss and fragmentation (Meanley 1969, Eddleman et al. 1988). It has recently been designated as a species of 'greatest conservation need' in 30 State Wildlife Action Plans, and as a species of 'high concern' in the North American Conservation Action Plan (Cooper 2008). Due to its secretive nature, infrequent vocalizations, cryptic plumage, and occupancy of densely vegetated wetlands, information about King Rail ecology and habitat use is lacking. Consequently, making management decisions critical to the recovery of the species remains challenging.

Several recent studies have investigated the effectiveness of call back surveys to determine overall habitat use and abundance of King Rails (Pierluissi and King 2008, Darrah and Krementz 2009, Drew and Collazo 2011). Callback surveys are hampered by imperfect detection probabilities. Studies that use this method alone cannot measure individual microhabitat preferences, and this limits their utility in informing management. Habitat selection in wading and marsh birds is influenced by many factors including vegetation structure (Conway et al. 1993, Bancroft et al. 2002), water depth (Kushlan 1976, Bancroft et al. 2002) and availability of appropriate food species (Maccarone and Brzorad 2005, Baschuk et al. 2012). Understanding habitat requirements of the King Rail requires detailed knowledge of such variables. Radio-telemetry has been used to investigate habitat use, home ranges, movements, juvenile dispersal, residency, population estimates, breeding behavior, and migratory characteristics of many bird species (Warnock et al. 1995, Anders et al. 1998, Bogner and Baldassarre 2002, Casazza et al. 2008, Arbeiter and Tegetmeyer 2011, Cline and Haig 2011, Kelley et al. 2011). Radio-telemetry has been successfully used on King Rails in Louisiana (Pickens and King 2013), and Clapper Rails (*Rallus longirostris*) (Conway et al. 1993, Casazza et al. 2008, Rush et al. 2010), the sister species to the King Rail that inhabits salt-marshes (Maley 2012). These studies have provided valuable data on movements, habitat, and foraging locations.

The King Rail is socially monogamous, exhibiting bi-parental care during the nesting period (Meanley 1992). The initiation and duration of the nesting period varies depending on latitude (Meanley 1969). King Rails along the Atlantic coast breed from March through August, with clutch sizes ranging from 4 to 12 eggs and an incubation period of 21 to 24 days (Meanley 1969). The brood-rearing stage may last for more than a month (Meanley 1969), and remains one of the least understood periods in the King Rail’s lifecycle. Yet, survival during the dependent period is suspected of being a factor limiting population growth (Cooper 2008). In other studies of nidifugous birds, nesting and brood-rearing habitats often differ (Mauser et al. 1994, Yerkes 2000), and brood survival rates are influenced by microhabitat characteristics such as cover and vegetation type (Rotella and Ratti 1992, Sveum and Crawford 1998).

MacKay Island National Wildlife Refuge (NWR) in coastal North Carolina appears to host a large number of King Rails year-round (Figure 1). The refuge is composed primarily of emergent natural marsh surrounding several managed waterfowl impoundments. Rogers (2013a) reported higher occupancy rates at MacKay Island NWR than at other sites surveyed by researchers that also followed the North American Marsh Bird Monitoring Protocol (Pierluissi and King 2008, Darrah and Krementz 2009). That the population at the refuge has a high density of breeders makes it ideally suited for investigating the habitat requirements of King Rails occupying natural marsh.

I used radio-telemetry to examine the year-round microhabitat requirements of the King Rail in northeastern North Carolina along the Atlantic coast during 2012 and 2013. I have broadly defined the population's breeding period as the beginning of nest initiation through brood independence (April 1-August 31), and the non-breeding period as the rest of the year (September 1-March 31). The objectives for my study were: 1) to characterize microhabitat use to detect differences between the breeding, brood-rearing, and non-breeding periods, 2) to quantify microhabitat nest site characteristics, and 3) to determine if King Rails modify their habitat preferences between the nesting and brood-rearing stages.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 1.1 The study area located at MacKay Island NWR. Currituck Sound and Back Bay are freshwater, and are separated from the Atlantic Ocean by narrow barrier islands.

1.3 METHODOLOGY

1.3.1 Study Area

MacKay Island NWR, which lies along the northern extent of the South Atlantic Coastal Plain, was established in 1960 along the Atlantic flyway under The Migratory Bird Act for the purpose of conserving and protecting migratory birds (USFWS 2008). MacKay Island NWR, located next to the village of Knotts Island in Currituck County, NC, is comprised of 3,329 ha of mixed hardwoods, pinewoods, and marsh. More than half of the refuge is classified as freshwater tidal marsh, a habitat type listed as rare or uncommon in North Carolina, with some impounded marsh for wildlife management (USFWS 2008). In 1992, a 0.75 ha impoundment was created to seed red swamp crayfish (*Procambarus clarkia*), a freshwater species native to the Gulf Coast, with the purpose of creating an additional food source for overwintering waterfowl. Water and salinity levels (<5 ppt) in these marshes are influenced by wind-driven tides and rainfall (Rogers et al. 2013b).

MacKay Island NWR is managed through the use of prescribed fire in three- to five-year cycles, maintaining the structure of the fire-dependent vegetation communities within the marsh while preventing the invasion of woody vegetation (Nyman and Chabreck 1995). Vegetation types are relatively homogenous throughout the study area, with freshwater emergents including black needlerush (*Juncus roemerianus*, hereafter known as *Juncus*), cordgrass (*Spartina sp.*), cattail (*Typha sp.*), and common reed (*Phragmites australis*, hereafter known as *Phragmites*). I divided the study site into a ‘northern’ and ‘southern’ section arbitrarily based on ease of access into the marsh from refuge roads. The marsh between these sections is continuous but was impractical to access due to logistical and time constraints.

1.3.2 Nest Searching and Field Measurements

Beginning in April 2013, King Rail locations were detected audibly or visually. Areas of emergent vegetation where King Rails were detected were systematically surveyed for nests every 3 to 5 days throughout the breeding season, with three technicians spaced approximately 3 meters apart to search the marsh. Systematic and thorough search efforts have been used successfully to locate King Rail nests in Louisiana (Pierluissi and King 2008) and at MacKay Island (Brackett 2013). The northern and southern sections of the refuge were searched with equal effort on alternate days. Particular attention was paid to areas with signs of muskrat (*Ondatra zibethicus*) activity, as these rodents are known to clear vegetation and create areas of open water and runways suitable for King Rail foraging and movement (Cooper 2008). In addition, areas dominated by *Juncus* were searched regardless of the known presence of King Rails since Brackett (2013) found 72% of nests in this marsh were built in *Juncus*.

All nests that contained at least one King Rail egg or shell fragments were fully documented, and the vegetative composition, supporting structure, and eggs described. Nests found during the egg laying stage were monitored daily to detect laying sequence irregularities arising from reproductive interference and to record water depth (±1.0 cm) at the nest. After clutch completion, nests were checked every 3 days to reduce disturbance. Since nest monitoring creates paths through the emergent vegetation, which could increase the chances of nest predation or abandonment, attempts were made to minimize both the visit rate and length of time spent during visits to the nests. Initiation dates of nests found after clutch completion were estimated by randomly floating 3 of the eggs in fresh water to estimate the developmental stage (Rush et al. 2007). Complete clutches were photographed to document inter-female variation in egg characteristics for the purpose of clutch identification. Photos were then used in determining renest attempts. The Universal Transverse Mercator (UTM) coordinates of each nest were recorded to within ±3 m error using a GPS unit (Garmin, model 76CSx and eTrex 20).

The following microhabitat characteristics were documented via visual estimation within a 10 m radius of the nest: percent cover of open water and each vegetative species >5%, water depth, percent canopy (woody vegetation >3 m in height), and distance to open water and edge. Open water was defined as at least one square meter of water where a King Rail could forage. A distinct change in vegetation community into another vegetation species, ditch, or pond was considered an 'edge'. The distance to open water and edge were inclusive if the distinct community change was at a channel or impoundment. To capture the habitat structure around the nests, microhabitat characteristics were collected 25 m from the nest in each cardinal direction.

Once hatching began, I returned to the nest daily to catch, sample and measure chicks until all eggs had hatched or were left cold. Because King Rail chicks are nidifugous (Meanley 1969), I approached nests rapidly to capture chicks before they exited the nest. Blood samples of up to 30µl were drawn from the femoral artery, and the weight (±0.1 g) and tarsus length (±0.1 mm) of each newly-hatched chick was recorded. To avoid resampling individuals, I applied a small dab of non-toxic acrylic paint on the nape feathers of sampled chicks.

1.3.3 Capturing, Marking, and Sampling King Rail

Three methods were used to capture adult King Rails, and these varied throughout the year. During the 2011 breeding season, Brackett and McRae (unpublished) developed an effective and unique method to capture King Rails late in the incubation stage. King Rails have a tendency to 'sit tight' on the nest during the latter part of the incubation stage. This provided the opportunity to surround the nest with overlapping mist nets, each anchored with tent stakes along the bottom rung, in a perimeter about 5 m from the nest. The incubating adult was then flushed toward the mist nets. If the capture was successful, the bird was quickly extracted from the net and processed. If a bird flew over or escaped under the mist nets, I raised the bottom rung of one mist net to allow the bird to get back on the nest and retreated for up to 30 minutes before attempting the capture again. This method was only used within a week or less of the estimated hatch date to reduce the risk of nest abandonment.

Whoosh nets were used to capture King Rails during the months of April and May. Whoosh nets cover an area approximately 40 feet x 10 feet, and can be set up in an inconspicuous location along roadside ditches or along the edge of an impoundment where rails were often seen. Whoosh nets (Doherty 2009) consist of a series of bungee cords, poles, and a trigger line that propel the net at a 45° angle over a target location that must be devoid of any emergent vegetation. Whoosh nets were set up along refuge roads where King Rails actively vocalized with ‘kek’ calls, which are used to attract a new mate (Zembal and Massey 1985). At least two people observed the predetermined target zone from an inconspicuous location 15 to 50 m away. A pre-recorded callback with looping ‘kek’ and ‘kek-burr’ tracks was used to lure rails into the target zone. Once the King Rail was within the target zone, the net was deployed and the bird was captured.

The third method used was spotlighting from an airboat at night, which has proven successful to capture a variety of rail species during the non-breeding season (Perkins et al. 2010, Pickens and King 2013). With assistance from refuge staff, two to three rail catchers and a driver piloted through the marsh using a spotlight (Brinkmann Q-beam, 3 million candlepower) to navigate and locate King Rails. Once a rail was flushed, the driver maneuvered the boat to the location where the bird was last seen and an attempt was made to capture the bird by hand or dip net.

Each captured adult was fitted with two bands on each tarsus, one with a uniquely numbered U.S. Geological Survey aluminum band and a color band and the other with two color bands for the purpose of identification on sight in the field. Time and location of capture, method used, bill height (±1 mm), bill width (±1 mm), bill length (±1 mm), and weight (±5 g) were recorded. A 50-μL blood sample was drawn from the brachial vein and stored at ambient temperature or 4ºC in 100% ethanol for later DNA extraction for genetic analysis. Since a reliable field protocol to identify the sex of Atlantic coast King Rail does not currently exist, a PCR-based diagnostic test was used as an independent method to determine sex of captured rails (Brackett 2013).

Adult king rails were fitted with a "glue-on" radio transmitter (Advanced Telemetry Systems, Isanti, MN; Model A2480, 3.6 g) with a backpack harness adapted from the design of Dwyer (1972) (see also Casazza et al. 2008). Each transmitter was attached to the bird using a double loop harness made of 0.5 cm Teflon webbing (Bally Ribbon Mills) that encircled the body. One loop was attached anterior to the wings and the other was positioned posterior to the wings. The harness and transmitter was ≤ 3% (range: 1.8-2.9%) of the bird's total body weight. The model A2480 has an estimated battery life of up to 258 days (about 8.5 months). King Rails were monitored closely immediately after affixing the transmitter and harness to ensure the well-being of the bird. Following a 24-hour acclimation period, birds with transmitters were tracked every one to three days during the breeding season, and at least twice every two weeks during the non-breeding season. The use of radio transmitters provided information on habitat use of King Rails, as well as home range size and bird movements (see Chapter 2).

1.3.4 Radiotracking and Microhabitat Assessment

Using a portable receiver (ATS, model R410 receiver) and a three-element folding Yagi antenna, I conducted “walk-ins” via the homing method as described by White and Garrott (1990) and Pickens and King (2013). Birds were approached to within 2 to 10 m and their coordinates were recorded using a GPS unit. Technicians were trained on how to minimize the likelihood of prematurely pushing a bird from its original location by first triangulating and using the strength of signal on the receiver to accurately estimate the location. Habitat variables were measured within a 10 m radius as described in Section 1.3.2. To compare habitat use and availability, I randomly selected an azimuth by spinning the compass bearing several times and moved 50 m from the bird location to record the same habitat variables. This allowed for the comparison of habitat characteristics controlled for date, while minimizing observer bias. If a random point fell on a road or in the middle of a canal, a new random point was taken. “Walk-ins” were conducted every 3 to 5 days on individual birds and every two to three days on individuals with dependent broods to minimize disturbance to the bird’s natural movements and behavior.

Adults with broods were stealthily tracked until chicks were seen or their vocalizations were detected, confirming the presence of the brood. Adults with broods often became agitated, alarm calling frequently while moving away from their brood when approached to within 5 m. Therefore, vegetation surveys were conducted quickly at chick locations.

1.3.5 Statistical Analyses

To compare between the breeding, non-breeding, and brood-rearing time periods, I ran a linear mixed model using SAS software (SAS version 9.3, Cary, NC, U.S.A.) with each individual King Rail modeled as a random effect to account for repeated measures on the same individual. To compare all nest, brood, and bird locations to their respective random locations, I averaged each measured variable per bird and then ran paired samples t-tests using SPSS version 20 (SPSS IMB, Armonk, NY, U.S.A.). Since renesting attempts are non-independent, I averaged values for nests considered 2nd or 3rd attempts. The variables at each cardinal direction were averaged and compared to those at each respective nest to reflect habitat availability immediately surrounding the nest location. Nest densities were calculated by omitting all renest attempts and dividing the total number of nests by the estimated total area searched regularly throughout the breeding season. Area searched was calculated using ArcMap 10.1. Results are reported as ±SE and figure error bars are ±1 SE.

1.4 RESULTS

1.4.1 Capture Effort and Predation Events

I captured 34 King Rails at MacKay Island NWR between June 10, 2012, and March 11, 2014. During the breeding season I caught 4 King Rails with a whoosh net along refuge roads, and 17 King Rails with mist nets at nesting locations. Thirteen were caught during the non-breeding season via spotlighting from an airboat; morphometrics and genetic sex determination revealed all were male (McRae and Kolts, unpublished). Since it is impossible to drive an airboat through shrubby or wooded habitat, airboat captures only occurred in emergent marsh. Processing time for all birds averaged 27 minutes (median=22 mins).

Of the 34 King Rails caught, 21 were affixed with transmitters. The average amount of time King Rails in the study wore a transmitter was 150.0±23.8 days (median=128 days). Three King Rails shed their transmitters within 10 days of attachment while I was honing the harness design. One predation event claimed a bird within two weeks of transmitter attachment, and two harness-related deaths occurred within one week of attachment. These 6 birds were omitted from all analyses. Two birds caught during the 2012 breeding season lost their transmitters before microhabitat surveys began, but were included in spatial analyses (See Chapter 2). Thus, microhabitat analyses included 13 King Rails. Six were fitted with transmitters during the non-breeding season and 7 during the breeding season.

Predation claimed 5 of the 15 radio-tagged King Rails. Three found transmitters were riddled with teeth marks, likely signs of a mammalian predator, and another was indented with a neat “V” where it rested at the base of the bird’s neck and was devoid of teeth marks. I assumed this was an avian predator since raptors are known to immobilize prey by severing the spinal cord (Fowler et al. 2009). The 5th predator could not be identified.

Inclement weather also may have played a role in predation events. From January 28-29, 2014, the study site received 20-25 cm of snow during an extended cold snap that caused all open water on the island to freeze over, including the impoundments. Two of the predation events were coincident with this cold snap. The average number of days between transmitter applications and predation events was 115±35 (median=87 days). All radio-tagged birds tracked during the breeding season (n=13) exhibited normal breeding behavior, such as ‘kekking’ to attract mates, egg-laying, incubating, or brood-rearing. One female deserted her nest after capture late in incubation. However, her mate remained and the nest survived to hatch. She was followed for 235 days before the transmitter fell off.

1.4.2 Reproductive Ecology

The first King Rail nest of the 2013 breeding season was found on April 14 with an estimated first egg date of March 31. A total of 63 nests were found, of which 48 were discovered while active. Thirteen nests (21%) found inactive had signs of predation and the fate of 2 nests could not be deduced. Twelve of the 63 nests (19%) were considered 2nd or 3rd attempts due to knowledge of where King Rail pairs occurred, time between nesting attempts, and proximity to former nests. Twenty-three nests were successful (37.7%), 2 were deserted (3.3%), and the rest were depredated (59.0%). There was no significant difference in microhabitat characteristics when comparing successful and failed nests (independent samples t-test: t=-0.245-1.287; P=0.203-0.916).

Seven nests (11.2%) were discovered in an area that had been burned by refuge staff in January of the same year. Estimated nest initiation dates in burned areas were considerably later than in unburned areas (May 20 vs. March 31), and only 1 of the 7 in burned areas successfully hatched. Delayed initiation dates were likely due to a lack of thick vegetation to provide nest concealment. Mean clutch size was 7.95±0.22 (range: 4 to 10 eggs). The mean proportion of eggs that hatched in hatched nests was 86±4% (range: 50-100%). A total of 67 chicks from 18 nests were captured for measurements and blood samples as part of a broader study including population genetic analysis.

1.4.3 Microhabitat Selection by Individual Rails

Obtaining microhabitat data necessitated wading into the marsh to survey vegetation at the exact point where the subject was located. I conducted 105, 39, and 47 walk-in surveys during the breeding, brood-rearing, and non-breeding periods, respectively. The average number of walk-ins was 12 per bird (range= 3 to 25) during the non-breeding and breeding seasons and 7 per bird (range= 3 to 9) during the brood period. Brood-rearing and breeding season points were separated in the analyses for individuals that covered both time periods (n=6). Variables analyzed included percent water, percent canopy, distance to edge, distance to water, water depth, and plant species encountered >10% of the total vegetation surveys. Plant species included *Juncus*, *Typha sp.*, *Phragmites*, loblolly pine (*Pinus taeda*), common three square (*Scirpus pungens*), Southern bayberry (*Myrica cerifera*), and unidentified grass species termed “grass sp”.

To determine if King Rails preferred certain cover types, I compared microhabitat structure at bird locations to time-matched random points. Bird preferences did not differ from random expectation given the cover types around their locations (paired samples t-test: t=-1.010-1.850; P=0.114-0.951; Figure 1.2), and birds were found to be distributed randomly with respect to open water (5.0±1.0 m vs. 8.4±2.5 m; paired samples t-test: t_{12}=-1.45, P=0.172) and habitat edge (12.3±1.2 m vs. 11.7±1.2 m; paired samples t-test: t_{12}=0.40, P=0.691). On average, King Rails preferred areas of greater canopy cover than what was available, but this was not significant at the α=0.05 level (4.0±1.2% vs 2.3±0.9%; paired samples t-test: t_{12}=1.97, P=0.072). This finding was strongly influenced by three female King Rails that moved to wooded marsh habitat during the late breeding season and remained there in the non-breeding season.

Microhabitat characteristics of King Rails tending broods similarly did not differ from microhabitat at randomly selected points (Range: P=0.199-0.988). However, broods tended to be led closer to edge (7.2±1.5 m vs. 18.9±4.7 m; paired samples t-test: t_6=-2.05, P=0.096) and to shallower water (4.2±1.1 cm vs. 10.2±3.1 cm; paired samples t-test: t_6=-1.61, P=0.167).

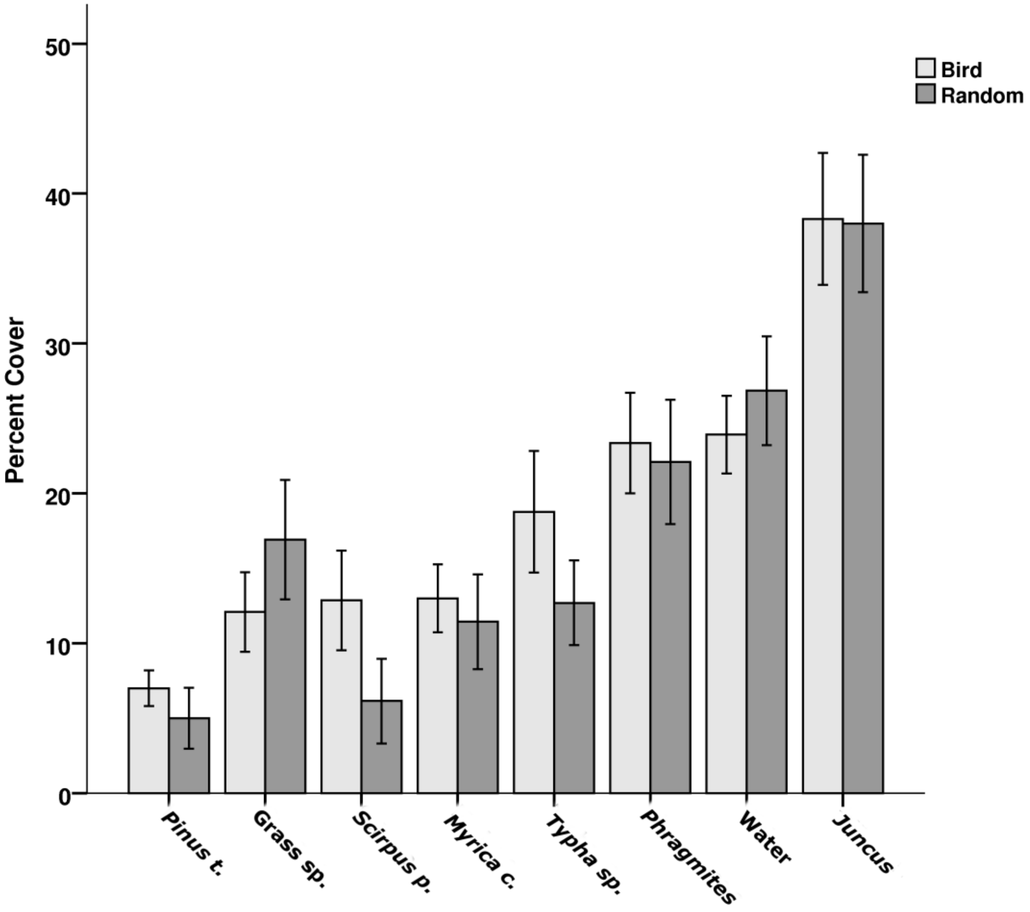


Figure 1.2. Percent cover of plant species identified at King Rail locations and random points. A point was selected at random 50 m away each time a King Rail position was recorded to provide a random sample of points that were time-matched. King Rail microhabitat selection was not significantly different from random expectation. Values presented are means ±SE.

While microhabitat characteristics did not change much across the breeding, brood-rearing, and non-breeding periods, parent King Rails took their broods into areas with less *Juncus*, the dominant marsh reed in which they build nests (RMANOVA: $F_{2,484}$=5.11, P=0.006; Figure 1.3). Individuals were located in areas with *M. cerifera* more often during the brood-rearing period (breeding: 13.0±6.4%; brood-rearing: 36.0±8.4%; non-breeding: 18.0±5.2%), but amounts did not differ statistically across all three periods (RMANOVA: $F_{2,489}$=2.54, P=0.08). *Post hoc* tests revealed that King Rails were significantly more likely to be found closer to open water during the non-breeding period than during the breeding period (Tukey's HSD, P=0.009; Figure 1.4). King Rails also spent the brood-rearing and non-breeding periods closer to habitat edge than during the breeding period (Tukey's HSD, brood-rearing: P=0.025; non-breeding: P=0.02; Figure 1.5).

1.4.4 Nesting and Brood-rearing Microhabitat Selection

Microhabitat preferences were analyzed for 63 King Rail nests found between April 14, 2013, and July 27, 2013. One nest, that hatched on May 18th and had a second clutch of eggs deposited in it beginning on June 20th, was removed from the analysis because timing and circumstance both suggested it was a renest by the same pair. King Rails selected nest sites with, on average, significantly less grass sp. (paired samples t-test: t_{36}=-2.47, P=0.018), less *Phragmites* (paired samples t-test: t_{30}=-2.56, P=0.016), less *Typha sp.* (paired samples t-test: t_{56}=-2.17, P=0.035), and less percent open water (paired samples t-test: t_{57}=-4.52, P=<0.0001) than was available in the surrounding area (Figure 1.6). No significant differences were found between nest sites and non-nest points in distance to open water (10.2±1.5 m vs. 8.4±1.0 m;

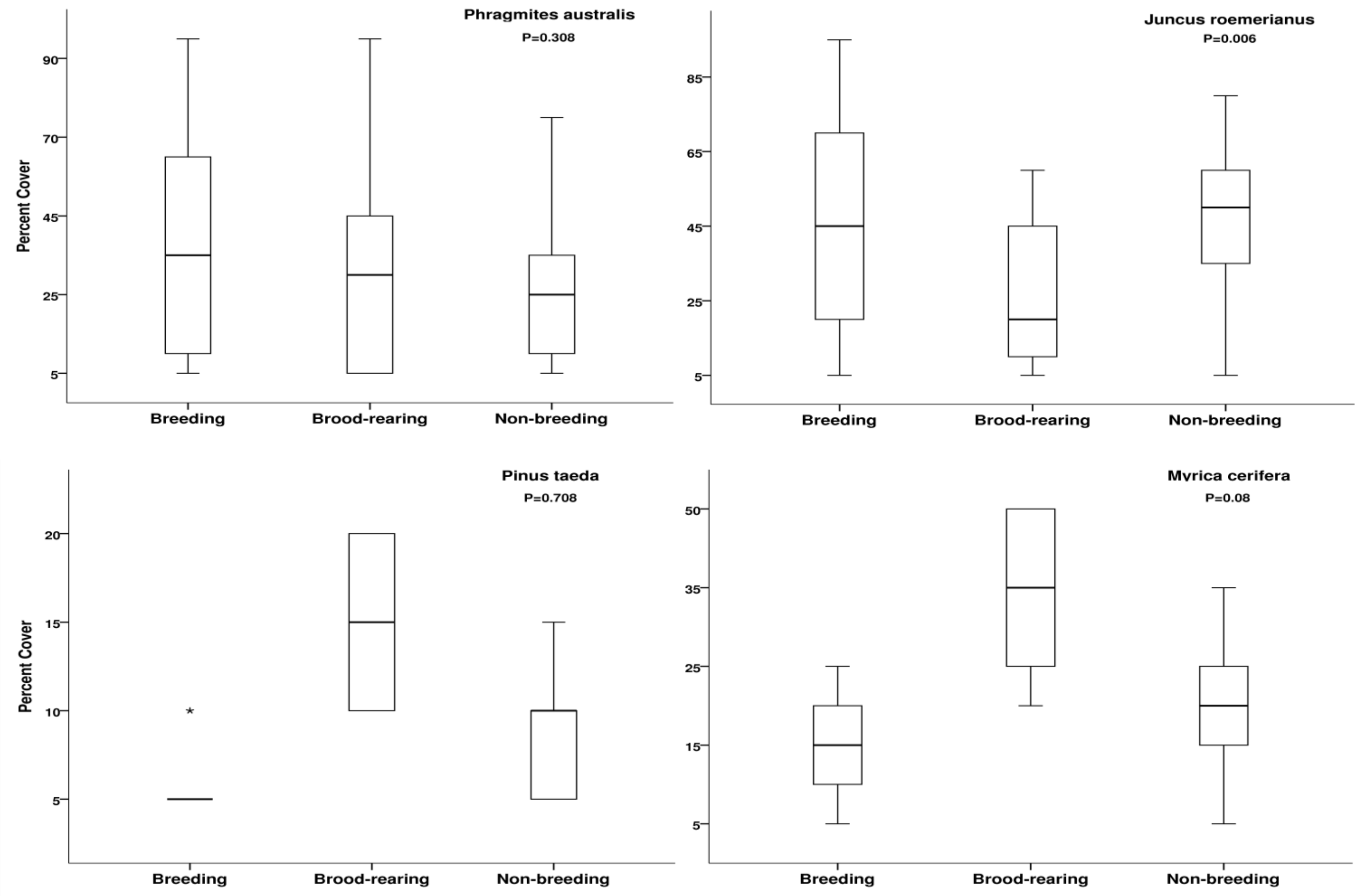


Figure 1.3. Vegetation cover and microhabitat use during three different time periods. Shown is the percent cover of four common vegetation species found throughout MacKay Island National Wildlife Refuge. *Pinus taeda* and *Myrica cerifera* are both woody species. Horizontal lines bisecting each box represent the median, and the bottom and top line of each box represents the 1st and 3rd quartile, respectively. The whiskers above and below each box extend to 1.5 times the height of the box. The asterisk represents an extreme outlier that is more than 3 times the height of the box.

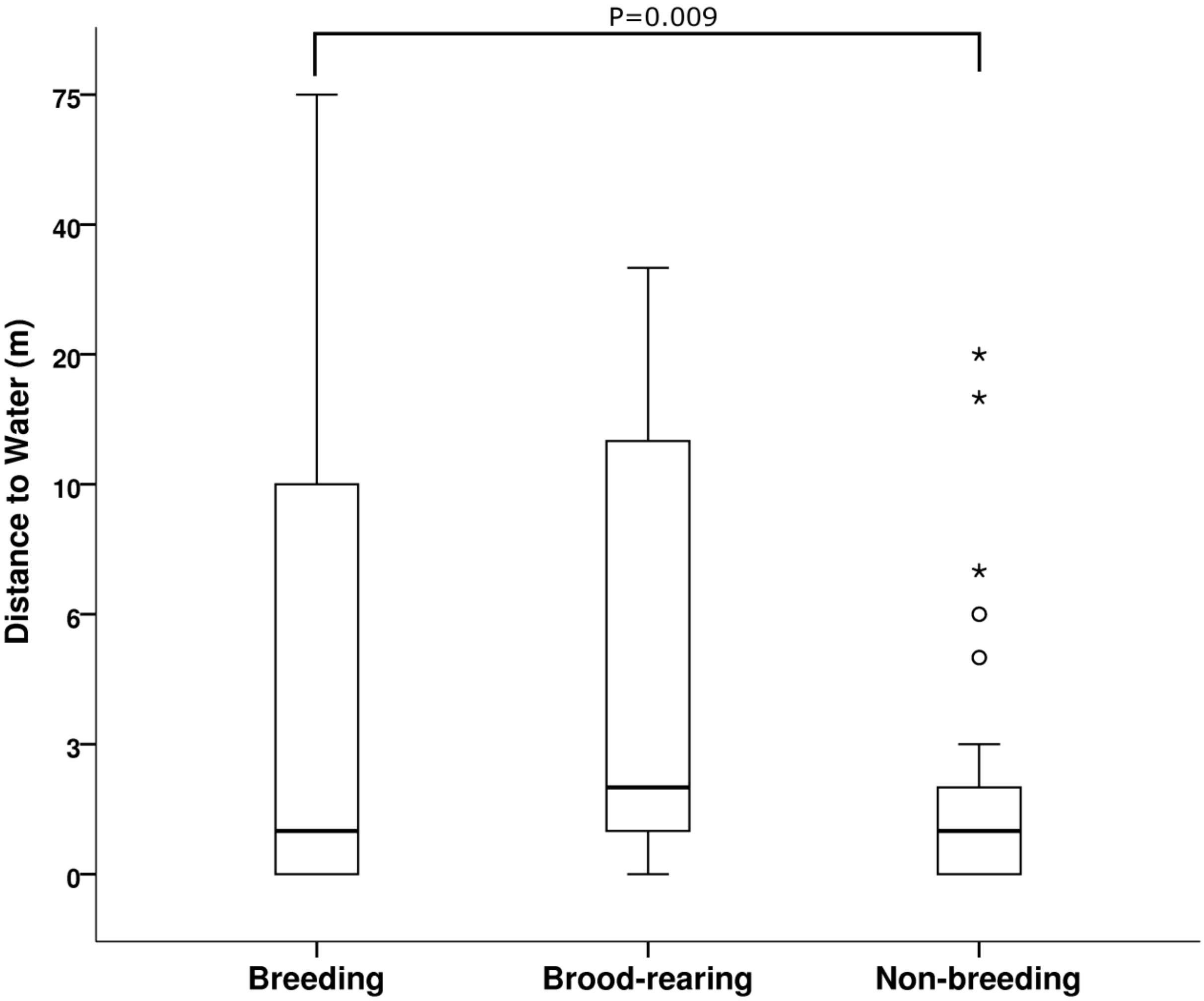


Figure 1.4. The distance of King Rails to open water during three different time periods. Horizontal lines bisecting each box represent the median, and the bottom and top line of each box represents the 1st and 3rd quartile, respectively. The whiskers above and below each box extend to 1.5 times the height of the box. Circles and asterisks are outliers greater than 1.5 and 3 times the height of the box, respectively.

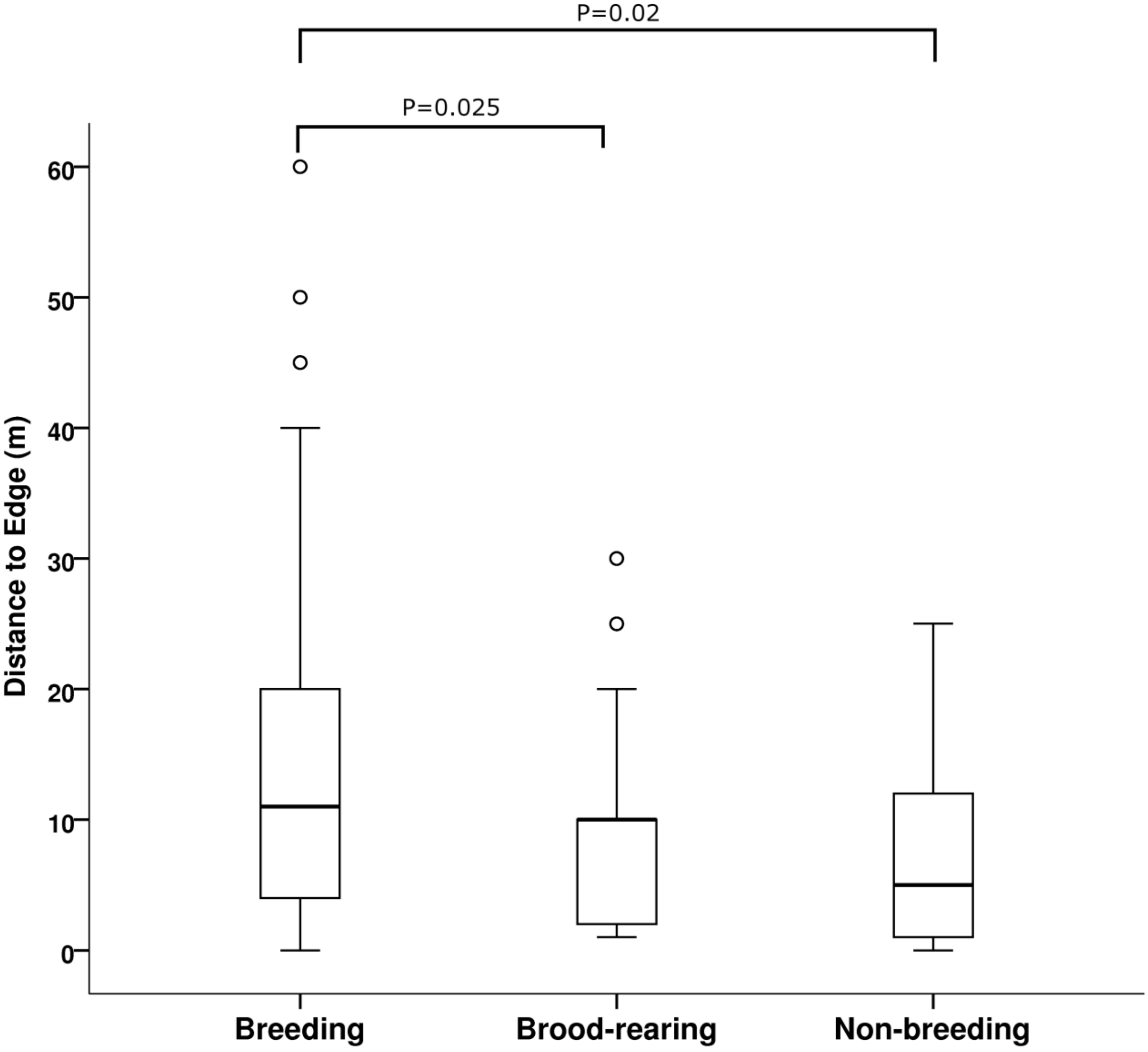


Figure 1.5. The distance of King Rails to habitat edge during three different time periods. Horizontal lines bisecting each box represent the median, and the bottom and top line of each box represents the 1st and 3rd quartile, respectively. The whiskers above and below each box extend to 1.5 times the height of the box. Circles are outliers greater than 1.5 the height of the box.

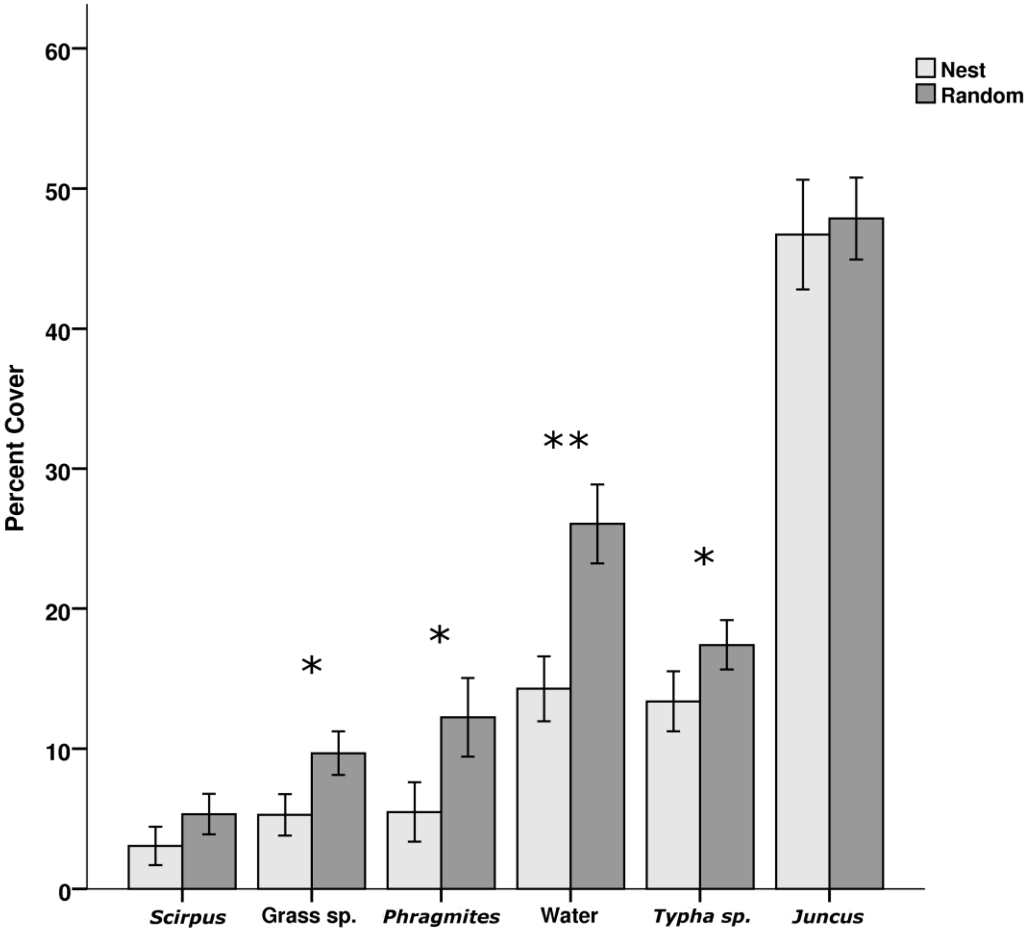


Figure 1.6 The percent cover of dominant marsh plant species and open water at nest locations vs. non-nest locations. King Rails nested in areas with less grass, less *Phragmites,* less *Typha sp.*, and less open water than what was available in the surrounding area. For categories with asterisks, the mean (±SE) differences are significant at the α=0.05 level (*) and α=0.001 level (**).

paired samples t-test: t_{61}=1.38, P=0.172) or distance to edge (13.6±1.5 m vs. 15.1±1.1 m; paired samples t-test: t_{61}=-1.08, P=0.287).

Nest densities were extrapolated from positions of found nests in large tracts of marsh that were regularly searched throughout the breeding season. Though found nests were not necessarily concurrent, effort was made to exclude renests by the same pairs. King Rail mean nest density was 28.6±9.0 nests/km^2. The northern section of the refuge, specifically around the Kitchin impoundment and along the causeway, had the highest nest density of 48.0±5.1 nests/km^2, including 2 nests that were built within 26 m of each other (Figure 1.7). The southern section, particularly areas adjacent to the East and Middle Pool impoundments, had nest densities of 15.6±7.3 nests/km^2 (Figure 1.8). Since habitat variables were found previously not to differ significantly between nest locations and nearby random points, I combined these to capture the habitat conditions throughout each principal nesting area. Distances of nests to water were significantly less in the area where nest densities were highest (5.6±0.9 m vs. 14.4±2.0 m; independent sample t-test: t_{47}=-4.41, P=0.001). All other habitat variables were not significantly different between the northern and southern sections.

King Rail nests were built primarily in *Juncus* (n=41, 66%). One nest, found on June 6th and constructed entirely of *Phragmites*, was located within a large *Phragmites* stand approximately 35 meters from the edge of the patch. Five nests were built in areas treated with Habitat® herbicide [imazapyr] in 2012 to control the spread of *Phragmites,* which is clonal and vegetatively spreads in radial patches (Amsberry et al. 2000). The application also impacted *Juncus*, creating small patches of dead vegetation which allowed for cryptic nests where the eggs blended in with their background. Three late nests (4.8%) were found after June 11 within the

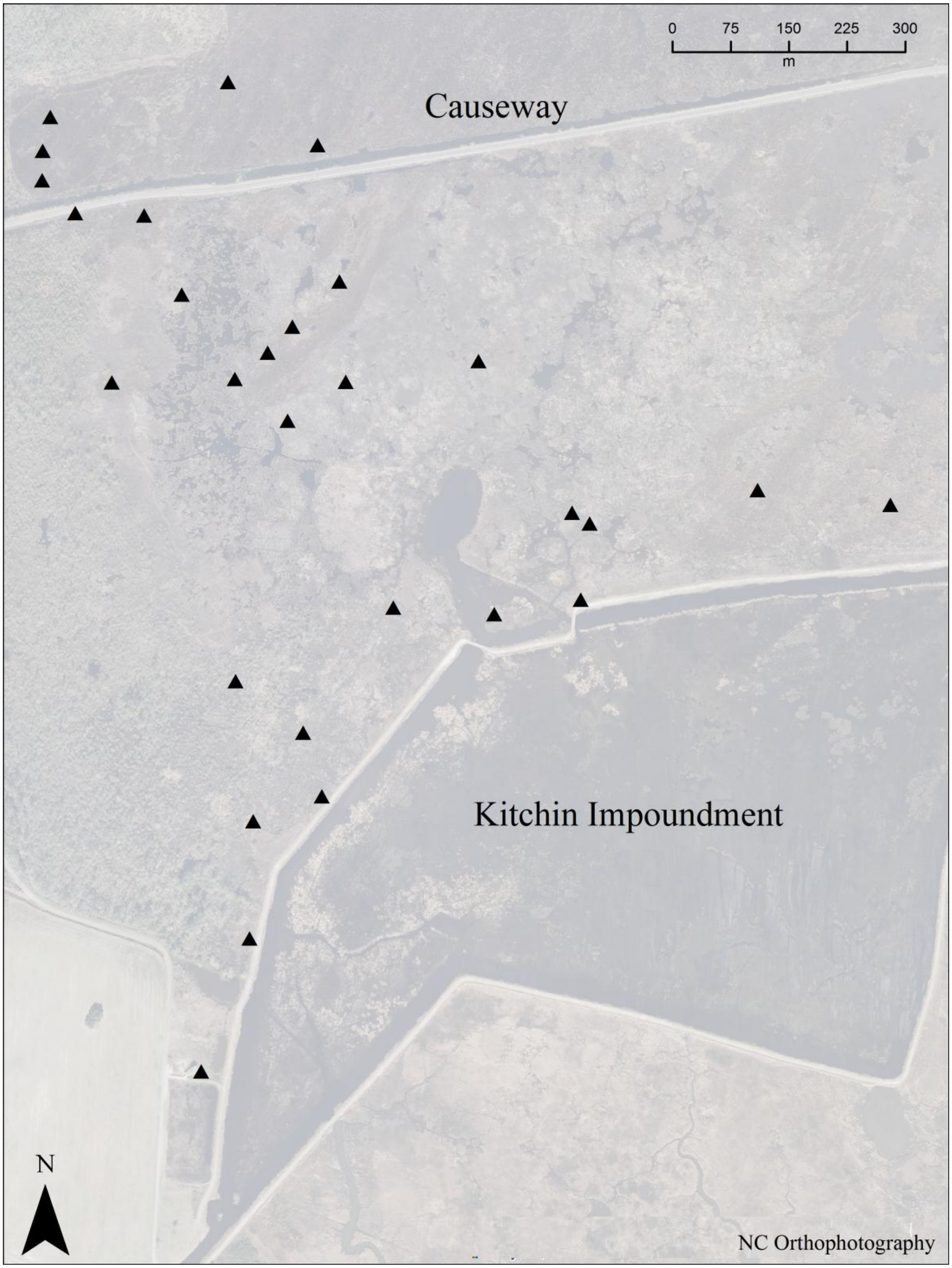


Figure 1.7 Nest locations (▲) on northern section of the refuge. Nests were found throughout the 2013 breeding season. Renests are excluded.

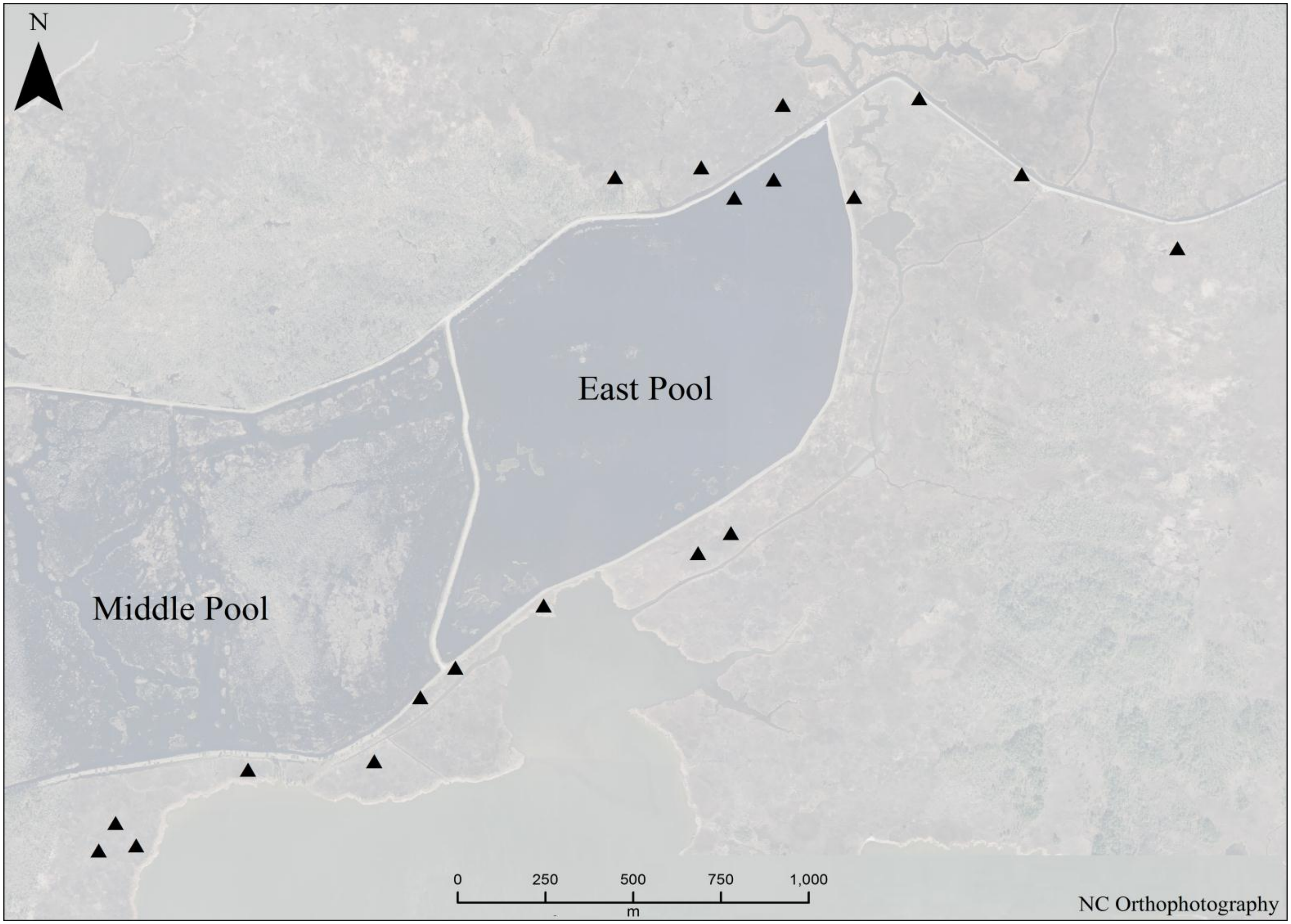


Figure 1.8 Nest locations (▲) on southern section of the refuge. Nests were found throughout the 2013 breeding season. Renests are excluded.

East Pool impoundment, and were built in *Typha sp.* patches. These were the only nests found in *Typha sp.*, and none survived beyond the egg-laying stage.

Six brood-rearing parents were tracked during the 2013 breeding season and 39 walk-in surveys were conducted (mean=7 per brood). Parents with broods tended to be located closer to habitat edge (7.2±1.5 m vs. 18.9±4.7 m; paired samples t-test: t_5=-2.05, P=0.096) and in shallower water (4.2±1.1 cm vs. 10.2±3.1 cm; paired samples t-test: t_5=-1.62, P=0.167) when compared with random points. While brood-rearing parents selected similar vegetation types to those surrounding their nest area, there was a significant difference in *Typha sp.* (paired samples t-test: t_3=3.62, P=0.036; Figure 1.9). This was mostly influenced by two of the six broods that were often located within thick *Typha sp.* patches while the parents were documented foraging along the edge of nearby open water. Parents also took their broods to areas with shallower water (3.3±0.6 cm) compared with the average water depth at their nests (8.7±2.0 cm; paired samples t-test: t_5=2.67, P=0.044). The MacKay Island marsh complex experienced a high wind event from June 29 until July 3, resulting in elevated water levels (as much as 0.5 m) throughout the study area. During this time, 3 radio-tagged parents moved their broods from natural marsh to impounded marsh, where water levels were maintained at a stable lower level. While tracking parents with broods between 1 and 3 weeks in age, all parents consistently alarm called when I was within 5-10 m of their broods. Alarm calling parents would slowly move towards dense stands of nearby *Phragmites* or *Typha sp.*, perhaps in an attempt to lure me away from the brood or call the brood to cover. As broods aged, they became increasingly difficult to locate, often moving away silently with the parent. I continued to follow radio-tagged adults less frequently beyond the brood-rearing stage. Adults tended to remain in the same vicinity.

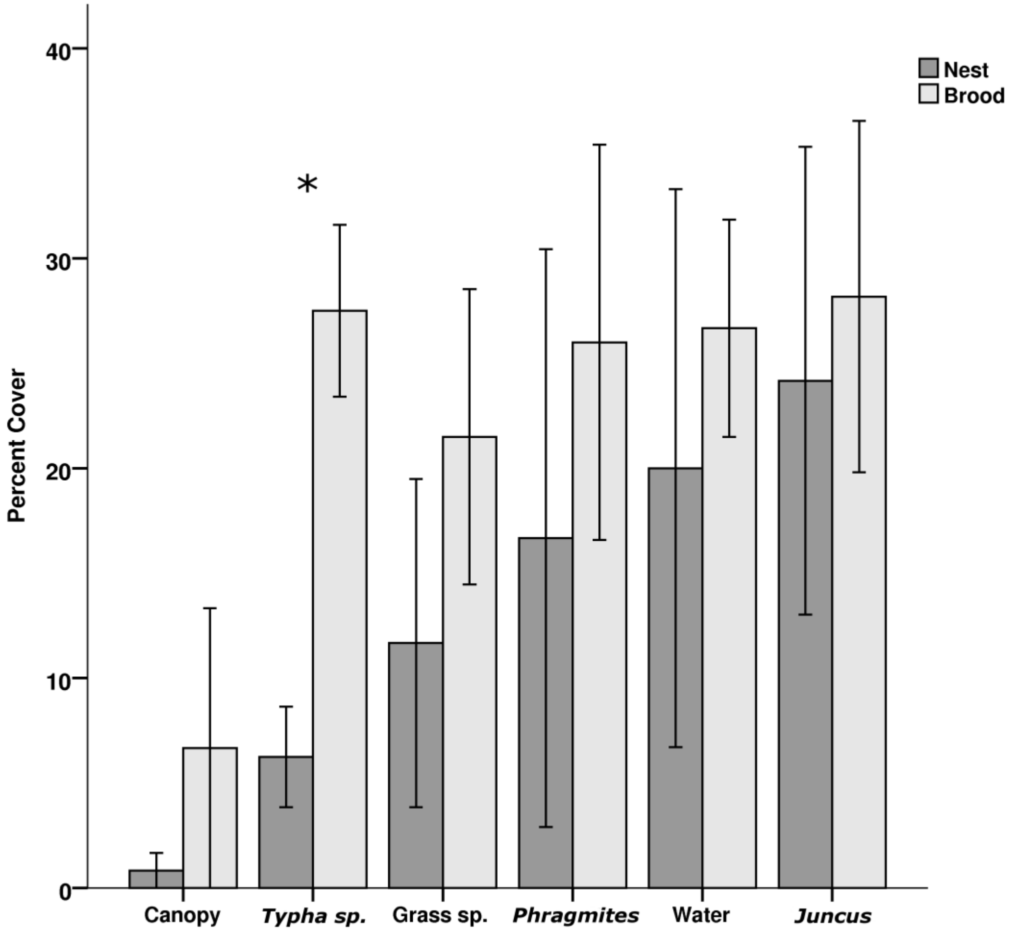


Figure 1.9 The percent cover of dominant marsh plant species, canopy, and water at brood and nest locations. The asterisk (*) denotes statistical significance at the α=0.05 level and values presented are means ±SE.

1.5 DISCUSSION

Along the Atlantic coast, King Rails selected microhabitat based on distance to open water and edge and selected vegetation cover differently during the brood-rearing period than the breeding and non-breeding periods. During the non-breeding period, King Rails tended to favor areas with greater canopy cover. These areas had as much as 70% canopy cover and were dominated by *P. taeda* and *M. cerifera*, two woody plant species that form raised platforms around the base of their trunks that results in a platform-laden habitat characterized by a mosaic of small open pools and elevated substrate. King Rails were sometimes flushed from these platforms where crayfish carapace pieces were frequently seen, indicating their usefulness for manipulating and consuming prey. Native to the southeastern United States, red swamp crayfish are commonly found in open and wooded freshwater marshes (Momot 1995), and are a preferred food for the King Rail (Meanley 1956).

Previous studies have shown evidence of a negative correlation between King Rail occupancy and woody vegetation. The majority of these studies investigated habitat preferences of King Rails only during the breeding period (Pierluissi and King 2008, Darrah and Krementz 2009, Bolenbaugh et al. 2012). By contrast, this study determined empirically that King Rails use wooded wetlands during the breeding, brood-rearing, and non-breeding stages of their life cycle. During the breeding season, I found King Rails in areas with measurable canopy cover only 18% of the time. This increased to 30% of the time during the non-breeding period. Similarly, in Louisiana during the few months prior to the breeding season, King Rails were seen using brushy levees along crayfish ponds and wet fallow fields when there was little cover elsewhere (Pierluissi and King 2008).

During the non-breeding period, the protective cover of emergent vegetation at MacKay Island senesces, which may initiate the movement of King Rails to wooded marsh. Coincident with this was the return of migrant Northern Harriers (*Circus cyaneus*), which are opportunistic predators capable of killing birds larger than adult King Rails (Tornberg and Haapala 2013). Northern Harriers course low over the ground, spending a majority of their foraging period in open wetlands (Preston 1990). Cooper's Hawks (*Accipter cooperii*) also frequented the refuge during the winter and are thought to avoid wooded areas too dense for flight below the canopy (Reynolds 1989). The movement of some King Rails to wooded marsh during the non-breeding season may thus be an aerial predator avoidance strategy. After using callback to elicit vocalizations from King Rails in emergent marshes, a Northern Harrier, on one occasion, and a Cooper's Hawk, on another, were immediately observed flying over the location of the calling King Rail. During the course of this study, mammalian predators, such as bobcat (*Lynx rufus*), river otters (*Lontra canadensis*), and raccoon (*Procyon lotor*) have also been observed using wooded edge at MacKay Island, indicating a potential tradeoff between soft-bottomed emergent marsh and the cover of wooded marsh. Five radio-tagged King Rails were depredated and I determined the class of likely predators. Two out of three mammalian predation events occurred in or near wooded marsh and one avian predation occurred in January, in open marsh. Additionally, two of these deaths occurred out in the open during an unusual cold snap when open water froze over for 5 days, possibly forcing King Rails to forage away from cover.

King Rails were found significantly closer to water during the non-breeding season than during the breeding season. King Rails are known to forage along the edge of open water (Meanley 1956, Pickens and King 2013). Winter average temperatures range from 0-12ºC along the northern extent of the Atlantic wintering range and greater energy demands on overwintering birds may necessitate higher foraging rates. During both the brood-rearing and non-breeding periods, King Rails were found significantly closer to edge habitat than during the breeding season. Invertebrates comprise a large part of the King Rail diet (Meanley 1956), and a greater number and diversity of aquatic invertebrates occur where open habitat is interspersed with emergent vegetation than in monotypic zones (Voigts 1976). Indeed, the interface between vegetation and water within marsh ecosystems is of importance to several other marsh bird species due to increased food availability (Rehm and Baldassarre 2007).

Nest densities were greater at my study site than the 3.4-4.8 nests/km^2 and 15.9 nests/km^2 reported in Louisiana rice fields by Pierluissi and King (2008) and Hohman et al. (1994), respectively. Meanley (1969) observed nest densities as great as 16.5 nests/km^2 in Arkansas, noting that nesting areas tended to be along areas of open water, such as ditches. Similarly, King Rail nest densities at MacKay Island were highest in areas with a mosaic of small, shallow pockets of open water amongst emergent vegetation.

My study differed from others as I actively searched suitable habitat multiple times throughout the breeding season. The King Rail breeding period is extensive, lasting from late March through August. On one occasion, a pair vacated their nesting area during the brood-rearing stage and a different pair of King Rails built a nest only 26 m away. High nest densities at MacKay are indicative of a robust breeding population of King Rails, providing the opportunity to better understand characteristics of a potential source population as the species declines throughout its range.

Nests were more likely to be found in *Juncus roemerianus* than any other plant species. *Juncus,* a grass-like, wetland obligate that tends to grow in dense tufts, dominates 21% of the coastal marshes in the south Atlantic states (Eleuterius 1976). Only a small number of nests were found in *Hibiscus moscheutos,* grass sp., *Typha sp.,* and invasive *Phragmites*. In other parts of its range, King Rails place nests in a variety of similar emergent vegetation types that also provide sufficient cover and structure to support the nest platform, such as river bulrush (*Schoenoplectus* fluviatilis), softrush (*Juncus effuses*), cattail, and rice fields (Meanley 1969). When comparing microhabitat characteristics at nest locations to those in the immediate surrounding area, King Rails select for greater concealment, placing nests far away from edge and open water and selecting microhabitat with significantly less open water. However, vegetation type and distance to water/edge had no effect on nest fate. Nests tended to be in locations farther from water and with less *Phragmites* than the microhabitat breeding individuals were more generally found in. Pickens and King (2013) also found individual King Rails used areas with *Phragmites* in Louisiana, presumably for cover. One adult in my study brought its brood into an area dominated by *Phragmites*, where it remained for the duration of the dependent period. *Phragmites* grows in dense monotypic stands, yet the lowest portion of the plant is often denuded of leaves, likely allowing for greater mobility and line of sight for King Rails. In Louisiana *Phragmites* is not considered an invasive, whereas the spread of *Phragmites* is actively managed at the Mackay Island refuge. While site-specific *Phragmites* control is effective in the short-term, treatments are costly and it is essentially impossible to eradicate completely without continued intervention (Ailstock et al. 2001). My study suggests that managing a heterogeneous marsh landscape with small patches of *Phragmites* might be appropriate for King Rails.

While King Rails did not tend to choose cover types selectively throughout the year, brood-rearing parents brought their young to areas with less *Juncus*. During the breeding and non-breeding periods, King Rails were located in areas dominated by *Juncus* more than two thirds of the time. By contrast, adults with broods were almost half as likely to be found in *Juncus*, indicating a significant shift in microhabitat use at a critical time in the King Rail life cycle. Since *Juncus* grows in dense clumps, chicks may become entangled and exhausted, much like Northern Bobwhite (*Colinus virginianus*) chicks become fatigued in dense vegetation (Hurst 1972).

King Rails with broods favored areas closer to edge and in shallower water. Broods in the Illinois and Upper Mississippi River Valley were similarly found using areas of shallow water (mean water depth 0.6 cm; Darrah and Krementz 2011). Between 1.5 and 30 days of age, the tarsus length of a young King Rail grows from about 20 mm to about 42 mm (Meanley and Meanley 1958). Though both adults and young can swim, shallow water likely allows greater mobility for the young, and increased foraging success for adults, since water depth limits foraging in wading birds (Kushlan 1976, Gawlik and Crozier 2007). This was observed when three brood-rearing pairs brought their families to areas with managed water levels during a flooding event. Managing water levels for rice and crayfish along the Gulf Coast may function similarly in meeting the needs of rail species, explaining their abundance in these agricultural habitats. Other studies of wetland obligates, such as Mallards (*Anas platyrhynchos*) and Redheads (*Aythya Americana*), have shown that hens bring their broods to seasonal wetlands that likely provide improved foraging opportunities (Mauser et al. 1994, Yerkes 2000). Similarly, Greater Sage-Grouse (*Centrocercus urophasianus*) broods use areas with more food forbs located near escape cover (Sveum and Crawford 1998). Adult King Rails' preference for edge when tending their young may thus have a twofold purpose. Edge habitat provides ample cover for broods to escape from predators, and helps satisfy the food demands of growing chicks.

Two King Rail broods were frequently located within *Typha sp.* patches. While King Rails rarely nested in *Typha sp.*, this softer broad-leaved reed was common as a secondary emergent species where king rails were located throughout the year. Another brood consistently used areas with high amounts of *M. cerifera* and on three separate occasions chicks were observed on elevated platforms at the base of *M. cerifera*. These platforms likely serve as dual-purpose refuges, keeping vulnerable broods out of the water, semi-covered, yet out of thick vegetation.

In summary, Atlantic coast King Rails choose different microhabitats in different seasons and in relation to stage of breeding. This is the first study to track radio-tagged King Rails throughout the year, and for the first time on the Atlantic coast. Because adults seek out areas of shallow water during the brood-rearing period, marshes that have emergent vegetation with consistently low water levels should be protected for King Rails. Land and refuge managers should consider lowering water levels within impoundments to assist rails during this critical period. Managing for increased vegetation heterogeneity and water interspersion through the use of prescribed fire or periodic flooding may help increase King Rail populations, as has been suggested in other studies (Rehm and Baldassarre 2007, Pickens and King 2013). In my study, King Rails preferred microhabitat with 25-35% open water. While *Typha sp.* and *Phragmites* appear to be avoided when nesting, patches near nest locations may provide essential cover for adults and their broods. Thus, managing a mosaic of patchy emergents interspersed with open water and a wooded/shrubby perimeter seems best suited for King Rails.

In view of the severe population declines observed in recent years, it is important to understand habitat requirements for the species throughout the year. This study quantified King Rail habitat use during the non-breeding season and provides the first indication that wooded marsh, with a thick understory of emergent vegetation, is a suitable habitat for wintering and brood-rearing King Rails.

Additionally, managers might consider increasing food item abundance like invertebrates (i.e. crayfish) where King Rails exist, as open water and edge preferences reflect the importance of food availability. Over a 20-year period in Louisiana, the greatest increase in wading bird populations was correlated with an expansion in commercial crayfish farming (Fleury and Sherry 1995). However, future research should carefully consider the impacts of introducing non-native invertebrates on local fauna and the surrounding landscape. The most extensive distribution of tidal freshwater marshes in North America is along the Atlantic coast (Odum et al. 1984), and their critical value for waterbirds (Haramis and Kearns 2007) cannot be overstated. These findings might benefit management decisions and help identify suitable natural habitat for the conservation of the King Rail along the Atlantic flyway to ensure its long-term survival.

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Chapter 2

Seasonal variation in home range and movements of the Atlantic coast King Rail

2.1 ABSTRACT

The King Rail (*Rallus elegans*) is a secretive marsh bird that inhabits densely vegetated wetlands throughout the eastern United States. Population declines in the last half of the 20th century have warranted recent investigations into King Rail biology. Yet, their migratory status, home range characteristics, and patterns of movement remain poorly known, particularly along the Atlantic coast. A greater understanding of the spatiotemporal patterns and movements of the King Rail are urgently needed to inform landscape models and to develop conservation strategies for this enigmatic bird. From 2012-2014, I quantified the home ranges and movements of King Rails at MacKay Island NWR. Through the use of capture, marking, resighting, and telemetry, evidence supports that at least a segment of the population is resident year-round. Mean King Rail home range size was 19.8±2.5 ha (95% kernel density) and adults were tracked in wooded, emergent, and impounded marsh. Females had significantly larger home ranges during the non-breeding season than males, and trended toward a higher rate of movement throughout the year. Within their year-round home ranges, males were more likely to be found where there was a greater percent cover of open water, indicative of higher quality habitat. Brood-rearing King Rails led their young considerable distances away from nesting locations (average maximum: 581±211 m), and frequently used impounded marsh. Summer draining of impounded wetlands that are seasonally flooded for wintering waterfowl allows regrowth of vegetation and provides

suitable habitat for King Rails. My results further highlight the use of wooded marsh during the brood-rearing period and particularly by females in the non-breeding season.

2.2 INTRODUCTION

Migration is theorized to be an adaptation in response to predator avoidance, intraspecific competition, and changes in ephemeral resources (Cox 1968, Greenberg 1980, Alerstam and Hedenstrom 1998). Thus, understanding the migratory status of a population can contribute to conservation planning for the species and the basic understanding of species ecology. The existence of resident populations may indicate suitable habitat that can maintain a year-round population. If a declining species is completely migratory, preserving wintering or stopover habitat becomes of great importance. Additionally, the movement of individuals between populations increases gene flow, which can lead to increased genetic variation, whereas the restricted movements of individuals within a population can lead to decreased genetic variation and inbreeding, potentially affecting the overall success of a species (Slatkin 1987).

Home ranges, defined by Burt (1943) as the area in which an animal normally travels, can be influenced by density dependent variables such as population size (Wunderle 1995), intraspecific competition (Greenberg 1986), habitat quality (Kelley et al. 2011), and resource availability (Rolando 1998). Thus, valuable knowledge of the spatiotemporal variation of a species' home range size could be gained from quantifying habitat characteristics, including environmental change over time (Kelley et al. 2011), as they likely shape the dynamics of a species' movement, local distribution, and population abundance (Morris 1987). For example, in some Neotropical avian migrants, males have been shown to defend higher quality habitat on wintering grounds while females use marginal habitat (Parrish and Sherry 1994, Wunderle 1995). This is presumably because males competitively exclude females from accessing areas of increased food availability (Parrish and Sherry 1994). Managing areas of increased habitat quality, once identified, is important for sustaining species at risk. For instance, the intentional periodic flooding of impounded aquatic areas allows for the management of vegetation and invertebrate species that benefit many avian wetland obligates (Fredrickson and Taylor 1982, Eddleman et al. 1988).

In addition to identifying the spatial requirements of a species, understanding the ecological factors influencing vital rates at different life stages would prove beneficial for conservation. In particular, the stage of early development in birds, from fledging to recruitment into the breeding population, greatly influences life histories and population dynamics (Lindström 1999). Indeed, brood survival, in combination with nesting success, exerts the greatest effect on population growth across all life stages (Wisdom and Mills 1997). Population modeling, as part of a recovery effort, is weakened without accurate brood survival rates and knowledge of density dependence (Wisdom and Mills 1997).

Understanding the spatial variation between life stages can provide important information about the population dynamics of secretive marsh birds. While standardized bird surveys are effective in determining population trends and habitat associations (Conway and Gibbs 2005, Pierluissi and King 2008, Budd and Krementz 2011), information on spatial requirements for many marsh birds remains sparse due to their secretive nature. The King Rail is a species of high conservation concern experiencing widespread population declines throughout the eastern United States (Eddleman et al. 1988, Cooper 2008). In contrast to recent studies, which have focused primarily on population estimates, nesting habitat, and site occupancy during the breeding season

(Darrah and Krementz 2009, Valente et al. 2011, Bolenbaugh et al. 2012), the present study investigated the intra- and inter-seasonal movements of the King Rail along the Atlantic coast.

I used radio-telemetry to investigate the seasonal movements and home range variation of the King Rail in northeastern North Carolina during 2012 and 2013. The objectives of my study were: first, to determine if King Rails in northeastern North Carolina are resident or migratory. Currently there is little quantitative information on residency patterns along the Atlantic coast. Second, I sought to determine if home range size varies between the breeding and non-breeding seasons. No other studies have determined the spatial requirements of the King Rail during the non-breeding season. I predicted home ranges would expand during the non-breeding seasons as resources became limited. Third, to test if there are differences in individual movements between the breeding, brood-rearing, and non-breeding periods, and lastly, to determine if specific microhabitat characteristics correlated with home range size. To conserve the few and dwindling populations, it is necessary to examine the spatial requirements of King Rails on an annual cycle, as single season approaches cannot effectively determine a species' spatial requirements (Cline and Haig 2011).

2.3 METHODOLOGY

2.3.1 Study Area

I conducted my research at MacKay Island National Wildlife Refuge (NWR) in 2012 and 2013. Located in northeastern North Carolina, MacKay Island's 1,932 ha of freshwater tidal marsh is dominated by emergent vegetation including *Juncus roemerianus* (hereafter known as *Juncus*), *Phragmites australis* (hereafter known as *Phragmites*), and *Typha sp*. (USFWS 2008).

Other habitats include mixed hardwoods and pinewoods. MacKay Island NWR is actively managed via the water control structures of 6 impoundments to help meet the needs of migrating and wintering waterfowl and other wetland birds. For a full site description, see Chapter 1.

2.3.2 Capture Methods and Transmitter Design

I used a combination of whoosh nets, mist nets, and spotlighting to capture King Rails throughout the study period. Once captured, basic morphometric measurements were taken and adults were fitted with a radio transmitter (Advanced Telemetry Systems, Isanti, MN; Model A2480, 3.6g) with a backpack harness adapted from the design of Dwyer (1972) (see also Casazza et al. 2008). For a full description of capture methods and transmitter design, see Chapter 1.

2.3.3 Field Protocol and Spatial Analysis

King Rails were monitored closely immediately after affixing the transmitter and harness. Following a 24-hour acclimation period, birds with transmitters were tracked every one to three days during the breeding season (April 1-August 31), and at least twice every two weeks during the non-breeding season (September 1-March 31). Using a portable receiver (ATS, model R410 receiver) and a three-element folding Yagi antenna, I conducted “walk-ins” and triangulated bird locations by taking compass bearings from 3-5 preset radio-tracking stations. All bearings on an individual were gathered within 30 minutes of each other to minimize error caused by large movements. Birds caught while incubating were monitored more frequently for possible changes in behavior or location directly before and after their clutches hatched. After hatching, locations of adults with broods were documented every one to three days via "walk-ins" or triangulation. Adults with broods were stealthily tracked until chicks were seen or juvenile vocalizations were detected, confirming the presence of the brood.

Triangulation locations were digitized using the maximum likelihood estimation method as computed by LOAS software (Location of a Signal; Ecological Software Solutions LLC). Ellipse errors were calculated from the data using a 95% confidence interval with a χ^2 distribution. I eliminated 15 locations (3%) with an error ellipse >10 ha since birds likely moved during triangulation. Using the computational options of the BIOTAS software (Ecological Software Solutions LLC), home ranges were calculated under a fixed kernel density analysis with least squares cross-validation as a smoothing parameter. In an effort to balance being as inclusive as possible with the number of birds I was able to collect data on, while maintaining the integrity of the fixed kernel density analysis, I estimated home ranges for birds with ≥14 points. Though small numbers of observations tend to overestimate home range size (Seaman et al. 1999), Börger et al. (2006) demonstrated in Roe Deer (*Capreolus capreolus*) and Common Kestrel (*Falco tinnunculus*) that home ranges normalize after collecting 10 fixes. Pickens and King (2013) found that, for King Rails in coastal Louisiana, home ranges typically did not increase after 20 fixes.

To determine if home range size differed between the breeding and non-breeding periods, I used a paired sample t-test for the subset of birds for which sufficient data were collected during both time periods. Because time-matched random points were found not to differ in microhabitat variables from bird locations (see Chapter 1), I combined the variables from bird and random locations to describe microhabitat variables within a home range. In addition, only 6 of the 191 (3%) random points fell outside of the 95% kernel density estimate contour for all birds. I ran a Pearson's correlation to test for habitat associations and home range size for 95% and 50% kernel densities. I tested for the effects of sample size on home range size by running a paired samples t-test on home ranges with >40 points and randomly subsampling the data points to 30 and to 20. I tested for the effects of the duration of transmitter exposure, in days, on home range size with a linear regression model. I calculated median, mean, and maximum distance between locations using Geospatial Modelling Environment (GME, Spatial Ecology LLC) for each bird. I then ran a linear mixed model controlling for repeated measures to calculate mean differences in movements between seasons. To compare differences in movements between sexes, I used an independent samples t-test. I also calculated movements of adults with broods. Results are reported as means ±SE and figure error bars are ±1 SE.

2.4 RESULTS

2.4.1 General Radiotelemetry Parameters

A total of 21 King Rails were captured and radio-tagged using the various capture methods (see Chapter 1) between June 10, 2012, and March 11, 2014. I analyzed 576 bird locations and estimated home range for 15 King Rails (n=6 females and 9 males; Figure 2.1) with ≥14 data points (median=42 per bird, range = 14 to 69) between June 15, 2012 and January 28, 2014. All locations for individual birds were documented at least 20 hours apart to ensure independence. The mean bearing error of telemetry signals from tracking stations was 2.68±1.14º and the mean distance from tracking stations to transmitter was 270±25 m

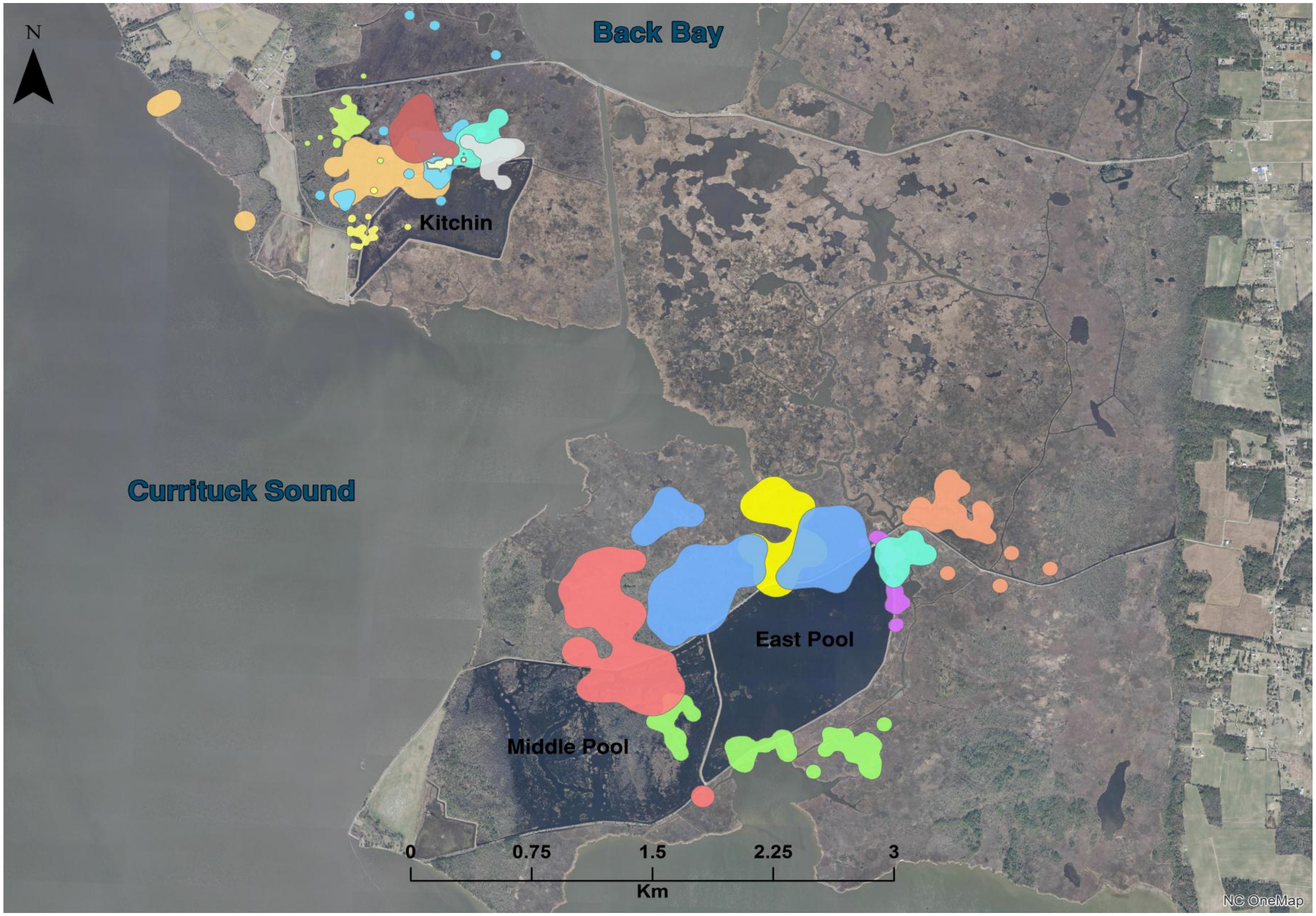

Figure 2.1 Overview of all home ranges documented on MacKay Island NWR from June 10, 2012, to March 11, 2014. Each color represents a single individual (n=15). Time frames for individuals do not necessarily overlap and individuals did not move between northern and southern sections of the refuge. Dark areas of map are open water impoundments labelled Kitchin, East Pool, and Middle Pool. Pale lines are roads.

Table 2.1. King Rail home range size at MacKay Island National Wildlife Refuge, NC, 2012-2013. Values presented are means ±1SE. Bracketed values indicate range of 95% kernel density range.

Season	95% Kernel Density (ha)	50% Kernel Density (ha)
Breeding (Apr 1 - Aug 31)	19.5±6.3 [1.0-70.8] (n=13)	2.7±1.0 (n=13)
Non-breeding (Sept 1 - Mar 31)	10.3±3.0 [0.5-34.4] (n=10)	1.4±0.4 (n=10)
Annual Average	19.8±2.5 [1.1-69.8] (n=15)	2.7±1.0 (n=15)

2.4.2 Home Range Size Variation

Home ranges tended to be larger during the breeding season than the non-breeding season (Table 2.1). However, due to capturing the majority of birds late in the incubation stage, many breeding season points were gathered during the brood-rearing period (n=95) when birds are no longer constrained to return to their nest. When I considered only individual birds sampled during both time periods (n=8; Figure 2.2 and 2.3), there was no difference in home range size between breeding and non-breeding periods (paired samples t-test: $t_7=1.12$, $P=0.3$). I found no effect of sample size on home range by comparing home range size of birds with >40 data points (range: 42-69) and randomly subsampling those data points to 30 points (paired samples t-test: $t_6=-1.27$, $P=0.25$) and 20 points (paired samples t-test: $t_6=-1.85$, $P=0.11$). The duration of transmitter application in days did explain a significant proportion of variance in home range size ($R^2=0.48$, $F_{1,13}=11.4$, $P=0.006$). However, when I remove a female from the analysis that carried a transmitter for 368 days, which is 120 days greater than the next longest duration, time is not a significant factor in the model ($R^2=0.19$, $F_{1,12}=2.6$, $P=0.13$).

I predicted that adults frequenting impoundments would have smaller home ranges, because they may not have had to travel as far between prey items when foraging. However, home ranges adjacent to impoundments were not different in size from home ranges that were not adjacent (n= 7 adjacent and 9 nonadjacent; independent samples t-test: $t_{14}=0.05$, $P=0.96$). There was a negative correlation between breeding home range size and percent open water (Pearson's correlation, 95% kernel: $r=-0.62$, $n=11$, $P=0.04$), but no correlation during the non-breeding period. I found no correlations between home range size and other habitat variables.

All 14 King Rails captured during the non-breeding season were male, suggesting differences in distribution by sex. Therefore, I compared home range size and movements

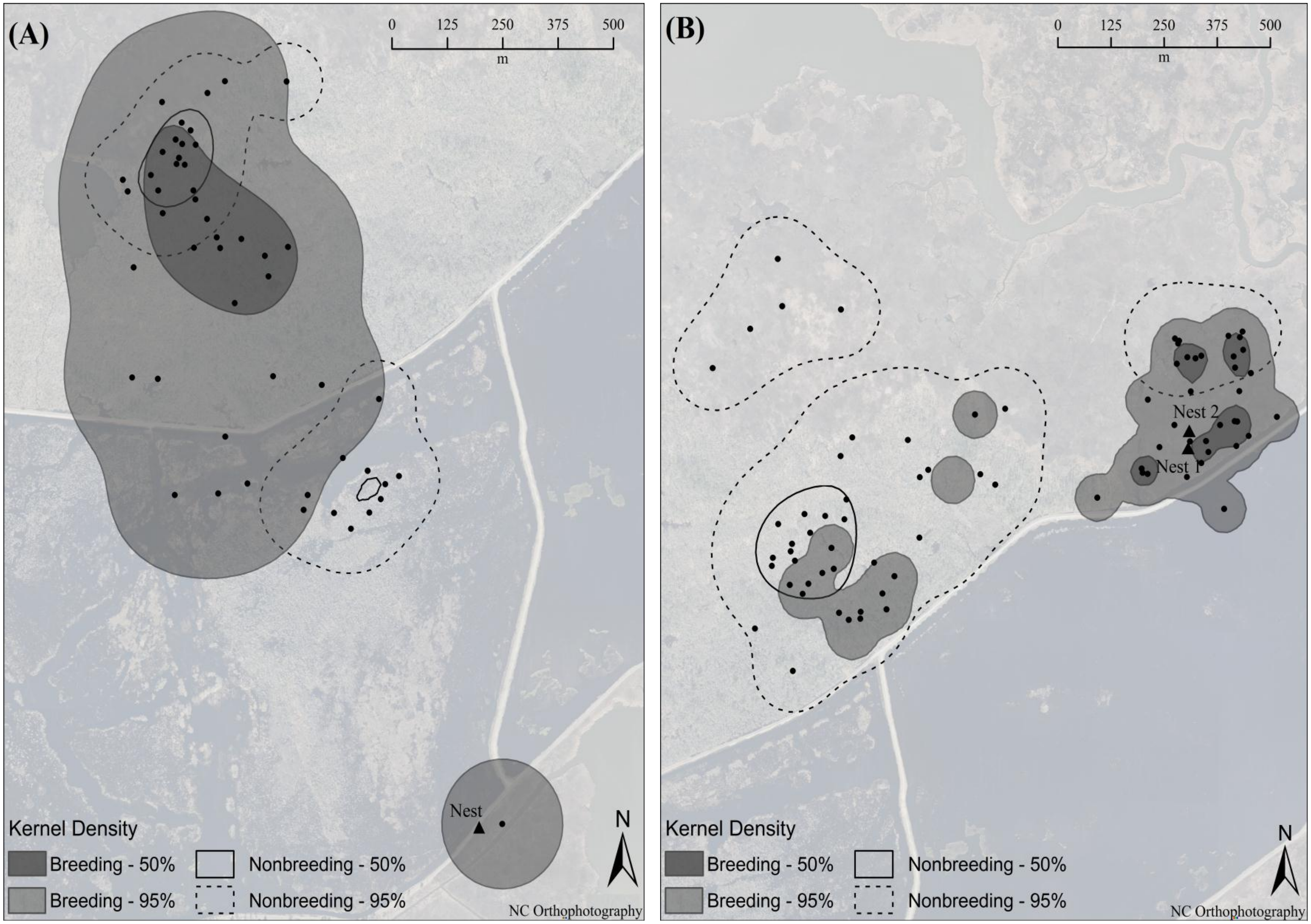

Figure 2.2. Variation in female King Rail home ranges between breeding and non-breeding seasons. Examples are shown for two females (**A&B**) caught on their nests. Points represent bird locations and nest locations are labeled.

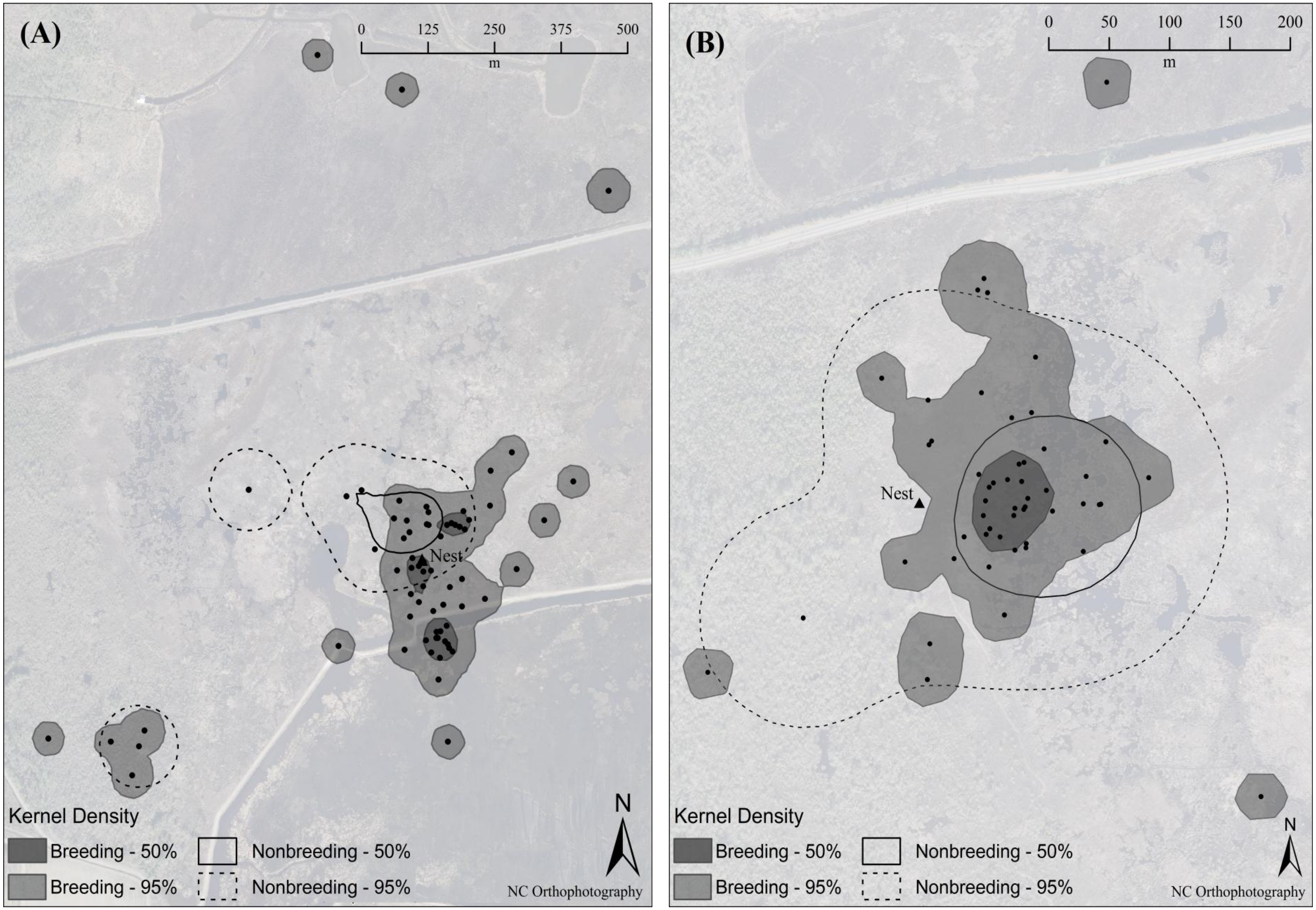

Figure 2.3. Variation in male King Rail home ranges between breeding and non-breeding seasons. Examples are shown for two males (**A** & **B**) both caught via spotlighting from an airboat, and followed as they paired, nested, and tended broods. Points represent bird locations and nest locations are labeled.

between sexes and found 95% kernel density home ranges differed by sex during the non-breeding period (independent samples t-test: t_7=-2.40, P=0.047), with males having significantly smaller home ranges (8.3±2.8 ha) than females (23.0±4.9 ha). Most of the measured microhabitat variables (see Chapter 1) were similar between sexes. However, males had a significantly greater percentage of open water within their home ranges (33.5±3.2%) than females (23.9±2.7%; independent samples t-test: t_{11}=2.25, P=0.046; Figure 2.4). Female home ranges contained a significantly greater percentage of *M. cerifera* (18.4±1.4%), a shrub species found in the understory of wooded areas, than males (9.4±3.2; independent samples t-test: t_5=2.85, P=0.036).

2.4.3 Individual Movements

When comparing individual movements of birds, I removed all brood locations from the analyses since limitations on brood mobility could potentially constrain parental movements. The mean distance traveled between observations for all birds was 158±8 m and the average maximum distance was 884±169 m. There was no difference in maximum or mean distances traveled between the breeding and non-breeding periods. Females tended to move greater mean distances (174±19 m) than males (130±19 m), though the difference was not significant (independent samples t-test: t_{12}=1.579, P=0.14). Since female home ranges during the non-breeding season were larger than males, I compared mean distance traveled during that period and found a stronger trend for females to move greater distances (173±29 m) than males (104±23 m; independent samples t-test: t_9=1.89, P=0.09; Figure 2.5). The average maximum distance traveled was also greater for females (1250±231 m) than males (718±227 m), but the difference was not statistically significant (independent samples t-test: t_{14}=1.61, P=0.13).

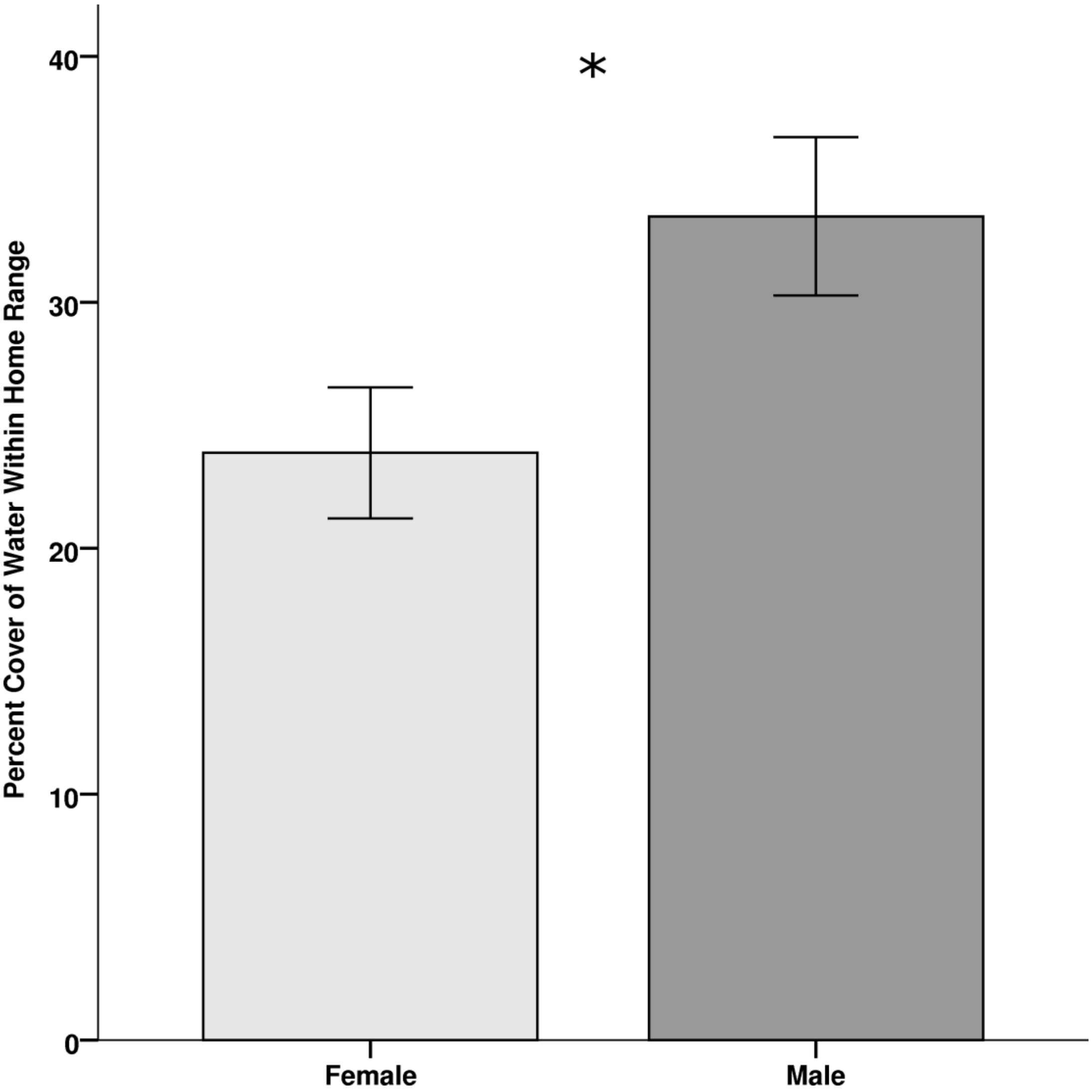

Figure 2.4. Male King Rails had more open water in their home ranges than females. Values presented are means ±SE.

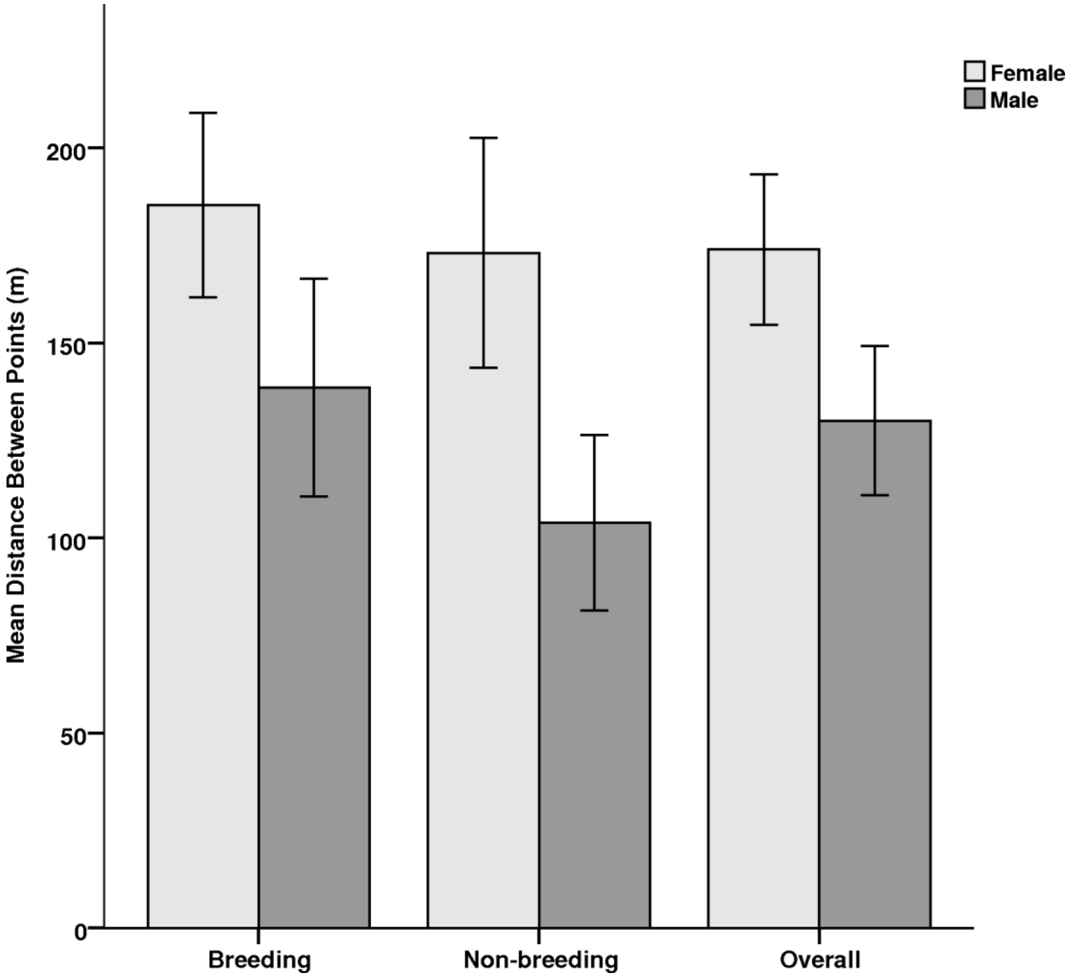

Figure 2.5. Female King Rails tended to travel greater distances between observations during the non-breeding season. Values presented are means ±SE.

Of the 8 King Rails tracked at MacKay Island NWR during both the breeding and the non-breeding season, 7 remained on the island. The exception was a female, captured on the nest on June 27, 2013, and documented on the island for 215 days with a maximum distance of 1797 m between points. Her signal was not detected from August 3 – September 17, 2013, but was detected again after September 17, 2013, in a wooded marsh area 450 m from her nesting location. She was last detected on January 28, 2014, moving west and across Currituck Sound.

Another female captured on June 23, 2012, moved 418 m on August 8, 2012, from her nesting area to wooded marsh. She remained within the wooded marsh for 248 days before moving back to her previous nesting area in April, 2013, where her first nesting attempt was discovered on May 27.

A male King Rail captured on March 2, 2013, was the only bird (out of 9) documented within wooded marsh during the study period. On March 31, he moved 600 m from his territory and remained in the wooded marsh until April 13. During this time, he was giving ‘kek’ calls. He briefly returned to his territory before moving 900 m north of the Marsh Causeway, which bisects part of the marsh, and he remained north of the causeway for 4 days before returning to his territory with a mate (Figure 2.6). This is the only instance of a male traveling a considerable distance from his territory.

Anecdotal records supported that the population at this site is at least partially resident. In addition to 7 radio-tagged King Rails remaining at the study site throughout the year, one male captured via airboat on February 2, 2013, was resighted incubating a clutch on June 16, 2013. Through DNA analysis, a male captured during the winter of 2012 was determined to be the father of a brood from 2011 (Brackett and McRae, unpublished). The winter residency of this individual was clearly not influenced by transmitter application. I lost the signal of two further

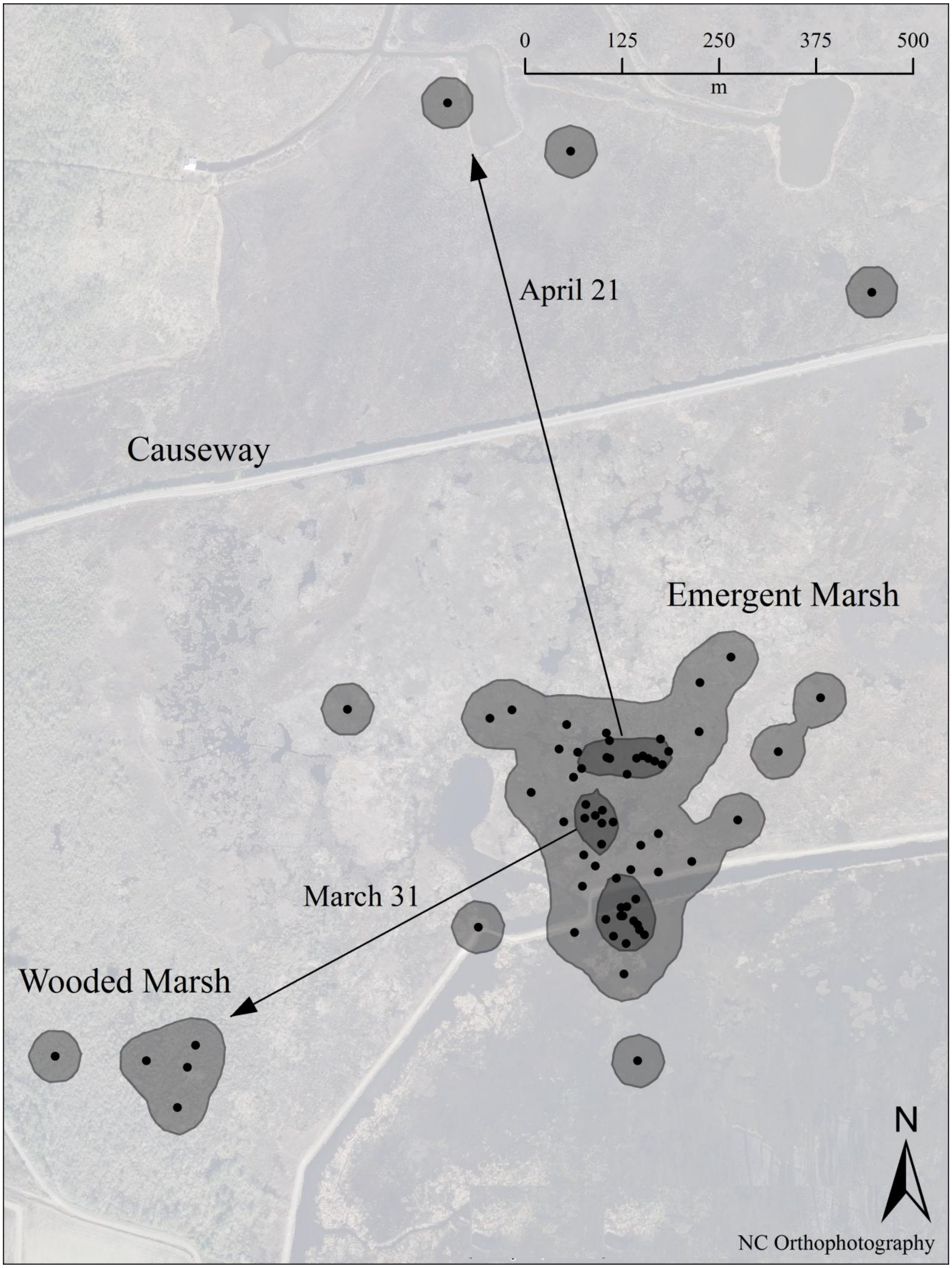

Figure 2.6. Map depicting movements of a male King Rail shortly before pairing with a mate. Forays during the pre-mating period were accompanied by bouts of ‘kek’ mating calls.

King Rails during the study period, which may have resulted from transmitter failure, migration, or predation, though 5 other transmitters were recovered after predation.

2.4.4 Brood Movements

During the breeding season, I tracked 6 King Rail broods. In the first two days after fledging, broods moved a mean distance of 89±27 m from their nests. Between days 3 and 5 post hatching, broods moved a mean distance of 312±144 m from their nest locations to microhabitat different than their nesting microhabitat (see Chapter 1). Brood movements averaged 157±13 m between sightings. Broods moved a maximum distance of 581±211 m from their nests over the course of the dependent period (mean=28.0±4.5 days, range=8-40). As broods became more mobile two weeks post-hatching, they were more difficult to detect in the emergent marsh, often stealthily moving away with the adult. The greatest amount of time between hatching and confirmation of a brood with a radio-tagged adult was 39 days (almost 6 weeks). The greatest distance traveled by a brood was more than one kilometer in a day (Figure 2.7), from emergent marsh across an impoundment to wooded marsh only 5 days after the last chicks hatched. High south winds between June 29 and July 3 raised water levels throughout the marsh complex and forced many King Rails onto refuge roads. This event coincided with the adult moving the brood out of the woods and into the Middle Pool impoundment where water levels remained lower and stable.

Two broods that hatched synchronously with one another in adjacent territories (Figure 2.8) were regularly observed frequenting emergent, natural marsh and impounded marsh. The adults were seen actively foraging in the impoundment carrying crayfish into patches of *Typha*

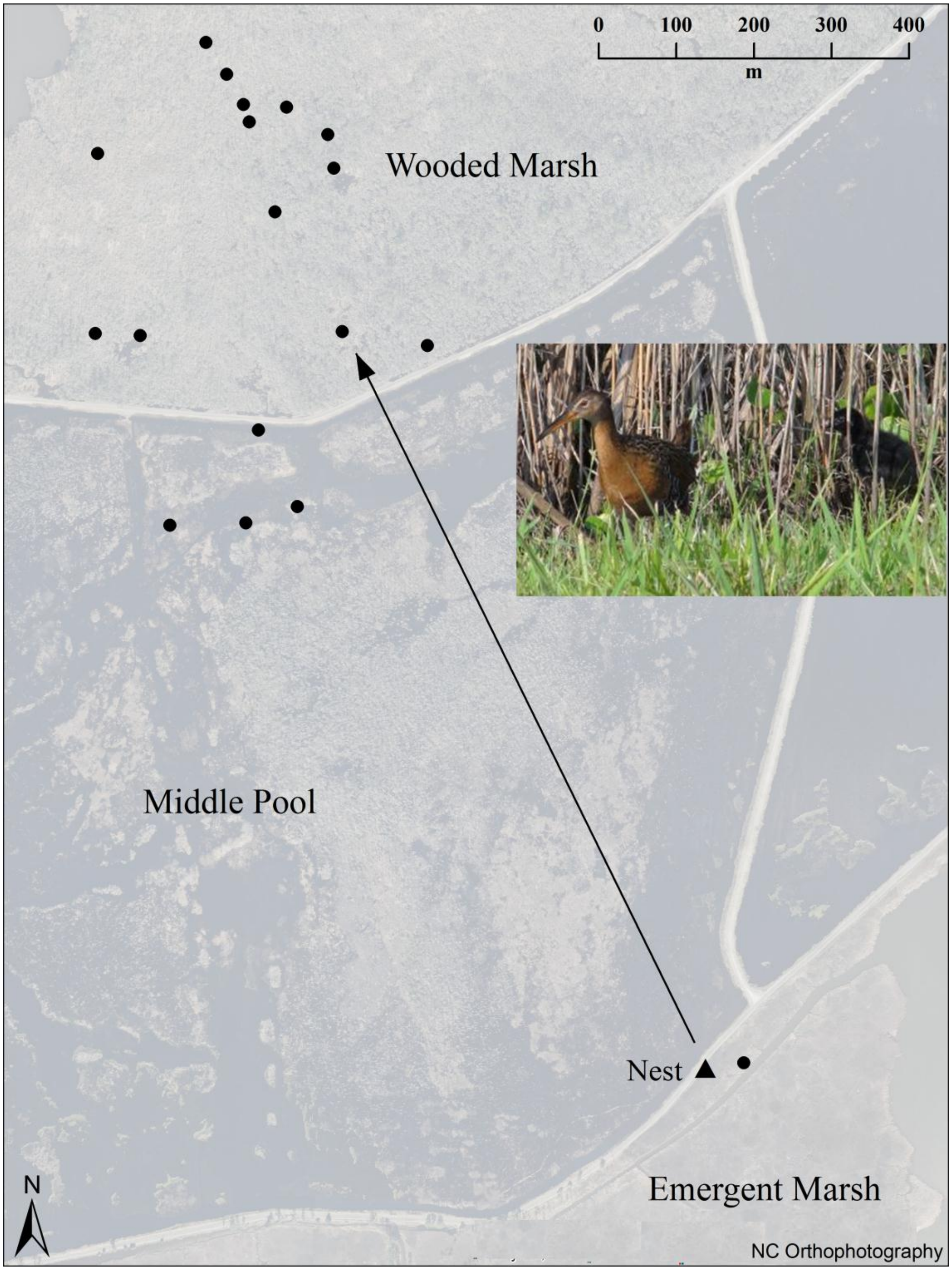

Figure 2.7. Movement of a brood between June 16, 2013, until July 6, 2013. Locations of the brood–rearing adult are shown in relation to its nest. The arrow represents the distance traveled from the nest (direct line = 1008 m), only 5 days after the last chick fledged. The darker area labeled Middle Pool is a managed impoundment. Inset photo given as an example of chick size (on right side of photo) between 2-3 weeks of age.

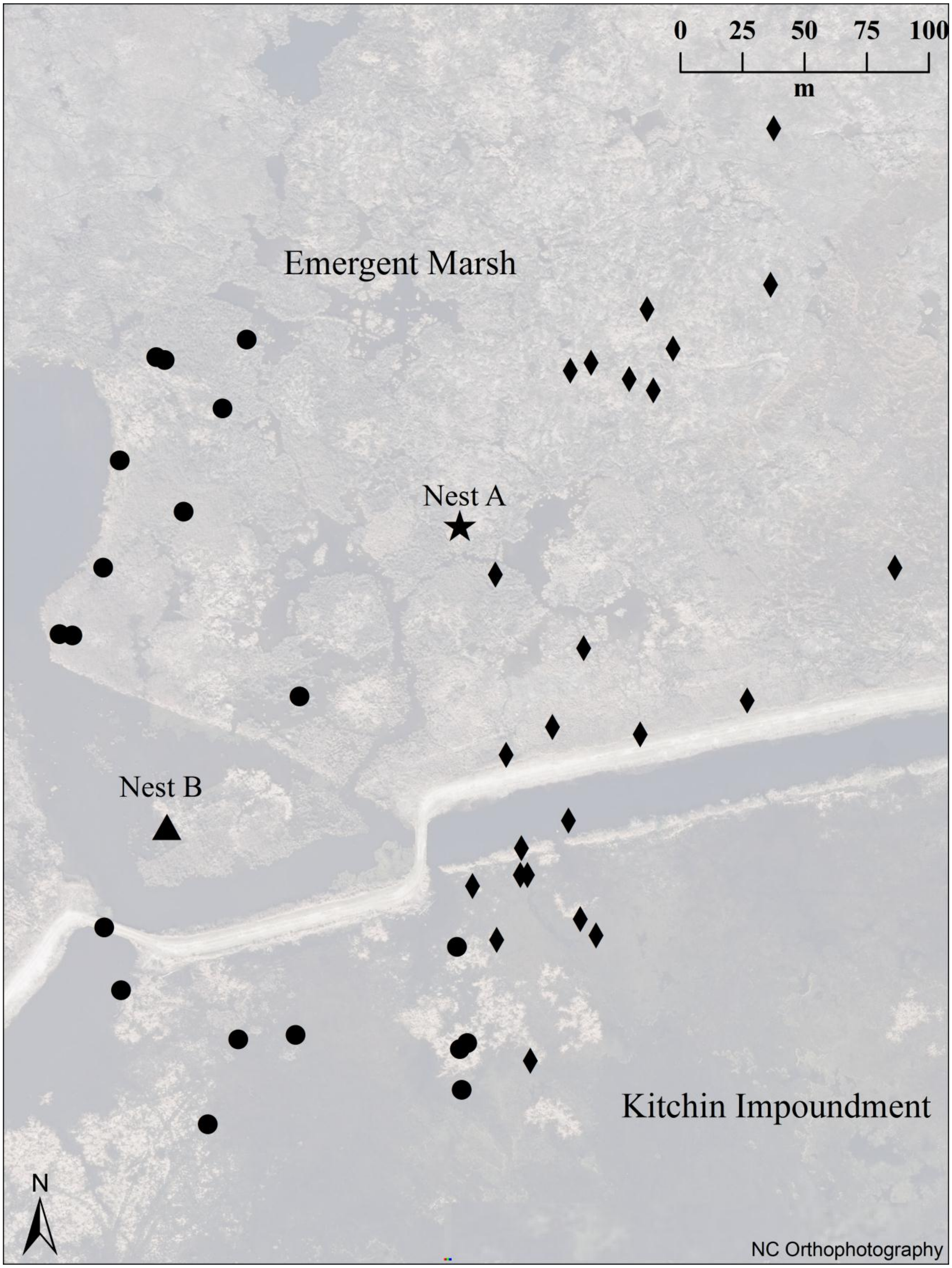

Figure 2.8. Proximity of two broods from adjacent territories from June 20 to July 26, 2013. Diamonds represent brood locations from Nest A, hatched on June 20, and circles represent brood locations from Nest B, hatched on June 28. Both broods moved between natural marsh and managed impoundment.

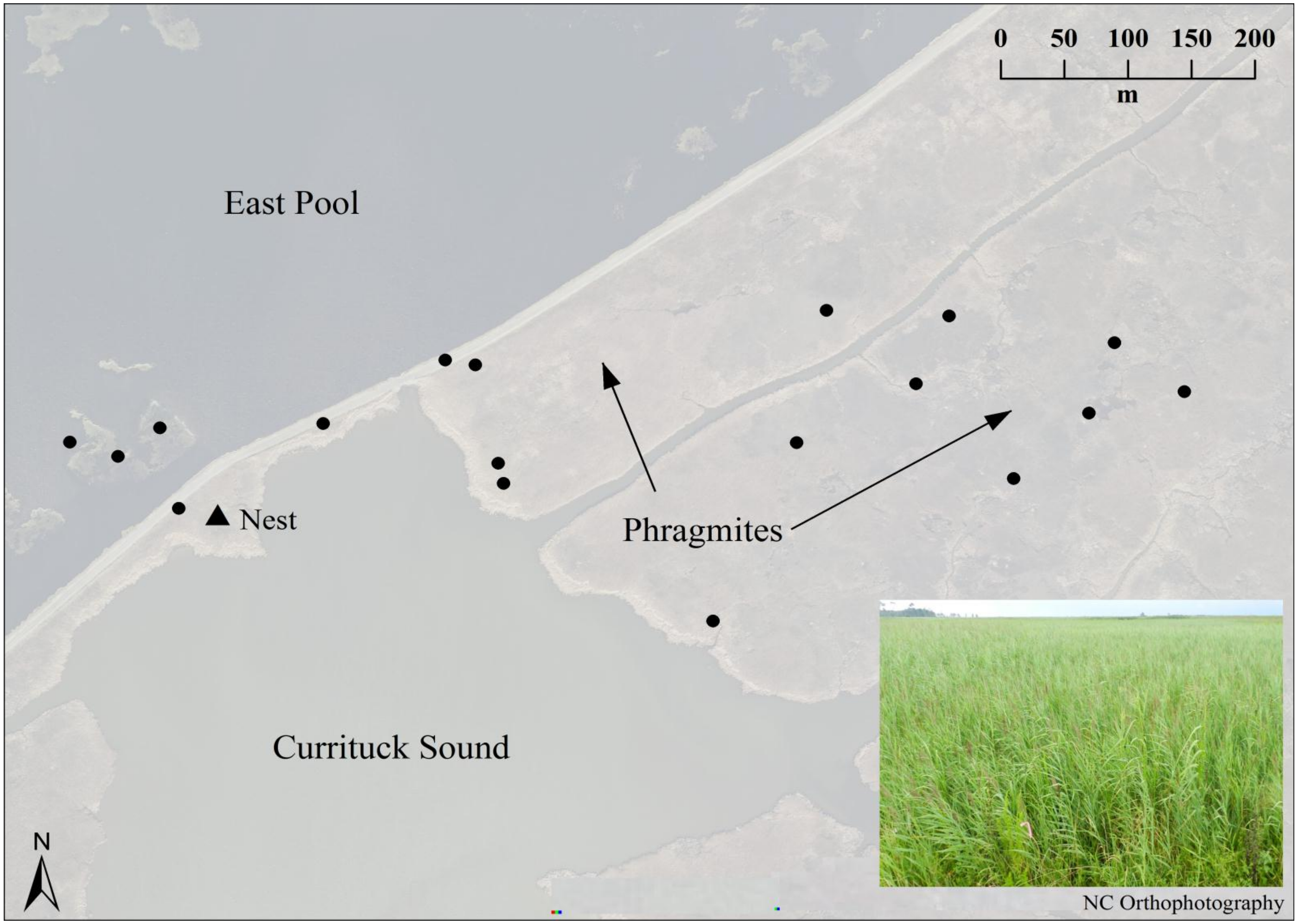

Figure 2.9. Locations of a brood-rearing adult in relation to the nest documented from June 28, 2013, until August 5, 2013. East Pool impoundment largely consists of open water habitat unsuitable for King Rails. Inset photo depicts the growth stage of *Phragmites* in which the brood was located.

sp. where their broods were located. A brood that hatched from a nest adjacent to East Pool (Figure 2.9), where the parent was observed foraging (n=5), was brought to an area dominated by invasive *Phragmites* with small patches of native marsh vegetation. The brood remained in that area until I could no longer detect the chicks at 5 weeks of age. I observed three other broods using the Kitchin and Middle Pool impoundments, including a banded adult with 3-week-old chicks.

2.4.5 Impoundment Use by King Rails

As prescribed in the refuge management plan (USFWS 2008), routine drawdown of impoundments occurs in spring. On May 14, 2013, between 0.6-0.8 m of water was drained from the East Pool, Middle Pool, and Kitchin impoundments at MacKay Island NWR (Figure 2.1), creating expansive mudflats with sporadic *Phragmites* and *Typha sp.* cover. Prior to that day, radio-tagged King Rails had been tracked only in natural marsh throughout the refuge. The day of the impoundment drawdown, a male captured in March was found inside the Kitchin impoundment for the first time. Thereafter, 15 out of 68 points (22%) comprising his home range were inside the impoundment where he was observed foraging. Three additional radio-tagged King Rails frequented the Kitchin impoundment (Figure 2.10) during the breeding season, and additional King Rail vocalizations were often heard coming from within the impoundments. Two King Rails were tracked within Middle Pool and East Pool during the breeding and non-breeding seasons with a total of 21 out of 40 locations (52.5%) and 15 out 50 locations (30%). In between nesting attempts in natural marsh, a radio-tagged female was tracked over two days in the East Pool. Additionally, I documented three nesting attempts within the East Pool during the first

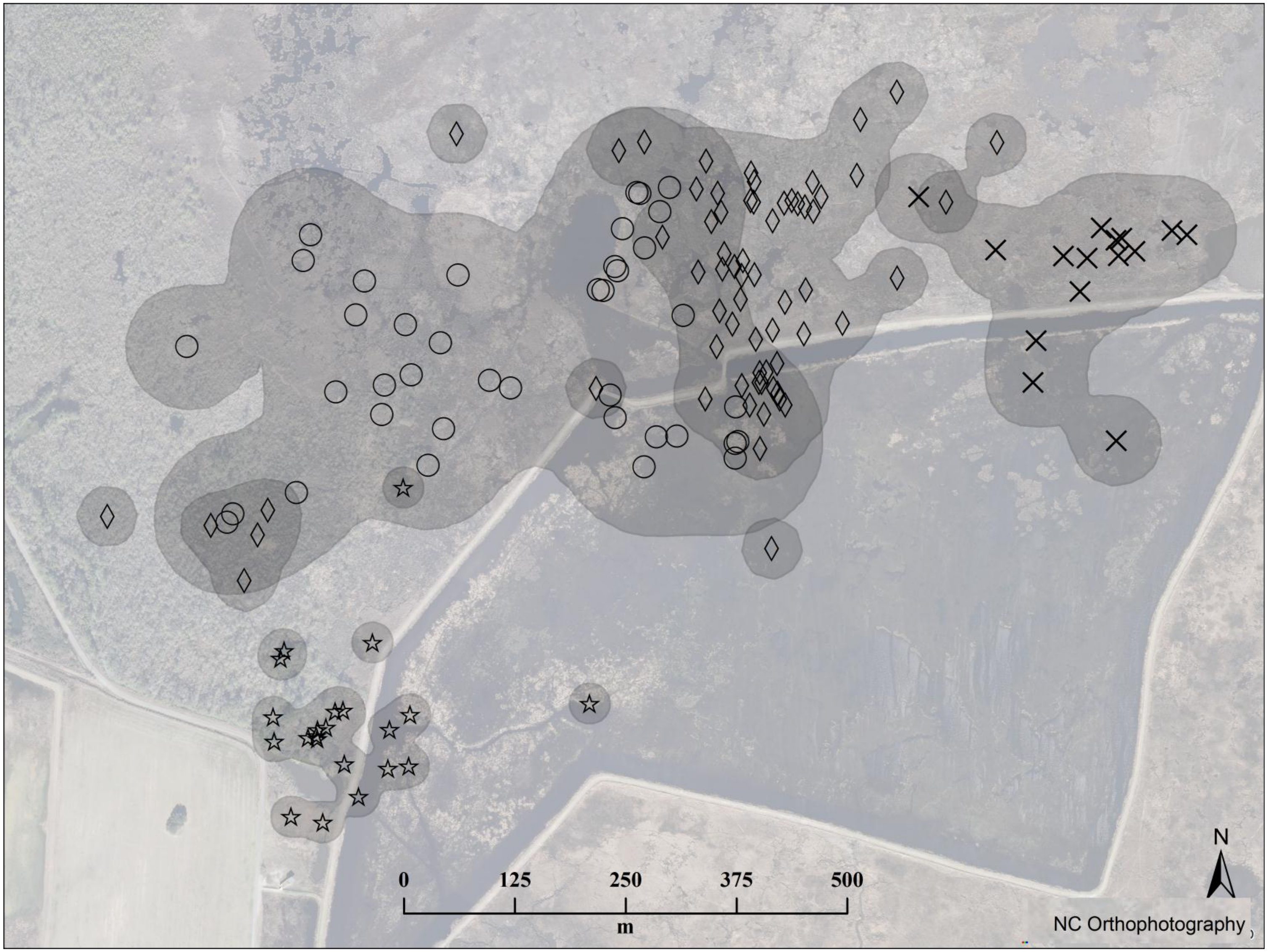

Figure 2.10. Depiction of four King Rail home ranges overlapping the Kitchin impoundment during the breeding season, 2013. Individual locations are marked, respectively, by stars, circles, diamonds, and x’s.

week of June, none of which were successful. On March 11, 2014, a King Rail was captured inside the Kitchin impoundment during a period of high water.

2.5 DISCUSSION

The ability to track individual King Rails along the Atlantic coast provided insights into the spatiotemporal ecology of a declining and secretive marsh bird. One goal of this study was to determine if King Rails maintain year-round residency along the North Carolina coast. While it is thought that the middle Atlantic states harbor resident populations, uncertainties remain (Meanley 1969, Cooper 2008). Despite a limited sample size, the presence of radio-tagged individuals, and anecdotal evidence of a few non-radio-tagged individuals remaining through the transition periods between the breeding and non-breeding season, suggests that at least a segment of the population is resident. A resident population would indicate adequate year-round habitat. In conjunction with evidence that this marsh supports a population with a positive growth rate (Brackett 2013), this underlines the need to preserve this and other freshwater marshes with similar habitat characteristics along the Atlantic coast to assist recovery efforts.

King Rail mean breeding home range sizes were larger than those in Louisiana (0.8-32.8 ha; Pickens and King 2013), possibly due to regional habitat differences, food availability, or habitat saturation in Louisiana. While quantifying home ranges with ≤30 points is generally not recommended because they overestimate home range size (Seaman et al. 1999), sample size did not affect home range estimates and Pickens and King (2013) found King Rail home ranges within the breeding season asymptote around 20 points. My larger home ranges may be influenced by more extended tracking periods, highlighting the importance of investigating year-round spatiotemporal requirements. Certainly, the inclusion of adults tending broods in my study increased home range size as territories broke down and they moved from nesting habitat to brood-rearing habitat (see Chapter 1).

Mean daily movement distances were similar to Gulf Coast King Rails (78-144m; Pickens and King 2013), and a related species, the Yuma Clapper Rail (*Rallus longirostris yumanensis*) (126-157 m; Conway et al. 1993). Though distances moved between sightings were similar on average to other studies, individual locations were documented over a greater time period. It is likely that the larger home ranges reported in this study are more representative of the spatial ecology of the species throughout the year, at least in this part of its range. This further illustrates the need for the collection of multi-seasonal data to fully document the spatial requirements of the King Rail. Ideally, to understand annual movements, it would be best to track individuals beyond one year, where possible. As transmitters are miniaturized, and built to last longer, this becomes more feasible.

On average, King Rail home ranges decreased in size during the non-breeding period. This was contrary to my prediction, and to the findings of (Conway et al. 1993) with the Yuma Clapper Rail, that inhabits freshwater marshes of the southwestern U.S. Home ranges would be expected to increase during the winter if there were a decrease in food availability. However, the King Rail diet varies considerably throughout the year, with animal prey constituting nearly 90% of its spring and summer diet and falling to 58% during the winter (Meanley 1956). A decrease in invertebrate abundance during the winter may result in King Rails using smaller areas with a greater abundance of plant food, such as browntop millet (*Panicum ramosum*) found within impoundments, tubers of arrowhead (*Sagittaria*), and woody plant seeds (Meanley 1956, Nassar et al. 1988). *Carex*, which was encountered within wooded marsh at the study site, is an important food source for the Yellow Rail (*Coturnicops noveboracensis*) (Robert et al. 1997) and seeds constituted 98% of migrating Soras' (*Porzana carolina*) diet in freshwater marshes (Webster 1964). During airboating excursions in October, I noticed an increase in Virginia Rail (*Rallus limicola*) and Sora (*Porzana carolina*) vocalizations and sightings that coincided with an abundance of insects (e.g. *Orthoptera*), potentially allowing for contraction of home ranges. As colder temperatures set in, there seemed to be a decrease in other rail species, but I could not detect a difference in King Rail abundance based on visual or auditory cues. Since rail species rarely vocalize and are not commonly seen during the non-breeding period (Meanley 1969, Conway et al. 1993), an undetected influx of overwintering King Rails which breed farther north could cause a contraction in winter home ranges. Because many of North Carolina's coastal freshwater marshes are highly influenced by wind driven tides (Odum et al. 1984), and winter months are accompanied by strong sustained north winds that decrease water levels and reveal expansive mudflats, home ranges may contract due to an increase in foraging opportunities. During the non-breeding period, King Rails were found closer to water and edge (see Chapter 1), areas of increased macroinvertebrate availability (Voigts 1976, Kaminski and Prince 1981, Rehm and Baldassarre 2007).

Home ranges differed by sex during the non-breeding period, with males having smaller home ranges than females. Along the Gulf Coast, King Rail home range size is inversely related to percent cover of open water (Pickens and King 2013). In conjunction with the sexual difference observed in home range size in my study, males had on average a greater percentage by area of open water within their home ranges than females, suggesting that males remain in higher quality habitat. Female home ranges differed from males with a greater percentage of *M. cerifera*, a common shrub species potentially used for cover and forage (see Chapter 1). In

Southport, N.C., wintering Clapper Rails were similarly observed moving to high marsh which had a greater abundance of *M. cerifera* than low marsh (Adams and Quay 1958).

Remarkably, all 14 King Rails captured during the winter in emergent marsh were male (see Chapter 1). Conversely, 4 out of 5 tracked females were observed using wooded marsh during the non-breeding season, further suggesting sexual segregation in habitat use during the winter. Only two males were observed in wooded marsh during the study. One entered a wooded area with its mate and brood and was depredated 2 days later. Another moved to the woods for 3 days while in search of a mate, which is intriguing considering my observations of 4 females using that habitat. Additionally, females tended to move greater distances between successive tracking points than males during both the breeding and non-breeding periods, possibly suggesting that females are using marginal habitat and have to travel farther to forage. However, females that experience an unsuccessful breeding season could potentially increase reproductive success by moving to another territory, possibly explaining their greater movements. Brackett and McRae (unpublished) observed a female switch mates between 2011 and 2012. Long term data and genetic analyses will be needed to establish whether males are more likely to be philopatric to breeding sites than females.

While sexual segregation in habitat use has never before been described in rails, it is well-documented in various Neotropical migrants (Morton 1990, Ornat and Greenberg 1990, Parrish and Sherry 1994), with food availability likely being the driving force behind habitat selection during the winter period (Greenberg 1986). Along the Gulf Coast, smaller Clapper Rail home ranges were associated with greater densities of fiddler crabs (Rush et al. 2010). Perhaps nonmigratory male King Rails remain within their breeding territories during the winter due to familiarity and an increase in food availability upon the departure of the female. Similar to the

Townsend's Solitaire (*Myadestes townsendi*), as pair bonds break down after the breeding season females may persist as nonterritorial floaters as resources decrease in the winter months (Salomonson and Balda 1977). Whether or not female use of wooded wetlands has adaptive value or occurs out of constraint remains to be seen. With populations declining throughout the King Rail's range, a better understanding of sexual differences in habitat use and winter survivorship is needed. If, for instance, the sex that provides the greatest parental investment (females in most monogamous birds; Trivers 1972) is limited by habitat availability during the non-breeding period, population persistence would be dependent on their survival. Further information on parental roles and division of labor in the King Rail would be needed to test this idea.

King Rail broods moved a substantial distance from their nests within the first few days of hatching. Considering chicks average 14-16 g when they hatch, movements of 100 m or more to different habitat (see Chapter 1) is a remarkable feat. Similar to movements in Mallard (*Anas platyrhynchos*) broods (Mauser et al. 1994), most relocations occurred within the first week as King Rail broods became progressively mobile between days 3 and 5. In contrast to chicks of waterfowl species that can self-feed at this developmental stage, King Rail chicks are dependent on parental feedings (Meanley 1969). King rail broods were never in the same location between successive tracking days and frequent moving may indicate a depletion of prey (Brinkhof 1997), or they may move in relation to variation in water level which can limit prey accessibility and offspring mobility (Bancroft et al. 2002). Chicks of Willow Grouse (*Lagopus lagopus*) move more frequently in areas with lower insect abundance, and adults with broods traveled greater distances than those without to satisfy the nutritional needs of their young (Erikstad 1985). A family of King Rails could quickly deplete an area of invertebrates and would need to move on to find new forage and sustain a brood. Estimated survival rates in the Midwest and Gulf Coast regions are between 4-15% for King Rail broods within the first two weeks of hatching (Darrah and Krementz 2011, Pickens and King 2013), and the increased movements I observed may reflect predator avoidance. Survivorship estimates could not be made in my study due to the difficulty in visual confirmation of the number of surviving chicks, and persistent alarm-calling from adults tending broods foiled attempts at auditory confirmation.

Three of the six King Rail broods followed consistently moved between natural marsh and impounded marsh. During a period of unusually high water levels in natural marshes throughout the study area, the three broods remained within the impoundments (where water level was held constant) before returning to natural marsh when water levels returned to normal. This underscores the importance of consistently low water levels during the brood-rearing period. Also at this time, a brood cared for by a lone female after her mate was depredated was observed mingling with a similar aged brood in an impoundment. This was the only time I saw overlapping broods. Loss of suitable habitat due to decreasing water levels is known to increase rail densities (Griese et al. 1980), which could lead to increased predation risk or intraspecific competition for food. Similar behavior results from increasing water levels since King Rails were observed out in the open along refuge roads during high water events. Since broods moved an average maximum distance of nearly 600 m from their nests, I would caution others conducting studies of rails against the assumption that brood locations are representative of nesting areas and vice versa. Additionally, because broods may converge on favorable habitat, estimating brood survival rates without identifiable parents may result in inaccuracies.

The use by rails of wetlands impounded for agricultural and wildlife management purposes is well documented, and the strategic manipulation of water levels at specific times of the year to provide a diverse integration of marsh edge, emergent vegetation, and open water, has been shown to be advantageous for waterbirds (Fredrickson and Taylor 1982, Eddleman et al. 1988, Galat et al. 1998). I found King Rails spent the majority of their time in emergent natural marsh, but would move to impoundments adjacent to natural marsh regardless of the time of the year. An unexpected finding of this study is the unique interplay of habitats with dynamic versus stable water levels, and how they might affect rail behavior and movements. While hydrologic variability increases emergent vegetation abundance (Galat et al. 1998), habitat heterogeneity (Rehm and Baldassarre 2007), and macroinvertebrate diversity (Voigts 1976), areas with stable water levels are clearly also important to the King Rail, especially during brood-rearing. Breeding rails may be particularly imperiled in coastal marshes because of greater and more unpredictable fluctuations in water levels than in inland marshes. This is especially true during the hurricane season that commences midway through the breeding season.

Previous research has investigated the breeding biology of the King Rail (Darrah and Krementz 2009, Valente et al. 2011, Bolenbaugh et al. 2012). In this study, the observed differences in spatiotemporal requirements highlight the importance of year-round investigations on the King Rail and other declining species. Optimally, as transmitter technology advances and longer-lasting models are miniaturized, tracking durations will be longer than one year. Fluctuations in home range size and extensive movements, especially during the brood-rearing period, reveal greater individual space requirements than previously reported when yearlong needs are considered. Furthermore, movement of independent and brood-rearing adults between impoundments and natural marsh illustrates the value of managed habitats bordering natural wetland, particularly as natural areas are becoming subjected to more extreme and unpredictable climatic events. Marshes with high interspersion that vary in water depth, provide optimal foraging opportunities, and have extensive areas of emergent vegetation for nesting and cover, can fulfill the needs of King Rails throughout the year.

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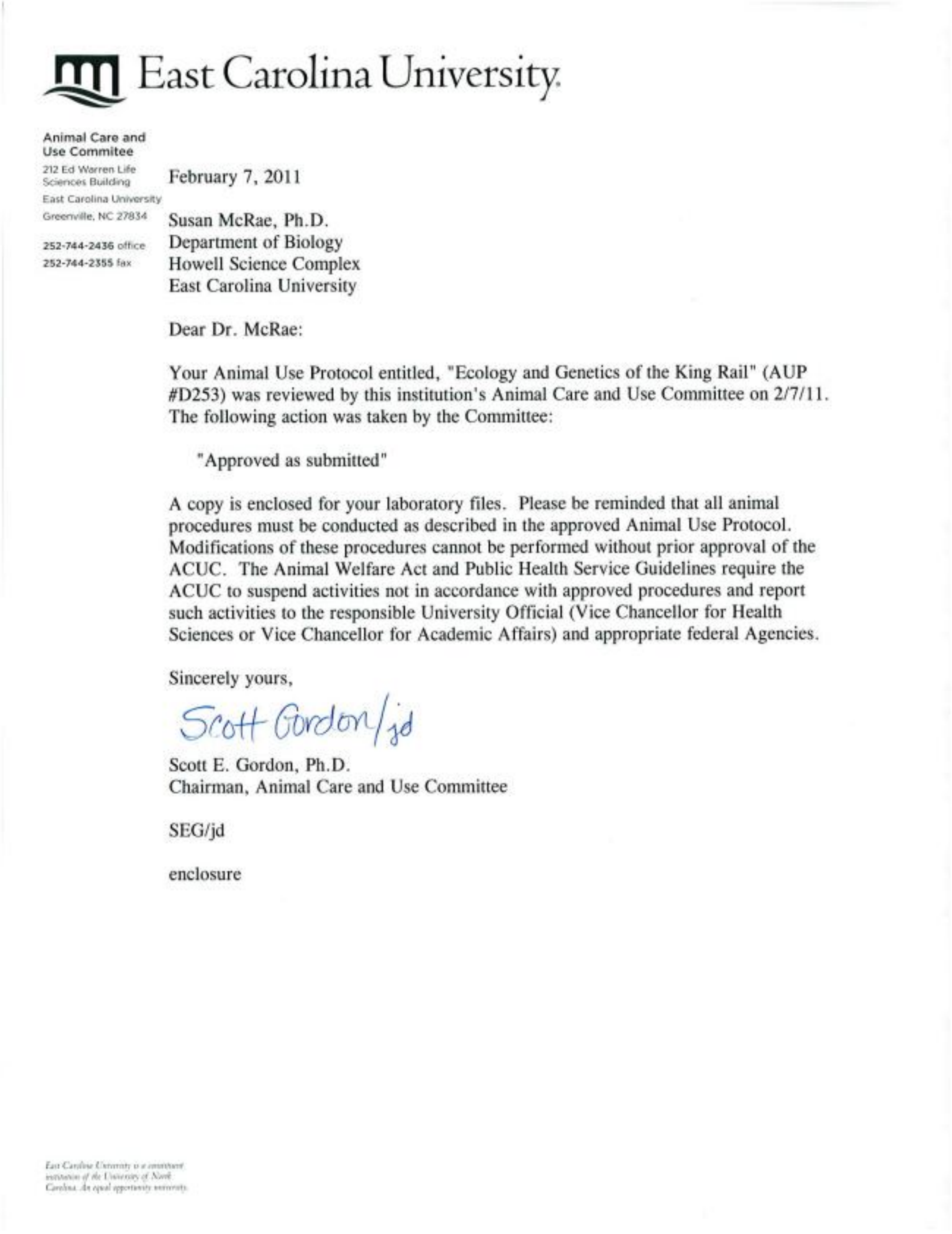
APPENDIX A: IACUC APPROVAL LETTER



East Carolina University.

Animal Care and Use Commitee
212 Ed Warren Life Sciences Building
East Carolina University
Greenville, NC 27834

252-744-2436 office
252-744-2355 fax

February 7, 2011

Susan McRae, Ph.D.
Department of Biology
Howell Science Complex
East Carolina University

Dear Dr. McRae:

Your Animal Use Protocol entitled, "Ecology and Genetics of the King Rail" (AUP #D253) was reviewed by this institution's Animal Care and Use Committee on 2/7/11. The following action was taken by the Committee:

"Approved as submitted"

A copy is enclosed for your laboratory files. Please be reminded that all animal procedures must be conducted as described in the approved Animal Use Protocol. Modifications of these procedures cannot be performed without prior approval of the ACUC. The Animal Welfare Act and Public Health Service Guidelines require the ACUC to suspend activities not in accordance with approved procedures and report such activities to the responsible University Official (Vice Chancellor for Health Sciences or Vice Chancellor for Academic Affairs) and appropriate federal Agencies.

Sincerely yours,

Scott Gordon/jd

Scott E. Gordon, Ph.D.
Chairman, Animal Care and Use Committee

SEG/jd

enclosure

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