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King Rail (*Rallus elegans*) Nesting and Brood-rearing Ecology in a Managed Wetland in Oklahoma, USA

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Abstract.—The King Rail (*Rallus elegans*) is a secretive marsh bird of conservation concern. Reproductive success is thought to be a limiting factor for the inland migratory population. Reproductive effort of King Rails was studied in southeastern Oklahoma, USA, from 2010-2012 using surveys, radio-telemetry, nest searching and brood observations. During 2011-2012, 27-29 King Rail territories were documented. Ten nests were located between the first week in April and the first week in July with a mean clutch size of 10.3 (SE = 0.80). Water depth at nests was shallow (< 15 cm), and nest sites were in locations with more visual obstruction, more microtopographic variation, and more woody stems, while open water cover was less than at random sites. Nine broods were followed and were found to use rearing sites that were in deeper water and had a greater percent of tall emergent vegetation and more woody vegetation than random sites. Brood size dropped from an average of nine to two chicks by the second week. Weekly brood survival rate was 0.87 (SE = 0.045), which resulted in a 29% probability of greater than one chick surviving to fledge at 9 weeks. Increasing reproductive success is a management concern for this inland migratory population of King Rails. *Received 8 December 2015, accepted 3 April 2016.*

Key words.—chick survival rate, clutch size, habitat use, King Rail, Oklahoma, *Rallus elegans*.

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The King Rail (*Rallus elegans*) is a secretive marsh bird of conservation concern as populations have declined markedly over the past 40 years (Cooper 2008; Pickens and Meanley 2015). Qualitative accounts indicate that inland migratory populations were once quite common but have experienced major population declines in the latter half of the 20th century (Cooper 2008). Bollenbaugh *et al.* (2012) sampled King Rails across the entire United States Midwest and found that King Rails were rare across this region. Because of this decline, King Rails are listed as threatened or endangered in 12 states (Cooper 2008).

Wetland loss and alteration are considered the major drivers responsible for declines in King Rails and many other wetland-dependent birds (Eddleman *et al.* 1988; Wilson *et al.* 2007). Wetland management approaches, specifically water level management and control of woody encroachment, can also affect habitat use of King Rails during the breeding season (Naugle *et al.* 1999; Darrah and Krementz 2010; Pickens and King 2014a, 2014b). Inland breeding King Rails are more likely to select nest sites dominated by short (< 1 m) emergent vegetation and deeper (~10 cm) standing water (Reid 1989; Darrah and Krementz 2011). In Missouri, based on 10 broods over 2 years, daily King Rail chick survival ranged from 0.92-0.96 (Darrah and Krementz 2011) and was hypothesized to be a limiting factor for population growth (Cooper 2008).

Our objectives were to document the nest and brood-rearing ecology of King Rails during the breeding season for the inland-occurring King Rail at a managed wetland complex in southeastern Oklahoma, USA. This information should help wetland managers make better management decisions for King Rails during the breeding season in inland areas.

METHODS

Study Area

The study area included restored wetlands in McCurtain County, Oklahoma, USA, in the Red River floodplain (Hoagland and Johnson 2004). We surveyed for King Rail at two public wetland management areas, Red Slough Wildlife Management Area (WMA) and Grassy Slough WMA, and a private wetland complex known as Walnut Bayou (Fig. 1). The wetland complexes were well over 1 km apart and had different management approaches and hydrology. During the course of the study, drought during the growing season went from abnormally dry in 2010 to a severe drought in 2012 (Tinker 2016).

Each wetland unit was composed of a wetland surrounded by a levee that had a water level control structure, and included more than one of the following wetland types: palustrine emergent, scrub-shrub, and forested wetlands that could be permanently, seasonally, or temporarily flooded (Cowardin *et al.* 1979). These sites were managed primarily on a 3-year rotation using water level manipulation, soil disturbance and fire to reduce invasion by woody species, especially black willow (*Salix nigra*). A few units contained deep water (> 1 m) from which other impoundments were flooded. Of the areas surveyed, Red Slough WMA was the most intensively managed site with an overall goal of maximizing diversity, restoring hydrology, re-establishing bottomland hardwoods, and providing waterfowl hunting opportunities.

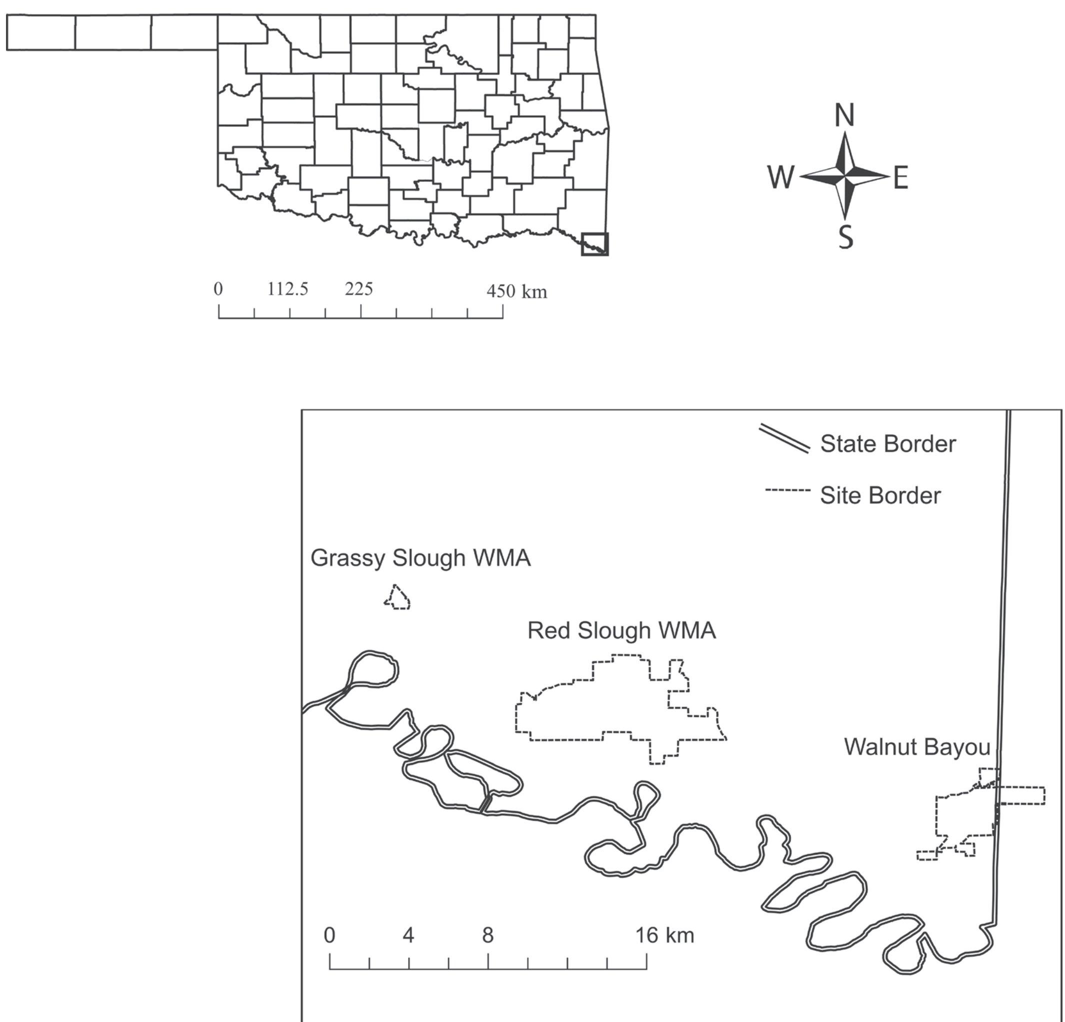

Figure 1. Three wetland complexes located in the southeast corner of McCurtain County, Oklahoma, where King Rail call broadcast surveys and breeding ecology studies were conducted from April through July 2010-2012. WMA = Wildlife Management Area.

Surveys

To locate King Rails for capture and to estimate the number of breeding King Rail pairs at the study sites, we used playback surveys over all 3 years. In 2010, we broadcast King Rail calls to elicit territorial responses at Red Slough WMA and so targeted King Rails only for capture, not to determine the number of territorial birds/pairs. In 2011, haphazard surveys, on the levee and inside the wetland, at Red Slough WMA and Grassy Slough WMA were conducted to locate and count breeding territories. All wetland units were surveyed at least twice. Again, to target King Rails for capture, we increased our survey effort up to five times in those wetlands appearing to have ideal habitat conditions based on review of the literature. In 2012, we randomly selected survey points at Red Slough WMA (n = 50 points), Grassy Slough WMA (n = 4 points), and Walnut Bayou (n = 10 points) stratified by dominant cover types: tall emergent ≥ 1 m, short emergent < 1 m and shrub-scrub. We conducted four surveys at each point from 14 April through 29 June 2012 following the Standardized North American Marsh Bird Monitoring Protocols (Conway 2011) to locate and count breeding territories.

Based on survey results, we targeted territorial King Rails for capture using mist nets, hoop-net traps, toe-snares, and airboat. We set up two mist nets in a "v" in the emergent vegetation and placed a King Rail decoy in the center and played calls. When a bird was close to the net, we would attempt to flush it into the mist net. Hoop-net traps were modified fish traps hidden in the emergent vegetation and placed at known King Rail territories only in 2012 (Fuertes *et al.* 2002). Toe-snare traps consisted of monofilament tied into a loop with a slipknot and attached to a thin bamboo dowel (T. Grazia, pers. commun.); we tied a series of 30 toe-snares together with trotline and inserted them into the ground around the decoy. We used an airboat at night in July 2011 and April 2012 to capture birds with a dip-net (Perkins *et al.* 2010).

We weighed and aged (Meanley 1969) each captured bird and attached a VHF transmitter using a modified backpack harness to adults (Haramis and Kearns 2000) or a necklace harness to juveniles. We allowed marked birds 3 days to adjust to the harness and transmitter before recording any habitat data. Based on triangulation, we estimated the location of each bird daily to within ~25 m.

Nest Ecology

We located nests using telemetry-marked King Rails to lead us to nests, by ground searches in areas where King Rails were heard eliciting territorial vocalizations (Meanly 1969), and by ground searches in areas where no King Rails were detected. In 2010, we searched for nests using one researcher; however, in both 2011 and 2012 two researchers searched the study site. In 2012, we formalized our ground searches by walking the length of each unit twice during the breeding season, and stopping and playing territorial calls along transects. In 2010, we backdated the date of laying assuming that the incubation period was 21 days (Meanley 1969). In 2011 and 2012, we estimated the age of the eggs upon discovery by floating the eggs in water using methods developed for the closely related Clapper Rail (*R. crepitans*) (Rush *et al.* 2007). We did not estimate nest success because of the small number of nests located.

To describe nest site habitat in 2012, we collected habitat data in a 12-m radius circular plot centered on the nest. To determine if nest site habitat was different than random habitat at the study sites, we collected habitat data at randomly selected sites in a 200-m radius plot corresponding to King Rail home range size estimated in South Carolina (McGregor *et al.* 2009). We measured water depth at the nest site and 4 m away in the four cardinal directions and used the average of all five measurements. We visually estimated the percent cover of short emergent, tall emergent and open water, and counted the total number of woody stems in the plot. Short emergents (< 1 m tall) were non-persistent plants that fall below the water surface at the end of the growing season (Cowardin *et al.* 1979) and included smartweeds (*Polygonum* spp.), bur-reeds (*Sparganium* spp.), arrowheads (*Sagittaria* spp.), and ovate false fiddleleaf (*Hydrolea ovata*). Tall emergents (≥ 1 m tall) were persistent plants that normally remain standing until the beginning of the next growing season (Cowardin *et al.* 1979) and included soft rush (*Juncus effusus*), cattails (*Typha* spp.), and shortbristle horned beaksedge (*Rhynchospora corniculata*). We quantified visual obstruction at three height intervals (0-0.3 m, 0.3-1 m, and 1-2 m) using a density cover board placed 4 m from the nest in the four cardinal directions and used the average of the four measurements. We quantified microtopography by measuring the distance from the ground to a level string at 1-m intervals (Courtwright and Findlay 2011). We collected six measurements in each cardinal direction and used the variance as an estimator of microtopography.

Brood Ecology

We located broods by locating telemetry-marked adult birds or by listening for territorial and brood-rearing vocalizations (Meanley 1969). For the five broods with unmarked parents, we tracked those broods over time by the age of the brood and where they occurred within each impoundment. Once we located a brood, the observer would watch from a distance (~15 m) and record the number of chicks. We estimated the age of the chicks in weeks using plumage and size characteristics (Meanley and Meanley 1958). We backdated the hatch date of broods assuming that the incubation period was 21 days (Meanley 1969).

In 2011 and 2012, we collected brood habitat data in a 50-m radius circular plot centered on the brood location point within 2 days or before any rise in water level due to rain or managed draining/flooding. Water depth was the average of the survey point and the four cardinal directions (5 m away) after every survey, telemetry location or brood observation. We visually estimated the percent cover of short emergent vegetation (< 1 m), tall emergent vegetation (≥ 1 m), and open water. We used transects running north-south and east-west to count the number of woody stems in every other 5-m square plot along the transects. Woody stems included shrubs and trees ≥ 4 cm DBH. Shrubs with multiple stems coming from the same rootstock were counted as one.

Survival Analysis

We used a known fate approach to estimate weekly survival probability ($\hat{S}$) of King Rail broods using detections of individuals in each brood age class across the breeding season $\hat{S}$. Because of our small sample of broods (n = 9), we were forced to combine broods across years. We assumed that the broods without a radio-marked adult that we monitored in the same management unit over time were not different broods moving into and out of the management unit. We estimated King Rail chick ages in weeks (Meanley and Meanley 1958), and each weekly age class was the weekly survival interval used in the survival analysis. Thus, temporal variation reflected variation in survival of weekly age classes across all broods and all years and did not reflect within season variation. Broods with greater than one surviving chick through 9 weeks were considered to have survived until fledging, as King Rail chicks become independent after 9 weeks (Meanley 1969).

We analyzed the weekly survival data using the known fate model in program MARK to generate estimates and model selection results (White and Burnham 1999). Because not all broods were associated with a radio-marked adult, we had to assume fates for some broods. We assumed that all broods survived up until the last interval they were seen, but that they then "died" at the end of the last interval detected. The only exception to this was for broods observed at 9 weeks that were defined as surviving the fledging period. We recognize that our approach is biased as we did not know with certainty that all broods died after we last detected them. Thus, our estimates should be considered a minimum weekly survival rate for King Rail broods in our study area.

There are several assumptions of this analysis: 1) all broods have an equal probability of being detected; 2) the sample is representative of the population; 3) the fates of all broods are independent; 4) brood ages were estimated accurately; and 5) survival probability was constant across age classes during the sampling period. The survival probabilities for individuals in the same brood are probably partially dependent, although this is more likely to affect the variance estimate rather than the mean (McGowan *et al.* 2009).

RESULTS

At Red Slough WMA, we located 17 King Rail territories in early to mid-May 2011 and 10-12 King Rail territories in mid-April to late June 2012. We detected no King Rails at Grassy Slough WMA or Walnut Bayou in either 2011 or 2012.

We found one nest in 2010, no nests in 2011 and nine nests in 2012 at Red Slough WMA. The earliest nest located was on 24 March 2010, while the latest located nest was on 13 July 2012. We did not know the incubation status of the 2010 clutch, so a conservative date of first egg laid for that 11-egg clutch was 13 March 2010. Backdating from the earliest hatching nest date (21 April 2012), we estimated an initial laying date of 1 April 2012, whereas the latest backdated laying date from a hatched clutch was 6 July 2012. Observed completed clutch sizes in 2012 ranged from 8-13 eggs (n = 6) for a mean clutch size of 10.3 (SE = 0.80). We located three nests with four or fewer eggs that we assumed were incomplete clutches.

We located nests in six different plant species (soft rush, Virginia wildrye (*Elymus virginicus*), shoreline sedge (*Carex hyalinolepis*), velvet panicum (*Dichanthelium scoparium*), shortbristle horned beaksedge, annual marsh elder (*Iva annua*)), but the use of soft rush was the most common (n = 5). Water depth at the nest was variable (0-15 cm deep) with a mean of 8.4 cm (95% CI = 2.04; Table 1). King Rails made nests in palustrine emergent vegetation with standing water, on man-made islands, and in dry grasslands that were 0-180 m from the nearest levee. Based on 95% CI overlap, King Rail nest sites were in locations with more visual obstruction, more microtopographic variation, and more woody stems, while open water cover was less than at random sites (Table 1).

In 2012, we did not locate any territorial pairs in units drawn down during that breeding season or in sites burned or disked during fall 2011. Emergent vegetation characteristic of moist soil management applications do not emerge until later in the breeding season (mid-June to July), and use by King Rails may depend on presence of standing water and food availability in the unit.

At Red Slough WMA, we caught and attached transmitters to three adults and two juveniles in 2010; one adult, one juvenile and one local in 2011; and one adult in 2012. We tracked one adult King Rail captured in 2010 from 26 March-4 April (9 days) whereupon we located the transmitter and a pile

Table 1. Mean habitat characteristics ± 95% CI, in a 12-m radius circular plot at King Rail nest sites and randomly chosen emergent wetland sites at Red Slough Wildlife Management Area from 19 April-13 July 2012. Cover refers to visual obstruction estimated with a density cover board at indicated height increments. Microtopography was determined by measuring the distance from ground to level string at 1-m increments in the four cardinal directions. Woody stem includes trees with DBH ≥ 4 cm, and shrubs with multiple stems were counted as one.

	Water Depth (cm)	Cover (0-0.3 m)	Cover (0.3-1 m)	Cover (1-2 m)	Microtopographic Variance	% Open Water	% Tall Emergent	% Short Emergent	# Woody Stems
Nest sites ($n = 9$)	8.4 (2.04)	14.5 (0.27)	25.5 (1.60)	4.7 (1.12)	50.4 (19.80)	13.3 (2.65)	43.1 (7.17)	25.8 (6.23)	7.2 (1.55)
Random sites ($n = 9$)	7.8 (1.92)	7.7 (1.86)	11.2 (2.72)	0.1 (0.04)	9.9 (3.35)	24.6 (5.51)	33.2 (4.94)	22.0 (5.35)	2.3 (0.64)

of feathers (source of mortality unknown). We tracked the second adult King Rail in 2010 from 11 April-6 May (26 days) whereupon the bird could not be located and was censored (radio failure or emigration out of study areas). We tracked the third adult King Rail in 2010 from 27 April-4 May (8 days) whereupon the transmitter and a pile of feathers were located (source of mortality unknown). We tracked two chicks in 2010 for 1 day each whereupon they slipped out of their transmitter harnesses. We tracked one adult King Rail in 2011 from 6 July-21 July (17 days) whereupon we located the transmitter with no marks on it and no remains of the adult bird. For the first 11 days, the bird remained in the same management unit moving a mean distance between daily location points of 66 m (SE = 15.4). On the 12th day, we located the adult rail approximately 3.5 km from the original site. We tracked one juvenile King Rail in 2011 from 6 July-8 July (2 days) whereupon we located the transmitter and the remains of the bird (source of mortality unknown). We tracked a downy chick in 2011 from 2 August-3 August (1 day) whereupon we found the transmitter with no marks on it; we believe the chick slipped out of the harness. We tracked one adult King Rail in 2012 from 11 April-11 June whereupon the bird was censored.

Of the five adults marked, only one adult was documented to nest. That bird successfully hatched a nest on 19 April 2012 and cared for the brood through 23 May 2012. The bird made a second nesting attempt, while brooding the first brood, laying 12 eggs. This nest failed on 13 May 2012. After the second nesting attempt, the adult bird and two young moved 565 m. The marked adult King Rail made a third nesting attempt that failed on 23 May 2012, and then the adult moved 1 km after which the bird was censored.

At Red Slough WMA, we made observations on four broods in 2010, three broods in 2011 and two broods in 2012 (Table 2). Broods ranged in age at first detection from < 1 week to ~9 weeks. Brood size declined for all broods that we tracked for more than 1 week. This decline in brood size was most

Table 2. Detection histories of King Rail broods during 2010-2012 at the Red Slough Wildlife Management Area.

	Estimated Age of the Brood (weeks)								
Date Brood Detected	1	2	3	4	5	6	7	8	9
27 April 2010[a]	6	2			2				
3 June 2012[a]	11				4				
21 April 2012[a]	10				2			2	
23 June 2011		2							
27 May 2010[a]					2				
2 June 2011							1	1	
7 June 2010									1
18 June 2010[a]									1
2 August 2011				4					

[a]Broods had either a parent or chick radio-marked.

evident between the first and second week when brood size went from an average of nine chicks to two chicks. Average brood size then remained at two until week seven whereupon it dropped to one. Backdating brood ages, broods hatched between the first week in April and the first week in July. We observed unique broods from 1-75 days at a mean of 18 days. We estimated that the weekly brood survival rate was 0.87 (SE = 0.045, 95% CI = 0.756-0.938). Based on our estimated weekly brood survival rate, we calculated that the minimum probability of a brood surviving 9 weeks was 0.29 (SE = 0.136, 95% CI = 0.103-0.601).

Based on 95% CI overlap, brood-rearing sites were in deeper water and had a greater percent of tall emergent vegetation and more woody vegetation than random sites (Table 3). Random sites tended to have a higher percent of open water or exposed soil, and a greater percent short emergent. The presence of shallow standing water or saturated soil with dense emergent cover nearby was a common component of brood-rearing habitat especially when other areas of the wetland complex went dry. Portions of wetland units burned or disked the previous year were generally avoided by brood-rearing adults; only two of 24 observations were in these burned or disked sites. The vegetation at these burned or disked sites was short (< 1 m) through about mid-June-July 2012.

DISCUSSION

King Rails in inland freshwater marshes typically nest in palustrine emergent wetlands, including rice fields, and occasionally in shrub swamps and upland fields near water (Meanley 1969; Pierluissi and King 2008; Pickens and Meanley 2015). In palustrine emergent wetlands, while plants are usually of the tussock or clump form, Pickens and Meanley (2015) felt that King Rails tended to nest in uniform stands. Darrah and Krementz (2011) also noted that in Missouri, USA, King Rails placed their nests in uniform stands of emergent wetland plants, using spikerushes (*Eleocharis* spp.) in particular.

Darrah and Krementz (2011) found that King Rails used different habitats during the nesting and brood-rearing seasons with nesting sites having deeper water (~6 cm) and a dominance of short emergent vegetation (~50%), compared to brood-rearing sites

Table 3. Mean habitat characteristics ± 95% CI at brood-rearing and random sites at Red Slough Wildlife Management Area from 21 April-20 June 2012.

	Water Depth (cm)	% Open Water or Exposed Soil	% Short Emergent	% Tall Emergent	# Woody Stems
Brood Site ($n = 9$)	6.2 (0.71)	20 (2.65)	7 (2.10)	61 (4.25)	3.6 (0.98)
Random Site ($n = 9$)	0.7 (0.29)	40 (5.47)	29 (5.25)	37 (5.06)	1.4 (0.41)

which had shallower water (~1 cm) and an absence of tall emergent vegetation (~1%). We found that both nesting and brood-rearing sites in our study area were in similar water depths (< ~10 cm) but that our nesting sites had less short emergent vegetation ($\bar{x}$ = 25% cover) than compared to what was observed in Missouri (> 50%; Darrah and Krementz 2011). Our brood-rearing sites did have a predominance of tall emergent vegetation (~60% cover) similar to brood-rearing sites in Missouri. We should note that Darrah and Krementz (2011) observed mean water depth at used nest and brood-rearing sites that were on average < 6 cm, thus it seems that King Rails are using stands that are at most shallowly flooded during the breeding season. Again, that King Rails use breeding areas with shallow water is consistent with Meanley's (1953) and Pickens and King's (2013) observation that the King Rail is a "damp habitat species." Pickens and King's (2014b) conclusion that the key management issue for breeding King Rails is their need for some water throughout the breeding season agrees with our conclusion. Contrary to this requirement for rails, moist soil management (Nelms 2007) often involves complete dewatering of management units at some point during the growing season. In addition, more often than not, dewatering occurs around the time of brood rearing when both food resource availability and escape from predators is paramount.

Bolenbaugh *et al.* (2012) hypothesized that King Rails require periodic habitat disturbance for maintaining suitable habitat over time at a site. While we did not formally test this hypothesis, we did observe that radio-marked King Rails neither nested in nor moved broods to management units that were either burned or disked the previous fall or that were drained at the beginning of that breeding season. That habitat disturbance is important to King Rails at our study site is supported by the observation that soft rush can form monotypic stands within only 3 years (R. Bastarache, pers. commun.), and soon thereafter black willow invades. Both monotypic stands and stands invaded by woody vegetation have been shown to deter King Rail use (Darrah and Krementz 2010, 2011; Pickens and King 2012).

Meanley (1969) and Pickens and Meanley (2015) remarked that no King Rails had been documented to double-brood unlike the closely related Clapper Rail for which double-brooding had been observed (Blandin 1963). While we did not document double-brooding, we did document that one telemetry marked bird successfully hatched and brooded one clutch and then made two subsequent nesting attempts that both failed. This is suggestive that King Rails do attempt to double-brood when sufficient time is available. Meanley (1969) and Pickens and Meanley (2015) both reported that ample time for double-brooding is available to King Rails nesting along the Gulf of Mexico coast in the southern United States where the breeding season can span 8 months. At our study area, we documented the egg-laying season spanning about 4 months (mid-March to mid-July). Adding 10 days for laying and 30 days for brooding (Meanley 1969), the breeding season at our study site spanned early March to early August, which is similar to the breeding season documented for King Rails in Stuttgart, Arkansas (Meanley 1969). This breeding season length should allow enough time for double-brooding.

Darrah and Krementz (2011) estimated the probability of a King Rail brood surviving a 9-week period to fledge ranged from 0.03-0.21 depending on when the brood hatched during the breeding season. Our point estimate of the probability of a King Rail brood surviving a 9-week period to fledge was slightly higher (0.29), but our 95% confidence interval overlapped (0.103-0.601) the estimates of Darrah and Krementz (2011). That our brood survival to fledging estimates are so similar to Darrah and Krementz's (2011) estimates suggests that our estimates are not unreasonable despite our analytical limitations. We assumed all broods we detected before 9 weeks "died" after our last contact with that brood and, under this assumption, our brood survival rate estimate should be considered a minimum estimate. Cooper (2008) speculated that brood rearing was likely a limiting factor for population growth.

In further examining both our brood count patterns over time and that of Darrah and Krementz (2011), both studies observed that the largest drop in brood size was around the first week after hatch. While the magnitude of the drop varied between the first and second week (Darrah and Krementz 2011: ~4 to 2 chicks; this study: 9 to 2 chicks), this pattern has also been observed in other rallids (Bell and Cordes 1977; Eddleman and Conway 1998; Tyler and Green 2004). In coastal King Rail broods, Pickens and King (2013) found that the average brood size declined from 4.7 during weeks 1-2 to 2.9 during weeks 3-4, hence the same pattern of brood size dropping rapidly during early brood rearing. Clearly, the early brood-rearing period is a time of high mortality. Learning what is driving this high mortality is an important area of research if wetland managers are to ameliorate this pattern.

The inland breeding King Rail population in the midwestern United States is rare and declining (Cooper 2008). King Rail nesting efforts are low, brood sizes rapidly drop during the first week, and brood survival is low (Reid 1989; Pierluissi and King 2008; Darrah and Krementz 2011; Pickens and King 2013). All of these breeding characteristics indicate that reproductive effort in this population is of concern and an area deserving of additional research. Management focused on nesting habitat needs and increasing brood survival rates is important for recovering the inland breeding King Rail population.

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