Do Nocturnally Migrating Passerines Concentrate Along the Coast of Lake Huron?

by

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Abstract

Many populations of North American migratory songbirds, especially aerial insectivores and Neotropical migrants, have been declining in the past few decades. The development of wind farms on many shorelines of the Great Lakes has raised concern for migratory birds passing through the area. The Great Lakes may represent a barrier to migratory birds which may result in a concentration of birds along the coast during nocturnal migration. I compared the abundance of nocturnal flight calls (NFCs) recorded by acoustic recorders among coastal and inland sites. I also used identified NFCs to determine whether species composition varies with proximity to the coast. I found variation in abundance among sites, but no consistent patterns in migration abundance or species composition in relation to distance from coast. Overall, there was no indication that birds concentrated at the coast during nocturnal migration. My results indicate that coastal wind farms may not present a greater risk to nocturnal migrants than interior wind farms.

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Introduction

A comprehensive Canada-wide study found major declines in populations of aerial insectivores, grassland birds and shorebirds (North American Bird Conservation Initiative, Canada, 2012). Nebel *et al.* (2010) used Breeding Bird Survey trends to determine that aerial insectivores have been decreasing in northeastern North America since the 1980s. A more recent study confirmed that the 1980s were a turning point towards the decline in aerial insectivore populations, and that the decline in certain groups such as swifts, swallows, and nightjars extended across North America (Smith *et al.* 2015). Population estimates of Neotropical migrants using Canadian Breeding Bird Survey data show that 41% of species have declined significantly since 1966, while only 18% of have increased (Sauer *et al.* 2014). The overall trend in decline may be due to a combination of various factors during their breeding (Calvert *et al.* 2013), and over-wintering seasons (Faaborg *et al.* 2013; Johnson *et al.* 2006), as well as due to hazards during active migration (Erickson *et al.* 2005).

Migration may be the most hazardous stage of the avian life cycle for many bird species (Sillett & Holmes 2002, Klaasen *et al.* 2014, Oppel *et al.* 2015). Confirmed causes contributing to the high mortality rate for large raptors include exhaustion (Oppel *et al.* 2015, Klaasen *et al.* 2014), hunting (Oppel *et al.* 2015), and collisions with tall man-made structures (Erickson, 2014). Satellite tracking of juvenile Egyptian Vultures (*Neophron percnopterus*) found that only 1 in 10 individuals were able to successfully survive through migration due to inexperience in navigation (Oppel *et al*. 2015). Survival estimates derived from capture-recapture modelling for Black-throated Blue Warblers (*Setophaga caerulescens*) in North America show that the lowest survival rate (50%) in its yearly cycle occurs during migration (Sillett & Holmes, 2002). Despite the concern for populations of North American migratory birds, migration mortality for small passerines is poorly understood in comparison to larger migrants. Long distance tracking techniques used on large raptors are impractical for small passerine individuals, and the lack of site fidelity in breeding and wintering periods for many species makes it difficult to track individual survival (Sillett & Holmes, 2002; Faaborg *et al*. 2010). However, the lack of research to confirm mortality rates does not necessarily mean there is a lack of concern.

Mortality due to midair collisions with tall man-made structures such as powerlines, communication towers, and wind turbines is a potentially major concern for passerines during migration (Evans 2000; Erickson *et al.* 2005; Kerlinger *et al.* 2014). This is a particular concern if migrating birds are concentrated in particular areas with a high density of tall man-made structures. For example, there is an increasing number of wind farms along the coast of the Great Lakes which has raised concern for the large numbers of birds passing through during migration, if birds concentrate along the coasts. The height of wind turbines presents a physical hazard and turbines may extend into the flight altitude range of nocturnally migrating passerines (Kerlinger *et al*. 2010). Although, the overall impact of wind turbines on birds may be small (Zimmerling *et al.* 2013), passerines make up most confirmed fatalities (Erickson *et al.* 2005, Erickson *et al.* 2014), and so could be affected in areas where they concentrate.

Radar observations of nocturnal migration found that birds may concentrate along coastlines of major bodies of water during nocturnal migration. This behavior may indicate migrating songbirds are reluctant to cross open water, or use coasts as a leading line during migration (Gagnon *et al.* 2010). Studies using radars have found concentrated activity along coastlines in Europe (Akesson 1993, Adams 1962) and North America (Lowery & Newman 1966; Richardson 1978; Gagnon *et al.* 2010; Bingman, Able & Kerlinger, 1982). In contrast, weather radar observations along several shorelines of the Great Lakes show no avoidance of migratory lake crossing (Diehl *et al*. 2003; Nilsson *et al.* 2014; Rathburn *et al.* 2013; Bowden *et al.* 2015). Coastal radar observations in southern Lake Ontario, western Lake Huron and eastern Lake Michigan have found nocturnal migrants to only concentrate near the coast shortly before dawn (Rathburn *et al*. 2013; Bowden *et al.* 2015). A marine radar study on the Ontario side of north-eastern Lake Huron found no evidence that birds concentrated at the coast during spring migration when compared to sites up to 20 kilometers inland (Villeneuve 2015). However, species cannot be distinguished on radar, so none of these studies had examined species composition of nocturnal migrants.

Acoustic recordings of nocturnal flight calls (NFCs) allow for species identification, and provide an alternative method to survey nocturnally migrating songbirds. Nocturnal flight calls are short, species specific vocalizations produced by many species that can be used to identify birds down to species or call groups based on the contour shape of the call viewed in a spectrogram (Evans & O'Brien, 2002). Monitoring of the diversity of nocturnal migrants can be used to establish baseline population information for creating management and conservation planning for migrating birds (Evans, 2000; Evans 2012; Farnsworth *et al.* 2009). For example, acoustic recording of nocturnal flight calls has been used to determine migration abundance of species of concern (i.e., Grasshopper Sparrow (*Ammondramus savannrum*) and Vesper Sparrow (*Pooecetes gramineus*)) to establish a bird monitoring database for the Department of Defence in the United States (Farnsworth *et al.* 2009). Several studies have suggested the abundance of nocturnal flight calls may be representative of the overall abundance of migrating songbirds. A study by Gagnon *et al.* in 2010 found a strong positive correlation (weighted mean $r = 0.53 \pm 0.26$) between radar and nocturnal flight call counts of migratory birds among nights of migration in autumn on the shorelines of the St. Lawrence estuary. Another comparison found a weakly positive correlation (r = 0.14 ± 0.04) between radar and NFC counts among nights of migration activity in Delaware (Horton, Shriver & Buler, 2014). A study in south Texas comparing NFC counts of Dickcissels (*Spiza americana*) and overall bird counts within a distance of 115 kilometers on a weather radar found strong temporal correlations among nights between the two methods (Larkin, Evans & Diehl, 2002). Although radars have a larger detection range than acoustic recorders, acoustic recorders have been able to detect migrants on nights of low migration activity which were undetected by weather radars (Gagnon *et al.* 2010).

Having a better understanding of songbird concentration with proximity to the coast during nocturnal migration would be an important step in assessing the impact of wind turbines or other obstacles on songbird migrants in coastal regions. The overall objective of my study is to use migratory night flight call data to test whether the Lake Huron coast influences spring and fall migration patterns of passerines. I test whether the abundance of birds was higher in coastal locations than inland locations. If there was a coastal effect on migration patterns, I would expect decreasing NFC abundance with increasing distance from the coastline, with the highest abundance of NFCs at the coast. I also test whether species composition differs among coastal and inland sites to determine whether some species may be migrating closer to the coastline.

Methods

Study Area

Six study sites (Figure 1) were selected to provide a range of distances in relation to the coast of Lake Huron (Table 1). The sites were split into two transects (northern and southern) with 3 sites per transect leading from the coast (Figure 1). The distance between the two transects measured along the coastline was 59 km. Distance from the coastline to sites along the northern transect ranged from 0.45 km to 16.2 km, and distance from the coastline to sites along the southern transect ranged from 1km to 20.6 km (Table 1).

In the northern transect, the coastal and further-inland sites were located on residential property, and the midway-inland site was located between residential property and farmland. In the southern transect, the coastal and midway-inland sites were located on the edge of farmland, while the further-inland site was located on the edge of a large nature reserve.

The microphone units were placed at least 150 m from nearby marine radars which were operating at the same time to avoid noise pollution. Each site had from 1 to 4 microphones recording simultaneously over the season (Table 1 and 2). The distance among microphones within sites ranged from 0.06 km to 0.41 km depending on the number of microphones (Table 2). Multiple microphones within a site were treated as replicates.

Microphones in the coastal and further-inland sites on the northern transect were situated on grass lawns near residential housing. The microphones in the midway-inland site followed a shallow creek running through the site. In the southern transect, microphones in the coastal site were placed between actively used farmland and a paved road. Microphones in the midway-inland site were located within actively used farmland, and microphones in the further-inland site were situated on the edges of a large forested nature reserve.

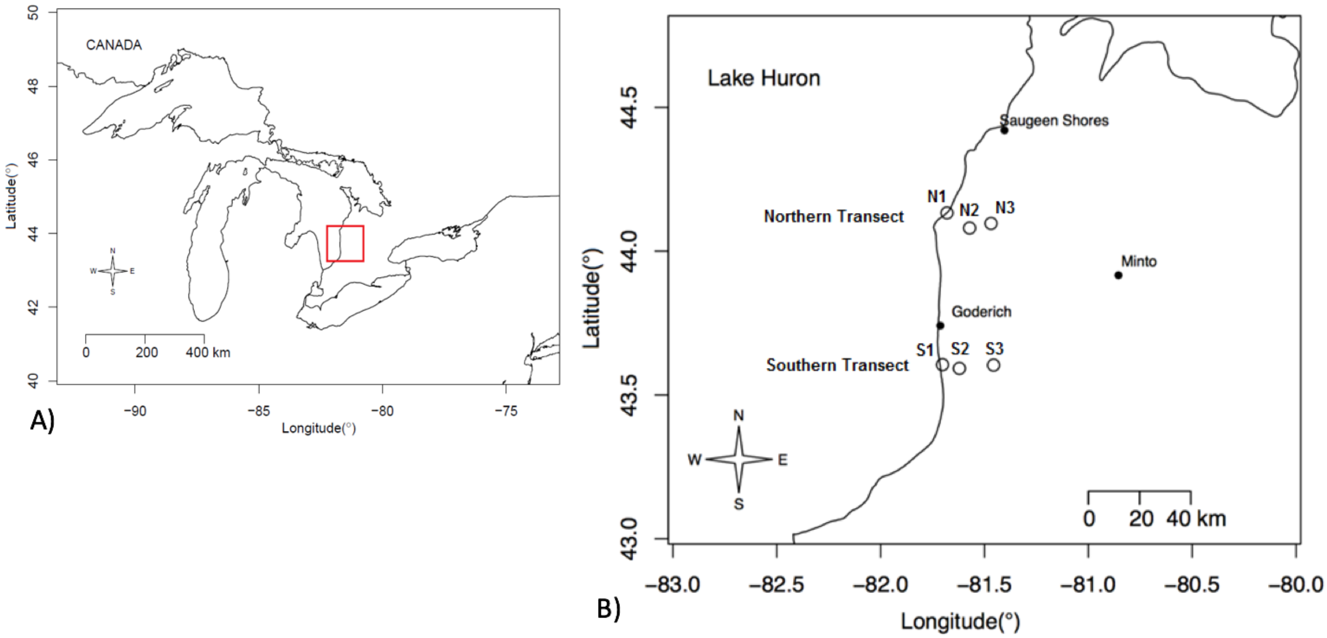

Figure 1: Map of A) the Great Lakes region with the study area boxed in red, and B) the eastern Lake Huron coastline where the study took place over 2013 and 2014. The sites are organized into two transects: the sites in the northern transect (N1, N2, N3) and the sites in the southern transect (S1, S2, S3).

Table 1: Summary of each site's distance from the coast (shortest distance from each site to the nearest coast) as well as number of microphones in each site each season. NA indicates sites which were not sampled in that season.

Site	Transect	Distance to Coast (km)	# Spring 2013 Mics	# Fall 2013 Mics	# Spring 2014 Mics	# Fall 2014 Mics
N1	North	0.45	NA	NA	1	1
N2		11	NA	NA	4	2
N3		16.2	NA	NA	1	2
S1	South	1	3	3	4	2
S2		7	1	2	1	NA
S3		20.6	1	3	4	2

Table 2: Summary of distance (in km) between SMX-units deployed within each site. In sites with 2 or more SMX-units, the distance between two furthest SMX-units and averaged distance between all adjacent SMX-units within the site were measured in km.

Year	Site	Microphones	Distance between two furthest SMX-units (km)	Average Distance Between All Adjacent SMX-units (km)
Spring 2013	S1	S1.1 S1.2 S1.3 S1.4	0.48	0.17
	S2	S2.1 S2.2	0.15	0.15
	S3	S3.1 S3.2	0.11	0.11
Fall 2013	S1	S1.1 S1.2	0.41	0.41
	S2	S2.1 S2.2	0.15	0.15
	S3	S3.1 S3.2	0.11	0.11
Spring 2014	N1	N1	-	-
	N2	N2.1 N2.2 N2.3 N2.4	0.18	0.06
	N3	N3	-	-
	S1	S1.1 S1.2 S1.3 S1.4	0.52	0.17
	S2	S2	-	-
	S3	S3.1 S3.2	0.19	0.19
Fall 2014	N1	N1	-	-
	N2	N2.1 N2.2	0.18	0.18
	N3	N3.1 N3.2	0.16	0.16
	S1	S1.1 S1.2	0.23	0.23
	S3	S3.1 S3.2	0.22	0.22

Recording Nocturnal Flight Calls

The length of data collection in each season, as well as start and end times of data collection varied between years (see Appendix A). In spring 2013, data collection started on April 20 and ended on May 31. In spring 2014, data collection started on April 30 and ended on May 26. In fall 2013, data collection started on August 9 and ended on October 9. In fall 2014, the season started on August 20 and ended on October 23.

Data were collected using Wildlife Acoustics Songmeter SM2 units and SMX-NFC microphones attached to poles at least 1 metre above ground. SMX-units consisted of a SMX-NFC microphone mounted on top of a piece of Plexiglas tile and protected with dense foam and a wire mesh. The microphones were not moved for the duration of the data collection period, and spaced evenly apart in sites that allowed for multiple microphone setups (Table 2).

Dates of coverage in each season differed among sites due to differences in availability of sites and failures or malfunctions in the Songmeters (see Appendix A). The SM2 units were usually programmed to start recording nocturnal flight calls (NFCs) 30 minutes before sunset and stop recording 30 minutes after sunrise in 30 minute segments. In some cases, the recording period extended longer into the morning, but I excluded any calls recorded more than 30 minutes after sunrise as "morning calls". All recordings were broken into 30-minute files which were timestamped with the date and start time as part of the file name:

Microphone_Date(yyyymmdd)_Time(hhmmss)

The recordings were saved in WAVE file format with 44100 Hz sampling rate and 16-bit depth. Routine checks on the units were conducted every 2 to 3 days to exchange memory cards before they filled up and batteries before they were depleted.

Call Extraction and Processing

Sound files were reviewed in spectrogram format using Raven Pro version 1.4 (Bioacoustics Research Program 2011). All potential nocturnal flight calls were selected and extracted for later identification. All extracted NFCs were timestamped in the file name, though there were some differences in the format of the extraction timestamp depending on the analyst.

Timestamp format for Spring 2013, Spring 2014, and Fall 2014:

<RecorderName>_<Frequency range*>_<start date of batch>.<time since the beginning of the batch>.<call annotation>.<filename annotation>.wav

e.g., GBBD2_HF_and_LF_20140929.024611.87.c.GBBD2_20140929_024300.wav

* "Frequency range" indicated the low (2 kHz-4 kHz) or high (6 kHz-8 kHz) frequency bands NFCS were normally found in.

Timestamp format for Fall 2013:

<RecorderName>_<Frequencyrange>_Date(yyyymmdd)_Time(hhmmss)_ Time(msms).wav

e.g., FDBD2_High_20130809_204412_18.wav

The timestamp in the extracted file was used to determine the date and time of the call. Analyses of Spring 2014 data combined several nights of data into one batch which led to several occasions of incorrect timestamp labelling. As a result, for that season, I used the date and start time of each original 30-minute file as the time of the call.

Three difference approaches were used for detecting and extracting nocturnal flight calls from the recordings. Calls in fall 2014 and spring 2013 were extracted by manually browsing and selecting from a spectrogram display over the full frequency range 0 kHz to 22 kHz in 30 second increments.

Calls in Spring 2014 were selected using the Raven Pro version 1.4 band energy limited detector (BLED; see Appendix B for settings used). This method automatically selected sounds louder than the background within the high frequency range (6-8 kHz) and low frequency range (2-4 kHz) and required manual review to determine whether these were potential NFCs.

Fall 2013 data were processed using Raven BLED selections and the flightCallR R package (Ross & Allen 2013). FlightCallR is a partially-automated classification method which uses randomForest models to categorize calls using a subset of categorized verification data (Ross & Allen 2013). Possible calls were automatically selected in Raven Pro using a BLED, and spectrogram features of each call (e.g., frequency (Hz), signal-to-noise-ratio threshold (dB)) were extracted using the seewave R package (Sueur, Aubin & Simonis 2008). A small, randomly selected subset of the BLED selections (5%) were manually classified as NFC or Noise to be used as verification data (Ross & Allen 2013). Once the accuracy of the model no longer improved with additional subsets (increments of 5%) of analyzed data, the model was considered a good fit for categorization (Ross & Allen 2013). The remainder of the uncategorized dataset were then categorized to NFC or Noise based on the features of the verification dataset (Ross & Allen 2013). This method was also attempted in Spring 2013, but was unable to efficiently extract low-frequency (2-4 kHz) calls due to the high number of spring peeper (*Pseudacris crucifer*) calls, so these data were reanalysed manually.

All extractions regardless of method were buffered with 0.2 seconds of silence before and after the NFC for easier review.

NFC identification

The extracted night flight calls (NFCs) were sent to two independent contractors Emily Griffith (ETG) and Anne Klingensmith (AEK) specializing in NFC identification.

Each potential NFC went through two rounds of review. The first round of review roughly categorized clips into taxonomic/contour-based categories or noise (see Appendix C and D). The second round of identification categorized the clips into species, species groups, or call groups (Table 3; Appendix D). The analysts considered the contour shape of the call viewed on a spectrogram as well as audio cues to determine final ID. Identifications including species names were shortened to species codes for efficiency. A species code typically uses the first two letters of each word within its name (ie. AMRE; American Redstart (*Setophaga ruticilla*)). Identification categories including call groups, noise, species codes and species names, as well as spectrogram examples of actual calls can be found in Appendix D.

The majority of the calls were identified by ETG, while AEK verified 20% of the calls from a subset of data from both years of data collection. Of the verified calls, 44% were a perfect match (same identification made independently by both AEK and ETG), and 10% of the calls were highly mismatched (e.g., one analyst classified to species, the other classified to unknown or a different species). The remainder of the verified data (46%) were comprised of mismatched identifications where one analyst classified to species and the other to a call group or category that included that species. The most conservative ID between the two contractors after the second round of review was selected as the final identification.

Table 3: Description of possible identification groups with listed examples.

Identification Type	Description	Example
Noise	Call is not considered a night flight call.	Animal calls (Spring Peeper, Coyote, Insect) Non-NFC Bird Sounds (Canada Goose, Killdeer) Other Noise (mechanical, human related noise)
Call Group	Call is considered a night flight call, but a more precise identification could not be made.	See Appendix C and D.
Other Species	Call is identified as species outside of the three main groups (Warbler, Thrush, Sparrow)	Indigo bunting (INBU), Scarlet Tanager (SCTA), Red Breasted Grosbeak (RBGR), Golden Crowned Kinglet (GCKI)
Warbler	Call is identified as a warbler species, or as a Call Group call likely to be a warbler	Yellow Warbler (YEWA), American Redstart (AMRE), DBUP Call Group, ZEWA Call Group
Thrush	Call is identified as a thrush species, or as a Call Group call likely to be a thrush	Wood Thrush (WOTH), Swainson’s Thrush (SWTH), THSH Call Group

Sparrow	Call is identified as a sparrow species, or as a Call Group call likely to be a sparrow	Field Sparrow (FISP), Song Sparrow (SOSP), CUPS Call Group, SPAR Call Group
Split Species	Call could be one of two possible species. The call was not clear enough for the analyst to a decision between the two species.	Fox Sparrow/Song Sparrow (FOSP/SOSP), Black Throated Green Warbler/Yellow-rumped Warbler (BTNW/YRWA), Scarlet Tanager/Veery (SCTA/VEER)

Call Count Adjustments

For one site in fall 2013, and several sites in spring and fall 2014, there were more extracted calls than we were able to send for identification. As a result, the contractor used an R script to randomly select approximately 50% of unidentified calls that were sent from each night for identification (see Appendix E).

Raw data extracted from the spectrograms often had a high percentage of false positive selections, and could not be used in analysis. As such, for nights of data that were only partially identified, unidentified data (nonID data) had to be assigned to species categories or noise based on proportions extrapolated from existing identified (ID data) data.

On nights with less than 50% ID data, the overall proportions of each ID category recorded at that microphone over the season were used to identify the rest of the nonID data. In nights with 50-99% identified calls, the proportions of each ID category recorded that night were used to adjust the nonID data. All identifications based on extrapolation were added to any existing identified data within the night.

Nights with <50% of identified data

ID+ (nonID)*Proportion of identified call over the season at microphone

Nights with >50% of identified data

ID+ (nonID)*Proportion of identified call over the night at microphone

On occasions when the Songmeter units recorded data outside of the specified time frame (i.e., morning calls), these calls were not counted within the night's data. This was done to standardize the recording times across nights and seasons.

Analysis

Nocturnal Flight Call Abundance Among Sites

A generalized linear mixed model (GLMM) was used to estimate the average nightly call count for each site, after controlling for date. A GLMM was conducted separately for each season using date (night of data collection) as a random effect, and the SiteID (site identification) as fixed effects (see Appendix E). Due to over-dispersion of the data, the data were fitted to a negative binomial probability distribution. The glmmADMB (Fournier et al. 2012) R package was used for analysis, and a rough bootstrap method was used to calculate 95% confidence intervals for the control variable (C. Roy personal communication; Appendix F). The data were then graphed using the ggplot2 (Wickham 2009) R package.

The ΔAIC values between GLMM models with and without a fixed effect (SiteID) were calculated to determine the model that best described the data. The AIC values were extracted from the GLMM output.

Species Composition Among Sites

Following methods described in Digby & Kempton (2012; pp. 107-109), a principal component analysis (PCA) was used to compare species composition among sites. Species composition used in the context of this study described the overall proportion of each species or species group identified in each site. In order to normalize the data, the smallest non-zero count (1) was added to the base dataset counts to account for any zeros in the count data during log transformation. The data were then centered and scaled to standardize the variance among species counts before performing the PCA. This accounted for variation among species counts, and distributed the variance more equally among PC1 and PC2 so that more abundant species did not disproportionately skew the variance among sites. Each season was analyzed separately in R (R Core Team, 2016) using the prcomp function from the stats package (R Core Team, 2016).

The number of principal components calculated was equal to the number of sites in each season's dataset (see Appendix H for datasets used). The first two principal components cumulatively explained a majority of the variance in each dataset (87-95%), so these were projected onto a biplot (see Appendix G) describing the variance among sites in each season. Principal component 1 was plotted on the x-axis, and principal component 2 was on the y-axis of the biplot. Loading vectors were coefficients of the variables on the principal components, and were calculated for each site in each PC (see Appendix G). Scores (species scores) were calculated for each row of species abundance based on the magnitude of each row's contribution to the principal components. Site loading vectors (arrows) and species scores (species codes) were projected onto biplots of the first two principal components (Digby and Kempton, 2012).

In order to avoid "redundancy" in the data analysis due to overlapping species counts in different identification groups, only NFCs identified to species (or split species IDs) were considered for the PCA analysis. Redundancy in this case, would be the species overlap in identifications which would result in multiple representations of any species included in multiple identification categories (O'Rourke and Hatcher, 2013). Any NFC identifications categorized only within a "call group" category (see Appendix D) were excluded from the PCA analyses.

Split species identifications were a conservative ID category that included calls of two species with similar NFCs that were sometimes unidentifiable to species. In order to avoid overlapping species identifications in the data by more than one category, species that had species specific IDs (e.g., BTNW, YRWA; Black-throated Green Warbler (*Setophaga virens*), Yellow-rumped Warbler (*Setophaga coronata*)) as well as split species IDs (e.g., BTNW/YRWA) were simplified as much as possible among all sites within a season. The sum of individual species IDs was compared to the number of split IDs for each site within a season. Of the two alternatives (Figure 2), the most common among sites was chosen as the method of simplification for all sites within that season. If there was a large proportion of split identifications for the two species groups, the sum of all three identification categories were combined into one split group category (see Figure 2a). If there was a smaller proportion of split IDs in comparison to the sum of both individual species IDs, the split identification counts were redistributed to the individual species counts based on the overall proportion of the species counts in that site (see Figure 2b).

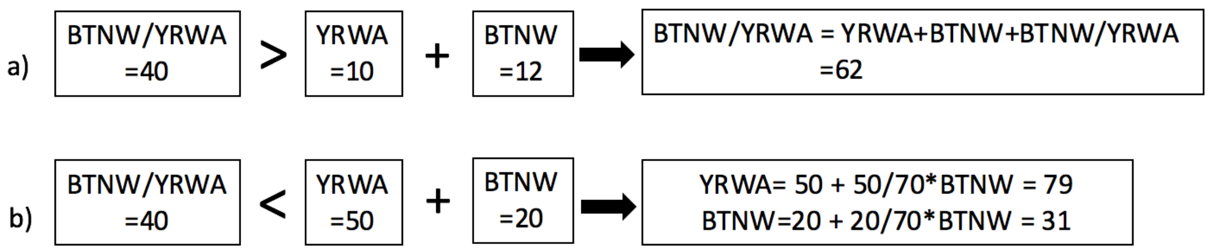

Figure 2: Diagram showing two scenarios of how split identifications were treated across all sites within a season. The most common alternative among sites was chosen as the method of simplification for that season. If the split identifications were more abundant than the individual species (example a), all three categories were combined. If the sum of the two individual species were greater than the number of split identification, then the split identifications were redistributed to the individual species based on the ratio of the individual species within the season (example b).

Results

In 2013, 17,367 potential calls were sent for identification, of which 8,077 calls were identified as night flight calls, 3,396 as noise, and 5,894 as diurnal calls (Table 4). The latter were identified, but excluded from the final analysis. In 2014, there were 56, 940 potential calls extracted by NWRC analysts, and 42,851 of those calls were sent to ETG and AEK for identification. Of the identified extractions, 32,092 clips were categorized as NFCs and 10,052 clips were categorized as noise. In fall, 707 diurnal calls were excluded from analysis. A portion of the extracted calls were not sent for identification (13,382), so the number of calls of each species and the proportion that were noise were extrapolated based on existing data (Table 5).

Table 4: Summary of 2013 call count data. The Identified calls were categorized as a NFC or noise by independent contractors. Diurnal calls are morning calls which were recorded due to error in setting up the end time during the data collection period. Night flight calls (NFCs) were identified to species, species group, or call group (see Appendix C). Noise identifications were excluded from the final analysis.

Sites and Mics in 2013			**Number of Calls**				
	Site ID	**Mic ID**	**Identified**	**Diurnal**	**NFC**	**Noise**	**# of Nights of Recording**
Spring 2013	S1	1	2410	0	403	2007	12
		2	884	0	492	392	21
		3	145	0	10	135	3
	S2	1	82	0	48	34	8
	S3	1	1636	0	960	676	35
		2	108	0	18	90	8
Fall 2013	S1	1	927	185	731	11	41
		2	3124	2063	1039	22	44
	S2	1	3237	1680	1552	5	58
		2	1849	53	1775	21	58
	S3	1	1158	590	568	0	58
		2	1807	1323	481	3	32
Total			17367	5894	8077	3396	378

Table 5: Summary of 2014 call count data. The identified number of calls were categorized as NFC or noise by independent contractors. Diurnal calls are morning calls which were recorded due to error in extending the end time during the data collection period. Night flight calls (NFCs) were identified to species, species group, or call group (see Appendix C). The number of extrapolated calls were calculated based on within-site or within-night proportions of categorized counts. Only the extrapolated NFC counts were used for analysis.

Sites and Mics in 2014			**Number of Calls**						
Spring 2014	**Site ID**	**Mic ID**	**Extracted**	**Identified**	**Diurnal**	**NFC**	**Noise**	**Extrapolated Calls (with NFC and noise)**	**# of Nights of Recording**
	N1	1	2290	2199	0	1196	1003	91	24
	N2	1	1050	1050	0	803	247	0	22
		2	982	345	0	157	188	637	19
		3	982	915	0	499	416	67	26
		4	335	309	0	68	241	26	24
	N3	1	1701	506	0	178	328	1195	32
	S1	1	465	213	0	109	104	252	24
		2	349	136	0	61	75	213	22
		3	460	400	0	238	162	60	23
		4	810	423	0	247	176	387	23
	S2	1	1271	883	0	197	686	388	37
	S3	1	1627	1415	0	354	1061	212	33
Total			12322	8794	0	4107	4687	3528	309

Table 5, *continued*

Fall 2014	Site ID	Mic ID	Extracted	Identified	Diurnal	NFC	Noise	Extrapolated Calls (with NFC and noise)	# of Nights of Recording
	N1	1	4451	4027	77	3213	737	347	42
	N2	1	1383	1179	0	1043	136	204	8
		2	7847	6484	40	5752	692	1323	35
	N3	1	4432	3571	89	2959	523	772	59
		2	2880	2269	21	1941	307	590	44
	S1	1	11440	7804	213	5973	1618	3423	54
		2	5480	2859	101	2440	318	2520	47
	S3	1	1287	1084	42	782	260	161	25
		2	5418	4780	124	3882	774	514	53
Total			44618	34057	707	27985	5365	9854	367

Predicted Nightly Call Counts

In all seasons, the models that incorporated site as a fixed effect were favored by AIC values over the models without a site effect, indicating variation in abundance among sites (ΔAIC for spring 2013 was 8.2; fall 2013 was 23.5; spring 2014 was 48.5; fall 2014 was 88.6). However, the pattern of variation varied among years, transects and seasons and was not generally consistent with the prediction of decreasing abundance with increasing distance from coast (Figure 3).

In spring 2013, the coastal (S1) and further inland (S3) sites detected similar amounts of nocturnal flight calls, which were higher than the number of calls detected at the midway-inland site (S2). The further-inland site detected a slightly (but not significantly) higher amount of calls than the coastal site. In spring 2014, the highest abundance of NFCs in the northern transect was detected at the coastal site (N1). The northern midway-inland and further-inland sites detected similar abundances of NFCs. In the southern transect, the coastal and further-inland sites detected more calls than the midway-inland site, however the coastal site detected a slightly (but not significantly) higher abundance than the further-inland site.

In the southern transect in fall 2013, the midway-inland site (S2) detected more NFCs than the coastal (S1) and further-inland (S3) sites. A similar pattern was seen at the midway-inland site (N2) in the northern transect in 2014. In the southern transect in 2014, the coastal site detected significantly more NFCs than the further-inland site. The number of calls detected at the coastal site was also greater than the further-inland site in fall 2013 and spring 2014, although the relationships were not significant.

There was a large variance in nightly flight call counts among nights of recording.

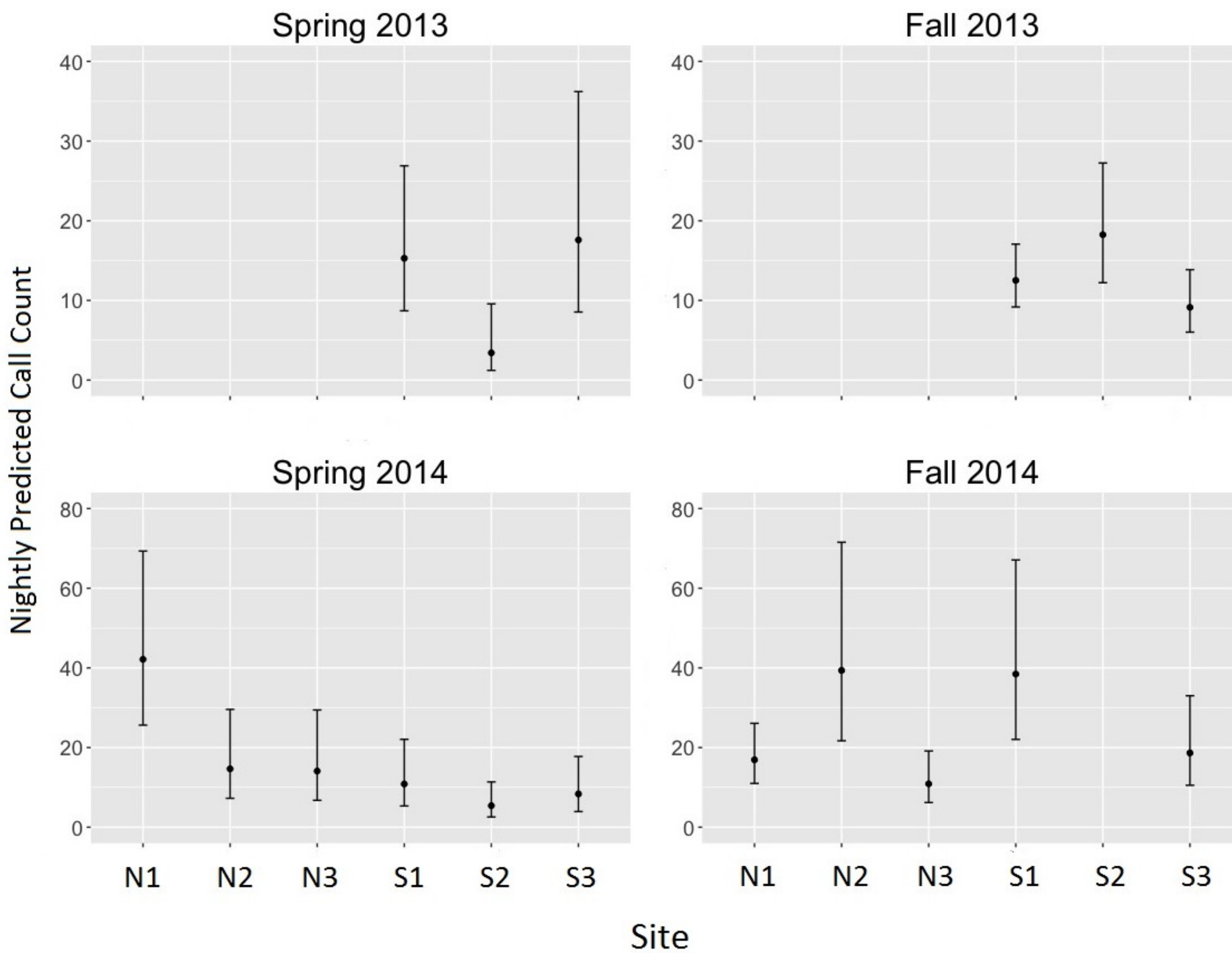

Figure 3: Predicted mean nightly call count with 95% confidence interval bars in each site per season show variation in bird abundance between sites and seasons. Northern transect sites were not sampled in 2013, and site S2 was not sampled in fall 2014. Northern transect sites: N1 (coastal site), N2 (midway-inland site), N3 (further-inland site). Southern transect sites: S1 (coastal site), S2 (midway-inland site), S3 (further-inland site).

Differences in Species Composition Among Sites

Analysis of the acoustic data revealed that generally all sites within a transect and season had similar overall species composition, as indicated by very similar scores on PC1 which explained most of the variance (Figures 4-7). PC2 did describe small differences in species composition among sites, but they were not consistent in relation to distance from coast. The angle between site vectors on the biplot described the relative variance in species composition among sites. The position of the species codes on the graph indicates their weighting on the PC axes. Species near the centre of the plot (0,0) had low overall weighting, indicating small numbers or little variance among sites. Species near the left or right of the plots were weighted heavily on PC1, while those near the top or bottom of the plot were weighted heavily on PC2.

Species composition varied among sites in spring 2013, with the most difference found between the coastal (S1) and midway-inland (S2) site, and the further-inland site intermediate. In contrast, in 2014, the coastal and mid-way inland sites on both transects (S1, S2, N1, and N2) had the most similar species compositions, while the two further-inland sites (N3 and S3) had very similar species compositions to each other, but distinct from the rest, and there was a clear divergence between the further-inland sites and the rest of the sites (N1, N2, S1, and S2).

In fall, the small difference in species composition between the southern coastal (S1) site and the further-inland (S3) site remained consistent from 2013 to 2014. In 2013, the divergence of the midway-inland site (S2) indicated that it had the most different species composition within the transect. In 2014, the northern coastal site diverged from the rest of the sites in both southern and northern transects. There was little variation in species composition among the sites in the southern transect and the inland sites in the northern transect.

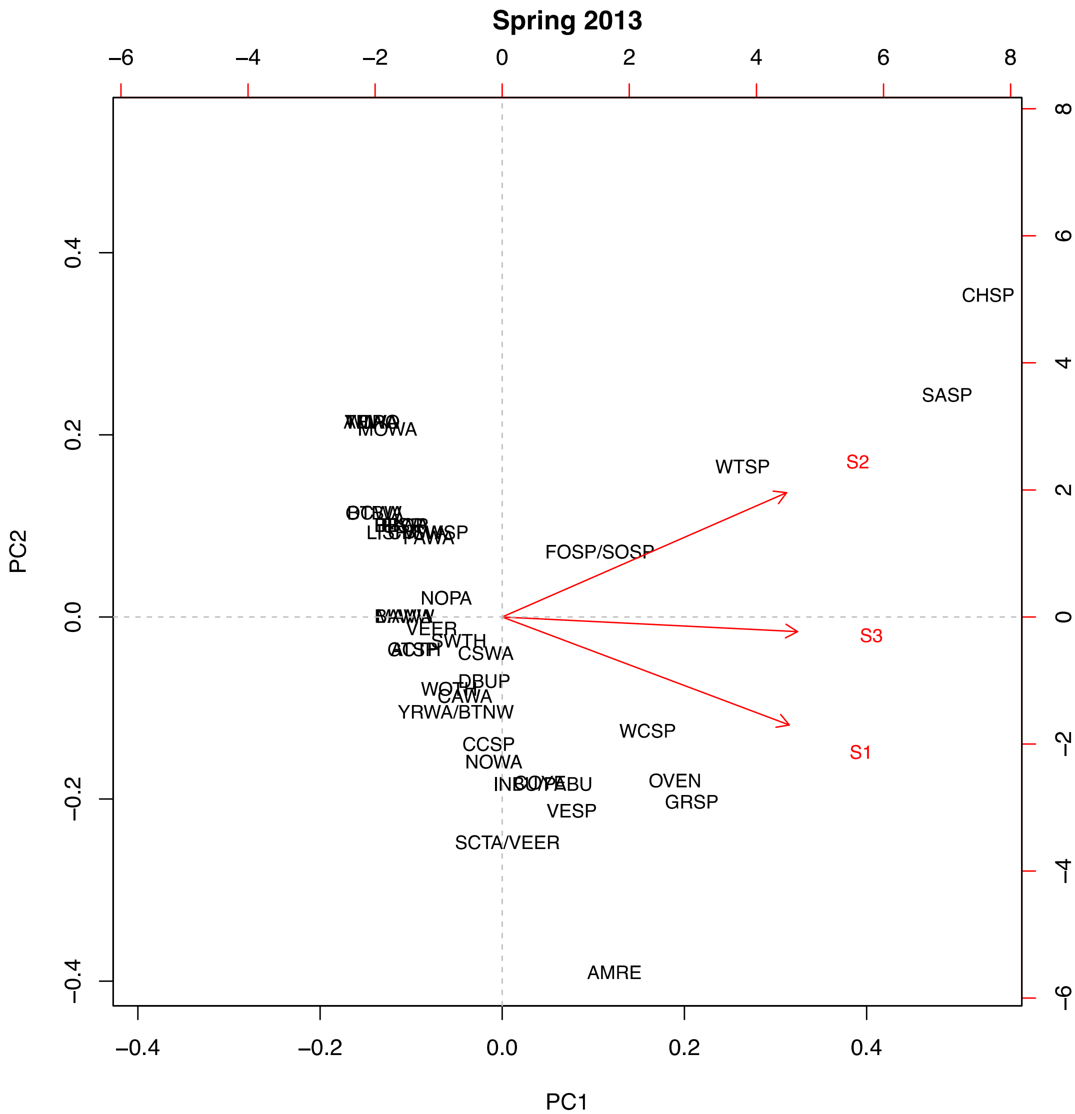

Figure 4: Biplot of the Principal Component Analysis (PCA) results for spring 2013 comparing species composition among sites on the southern transect (S1 (coastal), S2(midland), S3(inland)). All sites had similar scores on PC1 which explained 85% of the variation, indicating overall very similar species composition. PC2 explained 9.2% of the variation, and indicated the greatest difference between S1 and S2, while S3 was intermediate. The position of each species on the biplot represents its loading on the respective PC score (species codes in Appendix D).

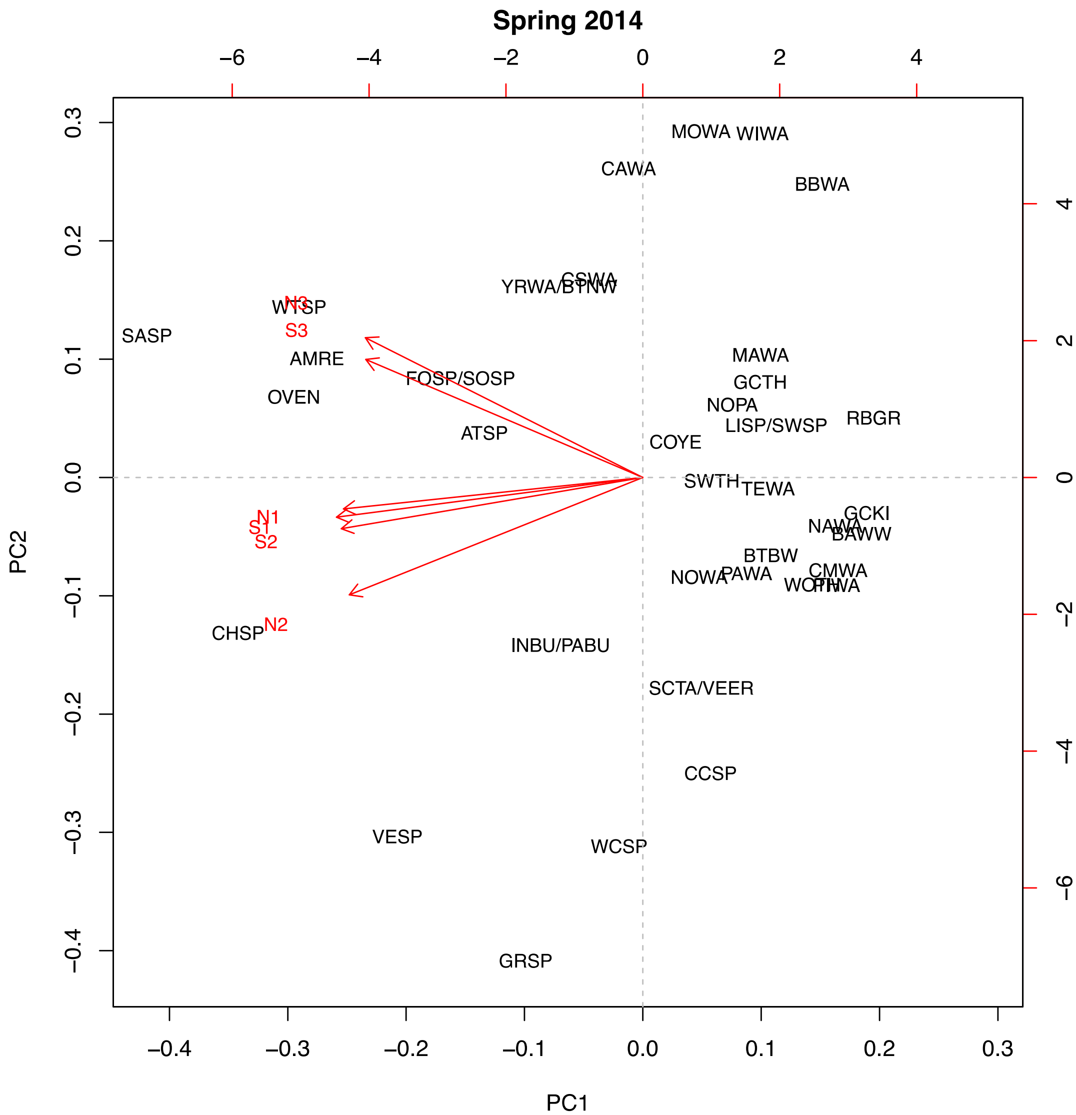

Figure 5: Biplot of the Principal Component Analysis (PCA) results for spring 2014 comparing species composition among sites in the southern transect (S1 (coastal), S2(midway-inland), S3(further-inland)), and the northern transect (N1 (coastal), N2 (midway-inland), N3 (further-inland)). All sites were positively correlated due to similar scores on PC1 which described 86.9% of the variation. PC2 described 8.1% of the variation and indicated that the further-inland sites were the most different in species composition.

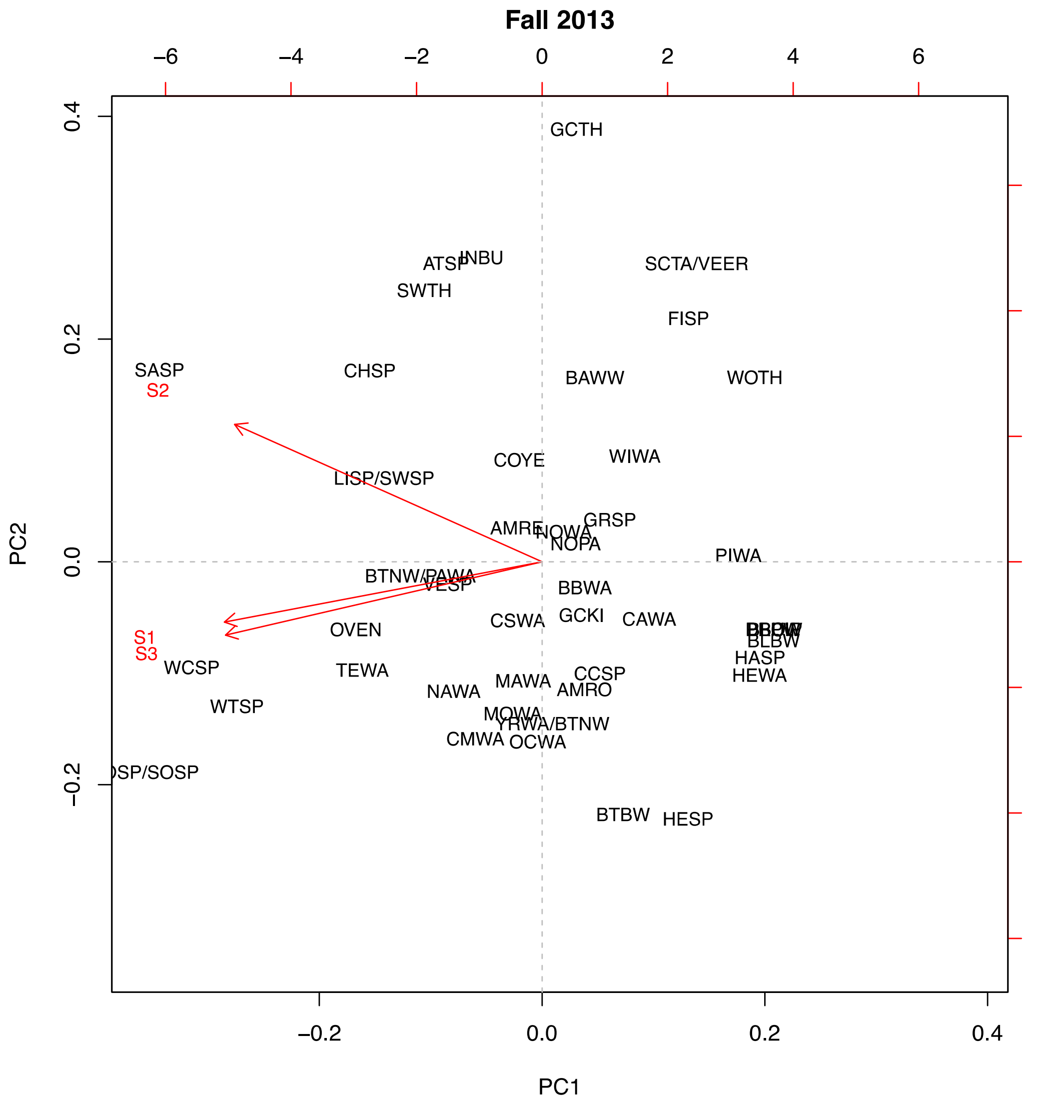

Figure 6: Biplot of the Principal Component Analysis (PCA) results for fall 2013 showing variance in species composition between sites by comparing the size of the angle between site vectors (red vectors). The southern transect sites were: S1 (coastal), S2(midway-inland), S3(further-inland). All sites were positively correlated due to similar values on PC1 which explained 86.6% of the variance. PC2 described 8.2% of the variance, and separated S2 from S1 and S3.

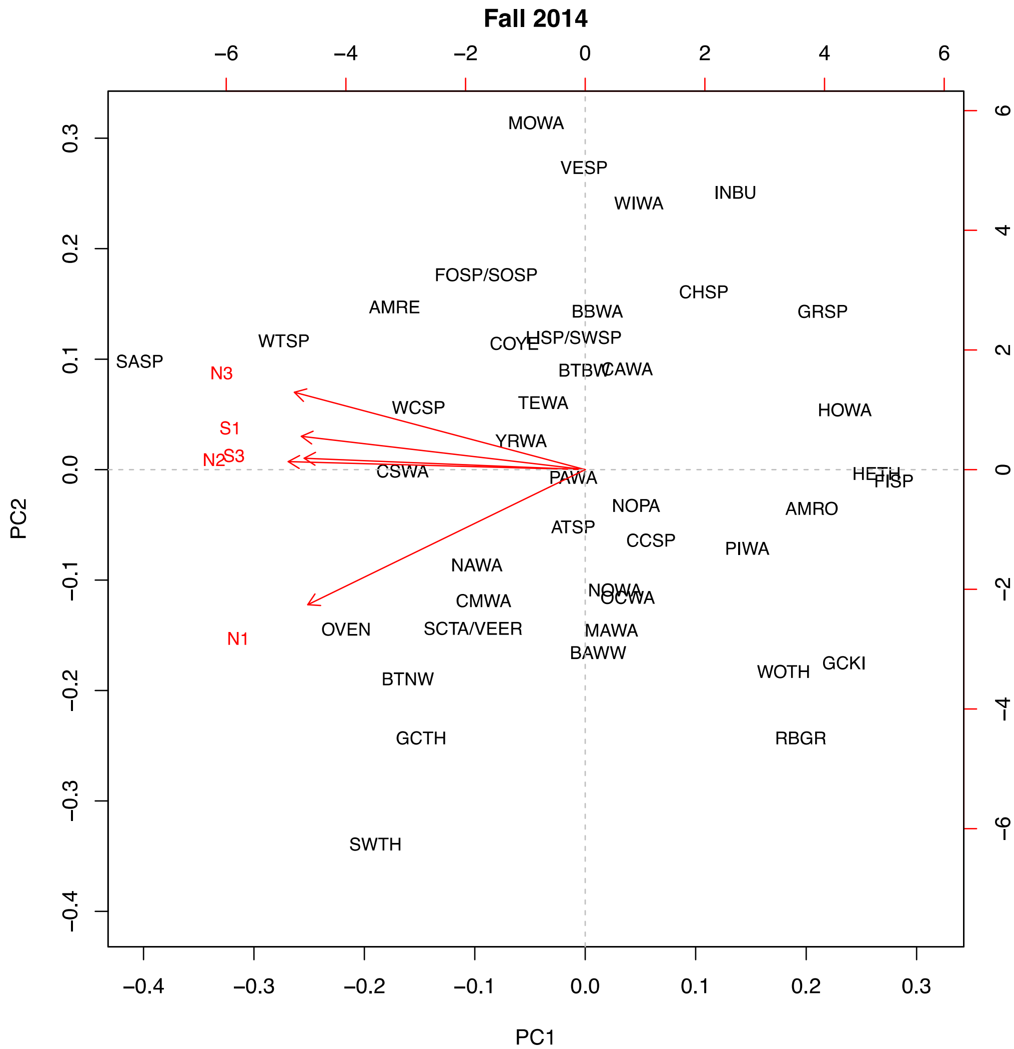

Figure 7: Biplot of the Principal Component Analysis (PCA) results for fall 2014 showing variance in species composition between sites by comparing the size of the angle between site vectors (red vectors). The sites in the northern transect were: N1 (coastal), N2(midway-inland), N3(further-inland). The southern transect sites were: S1 (coastal), S2(midway-inland), S3(further-inland). All sites were positively correlated due to similar values on PC1 which described 84.2% of the variation. PC2 described 6.1% of the variance which showed little variation among sites with the exception of N1.

Discussion

Acoustic recordings of nocturnal flight calls (NFCs) on the eastern coast of Lake Huron showed no consistent coastal effects on migration concentration in either spring or fall migration. Numbers of birds varied among sites, but the highest concentrations switched among coastal and inland sites depending on the season and transect. These results are consistent with those of a marine radar study conducted at some of the same sites in 2014, which found no consistent evidence of migrants concentrating at the coast during migration (Villeneuve 2015). Overall, both studies found a high abundance of nocturnal migrants at the coastal site in the northern transect, and no evidence of concentrated coastal migration in the southern transect. In the southern transect, the radar had detected the most migrants at the midway-inland site, and fewer calls in the coastal and further-inland sites. In comparison, my study had found the opposite pattern of abundance among sites in the southern transect using nocturnal flight calls.

Studies elsewhere around the Great Lakes have found no evidence of migrants concentrating at the coastline during nocturnal migration. Using radars, Bowden *et al.* (2015) found that birds generally did not avoid crossing the southern coast of Lake Huron during spring migration, and only concentrated at the coast near dawn, presumably to search for stopover locations. The same pattern was also found in coastal Lake Michigan (Bowden et al. 2015) and Lake Ontario (Rathburn et al. 2016). Overall, these studies provide no evidence that Lake Huron may be an ecological barrier for nocturnal migrants or that migrants concentrate at the shorelines during active migration.

My species composition analyses found variation in species composition among sites, but no consistent patterns in species composition of nocturnal migrants among sites, or between years. All sites within a season were positively correlated indicating generally similar composition. There were small differences in species composition among sites in each season. Similarly, Evans (2012) found several coastal acoustic recorders to be highly positively correlated in proportions of warbler and sparrow calls (Pearson's r value > 0.9, $p<0.001$) in New York State. In that study, warbler and sparrow proportions among coastal and inland sites 53-64 km apart were also found to be positively correlated, although to a lesser degree than proximal coastal sites (Pearson's r value 0.68-0.7, $0.016<p<0.02$) (Evans 2012). These studies show that while there may be small differences in species composition among sites, species composition may not be greatly influenced by coastlines.

The local habitat surrounding the study sites may have influenced call detection and abundance among sites. Sites closer to agricultural land often had a large amount of various background animal noises that may have blocked the detection of NFCs in the spectrogram. In spring, many sites recorded spring peepers (*Pseudacris crucifer*) calling continuously in the background within the same frequency band (2-4 kHz) as thrushes, buntings, and tanagers. Background noise interference may not have been the only influence of local landscape on call abundance. The further-inland site (S3) in the southern transect had detected a relatively high number of calls during spring migration which may have been influenced by its proximity to a provincial nature reserve. The forests, marshes, and fields within the reserve may have presented an attractive stopover site for many migrants. Similarly, a radar study by Rathburn *et al.* (2016) also found overall higher migration activity inland than along several Lake Ontario coastlines due to the proximity of the inland site to a nature reserve. The influence of the provincial nature reserve was unlikely to have affected the overall pattern of migration in coastal Lake Huron, but may have influenced the variation in NFC detected among sites.

The quality of the acoustic recordings may have varied among microphones and sites. If some microphones were more sensitive, they may have detected NFC at greater differences. We did not account for variation in microphone sensitivity among Songmeter units; however, multiple recorders were deployed at most sites which should have averaged out some variation. In spring, the quality of sound recorded in coastal and sometimes midway-inland sites were negatively affected by wind, which led to few or no NFC detections on very windy nights. While these locations may be ideal for wind energy collection, they were less ideal for acoustic data recording. The intensity (dB) of the calls detected by acoustic recorders may have been negatively influenced by atmospheric conditions (Horton *et al.* 2015), which in turn affects the quality of recordings and specificity of identifications. For example, the intensity (dB) of NFCs recorded at 150 m above ground level microphones would be negatively affected by high relative humidity (>50%) and temperatures between 10°C - 20°C in the atmosphere (Horton *et al.* 2015). Another confounding factor is that NFC detectability diminishes as the altitude of calls increase, and there may differences in NFC altitudes among species or among sites (Evans 2000). For acoustic studies, species calling at higher altitudes and during sub-optimal atmospheric conditions may be less likely to be detected.

Another limitation of NFC studies is that many behavioural aspects of night flight calls are still largely unknown. Flocking behavior is not common in passerines (Balcomb

1977); however, there is evidence of loose grouping by taxonomically similar migrants during nocturnal migration (Larkin & Szafoni 2009). Flight call activity may be higher for individuals flying in a 'loose flock' than those flying individually. A study by Morris *et al.* (2016) on captive warblers found higher call rates in response to conspecific playback calls. In particular, some species such as the American redstart (*Setophaga ruticilla*) had a high call rate, while Blackpoll warblers (*Setophaga striata*) had a disproportionately low rate of response calls (Morris *et al.* 2016). In acoustic studies, there may be a snowball effect in flight call abundance due to conspecific flight call response and loose flocking of similar species during migration. In addition, the proportions of infrequently calling birds such as Blackpoll warblers detected using acoustic recorders may not be truly representative of their migrant populations. Furthermore, some species groups such as vireos, mimids, and flycatchers do not make flight calls at all, leaving some gaps in our knowledge of species abundance based on flight call data (Farnsworth, 2004).

Overall, my study does not provide evidence that wind turbines near the coast of Lake Huron present a greater risk to migrating passerines than turbines up to 20.6 km inland. Despite the limitations in using acoustic recordings of nocturnal flight calls as a study method, my results show that NFCs can describe patterns (or a lack thereof) in both migration abundance and species composition. The use of acoustic recorders has been successfully used in many studies to assess songbird migration patterns in North America (Smith *et al.* 2015; Sanders & Mennill 2014a; Sanders & Mennill 2014b; Evans 1999; Evans 2000), and migration abundance detected between acoustic monitors and radars can vary in comparable ways among nights (Gagnon *et al.* 2010; Larkin *et al.* 2014;

Horton *et al.* 2014). As we continue to learn more about the behavioural aspect of nocturnal flight calls in various species, we will continue to improve the use of acoustic recordings of NFCs as a study method. Future studies may consider using transects of acoustic arrays to study the behaviour of frequently calling species across the landscape to determine location effects on NFC behaviour. Monitoring migration patterns before and after wind turbine development could also be used to compare the effects of wind turbines on local migration patterns.

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Appendix A : Tables Summarizing Duration and Length of the Data Collection Period in Each Season Sampled.

<u>Spring 2013</u>

Sites	Microphone in Site	Date Start (data available)	Date Ended (data available)	Total Nights Recorded
S1	1	30/04/2013	25/05/2013	14
	2	30/04/2013	20/05/2013	21
	3	30/04/2013	20/05/2013	21
S2	1	01/05/2013	07/05/2013	7
S3	1	02/05/2013	26/05/2013	25
	2	30/04/2013	26/05/2013	27

Fall 2013

Sites	Microphone in Site	Date Start (data available)	Date Ended (data available)	Total Nights Recorded
S1	1	10/08/2013	18/10/2013	38
	2	09/08/2013	20/08/2013	11
	3	26/08/2013	21/10/2013	50
S2	1	12/08/2013	16/10/2013	63
	2	16/08/2013	09/10/2013	35
S3	1	18/08/2013	18/10/2013	36
	2	04/09/2013	21/10/2013	32

Spring 2014

Sites	Microphone in Site	Date Start (data available)	Date Ended (data available)	Total Nights Recorded
N1	1	05/05/2014	28/05/2014	24
N2	1	27/04/2014	19/05/2014	21
	2	27/04/2014	30/05/2014	19
	3	27/04/2014	30/05/2014	26
	4	27/04/2014	30/05/2014	24
N3	1	28/04/2014	30/05/2014	33
S1	1	24/04/2014	31/05/2014	24
	2	24/04/2014	30/05/2014	22
	3	24/04/2014	30/05/2014	23
	4	25/04/2014	31/05/2014	23
S2	1	20/04/2014	31/05/2014	37
S3	1	24/04/2014	31/05/2014	33

Fall 2014

Sites	Microphone in Site	Date Start (data available)	Date Ended (data available)	Total Nights Recorded
N1	1	21/08/2014	23/10/2014	52
N2	1	20/08/2014	27/08/2014	7
	2	24/08/2014	24/10/2014	36
N3	1	20/08/2014	23/10/2014	65
	2	24/08/2014	21/10/2014	46
S1	1	21/08/2014	19/10/2014	59
	2	21/08/2014	23/10/2014	55
S3	1	10/09/2014	14/10/2014	26
	2	21/08/2014	17/10/2014	55

Appendix B : General Settings for the Songmeter SM2 units and Raven Pro Band Energy Limited Detector

<u>Songmeter SM2 Units Settings</u>

Setting	Input
Sample Rate (Hz)	44100
Compression	WAVE format
Gain Left (dB)	+12.0
Gain Right (dB)	+12.0
Timezone	UTC – 4:00

<u>General Raven Pro 1.4 Band Energy Limited Detector (BLED) Settings</u>

Settings were retrieved from J.Ross, personal communication.

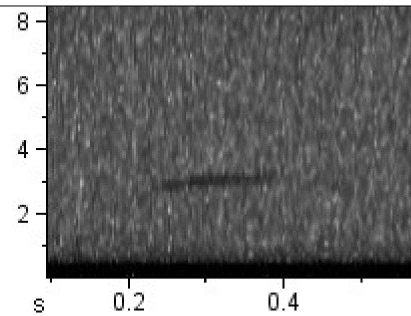
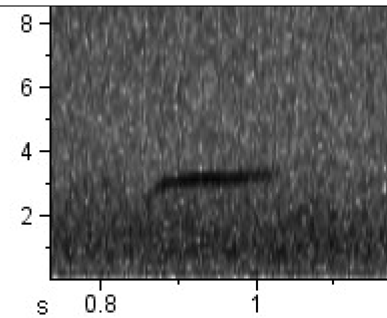
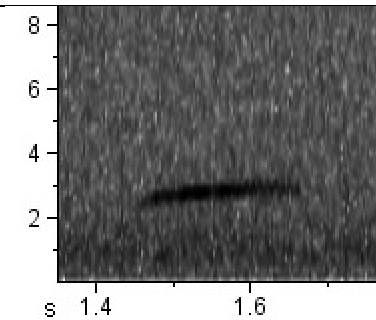
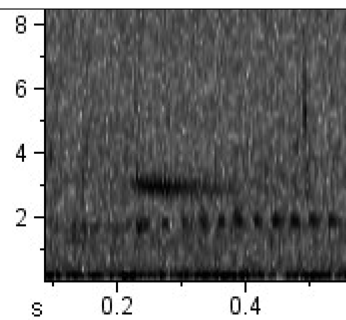
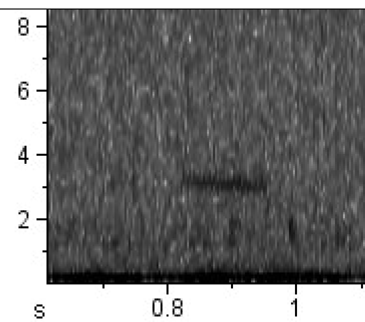
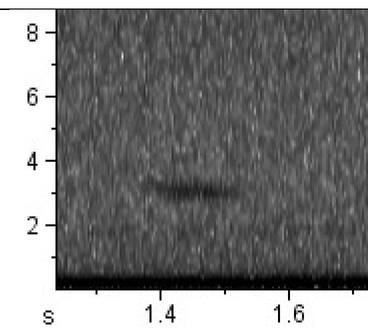
Parameter	Low Frequency	High Frequency
Minimum Frequency (Hz)	2250	6000
Maximum Frequency (Hz)	3750	11000
Minimum Duration (ms)	30.8	27.5
Maximum Duration (ms)	329.2	400
Minimum Separation (ms)	49.2	101.7
Minimum Occupancy (%)	20	25
SNR Threshold (dB)	4	3.5
Block Size (ms)	1000	499.3
Hop Size (ms)	246.7	250
Percentile	50	50

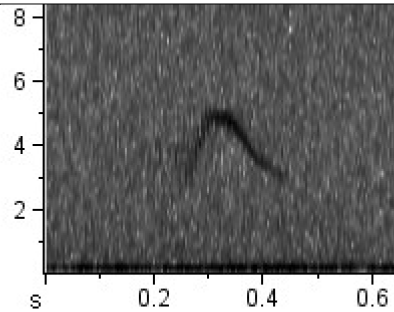
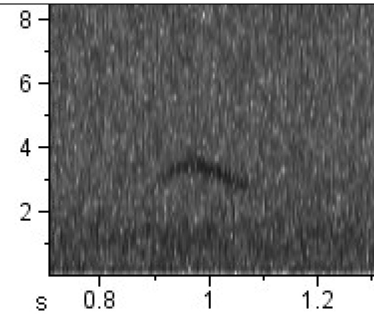
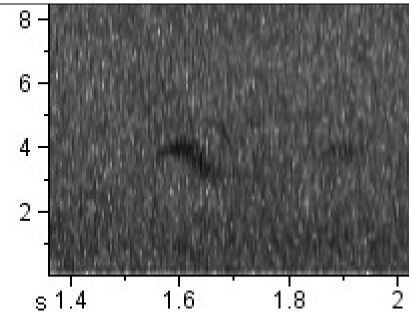
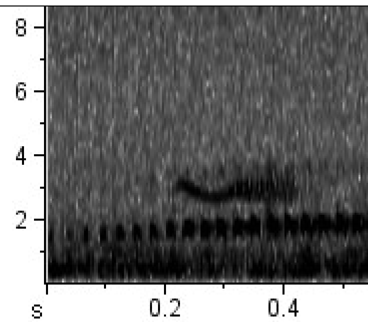
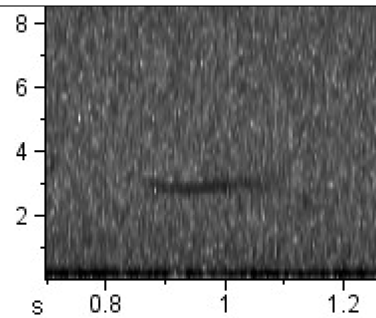
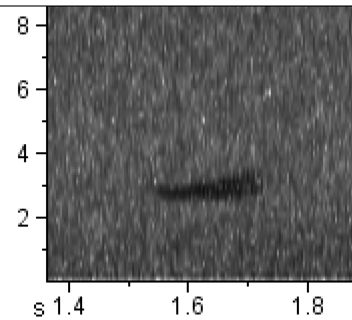
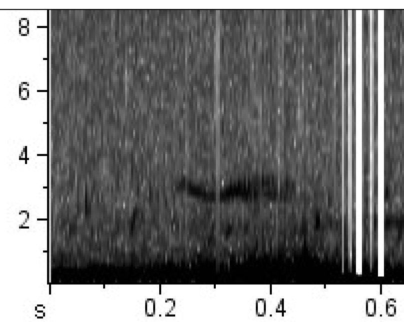
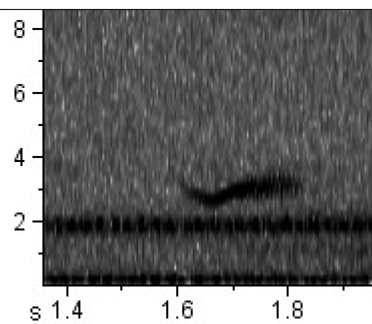
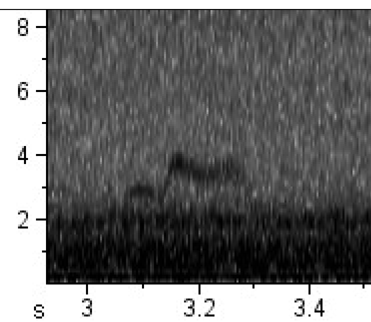
Appendix C : Call Group and Species Group categories used by ETG and AEK for Identification

Call Group Category	Description of Call (Species)
BZWA/BUZZ*	Calls with multiple points of inflection and dense modulation (HOWA, COYE, CSWA, INBU, BAWW)/(HOWA, COYE, CSWA, INBU, LISP, SWSP, BAWW) *BUZZ was introduced in 2014 identifications and BZWA was dropped as an identification category
CALL/Passerine	Unknown Passerine. No further species identification could be made
CUPS	Call which looks like a cup with a descending and ascending slope (CHSP, ATSP, VESP, FISP, FOSP, SOSP)
DBUP/Oreothlypis*	Call which is double-banded and have an ascending slope (BTNW, TEWA, OCWA, NAWA, MOWA, VESP, WCSP, YRWA)
Emberizidae	Calls which are determined to be a sparrow within the Emberizidae family (ATSP, CCSP, FOSP, LISP, SWSP, VESP, SASP)
IRRG	Calls which do not fit into contour shape based categories (AMRE, OVEN, BAWW, CMWA, NOWA, WIWA, INBU, GCKI, CAWA)
SBUP	Call which is single-banded with an ascending slope (PROW, YRWA, BTBW, OVEN, WCSP)
SBDN	Calls which are single-banded with a descending slope (PRAW, PAWA, NOPA, FISP)
SPAR	Unknown Sparrow
SPAR-A	Call which is most likely a sparrow, or possible AMRE
Spizella	Calls which are determined to be a sparrow genus (Spizella) of sparrows (ATSP, CHSP, FISP, CCSP)
THSH	Call which is determined to be a thrush without further identification
ZEWA	Call which contains multiple points of inflection (CMWA, CEWA, BBWA, BLBW, YEWA, BLPW, MAWA, NOWA)

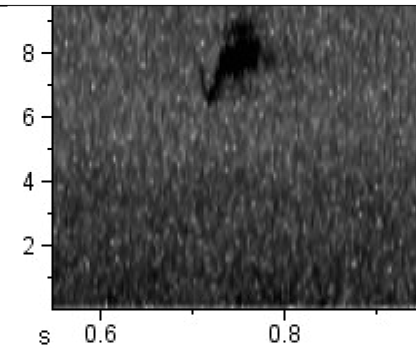
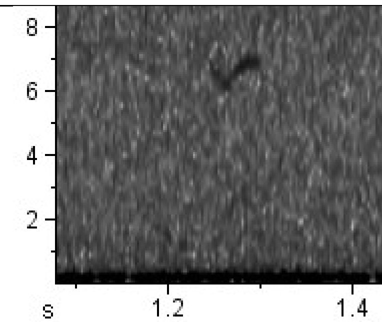
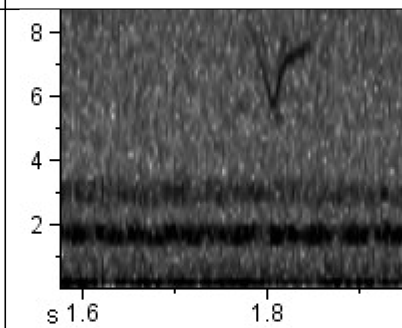
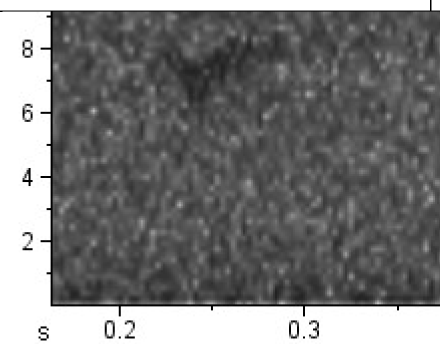
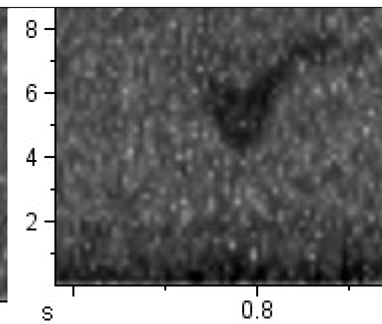
Appendix D : Spectrogram Examples of the Most Common Identifications in Categories: Thrush, Warbler, Sparrow, Call Group and Noise. The Frequency in KiloHertz is on the Y-axis and the Time in Seconds is on the X-axis.

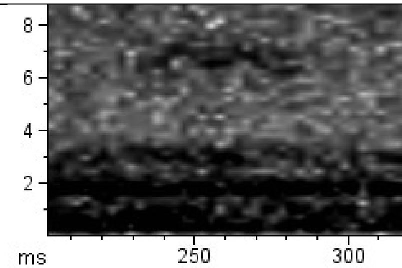
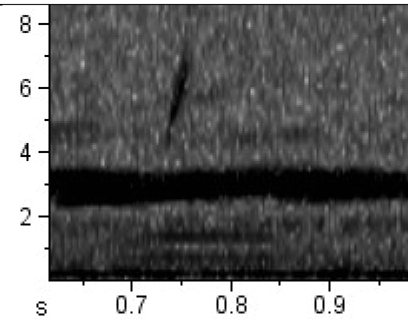
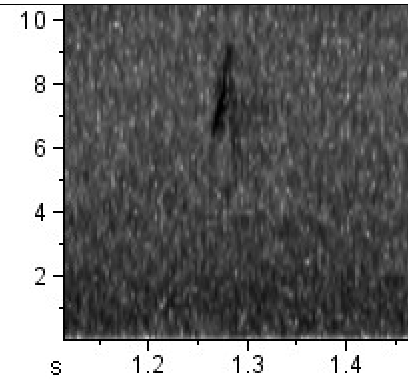
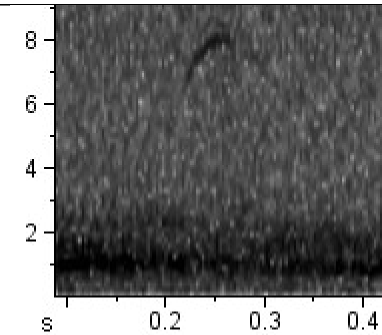
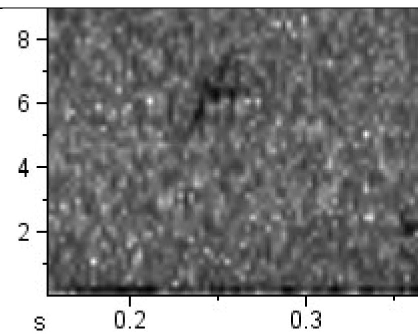
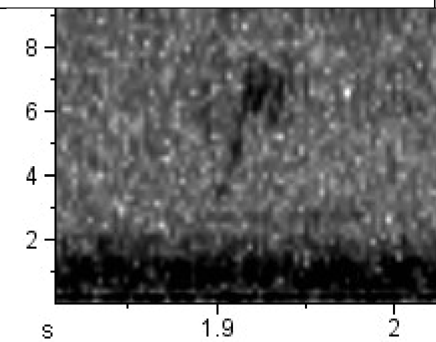
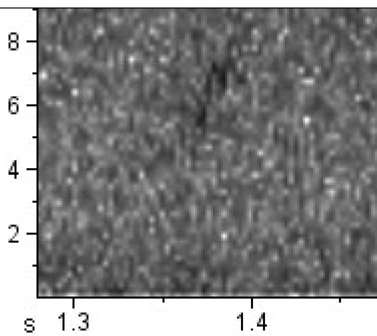
<u>Spectrogram examples of thrush calls</u>

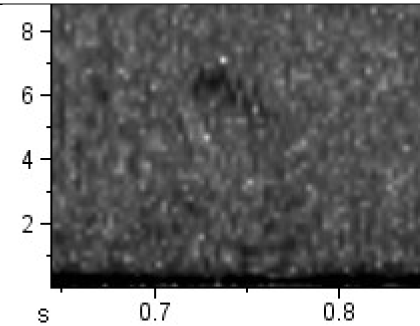
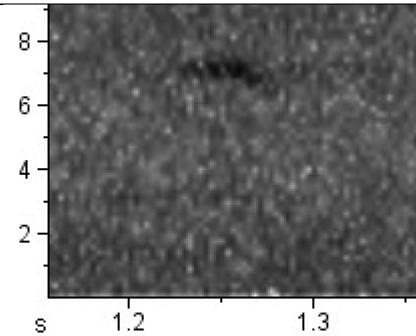
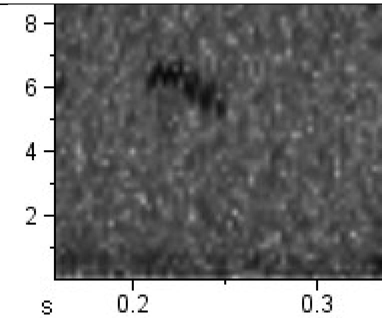
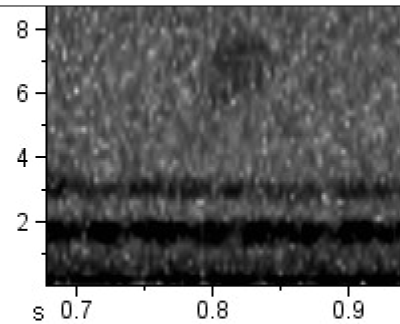
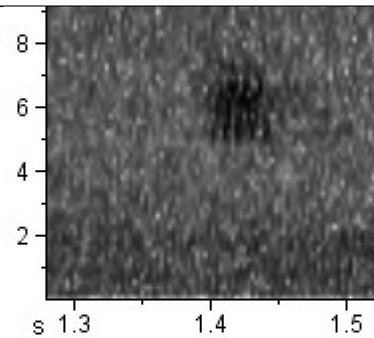
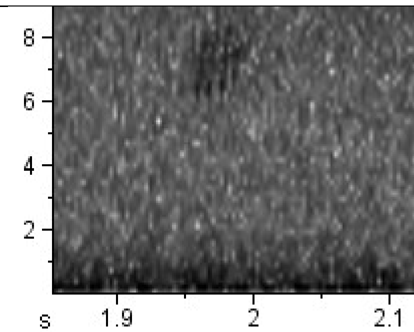
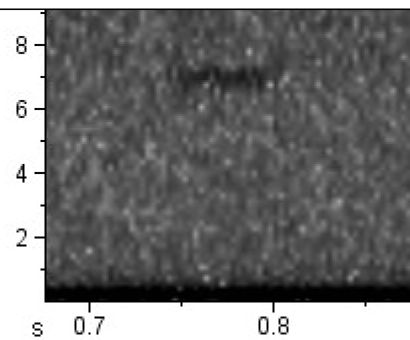
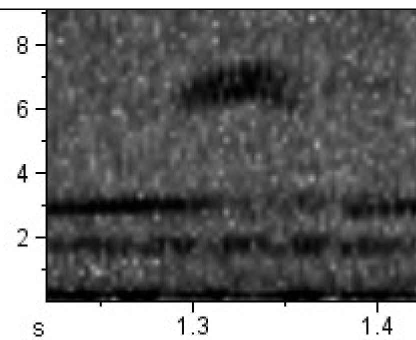
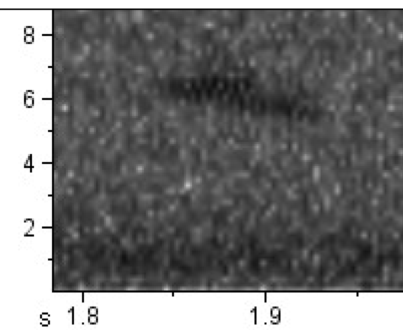
Species Code	**Species Name and Notes**	**Spectrogram 1**	**Spectrogram 2**	**Spectrogram 3**
SWTH	Swainson's Thrush (Catharus ustulatus)			
WOTH	Wood Thrush (Hylocichla mustelina)			

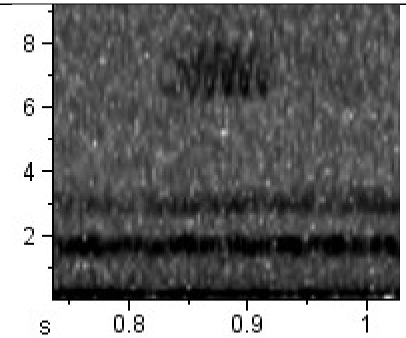
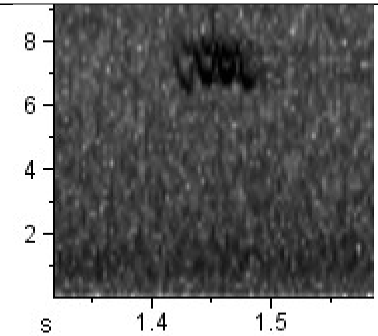
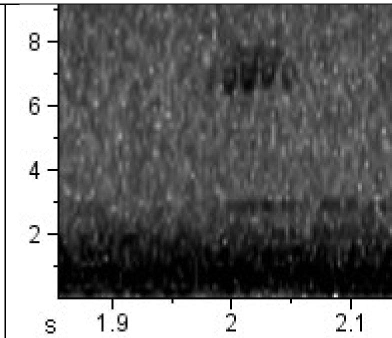
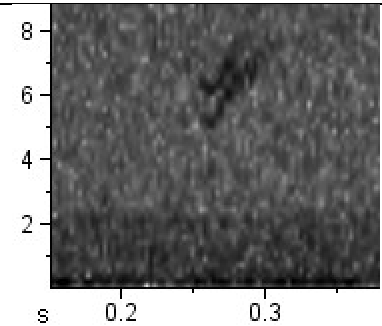
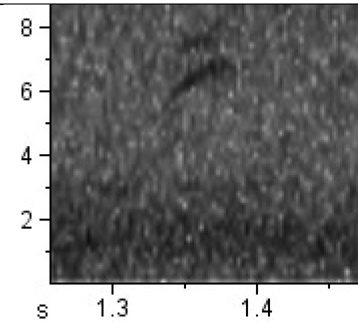
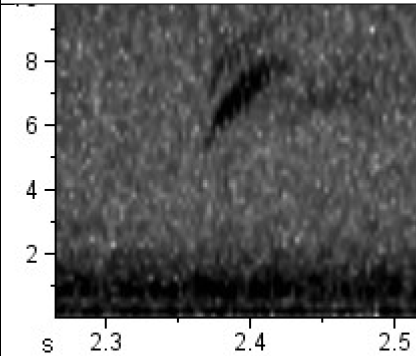
GCTH	Grey-cheeked Thrush (Catharus minimus)			
VEER	Veery (Catharus fuscescens)			
SCTA/ VEER	Scarlet Tanager/Veery (Piranga olivacea/Catharus fuscescens) Split species group			

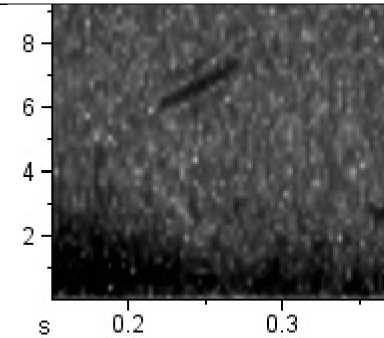
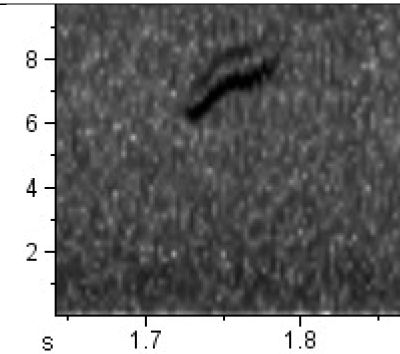
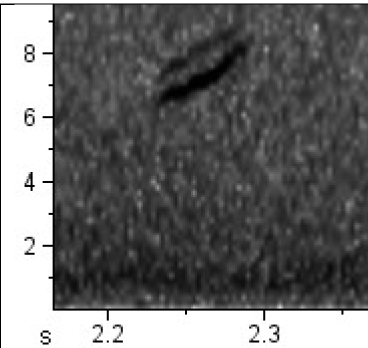
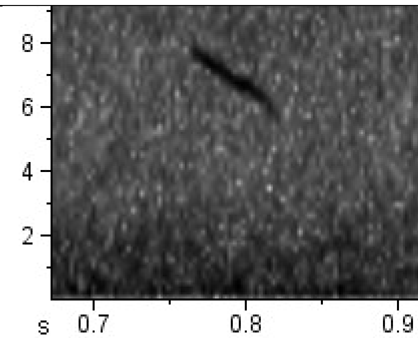
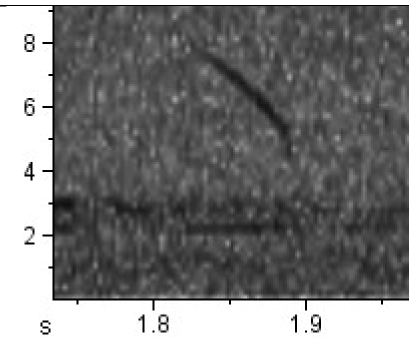
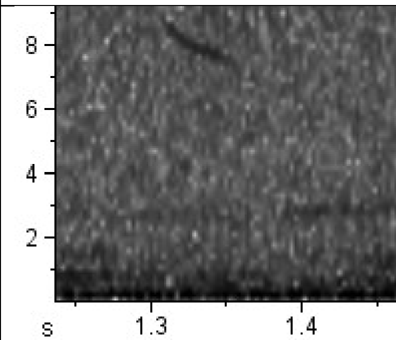
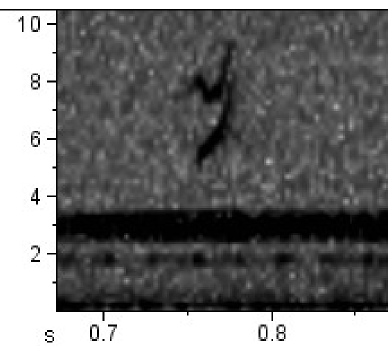
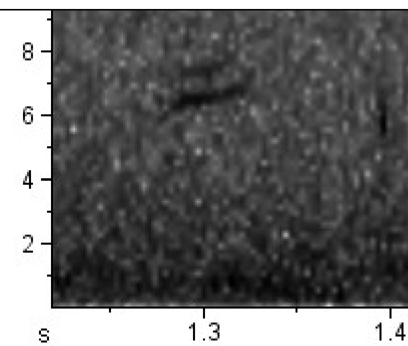
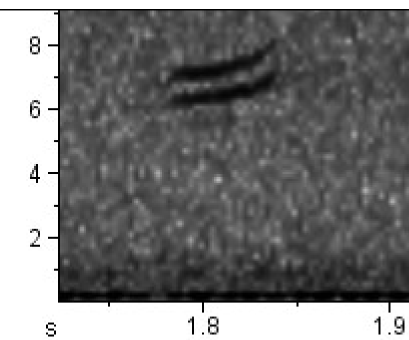
<u>Spectrogram examples of warbler calls.</u>

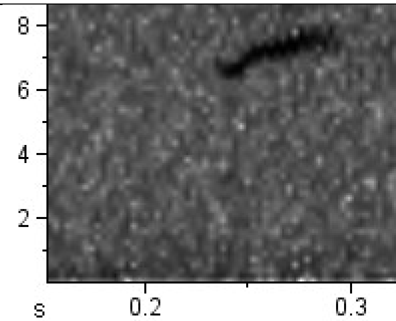
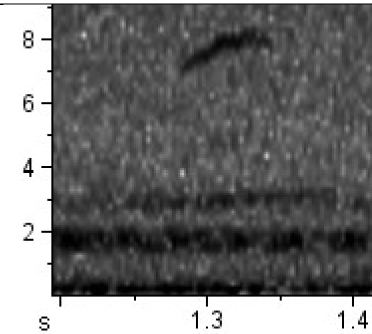
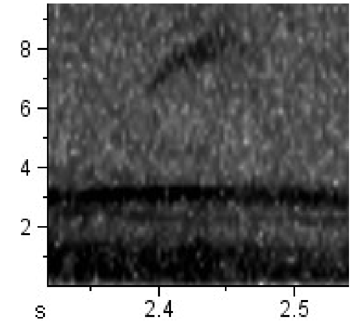
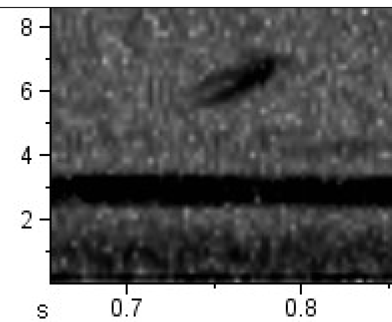
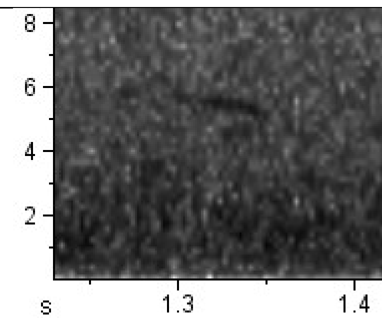
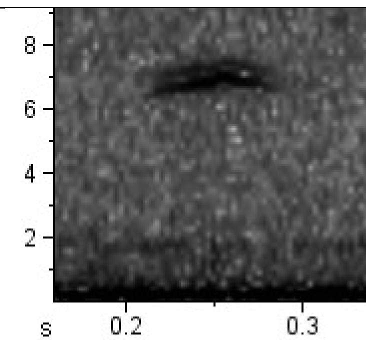
Species Code	**Species Name and Notes**	**Spectrogram 1**	**Spectrogram 2**	**Spectrogram 3**
AMRE	American Redstart (*Setophaga ruticilla*)			
BAWW	Black-and-white Warbler (*Mniotilta varia*)			

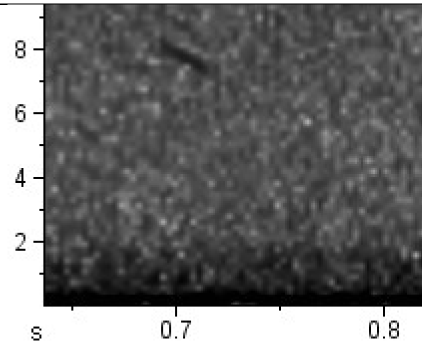
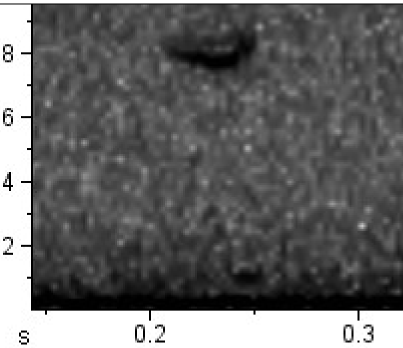
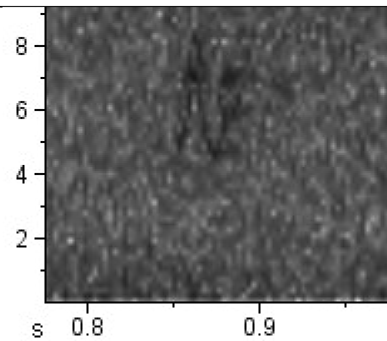
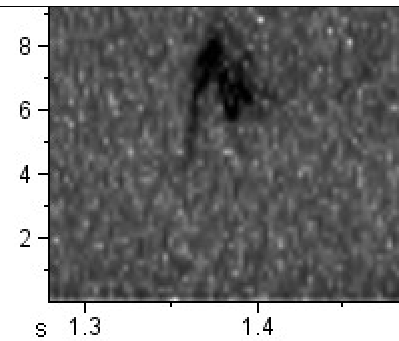
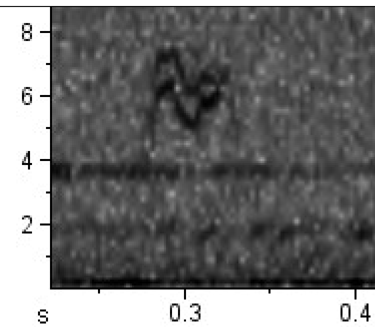
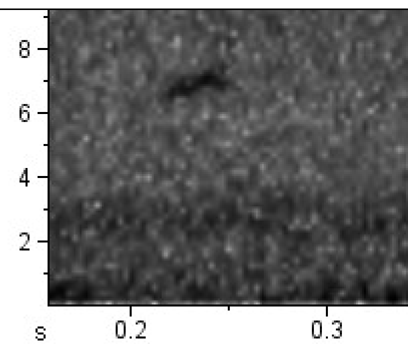
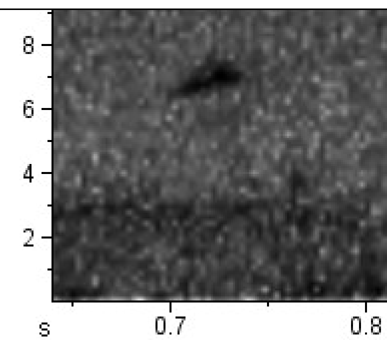
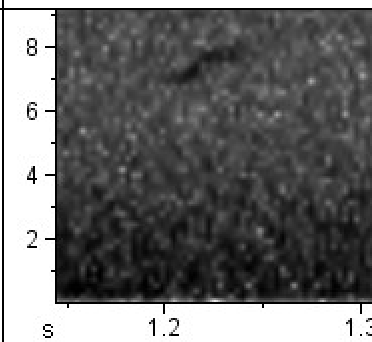
BBWA	Bay-breasted Warbler (Setophaga castanea)			
BTBW	Black-throated Blue Warbler (*Setophaga caerulescens*)			
CAWA	Canada Warbler (*Cardellina canadensis*)			

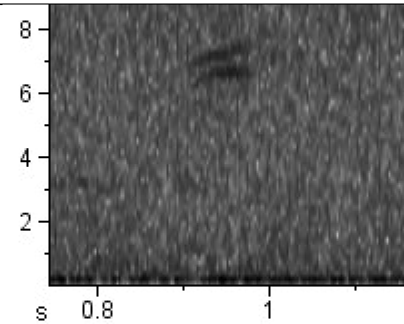
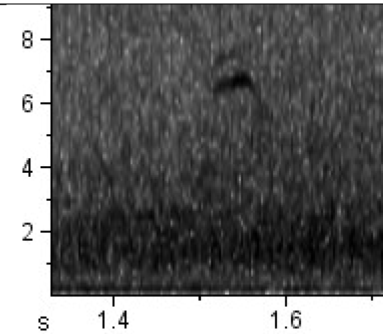
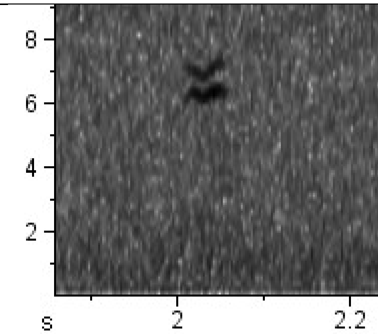
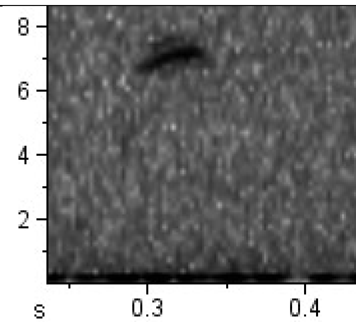
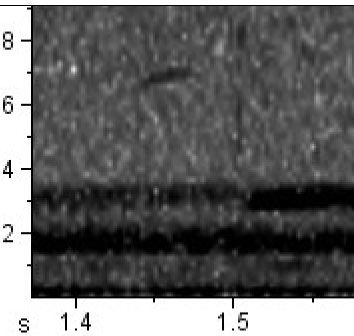
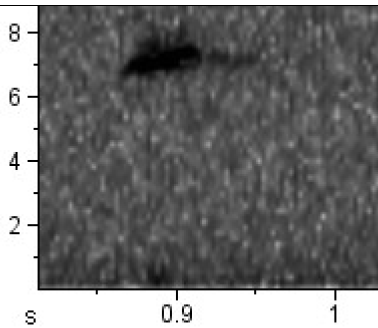
CMWA	Cape May Warbler (*Setophaga tigrina*)			
COYE	Common Yellowthroat (*Geothlypis trichas*)			
CSWA	Chestnut-sided Warbler (*Setophaga pensylvanica*)			

MAWA	Magnolia Warbler (*Setophaga magnolia*)			
MOWA	Mourning Warbler (*Geothlypis philadelphia*)			

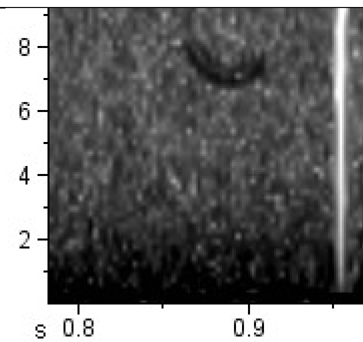
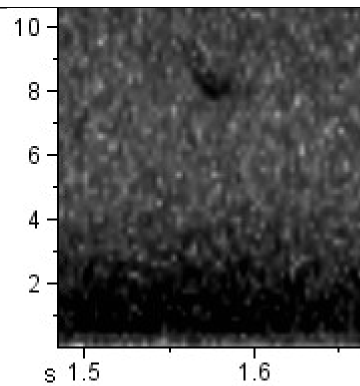
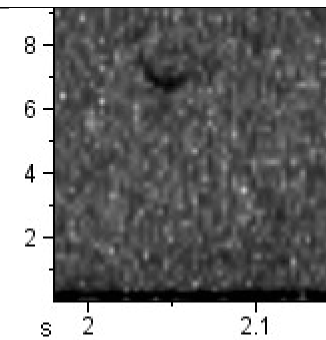
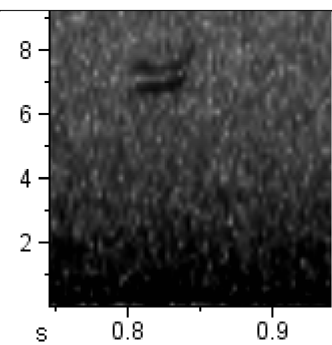
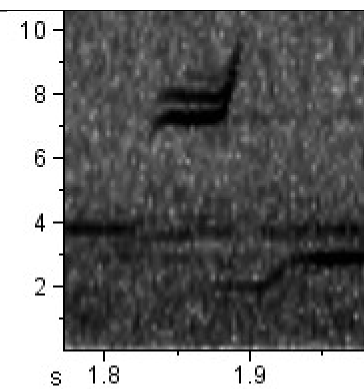
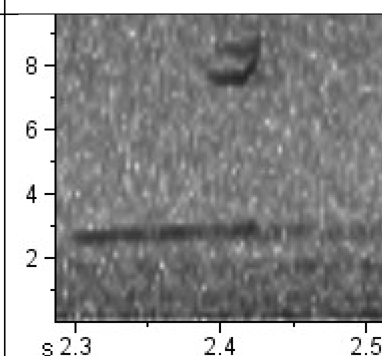
NAWA	Nashville Warbler (*Leiothlypis ruficapilla*)			
NOPA	Northern Parula (*Setophaga americana*)			
TEWA	Tennessee Warbler (*Leiothlypis peregrina*)			

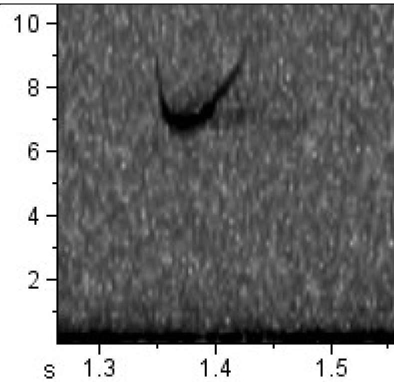
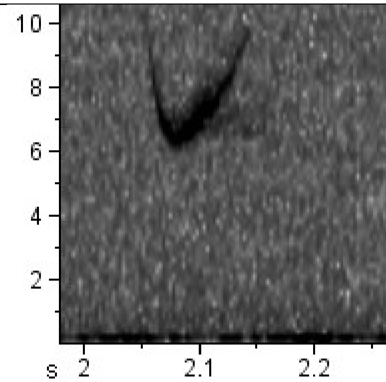
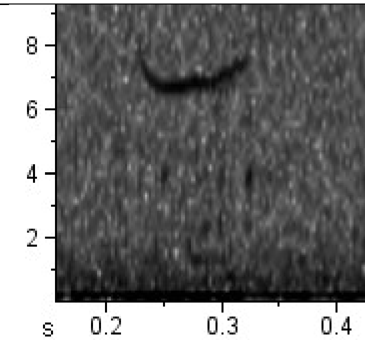
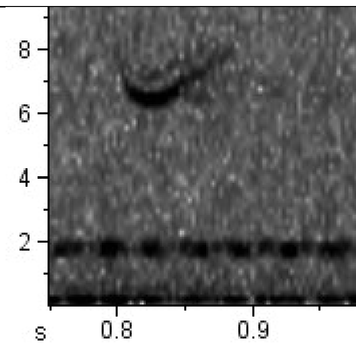
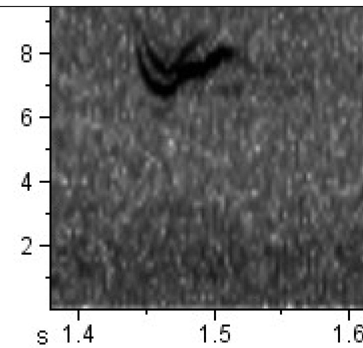
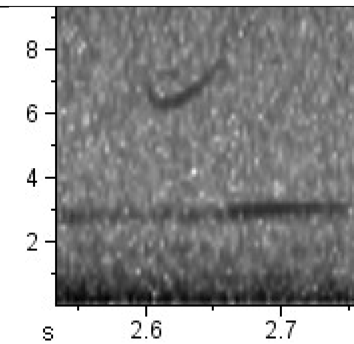
OVEN	Ovenbird (*Seiurus aurocapilla*)			
PAWA	Palm Warbler (*Setophaga palmarum*)			

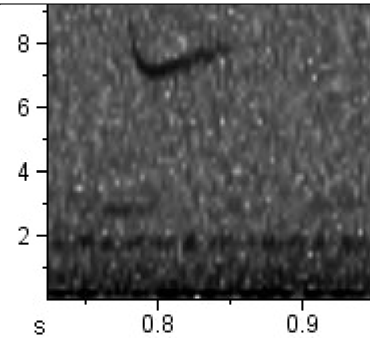
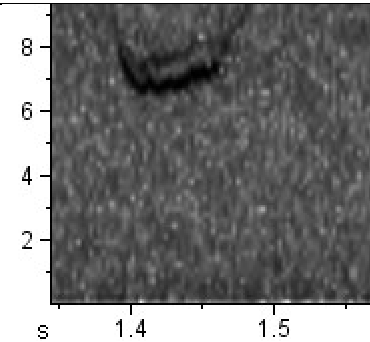
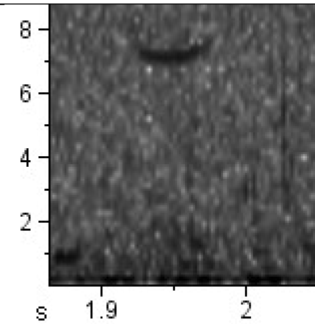
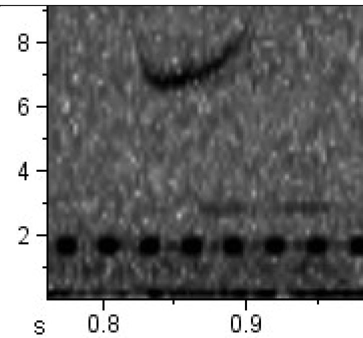
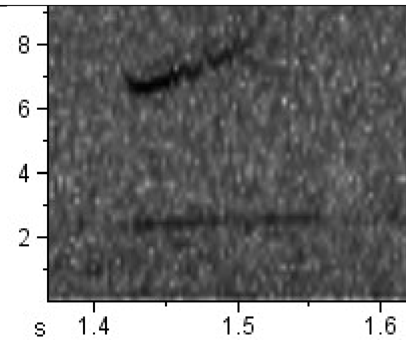
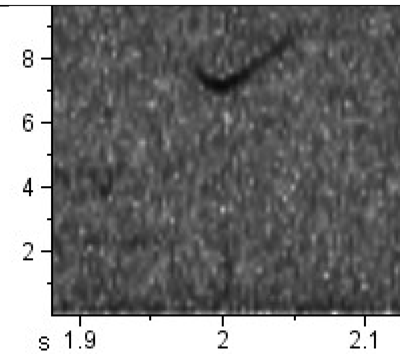
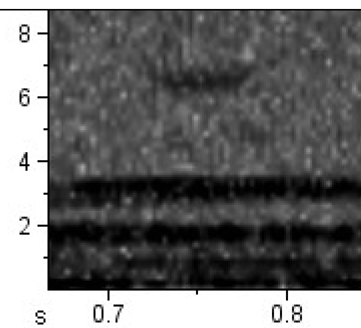
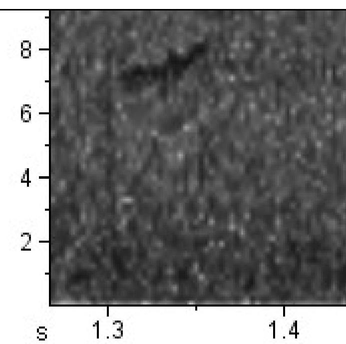
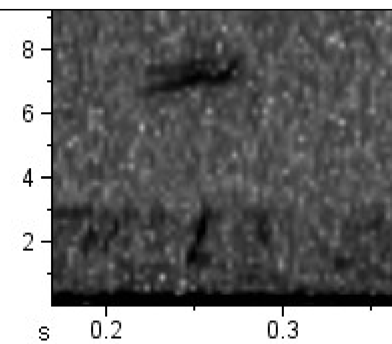
PIWA	Pine Warbler (*Setophaga pinus*)			
WIWA	Wilson's Warbler (*Cardellina pusilla*)			
YRWA	Yellow-rumped Warbler (*Setophaga coronata*)			

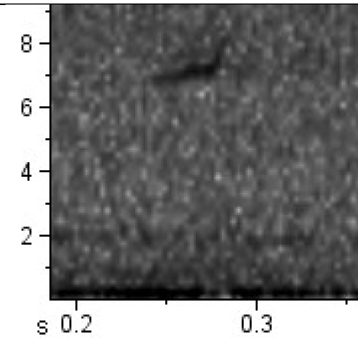
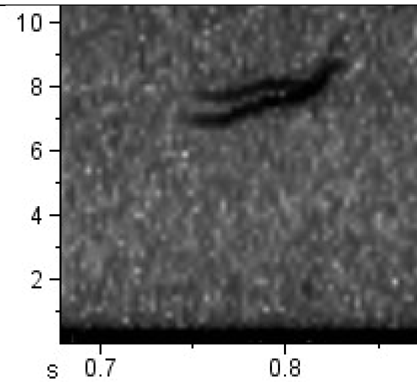
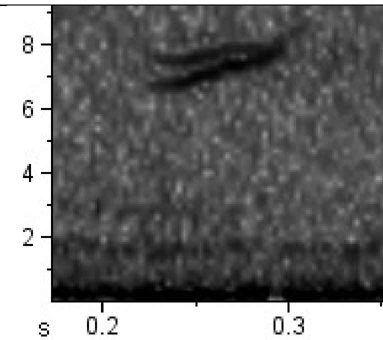
BTNW	Black-throated Green Warbler (*Setophaga virens*)			
YRWA/ BTNW	Yellow-rumped Warbler/Black-throated Green Warbler Split species identification			

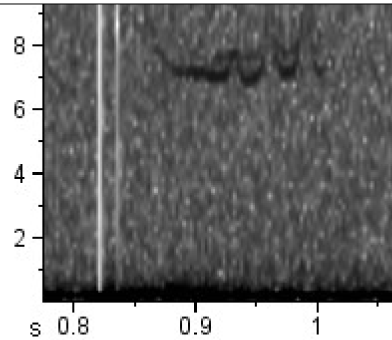
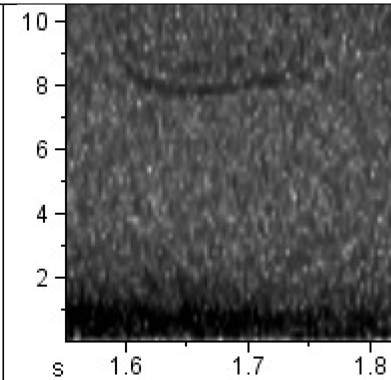
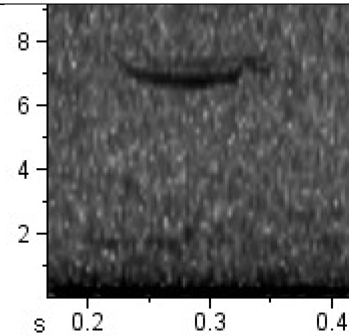
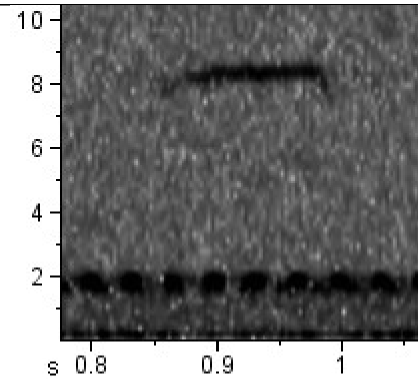
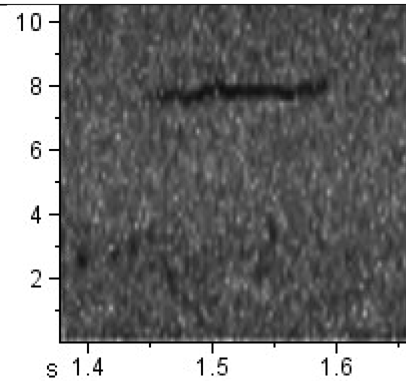
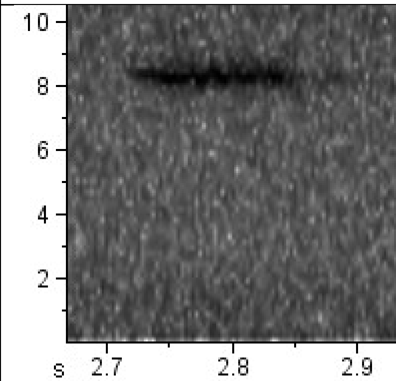
Spectrogram examples of sparrow calls.

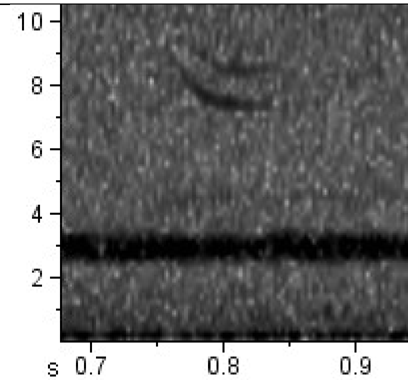
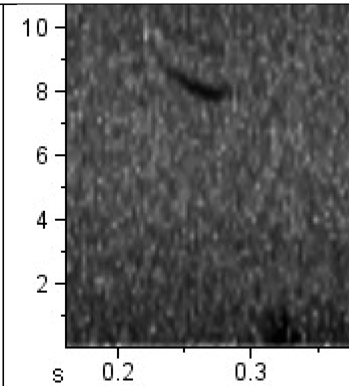
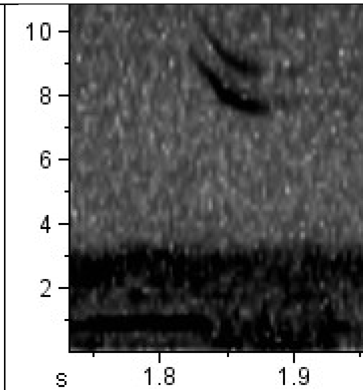
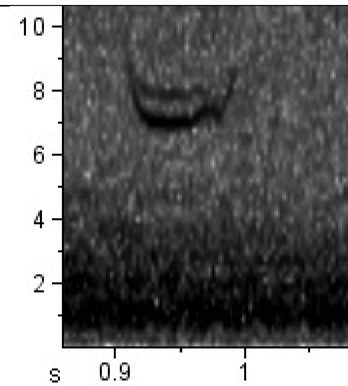
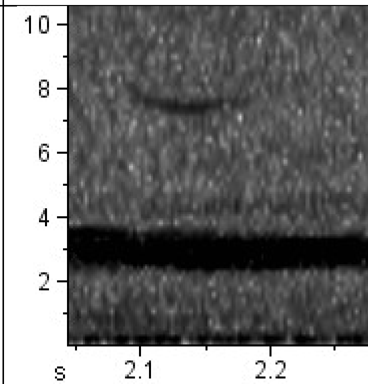
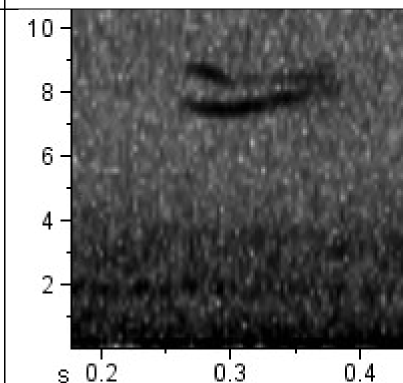
Species Code	Species Name and Notes	Spectrogram 1	Spectrogram 2	Spectrogram 3
ATSP	American Tree Sparrow (*Spizella arborea*)			
CCSP	Clay-coloured sparrow (*Spizella pallida*)			

CHSP	Chipping Sparrow (*Spizella passerina*)			
VESP	Vesper Sparrow (*Pooecetes gramineus*)			

CHSP /ATSP	Chipping Sparrow/American Tree Sparrow Split species identification			
CHSP/VESP	Chipping Sparrow/Vesper Sparrow Split species identification			
WCSP	White-crowned Sparrow (*Zonotrichia leucophrys*)			

WCSP/ CCSP	White-Crowned Sparrow/Clay-coloured Sparrow Split species identification			
WCSP/ VESP	White-crowned sparrow/Vesper Sparrow Split species identification			

WTSP	White-throated Sparrow (*Zonotrichia albicollis*)			
GRSP	Grasshopper Sparrow (*Ammodramus savannarum*)			

SASP	Savannah Sparrow (*Passerculus sandwichensis*)			
FOSP/ SOSP	Fox Sparrow/Song Sparrow (*Passerella iliaca/Melospiza melodia*) Split species identification			

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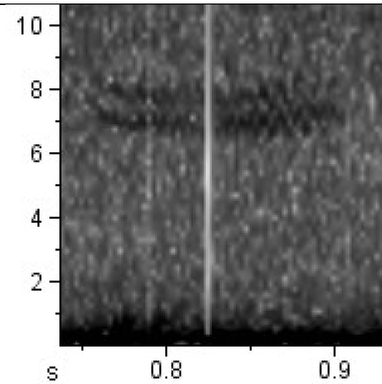
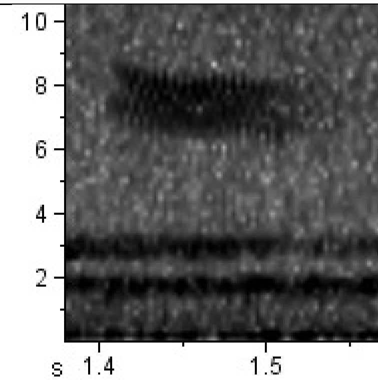
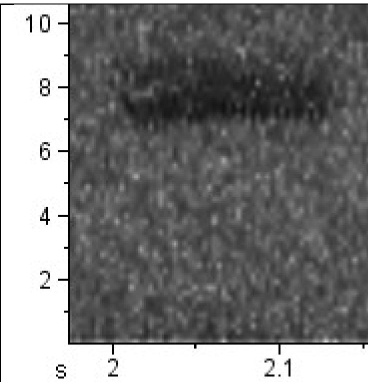
(Melospiza lincolnii/ Melospiza georgiana)
Split species identification</td>
<td></td>
<td></td>
<td></td>
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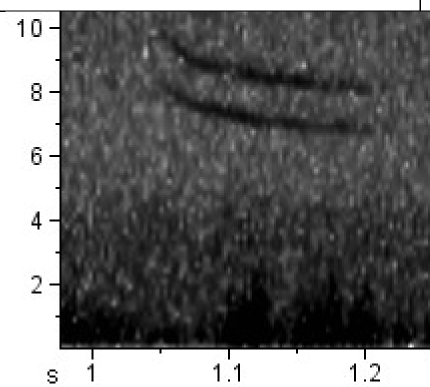
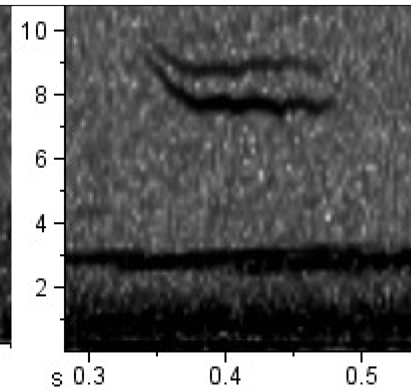
<td>pLCSP/
SASP</td>
<td>Possible Lincoln Sparrow/Savannah Sparrow
Split species identification</td>
<td></td>
<td></td>
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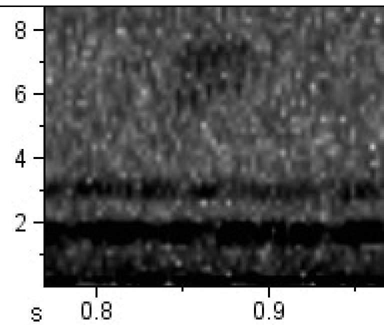
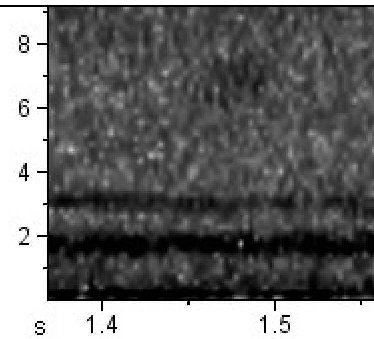
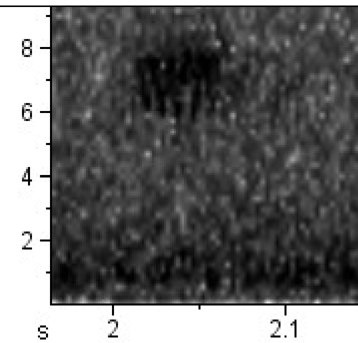
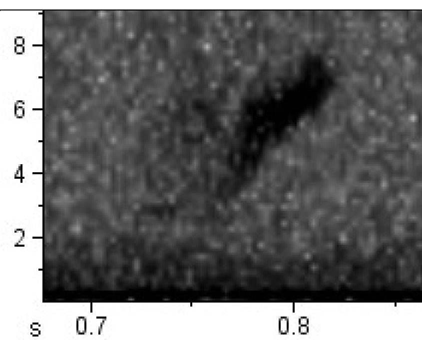
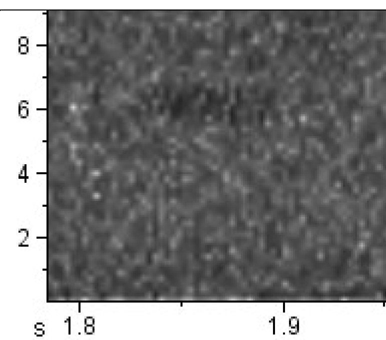
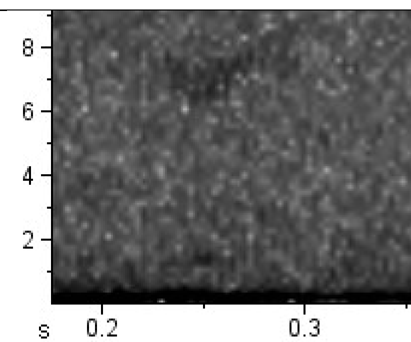
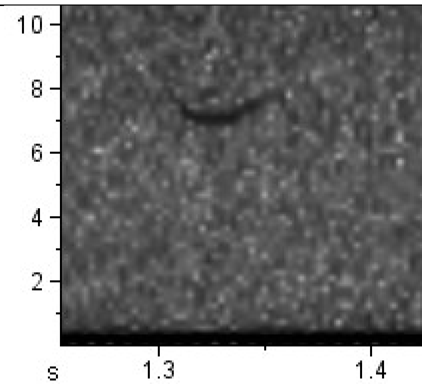
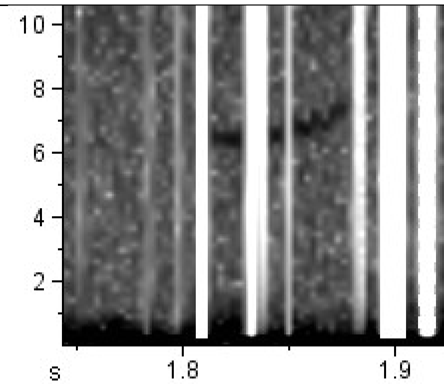
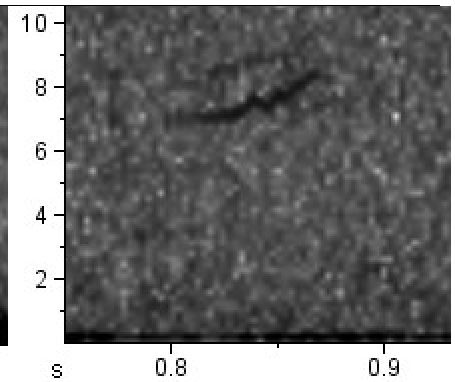
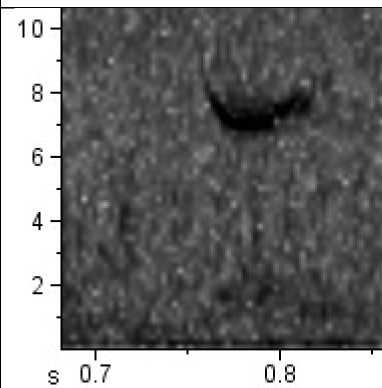
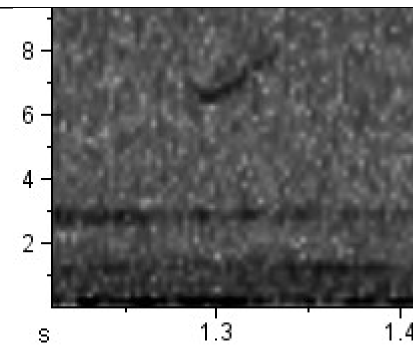
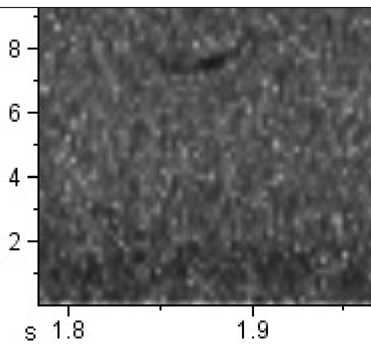
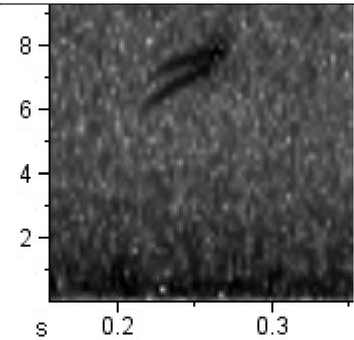
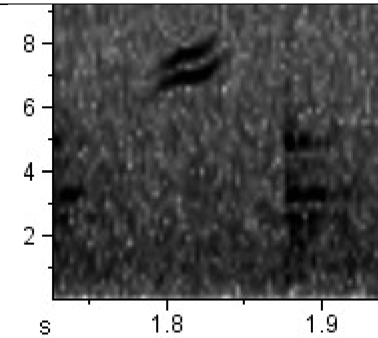
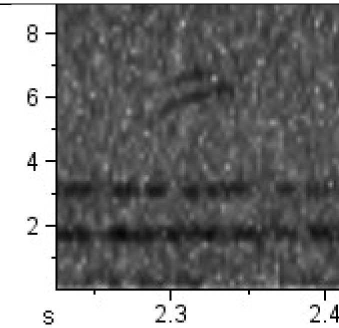
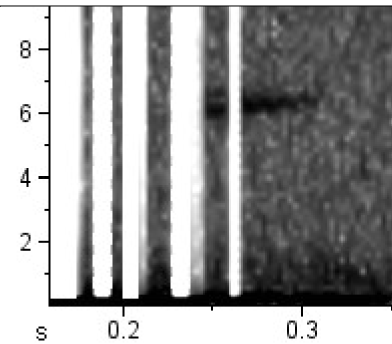
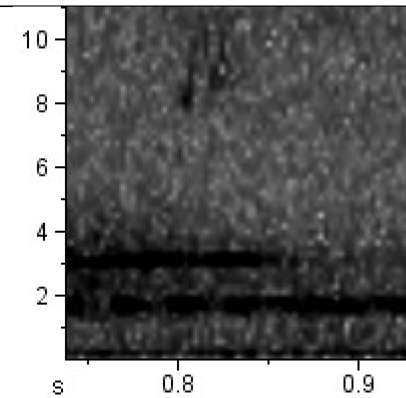
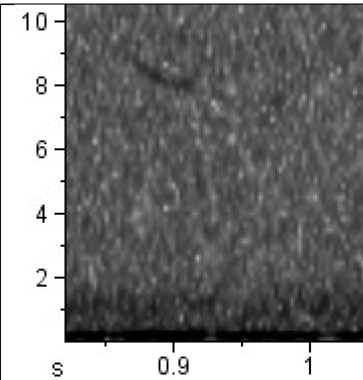
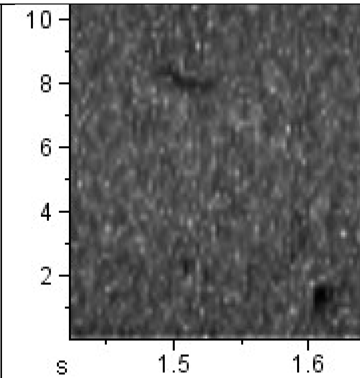
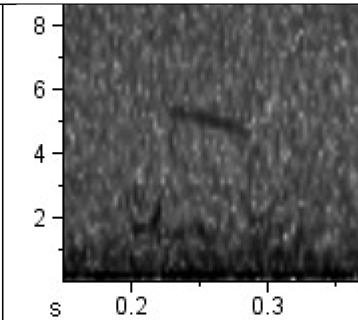
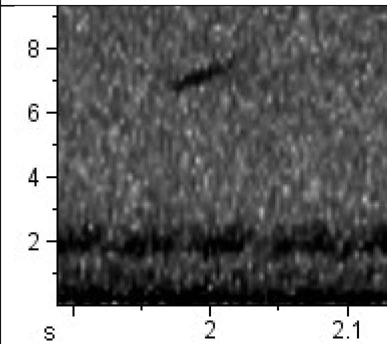
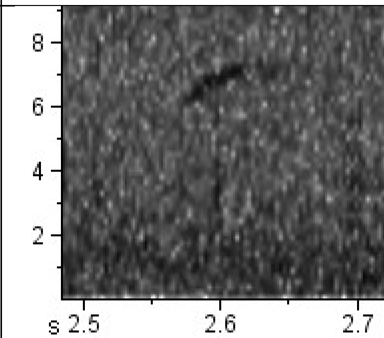
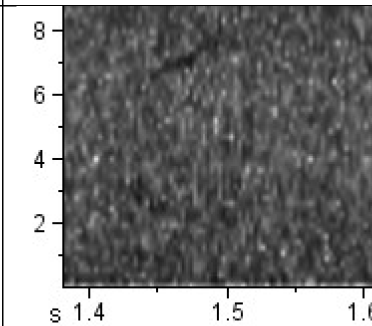
Spectrogram examples of call group identifications.

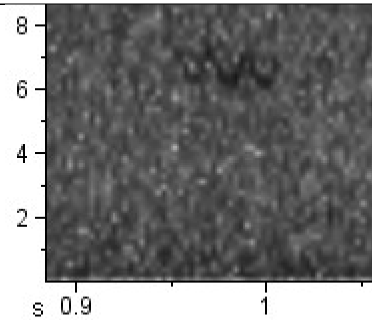
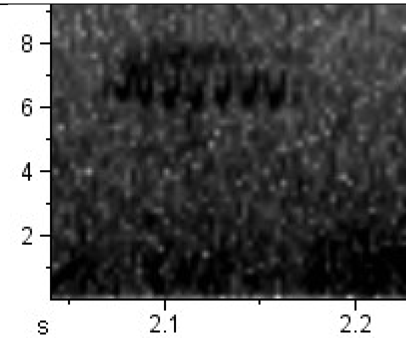
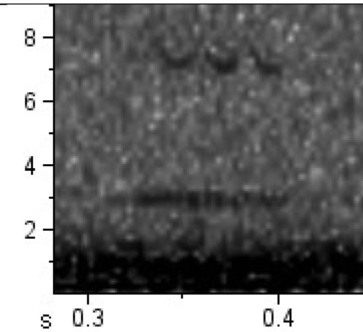
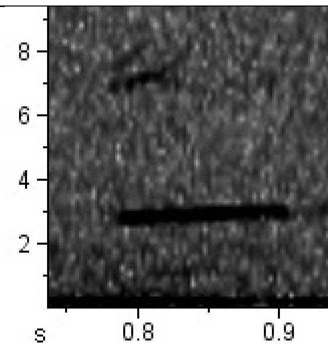
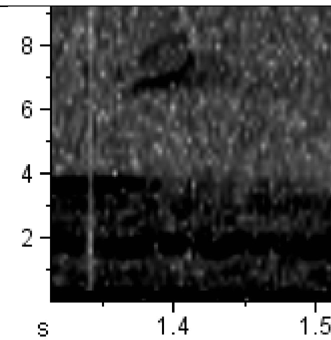
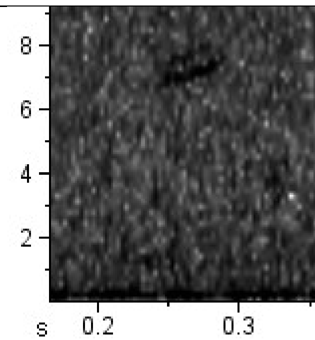
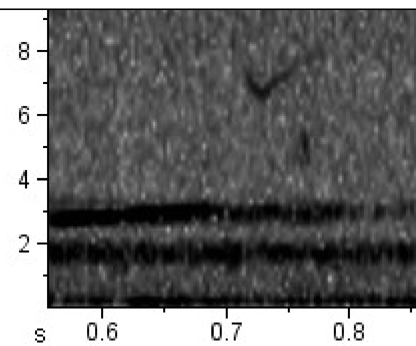
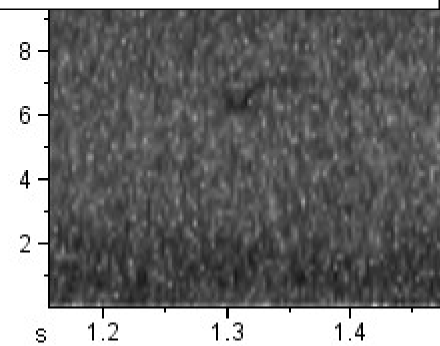
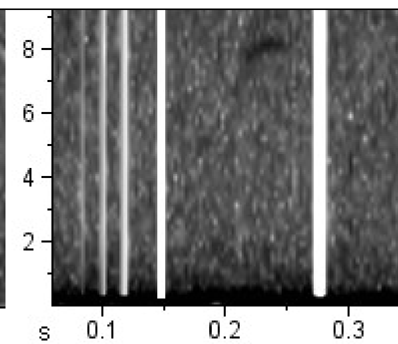
Species that can be categorized within that call group are listed below.

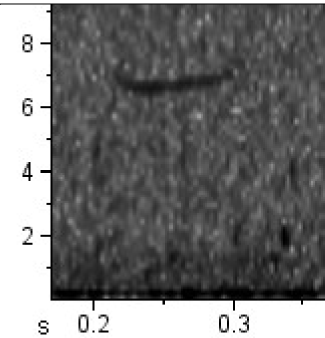
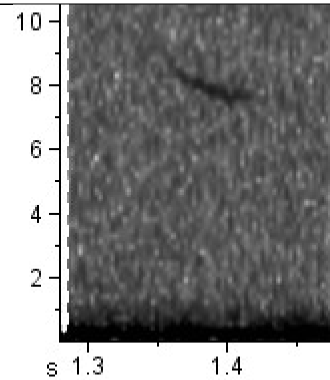
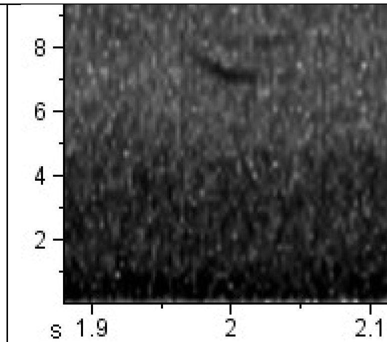
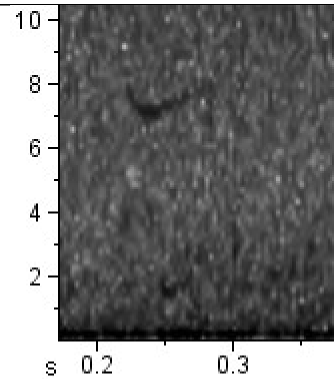
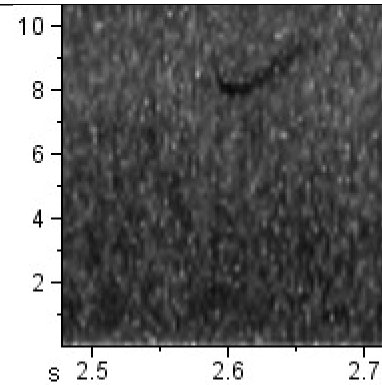
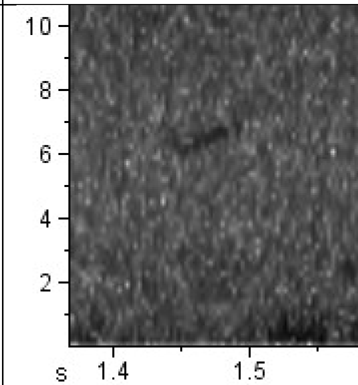
Species Code	**Species Name and Notes**	**Spectrogram 1**	**Spectrogram 2**	**Spectrogram 3**
BUZZ	Double banded oscillations Includes: HOWA, COYE, CSWA, INBU, SWSP, BAWW, LISP			
BZWA	Includes: HOWA, COYE, CSWA, INBU, BAWW			

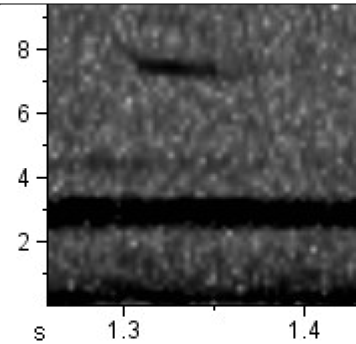
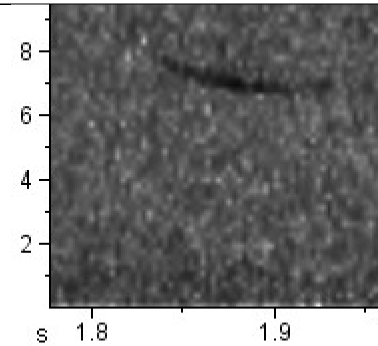
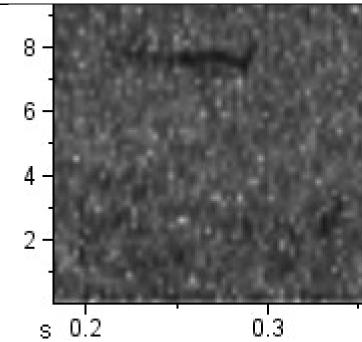
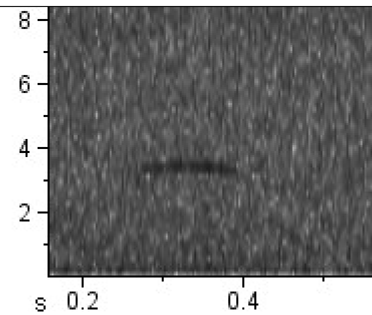
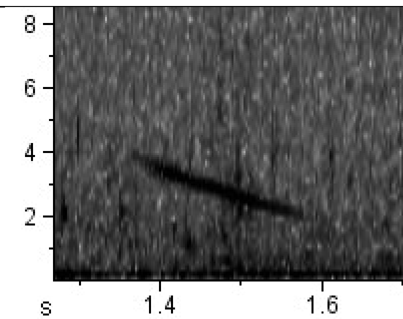
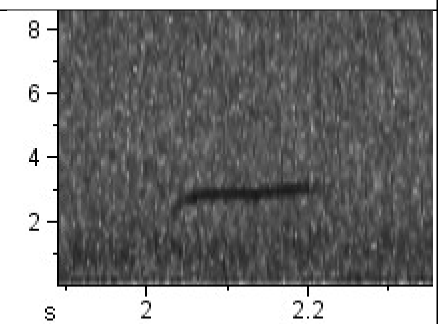
CALL	Night flight call that cannot be identified further			
CUPS	Single banded cup shape Includes: CHSP, ATSP, VESP, FISP, FOSP, SOSP			

DBUP	Double Band Upswoop Includes: BTNW, TEWA, OCWA, NAWA, MOWA, VESP, WCSP, YRWA			
Pass	Passerine Any call that looks like a passerine NFC, but cannot be identified further			

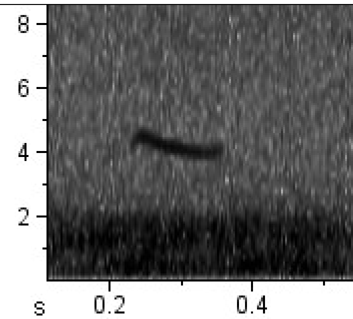
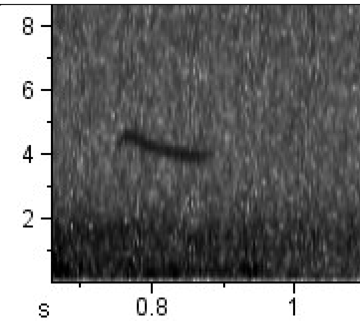
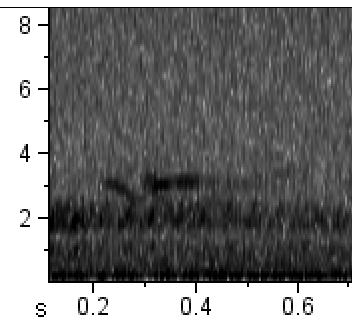
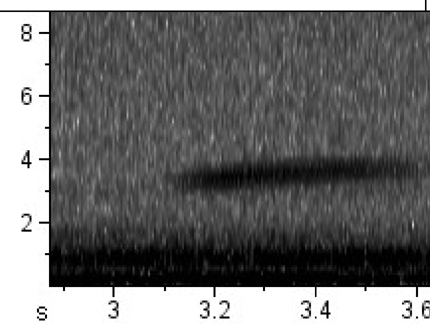
SBDN	Single band down-swoop Includes: PAWA, NOPA, FISP			
SBUP	Single band up-swoop Includes: PROW, YRWA, BTBW, OVEN, WCSP			

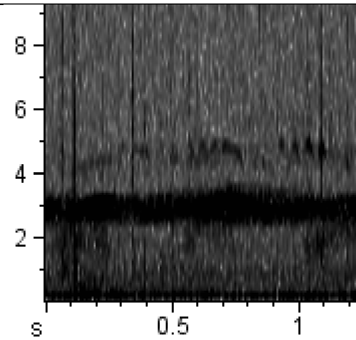
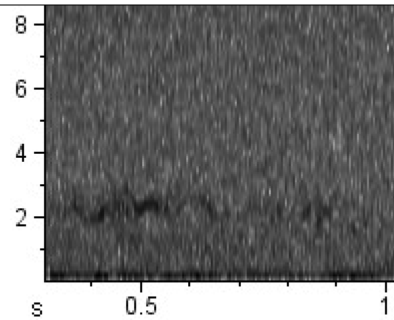
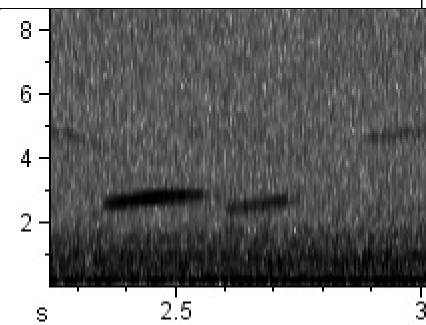
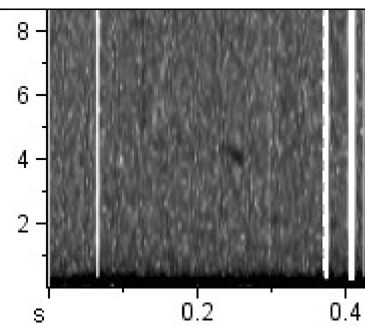
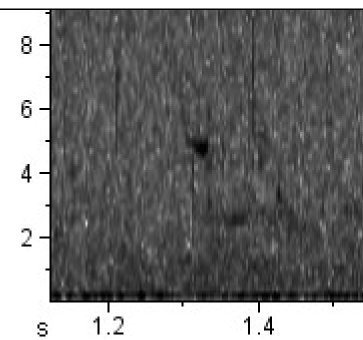
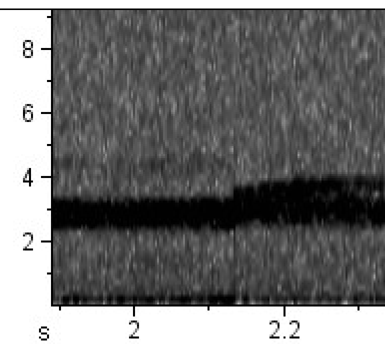
ZEWA	Single banded oscillations Includes: CMWA, CEWA, BBWA, BLBW, YEWA, BLPW, MAWA, NOWA			
OREO	*Oreothlypis* Includes same group of species as DBUP group			
IRRG	Irregular contour shape AMRE, OVEN, BAWW, CMWA, NOWA, WIWA, INBU, GCKI, CAWA			

EMBER	*Emberizidae* Includes: ATSP, CCSP, FOSP, LISP, SWSP, VESP, SASP, WCSP, WTSP, FISP, CHSP			
SPIZ	*Spizella* Includes: ATSP, CHSP, FISP, CCSP			

SPAR	Sparrow call – not further identified			
THSH	Calls within the lower frequency range that are thrush calls but cannot be distinguished further.			

Spectrogram examples of noise extracted as calls and excluded from analysis.

NOISE CODE	Species Name and Notes	Spectrogram 2	Spectrogram 3	Spectrogram 4
KILL	Killdeer (*Charadrius vociferus*)			
lowUNKN	Low frequency unknown calls			

NULL	Not a night flight call or any other noise category			
OTHR	Other animal species			
UNKN	Unknown noise			

Appendix E : R Code Used by E. Griffith to Randomly Select Unidentified Calls for Identification

R code was provided by Emily Griffith of Golden Crown Consulting, retrieved from personal communication.

Setting the Time and Date for the Extracted Files Using POSIX

```
$roughdate=gsub(pattern = &quot;(.*_LF_)(.*)(.c.*)&quot;,replacement =
&quot;\\2&quot;,alles$FilePath)
alles$DateTime=as.POSIXct(alles$roughdate, tz=&quot;EST&quot;,
format=&quot;%Y%m%d.%H%M%S.%OS&quot;)
```

Randomly Selecting Half of the Calls Within the Night

```
HN_D1=alles[sample(which(alles$loc == &quot;BSBD1&quot;),
(as.numeric(nrow(alles[alles$loc == &quot;BSBD1&quot;,])))/2),]
```

Sample – tells R to randomly select from a list based on a provided number.

as.numeric(nrow(alles[alles$loc == "BSBD1",])))/2) – tells R to count the number of files with the location “BSBD1”, and then divide that number by 2.

Appendix F : R Codes Used for Generalized Linear Mixed Model and Principal Component Analysis

The GLMM formula and bootstrap code were provided by Christian Roy from the Canadian Wildlife Service of Environment and Climate Change Canada

GLMM formula using SiteID as fixed effect:

```
new.fit <- glmmadmb(Call_Count ~ SiteID + (1|Jdays), family="nbinom", data=file)
```

GLMM formula using DistancetoCoast(km) and Year as fixed effects:

```
new.fitFall <- glmmadmb(Call_Count ~ DistancetoCoast + Year + (1|Jdays),
family="nbinom", data=file)
```

Note:

Call_Count: the number of identified calls per night

SiteID: (fixed effect) the identification code (N1-3 and S1-3) given to each site within the transects.

Jdays: (random effect) the Julian date of each night of data collection

DistancetoCoast: (fixed effect) the distance between each site and the nearest coastline measured in kilometers

Year: (fixed effect) the year that the data was collected in (2 levels: 2013 or 2014)

Bootstrap Confidence Interval formulae:

Lower interval:

```
pred.df$low_r =  sapply(1:nrow(pred.df),
function(i){quantile(exp(rnorm(1e6,pred.df$mean[i], pred.df$se[i])), prob=0.025)})
```

Higher interval:

```
pred.df$high_r =  sapply(1:nrow(pred.df),
function(i){quantile(exp(rnorm(1e6,pred.df$mean[i], pred.df$se[i])), prob=0.975)})
```

Script Used to Analyze Species Composition Using Principal Component Analysis:

```
Fileadd<-File+1 # add 1 to the base dataset
add1log.File <- log(Fileadd[, 1:3]) # log transform the data to normal distribution
#apply PCA using prcomp; center and scale the data
add1log_PCA <- prcomp(add1log.File, center = TRUE, scale. = TRUE)
summary(add1log_PCA) #summary of the importance of components (standard
dev,proportions)
screeplot(add1log_PCA, type="lines",col=3) #plot of the amount of variance accounted
for at each PC
PCArotationSP<-add1log_PCA$rotation #save the 'rotations' for viewing
biplot(add1log_PCA,cex=0.8) #plot the PCA results (species scores = row, site loading =
col)
abline(h = 0, v = 0, lty = 2, col = 8) #add the crosshair lines from 0,0
```

Appendix G : Results of the Principal Component Analysis (PCA) Showing Eigenvectors and Importance of Components

Summary of PCA results showing the eigenvector loadings for each site. The cumulative proportion describes that accumulated amount of variance in each principal component.

Spring 2013

Eigenvector (Principal Components)	PC1	PC2	PC3
S1	0. 5736587	-0.6533491	-0.4940148
S2	0.5681525	0.7518376	-0.3345787
S3	0. 5900156	-0. 0887417	0.8025001
Importance of Components:			
Standard deviation	1.5972	0.52777	0.4128
Proportion of Variance	0.8504	0.09285	0.0568
Cumulative Proportion	0.8504	0.94320	1.0000

Fall 2013

Eigenvector (Principal Components)	**PC1**	**PC2**	**PC3**
S1	-0.5842806	-0.3602705	-0.68486059
S2	-0.5654153	0.8235052	-0.04630987
S3	-0.5821698	-0.4382286	0.72720105
Importance of Components:			
Standard deviation	1.6142	0.49572	0.3852
Proportion of Variance	0.8686	0.08191	0.04952
Cumulative Proportion	0.8686	0.95048	1.0000

Spring 2014 (Showing the First Three Eigenvectors)

Eigenvector (Principal Components)	**PC1**	**PC2**	**PC3**
N1	-0.4175230	-0.1372609	0.47251701
N2	-0.4094043	-0.5126985	-0.19002453
N3	-0.3868085	0.6104298	0.50074846
S1	-0.4271441	-0.1733755	-0.05764211
S2	-0.4203963	-0.2235381	-0.04683336
S3	-0.3863376	0.5154094	-0.69595500
Importance of Components:			
Standard deviation	2.183	0.69698	0.54535
Proportion of Variance	0.794	0.08096	0.04957
Cumulative Proportion	0.794	0.87498	0.92455

Fall 2014 (Showing the First Three Eigenvectors)

Eigenvector (Principal Components)	**PC1**	**PC2**	**PC3**
N1	-0.4343840	-0. 6690220	0. 45467518
N2	-0.4666642	0. 1632938	0. 03061227
N3	-0.4532094	0. 3893771	-0. 43861445
S1	- 0.4422961	-0.3853968	-0.56011919
S3	-0.4387601	0.4749731	0.53499273
Importance of Components:			
Standard deviation	2.0517	0.55309	0.50690
Proportion of Variance	0.8419	0.06118	0.05139
Cumulative Proportion	0.8419	0.90306	0.95445

Appendix H : Summary of Species Counts in Each Season Used for the PCA

Spring 2013

Species Code	**S1**	**S2**	**S3**
AMRE	29	0	22
AMRO	0	0	1
BAWW	3	0	0
BBWA	1	0	1
BTBW	1	0	0
CAWA	5	0	2
CCSP	7	0	3
CHSP	107	17	235
VESP	9	0	25
ATSP	4	0	0
CMWA	1	0	2
COYE	8	0	12
CSWA	3	0	7
FISP	1	0	1
FOSP/SOSP	7	1	16
GCTH	4	0	0
GRSP	39	1	29
INBU/PABU	8	0	13
LISP/SWSP	1	0	2
MAWA	3	0	0
MOWA	0	0	2
NOPA	2	0	3
NOWA	8	0	3
OCWA	1	0	0
OVEN	35	1	21
PAWA	1	0	3
RBGR	1	0	1
SASP	89	11	227
SCTA/VEER	15	0	2
SWTH	3	0	3
TEWA	0	0	1
VEER	3	0	1
WCSP	26	1	14
WIWA	0	0	1

WOTH	5	0	1
WTSP	29	4	23
YRWA/BTNW	6	0	1

Fall 2013

Species Code	S1	S2	S3
AMRE	7	23	23
AMRO	37	4	2
BAWW	7	19	2
BBWA	4	8	12
BTBW	13	1	5
BTNW/PAWA	73	47	22
CAWA	2	3	6
VESP	24	36	38
ATSP	58	148	4
CHSP	126	201	15
CMWA	16	13	60
COYE	10	30	12
CSWA	15	14	17
FISP	2	9	0
FOSP/SOSP	1117	339	751
GCKI	7	7	9
GCTH	3	77	2
GRSP	7	8	3
INBU	9	116	12
LISP/SWSP	62	111	35
MAWA	11	10	26
MOWA	29	9	15
NAWA	67	19	20
NOPA	5	11	10
NOWA	8	13	8
OCWA	15	6	19
OVEN	101	74	71
PIWA	2	1	0
SASP	344	1902	340
SCTA/VEER	1	11	0
SWTH	20	179	21

TEWA	107	57	70
CCSP	8	4	7
WCSP	479	344	447
WIWA	1	9	6
WOTH	0	3	0
WTSP	389	178	268
YRWA/BTNW	48	5	4
BLBW	0	0	1
HESP	7	0	2
HEWA	0	0	2
BLPW	1	0	0
DBUIP	1	0	0
HASP	2	0	0
PROW	1	0	0

Spring 2014

Species Code	**N1**	**N2**	**N3**	**S1**	**S2**	**S3**
AMRE	89	71	58	42	20	17
BAWW	0	4	0	0	0	0
BBWA	2	0	6	0	0	0
BTBW	2	4	0	0	3	1
CAWA	6	4	10	17	0	6
CCSP	9	11	0	6	1	0
VESP	25	73	3	217	28	5
ATSP	30	21	8	26	5	9
CHSP	123	297	15	233	26	37
CMWA	1	5	0	0	0	0
COYE	5	13	0	5	0	12
CSWA	9	6	10	6	4	5
FOSP/SOSP	14	27	10	14	16	17
GCKI	0	3	0	0	0	0
GCTH	9	1	3	2	0	0
GRSP	39	135	3	10	8	0
INBU/PABU	13	34	6	17	4	1
LISP/SWSP	2	7	0	0	0	4
MAWA	3	2	0	2	0	5
MOWA	5	3	6	1	0	6

NAWA	3	2	0	0	0	0
NOPA	5	7	3	1	0	1
NOWA	5	11	0	9	0	3
OVEN	79	136	70	86	14	17
PAWA	5	4	0	2	1	1
PIWA	0	5	0	0	1	0
RBGR	0	0	0	2	0	0
SASP	289	336	115	111	39	86
SCTA/VEER	9	14	0	8	0	1
SWTH	24	3	3	3	0	0
TEWA	5	1	0	2	1	1
WCSP	23	29	0	8	3	1
WIWA	5	0	3	1	0	3
WOTH	5	4	0	0	0	0
WTSP	25	123	45	56	28	51
YRWA/BTNW	9	8	14	13	4	5

<u>Fall 2014</u>

Species Code	N1	N2	N3	S1	S3
AMRE	26	99	60	195	71
AMRO	1	4	1	0	3
BAWW	23	18	6	37	5
BBWA	5	10	11	64	12
BTBW	7	12	12	33	21
CAWA	6	4	13	23	14
CCSP	8	9	5	9	11
CHSP	2	1	7	30	5
ATSP	26	16	28	36	3
CMWA	51	30	24	63	25
COYE	11	27	19	87	30
CSWA	49	36	35	248	106
FISP	0	0	0	0	2
FOSP/SOSP	9	61	27	54	51
GCKI	3	0	0	8	0
GCTH	111	100	23	34	75
GRSP	0	2	3	0	3

HETH	0	1	0	0	2
HOWA	0	4	0	5	0
INBU	0	3	4	4	16
LISP/SWSP	6	25	11	50	14
MAWA	15	12	3	39	11
MOWA	3	31	24	81	26
NAWA	42	36	23	60	35
NOPA	6	9	2	44	14
NOWA	13	11	4	32	11
OCWA	12	22	6	6	10
OVEN	150	130	51	211	82
PAWA	10	9	6	40	48
PIWA	3	2	1	6	7
RBGR	4	0	0	0	22
SASP	280	828	554	1161	477
SCTA/VEER	55	55	20	62	24
SWTH	204	117	12	164	108
TEWA	10	29	13	35	30
VESP	3	16	24	42	13
WCSP	36	69	49	154	45
WIWA	1	11	4	66	14
WOTH	4	1	0	8	3
WTSP	81	197	197	256	226
YRWA	16	33	17	52	24
BTNW	117	49	27	170	54