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Yellow Rail (*Coturnicops noveboracensis*) Occupancy in the Context of Fire in Mississippi and Alabama, USA

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Abstract.—The Yellow Rail (*Coturnicops noveboracensis*) is a migratory bird with many aspects of its ecology poorly understood. The objective of this study was to examine effects of fire, vegetation structure, and landscape variables on site occupancy and detection probabilities for Yellow Rails overwintering in coastal pine savannas of Mississippi and Alabama. Between December and April, 2012-2013, dragline surveys for Yellow Rail were conducted at three conservation areas: two in Jackson County, Mississippi, and one in Mobile County, Alabama, USA. Site occupancy for Yellow Rail was 0.81 ± 0.06 (SD) with detection probabilities of 0.79 ± 0.09 (SD). Yellow Rail occupancy related negatively with time since fire, indicating fire provides conditions attractive to Yellow Rail overwintering throughout the study area. Yellow Rail use of wetland and fire-maintained habitats within coastal Mississippi during winter, coupled with continued loss of open grasslands and inadequate management of fire-dependent pine savanna habitats throughout the southeastern USA highlights the continued need to prioritize the conservation and effective management of herbaceous-dominated ecosystems. *Received 18 July 2015, accepted 5 January 2017.*

Key words.—Alabama, conservation, dragline, habitat, longleaf pine, Mississippi, occupancy, *Pinus palustris*, prescribed burning, Yellow Rail.

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Longleaf pine (*Pinus palustris*) ecosystems, pine savannas in particular, were once among the most expansive ecosystems in North America (Landers *et al.* 1995). It is estimated that prior to European settlement these ecosystems covered over 30 million ha in the southeastern United States (Frost 1993). These fire-dependent ecosystems frequently experienced low to moderate intensity fires produced by lightning and Native American activities (Brockway and Lewis 1997). Disruption of historical fire regimes, coupled with anthropogenic activities including habitat fragmentation and degradation, has been deemed responsible for the rapid decline of longleaf ecosystems (Brockway and Lewis 1997). Currently, longleaf pine ecosystems are among the most ecologically imperiled of all forested ecosystems in North America (Noss 1989; Simberloff 1993), with an area currently estimated to be less than 1.2 million ha (Brockway and Lewis 1997; Outcalt 2000; Frost 2006).

Disturbance, most notably fire, helped shape both historic and present-day vegetation structure of longleaf pine ecosystems (Platt 1999). Temporal and spatial heterogeneity in pyrogenic activity directly influences avian communities that inhabit fire-dependent ecosystems (Wiens 1974). Studies indicate prescribed fire is a beneficial management tool for avian species associated with longleaf pine systems (Tucker *et al.* 2003; Bechtoldt and Stouffer 2005). Subsequently, present day fire management programs aim to reintroduce fire into the landscape, resulting in dynamic habitat mosaics (Parr and Brockett 1999). However, information is lacking relating the effects of time since fire on occupancy for many avian species associated with longleaf pine ecosystems.

The Yellow Rail (*Coturnicops noveboracensis*), the second smallest of the North American rails, is a highly secretive marsh bird whose breeding range includes Canada and the northern Great Lakes region. The species winters along the Atlantic and Gulf Coastal Plains region from Texas to North Carolina, USA, primarily selecting high marsh habitat with dense, low undergrowth (Lima 1993; Butler *et al.* 2014; Leston and Bookhout 2015). As such, periodic disturbance including fire, herbivory, and flooding across breeding and wintering grounds appears critical in maintaining Yellow Rail habitat suitability (Burkman 1993; Mizell 1998; Austin and Buhl 2013). These disturbances recycle nutrients, increase ground cover biodiversity, remove litter, and top-kill woody vegetation, limiting encroachment (Platt 1999). In pine savanna habitats, fire suppresses woody encroachment and promotes herbaceous emergence (Lewis and Harshbarger 1976; Wilson *et al.* 1995). Burkman (1993) found that on the breeding grounds, Yellow Rail were more likely to be found in burned habitats having lower percentage of shrubs and higher percentage of sedges (*Carex lasiocarpa*) than control plots, suggesting suitability of habitat for Yellow Rail diminishes with the encroachment of woody plant species. Similarly, two previous studies conducted on Yellow Rail in Michigan noted a negative relationship between time since fire and Yellow Rail presence (Burkman 1993; Austin and Buhl 2013). Austin and Buhl (2013) found fire was the most important factor explaining the presence of Yellow Rail on their breeding grounds.

The goal of this study was to estimate occupancy rates for Yellow Rail as related to habitat features and management regimes in pine savannas along the northern Gulf Coast of Mississippi and Alabama, USA. We hypothesized that time since fire influenced Yellow Rail occupancy through its effects on habitat structure and composition. Given the discussion from above, we predicted Yellow Rail occupancy should: 1) decrease with time since fire; 2) be negatively related to woody vegetative cover and woody height; and 3) be positively related to herbaceous vegetation density.

METHODS

Study Area

The study areas comprised more than 9,150 ha of fire maintained pine savanna habitats in three conservation areas along the Gulf Coast of the USA currently managed for the restoration or maintenance of wet pine savanna habitat: two in Mississippi (Mississippi Sandhill Crane National Wildlife Refuge (NWR) and Jackson County Mitigation Bank), and the Grand Bay Savanna Forever Wild complex in Alabama (Fig. 1). Located in the Gulf Coastal Plain ecoregion, these study areas are characterized by low topography and infertile, acidic, saturated clay soils, with a temperate climate including hot summers (mean = 27 °C; precipitation = 32 cm) and mild, wet winters (mean = 9 °C; precipitation = 38 cm) (National Climatic Data Center 2015). Dominant pine savanna herbaceous cover includes wiregrass (*Aristida stricta*), muhly grass (*Muhlenbergia* spp.), toothache grass (*Ctenium aromaticum*), bluestem grasses (*Andropogon* spp.) and panic grasses (*Panicum* spp.) (Peet and Allard 1993). Dominant woody vegetation consists of St. John's-wort (*Hypericum brachyphyllum*), gallberry (*Ilex glabra*), wax myrtle (*Morella cerifera*), sweetbay magnolia (*Magnolia virginiana*), yaupon (*Ilex vomitoria*) and smilax (*Smilax domingensis*) (Peet and Allard 1993).

Mississippi Sandhill Crane NWR is managed with prescribed fire applied at 3-year return intervals where 1/3 of management units (40 total) are burned annually (Wilder 2008). Jackson County Mitigation Bank is just north of the Grand Bay National Estuarine Research Reserve/NWR (Fig. 1). This area extends over 150 ha and is managed periodically by prescribed burning (3-5 year fire return interval). Grand Bay Savanna Forever Wild complex consists of four contiguous tracts, totaling more than 2,000 ha (Fig. 1) and is managed with frequent prescribed burns (2-3 year fire return interval).

Survey Methods

Within the study area, we conducted surveys for Yellow Rails between December and April, 2012-2013. We defined a study site as a singular management unit with-

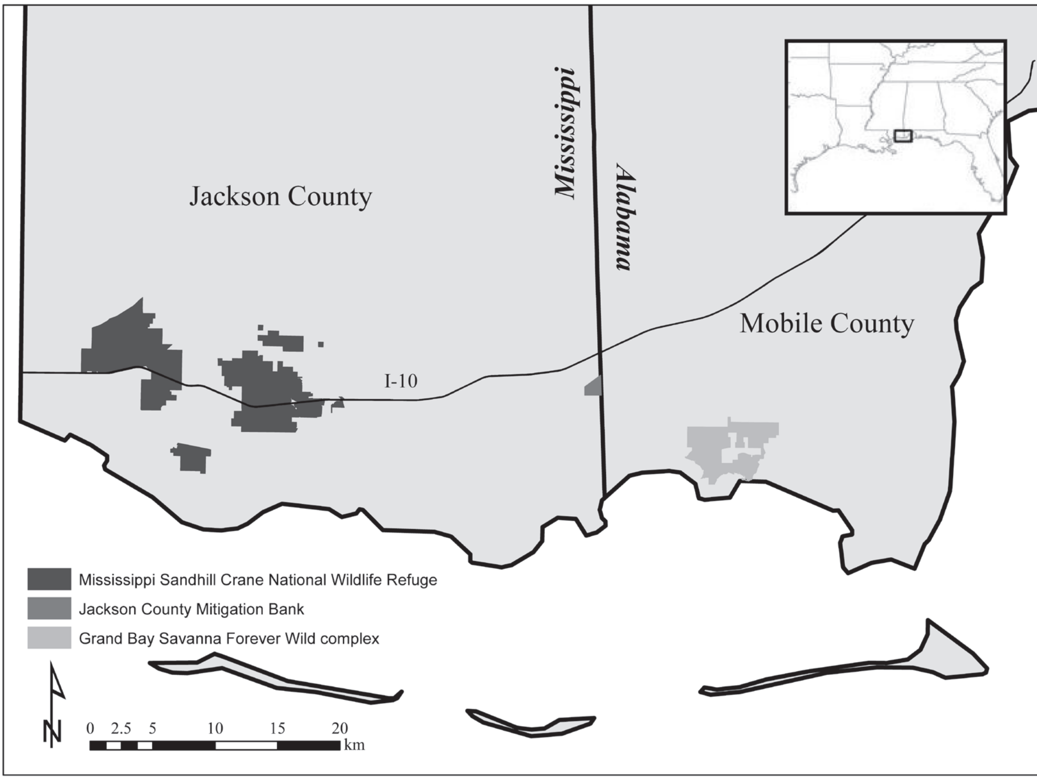

Figure 1. Study areas in Mississippi and Alabama, USA, 2012-2013.

in one of the three conservation areas and survey plot as the area surveyed within each study site, where each study site is associated with one survey plot. We selected 13 study sites based on fire history and feasibility to survey selected habitat, with 11 sites located within Mississippi Sandhill Crane NWR, one site in Jackson County Mitigation Bank and one site in the Grand Bay Savanna Forever Wild complex (Table 1). The size of each survey plot varied (1-5 ha) conditional upon logistical constraints, such as tree-line boundaries (Table 1). Primary habitat type of all survey plots was pine savanna.

We conducted surveys with a four-person field crew using a 15-m weighted dragline (Mizell 1998; Grace *et al.* 2005; Butler *et al.* 2010) with attached noisemakers (500-mL plastic bottles containing rocks and attached to the dragline at 0.5-m intervals) to create noise and disturbance throughout the vegetation, causing birds to flush from ground cover. Each member of the field crew used a Kelly's K-Light (5-LED 21 V Std Light) or a Boss Light (24v7). Two members of the crew pulled each end of the dragline at a walking speed (~1.6 kmph), while the other two members were spread equidistant behind the dragline. Surveys began 30 min after sunset and stopped after 3 hr or upon coverage of the entire survey plot (Mizell 1998; Grace *et al.* 2005; Butler *et al.* 2010).

During each transect pass, the survey crew walked in a straight line navigating to a fixed position established by a lantern hanging from a Shepherd's hook placed at each transect origin. At the end of each transect pass, the crew measured the distance (m) between each end of the bowed dragline. The crew then shifted perpendicular to the transect, moving one dragline length (15 m) to the right or left. After shifting over, the crew placed the lantern at the end of the dragline for navigating each pass. To determine the total area covered for each survey, we used a composite of dragline widths and the linear distances covered by each transect. Transect lengths were collected using the Tracks function on a handheld GPS unit (Garmin GPSMap76CSX). The crew then proceeded parallel to the transect using the lantern to navigate. For each survey plot, we standardized starting locations and the direction of line shift.

The survey crew directly noted Yellow Rail detections, using field identification characteristics (i.e., white secondary wing patches) and flight behavior (i.e., rapid, shallow wing-beats in a low arcing path) particular to this species. We recorded the initial flush location of detected Yellow Rails using a handheld GPS unit and placed a 1-m PVC pole vertically in the ground to facilitate subsequent collection of vegetation metrics during daylight hours. We surveyed each survey plot three times throughout the field season (December to April), with surveys at the same site all 14 or more days apart.

Habitat and Site Assessment

We measured plant community structure the day following each survey, at two locations per observed

Table 1. Characteristics associated with Yellow Rail study sites within study areas in Mississippi and Alabama, 2012-2013. Time since fire is averaged among three site visits.

Study Site	Site Area (ha)	Survey Area (ha)	Time Since Fire (days)
	Grand Bay Savanna Forever Wild Complex		
GBS	10	2.63	252
	Jackson County Mitigation Bank		
JCMB	18	1.97	746
	Mississippi Sandhill Crane National Wildlife Refuge		
G-05	54	5.43	315
G-07	49	2.97	633
G-11SE	28	2.69	683
G-11SW	5	3.13	714
G-12	10	1.01	1,021
G-13	9	2.52	291
G-14	156	4.38	1,386
G-15M	4	3.65	249
O-07S	20	2.66	1,032
O-10S	93	4.33	1,047
O-13	29	3.60	637

bird: 1) each location where we detected a Yellow Rail; and 2) a paired control point. We determined control point locations using a random numbers table, selecting a number between 1-360 for compass bearing and a number between 20-100, as a distance (in m) from the detection point. We then established circular plots (10-m radius) centered on each Yellow Rail or control point. Using a 2-m pole placed at the circular plot centroid, we measured point-intercept density by determining the lowest decimeter where the pole was greater than 50% obscured and recorded maximum height of woody and herbaceous vegetation within 25 cm of the pole (Robel *et al.* 1970). We measured vegetation height at 2-m intervals along four transects, one in each of the four cardinal directions radiating from the centroid (four measurements/transect), and recorded point-intercept density at the end of each 10-m transect, as observed toward the center of the plot at a height of 1 m. Additionally, we recorded diameter at breast height (DBH) of all trees greater than or equal to 7.5 cm DBH within the plot and visually estimated percent coverage of dominant woody (tree and shrub species) and herbaceous vegetation to the nearest 1%, totaling 100% across the plot. We also measured habitat characteristics at study plots where we detected no Yellow Rail (hereafter, “non-detection location”) throughout the field season by selecting five locations within each study plot using a random numbers table. To select each of the five points, we randomly selected one transect from among those traversed during the final survey, and then randomly selected a distance along that transect. We repeated this process each time we selected a sampling point.

For analytical purposes, we summarized vegetation characteristics by averaging all vegetation metrics collected at all random points to describe the vegetation at the study plot level associated with a given study site. At sites where we detected no Yellow Rail, we summarized site characteristics by averaging all vegetation metrics collected at all random points associated with a given site. We included site-averaged metrics in subsequent occupancy models.

For each study site, we calculated patch size (ha) and survey area (ha) using ArcGIS (Environmental Systems Research Institute 2011). We used 2013 high resolution orthoimagery (U.S. Geological Survey 2013) with 1-m resolution to calculate the area of open grassland in each study site using the area measure tool in ArcGIS (Environmental Systems Research Institute 2011). We calculated survey area using a composite of dragline widths and the linear distance covered by each transect for each survey event. We eliminated any areas of transect overlap from the calculations. We averaged survey areas among site visits for use in modeling site-occupancy by Yellow Rail.

Statistical Methods

We employed Markov chain Monte Carlo (MCMC) methods within a Bayesian framework using statistical package JAGS (Plummer 2013) and statistical package R2jags (Su and Yajima 2012) in statistical program R (R Development Core Team 2013) to model Yellow Rail detection probability and site occupancy (Kéry and Schaub 2012). Bayesian models followed the same maximum likelihood approach as described by MacKenzie *et al.* (2002). Site-occupancy models use replicated surveys within a survey plot to resolve the uncertainty of a recorded absence, which can occur when a species is absent or present but not detected (MacKenzie *et al.* 2006). Modeling Yellow Rail occupancy in the Bayesian framework allows us to provide direct probability statements about specific models while incorporating uncertainty into each model (Ellison 2004; Martin *et al.* 2005). This method extends logistic regression models with Bernoulli distributions for state (Ψ) and detection (ρ), accounting for error in detection (MacKenzie *et al.* 2002). Occupancy models provide estimates for Ψ, the estimated proportion of study sites occupied by the species, and ρ, the probability of detecting the species given it is present during a survey event. Assumptions of occupancy models include a closed population, absence of false presence, and that selection and scale of sampling areas are ecologically significant to the study species (MacKenzie *et al.* 2006).

We constructed occupancy models using a two-step selection process. First, we modeled ρ while Ψ was held constant (MacKenzie *et al.* 2002), only including covariates that could influence ρ. We considered those factors potentially influencing the detection probability of Yellow Rail using a dragline method to be DENSITY and WOOD. These covariates were therefore included as sample-specific, or detection-model covariates. Site covariates, those considered to affect Ψ, included herbaceous and woody height, herbaceous and woody percent cover, point-intercept density, patch size, survey area, stand DBH and time since fire (FIRE) (Table 2). Prior to running models, we scaled all continuous site covariates (mean = 0 and to unit SD) and examined correlations between all predictor variables for multicollinearity ($r > 0.5$) (Table 3) (Gehring *et al.* 2015).

Due to the inverse correlation of herbaceous cover and woody cover among sites, we selected woody cover to remain in the global model as previous studies indicated a negative relationship between Yellow Rail occurrence and woody cover (Burkman 1993; Martin 2012; Austin and Buhl 2013). Subsequently, we designated woody cover as a proxy for collected woody features and selected density to remain in the model to represent habitat structure. By including woody cover and density as habitat features in modeling occupancy, we were able to assess Yellow Rail occupancy as it relates to both vegetative structure and composition (Ribic *et al.* 2009). As patch size was highly correlated with survey area, we selected patch size to remain in occupancy modeling to evaluate the strength toward area sensitivity for Yellow Rail in pine savanna habitats (Robbins *et al.* 1989). Area sensitivity occurs when the size of a fragmented area influences a species' occupancy or abundance (Robbins *et al.* 1989).

We constructed a singular global model that included those variables we considered biologically significant to explain Yellow Rail occupancy. Rather than applying criteria to select among competing models, we based inference on output from this single model (Carillo-Rubio *et al.* 2014). This global model included the covariates DENSITY and WOOD on detection probability and DBH, DENSITY, FIRE, woody cover, and patch size as covariates on occupancy. We assigned all model parameters flat priors (Uniform (0, 0.01)). For the candidate model, we sampled from three MCMC chains for 50,000 iterations, discarding the first 5,000 iterations as "burn-in", and a thinning factor of 10 to minimize autocorrelation among iterations, producing 13,500 estimates for each model parameter. We evaluated chain convergence using R-hat < 1.1 (Gelman and Hill 2007), where R-hat values < 1.1 indicate adequate convergence to the principal distribution. For the global model, we considered parameters in which the 90% credible intervals did not overlap zero to affect Yellow Rail detection and occupancy. We also generated Bayesian P values (Gelman *et al.* 2014) to determine goodness of fit and to assess the proportion of posterior distribution values that were either > 0 or < 0 if parameter 90% credible intervals overlapped zero.

RESULTS

Throughout our study, we conducted a total of 53 surveys covering 485 ha (Table 1). During these surveys, we detected a total of 85 Yellow Rails across all sites and surveys. We detected multiple (two to six) rails per survey at sites G-05, G-11SE, G-11SW, G-13 and G-14 of the Mississippi Sandhill Crane NWR, at the Jackson County Mitigation Bank and at the Grand Bay Savanna Forever Wild complex. Individual birds were detected during surveys at G-05, G-11SW, G-13 and G-14 of

Table 2. Metrics used in generating site-occupancy estimates of Yellow Rail in pine savanna habitats of Mississippi and Alabama, USA, 2012-2013.

Variable	Description
DBH	Average diameter at breast height (cm) of trees ≥ 7.5 cm among sampled vegetation plots
DENSITY	Average height of point-intercept density (m) among vegetation plots
Herbaceous cover	Average herbaceous vegetation percent cover among vegetation plots
Herbaceous height	Average height (m) of herbaceous vegetation among vegetation plots
Patch size	Patch size (ha) of open grassland habitat associated with each study plot
Survey area	Average area (ha) surveyed among each survey visit
FIRE	Average time since fire (days) averaged among each survey visit
Woody height	Average height (m) of woody vegetation among sampled vegetation plots
Woody cover	Average woody vegetation percent cover among sampled vegetation plots

Table 3. Correlation matrix for habitat characteristics collected in pine savanna habitats of Mississippi and Alabama, USA, 2012-2013. See Table 2 for parameter definitions.

Parameter	DBH	DENSITY	Herbaceous Cover	Herbaceous Height	Patch Size	Survey Area	FIRE	Woody Height	Woody Cover
DBH	1.00								
DENSITY	-0.39	1.00							
Herbaceous cover	0.33	-0.11	1.00						
Herbaceous height	-0.26	**0.82**	0.00	1.00					
Patch size	-0.13	-0.31	0.22	-0.45	1.00				
Survey area	-0.25	-0.22	**0.59**	-0.11	**0.59**	1.00			
FIRE	0.11	-0.12	-0.06	-0.37	0.34	-0.31	1.00		
Woody height	0.06	-0.32	**-0.66**	-0.31	-0.07	-0.34	-0.07	1.00	
Woody cover	-0.33	0.11	**-1.00**	0.00	-0.22	**-0.59**	0.06	**0.66**	1.00

the Mississippi Sandhill Crane NWR, at the Jackson County Mitigation Bank and at the Grand Bay Savanna Forever Wild complex, while no individuals were detected during some surveys at sites G-07, G-11SE, G-11SW, G-12, O-07, O-10 and O-13 of the Mississippi Sandhill Crane NWR.

We detected Yellow Rail at least once at nine of our study sites (69%), for a total of 22 detections in 2012-2013. Mean occupancy probability among all sites, as derived from global model estimates, was 0.81 ± 0.06 (± SD) with a detection probability of 0.79 ± 0.09 (± SD). Posterior summaries and derived parameters from the global model indicated increased likelihood of Yellow Rail occupancy proximate to when supporting habitat had been last burned (Table 4), where the probability of Yellow Rail occupancy significantly decreased with time post burn (Table 4; Fig. 2). None of the other covariates considered were found to affect Yellow Rail occupancy or their detection.

DISCUSSION

This study reinforces the importance of implementing prescribed fire in managing pine savanna habitats for Yellow Rail in pine savanna habitats of the Gulf Coast of the USA. Similar to Burkman (1993), we found Yellow Rail occurrence was greatest at less than 2 years post burn, while we detected individuals in few sites at greater than 2 years post burn. Austin and Buhl (2013) reported similar results where, at a larger scale, time since fire was the most important factor explaining Yellow Rail presence during the breeding season. In addition, shorter fire return intervals in pine savanna ecosystems have been shown to influence the occur-

Table 4. Mean, standard deviation (SD), and 90% credible intervals (CRI) of landscape and habitat metrics included in the global model for Yellow Rail occupancy in pine savanna habitats of Mississippi and Alabama, USA, 2012-2013. Two asterisks (**) indicates parameter where the 95% CRI does not overlap zero. Single asterisk (*) indicates support of a moderate effect on occupancy where the 90% CRI does not overlap zero. $\hat{R}$ values for all parameter estimates were ≤ 1.02. Mean and variance of all predictor variables were standardized to improve model fit.

Parameter	Mean	SD	90% CRI
$\Psi(.)$**	14.04	4.90	(6.64, 22.72)
$\Psi(_{\text{DBH}})$	-3.22	5.66	(-11.90, 7.12)
$\Psi(_{\text{density}})$	8.30	7.21	(-2.80, 20.74)
$\Psi(_{\text{FIRE}})$*	-8.10	5.56	(-17.92, -0.08)
$\Psi(_{\text{patch size}})$	3.73	4.60	(-3.15, 11.58)
$\Psi(_{\text{woody cover}})$	-1.24	8.67	(-14.47, 13.38)
$\rho(.)$**	1.45	0.61	(0.51, 2.55)
$\rho(_{\text{density}})$	1.29	1.08	(-0.26, 3.24)
$\rho(_{\text{woody cover}})$	-0.91	1.00	(-2.46, 0.77)

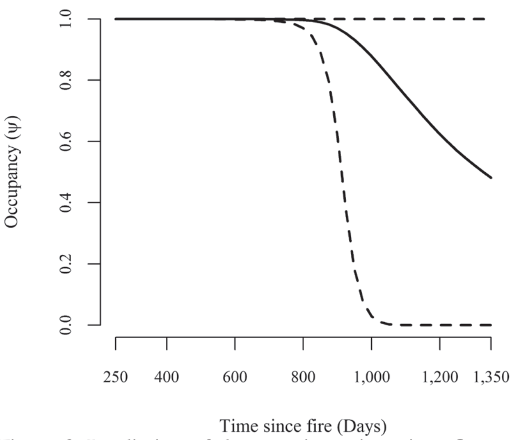

Figure 2. Prediction of the covariates time since fire as relevant to site-occupancy (solid line [with uncertainty 90% credible intervals, dashed line]) of Yellow Rail in pine savanna habitats of Mississippi and Alabama, USA, 2012-2013.

rence of other winter grassland bird species of conservation concern such as Henslow's Sparrow (*Ammodramus henslowii*) (Tucker *et al.* 2003; Bechtoldt and Stouffer 2005).

Information on the effects of habitat fragmentation and patch size on wintering bird species, including Yellow Rail, is imperative for the management of grassland habitats (Herkert *et al.* 1996). Of interest, we did not find support for patch size as a predictor of Yellow Rail occupancy during the nonbreeding season. In an evaluation of Yellow Rail breeding habitat in Michigan, USA, Austin and Buhl (2013) found landscape-level composition (measured within 300 m of survey points) was not strongly tied to Yellow Rail occupancy. Rather, Yellow Rail presence was influenced by local conditions (within 100 m of survey points), where the primary predictor of Yellow Rail presence was fire history. Within the historical wintering range of Yellow Rail in the southeastern USA, fires occurred in intervals of 1-3 years in pine savanna habitats (Frost 1995). Gonzalez-Benecke *et al.* (2015) found throughout the southeastern USA that increased fire frequency (2-4 year return interval) significantly reduced woody ground cover, but had little effect on herbaceous ground cover. They also found reduced fire frequency (> 3-year return interval) significantly increased basal area of trees throughout the study area (Gonzalez-Benecke *et al.* 2015). Thus, a more thorough exploration of the relationship between fire return intervals and Yellow Rail occupancy, both on wintering and breeding grounds, is justified.

Survey protocols for Yellow Rail on their breeding grounds incorporate the vocalization of the species for detection (Bazin and Baldwin 2007; Austin and Buhl 2013). However, anecdotal observations of wintering Yellow Rails suggest they rarely vocalize during the winter in pine savanna habitats (M. S. Woodrey, pers. commun.), observations consistent with a general pattern that temperate birds infrequently vocalize during the nonbreeding season (Fletcher *et al.* 2000). Thus, surveys targeting winter grassland bird species, such as the Yellow Rail, will require a specific method not involving the use of call-broadcast techniques.

In pine savanna habitats, fire and hydrology are two major factors controlling the distribution of vegetation and habitat structure (Noss 2013). Although we observed most study sites saturated with water at the soil level, rarely was there measureable surface water. On their wintering grounds in coastal Texas, Mizell (1998) found standing water depth was a strong determinant of Yellow Rail habitat use (mean = 1.3 cm). However, working in similar coastal prairie areas in eastern Texas, Grace *et al.* (2005) did not find a strong relationship between water depth and Yellow Rail habitat use. Yellow Rails are most often associated with a variety of emergent wetland habitats (Leston and Bookhout 2015), including pine savanna systems. Due to our inability to adequately assess hydrological conditions associated with Yellow Rail habitat use in pine savanna habitats, we suggest further research into the relationship between soil moisture and winter Yellow Rail distribution and abundance. A couple of potentially fruitful approaches could be the use of fine scale delineation of plant species according to their wetland indicator status or assessing soil moisture directly by collecting soil samples and drying them in a laboratory setting.

Fire is a key ecological process central to the restoration and management of longleaf pine systems (Platt 1999; Noss 2013). Based on evidence provided here coupled with historical fire intervals, we recommend managers target 2-year intervals to maintain habitat features attractive to wintering Yellow Rail in pine savanna habitats. Targeting a 2-year return interval would likely result in a series of burns implemented on a 3- to 4-year interval, given the vagaries of weather, the narrow environmental conditions necessary for burn permits, and required financial and personnel resources. Further, although a 2-year fire interval could provide habitats directly supporting Yellow Rail, a mosaic of habitat succession should be established to support broader longleaf pine management objectives. At the local level, managers can also reduce habitat fragmentation by combining management units and, where possible, removing unnecessary fire breaks. While fire breaks allow for the compartmentalization and control of prescribed fire, they also promote the fragmentation of habitat, disrupt hydrology and enable the spread of invasive species (Noss 2013).

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