Theses and Dissertations

2013

Evaluating the Use of Autonomous Recording Units to Monitor Yellow Rails, Nelson's Sparrows, and Le Conte's Sparrows

Anna Marie Sidie-Slettedahl
South Dakota State University

EVALUATING THE USE OF AUTONOMOUS RECORDING UNITS TO MONITOR
YELLOW RAILS, NELSON'S SPARROWS, AND LE CONTE'S SPARROWS

BY

ANNA MARIE SIDIE-SLETTEDAHL

A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Wildlife and Fisheries Sciences

South Dakota State University

2013

EVALUATING THE USE OF AUTONOMOUS RECORDING UNITS TO MONITOR YELLOW RAILS, NELSON'S SPARROWS, AND LE CONTE'S SPARROWS

This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Dr. Kent Jensen   Date
Thesis Advisor

Dr. David Willis   Date
Head, Department of Natural Resource
Management

Dr. Kinchel C. Doerner   Date
Dean, Graduate School

I would to dedicate this thesis to all people out there who struggle, just like me, with confidence and insecurity issues. A big fear in my life is being wrong and being judged by my peers. Stepping into a Master's program meant I was supposed to prove to people that I am self-assured with my research and that I deserved to have been given this opportunity. "What if I disappoint people? What if I can't do it? I don't want to make a fool of myself," I thought about a million times. Come to find out, if you take it one day at a time, are willing to get overwhelmed once in a while, and are not afraid to ask lots of questions, you will be able to do it. The proof is right here in this thesis. It was once something I thought was impossible, but I have now proven to myself I can do it. Not only this, I have also learned to be proud of what I can accomplish and have discovered the self-assuredness I will need in my career as a wildlife biologist. It takes a lot of passion and hard work, but if I can achieve something like this, so can you.

ACKNOWLEDGMENTS

TABLE OF CONTENTS

Page

Chapter 1 – Comparison of two survey methods (ARU versus standard survey) for detecting yellow rails, Le Conte's sparrows, and Nelson's sparrows

Chapter 2 – Environmental and temporal factors affecting detection of yellow rails, Le Conte's sparrows, and Nelson's sparrows

LIST OF ABBREVIATIONS

ARU	Autonomous recording unit
BBS	Breeding Bird Survey
DNR	Department of Natural Resources
LCSP	Le Conte's sparrow
mb	Millibars
n	Sample size
NESP	Nelson's sparrow
NWR	National Wildlife Refuge
SD card	Secure digital card
SGCN	Species of Greatest Conservation Need
SM-1	Song Meter (model 1)
TNC	The Nature Conservancy
WMA	Wildlife Management Area
YERA	Yellow rail

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

EVALUATING THE USE OF AUTONOMOUS RECORDING UNITS TO MONITOR

YELLOW RAILS, NELSON'S SPARROWS, AND LE CONTE'S SPARROWS

Anna Marie Sidie-Slettedahl

April, 2013

Population status and habitat use of yellow rails (*Coturnicops noveboracensis*) (YERA), Nelson's sparrows (*Ammodramus nelsoni*) (NESP), and Le Conte's sparrows (*Ammodramus leconteii*) (LCSP) are poorly known, so systematic surveys of these elusive species are needed to inform conservation planning and guide management. A standardized protocol for monitoring secretive marsh birds exists (Conway 2009, 2011); however, these species call at night and may be missed during early-morning marsh bird surveys.

I tested the effectiveness of autonomous recording units (ARUs) to survey these species by analyzing recorded vocalizations using bioacoustics software. I deployed 22 ARUs at 54 sites in northern Minnesota and eastern North Dakota, and conducted concurrent traditional broadcast surveys during May-June, 2010 and 2011. I compared ARU-based detections to the standard marsh bird monitoring protocol using a paired t-test, and used the robust design occupancy model in program MARK to estimate detection probabilities for each species by survey method. I found, on average, that ARUs detected 0.59 (LCSP), 0.76 (NESP), and 1.01 (YERA) fewer individuals per survey than were detected using the standard protocol. Detection probabilities using

ARUs were on average 0.23 (YERA), 0.32 (LCSP), and 0.39 (NESP) lower than the standard protocol. Reduced detection by ARUs was likely due to the ability of human observers to detect birds at greater distances. ARUs may provide an effective means of surveying nocturnal secretive marsh birds if investigators correct for differential detectability from ground-based surveys. Arguably, reduced detectability may be outweighed by the increased spatial and temporal coverage feasible with ARUs, resulting in more cumulative opportunities for detection.

I also identified factors that affect detection probability of YERA, LCSP, and NESP by manually scanning 3,035 three-minute ARU recordings for the presence/absence of these species. I related calling activity to hourly weather data from area weather stations. I used the generalized linear mixed models package in R, setting survey site as an *a priori* random effect to control for site to site variation, and using year, Julian day, precipitation, temperature, wind speed, atmospheric pressure, moonlight, and hours after sunset as fixed effects.

The best supported model for YERA indicated highest detection probability occurred 4 hours after sunset, early in the field season, with lower wind speeds and no precipitation. The best supported model of LCSP detection indicated that this species has low detection through the night, but with highest detection at 8 to 10 hours after sunset, early in the field season, with lower wind speeds, and with increased moonlight. The best supported model for NESP indicated highest detection during periods with low wind speeds, no precipitation, and brighter moonlight; with peak dates for detection being from late May through the first two weeks of June. I recommend that existing standard

protocols, or protocols developed for using ARUs to monitor these species, should

incorporate these results to provide more reliable information on estimates of population

trends, habitat uses, and distributions of these species of concern.

CHAPTER 1 – COMPARISON OF TWO SURVEY METHODS (ARUs VERSUS
STANDARD MARSH BIRD SURVEYS) FOR DETECTING YELLOW RAILS, LE
CONTE'S SPARROWS, AND NELSON'S SPARROWS

Population status and habitat use of yellow rails (*Coturnicops noveboracensis*)
(YERA), Nelson's sparrows (*Ammodramus nelsoni*) (NESP), and Le Conte's sparrows
(*Ammodramus leconteii*) (LCSP) are poorly known. The US Fish and Wildlife Service
and US Geological Survey have recently developed a standardized protocol for
monitoring secretive marsh birds, the Standardized North American Marsh Bird
Monitoring Protocol (Conway 2009, 2011) (hereafter, referred to as the standard
protocol). However, due to these species' tendency to call at night, they are often missed
during early morning standard marsh bird surveys. Systematic surveys of these elusive,
shallow wetland species are needed to better inform reliable management practices.

The YERA is one of the North America's least-studied birds (Robert and Laporte
1997, Acevedo and Villanueva-Rivera 2006). YERA are rarely seen because they inhabit
thick wetland vegetation and typically run rather than fly (Bookhout and Stenzel 1987,
Bookhout 1995), and may be more abundant than otherwise believed (Devitt 1939,
Bookhout 1995). For example, a disjunct population of YERA in Oregon, rediscovered
in the 1980's, was suspected to have been overlooked in the past due to the birds'
secretive and nocturnal habits and relatively small population (Stern et al. 1993).

LCSP and NESP frequently nest in the same habitat as YERA (Bookhout 1995)
and are also secretive (Lowther 2005, Shriver 2011). NESP are one of the most poorly
known North American sparrows (Nordhagen et al. 2005). All three species are listed as

"Species of Greatest Conservation Need" (SGCN) in Minnesota (Minnesota Department of Natural Resources 2006), North Dakota (Hagen et al. 2005) and South Dakota (South Dakota Department of Game, Fish and Parks 2006). In Wisconsin, YERA and NESP are listed as SGCN (Wisconsin Department of Natural Resources 2005); and in Michigan, YERA and LCSP are listed as SGCN (Eagle et al. 2005). The YERA has also been listed as a species of "High Concern" in the North American Waterbird Conservation Plan (Kushlan et al. 2002) and the Northern Prairie and Parkland Waterbird Conservation Plan (Beyersbergen et al. 2002).

The most important factor affecting YERA, NESP and LCSP populations is likely loss and degradation of habitat due to human activity (Murray 1969, Eddleman et al. 1988, Bookhout 1995, Shriver 2011). Hydrologic manipulation, particularly drainage of saturated wetlands for agriculture, is a leading cause of habitat loss (Stern et al. 1993). Negative structural changes may occur in vegetation communities, such as an increase in shrubs (Bookhout 1995) caused by changes in disturbance regimes. These changes could be exacerbated by climate change (Poiani and Johnson 1991, Johnson et al. 2005).

Effective survey techniques are necessary to successfully monitor species response to habitat change and dynamic environmental factors. Due to these species' secretive behaviors and tendency to call at night when most traditional surveys are not being conducted, and their use of difficult to access habitat, they are good candidates for surveying with audio recording units. The benefits of using recording units are that they can minimize observer bias, produce permanent records of surveys, potentially record calling activity over a 24 hour/day period, minimize disturbance to wildlife, and resolve problems associated with limited numbers of experienced field observers (Acevedo and

Villanueva-Rivera 2006, Celis-Murillo et al. 2009, Hutto and Stutzman 2009). Some

disadvantages to using recording units are not being able to record visual detections of

birds and the time required to review hours of recordings. Numerous bird studies have

been conducted using audio recorders, and some of these studies compared how point

counts in the field related to audio data analysis in the lab (Haselmayer and Quinn 2000,

Hobson et al. 2002, Acevedo and Villanueva-Rivera 2006, Celis-Murillo et al. 2009,

Hutto and Stutzman 2009, Venier et al. 2012). Many of these studies determined that

recording units were comparable to, or had advantages over, traditional point counts

(Haselmayer and Quinn 2000, Hobson et al. 2002, Acevedo and Villanueva-Rivera 2006,

Celis-Murillo et al. 2009, Venier et al. 2012). However, Hutto and Stutzman's (2009)

work on forest birds reported failure of the recording units to record a large proportion of

detections recorded by human observers, problems identifying sounds in the lab, and

prohibitive time and cost associated with recording units. They reported that they did not

provide cost-effective data collection when compared to traditional point count surveys.

Three of these studies compared traditional point counts to data recorded with

audio recorders using autonomous recording units (ARUs), which can be programed to

digitally record sounds on a pre-programmed schedule (Acevedo and Villanueva-Rivera

2006, Hutto and Stutzman 2009, Venier et al. 2012). This programming capability

enables recordings to be collected at specified times, saving on digital storage space and

prolonging battery life.

Modern ARUs are capable of recording thousands of hours of audio data in a

single field season (Agranat 2009), but it is often impractical to compile data from these

recordings by listening to digital files. Bioacoustics software also may be used to analyze

recordings by viewing spectrograms (visual depictions of frequency, intensity, duration, and variation of sound with time) or by automatically identifying instances of calling by individual species of birds within the recordings. Agranat (2007) estimated that 250 hours of recordings would take 250 hours to process by listening for call recognition, and only 80 hours to visually and aurally review the spectrograms of recordings. Further, bioacoustics software reduced the time to collect data from 250 hours of recordings to about one hour using automated scanning methods (Agranat 2007). Automated detection requires training the computer program with data of known vocalizations to build classification algorithms, which are statistical models that consider both spectral and temporal characteristics of the vocalizations and variability across the training data (Agranat 2007). These classification algorithms, or "recognizers", may be used to automatically locate and identify target species vocalizations.

Automated recognition using bioacoustics software is not foolproof. In a study of cerulean warblers (*Dendrocia cerulea*) by a team composed of the US Forest Service, San Dimas Technology and Development Center, Cornell Lab of Ornithology, Bioacoustics Research Program, and Wildlife Acoustics, Inc., found that the most accurate way to detect cerulean warblers from recordings was by manually scanning spectrograms (Agranat 2007). Manual scans of spectrograms could detect sounds that were too weak or corrupted to be clearly identified by ear or automatically detected using recognizers. A study of three species of woodpeckers (*Picidae*) (Swiston and Mennill 2009) also reported that automated scanning was much faster than manually scanning recordings, but automated scans delivered more false positive identifications and missed more target bird calls than manual scans.

The objective of my study was to quantify the detection probability of YERA, LESP, and NESP vocalizations using ARUs and automated and manual analysis of digital recordings and compare to the results from the standard protocol. I hypothesized that there would be modest to no difference between the estimated detection probabilities between methods.

STUDY AREA

The project was conducted in northwest Minnesota and northeast North Dakota (Figure 1.1). Survey sites in Minnesota were located at Glacial Ridge National Wildlife Refuge (NWR), Agassiz NWR, and surrounding state Wildlife Management Areas (WMAs), including Thief Lake WMA, and The Nature Conservancy (TNC) land. Survey sites were also located within Beltrami Island State Forest and Red Lake WMA, Roseau River WMA, and Caribou and Beaches Lake WMAs, and the surrounding TNC Wallace C. Dayton Conservation & Wildlife Area. In North Dakota, the survey site was located on state WMAs within Grand Forks County.

A majority of the survey sites were within the Tallgrass Aspen Parkland Biome, which is a mosaic of prairie and saturated sedge wetlands interspersed with groves of aspen (*Populus* spp.) or bur oaks (*Quercus macrocarpa*) (Minnesota DNR 2012*a*). Survey sites to the south and west at Glacial Ridge NWR and North Dakota were in landscapes transitioning to the Prairie Grassland Biome, specifically the Red River Prairie Subsection (Minnesota DNR 2012*a,b*). Ten thousand years ago, the flat topography of this area was formed under glacial Lake Agassiz. Today, much of the area is poorly drained with extensive sedge meadows, calcareous fens, wet prairies, and

peatlands (Allmann 1996). Glacial Ridge NWR is characterized by beach ridges striating the area with wet and mesic tallgrass prairie, willow thickets, sedge meadows, aspen stands and emergent wetlands (TNC 2012). The North Dakota survey site was within the Saline Area sub-ecoregion, characterized by wetlands consisting of saline ground water welling to the surface (Bryce et al. 1998). The eastern extent of the study area was within the Beltrami Island State Forest, which included the Red Lake WMA. At one time, the forest may have been an island in the ancient Lake Agassiz, with the lake's shores creating low sandy ridges. Today, the ridges are covered by pine and surrounded by lowlands and peat bogs (Minnesota DNR 2012*c*).

Saturated wetlands are primarily ground-water systems, but average annual precipitation for this area was 53.8 cm, and the average precipitation during the study period of March through July was 29.3 cm. The average maximum and minimum May through June temperatures (°C) are 21.8 and 7.6 (HPRCC 2012).

METHODOLOGY

I conducted my study from 1 May to 30 June 2010 and 2011. I established eight survey routes per year, each consisting of 10-11 survey stations. Survey stations were located mostly along roads, although some stations required walking to gain access. Routes were chosen by consulting with area managers and local birders, using observations in the Minnesota DNR's Natural Heritage Information System, and scouting for saturated wetlands on public lands.

I surveyed each route four times per season: early May (1-14 May), late May (15-31 May), early June (1-15 June), and late June (16-30 June). I used the Standardized

North American Marsh Bird Monitoring Protocol (Conway 2009, 2011) to survey each station, with the modification that surveys started one hour after sunset. Each standard protocol survey consisted of 5 minutes of passive listening, 30 seconds of broadcasted YERA calls, followed by 30 seconds of passive listening. LCSP and NESP calls were not broadcast per standard protocol (Conway 2009, 2011). Species recorded at survey sites included YERA, NESP, LCSP, and other marsh birds. I estimated the distance to each calling bird while conducting the standard surveys.

Twenty-two model SM-1 ARUs (built by Wildlife Acoustics, Inc.) were deployed each field season. One to four ARUs were deployed per route at survey stations at the beginning of the season. Each ARU was set to record from 2000 until 0800 every night for 10 of every 15 minutes.

I constructed wooden boxes that were just large enough to slide the ARU in from the top with the microphones extending out to protect the ARUs in the field and elevate them about 1 m off the ground. Boxes were mounted on a 1.5 m metal fence post that was pushed into the ground no further than 0.4 m, which allowed for removal at the end of the season.

Data were stored on 16 gigabyte (GB) secure digital (SD) cards in the SM-1 units. Song Meter Configuration Utility 1.9.2 (Wildlife Acoustics, Inc.) was used on a laptop computer to program a recording schedule onto ARUs instead of manually programming each unit. This schedule allowed for 13 days of recording before the SD cards were full, at which time they were replaced and the data downloaded onto an external hard drive for

storage. ARU batteries (four D-cells) were replaced at the same time that SD cards were changed and cards were re-used after downloading the data.

I timed standard surveys at stations with an ARU to coincide with a ten minute recording window to ensure that an entire six minute survey and responses were recorded. Standard surveys were conducted within 10 m of the ARU. If few or no target species were detected at ARU stations by late May, the ARUs were relocated to other stations where known target species were calling to ensure that I acquired a large sample of recorded target species calls. I did not move ARUs after the late May survey period.

In the laboratory I isolated the six minute recorded surveys from the rest of the recordings. I was unable to create accurate automatic recognizers; therefore recorded surveys were manually scanned by quickly visually and aurally reviewing segments of the spectrogram to detect vocalizations of any target species. Scans were done blindly, that is recorded survey files received new names so that the scanning technician did not know which field survey location or time the recording came from. I documented the presence or absence of target species and used a timer to keep track of the time required to manually scan each recorded survey. If target species were present on a recorded survey, I conducted a second review of the recording to estimate the number of each target species calling. Overlapping calls, high numbers of calls, and differing call volume intensities were used as criteria to estimate two or more individuals calling. If there was a discrepancy between the results of the two survey methods, I reviewed the standard survey data sheet and corresponding recording of the survey again to determine the most likely reason the two survey methods disagreed.

STATISTICAL METHODS

I used a paired t-test ($p = 0.05$) to evaluate potential differences between the number of birds detected using the standard marsh bird protocol and ARUs. Because ARUs were ineffective at identifying individual birds or distinguishing among multiple birds, I used occupancy modeling, which used data on detection versus non-detection of a species, and takes into consideration that if a species is not detected, it does not necessarily mean that it was absent. I estimated detection probabilities for each species, survey time period, and survey method.

The main assumptions of occupancy modeling are: (1) the site is closed to immigration and emigration throughout the field season; the occupancy state of the sites does not change during the period of surveying; (2) after accounting for modeled covariates, the probability of occupancy is equal across all sites; (3) after accounting for modeled covariates, the probability of detecting the species in a survey, given presence, is equal across all sites and surveys; (4) the detection of the species in each survey and detection histories observed at each location are independent of other sample locations (MacKenzie et al. 2006, p. 104).

Violations of the closure assumption usually lead to overestimates of the probability of occurrence (Rota et al. 2009). A practical way to address the closure assumption is to analyze survey data using robust design occupancy modeling, wherein sampling consists of secondary sampling periods nested within primary sampling periods. Populations are assumed to be closed to demographic changes between the secondary sampling periods but open between the primary sampling periods (Rota et al. 2009). My sampling design included four primary sampling periods (biweekly surveys), each with

two secondary sampling periods (concurrent surveys based on ARUs vs. standard surveys.)

Because the assumption of closure could not be confirmed between primary sampling periods, I used the robust design occupancy model (MacKenzie et al. 2003) implemented in program MARK (White and Burnham 1999) to estimate the following parameters:

Ψ_1 = initial probability of occupancy: the probability that a site is occupied by the species during the first survey at time (t) = 1

ε_t = local extinction: the probability that a site occupied by the species at time t becomes unoccupied by the species at t + 1, such as from the abandonment of a territory by a calling male, or a singing male becoming silent due to the onset of nesting

γ_t = colonization: the probability that a site unoccupied by the species at t is occupied by the species at t + 1, such as from a calling male entering a new territory

$p_{t,j}$ = detection probability: the probability of detecting the species, given occupancy, in survey j within primary period t

I did not expect each species to be equally abundant, so for initial occupancy Ψ_1 spp was modeled. For this particular analysis I was interested in comparing detection probabilities between survey methods, thus extinction and colonization (ε_t and γ_t) were considered as nuisance parameters and were estimated during the first stage of modeling. For notation, (spp) was used to denote differences in parameter values among species, the subscript (t) to indicate full temporal variation (unique estimates of the parameter for

each primary survey visit across the sampling season), (T) to indicate a linear trend

across sampling periods within the season, and (.) to indicate constant parameter values.

In models that included both species and a temporal effect (t or T), half of the temporal

models (t) and (T) were treated as fully interactive (e.g. spp*t or spp*T) and the

remaining models were treated as additive effects (spp + t, spp + T; i.e., all three species

exhibited parallel temporal variation). Given presence/absence of species effects, three

possible parameterizations for temporal variation (t, T, .), plus two additional additive

parameterizations (spp + t, spp + T), there were eight possible parameterizations for both

ε and γ, yielding 64 potential first-stage models. During the first stage, I only considered

one parameterization for Ψ_1 as (Ψ_1 spp), structured the parameter of interest, p_t, at its

most complex formulation p(spp*t*ARU), where ARU indicates survey method, and

considered alternate structures (., spp, t, T, spp*t, spp*T, spp + t, spp +T) for ε and γ.

Using the best approximating model from the first stage, 21 additional parameterizations

were investigated for variation in p (., spp, t, T, ARU, spp * t, spp * T, spp + t, spp + T,

spp + ARU, spp * ARU, t + ARU, t * ARU, T + ARU, T * ARU, spp + t + ARU, spp + T

+ ARU, spp * t * ARU, spp * T * ARU, spp * T + ARU, spp * t + ARU).

　　　　I used Akaike's information criterion (AIC) adjusted for small samples size

(AIC$_c$) to evaluate candidate models (Burnham and Anderson 2002) and summed model

weights (w_i) across models for each parameter occurring in multiple models. The

weights of all models sum to 1 and represent the relative likelihood of each model, given

the data and model set (Burnham and Anderson 2002). For each parameter (in stage 1, ε_t

and γ_t; in stage 2, p), I summed Akaike model weights (Σw_i) per function of time (t, T, or

.) and species (spp or .) of each parameter, and (ARU) for p. I determined the appropriate

parameterizations for the variables by regarding the best approximating model according to AIC_c, and evidence ratios (e.g., $\Sigma w(t)/ \Sigma w(T)$). For the second stage of modeling, models were considered competitive according to AIC_c if a model had a ΔAIC_c of ≤ 2. I considered models based on each parameterization and used model averaging to obtain parameter estimates and unconditional SEs for p (Burnham and Anderson 2002).

The final analysis that I conducted was using these estimated detection probabilities to estimate how many six minute ARU surveys would be necessary to be at least 95% sure of detecting a target species if they occupy the survey site. The detection probability from a survey repetition subtracted from one (1-p) states the probability of not detecting a target species if the site is occupied. I multiplied together these probabilities from one, two, three, four, or five survey repetitions until my probability of not detecting a target species was ≤ 0.05, indicating that I would be at least 95% sure of detecting that species in that many six minute surveys. If a species required more than four surveys, I used an averaged detection probability from the four estimated detection probabilities in the calculation.

<div align="center">RESULTS</div>

I collected 172 six minute recorded surveys from 53 ARU sites for three species (YERA, LCSP, and NESP). I estimated it was 3.6 times faster to manually scan recordings for presence/absence of species than listen to the entire six minute recorded survey. For each of the 3 target species there were 172 surveys, which yielded 516 chances for discrepancy between results of the two survey types (Table 1.1). Of those 516, target species were detected during 167 surveys (32.4%). A target species was

detected and a discrepancy between methods documented 58 out of the 167 (34.7%)

times. A majority of these discrepancies were due to the observer in the field detecting

the species, but the manual scan observer not detecting the species. Various possibilities

for discrepancies are described in Appendix A.

At sites where species were detected by at least one method, standard surveys

detected more individuals per survey point for all three species (mean 2.4, 1.6, 1.2 for

YERA, LCSP, and NESP, respectively) than did ARUs (1.4, 1.0, 0.4). The mean

differences were significantly greater than zero for YERA (n = 71, t = 7.11, $\underline{P}$ = 7.73E-

10), for LCSP (n = 75, t = 5.54, $\underline{P}$ = 4.37E-07), and NESP (n = 21, t = 4.99, $\underline{P}$ = 7.11E-

05), indicating that abundances for these species were underestimated using the ARU

recordings.

Occupancy Modeling

I applied fixed parameterizations of Ψ(spp) and p(spp*t)*ARU for the first stage

of modeling. The probability of local extinction (ε) increased linearly through time, but

the rate of increase did not differ between species (ε(T)) (Figure 1.2). Evidence ratios

(Table 1.2) indicated that this model (T) was 1.5 times better supported than other models

which described that local extinction (ε) changed through time, but it was not a linear

trend (t). Evidence ratios also indicated that the model predicted no variation between

species (.) for ε was 2.5 times more likely than models considering ε was unique for each

species (spp). For colonization probability (γ), each species exhibited a linear trend for

colonization through time, but they were not parallel among species (γ(spp*T)) (Figure

1.3). Colonization rates trended downwards for YERAs and LCSPs, with LCSPs being

consistently higher than YERAs, and colonization estimates trended upwards for NESPs.

Evidence ratios (Table 1.2) suggested that this model (T) was 3.1 times more likely than other models which described that colonization (γ) changed through time but was not a liner trend (t), or that described that colonization (γ) with no temporal variation across the season (.). Evidence ratios also indicated that the model describing variation between species (spp) for γ was 1.4 times better than models considering γ was not unique for each species (.).

Results from the second stage of modeling, with fixed parameterizations of ε (T) and γ (spp*T), indicated comparable support for several models (Table 1.3). For detection probability, the linear trend through time in which each species trend is not parallel (the species dependent trend model p(spp*T)+ARU) slightly outperformed the model with detection remaining constant through time for each species (p(spp)+ARU), the model with detection probability remaining constant through time for each species with an effect of ARU for each species (p(spp)*ARU), and the model with detection not dependent on species or time (p(.)+ARU). Therefore, I considered four different parameterizations for p, yielding four models with nearly equivalent AIC_c scores, which we averaged to obtain parameter estimates and SEs for YERA and LCSP. Given the small number of NESP detections, there were not enough data to support more complex models such as (p(spp)*ARU), therefore this model was excluded from the model averaging to estimate NESP detection probabilities. The model considering p(spp+T)+ARU contained an uninformative parameter, which does not explain enough variation to keep it in the model and therefore should not be interpreted as having an ecological effect (Arnold 2010), therefore was also not included in any of the model averaging for all three species. All top models included some form of ARU (i.e., +ARU,

*ARU) and indicated that detection probabilities did not differ among my 3 study species and were consistently higher using the standard survey protocol than with the ARU method. These estimated detection probabilities were used to determine how many of these six minute ARU surveys would be necessary to be at least 95% sure of detecting a target species if they occupy the survey site (Table 1.4).

DISCUSSION

My results document that manual scans of ARU recordings, specifically from SM-1 recording units (Wildlife Acoustics, Inc.), did not detect YERA, LCSP and NESP as well as a human observer in the field. There are several advantages of using human observers. Human observations generated a higher detection probability than ARUs for these three species, and humans were able to detect greater numbers of birds per occupied location than were ARUs. There are two possible explanations for the higher number of vocalizations detected by our field observers: (1) the field observers mistakenly reported target species, or (2) the birds were too quiet to be recorded by the ARU or were faint on the recording and were easily missed. I believe the latter is the most likely explanation. The primary advantage of employing field observers is that humans can detect birds at greater distances than ARUs. Hutto and Stutzman (2009) reported that 52.7% of human-only detections were of birds too distant for their ARUs to detect. Venier et al. (2012) also concluded that birds <25 m from the point count center were more likely to be detected by the ARU than birds sampled at the 51-100 m range. Hobson et al. (2002) concluded that the ability to detect birds with ARUs at greater distances was dependent

upon the species. Thus, distance to the target species likely explained the greater human-only detections in my study.

The standard protocol requires recording the detection of each individual species calling at a single survey site (Conway 2009, 2011). The challenge of identifying multiple birds is one of the greatest obstacles to using ARUs. A human observer in the field is able to approximate an azimuth and distance to calling birds to distinguish among individuals. The digital ARU recordings were recorded in stereo, but the underlying architecture of the analytical software I used did not allow the observer to listen in stereo because it was designed to be automatically scanned using recognizers and the manual scan of spectrograms. If future projects intend to obtain minimum counts of individual birds, a program where recordings may be listened to in stereo will be required. Different call volumes (e.g. loud versus faint) can also help determine if there is more than one individual calling on the recordings. However, it is necessary to assume that the individual did not move to a new location to start calling, did not face the other direction when calling, or a gust of wind did not interfere with the call's sound waves reaching the microphones.

How the bird vocalizes influences the ability to use ARUs to estimate the numbers of individuals, and estimate presence/absence. YERA, if close enough to be recorded by the ARU, typically call constantly for long periods. As such, it is more likely that two or more YERA will be heard calling simultaneously; overlapping calls are the only reliable way to know if there are more than one individual calling on an ARU recording. LCSP and NESP call more sporadically, making it more difficult to determine

if more than one individual is calling on a recording. More sporadic calling also results in a greater chance of the ARU scanning observer missing their call, especially if the call is faint or obscured by other noise. Alldredge et al. (2007) supported this notion and demonstrated that detection probabilities were greater for songbirds that had higher singing rates over birds with lower singing rates.

Despite the advantages of human observers over ARUs, there are benefits to using these units. No other published studies using recording units exist for these three species; however, there have been a number of studies of other bird species that compared the efficacy of recording units and human observers (Haselmayer and Quinn 2000, Hobson et al. 2002, Acevedo and Villanueva-Rivera 2006, Celis-Murillo et al. 2009, Hutto and Stutzman 2009, Venier et al. 2012). Most previous studies concluded that recording units were an effective method to collect information on bird communities and had advantages over traditional point counts. For example, ARUs can be left unattended in difficult-to-access areas for lengths of time dependent on the recording schedule, potentially lessening field visits to two trips per unit, while avoiding nocturnal survey visits and acquiring more cumulative opportunities for detection. They are therefore effective at determining presences/absence, if not abundances, and may be more practical in remote areas than human observers when this is the goal. Furthermore, recordings can be analyzed in a laboratory over time, making researchers less dependent upon skilled technicians and possibly avoiding the need to account for observer bias.

Hutto and Stutzman (2009) concluded that the extra time and cost associated with ARU usage did not justify their use. However, I believe ARUs could be more effective

and cost efficient than field observers depending upon the objectives and duration of the study in question and the nature of the study area (e.g., accessibility). Time spent in the lab analyzing the recordings is reduced with the use of spectrograms. A one-time purchase of ARUs, which would be used year after year, would save money by not hiring technicians every year. Hutto and Stutzman (2009) examined total species detected in their study area and their results indicated that human observers detected more species than ARUs. In total, 40.9% of the species detected in their study were detected by humans alone, 49.4% by humans and ARUs, and 9.7% by ARU only. My results somewhat contrasted this in that 32.3% of recorded detections were by humans only, 65.3% by both methods, and only 2.4% by ARU only.

Because I collected large numbers of recordings, generating accurate recognizers to scan recordings and automatically identify bird species calls was a primary objective of this project that was not achieved. The recognizers that I generated delivered many false negatives and more importantly, delivered unsatisfactory numbers of false positives to run without manually re-checking results. YERA recognizers were particularly challenging because of the similarities between frequency ranges and the shape of its simple "click" call on the spectrogram with that of chorus frog (*Pseudacris triseriata*) calls, parts of sedge wren (*Cistothorus platensis*) calls, and rain drops. A similar problem was described by Swiston and Mennill (2009) wherein they documented more false positives when automatically scanning for the simple double knock or "kent" calls of the ivory-billed woodpecker (*Campephilus principalis*) than when scanning for complex calls, such as the "cackle" of the pileated woodpecker (*Dryocopus pileatus*). Swiston and

Mennill (2009) concluded that humans are better than an automated scan at distinguishing between similar sounds and consider sound context while conducting a manual scan, especially when calls were faint, overlapped with other sounds, or had low signal-to-noise ratios.

The LCSP recognizer was the most successful I constructed, but as with the YERA recognizer, I had to manually re-check the scanned recordings. I was unable to create a satisfactory NESP recognizer because of the lack of quality training data and because we did not encounter this species often. I documented at least four different variations of the NESP call within my study area, which hindered the creation of a successful recognizer.

The main advantage of a spectrogram from ARUs is the visual feature that allows for faster and more accurate detection and identification of specific bird species during manual scans when compared to listening to recordings. However, listening to vocalizations can confirm identification; each of my 6-minute surveys could be manually scanned for the presence or absence of the three species in about 1.6 minutes. Nevertheless, developing better automated recognition technology may be the most important area of development associated with ARU use.

Another advantage of the spectrogram is discerning vocalizations when recordings are very busy with the cacophony of other calls, such as from amphibians or during dawn chorus times. A human observer in the field would have one chance to detect a calling species in a busy and loud setting. However, examining a recording in

the lab allows for review and consultation with peers to confirm species calls. This software also allows the user to isolate specific areas of the spectrogram and listen to them independently, without sound in lower or higher frequency ranges that may otherwise interfere with the call.

ARUs could be an appropriate avian survey technique depending upon species and study objectives. If the objective is to estimate the number of calling individuals, ARUs are likely not an appropriate tool. ARUs may be used to properly estimate presence/absence, frequency of occurrence, and calling intensity. ARUs also may be used to assess status and trend of species if relative abundance of calls in an acceptable index, rather than an index to relative abundance of individuals. For some species, such as YERA, the two metrics may be the same.

FIGURES, TABLES, AND APPENDICIES
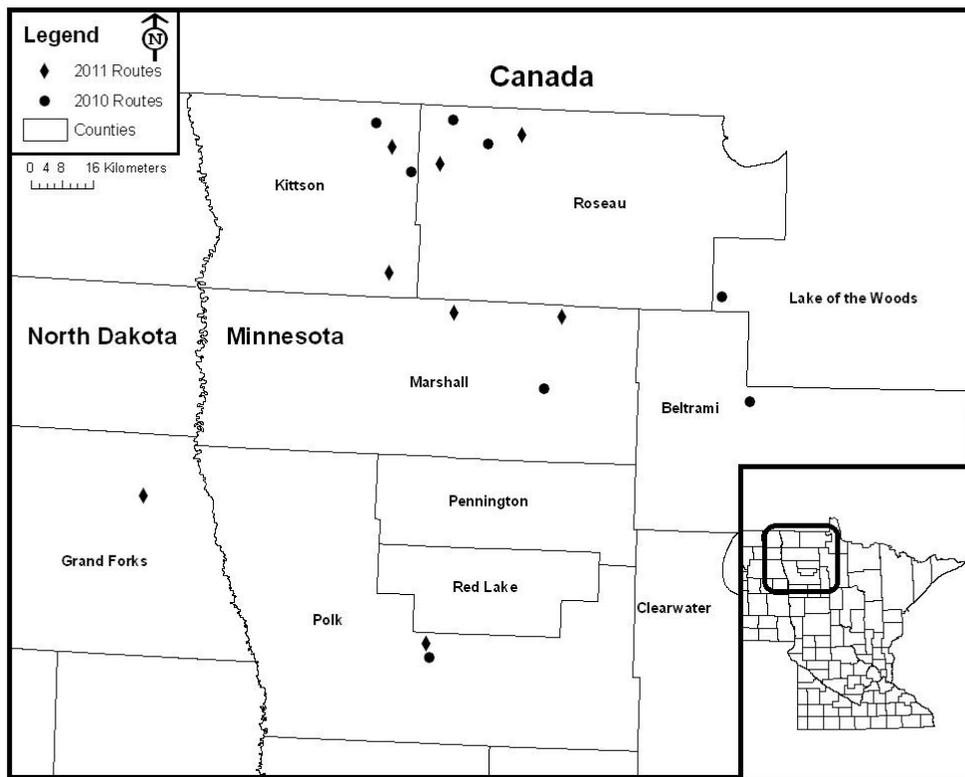
Figure 1.1. Study area for evaluating use of ARUs for monitoring YERA, LCSP, and NESP in saturated wetlands of northwest Minnesota and northeast North Dakota. Circles represent approximate locations of survey routes conducted in 2010, and diamonds represent approximate locations of survey routes conducted in 2011. Each survey route consisted of 10-11 survey stations, and ARUs were placed at 1-4 survey stations per survey route.

Table 1.1. Presence/absence estimates of three target species detected by two survey

methods (ARUs and the standard protocol) conducted simultaneously during 2010 and

2011 in northwest Minnesota and northeast North Dakota

	Species			
	YERA	LCSP	NESP	Total
Detected by Both Survey Methods	55	44	10	109
Detected only by Standard Method	15	28	11	54
Detected only by ARU Method	1	3	0	4
Not Detected	101	97	151	349
Total Surveys	172	172	172	516

Table 1.2. Cumulative model weights ($\sum w_i$) for sources of temporal and species variations in probabilities of detection of YERA, LCSP, and NESP during 2010 and 2011 in northwest Minnesota and northeast North Dakota, as determined by the robust design occupancy model

	Temporal variation			Species variation		ARU	
	Full (*t*)	Trend (*T*)	None (.)	Yes (Spp)	None (.)	Yes (ARU)	None (.)
ε	0.40	0.60	0.00	0.29	0.71	.	.
ɣ	0.20	0.61	0.20	0.59	0.41	.	.
p	0.05	0.49	0.46	0.80	0.20	1.00	0.00

Table 1.3. Best supported models of the initial probability of occupancy (Ψ1), local extinction (ε), local colonization (γ), and detection probabilities (p) from both methods for YERA, LCSP, and NESP during 2010 and 2011 in northwest Minnesota and northeast North Dakota, as determined by the robust design occupancy model. Model notation denotes a linear trend across years (T), variation by species (spp), a multiplicative effect of species by linear trend (spp*T), an additive effect of species by linear trend (spp + T), no temporal, linear or species variation (.). (ARU) indicates there was a difference in the detection probabilities estimated from the field surveys compared to the detection probabilities estimated from the manual scan method.

Model	Δ AIC$_c$	w_i	K	Dev
Ψ1(spp), ε(T), γ(spp*T), p(spp*T)+ARU	0.0000	0.2423	18	785.2885
Ψ1(spp), ε(T), γ(spp*T), p(spp)+ARU	0.2612	0.2126	15	791.9560
Ψ1(spp), ε(T), γ(spp*T), p(spp+T)+ARU[†]	0.6118	0.1784	16	790.1795
Ψ1(spp), ε(T), γ(spp*T), p(spp)*ARU	1.3260	0.1249	17	788.7583
Ψ1(spp), ε(T), γ(spp*T), p(.)+ARU	1.3404	0.1240	13	797.2646

† The model considering p(spp+T)+ARU contained an uninformative parameter, therefore was not included in the model averaging for all three species.

Table 1.4. The probability of detecting a YERA, LCSP, or NESP if they occupied the survey site with respect to the number of six minute ARU surveys conducted during 2010 and 2011 in northwest Minnesota and northeast North Dakota.

	6 Minute Surveys				
Species	1	2	3	4	5
YERA	72.6%	92.3%	97.8%	.	.
LCSP	53.2%	80.7%	93.1%	97.8%	.
NESP	51.1%	75.9%	88.0%	94.0%	97.0%

Figure 1.2. Local extinction estimates (ε) determined from the best supported model

from the first stage of modeling, which was to determine the nuisance parameters of ε

and γ. The best supported model denotes a linear trend across the season (T) with no

effect of species
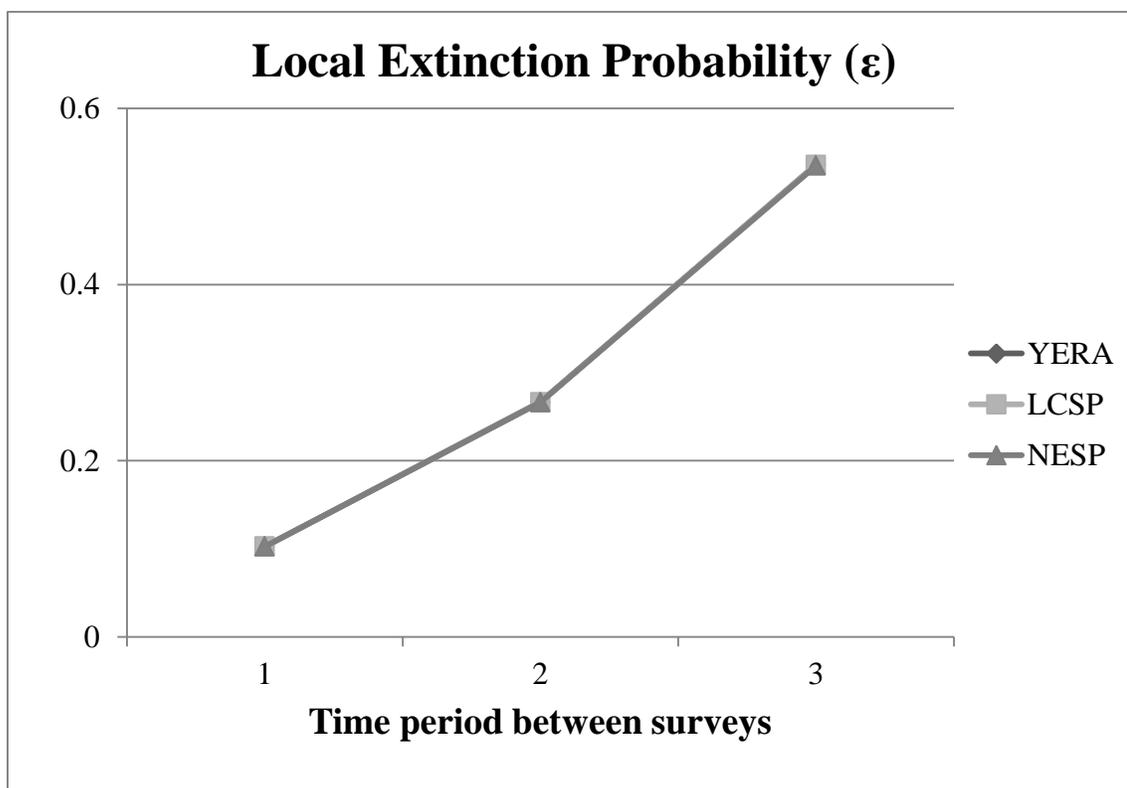
Figure 1.3. Local colonization estimates (γ) determined from the best supported model

from the first stage of modeling, which was to determine the nuisance parameters of ε

and γ. The best supported model denotes a linear trend across the season (T) with a

multiplicative effect of species
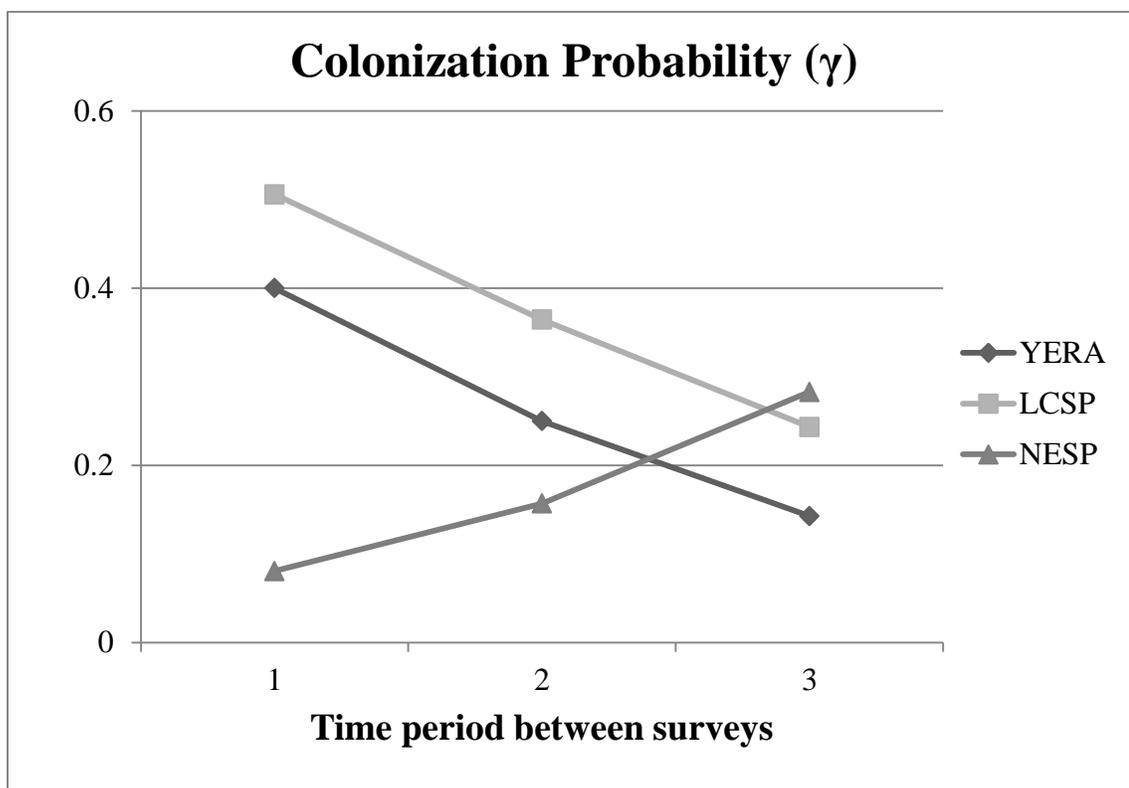
Figure 1.4. Model-averaged parameter estimates and 95% confidence intervals for

detection probabilities determined using ARUs and the standard protocol for YERA

during 2010 and 2011 in northwest Minnesota and northeast North Dakota, determined

by the second stage of modeling with the robust design occupancy model
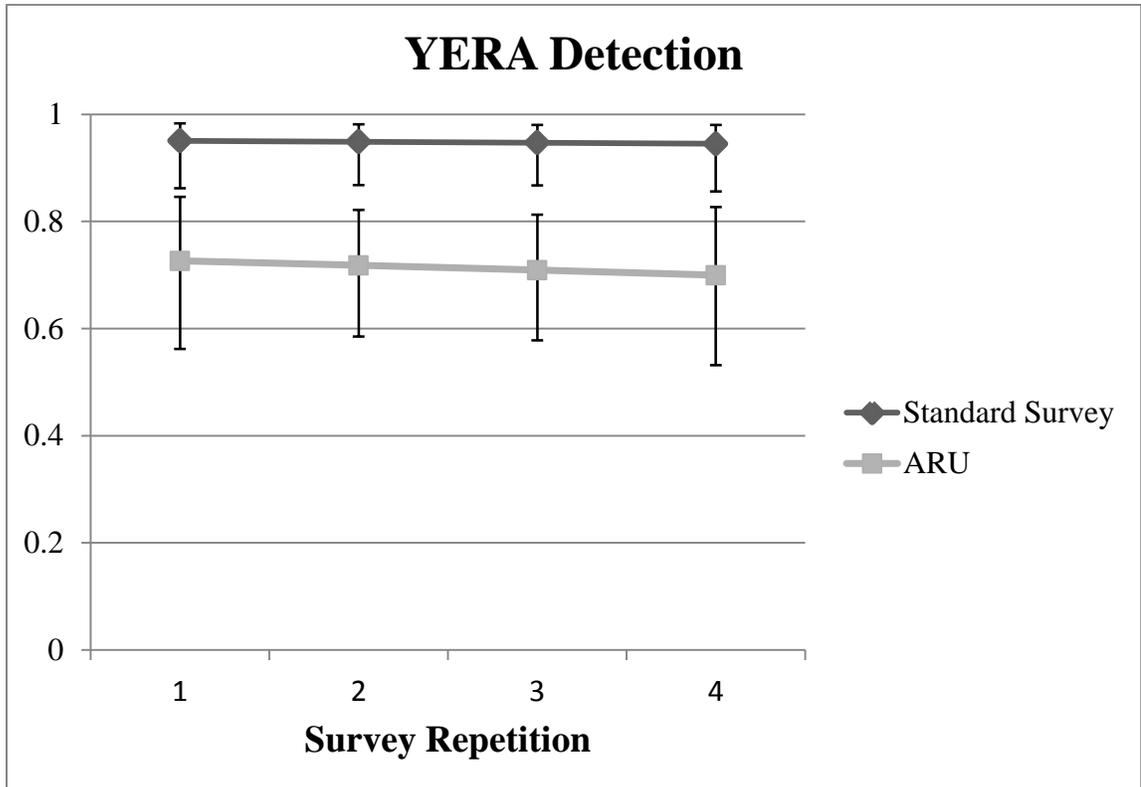
Figure 1.5. Model-averaged parameter estimates and 95% confidence intervals for

detection probabilities determined using ARUs and the standard protocol for LCSP

during 2010 and 2011 in northwest Minnesota and northeast North Dakota, determined

by the second stage of modeling with the robust design occupancy model
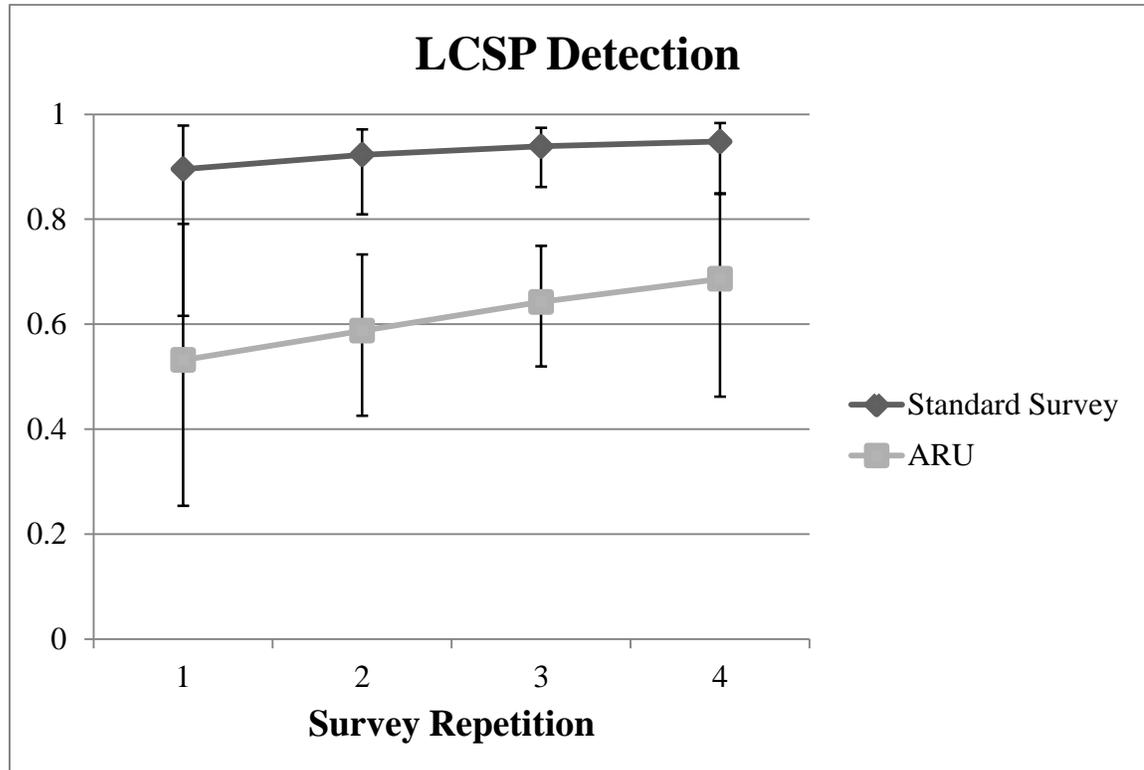
Figure 1.6. Model-averaged parameter estimates and 95% confidence intervals for detection probabilities determined using ARUs and the standard protocol for NESP during 2010 and 2011 in northwest Minnesota and northeast North Dakota, determined by the second stage of modeling with the robust design occupancy model
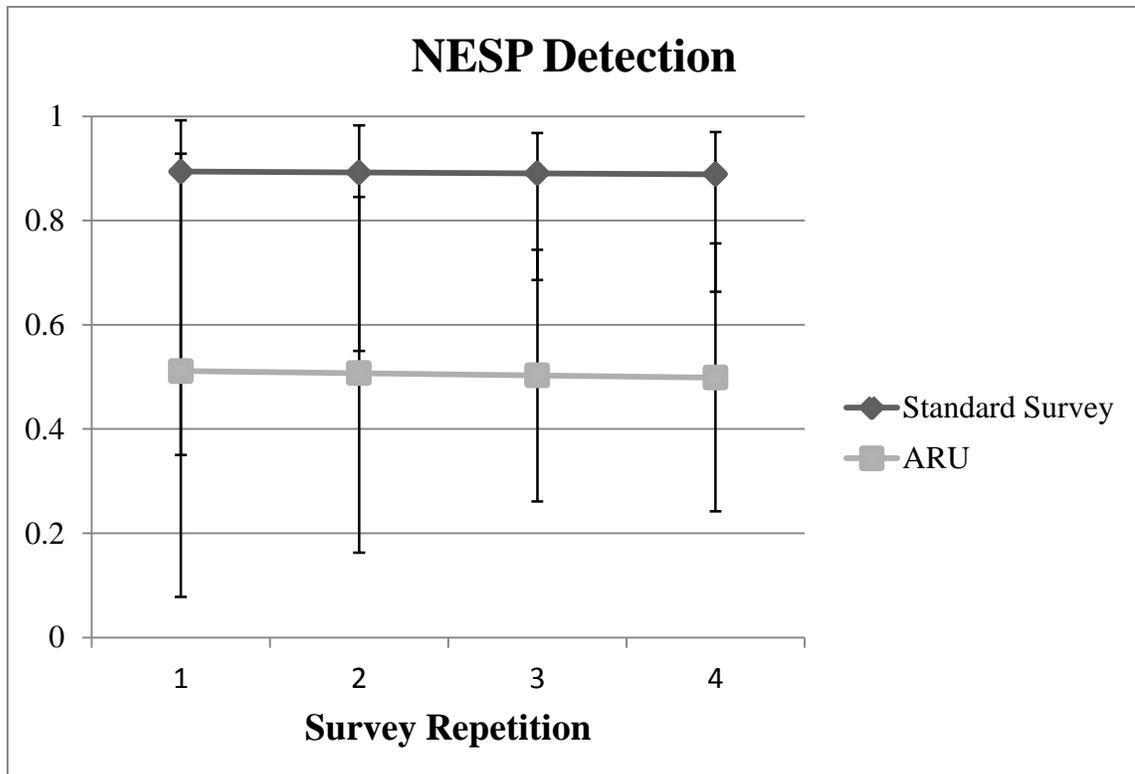
(Appendix A)

Probable Discrepancy Reason Codes: Standard Survey vs. Manual Scan (ARU)

A: Target species was detected during standard survey but was not detected on recording spectrogram during the manual scan. Upon review of the spectrogram, target species call could not be located, even though the standard survey data sheet gives specific minutes when species was supposedly heard calling, most likely because it was too faint to see or hear and to get recorded by the ARU.

-OR-

The standard survey observer *did not* hear target species but recorded it on data sheet, saying it was detected, accidentally.

B: Target species was detected during the standard survey but was not detected on the recording spectrogram during the manual scan. However, upon review of the spectrogram, target species call was located on the spectrogram but was very faint and easily missed by the manual scan observer. C*all was easily missed during the manual scan*, most likely due to call being very faint, and often times due to the combination of a faint call and infrequent calling of species.

C: Target species was detected during the standard survey but was not detected on the recording spectrogram during the manual scan. However, upon review of the spectrogram, target species call was easily located, and was assumed missed due to a *manual scanning error*. Target species' call may be somewhat masked by other species calling, but not unidentifiable on recording/spectrogram.

D: Target species was not detected during the standard survey but was detected on the recording spectrogram during the manual scan. Due to a *standard survey observer error*, observer failed to record a target species as being detected on data sheet, but target species was clearly heard/seen upon review of recording's spectrogram.

E: Target species was detected during the standard survey but was not detected on the recording spectrogram during the manual scan due to extremely loud background noise, such as frogs. Upon review of the spectrogram, target species could not be located. (Similar to A)

F: Target species was detected during the standard survey but was not detected on the recording spectrogram during the manual scan due to extremely loud background noise, such as frogs. However, upon review of the spectrogram target species was located, but the target species call was *very difficult to detect and was easily missed*. (Similar to B)

G: Target species was detected during the standard survey but was not detected on the recording spectrogram. The section of the recording that target species was supposedly calling was missing due to timing of ARU and station survey observer's time being inconsistent, so target species was not located on recording because it was not actually recorded by the ARU. Or, target species was detected during the standard survey but was not detected on the recording spectrogram due to poor quality recording/malfunctioning ARU.
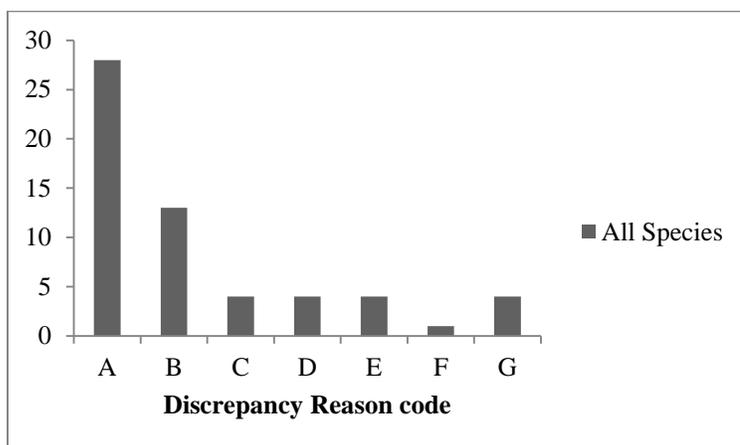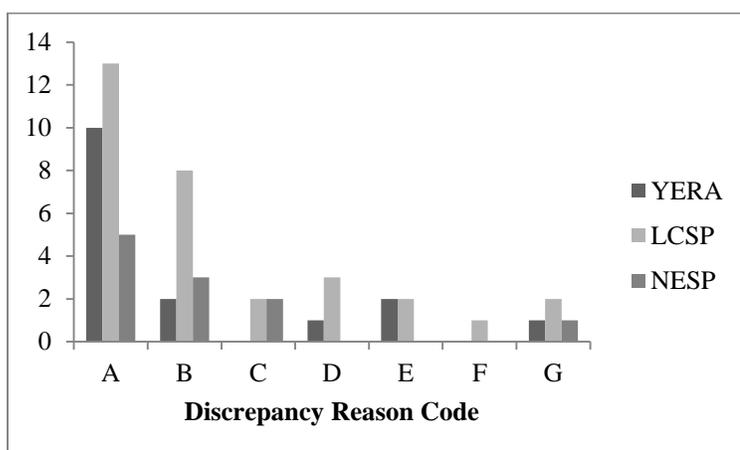
	Species			
	YERA	LCSP	NESP	Total
Detected by Both Survey Methods	55	44	10	109
Detected only by Standard Method (Reason Codes: A, B, C, E, F, G)	15	28	11	54
Detected only by ARU Method (Reason Code: D)	1	3	0	4
Not Detected	101	97	151	349
Total Surveys	172	172	172	516

LITERATURE CITED

Acevedo, M. A., and L. J. Villanueva-Rivera. 2006. Using automated digital recording
systems as effective tools for the monitoring of birds and amphibians. Wildlife
Society Bulletin 34:211-214.

Agranat, I. D. 2007. Automatic detection of cerulean warblers using autonomous
recording units and Song Scope Bioacoustics Software. Wildlife Acoustics, Inc.

_____. 2009. Automatically identifying animal species from their vocalizations. Wildlife
Acoustics, Inc.

Alldredge, M. W., T. R. Simons, and K. H. Pollock. 2007. Factors affecting aural
detections of songbirds. Ecological Applications 17:948-955.

Allmann, L. 1996. Far from tame: reflections from the heart of a continent. University of
Minnesota Press, Minneapolis.

Arnold, T. W. 2010. Uninformative parameters and model selection using Akaike's
information criterion. Journal of Wildlife Management 74:1175-1178.

Beyersbergen, G.W., N.D. Niemuth, and M.R. Norton, coordinators. 2004. Northern
Prairie & Parkland Waterbird Conservation Plan. A plan associated with the
Waterbird Conservation for the Americas initiative. Published by the Prairie
Pothole Joint Venture, Denver, Colorado. 183 pp

Bookhout, Theodore A. 1995. Yellow Rail (*Coturnicops noveboracensis*), The Birds of
North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology;
Retrieved from the Birds of North America Online:
http://bna.birds.cornell.edu/bna/species/139

Bookhout, T. A., and J. R. Stenzel. 1987. Habitat and movements of breeding yellow

    rails. Wilson Bulletin 99:441-447.

Bryce, Sandra. James M. Omernik, David E. Pater, Michael Ulmer, Jerome Schaar, Jerry

    Freeouf, Rex Johnson, Pat Kuck, and Sandra H. Azevedo. 1998. Ecoregions of

    North Dakota and South Dakota. Jamestown, ND: Northern Prairie Wildlife

    Research Center Online.

    <http://www.npwrc.usgs.gov/resource/habitat/ndsdeco/index.htm>

    (Version 30NOV1998).

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a

    practical information-theoretic approach, 2nd ed. Springer, New York.

Celis-Murillo, A., J. L. Deppe, and M. F. Allen. 2009. Using soundscape recordings to

    estimate bird species abundance, richness, and composition. Journal of Field

    Ornithology 80:64-78.

Conway, C. J. 2009. Standardized North American marshbird monitoring protocols. U.S.

    Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit.

Conway, C. J. 2011. Standardized North American marsh bird monitoring protocol.

    Waterbirds 34:319-346.

Conway, C. J., and C. P. Nadeau. 2010. The effects of conspecific and heterospecific

    call-broadcast on detection probability of marsh birds in North America.

    Wetlands 30:358-368.

Devitt, O. E. 1939. The yellow rail breeding in Ontario. Auk 56:238-243.

Eagle, A.C., E.M. Hay-Chmielewski, K.T. Cleveland, A.L. Derosier, M.E. Herbert, and R.A. Rustem, eds. 2005. Michigan's Wildlife Action Plan. Michigan Department of Natural Resources. Lansing, Michigan. 1592 pp. http://www.michigan.gov/dnrwildlifeactionplan

Eddleman, W. R., F. L. Knopf, B. Meanley, F. A. Reid, and R. Zembal. 1988. Conservation of North American rallids. Wilson Bulletin 100:458-475.

Hagen, Sandra K., Patrick T. Isakson, and Steve R. Dyke. 2005. North Dakota Comprehensive Wildlife Conservation Strategy. North Dakota Game and Fish Department. Bismarck, ND. 454 pp. http://www.nd.gov/gnf/conservation/cwcs.html

Haselmayer, J., and J. S. Quinn. 2000. A comparison of point counts and sound recording as bird survey methods in Amazonian Southeast Peru. Condor 102:887-893.

High Plains Regional Climate Center [HPRCC]. 2012. Historical Climate Data Summaries. <http://www.hprcc.unl.edu/data/historical/>. Accessed 1 Jun 2012.

Hobson, K. A., R. S. Rempel, G. Hamilton, B. Turnbull, and S. L. V. Wilgenburg. 2002. Acoustic surveys of birds using electronic recordings: new potential from an omnidirectional microphone system. Wildlife Society Bulletin 30:709-720.

Hutto, R. L., and R. J. Stutzman. 2009. Humans versus autonomous recording units: a comparison of point-count results. Journal of Field Ornithology 80:387-398.

Johnson, W. C., B. V. Millett, T. Gilmanov, R. A. Voldseth, G. R. Guntenspergen, and D. E. Naugle. 2005. Vulnerability of northern prairie wetlands to climate change. BioScience 55(10):863-872.

Kushlan, J. A., M. J. Steinkamp, K. C. Parsons, J. Capp, M. A. Cruz, M. Coulter, I. Davidson, L. Dickson, N. Edelson, R. Elliot, R. M. Erwin, S. Hatch, S. Kress, R. Milko, S. Miller, K. Mills, R. Paul, R. Phillips, J. E. Saliva, B. Sydeman, J. Trapp, J. Wheeler, and K. Wohl. 2002. Waterbird Conservation for the Americas: The North American Waterbird Conservation Plan, Version 1. Waterbird Conservation for the Americas. Washington, DC, U.S.A.

Lowther, Peter E. 2005. Le Conte's Sparrow (*Ammodramus leconteii*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/224

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press San Diego, California, USA.

MacKenzie, D. I., J. D. Nichols, J. E. Hines, M. G. Knutson, and A. B. Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology 84:2200-2207.

Minnesota Department of Natural Resources, 2006. Tomorrow's Habitat for the Wild and Rare: An Action Plan for Minnesota Wildlife, Comprehensive Wildlife Conservation Strategy. Division of Ecological Services, Minnesota Department of Natural Resources.

Minnesota Department of Natural Resources [DNR]. 2012*a*. Minnesota's Biomes. <http://www.dnr.state.mn.us/biomes/index.html>. Accessed 1 Jul 2012.

Minnesota Department of Natural Resources [DNR]. 2012*b*. Ecological Classification System. <http://www.dnr.state.mn.us/ecs/index.html>. Accessed 1 Jul 2012.

Minnesota Department of Natural Resources [DNR]. 2012*c*. Beltrami Island State Forest. <http://www.dnr.state.mn.us/state_forests/sft00005/about.html>. Accessed 1 Jul 2012.

Murray, B. G., Jr. 1969. A comparative study of the Le Conte's and sharp-tailed sparrows. Auk 86:199-231.

Nordhagen, T. J., M. P. Nordhagen, and P. Hendricks. 2005. Nelson's sharp-tailed sparrow nest parasitized by brown-headed cowbird. Wilson Bulletin 117:403-404.

Poiani, K. A., and W. C. Johnson. 1991. Global warming and prairie wetlands. BioScience. 41(9): 611-618.

Robert, M., and P. Laporte. 1997. Field techniques for studying breeding yellow rails. Journal of Field Ornithology 68:56-63.

Rota, C. T., R. J. Fletcher Jr, R. M. Dorazio, and M. G. Betts. 2009. Occupancy estimation and the closure assumption. Journal of Applied Ecology 46:1173-1181.

Shriver, W. Gregory, Thomas P. Hodgman and Alan R. Hanson. 2011. Nelson's Sparrow (*Ammodramus nelsoni*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/719

South Dakota Department of Game, Fish and Parks. 2006. South Dakota Comprehensive Wildlife Conservation Plan. South Dakota Dept. of Game, Fish and Parks, Pierre, Wildlife Division Report 2006-08.

Stern, M. A., J. F. Morawski, and G. A. Rosenberg. 1993. Rediscovery and status of a
   disjunct population of breeding yellow rails in southern Oregon. Condor 95:1024-
   1027.

Swiston, K. A., and D. J. Mennill. 2009. Comparison of manual and automated methods
   for identifying target sounds in audio recordings of pileated, pale-billed, and
   putative ivory-billed woodpeckers. Journal of Field Ornithology 80:42-50.

The Nature Conservancy [TNC]. 2012. Minnesota Glacial Ridge Project.
   <http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/minnesot
   a/placesweprotect/glacial-ridge-project.xml>. Accessed 1 Jul 2012.

Venier, L. A., S. B. Holmes, G. W. Holborn, K. A. McIlwrick, and G. Brown. 2012.
   Evaluation of an automated recording device for monitoring forest birds. Wildlife
   Society Bulletin 36:30-39.

Wisconsin Department of Natural Resources. 2005. Wisconsin's Strategy for Wildlife
   Species of Greatest Conservation Need. Madison, WI.

CHAPTER 2 – ENVIRONMENTAL AND TEMPORAL FACTORS AFFECTING

DETECTION OF YELLOW RAILS, LE CONTE'S SPARROWS, AND NELSON'S

SPARROWS

Marsh bird populations appear to be declining in North America due to the loss of suitable wetlands (Eddleman et al. 1988, Conway et al. 1994). The yellow rail (*Coturnicops noveboracensis*) (YERA) is one of the North America's least-studied birds (Robert and Laporte 1997) and although rarely seen, it may be more abundant than previously thought (Devitt 1939, Stern et al. 1993, Bookhout 1995). Le Conte's sparrows (*Ammodramus leconteii*) (LCSP) and Nelson's sparrows (*Ammodramus nelsoni nelsoni*) (NESP) also frequently nest in the same habitat as YERA (Bookhout 1995). Both of these sparrow species are elusive and secretive (Rising 1996, Lowther 2005, Shriver 2011), and the NESP has been described as one of North America's most-poorly known sparrows (Nordhagen et al. 2005). All three species are listed as "Species of Greatest Conservation Need" (SGCN) in Minnesota (Minnesota Department of Natural Resources 2006), North Dakota (Hagen et al. 2005) and South Dakota (South Dakota Department of Game, Fish and Parks 2006). In Wisconsin, YERA and NESP are listed as SGCN (Wisconsin Department of Natural Resources 2005); and in Michigan, YERA and LCSP are listed as SGCN (Eagle et al. 2005). The YERA has also been listed as a species of "High Concern" in the North American Waterbird Conservation Plan (Kushlan et al. 2002) and the Northern Prairie and Parkland Waterbird Conservation Plan (Beyersbergen et al. 2002).

The Breeding Bird Survey (BBS), an extensive roadside survey program, is designed and implemented to provide long-term data on population trends and status of nesting birds across the United States and Canada (Robbins 1986, Link and Sauer 1998, Sawer et al. 2011). However, this survey has deficiencies associated with it, particularly for wetland and nocturnal species (Gibbs and Melvin 1993, Lawler and O'Connor 2004). As with many other species of marsh birds, YERA may go undetected during traditional passive roadside surveys due to their secretive nature, remote and difficult-to access habitats, and nocturnal calling habits.

Call-broadcast surveys require the broadcast of prerecorded calls to elicit vocalizations. Numerous authors have demonstrated the positive effect of call-broadcast surveys for monitoring many marsh bird species by increasing the detection rate compared to passive surveys (Gibbs and Melvin 1993, Lor and Malecki 2002, Allen et al. 2004, Conway et al. 2004, Conway and Gibbs 2005, Conway and Nadeau 2010). The Standardized North American Marsh Bird Monitoring Protocol (Conway 2009, 2011) was implemented recently to unite survey efforts of secretive marsh birds across the continent. This protocol lists the YERA and NESP as focal species and the LCSP as a non-focal species.

Morning and evening surveys are considered the best for detecting marsh birds with call-broadcast surveys (Conway and Gibbs 2011), but YERA tend to call at night (Devitt 1939, Stenzel 1982, Bookhout and Stenzel 1987, Gibbs et al. 1991, Bookhout 1995, Robert and Laporte 1997) and may be underrepresented. LCSP and NESP have also been known to call at night (Murray 1969, Rising 1996, Lowther 2005, Shriver

2011). I was interested in identifying factors that explain detection probability of these three species and how these factors may be incorporated into existing survey protocols to improve their reliability.

Conway and Gibbs (2011) discussed intrinsic and extrinsic factors affecting detection probability of marsh birds, and suggested important factors that may affect YERA calling and detection, such as time of day, weather conditions, and seasonal variation. Using these suggestions, I hypothesized that the following factors would influence YERA calling and/or detection: time of night, Julian day, temperature, wind speed, precipitation, atmospheric pressure, and moonlight.

STUDY AREA

The project was conducted in northwest Minnesota and northeast North Dakota (Figure 1.1). Survey sites in Minnesota were located at Glacial Ridge National Wildlife Refuge (NWR), Agassiz NWR, and surrounding state Wildlife Management Areas (WMAs), including Thief Lake WMA, and The Nature Conservancy (TNC) land. Survey sites were also located within Beltrami Island State Forest and Red Lake WMA, Roseau River WMA, and Caribou and Beaches Lake WMAs, and the surrounding TNC Wallace C. Dayton Conservation & Wildlife Area. In North Dakota, the survey site was located on state WMAs within Grand Forks County.

A majority of the survey sites were within the Tallgrass Aspen Parkland Biome, which is a mosaic of prairie and saturated sedge wetlands interspersed with groves of

aspen (*Populus* spp.) or bur oaks (*Quercus macrocarpa*) (Minnesota DNR 2012*a*).

Survey sites to the south and west at Glacial Ridge NWR and North Dakota were in

landscapes transitioning to the Prairie Grassland Biome, specifically the Red River

Prairie Subsection (Minnesota DNR 2012*a,b*). Ten thousand years ago, the flat

topography of this area was formed under glacial Lake Agassiz. Today, much of the area

is poorly drained with extensive sedge meadows, calcareous fens, wet prairies, and

peatlands (Allmann 1996). Glacial Ridge NWR is characterized by beach ridges striating

the area with wet and mesic tallgrass prairie, willow thickets, sedge meadows, aspen

stands and emergent wetlands (TNC 2012). The North Dakota survey site was within the

Saline Area sub-ecoregion, characterized by wetlands consisting of saline ground water

welling to the surface (Bryce et al. 1998). The eastern extent of the study area was within

the Beltrami Island State forest, which included the Red Lake WMA. At one time, the

forest may have been an island in the ancient Lake Agassiz, with the lake's shores

creating low sandy ridges. Today, the ridges are covered by pine and surrounded by

lowlands and peat bogs (Minnesota DNR 2012*c*).

Saturated wetlands are primarily ground-water systems, but average annual

precipitation for this area was 53.8 cm, and the average precipitation during the study

period of March through July was 29.3 cm. The average maximum and minimum May

through June temperatures (°C) are 21.8 and 7.6 (HPRCC 2012).

METHODS

I conducted my study from 1 May to 30 June, 2010 and 2011. I established eight

survey routes per year, each consisting of 10-11 survey stations, and located survey

stations mostly along roads, although some stations required walking to gain access. Routes were chosen by consulting with area managers and local birders, using observations in the Minnesota DNR's Natural Heritage Information System, and scouting for characteristic saturated wetland habitat on public lands.

Twenty-two SM-1 ARUs (built by Wildlife Acoustics, Inc.) were deployed each field season. One to four ARUs were deployed per route at survey stations at the beginning of the season. Each ARU was set to record from 2000 until 0800 every night for 10 of every 15 minutes.

I constructed wooden boxes that were just large enough to slide the unit in from the top with the microphones extending out to protect the ARUs in the field and elevate them about 1 m off the ground. Boxes were mounted on a 1.5 m metal fence post that was pushed into the ground no further than 0.4 m, which allowed for removal at the end of the season.

Data were stored on 16 gigabyte (GB) secure digital (SD) cards in the SM-1 units. Song Meter Configuration Utility 1.9.2 (Wildlife Acoustics, Inc.) was used on a laptop computer to program a recording schedule onto ARUs instead of manually programming each unit. This schedule allowed for 13 days of recording before SD cards were full, at which time they were replaced and downloaded onto an external hard drive for storage. I replaced ARU batteries (four D-cells) at the same time that SD cards were changed, and re-used SD cards after downloading.

Call-broadcast surveys were conducted along survey routes four times throughout the season. I used the call-broadcast protocol as described in the Standardized North American Marsh Bird Monitoring Protocol (Conway 2009, 2011), which started one hour after sunset. Each survey consisted of five minutes of passive listening, 30 seconds of broadcasted YERA calls, followed by 30 seconds of passive listening. If after the early and late May round of surveys, none or very few target species were detected at ARU stations, I relocated ARUs to survey sites with known target species calling to insure that I acquired a large sample of recorded of target species calls. I did not move ARUs after the early-June surveys were started.

I collected recordings from 53 sites over the 2 field seasons; however I only used recordings for this analysis from 43 sites where target species were previously detected while conducting call-broadcast surveys. I used data from in between the first and last detection of target species from each site to reduce potential bias associated with local extinction and colonization at survey sites during the field season; that is, only sites where target species were detected ≥2 times were used.

I manually scanned digital ARU recordings by visually examining the spectrogram and listening to segments of the recording to detect calling of any target species calling. I subsampled recordings; sampling the first three minutes of every third hour of every third night per ARU-site. I staggered hours and days sampled among neighboring ARUs so that they were not sampled on the same schedule and documented the presence or absence of target species for each recording.

I collected hourly weather data from 11 weather stations in the vicinity of ARUs for every day of both field seasons. These data were downloaded from the Real-time Observation Monitor and Analysis Network (ROMAN) website (ROMAN 2012). Different types of weather stations with varying amounts and types of data were available, so I combined data from multiple stations to compile a complete data set of environmental factors. Variables of interest included: wind speed (km/hr), precipitation (yes or no), temperature (°C), atmospheric pressure (mb), and moonlight (illumination index). I calculated the illumination index by multiplying the percent of sky not obscured by cloud cover (1- cloud cover) by percent of moon illuminated, and then multiplied that by 1 if the moon had risen and the sun was down; otherwise I multiplied the product by 0.

STATISTICAL ANALYSES

I used generalized linear mixed models (package lme4) in R (R Development Core Team 2011), version 2.15.0 (Bates et al. 2012) to evaluate sources of variation in species detection (YERA, LCSP, and NESP, where 0 = non-detection and 1 = detection of target species). For each response variable (YERA, LCSP, or NESP), I considered 8 potential covariates: (1) year (YEAR), (2) Julian day (DATE), (3) precipitation (PRECIP), (4) temperature (TEMP), (5) wind speed (WIND), (6) atmospheric pressure (PRESSURE), (7) moonlight (MOON), and (8) hours after sunset (TIME; Table 2.1). DATE and PRESSURE data were standardized for analysis by centering the data around their means. I controlled for ARU site specific habitat variation by including "station" as an *a priori* random effect in all models.

I used Pearson's correlation tests to determine if any covariates were correlated, and did not used two covariates in the same model if the score was $\leq$ -0.7 or $\geq$ 0.7. I used a forward selection approach to model-fitting because of small sample size to avoid over fitting of models. For detection, I began with a null model that included an intercept and a random effect for station. To this model I added each of the 8 covariates individually and ranked these models on the basis of Akaike's information criterion corrected for small sample size (AIC_c). After each step, I rejected any uninformative covariates that led to an increase in AIC_c scores (Arnold 2010). If more than one covariate reduced AIC_c compared to the null model, the model with the least AIC_c value was used as a base model for considering additional, non-rejected covariates. Quadratic terms (e.g., $TIME^2$) and interaction terms (e.g., TIME*WIND) were also considered if deemed reasonable. When additional covariates no longer led to a reduction in AIC_c, the best supported model from the previous step was kept as the top supported model.

I created prediction graphs for the variables of the best supported model for each species. These graphs include uncertainty due to the fixed effects only, and the 95% prediction intervals represent the probability of detecting an individual at an average site; they do not account for the uncertainty in the random effects of station.

RESULTS

Pearson's correlation tests indicated no covariate pairs had scores that were $\leq$ -0.7 or $\geq$ 0.7. I obtained presence/absence data for three species (YERA, LCSP, and NESP)

from 3,035 three minute recordings collected by ARUs deployed at 43 different survey

stations in northwest Minnesota and northeast North Dakota during 2010 and 2011.

Using only data with ≥2 detections, the dataset included 565 YERA detections from 32

stations, 932 LCSP detections from 39 stations, and 123 NESP detections from 20

stations.

The best approximating model for YERA detection using ARUs included a

quadratic term for TIME (TIME^2). YERA are more likely to be detected in the middle of

the night and less likely closer to sunset or sunrise (Figure 2.2). YERA detection

probability declined with increasing wind speeds (Figure 2.3) and advancing calendar

date (Figure 2.4). YERA detection also declined with precipitation, with detection

probabilities estimated at 0.63 (95% CI = 0.55 and 0.71) if there was no precipitation

versus 0.47 (95% CI = 0.36 and 0.59) if there was precipitation.

The best approximating model for LCSP also included a quadratic term for TIME

(TIME^2). LCSP had a slightly higher detection probability before sunset, but they were

more likely to be detected as night progressed and sunrise approached (Figure 2.5).

LCSP detection decreased with increased wind speeds (Figure 2.6) and with advancing

calendar date (Figure 2.7). Detection increased slightly with percent moonlight (Figure

2.8).

The best approximating model for NESP included the covariates PRECIP, DATE,

WIND, and MOON. Detection probabilities estimated for NESP were 0.22 (95% CI =

0.16 and 0.30) if there was no precipitation and 0.08 (95% CI = 0.03 and 0.16) if there

was precipitation. Detection for NESP decreased as wind speed increased (Figure 2.9).

Julian date was related to detection in a quadratic fashion, with a short, optimal time for

detection around 7 June (Figure 2.10). The best approximating model indicated a slight

increase in NESP detection with the increase of percent moonlight (Figure 2.11).

Parameter estimates with standard errors for all three species are provided in Table 2.2.

DISCUSSION

Quantifying factors that affect detectability of YERA, LCSP and NESP is

essential to the refinement of survey methods, especially for birds that are known to be

secretive and difficult to detect. Accounting for these factors in standard survey

protocols will improve survey reliability, accelerate learning about population trends, and

help identify key habitat areas.

My results indicated that detection of YERA was strongly affected by the time of

night the survey was conducted. Many sources have stated that YERA are mostly a

nocturnal species (Devitt 1939, Stenzel 1982, Bookhout and Stenzel 1987, Gibbs et al.

1991, Bookhout 1995, Robert and Laporte 1997), and I was able to confirm this by

determining that peak calling for YERA was 3 to 5 hours after sunset. At times when

most standard surveys are done, near sunrise or sunset, YERA detection probability was

less than 20%, compared to 60% in the middle of the night. Conducting call-broadcast

surveys may help to elicit a YERA response during these lower probability times

(Conway and Nadeau 2010); however, the highest probability of detection, even without broadcasting calls, is in the middle of the night.

Time of night also affected detectability of LCSP, but in an opposite fashion than with YERA. LCSP call at night, but were more likely to be detected during traditional survey hours in the morning, which was consistent with other published studies (Murray 1969, Rising 1996, Lowther 2005). Time of night of the survey was not an important factor in NESP detection; however, my sample sizes of NESP were small. Although not significant, most detections of NESP occurred between 0 and 3 hours after sunset, with a small peak increase in detections near sunrise. There may be more NESP calling during the busy dawn chorus, but they may go undetected when scanning the recording because their call is less strident than other species'. Thus, they are most likely detected when the recording has minimal background noise, which is most often at night. Other researchers (Murray 1969, Rising 1996, Shriver 2011) also reported that NESP commonly call at night.

Detection of all three species was negatively affected by wind speed. This may have been due to interference of wind noise across the microphones of the ARU. With higher wind speed, there was more "static" on the recordings, which caused difficulties in hearing target birds or visually identifying their calls on the spectrogram. Wind noise may inhibit detection of birds even during standard point count surveys in the field. The Standardized North American Marsh Bird Monitoring Protocol (Conway 2009, 2011) recommends only conducting surveys when wind speed is <20 km/hr. Conway (2009,

2011) further suggests that winds not only affect the detection probability of marsh birds, but potentially affect the calling probability as well.

The influence of moonlight was suspected to be important, and has been shown to affect the detection of other nocturnal calling species (Hardy and Morrison 2000, Wilson and Watts 2006) and other marsh birds (Spear et al. 1999). My results indicate that moonlight did not affect YERA detection, but had slight positive influences on LCSP and NESP detection probabilities. I conducted an additional analysis to confirm these findings, by running the data for nocturnal hours only. Indeed, moonlight remained in the model for LCSP, confirming that it does matter when it is the only light source; however, moonlight was not retained in the NESP model.

A potential limitation of my NESP model was the relatively small number of detections. In the data set, there were 565 YERA detections from 32 stations, 932 LCSP detections from 39 stations, but only 123 NESP detections from 20 stations. Small sample sizes may reduce precision and power to detect the effect of environmental covariates on vocalization. Another potential limitation of my analysis is the distance of weather stations from ARUs. I tried to collect hourly weather data from stations that were close to the ARUs, but some of the ARUs in more remote areas were as far as 38 km from the nearest weather station. Thus, if data from stations far from the ARU sites did not reflect conditions experienced at the site, estimates could be biased accordingly.

MANAGEMENT IMPLICATIONS

It is clear that traditional morning or evening bird surveys will not offer the best chance of detecting YERA. Surveys for YERA should be conducted 3 to 5 hours after sunset. A practical way of surveying YERA at night is to use ARUs, which can be left unattended in the field. ARUs may provide information on the presence/absence of YERA, estimates of frequency of occurrence, and calling intensity. ARUs are fully compatible with occupancy modeling for presence/absence data, but if investigators want to estimate abundance they may not be the best tool (Chapter 1, this volume). Peak calling time information can be used to refine recording schedules on ARUs so to be able to save on digital data storage space and battery life, as well as time spent in the field maintaining ARUs. If project goals are to determine the presence of LCSP and/or NESP, night time surveys targeting YERA will suffice; it is likely to detect these sparrow species even if the only targeted bird is the YERA. However, traditional morning surveys are optimal for LCSP detection, and standard morning surveys are sufficient. If project goals are to determine the presence of NESP, seasonal differences in calling activity from the other species should be considered.

FIGURES AND TABLES
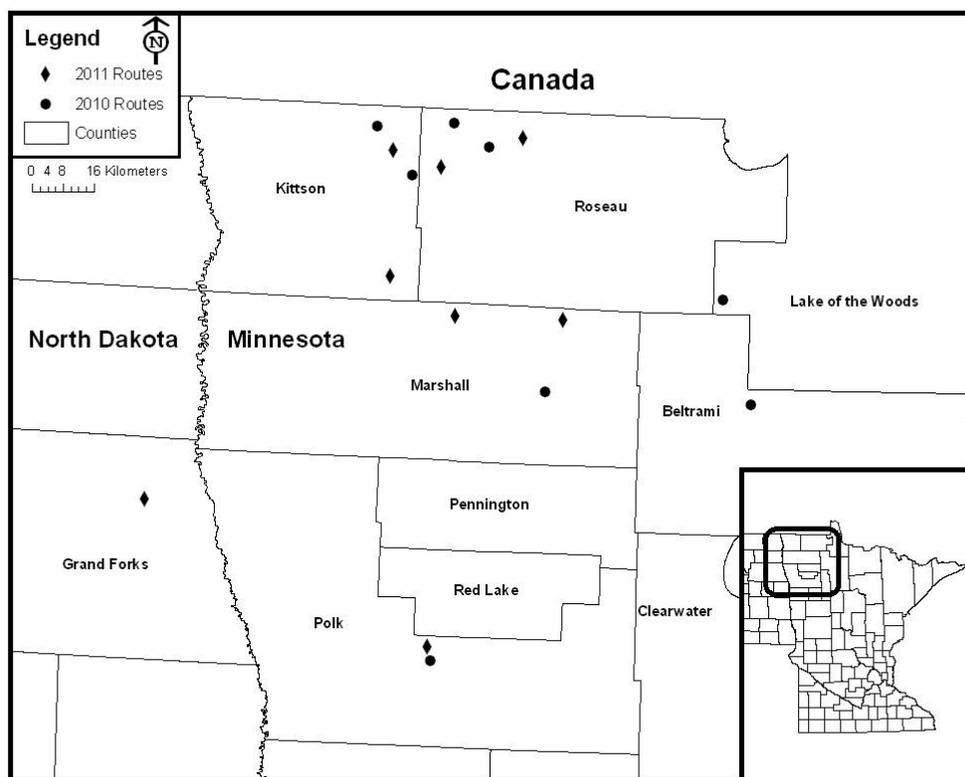
Figure 2.1. Study area for determining factors affecting detection probabilities for YERA, LCSP, and NESP in saturated wetlands of northwest Minnesota and northeast North Dakota. Circles represent approximate locations of survey routes conducted in 2010, and diamonds represent approximate locations of survey routes conducted in 2011. Each survey route consisted of 10-11 survey stations, and ARUs were placed at 1-4 survey stations per survey route

Table 2.1. Variables, measured as fixed effects, used to estimate detection probability for

YERA, LCSP, and NESP during 2010 and 2011 in northwest Minnesota and northeast

North Dakota

Variables		Mean	SD	Range
YEAR	Year (0 = 2010, 1 = 2011)	.	.	.
DATE, DATE^2	Julain day (1 = 1 May)	.	.	.
PRECIP	Precipitation (1 = yes, 0 = no)	.	.	.
TEMP	Temperature (C°)	12.6	5.2	-4.4 to 28
WIND	km/hr	11.0	7.7	0 to 46.8
PRESSURE	Atmospheric pressure (mb)	976.4	8.4	938.6 to 1014.8
MOON	% Moonlight	.	.	.
TIME, TIME^2	Hours after sunset	.	.	.

Table 2.2. Top model parameter estimates and standard errors for variables used to estimate detection probability for YERA, LCSP, and NESP during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Models were selected using a forward selection approach to model-fitting and were ranked on the basis of Akaike's information criterion corrected for small sample sizes (AIC$_c$).

	YERA		LCSP		NESP	
	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	-0.4369	0.2145	-0.3902	0.1794	-0.9505	0.2623
YEAR	.	.	.	.	.	.
DATE	-0.0150	0.0048	-0.0101	0.0033	-0.0147	0.0112
DATE^2	.	.	.	.	-0.0027	0.0008
PRECIP	-0.6498	0.1910	.	.	-1.2421	0.4182
TEMP	.	.	.	.	.	.
WIND	-0.0609	0.0094	-0.0497	0.0070	-0.0334	0.0148
PRESSURE	.	.	.	.	.	.
MOON	.	.	0.0057	0.0017	0.0077	0.0035
TIME	0.7927	0.0635	-0.0160	0.0428	.	.
TIME^2	-0.0947	0.0071	0.0145	0.0047	.	.

Figure 2.2. Effects of the time of night on the detection probability of YERA during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where YERA presence/absence was modeled as a function of hours after sunset. $YERA = \beta_0 + \beta_1 * TIME + \beta_2 * TIME^2$, where $\beta_0 = -0.44 \pm 0.21$ [SD], $\beta_1 = 0.79 \pm 0.06$, and $\beta_2 = -0.09 \pm 0.01$. Dotted lines indicate $\pm SE$. The vertical gray bar indicates approximate sunrise times.
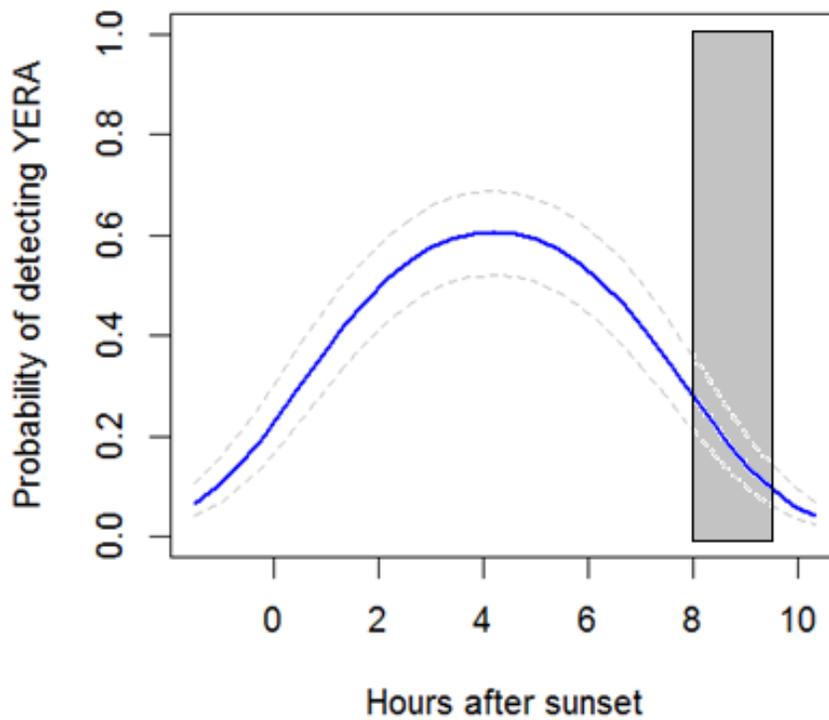
Figure 2.3. Effects of wind speed on the detection probability of YERA during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where YERA presence/absence was modeled as a function of wind speed. YERA = $\beta_0 + \beta_1 * WIND$, where $\beta_0 = -0.44 \pm 0.21$ [SD], $\beta_1 = -0.06 \pm 0.01$. Dotted lines indicate $\pm$SE.
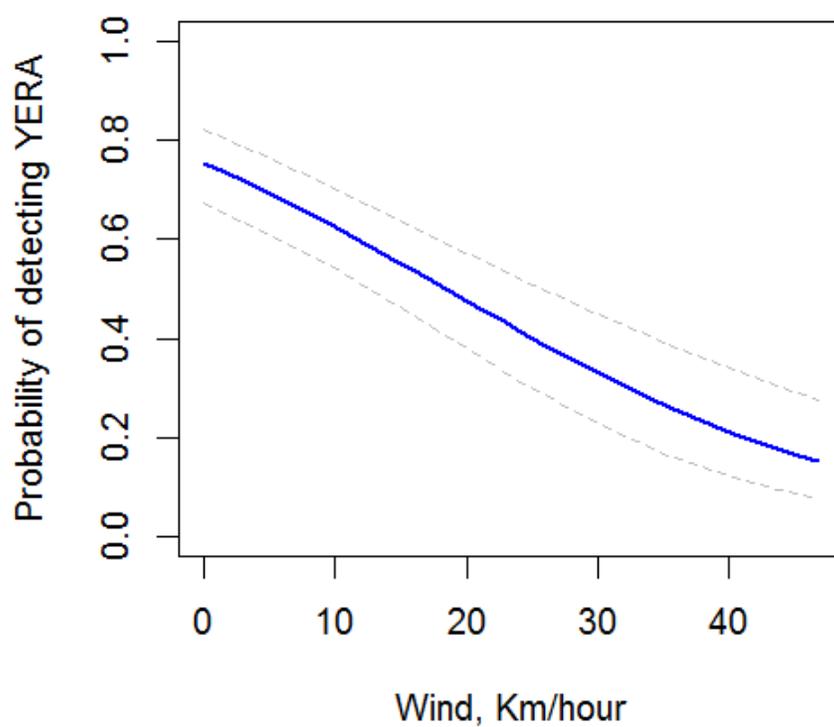
Figure 2.4.   Effects of Julian date on the detection probability of YERA during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where YERA presence/absence was modeled as a function of Julian date. YERA = $\beta_0 + \beta_1$ * DATE, where $\beta_0 = -0.44 \pm 0.21$ [SD], $\beta_1 = -0.02 \pm 0.01$. Dotted lines indicate ±SE.
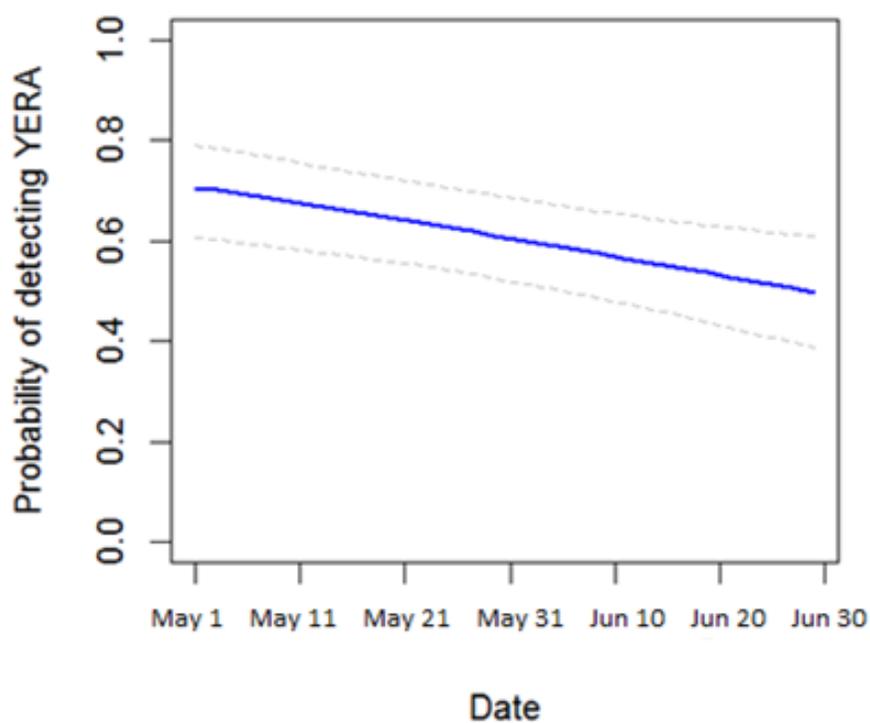
Figure 2.5.   Effects of the time of night on the detection probability of LCSP during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where LCSP presence/absence was modeled as a function of hours after sunset. LCSP = $\beta_0 + \beta_1 * TIME + \beta_2 * TIME^2$, where $\beta_0 = -0.39 \pm 0.18$ [SD], $\beta_1 = -0.02 \pm 0.04$, and $\beta_2 = 0.01 \pm 0.01$. Dotted lines indicate $\pm$SE. The vertical gray bar indicates approximate sunrise times.
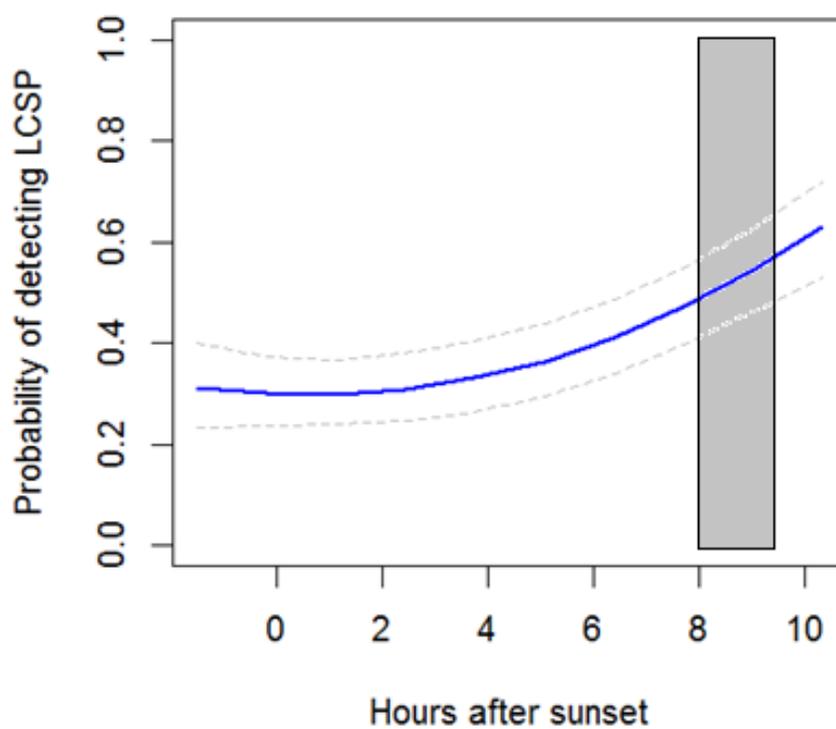
Figure 2.6. Effects of wind speed on the detection probability of LCSP during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where LCSP presence/absence was modeled as a function of wind speed. LCSP = $\beta_0 + \beta_1$ * WIND, where β_0 = -0.39 ± 0.18 [SD], β_1 = -0.05 ± 0.01. Dotted lines indicate ±SE.
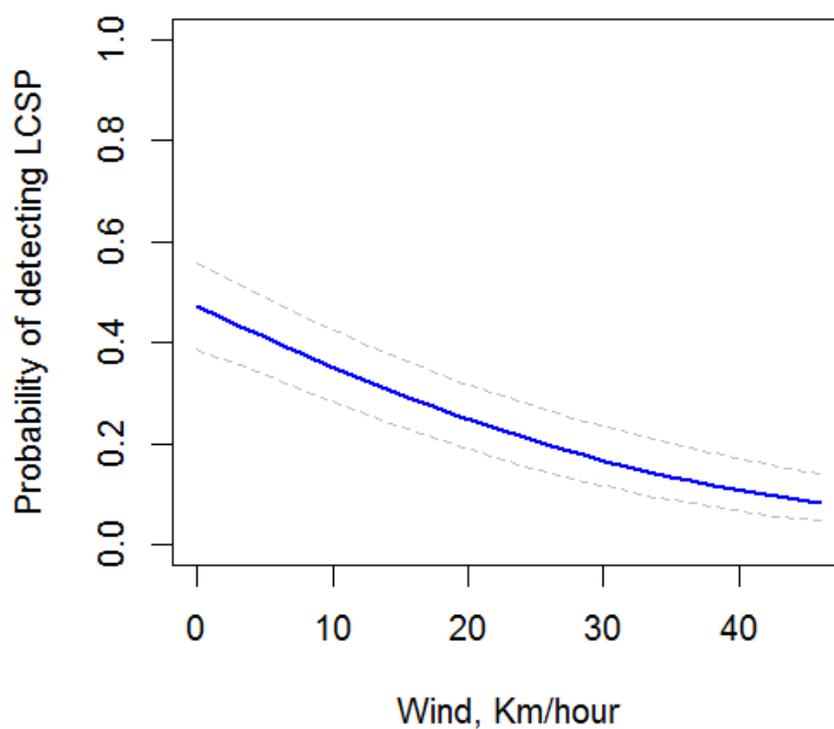
Figure 2.7. Effects of Julian date on the detection probability of LCSP during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where LCSP presence/absence was modeled as a function of Julian date. $LCSP = \beta_0 + \beta_1 * DATE$, where $\beta_0 = -0.39 \pm 0.18$ [SD], $\beta_1 = -0.01 \pm 0.003$. Dotted lines indicate $\pm SE$.
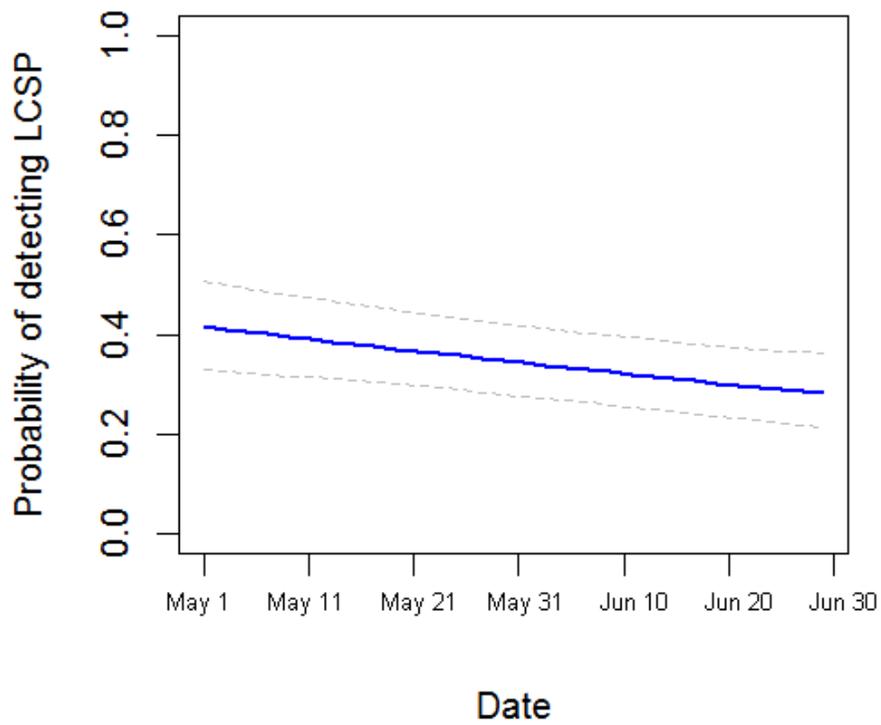
Figure 2.8. Effects of moonlight on the detection probability of LCSP during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where LCSP presence/absence was modeled as a function of moonlight. $LCSP = \beta_0 + \beta_1 * MOON$, where $\beta_0 = -0.39 \pm 0.18$ [SD], $\beta_1 = 0.01 \pm 0.002$. Dotted lines indicate $\pm SE$.
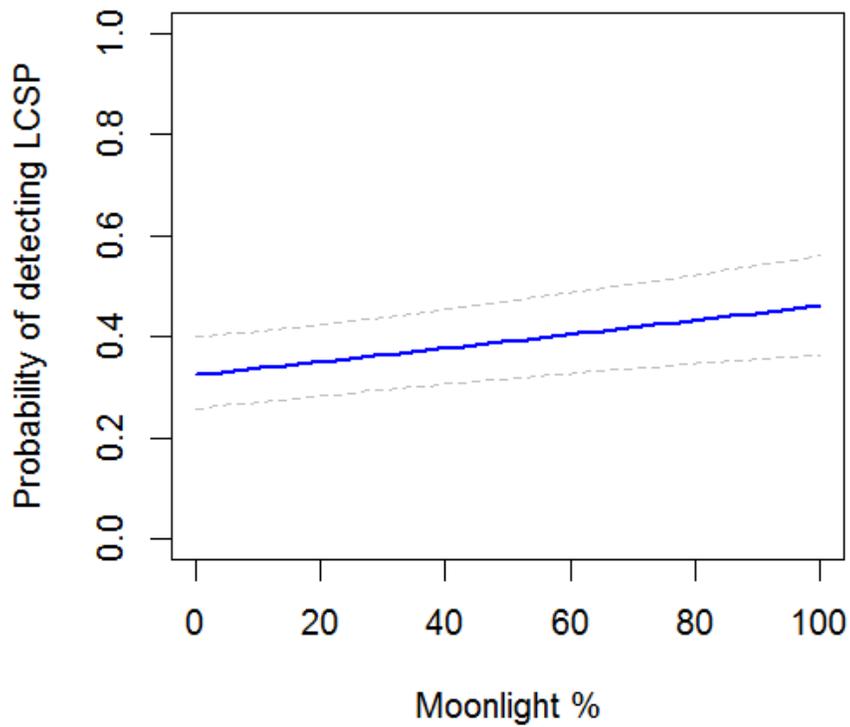
Figure 2.9. Effects of wind speed on the detection probability of NESP during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where NESP presence/absence was modeled as a function of wind speed. $NESP = \beta_0 + \beta_1 * WIND$, where $\beta_0 = -0.95 \pm 0.26$ [SD], $\beta_1 = -0.03 \pm 0.01$. Dotted lines indicate $\pm SE$.

Figure 2.10. Effects of Julian date on the detection probability of NESP during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where NESP presence/absence was modeled as a function of Julian date. $NESP = ß_0 + ß_1 * DATE + ß_2 * DATE^2$, where $ß_0 = -0.95 \pm 0.26$ [SD], $ß_1 = -0.01 \pm 0.01$, and $ß_2 = -0.003 \pm 0.001$. Dotted lines indicate $\pm SE$.
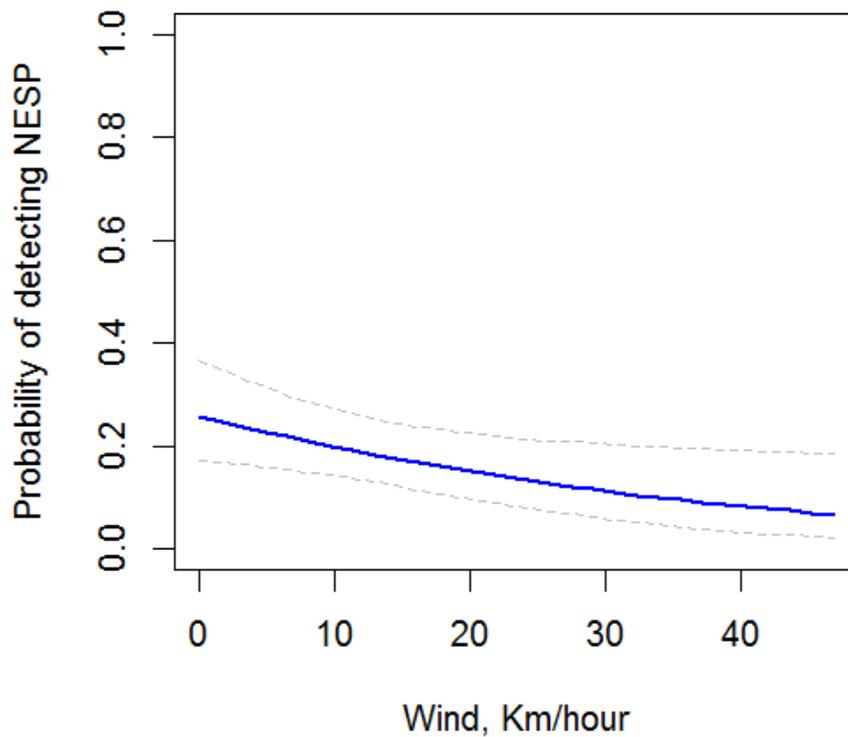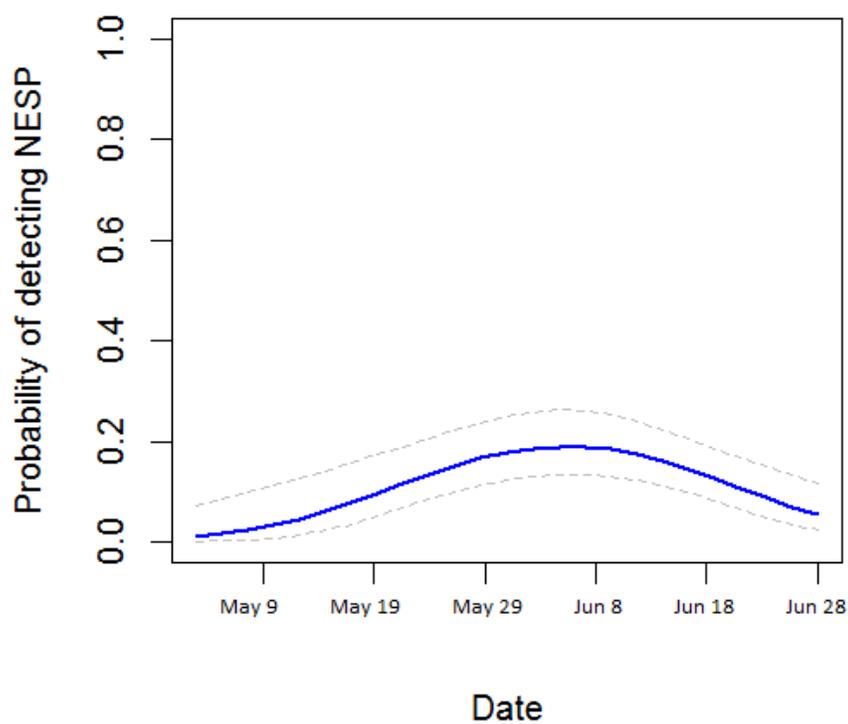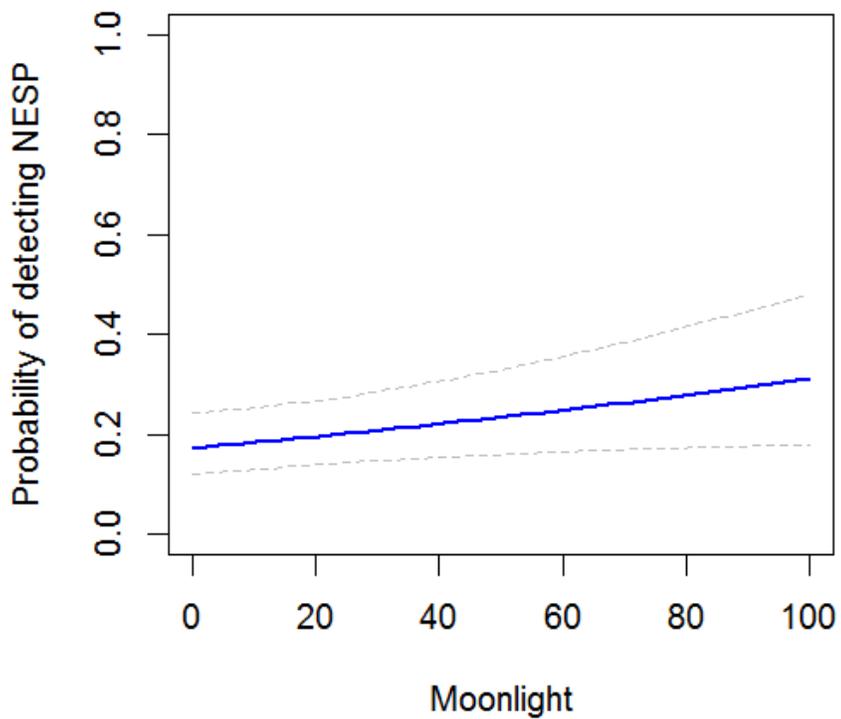
Figure 2.11. Effects of moonlight on the detection probability of NESP during 2010 and 2011 in northwest Minnesota and northeast North Dakota. Regression line represents the linear model where NESP presence/absence was modeled as a function of moonlight. $NESP = \beta_0 + \beta_1 * MOON$, where $\beta_0 = -0.95 \pm 0.26$ [SD], $\beta_1 = 0.01 \pm 0.004$. Dotted lines indicate $\pm SE$.

LITERATURE CITED

Allen, T., S. L. Finkbeiner, and D. H. Johnson. 2004. Comparison of detection rates of breeding marsh birds in passive and playback surveys at Lacreek National Wildlife Refuge, South Dakota. Waterbirds 27:277-281.

Allmann, L. 1996. Far from tame: reflections from the heart of a continent. University of Minnesota Press, Minneapolis.

Arnold, T. W. 2010. Uninformative parameters and model selection using Akaike's information criterion. Journal of Wildlife Management 74:1175-1178.

Bates, D., M. Maechler, and B. Bolker. 2012. Linear mixed-effects models using S4 classes. http://cran.R-project.org/package=lme4. R package version 0.999375-42.

Beyersbergen, G.W., N.D. Niemuth, and M.R. Norton, coordinators. 2004. Northern Prairie & Parkland Waterbird Conservation Plan. A plan associated with the Waterbird Conservation for the Americas initiative. Published by the Prairie Pothole Joint Venture, Denver, Colorado. 183 pp

Bookhout, Theodore A. 1995. Yellow Rail (*Coturnicops noveboracensis*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/139

Bookhout, T. A., and J. R. Stenzel. 1987. Habitat and movements of breeding yellow rails. Wilson Bulletin 99:441-447.

Bryce, Sandra. James M. Omernik, David E. Pater, Michael Ulmer, Jerome Schaar, Jerry Freeouf, Rex Johnson, Pat Kuck, and Sandra H. Azevedo. 1998. Ecoregions of

North Dakota and South Dakota. Jamestown, ND: Northern Prairie Wildlife

Research Center Online.

<http://www.npwrc.usgs.gov/resource/habitat/ndsdeco/index.htm>

(Version 30NOV1998).

Conway, C., and J. Gibbs. 2011. Summary of intrinsic and extrinsic factors affecting

detection probability of marsh birds. Wetlands 31:403-411.

Conway, C. J. 2009. Standardized North American marshbird monitoring protocols. U.S.

Geological Survey, Arizona Cooperative Fish ans Wildlife Research Unit.

Conway, C. J. 2011. Standardized North American marsh bird monitoring protocol.

Waterbirds 34:319-346.

Conway, C. J., W. R. Eddleman, and S. H. Anderson. 1994. Nesting success and survival

of virginia rails and soras. Wilson Bulletin 106:466-473.

Conway, C. J., and J. P. Gibbs. 2005. Effectiveness of call-broadcast surveys for

monitoring marsh birds. Auk 122:26-35.

Conway, C. J., and C. P. Nadeau. 2010. The effects of conspecific and heterospecific

call-broadcast on detection probability of marsh birds in North America.

Wetlands 30:358-368.

Conway, C. J., C. Sulzman, and B. E. Raulston. 2004. Factors affecting detection

probability of California black rails. Journal of Wildlife Management 68:360-370.

Devitt, O. E. 1939. The yellow rail breeding in Ontario. The Auk 56:238-243.

Eagle, A.C., E.M. Hay-Chmielewski, K.T. Cleveland, A.L. Derosier, M.E. Herbert, and

R.A. Rustem, eds. 2005. Michigan's Wildlife Action Plan. Michigan Department

of Natural Resources. Lansing, Michigan. 1592 pp.

http://www.michigan.gov/dnrwildlifeactionplan

Eddleman, W. R., F. L. Knopf, B. Meanley, F. A. Reid, and R. Zembal. 1988. Conservation of North American rallids. Wilson Bulletin 100:458-475.

Gibbs, J. P., and S. M. Melvin. 1993. Call-response surveys for monitoring breeding waterbirds. Journal of Wildlife Management 57:27-34.

Gibbs, J. P., W. G. Shriver, and S. M. Melvin. 1991. Spring and summer records of the yellow rail in Maine. Journal of Field Ornithology 62:509-516.

Hagen, Sandra K., Patrick T. Isakson, and Steve R. Dyke. 2005. North Dakota Comprehensive Wildlife Conservation Strategy. North Dakota Game and Fish Department. Bismarck, ND. 454 pp.

http://www.nd.gov/gnf/conservation/cwcs.html

Hardy, P. C., and M. L. Morrison. 2000. Factors affecting the detection of elf owls and western screech owls. Wildlife Society Bulletin 28:333-342.

High Plains Regional Climate Center [HPRCC]. 2012. Historical Climate Data Summaries. <http://www.hprcc.unl.edu/data/historical/>. Accessed 1 Jun 2012.

Kushlan, J. A., M. J. Steinkamp, K. C. Parsons, J. Capp, M. A. Cruz, M. Coulter, I. Davidson, L. Dickson, N. Edelson, R. Elliot, R. M. Erwin, S. Hatch, S. Kress, R. Milko, S. Miller, K. Mills, R. Paul, R. Phillips, J. E. Saliva, B. Sydeman, J. Trapp, J. Wheeler, and K. Wohl. 2002. Waterbird Conservation for the Americas: The North American Waterbird Conservation Plan, Version 1. Waterbird Conservation for the Americas. Washington, DC, U.S.A.

Lawler, J. J., and R. J. O'Connor. 2004. How well do consistently monitored breeding

    bird survey routes represent the environments of the conterminous United States?

    Condor 106:801-814.

Link, W. A., and J. R. Sauer. 1998. Estimating popoulation change from count data:

    application to the north american breeding bird survey. Ecological Applications

    8(2):258-268.

Lor, S., and R. A. Malecki. 2002. Call-response surveys to monitor marsh bird population

    trends. Wildlife Society Bulletin 30:1195-1201.

Lowther, Peter E. 2005. Le Conte's Sparrow (*Ammodramus leconteii*), The Birds of

    North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology;

    Retrieved from the Birds of North America Online:

    http://bna.birds.cornell.edu/bna/species/224

Minnesota Department of Natural Resources, 2006. Tomorrow's Habitat for the Wild and

    Rare: An Action Plan for Minnesota Wildlife, Comprehensive Wildlife

    Conservation Strategy. Division of Ecological Services, Minnesota Department of

    Natural Resources.

Minnesota Department of Natural Resources [DNR]. 2012*a*. Minnesota's Biomes.

    <http://www.dnr.state.mn.us/biomes/index.html>. Accessed 1 Jul 2012.

Minnesota Department of Natural Resources [DNR]. 2012*b*. Ecological Classification

    System. <http://www.dnr.state.mn.us/ecs/index.html>. Accessed 1 Jul 2012.

Minnesota Department of Natural Resources [DNR]. 2012*c*. Beltrami Island State

    Forest. <http://www.dnr.state.mn.us/state_forests/sft00005/about.html>.

    Accessed 1 Jul 2012.

Murray, B. G., Jr. 1969. A comparative study of the Le Conte's and sharp-tailed sparrows. Auk 86:199-231.

Nordhagen, T. J., M. P. Nordhagen, and P. Hendricks. 2005. Nelson's sharp-tailed sparrow nest parasitized by brown-headed cowbird. Wilson Bulletin 117:403-404.

R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/

Real-time Observation Monitor and Analysis Network [ROMAN]. 2012. Current weather summaries. < http://raws.wrh.noaa.gov/roman/>. Accessed 1 Jun 2012.

Rising, J. D. 1996. A guide to the identification and natural history of the sparrows of the United States and Canada. Academic Press, San Diego, California.

Robbins, C. S., D. Bystrak, and P. H. Geissler. 1986. The Breeding Bird Survey: its first fifteen years, 1965-1979. Fish and Wildlife Service Resources Publication, Washington, DC.

Robert, M., and P. Laporte. 1997. Field techniques for studying breeding yellow rails. Journal of Field Ornithology 68:56-63.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, Results and Analysis 1966 - 2010. Version 12.07.2011 USGS Patuxent Wildlife Research Center, Laurel, MD

Shriver, W. Gregory, Thomas P. Hodgman and Alan R. Hanson. 2011. Nelson's Sparrow (*Ammodramus nelsoni*), The Birds of North America Online (A. Poole, Ed.).

Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America

Online: http://bna.birds.cornell.edu/bna/species/719

South Dakota Department of Game, Fish and Parks. 2006. South Dakota

Comprehensive Wildlife Conservation Plan. South Dakota Dept. of Game, Fish

and Parks, Pierre, Wildlife Division Report 2006-08.

Spear, L. B., S. B. Terrill, C. Lenihan, and P. Delevoryas. 1999. Effects of temporal and

environmental factors on the probability of detecting California black rails.

Journal of Field Ornithology 70:465-480.

Stenzel, J. R. 1982. Ecology of breeding yellow rails at Seney National Wildlife Refuge.

The Ohio State University, Columbus, Ohio.

Stern, M. A., J. F. Morawski, and G. A. Rosenberg. 1993. Rediscovery and status of a

disjunct population of breeding yellow rails in southern Oregon. Condor 95:1024-

1027.

The Nature Conservancy [TNC]. 2012. Minnesota Glacial Ridge Project.

<http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/minnesot

a/placesweprotect/glacial-ridge-project.xml>. Accessed 1 Jul 2012.

Wilson, M. D., and B. D. Watts. 2006. Effect of moonlight on detection of whip-por-

wills: implications for long-term monitoring strategies. Journal of Field

Ornithology 77:207-211.

Wisconsin Department of Natural Resources. 2005. Wisconsin's Strategy for Wildlife

Species of Greatest Conservation Need. Madison, WI.