Section 6 (Texas Traditional) Report Review

Form emailed to FWS S6 coordinator (mm/dd/yyyy): 10/17/2017

TPWD signature date on report: 8/31/2017

Project Title: Occupancy, distribution, and abundance of Black Rails (Laterallus jamaicensis) along the Texas Gulf Coast.

Final or Interim Report? Final

Grant #: TX E-162-R

Reviewer Station: Corpus Christi ESFO

Lead station concurs with the following comments: Yes

Interim Report (check one):	**Final Report (check one):**
☐ Acceptable (no comments)	☒ Acceptable (no comments)
☐ Needs revision prior to final report (see comments below)	☐ Needs revision (see comments below)
☐ Incomplete (see comments below)	☐ Incomplete (see comments below)

Comments:

FINAL PERFORMANCE REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. TX E-162-R

(F14AP00822)

Endangered and Threatened Species Conservation

Occupancy, distribution, and abundance of Black Rails (*Laterallus jamaicensis*) along the Texas Gulf Coast.

Prepared by:

Clay Green

TEXAS
PARKS &
WILDLIFE

Carter Smith
Executive Director

Clayton Wolf
Director, Wildlife

31 August 2017

FINAL REPORT

STATE: ____Texas_______________ GRANT NUMBER: ___TX E-162-R-1__

GRANT TITLE: Occupancy, distribution, and abundance of Black Rails (*Laterallus jamaicensis*) along the Texas Gulf Coast.

REPORTING PERIOD: ____1 September 2014 to 31 August 2017_

OBJECTIVE(S). Develop an effective, practical survey protocol for Black Rails to determine occupancy rates, spatial patterns in distribution, population size and habitat associations.

Segment Objectives:
Task 1. *Sept 2014 – Dec 2014:* Purchase of field equipment and supplies. Identify specific study areas through use of local site reconnaissance, satellite imagery and GIS, and available rail sighting data (e.g. rail walks at NWRs, E-Bird, biologists at NWRs and WMAs). Collect aerial photography and LiDAR elevation datasets. Advertise for field assistants for 2015 breeding surveys.

Task 2. *Jan – March 2015:* Use GIS to determine point count survey locations across all study sites. Our goal will be to survey 50-100 point counts per study site, based on study site size and habitat, for a total of >200 locations per season. Field assistants will be hired and general field methodology training will be conducted for all observers.

Task 3. *Apr – Jul 2015:* Conduct point count surveys during breeding season. We will survey >200 locations per year and individual points will be surveyed 3-4 occasions per year based on detection rates. The data will be used to evaluate the effectiveness of our call-back surveys. Acoustic recorders will continuously record biological sounds at these sites for 3-4 weeks and then moved to new location for further monitoring.

Task 4. *Aug 2015 – Feb 2016:* Conduct first breeding season analysis to generate initial estimates of detectability, occupancy, and abundance. Acoustic data will be analyzed with song/call recognition software, specifically searching for “kic-kic-kerr” call but also for growl vocalization “grr” (Eddleman et al 1994, Conway et al. 2004). A subsample of acoustic recordings will be reviewed by graduate student to estimate potential error rate from song/call recognition software. Peak calling periods will be described from the acoustic recorder results. Hire new field assistants for 2016 surveys in event we do not have returning assistants from 2015 breeding surveys. Identify and conduct reconnaissance of potential new study sites (i.e. new point counts) based on presence/absence acoustic monitoring of areas not surveyed by point count from previous season.

Task 5. *Mar – Jul 2016:* Conduct second season of point count and habitat surveys during breeding season. Surveys will be conducted using similar methodology and experimental design from 2015 breeding season. Surveys will be adjusted based on data and calling periods from the first season, and placement of survey points may be stratified based on preliminary results and observations.

Task 6. *Aug 2016 – Dec 2016:* Conduct analysis for the two breeding seasons. Analyze habitat factors that influence occupancy and abundance of Black Rails.

Task 7. *Jan – Aug 2017:* Continue habitat analyses, develop species distribution model from Black Rail survey data (Task 3 and 5), broad-scale GIS spatial data (Task 4), and statistical analyses (Task 6). Write final report, thesis, and prepare manuscripts for publication submission.
Significant Deviations:

None.

Summary Of Progress:

Please see Attachment A.

Location: Study sites include McFaddin, Brazoria, Anahuac and San Bernard National Wildlife Refuges, Mad Island Preserve (TNC) and Mad Island, Matagorda and Justin Hurst WMAs of the Texas coast.

Cost: ___Costs were not available at time of this report, they will be available upon completion of the Final Report and conclusion of the project.__

Prepared by: _Craig Farquhar_____________ Date: _31 August 2017

Approved by: ________________________________ Date:_____31 August 2017_
C. Craig Farquhar

Final Report

Occupancy, distribution, and abundance of Black Rails (*Laterallus jamaicensis*) along the Texas Gulf Coast.

Prepared by:

James D. M. Tolliver

Principle Investigator: Dr. M. Clay Green, Professor, Department of Biology, 601 University Drive, Texas State University, San Marcos, Texas 78666. E-mail: claygreen@txstate.edu; Phone: 512-245-8037

Co-Principle Investigator: Dr. Floyd (Butch) Weckerly, Professor, Department of Biology, 601 University Drive, Texas State University, San Marcos, Texas. E-mail: fw11@txstate.edu; Phone: 512-245-3353

Research Collaborator: Amanda A. Moore

Abstract

Eastern black rails (*Laterallus jamaicensis jamaicensis*) are a subspecies of conservation concern. These birds vocalize infrequently and inhabit dense vegetation making them difficult to detect. We conducted the first large scale study of black rail occupancy and abundance in Texas. We conducted repeat point count surveys at 308 points spread across six study sites from mid-March to late-May in 2015 and 2016. Each point count survey was a 6-minute call-playback broadcast where birds were detected acoustically. Our study sites were located at Anahuac, Brazoria, and San Bernard National Wildlife Refuges, Mad Island Wildlife Management Area, Clive Runnel's Mad Island Marsh Preserve, and Powderhorn Ranch Preserve. We estimated the fit of 19 occupancy and 19 abundance models that also accounted for imperfect detection. Occupancy and abundance increased with woody, *Spartina*, non-*Spartina* herbaceous, and intermediate marsh cover. Black rail occupancy and abundance estimates were similar between years. From the estimated detection probabilities, we determined that ~16 repeated surveys could establish black rail presence at survey points. We found that the total area occupied by black rails and total number of rails between sites were similar. However, there was an insignificant decline from north east to south west. We reached two main conclusions. One, black rail management during the breeding season, in Texas, should focus on *Spartina* cover as occupancy and abundance estimates were highest when *Spartina* cover was high. Two, effort to establish black rail presence from naïve occupancy estimates is impractical. Monitoring efforts of black rails should design studies that estimate distribution and abundance while accounting for imperfect detection.

Introduction

Knowledge of a species' distribution and abundance forms the bedrock for any species conservation effort. Distribution, or occupancy, is the extent of area inhabited by populations. Abundance is the number of individuals in a population. Knowledge of a species' distribution provides a spatial reference for survey efforts and management actions. Estimating abundance is needed to monitor population trends over time. Both state variables, occupancy and abundance, are used to set conservation goals and establish conservation status of a species. Therefore, reliable estimates of occupancy and abundance are vital to the conservation of a species (Kéry et al. 2005, MacKenzie et al. 2006, Hunt et al. 2012, Veech et al. 2016). Species behavior and habitat often influence the reliability of occupancy and abundance estimates (Royle 2004, Kéry et al. 2005, MacKenzie et al. 2006, Hunt et al. 2012, Veech et al. 2016). Detection of individuals or a species is rarely 100% (MacKenzie et al. 2002, Royle 2004, MacKenzie et al. 2006, Veech et al. 2016). For example, abundance and occupancy estimates of cryptic species, those species that allude detection, tend to be biased low. Therefore, techniques that account for imperfect detection are needed to obtain less biased estimates of occupancy and abundance.

Conceptually, population estimation can be expressed by the following formula:

$$\widehat{N} = \frac{C}{\hat{p}} \qquad 1$$

where $\widehat{N}$ is the estimated abundance, C is the number of individuals counted, and $\hat{p}$ is the estimated probability of detecting an individual when it is available to be detected in a survey area (Nichols 1992). Correcting for detectability is often difficult (Royle 2004, MacKenzie et al. 2006), nonetheless, numerous estimators have been developed to estimate $\hat{p}$. Royle (2004) discussed the impracticalities and the inadequacies of some of these techniques, such as mark-recapture estimates of $\hat{p}$ and subjective selection of $\hat{p}$. He argued that mark-recapture is not feasible on a large scale and that arbitrary selection of $\hat{p}$ can yield unrealistic abundance estimates.

Counts obtained from systematic surveys are often used as indices for abundances. Indices are useful approximations of abundance when surveys represent a constant proportion of the actual population size (Johnson 1995, White 2005, Weckerly 2007). Yet, the assumption of constant proportionality is rarely met (Nichols 1992, Johnson 1995, Anderson 2001, Royle 2004, Weckerly 2007) because detection of individuals can vary spatially and temporally (Royle et al. 2005, Veech et al. 2016). Such variation in detections may result in counts that misrepresent true variation in population abundance. Johnson (2008) relaxed the condition of constant proportionality and showed that as long as the variation in detectability was less than the variation in counts, indices capture abundance dynamics correctly. Detection of cryptic species, however, is low and probably varies with a variety of environmental factors (Legare et al. 1999, MacKenzie et al. 2002, Conway and Gibbs 2005, MacKenzie et al. 2006, Conway 2011). Therefore, variation in counts may not actually capture variation in abundance (Nichols 1992, MacKenzie and Kendall 2002, Royle 2004, MacKenzie et al. 2006, Hunt et al. 2012).

Difficulties in estimating abundance due to variation in detection has led researchers to use occupancy as a surrogate for abundance (MacKenzie et al. 2002, MacKenzie et al. 2006). MacKenzie et al. (2002) developed a method for modeling occupancy in a closed population that incorporates detection probability. A closed population is one in which there is no dispersal of individuals in or out of the survey area during the time surveys are conducted. Presence and non-detection data, from repeated surveys, of spatially referenced survey points is needed to estimate detection probability and occupancy based on covariates that could affect either detection or occupancy. MacKenzie et al. (2006) further expanded the model to incorporate changes in occupancy over time. These multi-season models could also include covariates that influence the decrease or increase in occupancy.

Much like occupancy models, *N*-mixture models use count data from repeated surveys of spatially referenced survey points and covariates to estimate abundance and detection probability (Royle 2004, Kéry et al. 2005, Hunt et al. 2012, Veech et al. 2016). *N*-mixture models use statistical distributions such as the Poisson, zero-inflated Poisson and negative binomial distributions to estimate abundance and the binomial distribution to estimate detection probabilities (Royle 2004, Kéry et al. 2005, Veech et al. 2016). Like multi-season occupancy estimation, *N*-mixture models can also accommodate temporal changes in abundance via parameters estimating recruitment and apparent survival (Dail and Madsen 2011, Hostetler and Chandler 2015).

Black rails (*Laterallus jamaicensis*) represent a model species for the use of occupancy and *N*-mixture models. These rails are small (~15 cm total length), secretive marsh birds found in North, Central, and South America as well as the Caribbean Islands (Taylor 1998). In North America there are two subspecies: the California black rail (*L. j. courturnicops*) and the eastern black rail (*L. j. jamaicensis*) (Eddleman et al. 1988, Taylor 1998). Eastern black rails occur in coastal marshes along the Gulf and Atlantic states (Eddleman et al. 1988, Eddleman et al. 1994, Taylor 1998). There are some interior populations which breed inland in the Midwest and Appalachian states (Eddleman et al. 1988, Eddleman et al. 1994, Taylor 1998, Butler et al. 2015). Although the California black rail has been studied (Evens et al. 1991, Evans and Nur 2002, Spautz et al. 2005, Richmond et al. 2008, Risk et al. 2011), the eastern subspecies has received less attention. Some studies have been conducted in Florida and along the Atlantic seaboard yet there has been little work on estimating distribution and abundance of black rails along the Texas coast (Legare et al. 1999, Watts 2016).

The eastern black rail subspecies is in review for listing under the Endangered Species Act. This status assessment was instigated because populations are perceived as declining throughout the eastern and southeastern United States (Watts 2016). With eastern black rails under probable decline in the Atlantic states, it is important to assess the status of black rails in Texas. Texas populations have not been monitored at a large scale and baseline occupancy and abundance data are rare (except see Butler et al. 2015).

A majority of Rallidae, or rails, are secretive because these birds inhabit and conceal themselves in densely vegetated habitats and their vocalizations are infrequent (Eddleman et al. 1988, Taylor 1998). Additionally, rails generally dwell on the ground, run to escape danger rather than fly, and rarely perch on vegetation (Taylor 1998, Sibley 2000). The escape behavior, infrequent calling, and concealment in dense habitats makes detection of rails challenging. Eastern black rails are no exception to the overall character of this taxa. They inhabit marshes and wet prairies containing dense stands of cordgrasses (*Spartina* spp.), sea oxeye daisy (*Borrichia frutescens*), and glassworts (*Salicornia* spp.) (Legare et al. 1999, Butler et al. 2015). In addition, their calling rate is relative low. Legare et al. (1999) reported that radio tagged females and males called a maximum of 20% and 50% of the time, respectively, during surveys conducted in the breeding season. Given this information, perhaps it is unsurprising that Butler et al. (2015) estimated a maximum detection probability of 0.16. The prevailing evidence indicates that eastern black rails are difficult to detect by sight or sound.

To elicit black rails, and rails in general, to call, broadcast surveys of vocalizations are used to increase detection (Legare et al. 1999, Spear et al. 1999, Conway et al. 2004, Conway 2011, Butler et al. 2015). Most often, call-playback broadcast surveys (hereafter call surveys) are conducted at points systematically placed across the landscape (Evens et al. 1991, Evans and Nur 2002, Spautz et al. 2005, Richmond et al. 2008, Richmond et al. 2010). Black rail surveys are also generally conducted at night or during the morning and evening (Evans et al. 1991, Legare et al. 1999, Evans and Nur 2002, Spautz et al. 2005, Butler et al. 2015). During these times, black rails are considered to call most frequently and hence most likely to respond to a played call.

Our overarching goals were to estimate eastern black rail habitat associations, distribution, and abundance while accounting for factors affecting detection along the Texas coast. To our knowledge, Butler et al. (2015) is the only study to estimate eastern black rail detection and occupancy in Texas and they did not integrate their detection models with their occupancy models. Additionally, this is the first study to estimate black rail abundance with *N*-mixture models in Texas. We conducted repeated call broadcast surveys at six study sites along the Texas coast. Also, we measured a set of covariates we thought would influence black rail detection, occupancy, and abundance.

Objectives

Our specific objectives were to: (1) determine influential covariates affecting detection of the eastern black rail; (2) determine habitat covariates that were related to black rail occupancy and abundance; (3) develop a monitoring protocol to estimate black rail occupancy and abundance.

Location

The 6 sites were at Anahuac National Wildlife Refuge (NWR) in Chambers County, Brazoria NWR in Brazoria County, San Bernard NWR in Brazoria and Matagorda Counties, Mad Island Wildlife Management Area and Clive Runnells Family Mad Island Marsh Preserve (Mad Island Marsh) in Matagorda County, and Powderhorn Ranch Preserve in Calhoun County (Fig. 1). These sites represent a diversity of land ownership from federally owned NWRs to non-governmentally owned Mad Island Marsh and Powderhorn Ranch.

Anahuac NWR (Fig. 2) is transected by bayous running north and south which are flanked by thickets, rice fields, freshwater marshes, moist-soil units, and bluestem prairies in the north. The freshwater marshes and prairies give way to brackish and salt marshes. Finally, the marshes are replaced by estuaries and the Intracoastal Waterway at the refuge's southern extent. The 13,759 ha of Anahuac NWR receive ~145 cm of precipitation per year with the greatest precipitation events occurring in the summer (Baker et al. 1994). Temperatures can exceed 32˚C in the summer and be lower than 6˚C in the winter (Baker et al. 1994).

Brazoria NWR (Fig. 3) has 17,973 ha of bluestem uplands, freshwater, brackish, and salt marshes in addition to ponds and woody thickets. The bluestem uplands of Brazoria NWR are intermixed with the woody thickets and freshwater, brackish, and salt marshes throughout the northern extent of the refuge. Brackish and salt marshes dominate the southern part of the refuge and recede inland from the estuaries and bays at the southern and southeastern boarders of the refuge. Where Brazoria NWR is a contiguous refuge, the 21,853 ha of San Bernard NWR (Fig. 4) are spread across Brazoria and Matagorda counties. San Bernard contains, north to south, Columbia hardwoods, cypress swamps, freshwater, brackish, and salt marshes. Freshwater marshes, lakes, Gulf Coastal Prairies, and invasive monocultures make up the remainder of San

Bernard NWR. The greatest precipitation events at San Bernard and Brazoria NWRs occur in autumn (Baker et al. 1994). These refuges receive < 127 cm of precipitation each year and seasonal changes are evident from summer highs in the 30s˚C and winter lows in the 10s˚C (Baker et al. 1994).

Mad Island Wildlife Management Area (Fig. 5) consists of 2,913 ha of brushy and coastal prairie uplands that are protected from coastal flooding by salt and freshwater marshes. Mad Island Marsh, which borders Mad Island Wildlife Management Area to the west, is made up of 2,858 ha of fresh and saltmarshes and by bushy thickets and inland tallgrass prairie. The Mad Islands receive ~ 114 cm of annual precipitation (Baker et al. 1994). Precipitation events are highest in autumn with temperatures reaching 31˚C in the summer and lows of ~5˚C in the winter (Baker et al. 1994).

Powderhorn Ranch (Fig. 6) comprises 6,981 ha of scrub woodlands, virgin coastal live oak (*Quercus agrifolia*) forests, and bluestem grasslands. Additionally, the preserve has extensive saltmarshes around Powderhorn Lake's periphery and bayou fed freshwater wetlands interspersed throughout the property. Annual precipitation at the Ranch is 106 cm (Baker et al. 1994). Summer temperatures reach up to 33˚C and winter temperatures are as low as 7˚C (Baker et al. 1994).

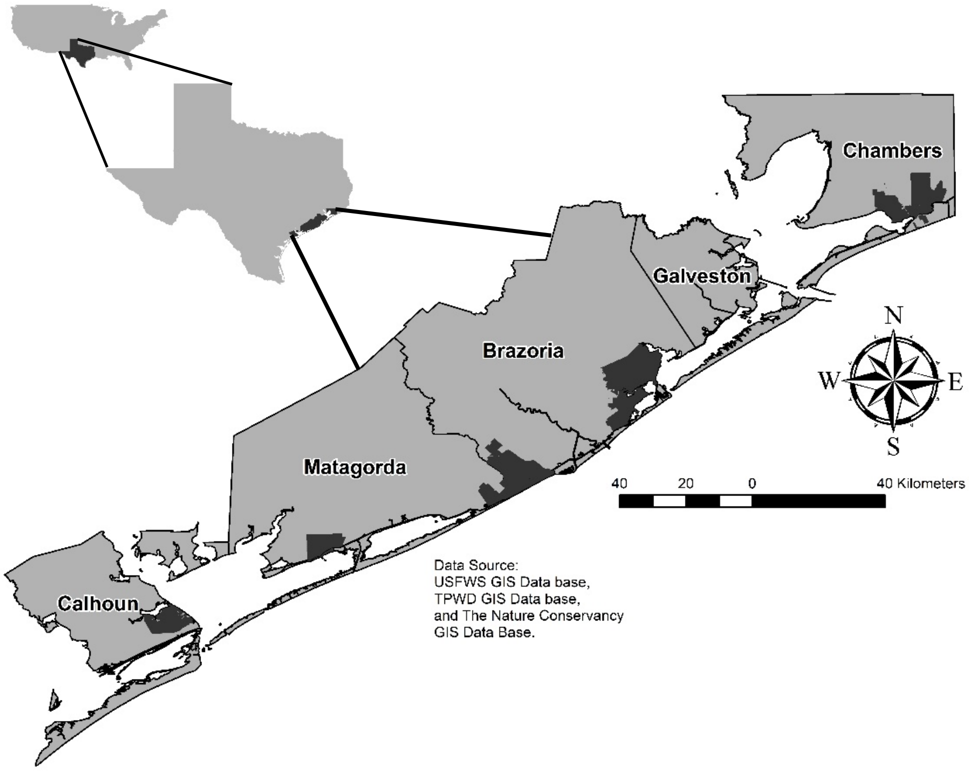


Figure 1. Black rail (*Laterallus jamaicensis*) study sites. Shown are the 6 study sites surveyed for black rails with point count stations from mid-March to the end of May (2015 and 2016). Dark gray indicates areas selected for study and light gray indicates contextual area. From northeast to southwest are Anahuac National Wildlife Refuge (NWR), Brazoria NWR, San Bernard NWR, Mad Island Wildlife Management Area and Clive Runnells Family Mad Island Marsh Preserve (shown in the same polygon), and Powderhorn Ranch Preserve.

Methods

Task 1. Sept 2014 – Dec 2014: Purchase of field equipment and supplies. Identify specific study areas through use of local site reconnaissance, satellite imagery and GIS, and available rail sighting data (e.g. railwalks at NWRs, E-Bird, biologists at NWRs and WMAs). Collect aerial photography and LiDAR elevation datasets. Advertise for field assistants for 2015 breeding surveys.

Task 2. Jan – March 2015: Use GIS to determine point count survey locations across all study sites. Point counts will be spaced ≥ 200 m based on prior detection estimates, published home ranges (Legare and Eddleman 2001), and environmental gradients; current recommendation on U.S. east coast Black Rail surveys is 400 m spacing (Black Rail Working Group). We will survey from at least 3 study sites along the Upper and Middle Texas Coast. Our goal will be to survey 50-100 point counts per study site, based on study site size and habitat, for a total of >200 locations per season. Field assistants will be hired and general field methodology training will be conducted for all observers.

Task 3. Apr – Jul 2015: Conduct point count surveys during breeding season. Transects of surveys points will allow an individual observer to conducted ~12 surveys per morning or evening. Surveys will be conducted 1.5 hr before sunrise to 2.5 hr after sunrise. Evening surveys will be considered as Black Rails have been detected during evening surveys in Texas (Brent Ortego, TPWD, pers. comm.; Jennifer Wilson, USFWS, pers. comm.), but high winds often make this difficult (Conway et al. 2004). Surveys will consist of a 6-minute sampling period: 3-minute passive monitoring and 3-minute broadcast call (Conway et al. 2004). Black Rail calls will be broadcasted on 90 decibel speakers for 30 seconds followed by 30 seconds of silence. We will survey >200 locations per year and individual points will be surveyed 3-4 occasions per year based on detection rates. Estimates of vegetation composition and coverage (~100 m radius) around each survey point will be collected. Acoustic recorders will be placed at known Black Rail locations to continuously monitor rail calling periods. The data will be used to evaluate the effectiveness of our call-back surveys. Acoustic recorders will continuously record biological sounds at these sites for 3-4 weeks and then moved to new location for further monitoring.

Task 4. Aug 2015 – Feb 2016: Conduct first breeding season analysis to generate initial estimates of detectability, occupancy, and abundance. Acoustic data will be analyzed with song/call recognition software, specifically searching for "kic-kic-kerr" call but also for growl vocalization "grr" (Eddleman et al. 1994, Conway et al. 2004). A subsample of acoustic recordings will be reviewed by graduate student to estimate potential error rate from song/call recognition software. Peak calling periods will be described from the acoustic recorder results. For the species distribution model, we will identify and develop a variety of spatially explicit broad-scale habitat characterizations hypothesized to influence black rail occupancy. Potential predictors include mean precipitation (WorldClim GIS layer: <http://worldclim.org/current>), distance to coast or bay, LiDAR elevation (TNRIS GIS layer: http://www.tnris.org/elevation/), elevation heterogeneity, and topographic wetness indices. Satellite imagery will be used as needed to create spatially explicit habitat predictors as relevant variables are discovered from field research. For example, vegetation classifications may be useful (e.g., *Spartina patens* dominated areas), open water, and various indices (e.g., Normalized Difference Vegetation Index, wetness index) could be used. In this way, GIS layers may be developed specifically for black rail habitat. Hire new field assistants for 2016 surveys in event we do not have returning assistants from 2015 breeding surveys. Identify and conduct reconnaissance of potential new study sites (i.e. new point counts) based on presence/absence acoustic monitoring of areas not surveyed by point count from previous season.

Task 5. Mar – Jul 2016: Conduct second season of point count and habitat surveys during breeding season. Surveys will be conducted using similar methodology and experimental design from 2015 breeding season. Surveys will be adjusted based on data and calling periods from the first season, and placement of survey points may be stratified based on preliminary results and observations.

Task 6. Aug 2016 – Dec 2016: Conduct analysis for the two breeding seasons. Analyze habitat factors that influence occupancy and abundance of Black Rails.

Task 7. Jan – Aug 2017: Continue habitat analyses, develop species distribution model from Black Rail survey data (Task 3 and 5), broad-scale GIS spatial data (Task 4), and statistical analyses (Task 6). Write final report, thesis, and prepare manuscripts for publication submission.

Results

Task 1. Field equipment and supplies were purchased in the spring of 2015 with some equipment bought throughout the summer and into the fall of 2015 and 2016. The 6 study sites of Anahuac NWR, Brazoria NWR, San Bernard NWR, Mad Island Wildlife Management Area, Mad Island Marsh, and Powderhorn Ranch Preserve were chosen for our field sites as these represented a precipitation and habitat gradient we thought might be correlated with black rail distribution and abundance. Anahuac in the north east had the highest precipitation and likeliest black rail habitat while Powderhorn in the south west had the lowest precipitation and least amount of black rail habitat. The Texas Parks and Wildlife's habitat inventory images were used to select monitoring locations based on possible black rail habitat. We obtained satellite images of all of the study sites in October 2015. Field assistants were hired for the 2015 field season.

Task 2. For ease of access surveys were conducted along roads, levees, and fire breaks that permeated presumed black rail habitat. We established 375 point count stations across the six study sites, with 105 points at Anahuac NWR, 80 points at Brazoria NWR, 65 points at San

Bernard NWR, 84 points at Mad Island Wildlife Management Area and Mad Island Marsh, and 41 points at Powderhorn Ranch. Point count stations were established with the following stratified random approach. Points were plotted 400 meters apart in ArcGIS (Environmental Systems Research Institute, Inc., Redlands, CA) along all roads, levees, and fire breaks at each study sites. All Field technicians had 1 – 3 days of training before surveys were conducted.

Tasks 3 and 5. There were 3,425 call playback surveys conducted and vegetation was sampled at 308 points from mid-March to the end of May, 2015 and 2016 (Figs. 2 – 6). Vegetation was not sampled or surveys were not conducted at 67 points (included in Figs. 2 – 6 but excluded from data analysis) in 2015 because of flooding of roads and other logistical constraints. There was a mean of 11.12 surveys per point count station over both years—with a minimum of three and a maximum of eight surveys per year. Over the two years we had a total of 190 detections of one or more black rails (hereafter species detection) at 92 survey points. We had a total of 239 individual black rail detections with 151 detections of one rail per survey, 32 detections of two rails per station, five detections of three rails per survey, one detection of four rails per survey, and one detection of five rails per survey.

Task 4. Initial breeding season estimates (estimations made with data only from the 2015 breeding season). Mean detectability (probability of detecting at least one bird) was estimated at 0.26 (SE=0.04) and varied with lunar phase, wind speed, and temperature. Mean occupancy was estimated at 0.22 (SE=0.06) and was mostly influenced by herbaceous and *Spartina* spp. percent cover.

We considered the following GIS layers for influences on black rail occupancy and abundance: Normalized Difference Vegetation Index, Modified Difference Water Index, and percent cover Intermediate Marsh and Open Water (Enwright et al. 2015) at each study site. Only intermediate marsh and open water cover influenced black rail occupancy. These site level influences were incorporated into the occupancy and abundance analysis.

Task 6. A global occupancy model (containing all measured habitat covariates) appeared to fit the data (χ^2 = 2780.443, P = 0.141) and had low over-dispersion ($\hat{C}$ = 1.19). Likewise a global abundance model fit the data (χ^2 = 3,769.3, P = 0.077) and had little over-dispersion ($\hat{C}$ = 1.06). We selected a point-level and site-level models (mixed-level) where occupancy and abundance were influenced by herbaceous, *Spartina*, woody, and intermediate marsh cover (Tables 1 and 5). We choose this model (Table 1) for black rail occupancy because it had the lowest AIC_C (Akaike Information Criterion corrected for small sample size) by > 3.00 ΔAIC_C units (Burnham and Anderson 2002, Tolliver 2017). We selected the simpler mixed-level abundance model because the additional parameters in the global model seemed to have little influence (P > 0.15, Arnold [2010]; Table 5). The selected occupancy and abundance models had estimated Nagelkerke's R^2's of 0.30 and 0.32, respectively.

Black rail occupancy increased with herbaceous (min = 0%; max = 97.5%), *Spartina* (min = 2.5%; max = 97.5%), and woody (min = 2.5%; max = 97.5%) cover, at the point-level (Figs. 7 and 9 [a, b, d], Tables 3 and 5) and intermediate marsh at the site-level (Fig. 7c). The highest estimated occupancy (> 70%) and abundance (> 2.5 rails/point) were associated with survey points having > 90% *Spartina* cover (Figs. 7 and 8).

Mean occupancy was similar between 2015 ($\bar{\psi}$ = 0.27, SE = 0.03) and 2016 ($\bar{\psi}$ = 0.27, SE = 0.04). Yet, there was some colonization of survey points in 2016. Mean colonization was 0.12 (SE = 0.04), however, no extinction was detected (Table 1). Burned/unburned points between 2015 and 2016 survey seasons did not appear to influence mean black rail colonization of survey points (Table 1). Mean species probability of detection was 0.18 (SE = 0.02).

Mean occupancy per site was similar between all study sites except Powderhorn Ranch and Anahuac NWR (Table 2). Anahuac had a higher occupancy rate than Powderhorn Ranch in 2015 and overlapped the 95% confidence interval of Powder Ranch in 2016. Although Powderhorn Ranch did overlap confidence intervals with the Mad Islands in 2015 it also overlapped zero (Table 2). In 2016 all occupancy estimates per site were similar (within each other's 95% confidence bounds). Total occupied area was estimated by multiplying each study site's area by the estimated occupancy rate. Anahuac, Brazoria, and San Bernard National Wildlife Refuges had a similar estimated area occupied by black rails and more area occupied than the Mad Islands and Powderhorn Ranch. While estimated occupied area was similar between the Mad Islands and Powderhorn Ranch in both years, in 2015 Powderhorn Ranch's occupied area was not different from zero (Table 2).

Mean abundance insignificantly declined between 2015 (0.96 rails/point; 95% credible interval [CI] = 0.28 – 3.13) and 2016 (0.91 rails/point; CI = 0.28 – 2.45). Mean recruitment was 0.21 rails/points (SE = 0.08) in unburned areas but 7.19 rails/point (SE = 2.73) in areas burned between 2015 and 2016. The apparent survival rate was 0.43 rails/point (SE = 0.11). The negative-binomial dispersion parameter did not differ from zero ($\hat{\alpha}$ = 0.073; SE = 0.420). Mean individual detection was 0.07 (SE = 0.02).

Mean abundance was similar between all sites though mean estimates declined from Anahuac NWR to Powderhorn Ranch (Table 2). Total abundance was estimated with the following formula:

$$\frac{\bar{\lambda}}{12.56}(\bar{\psi}A) \qquad 2$$

Where $\bar{\lambda}$ is the mean abundance per point per site, 12.56 = area (ha) of a circle with a radius of 200 m, $\bar{\psi}$ is the mean occupancy, and A the contiguous area (ha) of each study site. Total abundance at each site was similar in 2016 yet there were more total rails at Anahuac NWR than Powderhorn Ranch in 2015. Though Powderhorn Ranch estimates were similar to other sites they were not significantly different from zero.

Assuming mean values for covariates (detection: wind = 6 – 10 km/hr, lunar phase = half-moon [7.8], average survey temperature = 23.25 ˚C; occupancy: herbaceous = 38.44%, *Spartina* = 35.58%, woody = 26.31%, intermediate marsh = 42.02%) and a survey point was occupied by ≥1 black rail, the survey effort or number of surveys required to have a 0.95 probability of detecting the species was 16 (Fig. 8).

Task 7. James Tolliver wrote and successfully defended (3-April-17) his thesis from this project entitled “Eastern black rail (*Laterallus jamaicensis jamaicensis*) occupancy and abundance estimates along the Texas coast with implications for survey protocols.” A publication was prepared and submitted to the peer-reviewed *Journal of Wildlife Management* entitled “Occupancy and abundance estimates for black rails with implications for survey protocols along the Texas coast” on 4-July-2017. Acoustic sampling data and the species distribution model are still in the analysis and development stage (Significant Deviations).

Table 1. Model selection summary of 19 models estimating multi-seasonal occupancy of black rail (*Laterallus jamaicensis*). Included in the table are model parameters (Model), number of parameters estimated (*K*), the difference between the top ranked model's AIC$_C$ and a model's AIC$_C$ (ΔAIC$_C$), deviance (deviance), and the estimated Nagelkerke's R^2 (R^2) for the top five models. The remaining models are given in descending ΔAIC$_C$ order in the footnote. Primary periods were 2015 and 2016 and secondary periods were three to eight repeated call broadcast surveys from March to May (2015 and 2016). Included in models were combinations of multiscale occupancy ($\hat{\psi}$) covariates (point-level and site-level), an influence of burning on colonization ($\hat{\gamma}$), constant extinction ($\hat{\varepsilon}$), and detection probability ($\hat{p}$) influences. Point-level covariates were: percent cover of non-*Spartina* herbaceous spp. (herb.), *Spartina* spp. (*spartina*), and woody species (woody); and if points were grazed (grazed). Site-level covariates were percent cover of intermediate marsh (INTM) and open water. Colonization was influenced by a binomial covariate where unburned was the reference category. Detection probability influences were wind speed (wind), lunar phase (lunar), and average survey temperature (temp.).

Model	*K*	ΔAICc	Deviance	R^2
$\hat{\psi}$(herb. + spartina + woody + INTM), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar)	12	0.00	1155.14	0.30
$\hat{\psi}$(herb. + spartina + woody + graze + INTM + open water), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar)	14	3.02	1152.65	0.30
$\hat{\psi}$(herb. + spartina + INTM), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar)	11	3.38	1161.17	0.28
$\hat{\psi}$(herb. + spartina), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar)	10	7.95	1168.33	0.27
$\hat{\psi}$(spartina + INTM), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar)	10	7.96	1168.34	0.27

[a] $\hat{\boldsymbol{\psi}}$(spartina + woody + INTM),$\hat{\gamma}$(burned),$\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(herb. + spartina + woody + graze), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.),$\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(spartina + woody + graze + INTM + open water),$\hat{\gamma}$(burned), $\hat{\varepsilon}$(.),$\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(spartina), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.),$\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(herb. + woody + graze + INTM + open water), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.),$\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(herb. + Spartina + INTM),$\hat{\gamma}$(burned), $\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(INTM + open water),$\hat{\gamma}$(burned), $\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(INTM), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.),$\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(open water),$\hat{\gamma}$(burned), $\hat{\varepsilon}$(.),$\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(herb.), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.),$\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(woody),$\hat{\gamma}$(burned), $\hat{\varepsilon}$(.),$\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(.), $\hat{\gamma}$(burned), $\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar); $\hat{\boldsymbol{\psi}}$(graze),$\hat{\gamma}$(burned), $\hat{\varepsilon}$(.), $\hat{p}$(wind + temp. + lunar), $\hat{\boldsymbol{\psi}}$(.), $\hat{\gamma}$(.), $\hat{\varepsilon}$(.), $\hat{p}$(.).

Table 2. Estimated occupancy and abundance for the six study sites surveyed for black rails (*Laterallus jamaicensis*) from mid-March to the end of May (2015 – 2016). Included in the table are the field sites where surveys were conducted (Field Site), the number of points at each field site (*n*), mean occupancy of black rails at each study site, mean abundance of black rails at each study site, the estimated area that black rails occupied at each study site (Estimated Occupied Area), and the estimated total abundance of black rails at each study site (Estimated abundance). Estimates are given for both 2015 and 2016 with 95% confidence intervals in parentheses. Total number of hectares occupied and total number of black rails over the six study sites are given at the bottom of the table.

Field Site	*n*	Mean Occupancy		Mean Abundance (rails/point)		Estimated Occupied Area (hectares)		Estimated Abundance (number of rails)	
		2015	2016	2015	2016	2015	2016	2015	2016
Anahuac NWR	86	0.40 (0.33 – 0.46)	0.31 (0.24 – 0.39)	1.66 (0.50 – 4.77)	1.30 (0.38 – 3.38)	5,476 (4,591 – 6,360)	4,289 (3,252 – 5,325)	724 (183 – 2,414)	443 (99 – 1,434)
Brazoria NWR	67	0.31 (0.25 – 0.46)	0.28 (0.21 – 0.36)	1.09 (0.27 – 3.61)	0.64 (0.22 – 1.95)	5,651 (4,497 – 6,807)	5,140 (3,786 – 6,493)	489 (96 – 1,957)	260 (67 – 1,867)
San Bernard NWR	63	0.26 (0.19 – 0.32)	0.33 (0.25 – 0.40)	0.79 (0.25 – 2.79)	1.17 (0.44 – 2.84)	4,339 (3,264 – 5,413)	5,514 (4,254 – 6,774)	272 (66 – 1,204)	516 (150 – 1,532)
Mad Island WMA and Mad Island Marsh Preserve	58	0.19 (0.12 – 0.25)	0.25 (0.17 – 0.32)	0.45 (0.16 – 1.84)	0.64 (0.17 – 2.03)	1,081 (710 – 1,452)	1,422 (988 – 1,857)	39 (9 – 213)	55 (13 – 301)
Powderhorn Ranch Preserve	34	0.03 (- 0.04 – 0.09)	0.10 (0.02 – 0.17)	0.11 (0.00 – 0.85)	0.46 (0.00 – 1.88)	178 (- 271 – 626)	690 (164 – 1,216)	2 (0 – 42)	25 (0 – 182)
					Total:	16,725 (12,791 – 20,658)	17,055 (12,444 – 21,665)	1,526 (354 – 5,830)	1,299 (329 – 5,316)

Table 3. Parameter estimates of the selected multi-season occupancy model for black rails (*Laterallus jamaicensis*) on the Texas coast. Primary periods were 2015 and 2016 and secondary periods were three to eight repeated call broadcast surveys from March to May (2015 and 2016). Included in the model were multiscale occupancy ($\hat{\psi}$) covariates (point-level and site-level), an influence on colonization ($\hat{\gamma}$), constant extinction ($\hat{\varepsilon}$), and influences on detection probability ($\hat{p}$). Point-level covariates were: percent cover of non-*Spartina* herbaceous spp. (herb.), *Spartina* spp. (*spartina*), and woody species (woody) and a site level covariate: percent cover of intermediate marsh (INTM). Colonization was modeled to influence immigration by a binomial covariate with unburned as the reference category. Detection probability influences were wind speed (wind), lunar phase (lunar), and average survey temperature (temp.). Intercept coefficients are denoted by b0.

Parameter	Estimate	SE	*P*
$\hat{\psi}_{\text{b0}}$	- 1.596	0.284	< 0.001
$\hat{\psi}_{\text{herb.}}$	1.656	0.560	0.003
$\hat{\psi}_{spartina}$	2.795	0.608	< 0.001
$\hat{\psi}_{\text{woody}}$	0.696	0.282	0.014
$\hat{\psi}_{\text{INTM marsh}}$	0.695	0.235	0.003
$\hat{\gamma}_{\text{b0}}$	- 1.952	0.321	< 0.001
$\hat{\gamma}_{\text{burned}}$	0.949	0.646	0.141
$\hat{\varepsilon}_{\text{b0}}$	- 0.450	0.385	0.242
$\hat{p}_{\text{b0}}$	- 1.514	0.120	< 0.001
$\hat{p}_{\text{wind}}$	- 0.439	0.105	< 0.001
$\hat{p}_{\text{temp.}}$	0.181	0.094	0.054
$\hat{p}_{\text{lunar}}$	0.338	0.095	< 0.001

Table 4. Model selection analysis of 19 candidate models for open *N*-mixture models of black rail (*Laterallus jamaicensis*) abundance. Primary periods were 2015 and 2016 and secondary periods were three to eight repeated call broadcast surveys from March to May (2015 and 2016). Included were combinations of multiscale abundance ($\hat{\lambda}$) covariates (point-level and site-level), an influence from burning on recruitment ($\hat{\gamma}$), constant apparent survival ($\hat{w}$), and influences on individual detection probability ($\hat{r}$). Point-level covariates were: percent cover of non-*Spartina* herbaceous species (herb.), *Spartina* species (*spartina*), and woody species (woody); and if points were grazed (grazed). Site-level covariates were percent cover of intermediate marsh (INTM) and open water. Recruitment was influenced by a binomial covariate where unburned was the reference category. Influences on $\hat{r}$ were wind speed (wind), lunar phase (lunar), average survey temperature (temp.), and ambient noise (noise). The negative binomial distribution was used to estimate abundance. Included in the table are model parameters (Model), number of parameters (*K*), the difference between the top ranked model AIC and model$_i$'s AIC (ΔAIC), model deviance, and Nagelkerke's R^2 (R^2). The top five models with the smallest ΔAIC are given in the table with the remaining models presented in descending ΔAIC order in the footnote.

Model	*K*	ΔAIC	Deviance	R^2
$\hat{\lambda}$(herb. + spartina + woody + graze + INTM + open water), $\hat{\gamma}$(burned), $\hat{w}$(.), $\hat{r}$(wind + temp. + lunar + noise), $\hat{\alpha}$	16	0.00	1,460.41	0.33
$\hat{\lambda}$(herb. + spartina + woody + INTM), $\hat{\gamma}$(burned), $\hat{w}$(.), $\hat{r}$(wind + temp. + lunar + noise), $\hat{\alpha}$	14	1.22	1,465.63	0.32
$\hat{\lambda}$(herb. + spartina + INTM), $\hat{\gamma}$(burned), $\hat{w}$(.), $\hat{r}$(wind + temp. + lunar + noise) $\hat{\alpha}$	13	2.95	1,469.36	0.31
$\hat{\lambda}$(spartina + woody + graze + INTM + open water), $\hat{\gamma}$(burned), $\hat{w}$(.), $\hat{r}$(wind + temp. + lunar + noise) $\hat{\alpha}$	15	5.19	1,467.60	0.32
$\hat{\lambda}$(spartina + INTM), $\hat{\gamma}$(burned), $\hat{w}$(.), $\hat{r}$(wind + temp. + lunar + noise) $\hat{\alpha}$	12	7.46	1,475.86	0.30

[a] $\hat{\lambda}$(spartina + woody + INTM),$\hat{\gamma}$(burned), $\hat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$(herb. + spartina),$\hat{\gamma}$(burned), $\hat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; Footnote continued on next page

$\hat{\lambda}$(herb + spartina + woody + graze),$\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$(herb. + woody + graze + INTM + open water),$\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$(spartina), $\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$(herb. + woody + INTM), $\hat{\gamma}$(burned), $\widehat{w}$(.), $\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$(INTM + open water), $\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$ (INTM), $\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$(open water), $\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$(herb.), $\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise), $\hat{\alpha}$; $\hat{\lambda}$(woody), $\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$(.),$\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise), $\hat{\alpha}$; $\hat{\lambda}$(graze),$\hat{\gamma}$(burned), $\widehat{w}$(.),$\hat{r}$(wind + temp. + lunar + noise),$\hat{\alpha}$; $\hat{\lambda}$(.),$\hat{\gamma}$(.), $\widehat{w}$(.),$\hat{r}$(.),$\hat{\alpha}$.

Table 5. Parameter estimates of the selected open *N*-mixture model for black rail (*Laterallus jamaicensis*) abundance on the Texas coast. Primary periods were 2015 and 2016 and secondary periods were three to eight repeated call broadcast surveys from March to May (2015 and 2016). Included in the model were multiscale abundance ($\hat{\lambda}$) covariates (point-level and site-level) and constant recruitment ($\hat{\gamma}$) influences, apparent survival ($\hat{w}$), and individual detection probability ($\hat{r}$) influences. Point-level covariates were: percent cover of non-*Spartina* herbaceous spp. (herb.), *Spartina* spp. (*Spartina*), and woody spp. (woody) and a site-level covariate: percent cover of intermediate marsh (INTM). Recruitment was influenced by burned areas (burned) where unburned was the reference category. Detection probability influences were wind speed (Wind), lunar phase (Lunar), and average survey temperature (Temp.). Included in the table are parameter estimates, standard error for parameter estimates (SE), and the associated *P*-values (*P*). Intercept coefficients are denoted by b0.

Parameter	Estimate	SE	*P*
$\hat{\lambda}_{\text{b0}}$	- 0.770	0.325	0.018
$\hat{\lambda}_{\text{Herb.}}$	1.048	0.382	0.006
$\hat{\lambda}_{Spartina}$	1.804	0.378	< 0.001
$\hat{\lambda}_{\text{Woody}}$	0.387	0.192	0.044
$\hat{\lambda}_{\text{INTM}}$	0.547	0.144	< 0.001
$\hat{\gamma}_{\text{b0}}$	- 1.550	0.367	< 0.001
$\hat{\gamma}_{\text{burned}}$	1.970	0.380	< 0.001
$\hat{w}_{\text{b0}}$	- 0.304	0.441	0.491
$\hat{r}_{\text{b0}}$	- 2.643	0.292	< 0.001
$\hat{r}_{\text{Wind}}$	- 0.455	0.093	< 0.001
$\hat{r}_{\text{Temp.}}$	0.172	0.079	0.029
$\hat{r}_{\text{Lunar}}$	0.208	0.079	0.008
$\hat{r}_{\text{Noise}}$	- 0.455	0.084	0.050
$\hat{\alpha}$	0.073	0.420	0.863

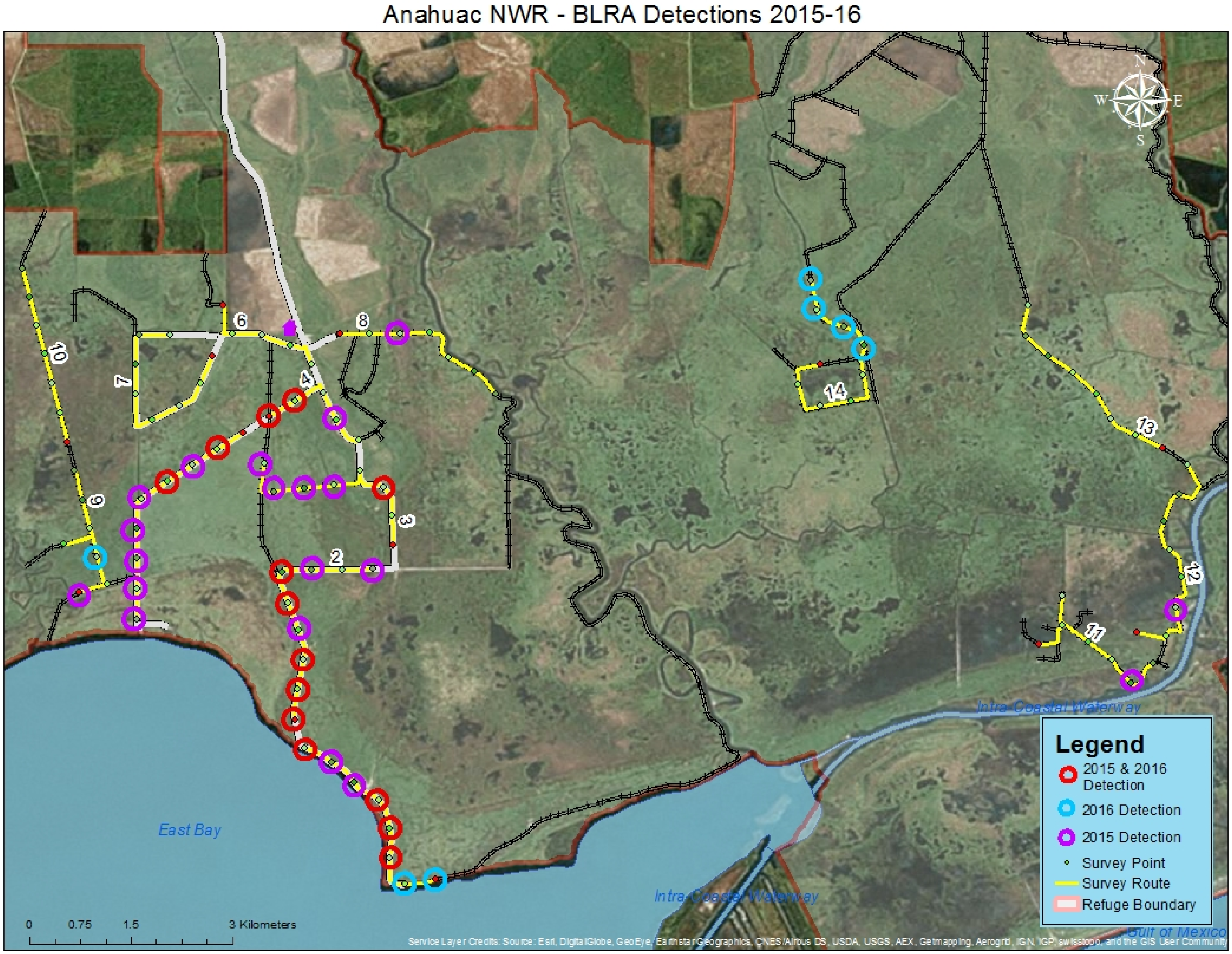


Figure 2. Detections for black rails (*Laterallus jamaicensis jamaicensis*) at Anahuac National Wildlife Refuge. Data collected from mid-March to the end of May (2015 – 2016).

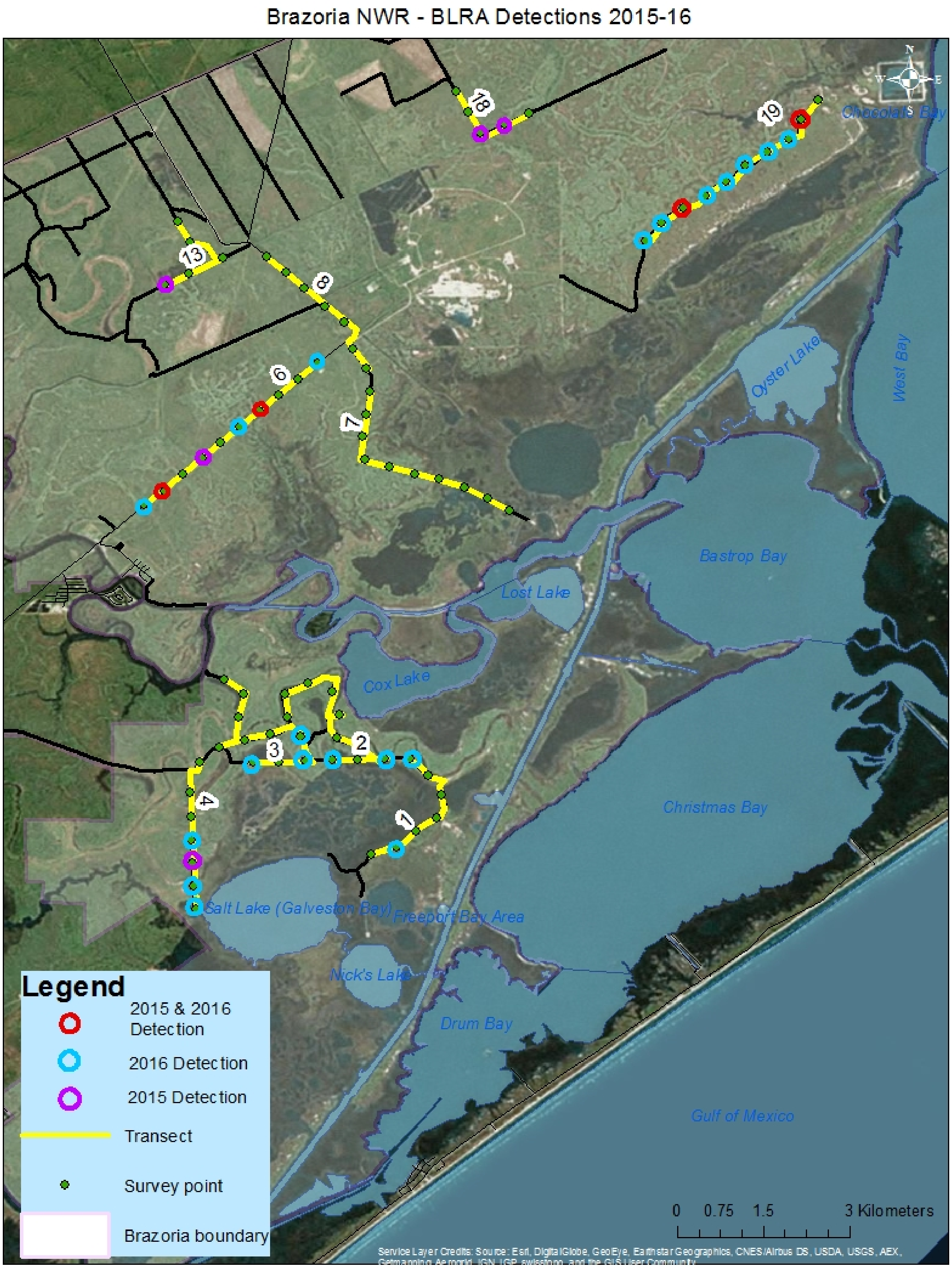
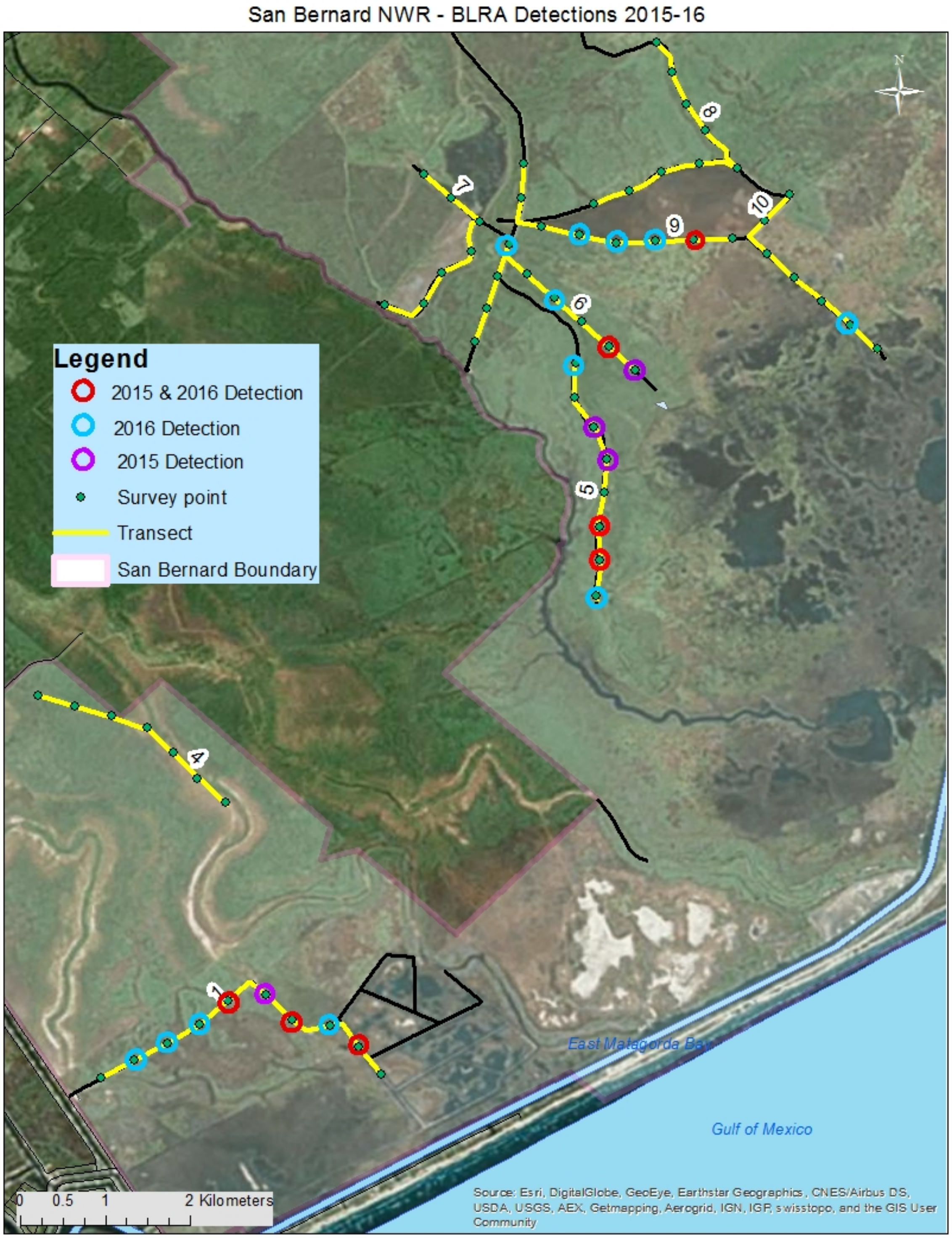


Figure 3. Detections for black rails (*Laterallus jamaicensis jamaicensis*) at Brazoria National Wildlife Refuge. Data collected from mid-March to the end of May (2015 – 2016).


San Bernard NWR - BLRA Detections 2015-16

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4. Detections for black rails (*Laterallus jamaicensis jamaicensis*) at Brazoria National Wildlife Refuge. Data collected from mid-March to the end of May (2015 – 2016).

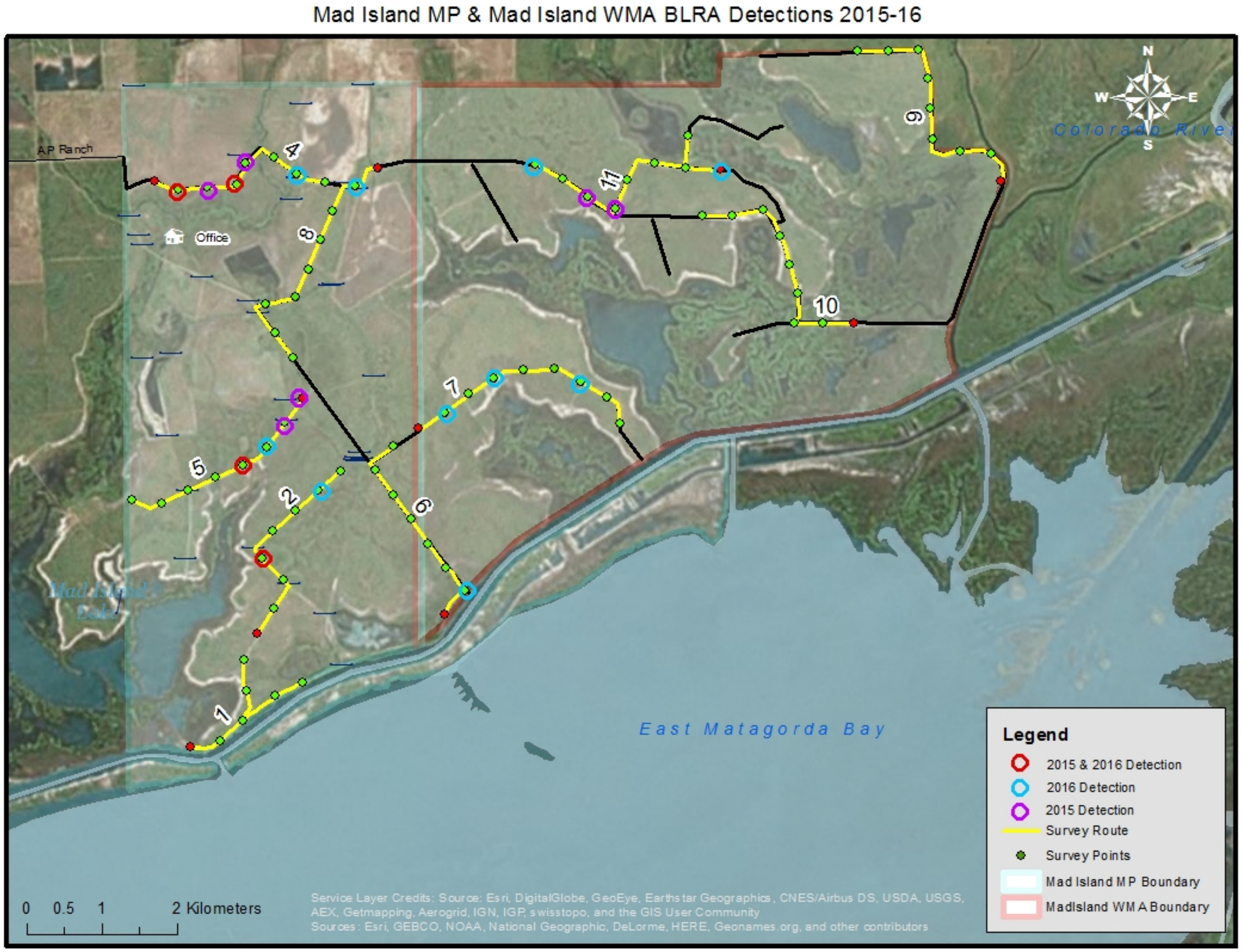
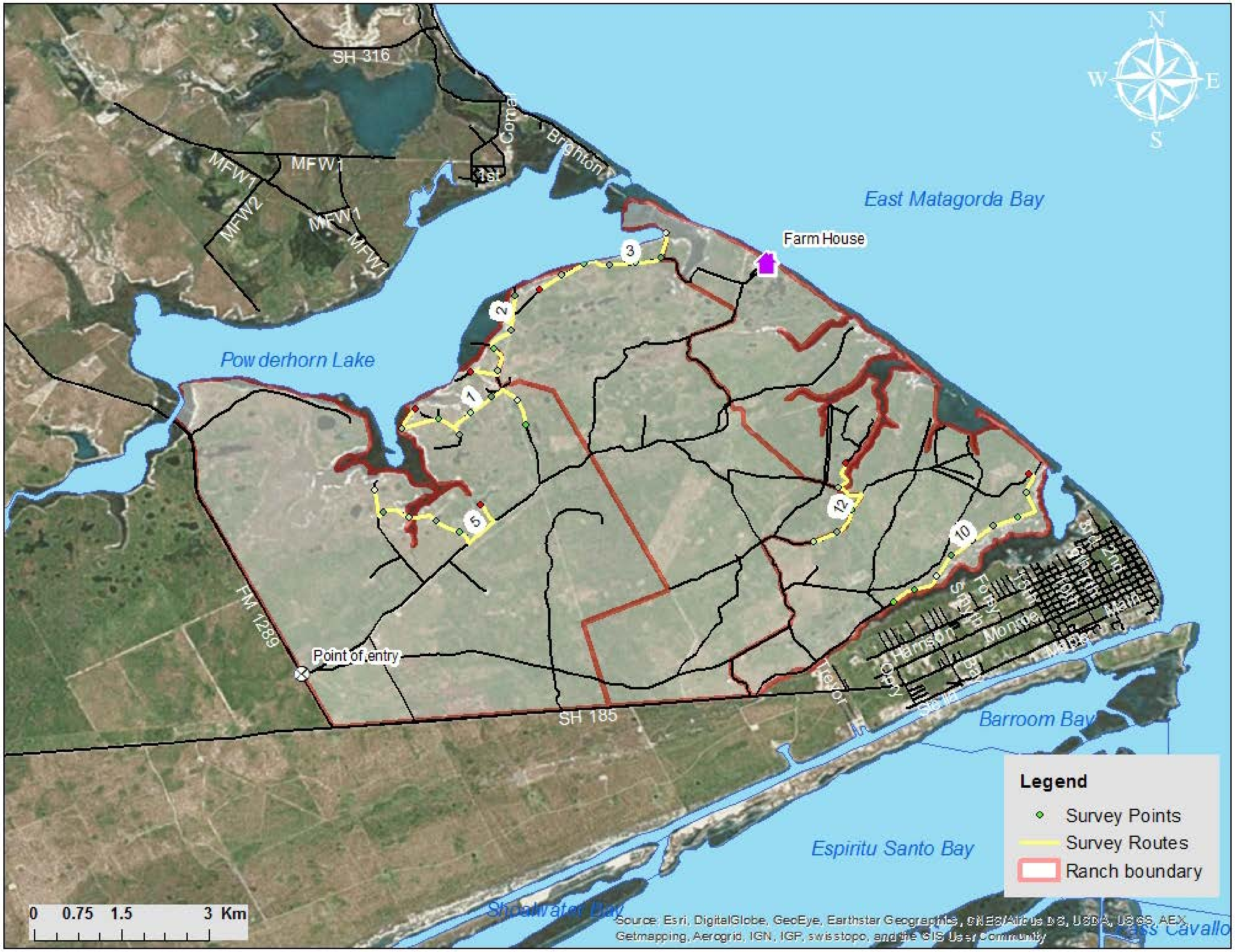


Figure 5. Detections for black rails (*Laterallus jamaicensis jamaicensis*) at Clive Runnells Family Mad Island Marsh Preserve (Mad Island MP) and Mad Island Wildlife Management Area (WMA). Data collected from mid-March to the end of May (2015 – 2016).



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6. Survey locations for black rails (*Laterallus jamaicensis jamaicensis*). No black rails were detected during surveys conducted from mid-March to the end of May (2015 – 2016).

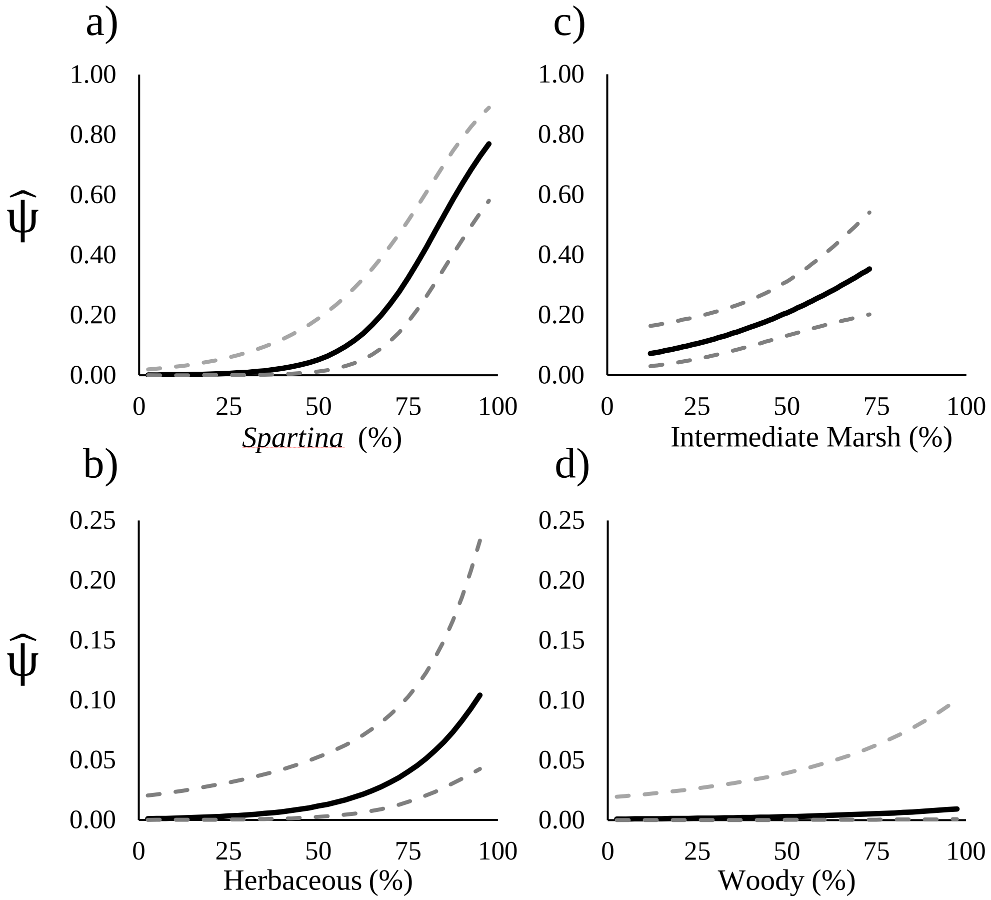


Figure 7. Estimated habitat relationships with black rail (*Laterallus jamaicensis*) occupancy. Shown are the estimated relationships (solid black lines), and 95% confidence intervals (broken gray lines), of multiscale covariates influencing black rail occupancy ($\widehat{\psi}$) at 6 sites across the Texas coast. Covariates were a) cordgrass species (*Spartina* spp. %) cover, b) non-*Spartina* herbaceous species cover, c) intermediate marsh cover, and d) woody species cover. a), b), and d) are at the scale of a survey point while c) is at the scale of a survey site.

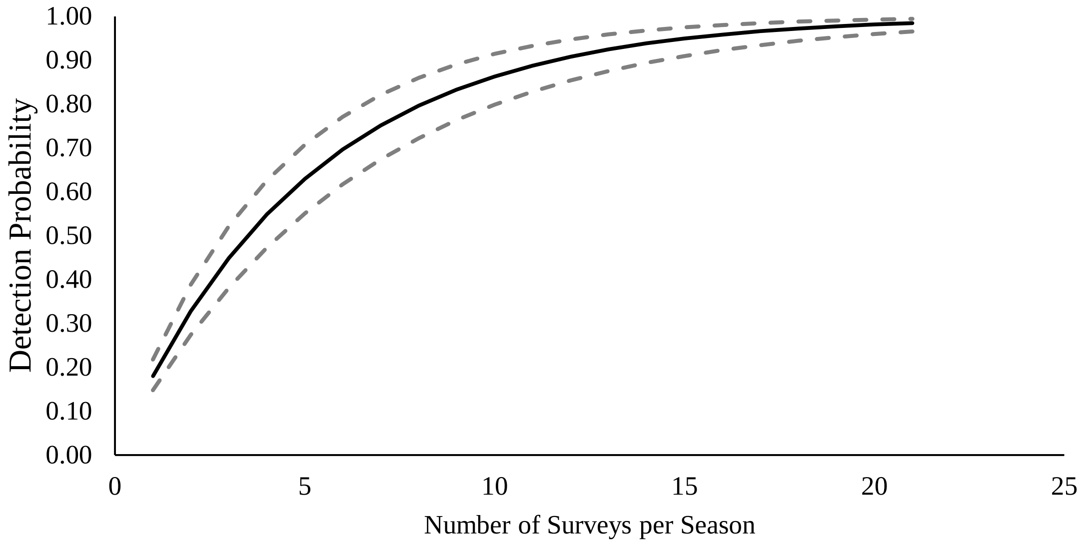


Figure 8. Survey effort required to establish presence of black rails (*Laterallus jamaicensis*). Shown is the estimated relationship between black rail detection (solid black line), and 95% confidence intervals (broken gray lines), and number of surveys of a site per season at 6 study sites across the Texas coast.

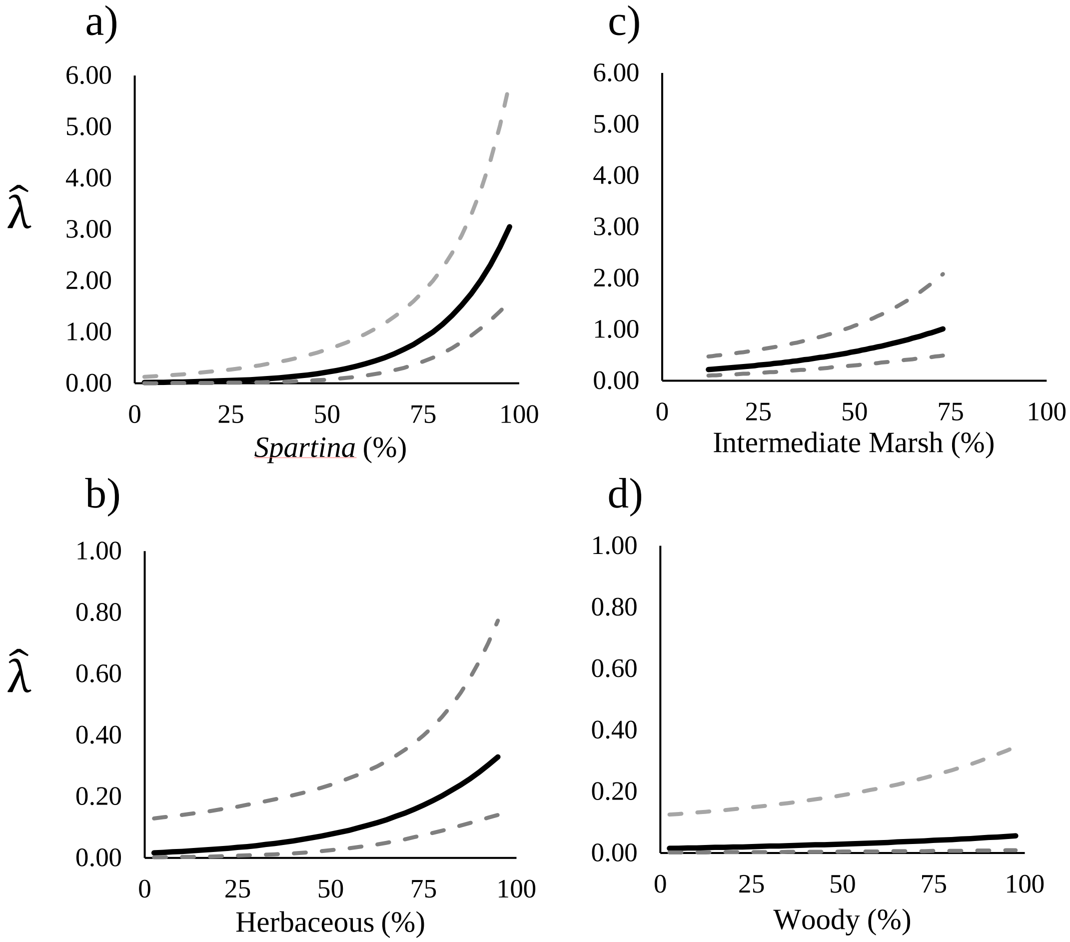


Figure 9. Estimated habitat relationships with black rail (*Laterallus jamaicensis*) abundance. Shown are estimated relationships (solid black lines), and 95% confidence intervals (broken gray lines), of multi-scale covariates influencing black rail abundance ($\hat{\lambda}$) at 6 sites across the Texas coast. Covariates were a) cordgrass (*Spartina*) cover, b) non-*Spartina* herbaceous cover, c) intermediate marsh cover, and d) woody spp. cover. a), b), and d) are at the scale of a survey point while c) is at the scale of a survey site.

Discussion

Our results indicate that black rail detection was influenced most by wind speed, temperature, moon phase, and ambient noise (individual detection only). Black rail occupancy and abundance were influenced at the spatial scales of the point, by *Spartina*, herbaceous, and woody cover and the site, by intermediate-brackish marsh cover. Black rails occupied areas in 2016 that were not occupied in 2015. The proportion of rails similar between years was ~40% per point and there was an increase in the number of rails at points that were burned. Yet, black rail occupancy and abundance were similar between 2015 and 2016. Similarities in annual occupancy and abundance might be because differences were slight and beyond what could be detected with inter-point variation in colonization, extinction, recruitment, and survivorship. Recruitment varied widely and points that were burned made up a minority of the total points (~22%). The low number of burned points along with the variation in recruitment between points may have reduced the ability to detect increases in abundance. Occupancy and abundance were similar between sites though Anahuac NWR had higher mean occupancy and abundance than Powderhorn Ranch in 2015.

Black rails were most vocal and easiest to hear when wind speeds were low (below 11 km/hr), the moon was full the night before the survey, temperatures were above 21˚C, and ambient noise levels were low. Black rail vocalizations were not influenced by time of day, time of survey, or Julian date. For individual covariates, these results are similar to those found in other black rail studies yet the combined influence of wind, temperature, moon phase, and noise level is unique to our study. Spear et al. (1999) reported that both moon phase and temperature influenced California black rail vocalizations. Legare et al. (1999) did not examine moon phase, but did report that temperature had a positive influence on eastern black rail vocalizations.

Previous studies did not report wind as an influential variable (Legare et al. 1999, Spear et al. 1999, Butler et al. 2015). Wind was an important influence in our model and probably decreases an observer's ability to hear birds vocalizing and may decrease vocalization rates (Conway 2011). We did conduct surveys when wind speeds exceeded the recommended maximums of ≥ 11 km/hr (Butler et al. 2015) and 25 km/hr (Evens et al. 1991, Legare et al. 1999, Spear et al. 1999, Conway 2011) at which survey should not be conducted. However, wind speeds are often highly variable and can change quickly on the Texas coast. Logistically, stopping and starting surveys when these thresholds had been breached would have been impractical.

Cloud cover variables have been reported to influence black rail vocalizations (Spear et al. 1999, Butler et al. 2015). Yet none of our cloud cover covariates greatly influenced black rail vocalizations (Appendices A and B). The influence of cloud cover variables is inconsistent across studies, Spear et al. (1999) reported vocalizations to decrease with cloud cover, while Butler et al. (2015) reported the opposite relationship, and Legare et al. (1999) reported cloud cover to have no influence. It is also difficult to assess the importance of the cloud cover variables in the studies that reported them as influential. Butler et al. (2015) only reported the cumulative AIC weight of cloud cover and did not report the magnitude of influence (covariate coefficient) while Spear et al. (1999) was not looking for the most parsimonious model to estimate black rail detection and thus did not perform a model selection analysis. As such, the magnitude of influence from cloud cover variables is difficult to assess in particular studies much less in the context of the species.

We also detected no effect from Julian day or diel period, yet, prior studies have reported both as influencing black rail vocalization frequency (Legare et al. 1999, Spear et al. 1999, Conway et al. 2004, Butler et al. 2015). It is not surprising that Julian date was not influential in our study though both time of year and month have been reported to influence black rail vocalizations. We conducted our surveys when breeding is thought to occur in Texas. Others surveyed outside of and during the breeding season (Spear et al. 1999, Conway et al. 2004). Our focus on the breeding season likely prevented the detection of a possible relationship between calling frequency and Julian date because the breeding season is when black rails are most vocal (Legare et al. 1999, Spear et al. 1999, Conway et al. 2004). Diel periods or time of day has often been shown to influence black rail vocalizations. Mornings, evenings, and nights are times in which black rails are vocal with nights reported to be the peak in vocalizations (Reynard 1974, Eddleman et al. 1994). Studies that report differences in vocalization frequency between mornings and evenings might have conducted a dissimilar number of surveys between the two periods. This amount of unevenness in survey effort might have influenced findings especially considering the low detection probability of black rails. We had similar survey effort in the morning and evening.

Additionally, the differences between our results and others could be a result of geographic variation and taxa-specific behavior. It has been reported that different populations of black rails vary in vocalization peaks throughout the day and night (Kerlinger and Wieber 1990, Conway et al. 2004). Eastern black rails and California black rails are known to differ in vocalization behaviors (Conway et al. 2004, Butler et al. 2015). Therefore, the detection patterns we report may be unique to black rails inhabiting the Texas coast.

If vocalizations vary by region and subspecies then mean species detection might also vary. We estimated that, during one survey in a single season under mean conditions, we had an 18% (SE = 2.0) chance of detecting the species if present. This is similar to the night detection probability (0.16 ± 0.05) but higher than the mean species detection probability (0.09 ± 0.04) previously reported for Texas eastern black rails (Butler et al. 2015). Our estimated species detection is also similar to Legare et al.'s (1999) detection probability for female eastern black rails in Florida. California black rails, however, have been consistently reported to have much higher detection probabilities (0.75 – 0.85; Conway et al. 2004, Richmond et al. 2008). The eastern black rail subspecies, therefore, seems to have a lower detection rate than their California counterparts.

Very low individual detection of species (< 15%) can have adverse effects on the estimation of abundance with *N*-mixture models (Royle 2004, Veech et al. 2016). Veech et al. (2016), applied *N*-mixture models to simulated data. Their findings indicated that when individual detection drops below 5%, estimates of abundance may be biased high. Consequently, when detection probability is < 0.15, *N*-mixture model estimates should be viewed with caution. However, their simulations considered density dependent and random heterogeneity in detection, wherein calling rate and detection of birds is not constant but increases with abundance. Density dependence heterogeneity may be reduced when calls are elicited by call-playback. If this is the case for black rails, our survey techniques may have reduced any heterogeneity in detection induced by differences in density. Our estimates of mean abundance 0.91 and 0.96 rails/point are similar to those which have estimated abundance in California (0.08 – 2.10 rails/station; Evens et al. 1991). Therefore, our estimates of abundance appear plausible.

Estimates of occupancy and abundance can be biased by a lack of independence between survey points. Butler et al. (2015) attempted to decrease autocorrelation in black rail detections by spacing points 800 meters apart instead of the 400 meters suggested by Conway (2011). Nevertheless, in our results relatively few rails seemed to be detected more than 150 meters away from our survey points (15/234). The decrease in detections beyond 150 meters that we observed, is similar to other studies which have examined detection of black rails in relation to distance (Spear et al. 1999, Legare et al. 1999, Conway 2004). Spacing survey points 400 meters apart is likely adequate to circumvent the detection of the same individuals between adjacent survey points. Additionally, black rail home ranges, in other populations, are relatively small (0.62 – 1.3 ha; Legare and Eddleman 2001). If home ranges of Texas black rails are similar it is unlikely individual rails moved between survey points within the breeding season. Therefore, we think each point count station was likely independent during our study.

Total area and total rail estimates reported may not be accurate as they could have been distorted when scaled up. Based on the assumption of independence between point counts, we assumed 200 m was the radius we sampled, however we could have been sampling a smaller or larger area. Though Black Rail population estimates are critical for meeting management and conservation goals, it is difficult to ascertain the accuracy of these estimates. Thus mean point estimates over time may be more reliable and helpful in population monitoring rather than estimating the total number of individuals at a field site. Caution should be taken when using these techniques to estimate abundance and these estimations should be viewed as “ball park” figures rather than hard estimates. More research into the accuracy of *N*-mixture models and the expansion formula given in the Results section, should be conducted before considering these estimation techniques to be reliable.

We conducted our surveys along roadsides, roadbeds, and along fire breaks. This may have biased our estimates of occupancy and abundance by limiting survey sites to edge habitat (Bart et al. 1995, Keller and Scallan 1999) in otherwise expansive marsh areas. Nonetheless, limiting our points to these areas allowed for quick and efficient navigation to and between survey points. The efficiency of this method allowed us to sample far more points than would have been possible in a completely random design. Additionally, roadside sampling reduces habitat disturbance (i.e. trampling of the marsh vegetation); which has been speculated to decrease black rail detection probability (Butler et al. 2015). Proponents of this idea, suggest black rails may hunker down and not vocalize or run from disturbed areas thus decreasing their detectability. Thus in addition to their efficiency, roadside surveys may have higher detection rates than survey conducted within the marsh.

Occupancy and abundance were influenced by environmental factors (model covariates) at two spatial scales, the site level and the point level. Black rail abundance and occupancy increased with the cover of intermediate-brackish marsh cover. The magnitude of influence, however, of this covariate was relatively low. The low influence may be the product of temporal inconsistency. That is, the raster data (Enwright et al. 2015) we used to estimate the percent cover of intermediate-brackish marsh per site was collected in 2013 whereas our data was collected in 2015 and 2016. It is possible that the percent cover of intermediate-brackish marsh increased in those years at some of our study sites and decreased in others. However, it is unlikely that the percent cover would vary that drastically over the spatial extent we examined. Another interpretation for the low magnitude of influence is an ecological one. Black rails are territorial and are likely distributed despotically across the landscape (Freckleton et al. 2005). In this case, there may be quality intermediate-brackish marsh habitat that is simply not occupied by black rails because they are a rare species. Thus the low magnitude of influence could be a result of black rail scarcity on the landscape.

At the point level, habitats with high *Spartina* cover were most often occupied by black rails and had the highest estimated number of black rails. *Spartina* cover consisted of two species of cordgrass, saltmeadow cordgrass (*S. patens*), and gulf cordgrass (*S. spartinae*). Although smooth cordgrass (*S. alterniflora*) was recorded in this general category very few of our points were dominated by this species. Other authors have reported and suggested that black rail habitat preferences are based on structure rather than specific species of vegetation (Rundle and Fredrickson 1981, Flores and Eddleman 1995, Tsao et al. 2009). This structure is characterized by high stem counts and a closed canopy of grasses and forbs (Tsao et al. 2009). Saltmeadow and gulf cordgrass are inherently very dense. Gulf cordgrass is this way because of its high stem count and the closeness of individual bunches (Butler et al. 2005). Saltmeadow cordgrass achieves this structure through a rhizomatous growth habit that gives rise to tall, dense, monocultures.

Woody and herbaceous cover were also included in the top occupancy and abundance models but the regression coefficients for these covariates were much less than for *Spartina*. The woody component might have been influential because high marsh and coastal prairie, which are dominated by saltmeadow and gulf cordgrass in Texas, often has dispersed patches of eastern baccharis (*Baccharis halimifolia*) and/or Jesuit’s bark (*Iva frutescens*), both shrub species. Black rails might have occupied areas with high herbaceous cover when it had high stem count.

Black rail occupancy was not influenced by burning yet the number of black rails increased in burned areas. The influence of fire on black rails is inconsistent in the literature. Black rails have been reported to increase in abundance a few years after a burn (J. Wilson, United States Fish and Wildlife Service, unpublished data). On the other hand, fire has been reported to have no influence on black rail spatial patterns (Conway and Nadeau 2010). Clearly, more work is needed to assess the influence of burning on habitat and black rail movement and demography.

Black rail distribution and abundance appears to be strongly tied to *Spartina* cover. The focus of black rail habitat management should be on the enhancement and proliferation of *Spartina* stands along the Texas coast. Black rail survey points should be spaced at least 400 meters apart. Under average environmental conditions, the required number of surveys (~16) to establish presence of black rails at survey points, seems unattainable within an 8 – 10 week breeding season. Likely, the most practical way of attaining reliable estimates of black rail population states is the use of models that account for imperfect detection and environmental heterogeneity. With a standard occupancy survey design for the Texas coast, based on our average rate of detection and occupancy, precise estimates (CV = 20%) of black rail occupancy could be obtained with seven surveys per survey point per season with 130 points (MacKenzie and Royle 2005). Alternatively using a removal design, where points are removed upon the first detection of a black rail, at least 12 surveys could be performed at 93 points (MacKenzie and Royle 2005). Abundance estimates could also be obtained from these surveys. We suggest that one of these two methods be used to estimate black rail population states with similar broadcast surveys to those described by Tolliver (2017).

Acknowledgments

We thank our field technicians C. Farrell, T. Hohman, H. Erickson, J. Hohman, B. Baird, C. Caldwell, and M. Torres. J. Wilson, S. Goertz, P. Walther, J. Martinez, B. Westrich, J. Moon, M. Milholland, and R. Bracken provided advice, housing, and/or logistical support. Funding was from Texas Parks and Wildlife Department Section 6 Grant and Texas Comptroller of Public Accounts.

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APPENDIX SECTION

APPENDIX A

Below are the results from preliminary analyses on influences of detecting one or more black rails. Analysis was conducted on survey data from 4,023 surveys performed at 375 points from mid-March to the end of May (2015 and 2016) at 6 study sites across the Texas coast. Sample sizes were larger for these preliminary analyses as points were not excluded when they lacked vegetation data or were only sampled in one year. Figure A1 was estimated from the final occupancy model and therefore has the same sample sizes as described in the text.

Table A1. Black rail (*Laterallus jamaicensis*) detection model selection analysis for single covariate models. Covariates were selected when all covariate parameter estimates had an absolute Z-score ≥ 1.41. Covariates included in the models were change in barometric pressure (PB), Julian date (JD), lunar phase (Lunar), cloud cover (Sky), average survey temperature (Temp.), Time after dawn survey start time (TSS), time of day (diel), whether black rail calls or clapper rail calls were played first (CO), ambient noise (Noise), and wind speed (Wind). The table includes: model statements (Model), influences on detection (covariate), covariate parameter estimates (parameter estimate), Z-scores for estimates (Z-score) and t-scores for estimates (t-score). Models selected to be used in AIC$_C$ model selection were wind, Lunar, Noise, CO, and Temp.

Model	Covariate	Parameter Estimate	Z-score	t-score
$\hat{\psi}(.), \hat{p}(\text{Wind})$	Wind	- 0.37	- 4.49	5.1
$\hat{\psi}(.), \hat{p}(\text{Lunar})$	Lunar	0.34	4.29	92.9
$\hat{\psi}(.), \hat{p}(\text{Noise})$	Noise	- 0.19	- 2.56	24.4
$\hat{\psi}(.), \hat{p}(\text{CO})$	CO	- 0.36	- 2.32	26.8
$\hat{\psi}(.), \hat{p}(\text{Temp.})$	Temp.	0.13	1.66	66.6
$\hat{\psi}(.), \hat{p}(\text{Sky})$	Clear Sky	0.35	2.00	70.0
	Variable Sky	- 0.15	- 0.77	42.3
	Overcast	- 9.27	- 0.01	49.9
	Fog	- 0.89	- 1.19	38.1
	Drizzle	0.05	0.06	50.6
	Showers	- 9.07	- 0.08	49.2
$\hat{\psi}(.), \hat{p}(\text{TSS})$	TSS	0.07	0.97	59.7
$\hat{\psi}(.), \hat{p}(\text{Diel})$	Diel	0.10	0.70	57.0
$\hat{\psi}(.), \hat{p}(\text{JD})$	JD	0.02	0.29	52.9
$\hat{\psi}(.), \hat{p}(\text{PB})$	PB	0.02	0.10	51.0

Table A2. Model selection analysis for single-season occupancy models of black rail (*Laterallus jamaicensis*) detection. Included were all possible combinations of the covariates wind speed (Wind), lunar phase (Lunar), ambient noise (Noise), whether black rail calls or clapper rail calls were played first (CO), and average survey temperature. Included in the table are model statements (Model), number of parameters (*K*), the difference between the top ranked model $\mathrm{AIC_C}$ and model's $\mathrm{AIC_C}$ ($\Delta\mathrm{AIC_C}$), and the model deviance (deviance). Three models were ranked as competing (within 2 $\Delta\mathrm{AIC_C}$); the model including wind, average survey temperature, and lunar phase was selected from these competing models because it was the most parsimonious model of the three.

Model	*K*	$\Delta\mathrm{AIC_C}$	Deviance
$\hat{\psi}(.)$, $\hat{p}$(Wind + Temp + Noise + Lunar)	6	0.00	1,572.77
$\hat{\psi}(.)$, $\hat{p}$(Wind + Temp + Lunar)	5	1.33	1,576.34
$\hat{\psi}(.)$, $\hat{p}$(Global)	7	1.59	1,572.08
$\hat{\psi}(.)$, $\hat{p}$(Wind + Lunar)	4	8.84	1,586.03
$\hat{\psi}(.)$, $\hat{p}$(Wind + Noise + Lunar)	5	8.90	1,583.91
$\hat{\psi}(.)$, $\hat{p}$(Wind + Lunar + Call Order)	5	10.59	1,585.59
$\hat{\psi}(.)$, $\hat{p}$(Temp. + Noise + Lunar)	5	15.67	1,590.67
$\hat{\psi}(.)$, $\hat{p}$(Wind + Temp. + Noise + Call Order)	6	15.79	1,588.56
$\hat{\psi}(.)$, $\hat{p}$(Wind + Temp. + Call Order)	5	15.82	1,590.82
$\hat{\psi}(.)$, $\hat{p}$(Temp. + Noise + Lunar + Call Order)	6	16.22	1,588.99
$\hat{\psi}(.)$, $\hat{p}$(Wind + Temp. + Noise)	5	16.46	1,591.46
$\hat{\psi}(.)$, $\hat{p}$(Wind + Temp.)	4	16.92	1,594.11
$\hat{\psi}(.)$, $\hat{p}$(Noise + Lunar)	4	21.17	1,598.36
$\hat{\psi}(.)$, $\hat{p}$(Noise + Lunar + Call Order)	5	22.39	1,597.39
$\hat{\psi}(.)$, $\hat{p}$(Wind + Call Order)	4	22.51	1,599.71
$\hat{\psi}(.)$, $\hat{p}$(Wind)	3	22.81	1,602.16
$\hat{\psi}(.)$, $\hat{p}$(Wind + Noise)	4	23.41	1,600.60
$\hat{\psi}(.)$, $\hat{p}$(Temp. + Lunar)	4	23.93	1,601.12
$\hat{\psi}(.)$, $\hat{p}$(Lunar)	3	26.67	1,606.01
$\hat{\psi}(.)$, $\hat{p}$(Lunar + Call Order)	4	27.01	1,604.20
$\hat{\psi}(.)$, $\hat{p}$(Temp. + Noise + Call Order)	5	33.15	1,608.15
$\hat{\psi}(.)$, $\hat{p}$(Temp. + Noise)	4	36.21	1,613.40
$\hat{\psi}(.)$, $\hat{p}$(Noise + Call Order)	4	37.09	1,614.29
$\hat{\psi}(.)$, $\hat{p}$(Temp. + Call Order)	4	38.35	1,615.54
$\hat{\psi}(.)$, $\hat{p}$(Noise)	3	39.03	1,618.38
$\hat{\psi}(.)$, $\hat{p}$(Call Order)	3	40.28	1,619.63
$\hat{\psi}(.)$, $\hat{p}$(Temp.)	3	42.96	1,622.30
$\hat{\psi}(.)$, $\hat{p}(.)$	2	43.73	1,625.18

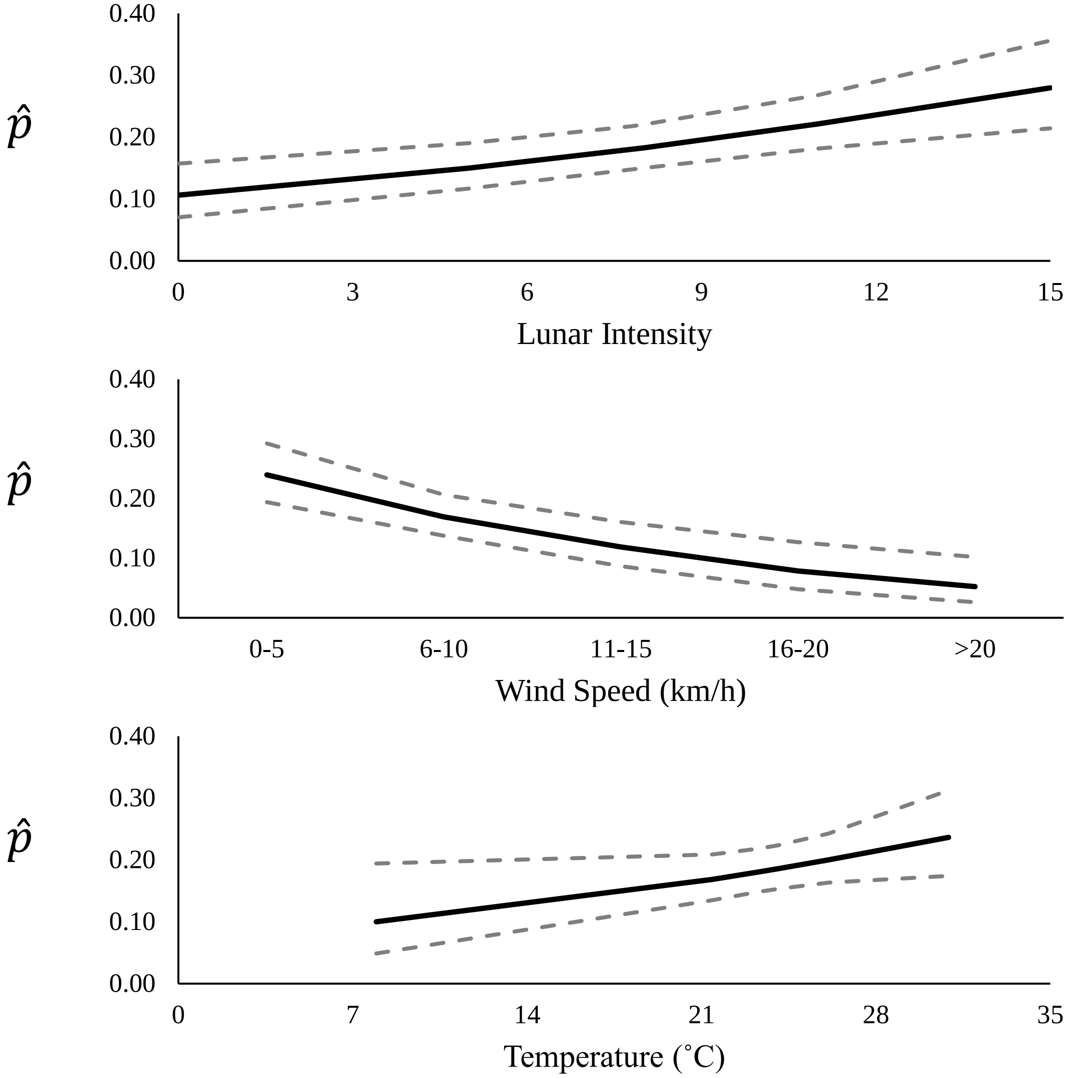

Figure A1. Estimated influences on black rail (*Laterallus jamaicensis*) species detection. Shown are the estimated relationships (solid black lines), and 95% confidence intervals (broken gray lines), of covariates influencing detection of one or more black rails ($\hat{p}$) at 6 sites across the Texas coast. Covariates were moon phase (lunar intensity) that ranged from no moon (0) to full moon (15) (top), wind speed in five continuous discrete ranges of wind speed (middle), and the continuous random factor of temperature (bottom).

APPENDIX B

Below are the results of preliminary analyses of influences on individual black rail detection. Analyses were conducted on survey data from 4,023 surveys performed at 375 points from mid-March to the end of May (2015 and 2016) at 6 study sites across the Texas coast. Reported sample sizes are larger than those in the text because points were not excluded when they had no vegetation data or were only sampled in one year. Figure B1 was estimated with the final negative binomial model and therefore has the same sample sizes as reported in the text.

Table B1. Individual black rail (*Laterallus jamaicensis*) detection model selection analysis for single covariate models. Covariates were selected when all covariate parameter estimates had an absolute Z-score ≥ 1.41. Covariates included in the models were change in barometric pressure (PB), Julian date (JD), lunar phase (Lunar), cloud cover (Sky), average survey temperature (Temp.), Time after dawn survey start time (TSS), time of day (diel), whether black rail calls or clapper rail calls were played first (CO), ambient noise (Noise), and wind speed (Wind). The table includes: model statements (Model), influences on detection (covariate), covariate parameter estimates (parameter estimate), Z-scores for estimates (Z-score) and t-scores for estimates (t-score).

Model	Covariate	Parameter Estimate	Z-score	t-score
$\hat{\lambda}(.), \hat{r}(\text{Wind})$	Wind	- 0.41	- 5.47	- 4.7
$\hat{\lambda}(.), \hat{r}(\text{Lunar})$	Lunar Phase	0.27	3.99	89.9
$\hat{\lambda}(.), \hat{r}(\text{Noise})$	Noise	- 0.23	- 3.36	16.4
$\hat{\lambda}(.), \hat{r}(\text{CO})$	CO	- 0.39	- 2.86	21.4
$\hat{\lambda}(.), \hat{r}(\text{Temp.})$	Temp.	0.11	1.68	66.8
$\hat{\lambda}(.), \hat{r}(\text{Sky})$	Clear Sky	0.21	1.38	63.8
	Variable Sky	- 0.25	- 1.51	34.9
	Overcast	- 8.57	- 0.02	49.8
	Fog	- 1.10	- 1.50	35.0
	Drizzle	- 0.41	- 0.55	44.5
	Showers	- 8.10	- 0.15	48.6
$\hat{\lambda}(.), \hat{r}(\text{Diel})$	Diel	0.16	1.27	62.7
$\hat{\lambda}(.), \hat{r}(\text{TSS})$	TSS	0.08	1.24	62.4
$\hat{\lambda}(.), \hat{r}(\text{Baro})$	Baro.	0.60	1.17	61.7
$\hat{\lambda}(.), \hat{r}(\text{JD})$	JD	0.03	0.47	54.7

Table B2. Model selection analysis for single-season Poisson *N*-mixture models of individual black rail (*Laterallus jamaicensis*) detection. Included were all possible combinations of the covariates wind speed (Wind), lunar phase (Lunar), ambient noise (Noise), whether black rail calls or clapper rail calls were played first (CO), and average survey temperature. Included in the table are model statements (Model), number of parameters (*K*), the difference between the top ranked model AIC and model's AIC (ΔAIC), and the model deviance (deviance). Three models were ranked as competing (within 2 ΔAIC); the model including wind, average survey temperature, and lunar phase was selected from these competing models because it was the most parsimonious model of the three.

Model	*K*	ΔAIC	Deviance
$\hat{\lambda}(.), \hat{r}$(Wind + Temp + Noise + Lunar)	6	0.00	1,926.12
$\hat{\lambda}(.), \hat{r}$(Global)	7	1.16	1,925.00
$\hat{\lambda}(.), \hat{r}$(Wind + Temp + Lunar)	5	3.85	1,932.20
$\hat{\lambda}(.), \hat{r}$(Wind + Temp. + Noise + Call Order)	6	10.12	1,936.24
$\hat{\lambda}(.), \hat{r}$(Wind + Noise + Lunar)	5	11.12	1,939.47
$\hat{\lambda}(.), \hat{r}$(Wind + Temp. + Noise)	5	11.31	1,939.66
$\hat{\lambda}(.), \hat{r}$(Wind + Temp. + Call Order)	5	12.53	1,940.88
$\hat{\lambda}(.), \hat{r}$(Wind + Lunar)	4	12.92	1,943.46
$\hat{\lambda}(.), \hat{r}$(Wind + Temp.)	4	14.22	1,944.76
$\hat{\lambda}(.), \hat{r}$(Wind + Lunar + Call Order)	5	14.35	1,942.70
$\hat{\lambda}(.), \hat{r}$(Wind + Noise)	4	21.18	1,951.73
$\hat{\lambda}(.), \hat{r}$(Wind + Call Order)	4	21.67	1,952.22
$\hat{\lambda}(.), \hat{r}$(Wind)	3	22.33	1,955.02
$\hat{\lambda}(.), \hat{r}$(Temp. + Noise + Lunar + Call Order)	6	23.15	1,949.27
$\hat{\lambda}(.), \hat{r}$(Temp. + Noise + Lunar)	5	24.23	1,952.58
$\hat{\lambda}(.), \hat{r}$(Noise + Lunar)	4	30.38	1,960.93
$\hat{\lambda}(.), \hat{r}$(Noise + Lunar + Call Order)	5	30.45	1,958.80
$\hat{\lambda}(.), \hat{r}$(Temp. + Noise + Call Order)	5	35.61	1,963.96
$\hat{\lambda}(.), \hat{r}$(Temp. + Lunar)	4	38.28	1,968.82
$\hat{\lambda}(.), \hat{r}$(Lunar + Call Order)	4	39.49	1,970.03
$\hat{\lambda}(.), \hat{r}$(Lunar)	3	40.87	1,973.57
$\hat{\lambda}(.), \hat{r}$(Noise + Call Order)	4	41.19	1,971.73
$\hat{\lambda}(.), \hat{r}$(Temp. + Noise)	4	41.56	1,972.11
$\hat{\lambda}(.), \hat{r}$(Noise)	3	45.28	1,977.98
$\hat{\lambda}(.), \hat{r}$(Temp. + Call Order)	4	46.25	1,976.79
$\hat{\lambda}(.), \hat{r}$(Call Order)	3	48.78	1,981.48
$\hat{\lambda}(.), \hat{r}$(Temp.)	3	54.36	1,987.05
$\hat{\lambda}(.), \hat{r}$(.)	2	55.17	1,989.98

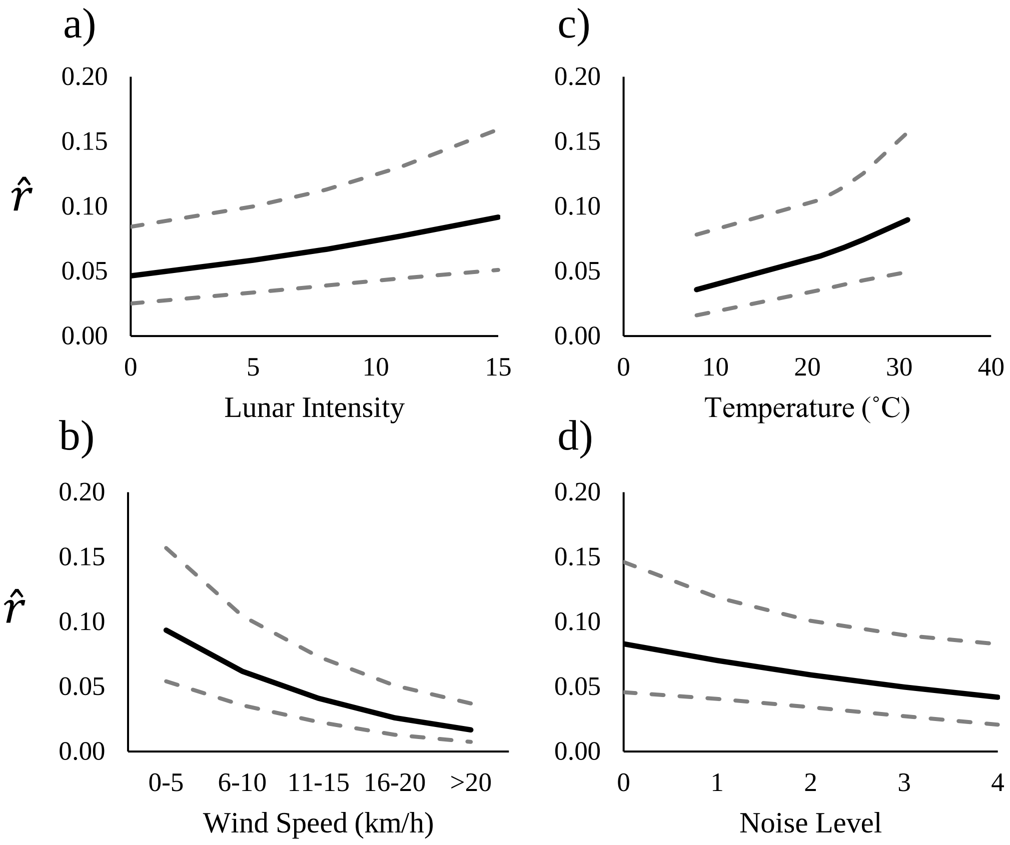

Figure B1. Estimated influences on individual black rail (*Laterallus jamaicensis*) detection. Shown are the estimated relationships (solid black lines), and 95% confidence intervals (broken gray lines), of covariates influencing detection of individual black rails ($\hat{r}$) at 6 sites across the Texas coast. Covariates were a) moon phase (lunar intensity) that ranged from no moon (0) to full moon (15), b) wind speed in five continuous discrete ranges of wind speed, c) the continuous random factor of temperature, and the discrete random variable ambient noise (noise level) which ranged from no ambient little ambient noise (1) to intense ambient noise (5).

Supplementary Information

Please find attached a zip file containing data sets from the surveys described in the text. There are several files which are explained in detail in the Read-Me file. We recommend consulting this document before examining the data.

Significant Deviations

Outlined below are deviations from the tasks set in the original project proposal.

Task 2. We only surveyed 34 points at Powderhorn Ranch this was due to little to no black rail habitat in the interior of the preserve.

Task 3. Surveys consisted of a passive period followed by black rail and clapper rail *Rallus crepitans* calls. Heterospecific calls presumably increase black rail detection (Conway & Nadeau, 2010). The sequence was similar to that described by Conway (2011) but with only four minutes of passive surveying and species order was reversed at each site visit. We reversed calls to assess its influence on detection (Conway & Gibbs, 2005). These alterations were made to more closely match the North American Marsh Bird Monitoring Protocol as it is used at some public sites to survey rails and other marsh birds. Vegetation was surveyed within 50 m of each survey point over 100 m because it was a smaller area and could be quickly assessed from each survey point.

Task 4. All acoustic recording work is still underway. This part of the project was shifted from the work of the master's student, James Tolliver, to Amanda Moore, PhD student, funded by the Texas Comptroller for Public Accounts to research black rails. This was due to the high work load given to James Tolliver for the development of N-mixture and occupancy models. New study sites and new survey points were considered, however reliable transition rates and the inability to sample vegetation, due to logistical constraints, at certain sites both years made data analysis difficult. Therefore, only points and sites surveyed in both years were included in the final data analysis (Tolliver 2017).

Task 7. The species distribution model is also still under development. This is due to insufficient time for the full development of the model and the need for telemetry and mark-recapture studies to further determine status and distribution of the species for ecological modeling. This model will be developed by Amanda Moore and included as a chapter in her dissertation.