SPECIES RICHNESS AND HABITAT USE OF SECRETIVE MARSH BIRDS IN MANAGED WETLANDS IN THE ARKANSAS RIVER VALLEY OF WESTERN ARKANSAS

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of the requirements for the degree of
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By

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ABSTRACT

I documented the distribution and habitat use by secretive marsh birds on public lands in the Arkansas River Valley of western Arkansas and related wetland management practices to marsh bird species richness. I found that detections of marsh birds were rare in the western Arkansas River Valley. I conducted repeated broadcast surveys at 30 sites in 2009 and detected 37 pied-billed grebe, 5 American bitterns, 3 least bitterns, 1 king rail, 3 soras, and 89 American coots while in 2010, I surveyed 33 points and detected 27 pied-billed grebe, 5 American bitterns, 4 least bitterns, 1 king rail, 19 soras, and 161 American coots. To determine effects of habitat composition on marsh bird occupancy, I used binomial regression analysis to test the fit of my data across a series of models containing habitat variables measured within 50 m (open water, tall emergent vegetation, and interspersion) and 400 m (emergent herbaceous wetland and pasture). Both tall emergent vegetation and interspersion had a positive effect on marsh bird detections. Emergent herbaceous wetland had a positive effect on marsh bird detections. To determine effects of water level management, I modeled species richness as a function of drawdown timing, survey year, impoundment, and wildlife management area using simple logistic regression. I found that delaying draining of wetland impoundments until after migration and nest initiation had a positive effect on secretive marsh bird species richness.

This thesis is approved for
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INTRODUCTION

Secretive marsh birds which include king rail (*Rallus elegans*), Virginia rail (*R. limicolor*), sora (*Porzana carolina*), American bittern (*Botaurus lentiginosus*), pied-billed grebe (*Podilymbus podiceps*) and common moorhen (*Gallinula chloropus*) occupy wetlands throughout North America. Although difficult to survey (Conway 2008), recent evidence suggests that most secretive marsh bird populations are in decline (Sauer et al. 2005, U.S. Fish and Wildlife Service 2002, Conway 2008). American bitterns, least bitterns, king rails, Virginia rails and soras are U.S. Fish and Wildlife Service species of conservation concern (Rich et al. 2004). The king rail is also listed as a species of greatest conservation need in Arkansas (Anderson 2006). The reasons for these population declines are many but are probably most strongly related to the decline of palustrine emergent wetlands in North America (Eddleman et al. 1988). Most of these remaining wetlands are protected on either state or federal lands (Reid 1989). Ironically these wetlands have less value to marsh birds because they are being managed for other species, mainly waterfowl (Rundle 1980, Anderson 2006).

Secretive marsh birds generally need moderately dense stands of emergent vegetation interspersed with areas of open water and floating or submerged vegetation (Conway 1995, Muller and Storer 1999, Bannor and Kiviat 2002, Porej 2004). Marsh birds usually avoid areas without standing water or large areas of open water that lack vegetative cover (Weber 1978). Lor and Malecki (2006) found that the “hemi-marsh” (50:50 vegetation to water) was good for least bitterns and pied-billed grebes but not for other marsh bird species like rails and American bitterns; the latter preferred >70% vegetative cover. Rehm (2006) also found that the abundance of secretive marsh birds was positively related to "edge density" or amount of water-vegetation interface. Emergent vegetation is used for escape cover, foraging, and nest construction (Muller and Storer1999). The American bittern, least bittern, pied-billed grebe and sora tend to concentrate close to the water-vegetation interface because it provides both nesting and foraging opportunities out of the reach of predators, e.g. raccoons (*Procyon lotor*), snakes, and crows.

Secretive marsh bird nests are typically suspended above the water from stems of emergent vegetation or located at the base of clumps of vegetation at the water's surface with the exception of the pied-billed grebe and common moorhen. Pied-billed grebes and common moorhens may nest in the open with the nest platform anchored to emergent vegetation (Muller and Storer 1999, Banner and Kiviat 2002). Nest platforms of secretive marsh birds are constructed from surrounding vegetation, usually cattail (*Typha* spp.), bulrush (*Scirpus* spp.), reed (*Sparganium* spp.) and sedge (*Carex* spp.) (Rodgers and Schwikert 1999, Zimmerman et al 2003, Lowther et al 2009). Average water depths at secretive marsh bird nests range from 20cm for sora to > 60cm for king rail (Melvin and Gibbs 1996, Muller and Storer 1999, Lor and Malecki 2006, Darrah 2008).

The presence of secretive marsh birds in Arkansas is rare, even in the Lower Mississippi River Alluvial Valley (hereafter LMAV) where habitat quality and availability is high. Budd (2007) estimated marsh bird occupancy rate of around 22% at sites surveyed in the LMAV. The migration of secretive marsh birds in Arkansas begins in March and continues through the end of May (James and Neal 1986). The earliest migrants include king rail, sora, American bittern, and pied-billed grebe. Records of breeding individuals are rare outside of the LMAV in Arkansas (James and Neal 1986). Of the 4 species that have been recorded exhibiting breeding behavior (pied-billed grebe, American bittern, least bittern and king rail), the least bittern was the most common (James and Neal 1986). For most species of secretive bird in Arkansas nesting starts in early March and continues through June with the exception of the pied-billed grebe which continues to nest through October.

Recently in Arkansas, habitat use by secretive marsh birds was assessed in the LMAV by Budd (2007). He found secretive marsh birds breeding in the LAMV occupied < 22% of sites surveyed and that two variables influencing habitat selection by least bitterns were proportion of emergent vegetation and proportion of forest in the survey area. Budd (2007) estimated distribution and habitat use of marsh birds in the Arkansas Delta, but secretive marsh bird distribution, abundance and habitat use in Arkansas outside of the Delta is poorly understood (James and Neal 1986). Effects of management practices used on publicly owned wetland units in the Arkansas River Valley are also poorly understood for marsh birds.

Many studies have investigated effects of vegetation structure (Porej 2004, Lor and Malecki 2006, Rehm 2006), water depth (Taft et al 2002) and annual changes in wetland hydrology (Craigie et al 2003, Jobin et al 2009) on waterbirds, including secretive marsh birds. In Québec, when interannual water level fluctuations left normally flooded impoundments dry, least bittern breeding pair density decreased (Jobin et al 2009). Fluctuating water levels during the breeding season, either flooding or drying wetlands, have also been shown to cause marsh dependent species to abandoned nests or nesting colonies in search of areas where water levels are more stable (Lowther 1977, Kushlan 1986). Few studies have examined effects of water level management techniques, including timing and extent of water removal, on marsh bird use of artificial wetlands (Frederick and Taylor 1982).

The objectives of my study were to: 1) document the distribution of secretive marsh birds on public lands along the Arkansas River of western Arkansas, 2) evaluate habitat use by marsh birds there, and 3) relate wetland management practices to the proportion of sites where marsh birds were detected.

STUDY AREA

I surveyed freshwater impoundments on public lands along the Arkansas River in western Arkansas from Little Rock (Pulaski Co.) to Fort Smith (Sebastian Co.). The Arkansas River Valley of western Arkansas (ARV) is 1,592,843 ha that lie between the Ozark and Ouachita mountain ranges (Woods et al 2004). The landscape is characterized by undulating floodplains with occasional hard sandstone-capped hills, ridges and mountains. I surveyed sites including Frog Bayou Wildlife Management Area (hereafter WMA), Vernon Bell Slough WMA, Ed Gordon/Point Remove WMA, Petit Jean River WMA, Dardanelle WMA, Ozark Lake WMA, and Holla Bend National Wildlife Refuge (hereafter NWR) (Figs. 1-10). Within Petit Jean WMA, I surveyed Pullen Pond, the Blacklands Moist-Soil Unit (hereafter MSU), Slaty MSU, and Olin Cain MSU. Within Dardanelle WMA, I surveyed points in the McKennen Bottoms Waterfowl Rest Area (hereafter WRA) and the Potter's Pothole WRA. Within Ozark Lake WMA, I surveyed points in the Dyer Lake waterfowl impoundments. These areas are primarily managed for migrating and wintering waterfowl.

METHODS

Site Selection

I chose management areas to survey that were within 10 km of the Arkansas River and had managed wetland units. Wetland units were wetland areas whose water levels were being managed artificially by state and federal personnel. In 2009, I randomly located survey points on levees. In 2010, I randomly located survey points ≥ 50 m off of the levees into the marsh to reduce the effect of edge on marsh bird detections. I selected 1-8 points for each management area (Table 1).

Marsh Bird Surveys

I surveyed for marsh birds using the Standardized North American Marsh Bird Monitoring Protocols (Conway 2008). I conducted surveys 30 minutes before sunrise to 3 hours after sunrise and 3 hours before sunset to 30 minutes after sunset. To prevent double counting of marsh birds, I placed my points ≥ 400 m apart (Conway 2008). I did not conduct surveys during sustained rain or when the wind speed was ≥ 20 km/hr. The broadcast calls were played using an Apple® iPod MP3 player and portable speakers set at a volume of 80-90 dB (Budd 2007, Conway 2008). Broadcast audio recordings were obtained from C. J. Conway (USGS Arizona Cooperative Fish and Wildlife Research Unit). The call broadcast included 5 minutes of silence (a passive period) followed by 30 seconds of breeding and territorial calls and 30 seconds of silence for each focal species.

I surveyed marsh birds from 15 April - 7 June 2009 and from 2 April - 1 June 2010. I based the survey period on available information of marsh bird breeding seasons and historic records of sightings in the survey area (James and Neal 1986, Arkansas Audubon Society 2010). Focal species were those species which have been known to occur in the western Arkansas River Valley in Arkansas (James and Neal 1986). The focal marsh bird species were, in order of broadcast breeding and territorial calls, the least bittern, sora, king rail, American bittern, common moorhen, and pied-billed grebe. I also recorded the number of American coots (*Fulica americana*) and Virginia rails, marsh-dependent species of concern (Conway 2008), present at each point. I recorded any opportunistic observations, i.e. detections made outside of the 11- minute survey period, of secretive marsh birds at each management area. Since I recorded habitat data up to 400 m from each survey point, I only recorded opportunistic observations for secretive marsh birds if they were observed within 400 m of one of my survey points.

I attempted to survey each point three times during my survey period in 2009 and 2010 which is the suggested minimum number of surveys to account for temporal variation in marsh bird species detection (Conway 2008). Due to the probability of detecting secretive marsh birds being < 1, multiple surveys at each site were needed to accurately determine if a species was not detected at a site on a particular occasion or if it truly was not there (MacKenzie et al 2006). In the Upper Mississippi River/Great Lakes Joint Venture region, detection probabilities for marsh birds ranged from 0.16 for the Virginia rail to 0.50 for the pied-billed grebe (Bolenbaugh 2010). In the LMAV, Budd (2007) reported similar detection probabilities which ranged from 0.39 for the pied-billed grebe and king rail to 0.58 for the least bittern. I continued to survey sites that dried up during my survey period to make sure that marsh birds did not continue to use these areas (Budd 2007). Marsh birds have been known to nest or forage in dry sites in close proximity to bodies of water (Meanley 1953, Stewart 1975).

Habitat

I collected habitat data in a 50-m and 400-m radius of each point. Measurements in the 50-m radius were collected in a circle in front of each point (50 m out in the marsh) and included proportion of open water, tall emergent vegetation (> 1 m tall), and species with ≥ 1% coverage. Interspersion within a 50-m radius of the survey point was calculated using field drawings of each point and estimating proportion of the area that contained water-vegetation interface of the total area within a 50-m radius using grid paper (Rehm and Baldassarre 2007).

Habitat data in the 400-m radius was collected using ESRI® ArcGIS® 9.2 (Copyright © 1999-2006 ESRI Inc.), FRAGSTATS 3.3, and land cover information from the 2001 National Land Cover Database (NLCD 2001). In areas where survey points were clustered and 400-m habitat radiuses for each point would overlap each other, I selected a mid-point and collected data within 400-m of the mid-point. Measurements included proportion of the area covered by pasture/grassland, open water, and emergent herbaceous wetlands (Table 2). In areas where the 2001 NLCD land cover information was notably out of date (i.e. the management areas had not yet been established when the land cover information was recorded), I used aerial images of my survey areas taken in 2006 for the National Agriculture Imagery Program (NAIP 2006). Using ArcGIS 9.2 I digitized shape files around each habitat type and used the Calculate tool to determine portion of the area covered by each. Since I used 2006 aerial images, the proportion of area covered by the 400 m habitat variables for each point are the same for both years.

Management

I contacted the area managers and documented management practices used in each wetland unit at each management area for the past 2 years, including timing of water drawdowns, soil manipulation, and reflooding. The timing of reflooding and soil manipulation was relatively consistent among wetland impoundments in the management areas I surveyed. Water was pumped on to impoundments starting in November in preparation for fall duck hunting season and soil was disked or tilled during spring as needed to control nuisance vegetation and promote moist-soil plants, usually every year or every other year. The aspect of management that varied among wetland impoundments was timing of water drawdown in spring. For the purpose of my study, timing of a drawdown was considered “early” when an impoundment was completely dewatered, leaving only exposed mudflat and/or dry land, before 15 May. The timing of a drawdown was considered “late” when an impoundment had not been completely dewatered by 15 May. A late drawdown could have occurred in the following ways: 1) the wetland manager started pulling water off the impoundment after 15 May, 2) the manager started pulling water off the impoundment before 15 May but it was done slowly over the course of several weeks, 3) water was allowed to evaporate throughout summer or 4) the manager was unable to completely drain off all water in the impoundment because of weather or topography, leaving a portion of the impoundment that remained flooded throughout the survey period. I chose 15 May to differentiate between early and late drawdowns because activities of secretive marsh birds for which water availability is critical (i.e. migration and nesting) take place from the beginning of March through June in the Arkansas River Valley (James and Neal 1986).

Data Analysis

I used binomial regression analysis (GLM) function, Program R 2010) to investigate effects of several habitat variables at two spatial scales (Table 2) on the proportion of sites where each species of secretive marsh bird was detected. For modeling purposes, a species was considered “detected” at a site if it was detected during any of the three survey rounds within 200 m of the survey point. Detection and identification of a marsh bird ≥ 200 m from the observer is not reliable. Based on a thorough literature review, I developed a priori models for each species containing only one habitat variable with detection of the species during my survey period as the response variable (1 - detected, 0 - not detected) (Tables 3, 4, 5). To account for variation in local habitat conditions among years, I also developed a second set of models for the 50-m radius habitat variables which included a year effect. Small sample sizes would not allow running of models with > 3 estimated parameters. I compared each model containing habitat variables to a constant model for each species to test the null hypothesis that habitat had no effect on proportion of sites where each species was detected. I selected among the candidate models using their Akaike's Information Criterion values corrected for small sample sizes (hereafter AICc), and I considered models with a ΔAICc < 2 to have substantial support (Burnham and Anderson 2002). A small sample size correction for AIC is necessary when n/k < 40, where n is the number of points surveyed and k is the number of parameters (Burnham and Anderson 2002).

To determine effect of drawdown timing on marsh bird use of public land impoundments, I used the program SPECRICH2 (Nichols et al 1998) to calculate a species richness estimate for marsh birds at each survey point based on detection histories for each species collected during my three survey rounds. Based on the distribution of estimated species richness values across wetland units (Fig. 11), I used a Poisson regression model to investigate effect of water drawdown.

I modeled species richness as a function of drawdown timing (DD), survey year (YR), impoundment (IMPD) and wildlife management area (WMA) (GLMR function, Program R 2010). Since I randomly chose survey points throughout my survey area and variance among impoundments and WMAs was not my primary interest, I ran the global model with both IMPD and WMA as random variables to reduce the number of parameters being estimated. I set both DD and YR as fixed variables. By making IMPD and WMA random variables, these models could not be used to estimate effect of each individual impoundment or each individual wildlife management area.

RESULTS

During the 2009 field season, the Arkansas River Valley received 125-300% of normal rainfall across the study area (Fig. 12-13). Most impoundments and levees were inundated across the survey area in May. As a result of that flooding, I was only able to survey 23 of 33 survey points 3 times and 7 points 2 times. I surveyed points in 16 of the 19 wetland impoundments within my survey area. I was unable to survey any points at Ed Gordon Point Remove WMA in 2009. In 2009, I detected 98 birds during the first round of surveys (April 11-May 1), 28 birds during round two (May 6-May 23), and 10 birds during round three (June 3-June 6; Table 6). In 2010, due to favorable weather conditions (Figs. 14-15), I was able to survey all 33 points 3 times, including those at Ed Gordon Point Remove WMA. In 2010, I detected 125 birds during the first round of surveys (April 2-April 10), 51 birds during round two (April 16-May 7), and 38 birds during round three (May 15-June 3; Table 6).

Species Accounts

In 2009, 53 of 56 detections for pied-billed grebes were made at Frog Bayou WMA, McKennen Bottoms, and Pullen Pond of Petit Jean River WMA. In 2010, 18 of 27 detections of pied-billed grebes were made at Frog Bayou. In 2009, I detected pied-billed grebes consistently during survey rounds 1 and 2, with 13 and 18 birds, respectively, but then detections dropped to 6 in round 3 (Table 6). In 2010, 14 of 24 detections of pied-billed grebes were made during survey round 1 (Table 6).

I observed 4 American bitterns opportunistically at Frog Bayou WMA (2), Petit Jean WMA (1) and Vernon Bell WMA (1). In 2009, 3 of 5 detections of American bitterns were made during survey round 2 (Table 6). In 2010, all detections of American bitterns were made at Frog Bayou WMA, 4 of 5 during survey round 1 (Table 6, 7).

All detections for least bitterns were made at Frog Bayou WMA. I did not detect least bitterns in my study area until survey round 2 in 2009 and round 3 in 2010 (Table 6).

I detected no king rails during my surveys in 2009. However, in 2009, I observed 2 king rails calling from unit 3 on 3 occasions. In 2010, I detected one king rail on one occasion during survey round 1 at Frog Bayou (Tables 6, 7).

I detected no Virginia rails during my surveys in 2009 or 2010. However, I observed 3 Virginia rails opportunistically at Frog Bayou WMA during the first week of April 2009. The Virginia rails were within 10 m of a king rail. Both species were responding to the broadcast of the king rail calls.

In 2009, I detected 2 soras during survey round 1 at Dardanelle WMA McKennen Bottoms Waterfowl Rest Area (WRA) (Tables 6, 7). In 2010, all detections for soras were made at Frog Bayou WMA with the exception of one bird detected at Holla Bend NWR on one occasion during survey round 3 (Tables 6, 7). The number of sora detected in my survey area was highest during survey round 3 (Table 6).

In 2009, I detected one flock of 60 American coots on one occasion at Frog Bayou. I detected the most American coots during survey round 1 (80 birds); I only detected 6 American coots during round 2 and 3 American coots during round 3 (Table 6). In 2010, I observed 126 birds opportunistically at Frog Bayou, of which one flock of 123 birds was observed during survey round 1 (Table 6, 7). I detected no common moorhens during the 2009 or 2010 field seasons.

Evidence of Breeding

I observed evidence of breeding for the pied-billed grebe and the least bittern only at Frog Bayou WMA. I observed four juvenile pied-billed grebes in 2000 and 2010 and a least bittern chick with two adults in 2009.

Habitat

I was unable to determine effects of habitat variables on probability of detecting king rails, least bitterns or American bitterns due to a lack of detections for these species (Table 8).

The top models for the probability of detecting soras included proportion of emergent herbaceous wetland within 400 m and proportion of tall emergent vegetation within 50 m (Table 3). The beta estimates for emergent herbaceous wetland ($\hat{\beta}$ = 6.715, SE = 2.331) and tall emergent vegetation ($\hat{\beta}$ = 4.407, SE = 1.548) suggested that each had a positive effect on the probability of detecting soras (Figs. 16, 17). There was little support for year differences on the probability of detecting soras (Table 3).

The top model for the probability of detecting pied-billed grebes included proportion of tall emergent vegetation within 50 m. The beta estimate for tall emergent vegetation suggested that it had a positive effect on pied-billed grebe presence ($\hat{\beta}$ = 2.466, SE = 1.528) (Fig. 18). Survey year 2010 had a negative effect on probability of detecting pied-billed grebes ($\hat{\beta}$ = -2.579, SE = 0.813).

The top model for the probability of detecting American coot included amount of interspersion within 50 m. The beta estimate for interspersion suggested that it had a positive effect on probability of detecting American coots ($\hat{\beta}$ = 15.25, SE = 5.798; Fig. 19). There was also support for the model AMCO (YR+INTER; Table 5). Survey year 2010 had a negative effect on probability of detecting American coots ($\hat{\beta}$ = -1.540, SE = 0.846).

Drawdown

In 2009, 11 of 33 points I surveyed for secretive marsh birds had water completely drawn down by 15 May (Table 9). Of the 11 points where water was drawn down early, only 4 points were drawn down for managers to perform necessary maintenance or soil disturbance.

In 2010, 20 of 33 survey points were drawn down by 15 May (Table 10). Of the 20 points drawn down early, only 7 points were drawn down to perform maintenance on the impoundments or soil disturbance.

I used 60 observations in 2009 and 2010, minus 3 observations from Ed Gordon because I was unable to survey in that area in 2009, to model water management effects. The model with the lowest AICc score included variables for DD, YR and IMPD (Table 11). Late drawdowns had a positive effect on marsh bird species richness ($\hat{\beta}$ = 2.006, SE = 0.444). The effect for survey year was not significant ($\hat{\beta}$ = -0.118, SE = 0.285). I was unable to estimate the effect of IMPD on marsh bird species richness because it was a random variable.

DISCUSSION

Detections of secretive marsh birds in the Arkansas River Valley of western Arkansas during my study were rare, consistent with their status as species of high conservation concern in the National Waterbird Conservation Plan (Kushlan et al 2002), species of conservation concern by the USFWS, and species of greatest conservation need in the Arkansas Wildlife Action Plan (Anderson 2006). In the Mississippi Alluvial Valley, Budd (2007) found that occupancy rates for secretive marsh birds were low. Site occupancy estimates reported for pied-billed grebe, least bittern and king rail in the Delta, 0.13 – 0.21 (SE = 0.05), 0.18 - 0.27 (SE = .05), and 0.22 (SE = .07) respectively, supporting the observation that secretive marsh birds are rare in Arkansas (Budd 2007). In the Arkansas River Valley, secretive marsh birds are seen in small numbers for short periods of time during spring migration (James and Neal 1986).

In the past, observations of breeding secretive marsh birds have been rare in Arkansas. There have been records of pied-billed grebe, American bittern, least bittern, king rail, and common moorhen nests or juvenile birds in the Mississippi Alluvial Valley and South Central Plains regions of Arkansas from 1986 to the present but not in large numbers (Arkansas Audubon Society 2010). Historically, American bitterns and least bitterns have been observed nesting in the western Arkansas River Valley, but only in small numbers (James and Neal 1986, Arkansas Audubon Society 2010). In the Mississippi Alluvial Valley, Budd (2007) reported little evidence of nesting (e. g. broods, active nests, or initiated nests) by pied-billed grebe, least bittern, king rail, and common moorhen.

The vegetation community (i.e. species composition and structure) and water level management techniques in use at most of the points I surveyed in the western Arkansas River Valley in 2009 and 2010 were not conducive to marsh bird occupancy. Many wetland units were completely drained before peak marsh bird migration and breeding in April and June to promote the growth of seed-producing annuals. The units that were dry during my survey period had a high proportion of dry land, mudflat, standing dead coffee bean *(Sesbania exaltata*), standing dead soybean (*Glycine max*), or broomsedge (*Andropogon virginicus*). When the units were flooded, most were dominated by short emergent annual smartweeds (*Polygonum* spp.) or large expanses of open water with little vegetation cover. The exceptions to these observations were the units at Frog Bayou WMA and McKennen Bottoms (2009 only), which had higher proportions of open water interspersed with short emergent perennial and annual smartweeds and tall emergent vegetation including cattails, rushes, horned beaksedge (*Rhynchospora corniculata*), and sedges. Management for these two areas delayed drawing down water in impoundments until after 15 May or, if they started drawing down impoundment water early, water was drawn down slowly over several weeks.

In 2009, king rails, Virginia rails, and soras were heard calling consistently at Frog Bayou WMA in the last two weeks of March and the first two weeks of April (Arkansas Audubon Society 2010). These species were not detected during my survey period, 15 April – 7 June. In 2010, I detected no Virginia rails and only one king rail at Frog Bayou WMA during the first week of April, even though I started my surveys on 1

April. The presence of these species in March and early April and then not detected for the rest of the breeding season could be explained by migratory birds, birds that attracted a mate and stopped vocalizing, or birds that left the survey area as favorable habitat became unavailable. Detections of soras in 2010 increased as the survey period progressed with the highest number of soras detected in survey round three. The detection pattern for soras could possibly be due to prolonged flooding caused by excessive rainfall in April and May 2009. In Colorado, soras abandoned nests with eggs when area floods increased nest site water levels by 3.1 cm (Griese et al 1980). The detection pattern for sora in 2010 is consistent with historic records in Arkansas in which most soras were observed in late April and May with the exception of rare winter residents (Budd 2007, Valente 2009, Arkansas Audubon Society 2010).

The detection pattern for American coots in both years, with the majority of detections in survey round one and then dropping off dramatically in rounds two and three, could be explained by migratory birds, birds that attracted a mate and stopped vocalizing or birds that left the area as favorable habitat became unavailable. American coots detected in my survey area could have been breeding pairs but it is unlikely since there are few records of American coots breeding in Arkansas (James and Neal 1986). Studies conducted the Mississippi Alluvial Valley and in northern Louisiana, reported no observations of breeding American coots (Budd 2007, Valente 2009). I did not observe any evidence of nesting or chicks in my survey area; however, no nest searches were conducted.

The detection pattern of pied-billed grebes at Frog Bayou WMA in 2009 and 2010, decreasing as the survey period progressed in a few areas while continuing through the survey period in others could be explained by migratory birds, birds that attracted a mate and stopped vocalizing or birds that left the area as favorable habitat became unavailable. The gradual decline in pied-billed grebe detections over the course of my surveys in both 2009 and 2010, coupled with the observation of adults with chicks in 2009, indicated that pied-billed grebes nested at Frog Bayou WMA. At other management areas, pied-billed grebes were only detected during survey round 1, which was coincident with the sudden dewatering of wetland units early in the breeding season.

In my study, the local scale habitat variables that influenced the number of sites where secretive marsh birds were detected were tall emergent vegetation and the amount of interspersion within 50 m. Tall emergent vegetation had a positive effect on sora and pied-billed grebe detection. Other studies investigating marsh bird habitat selection have found mixed results for the effect of tall emergent vegetation. Lor and Malecki (2006) found that probability of detecting sora was negatively affected by vegetation height. In southern Manitoba, detection of pied-billed grebe increased with increased proportions of tall emergent cattail (Hay 2006). In the Upper Mississippi River/Great Lakes Joint Venture Region, occupancy of Virginia rails was positively influenced by the proportion of tall emergent vegetation at the local level, but least bittern site occupancy was negatively influenced by proportion of tall emergent vegetation at the local level (Bolenbaugh 2010). However, Valente (2009) found that least bittern site occupancy was unaffected by proportion of tall emergent vegetation. Qualitatively, during my surveys I detected least bitterns in stands of tall emergent cattail and horned beaksedge. Hay (2006) also found that least bitterns were associated with sites with increased proportions of cattail within 50 m. Tall emergent vegetation provides nesting and escape cover for secretive marsh birds during migration and the breeding season (Muller and Storer 1999, Bogner and Baldassarre 2002, Hay 2006, Lowther et al 2009). Secretive marsh birds will typically construct their nests from surrounding vegetation, generally tall emergent species like cattail, bulrush, reed and sedge (Rodgers and Schwikert 1999, Zimmerman et al 2003, Lowther et al 2009). Least bitterns have been observed using tall emergent vegetation as a perch while foraging (Budd and Krementz 2010).

Proportion of interspersion at the local level, within 50 m, also had a positive effect on proportion of sites where I detected soras and American coots (see also Rehm and Baldassare 2007, Darrah 2008, Bolenbaugh 2010). Interspersion values for my survey points were higher in 2009 due to lack of water available on the impoundments in 2010. When impoundment water was drawn down, pockets of open water among stands of emergent vegetation were transformed into mudflat and the mixing of water and vegetation decreased. Similar results for the effect of interspersion on marsh bird use of wetlands have been found for king rail, Virginia rail, least bittern, American bittern, and pied-billed grebe. In New York, sora abundance was positively related to edge density or interspersion (Rehm 2006). Also in New York, Gibbs et al (1992) found that least bitterns and soras tended to nest close to edges among different vegetation types and near the water-vegetation interface. Likewise, in Iowa marshes, sora density was positively correlated with amount of edge within a wetland (Johnson and Dinsmore 1986). In the Delta of Arkansas, least bitterns tended to concentrate breeding activities on marshes with increased interspersion (Budd and Krementz 2009). Many marsh birds feed and nest along the water-vegetation interface (Gibbs et al 1992). Increased heterogeneity of plant species composition and structure within a wetland is correlated with increased diversity and abundance of invertebrates which is the primary food source for many waterbirds (Voigts 1976, Kratzer and Batzer 2007). Increased interspersion and vegetation heterogeneity can be attained by creating microtopography, or ridge and swale, within wetland impoundments (Vivian-Smith 1997, Bruland and Richardson 2005, Simmons et al 2009). The swales or depressions, which remain flooded through summer, provide open water and invertebrates for foraging and residual emergent vegetation for cover until new emergent vegetation germinates and the impoundment is once again flooded for wintering water birds (Fredrickson and Taylor 1982. In my study area, marsh bird species richness was highest in impoundments where soil had been removed from the interior of the wetland to build levees, leaving small depressions that held water throughout the growing season, even when the remainder of the impoundment had been drained.

The landscape scale habitat variable that influenced proportion of sites where marsh birds were detected was proportion of emergent herbaceous wetland within 400 m. Emergent herbaceous wetland had a positive effect on proportion of sites where soras and American coots were detected. Similar results for sora and other secretive marsh birds have been found elsewhere. In New York, marsh bird species richness was positively correlated with amount of marsh within 5 km (Rehm 2006). In the Upper Mississippi River/Great Lakes Joint Venture region, proportion of emergent herbaceous wetland within 5 km positively influenced occupancy by American bittern, least bittern, Virginia rail, sora, pied-billed grebe, and common moorhen (Bolenbaugh 2010). The positive relationship between marsh bird presence and emergent herbaceous wetland within 400 m suggests that habitat selection begins with the selection of areas within the landscape containing large proportions of wetland and is followed by selection of local microhabitat based on species specific habitat requirements. Isolated wetland units surrounded by agriculture or developed land, like those typical in my study area, may not be used by marsh birds despite favorable local habitat composition because they are overshadowed in the landscape by unappealing habitat.

In my study area, marsh birds were detected most often at sites where impoundment water was not drained down until after 15 May. The lack of standing water in wetland units in 2010, by design or lack of adequate rainfall, could explain the negative effect of survey year 2010 on the proportion of sites where I detected pied-billed grebe and American coot, both of which are reliant on deep water habitat for nesting and foraging opportunities. After the wetland units were completely dewatered in 2010, no adequate nesting habitat existed for these species at the survey sites and breeding and nesting birds likely moved on to more permanent bodies of water elsewhere. Similar results have been observed for marsh dependent species in other areas. In southeastern Missouri, rail use of managed wetland units was greatest when water was drained from mid to late May (Rundle and Frederickson 1980). Early spring drawdowns that expose mudflats during marsh bird breeding season make impoundments unavailable for nesting birds and attract potential predators (e.g. crows, raptors, and raccoons) by making vertebrate and invertebrate prey readily available (Frederickson and Taylor 1982). Once marsh bird nesting is initiated, removal of water would expose eggs or chicks to these predators as well. In the Florida Everglades, white ibis (*Eudocimus albus*) abandoned large nesting colonies if water levels suddenly dropped exposing them to predation and reducing foraging habitat (Kushlan 1986). In Alberta, sora abandoned nest sites used in previous years with more favorable vegetation composition to nest in alternative vegetation at sites which had adequate water levels (Lowther 1977). Jobin et al (2009) found that least bitterns were highly sensitive to interannual changes in water level and that draining man-made impoundments during the breeding season decreased number of breeding pairs, while unexpected flooding of man-made impoundments increased number of breeding pairs. Stable water level conditions during the breeding season are necessary for many secretive marsh birds and other marsh dependent species to nest successfully. If wetlands flood or dry unexpectedly during nesting, entire clutches could be lost to inundation or predation or are prematurely abandoned. Late growing season drawdowns promote growth of perennial vegetation commonly used by secretive marsh birds for nesting during breeding season and escape cover during migration (Rundle 1980, Frederickson and Taylor 1982, Zimmerman et al 2003). Once nests have hatched, drawing down water in impoundments would provide adequate foraging opportunities for marsh bird broods and other water birds by creating shallow water or mudflats and concentrating invertebrates. Late drawdowns and autumn tilling or disking of impoundments have been found to be sufficient to create plant and invertebrate communities that would benefit waterfowl while leaving impoundments flooded for spring migrating or nesting water birds (Fredrickson and Taylor 1982, Gray et al 1999).

MANAGEMENT IMPLICATIONS

There is no single water level management regimen that would provide each habitat requirement of all water birds that utilize publically owned wetlands. However, management regimens could be augmented to potentially support a higher diversity of waterbirds than is currently observed on most of the state owned wetlands in the Arkansas River Valley of western Arkansas.

My data suggest that delaying water drawdowns until after peak marsh bird migration and nest initiation provides minimum habitat for marsh birds. At the local scale, water level manipulation and soil disturbance that increases interspersion and vegetation heterogeneity within wetland impoundments would make wetland impoundments more attractive to marsh birds.

Within a wetland complex with numerous impoundments, drawdown timing and vegetation manipulation regimens could be alternated among impoundments on a rotation longer than 2-3 years to provide habitat for both secretive marsh birds and other waterbirds simultaneously (Eddleman et al 1988). Longer rotations for water level and soil disturbance regimens could promote the growth of perennial vegetation, which is robust enough to withstand damage caused by ice and wintering waterfowl and provide escape cover until new vegetation can germinate (Rundle 1980, Eddleman et al 1988; but see also Weller 1981, Frederickson and Taylor 2007). Conducting management activities on a rotation ensures that there is adequate habitat for all marsh dependent species during migration and breeding seasons, regardless of time of year, and allows for impoundment maintenance and soil disturbance.

When making decisions regarding acquisition of land, either for expansion of established management areas or creation of new ones, looking for areas in the landscape that already contain a large proportion of emergent herbaceous wetlands would prevent creation of isolated wetlands which may be overlooked by marsh birds because they are surrounded by a large proportion of unfavorable habitat.

Managing wetlands for the habitat diversity that attracts marsh birds could also provide habitat for other wetland dependent wildlife including waterfowl, wading birds, shorebirds, reptiles, amphibians, invertebrates, and mammals (Frederickson and Taylor 2007, Mitsch and Gosselink 2007). Also, increasing topographic and vegetative heterogeneity within wetland impoundments could increase their surface water holding capacity and reduce the effects of flooding events to surrounding areas (Tweedy and Evans 2001, Mitsch and Gosselink 2007).

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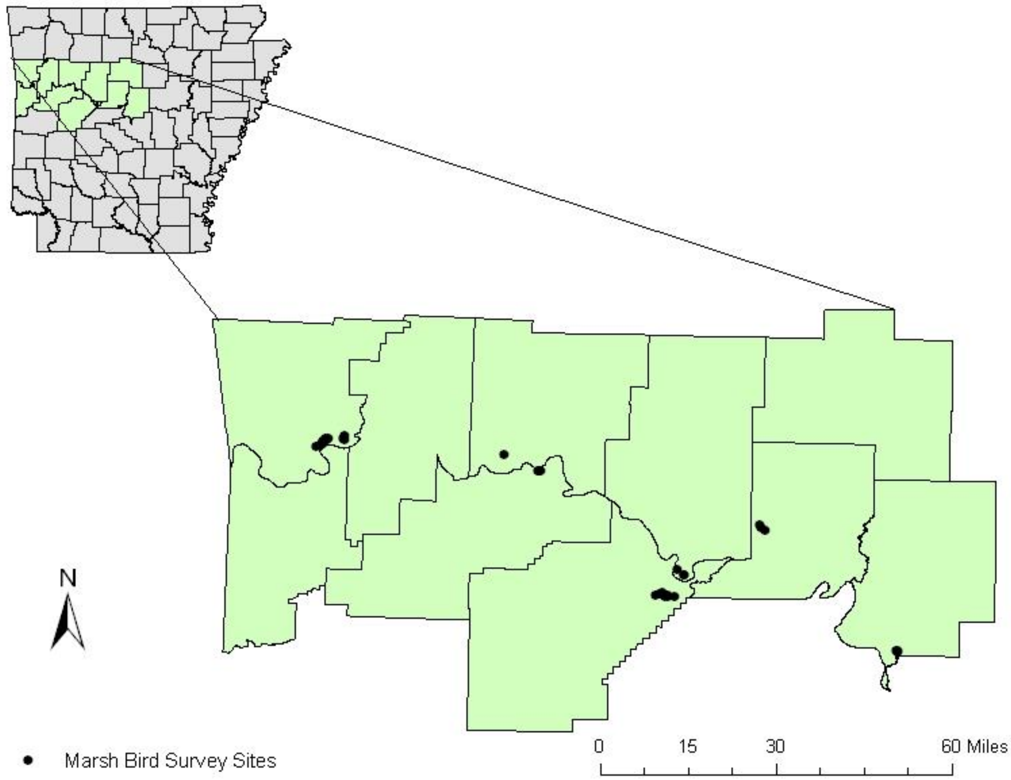

Figure 1. Distribution of management areas surveyed for secretive marsh birds in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 2 for site names and UTM coordinates.

Figure 2. Points surveyed for secretive marsh birds at the Dyer Lake northeastern waterfowl rest area of Ozark Lake WMA in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 2 for UTM coordinates.

Figure 3. Points surveyed for secretive marsh birds at the Dyer Lake southeastern waterfowl rest area of Ozark Lake WMA in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 2 for UTM coordinates.

Figure 4. Points surveyed for secretive marsh birds at Ed Gordon WMA in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 2 for UTM coordinates.

Figure 5. Points surveyed for secretive marsh birds at Frog Bayou WMA in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 2 for UTM coordinates.

Figure 6. Points surveyed for secretive marsh birds at Holla Bend NWR in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 2 for UTM coordinates.

Figure 7. Points surveyed for secretive marsh birds at the MacKennen Bottoms waterfowl rest area of Dardanelle WMA in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 2 for UTM coordinates.

Figure 8. Points surveyed for secretive marsh birds at Petit Jean River WMA in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 2 for UTM coordinates.

Figure 9. Points surveyed for secretive marsh birds at the Potter's Pothole waterfowl rest area of Ozark Lake WMA in the Arkansas River Valley in western Arkansas, AR, USA in 2009 and 2010. See Appendix 2 for UTM coordinates.

Figure 10. Points surveyed for secretive marsh birds at Vernon Bell Slough WMA in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 2 for UTM coordinates.

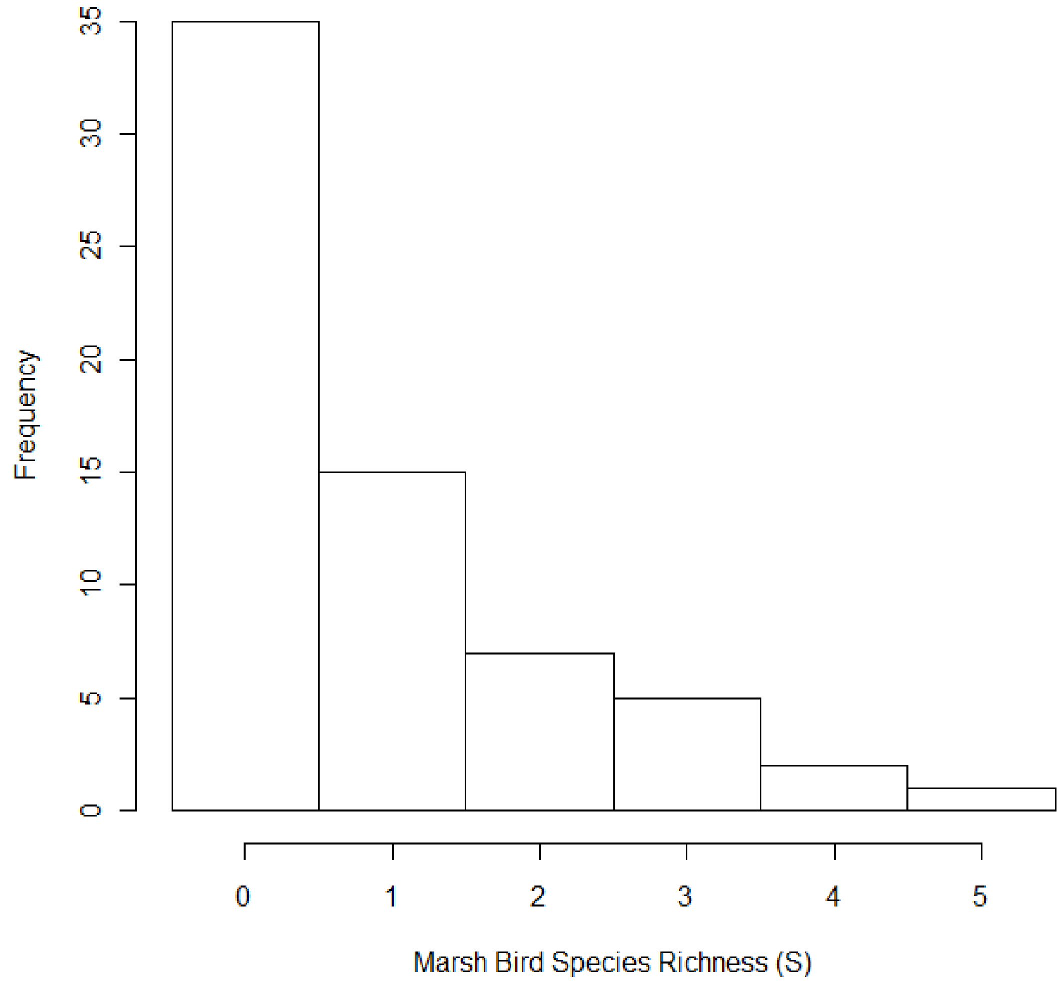

Figure 11. Distribution of marsh bird species richness (S) for points surveyed in the Arkansas River Valley of western Arkansas, USA in 2009 and 2010.

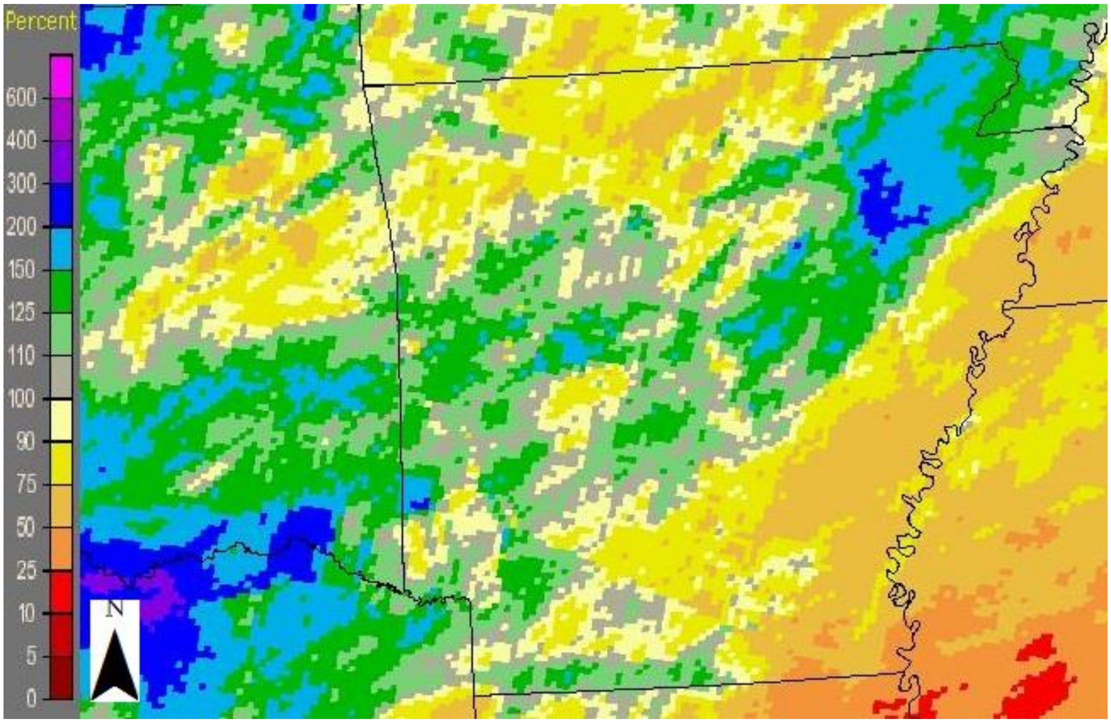

Figure 12. Percent of normal rainfall in April 2009 for Arkansas, USA[a].

[a]National Oceanic Atmospheric Administration (NOAA 2009). National Weather Service Advanced Hydrologic Prediction Service.

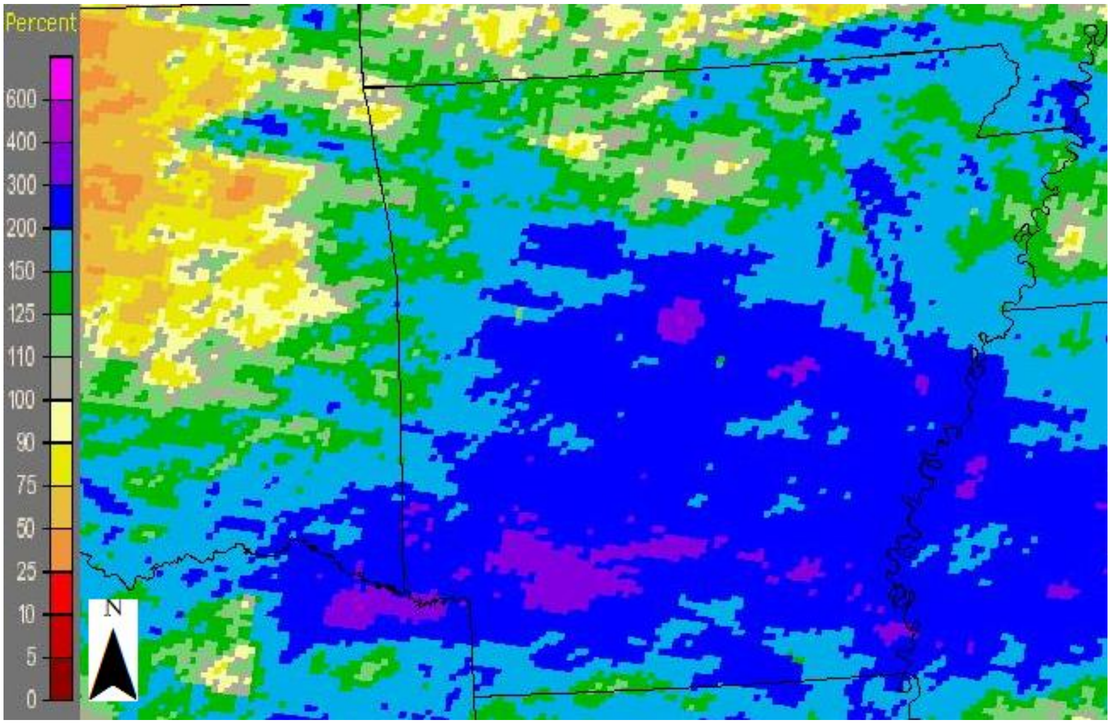

Figure 13. Percent of normal rainfall in May 2009 for Arkansas, USA[a].

[a]National Oceanic Atmospheric Administration (NOAA 2009). National Weather Service Advanced Hydrologic Prediction Service.

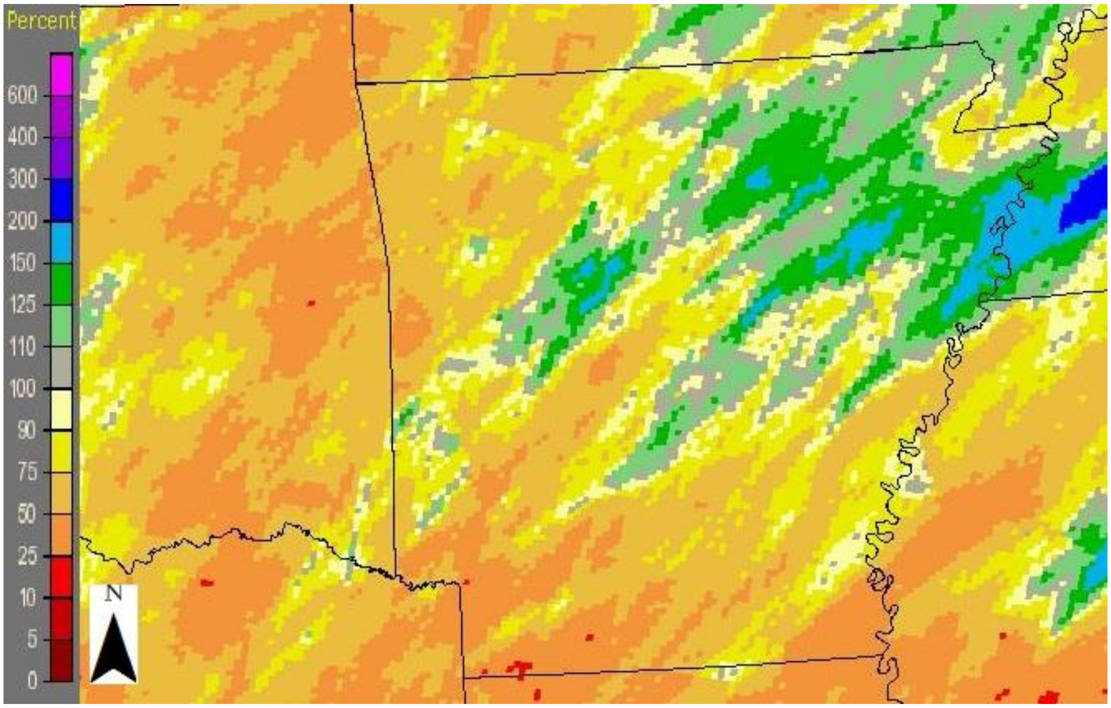

Figure 14. Percent of normal rainfall in April 2010 for Arkansas, USA[a].

[a]National Oceanic Atmospheric Administration (NOAA 2009). National Weather Service Advanced Hydrologic Prediction Service.

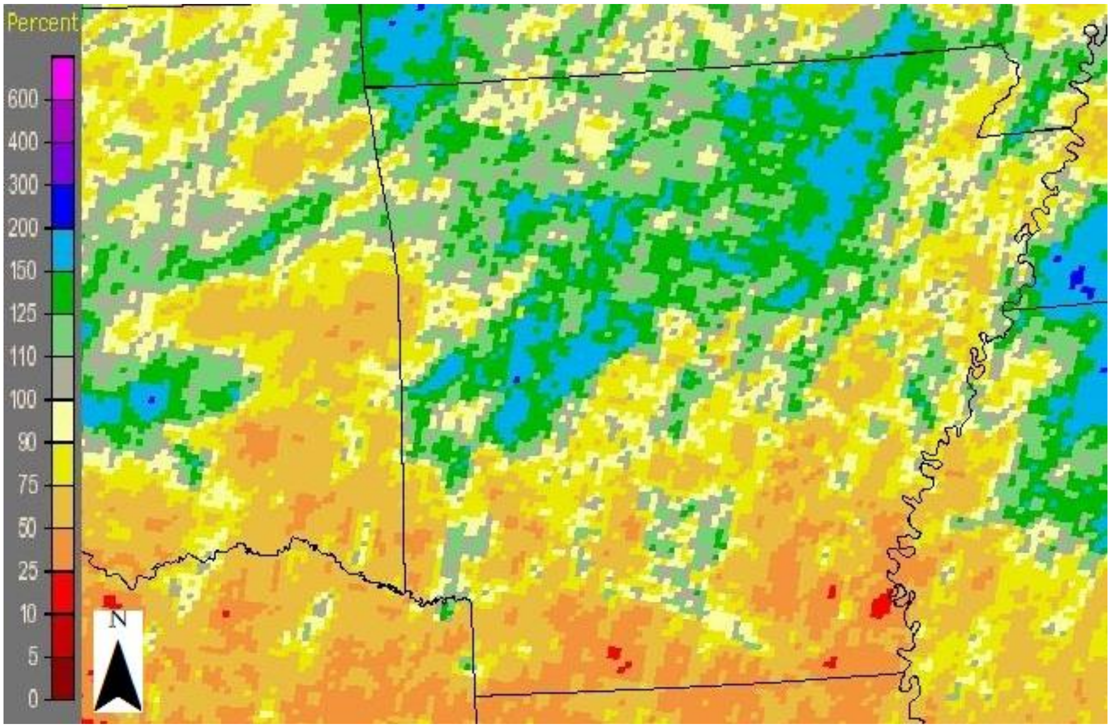

Figure 15. Percent of normal rainfall in May 2010 for Arkansas, USA[a].

[a]National Oceanic Atmospheric Administration (NOAA 2009). National Weather Service Advanced Hydrologic Prediction Service.

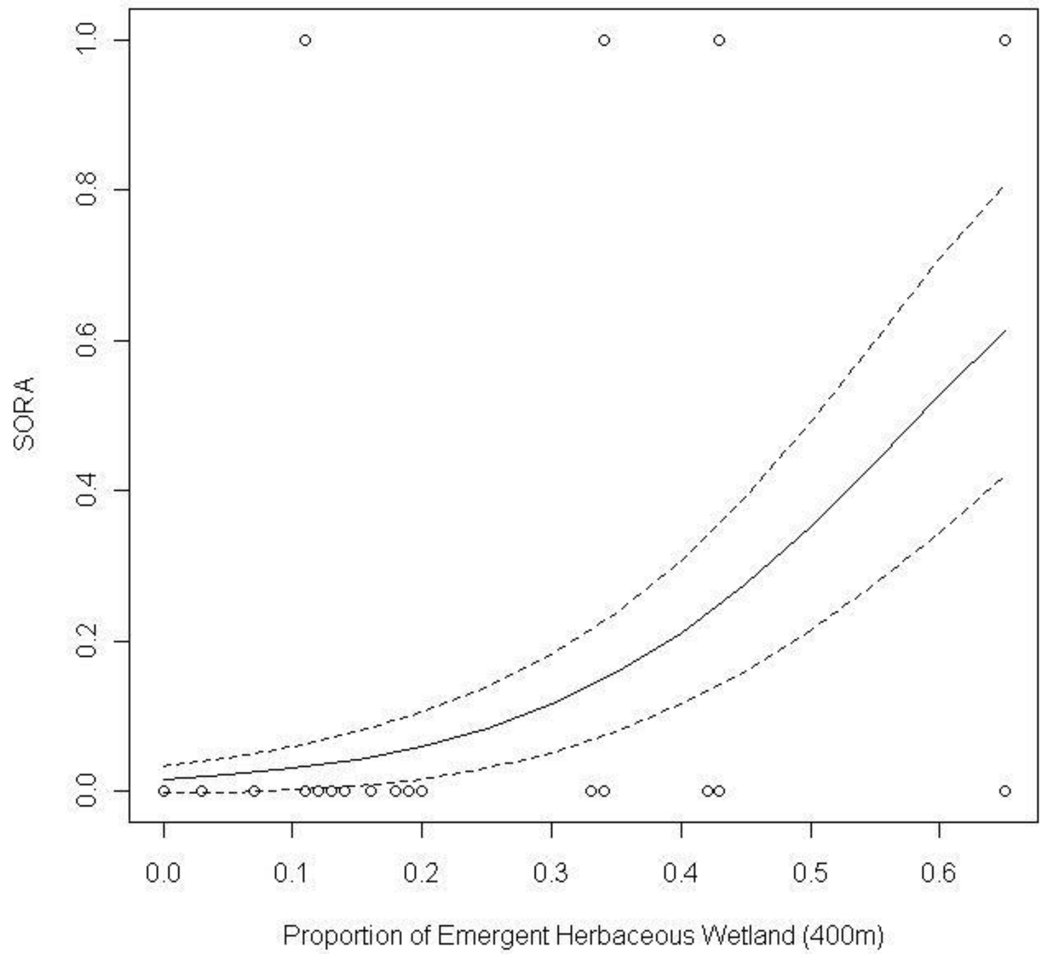

Figure 16. The relationship between the probability of detecting sora and proportion of emergent herbaceous wetlands within 400 m at points surveyed for secretive marsh birds in the Arkansas River Valley, AR in 2009 and 2010. The dashed line represents the standard errors.

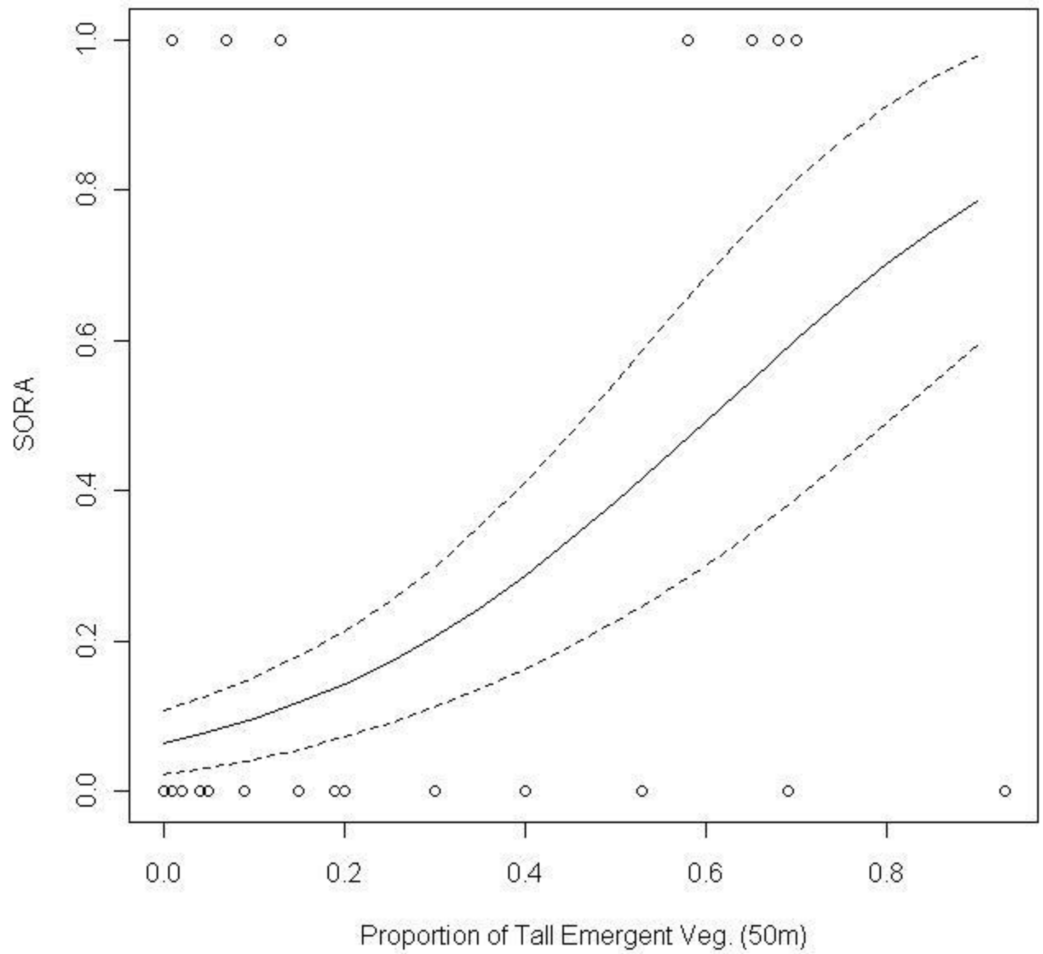

Figure 17. The relationship between the probability of detecting sora and the proportion of tall emergent vegetation within 50 m at points surveyed for secretive marsh birds in the Arkansas River Valley, AR in 2009 and 2010. The dashed line represents the standard errors.

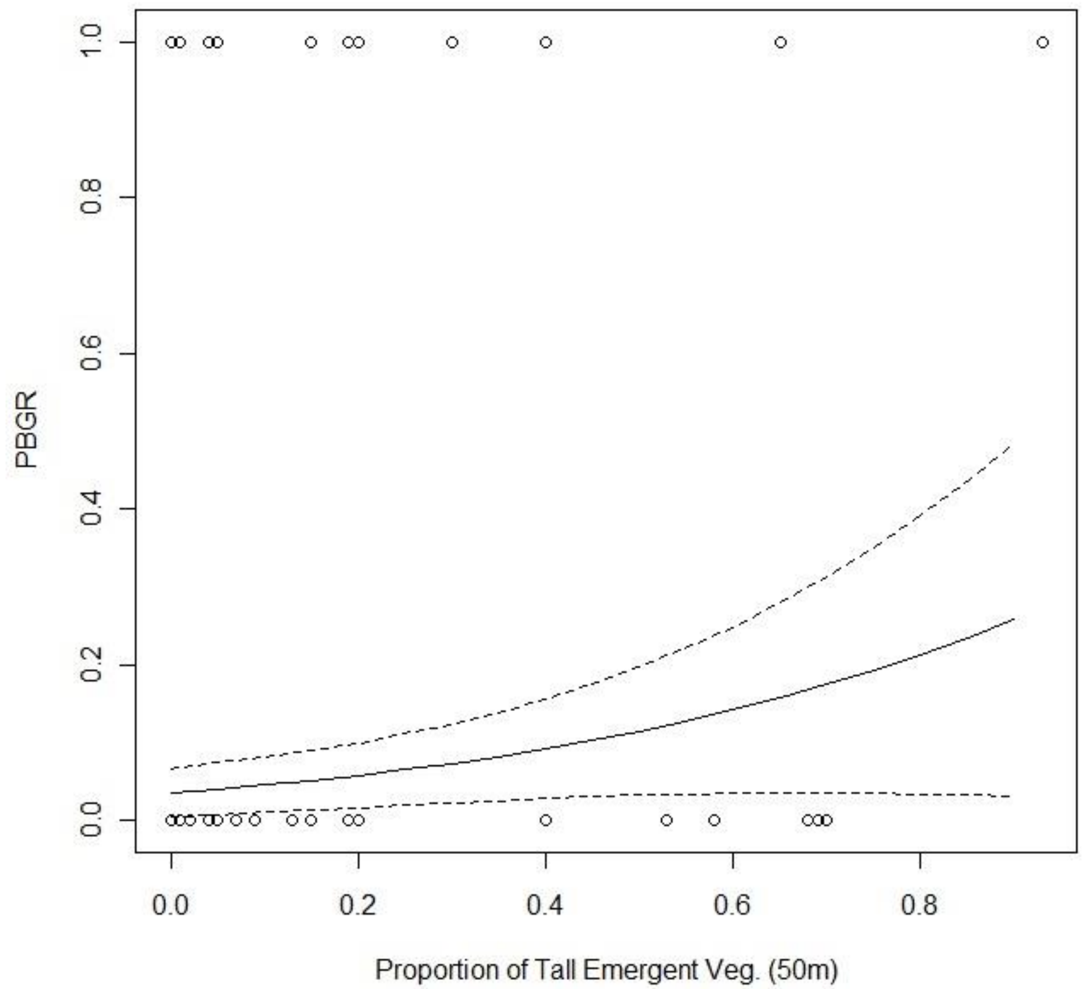

Figure 18. The relationship between the probability of detecting pied-billed grebe and the proportion of tall emergent vegetation within 50 m at points surveyed for secretive marsh birds in the Arkansas River Valley, AR in 2009 and 2010. The dashed line represents the standard errors.

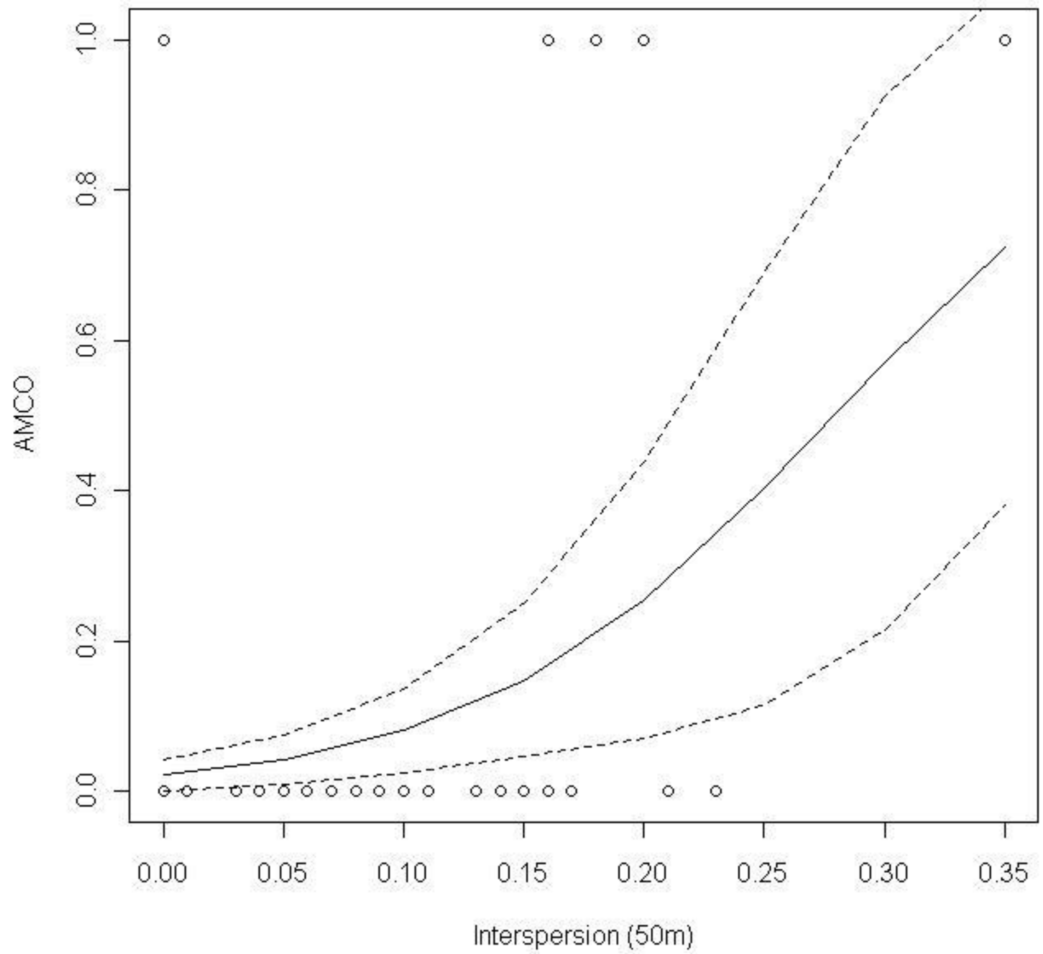

Figure 19. The relationship between the probability of American coot and the proportion of interspersion within 50 m at points surveyed for secretive marsh birds in the Arkansas River Valley, AR in 2009 and 2010. The dashed line represents the standard errors.

Table 1. Number of survey points, number of surveys conducted in 2009 and the number of surveys conducted in 2010 for each management area surveyed for secretive marsh birds in the Arkansas River Valley of western Arkansas, USA in 2009 and 2010.

	Number of Points	Number of Surveys	
Management Unit		2009	2010
Frog Bayou	9	3	3
Petit Jean	10	3	3
McKennen Bottoms	3	3	3
Potters Pothole	1	3	3
Holla Bend	1	3	3
Vernon Bell Slough	3	2	3
Dyer Lake	4	2	3
Ed Gordon	3	0	3

Table 2. Descriptions for habitat variables collected within 50 m and 400 m of each point surveyed for secretive marsh birds in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010.

Scale	Variable	Definition[a]
50 m	Open Water (OW)	Standing water or water partially covered by floating vegetation
	Tall Emergent (TE)	Emergent vegetation > 1m tall
	Interspersion (INTER)	Water-vegetation interface
400 m	Emergent Herbaceous Wetland (EHW)	Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water
	Pasture (PAST)	Areas dominated by upland grasses and forbs

[a]Definitions for habitat variables measured at 400 m are based on those described by the U.S. Environmental Protection Agency to classify habitat types for the National Land Cover Dataset (NLCD 2010).

Table 3. Model selection results for effect of habitat variables on proportion of sites where soras were detected in 2009 and 2010 in the Arkansas River Valley of western Arkansas, USA. Only models that explained the detection probability better than the constant model were included in this table. AICc – Akaike's Information Criterion corrected for small sample size, measure of the goodness of fit of each statistical model, ΔAICc – the difference in AICc estimates relative to the top model, k- number of estimated parameters. Variable abbreviations are given in Table2.

Model	k	AICc	Δ AICc
SORA(EHW)	2	37.86	0.00
SORA(TE)	2	39.75	1.89
SORA(YR+ TE)	3	41.02	3.16
SORA(YR+ INTER)	3	42.02	4.16
SORA(INTER)	2	45.23	7.37
SORA(Null)	1	46.61	8.75

Table 4. Model selection results for effect of habitat variables on proportion of sites where pied-billed grebes were detected in 2009 and 2010 in the Arkansas River Valley of western Arkansas, USA. Only models that explained the detection probability better than the constant model were included in this table. AICc – Akaike's Information Criterion corrected for small sample size, measure of the goodness of fit of each statistical model, ΔAICc – the difference in AICc estimates relative to the top model, k- number of estimated parameters. Variable abbreviations are given in Table2.

Model	k	AICc	Δ AICc
PBGR(YR+TE)	3	61.99	0.00
PBGR(YR)	2	62.29	0.30
PBGR(YR+INTER)	3	64.24	2.25
PBGR(YR+OW)	3	64.30	2.31
PBGR(INTER)	2	72.23	10.24
PBGR(PAST)	2	72.89	10.90
PBGR(Null)	1	74.74	12.75

Table 5. Model selection results for effect of habitat variables on proportion of sites where pied-billed grebes were detected in 2009 and 2010 in the Arkansas River Valley of western Arkansas, USA. Only models that explained the detection probability better than the constant model were included in this table. AICc – Akaike's Information Criterion corrected for small sample size, measure of the goodness of fit of each statistical model, ΔAICc – the difference in AICc estimates relative to the top model, k- number of estimated parameters. Variable abbreviations are given in Table2.

Model	k	AICc	Δ AICc
AMCO(INTER)	2	47.08	0.00
AMCO(YR+INTER)	3	48.84	1.76
AMCO(YR+EHW)	3	51.08	4.00
AMCO(YR)	2	52.72	5.64
AMCO(EHW)	2	52.74	5.66
AMCO(YR+OW)	3	54.29	7.21
AMCO(Null)	1	54.47	7.39

Table 6. Number of each secretive marsh bird species detected or observed opportunistically during each round of surveys conducted in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 1 for species codes.

	2009			2010		
	Round 1	Round 2	Round 3	Round 1	Round 2	Round 3
AMBI	1	3	1	4	1	0
AMCO	80	6	3	20	13	2
KIRA	0	0	0	1	0	0
LEBI	0	1	0	0	0	2
PBGR	13	18	6	14	7	3
SORA	3	0	0	0	7	8

Table 7. Number of each marsh bird species detected or observed opportunistically in each management unit or moist-soil unit (MSU) at each wildlife management area (WMA) or national wildlife refuge (NWR) surveyed for secretive marsh birds in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010. See Appendix 1 for 4-letter species codes.

	KIRA		SORA		LEBI		PBGR		AMCO		AMBI	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Frog Bayou WMA												
Unit 1	0	0	0	0	0	0	1	1	1	0	0	0
Unit 2	0	0	0	0	0	0	0	0	0	0	0	0
Unit 3	1	1	1	7	0	0	3	5	0	0	0	2
Unit 4	0	0	0	4	7	2	6	0	14	10	0	0
Unit 5	0	0	0	0	0	0	2	0	0	0	1	1
Unit 6	0	0	0	7	0	1	1	12	1	148	1	2
Unit 7	0	0	0	0	0	0	2	0	60	0	0	0
Dardanelle WMA												
McKennen Bottoms	0	0	2	0	0	0	19	0	15	0	2	0
Potters Pothole	0	0	0	0	0	0	1	2	0	0	0	0
Holla Bend NWR	0	0	0	1	0	0	2	0	0	0	0	0
Petit Jean WMA												
Blacklands MSU	0	0	1	0	0	0	0	0	0	0	0	0
Olin Cain MSU	0	0	0	0	0	0	0	0	0	0	2	0
Slaty MSU	0	0	0	0	0	0	0	6	0	1	0	0
Pullen Pond	0	0	0	0	0	0	19	1	1	2	0	0
Vernon Bell Slough WMA	0	0	0	0	0	0	0	0	0	0	1	0
Ozark Lake WMA												
Dyer Northeast	0	0	0	0	0	0	0	0	0	0	0	0
Dyer Southeast	0	0	0	0	0	0	0	0	0	0	0	0
Ed Gordon WMA												
Unit 1	na[a]	0	na	0	na	0	na	0	na	0	na	0
Unit 2	na	0	na	0	na	0	na	0	na	0	na	0
Unit 3	na	0	na	0	na	0	na	0	na	0	na	0

[a] na represents a missing observation.

Table 8. Number of sites at which each species of secretive marsh bird was detected in the Arkansas River Valley in western Arkansas, USA in 2009 and 2010.

Species	Number of Sites	
	2009	2010
King Rail	0	1
Sora	2	5
Least Bittern	1	1
American Bittern	5	5
Pied-billed Grebe	8	3
American Coot	8	7

Table 9. Management activities conducted on each wetland or moist-soil unit (MSU) at each wildlife management area (WMA) or national wildlife refuge (NWR) surveyed for secretive marsh birds in Arkansas River Valley in western Arkansas, USA, in 2009.

Wetland Unit	Water Available in April	Water Available in May	No water available	disked	planted	herbicide	burned
Frog Bayou WMA							
Unit 1	x						
Unit 2	x	x					
Unit 3	x	x		x	x		
Unit 4	x	x					
Unit 5	x	x		x	x		
Unit 6	x	x		x	x		
Unit 7							
Dardanelle WMA							
McKennen Bottoms	x	x					
Potters Pothole	x	x					
Holla Bend NWR	x	x					
Petit Jean WMA							
Blacklands MSU			x				
Olin Cain MSU	x						
Slaty MSU	x						
Pullen Pond	x	x					
Vernon Bell Slough WMA	x						
Ozark Lake WMA							
Dyer Northeast			x		x		
Dyer Southeast		x		x		x	
Ed Gordon WMA							
Unit 1	x	x					
Unit 2	x	x					
Unit 3	x	x					

Table 10. Management activities conducted on each wetland or moist-soil unit (MSU) at each wildlife management area (WMA) or national wildlife refuge (NWR) surveyed for secretive marsh birds in the Arkansas River Valley in western Arkansas, USA, in 2010.

Wetland Unit	Water Available in April	Water Available in May	No water available	disked	planted	herbicide	burned
Frog Bayou WMA							
Unit 1	x						
Unit 2	x	x					
Unit 3	x	x					
Unit 4	x	x					
Unit 5	x	x		x	x		
Unit 6	x	x					
Unit 7			x	x	x	x	
Dardanelle WMA							
McKennen Bottoms			x	x		x	
Potters Pothole	x			x	x	x	
Holla Bend NWR		x					
Petit Jean WMA							
Blacklands MSU	x						
Olin Cain MSU	x						
Slaty MSU	x						
Pullen Pond	x	x					
Vernon Bell Slough WMA	x						
Ozark Lake WMA							
Dyer Northeast	x						
Dyer Southeast		x					
Ed Gordon WMA							
Unit 1			x				
Unit 2	x	x					
Unit 3	x						

Table 11. Model selection results for effect of drawdown timing (DD), survey year (YR), impoundment (IMPD) and wildlife management area (WMA) on secretive marsh bird species richness (S) in Arkansas River Valley in western Arkansas, USA in 2009 and 2010. AICc – Akaike's Information Criterion corrected for small sample size, measure of the goodness of fit of each statistical model, ΔAICc – the difference in AICc estimates relative to the top model, k- number of estimated parameters.

Model	k	AICc	ΔAICc
S(DD + YR + IMPD)	4	72.71	0.00
S(DD + YR + IMPD +WMA)	5	74.91	2.20
S(DD + YR + WMA)	4	75.98	3.27
S(DD)	2	146.6	73.88
S(DD + YR)	3	148.4	75.70
S(YR)	2	180.0	107.3
S(Null)	1	181.1	108.4

Appendix 1. Secretive marsh bird species common names and 4-letter species codes.

Species	Species Code
American Bittern	AMBI
American Coot	AMCO
King Rail	KIRA
Least Bittern	LEBI
Pied-billed Grebe	PBGR
Sora	SORA

Appendix 2. Management areas and UTM coordinates of sites surveyed for secretive marsh birds in the Arkansas River Valley of western Arkansas, USA in 2009 and 2010.

Management Area	Site	Easting	Northing
Petit Jean WMA	Blk1	489710	3882125
	Blk2	490339	3881854
	Blk3	490425	3882154
	Oc1	489660	3881771
	Pull1	487287	3882207
	Pull2	488866	3882802
	Pull3	488871	3883018
	Pull 4	488622	3882675
	Pull5	488411	3882819
	Slty1	492462	3881904
Ozark Lake WMA	Dne1	401780	3926366
	Dne2	401560	3926207
	Dse1	401537	3925035
	Dse2	401259	3925287
Ed Gordon WMA	Eg1	515584	3901476
	Eg2	515878	3901075
	Eg3	517217	3900106
Frog Bayou WMA	Fb1	393844	3923263

Appendix 2 continued.

Management Area	Site	Easting	Northing
	Fb2	397011	3925509
	Fb3	396230	3925286
	Fb4	396573	3925125
	Fb5	395694	3924594
	Fb6	395643	3924280
	Fb7	395366	3924387
	Fb8	394842	3923536
	Fb9	395599	3923947
Holla Bend NWR	Hb1	493199	3889341
Dardanelle WMA	Mb1	454862	3916419
	Mb2	455029	3916397
	Mb3	455446	3916508
	Pp1	445385	3921148
Vernon Bell Slough WMA	Vb1	553619	3866702
	Vb2	553746	3867035
	Vb3	553232	3866824