MONITORING AVIAN NOCTURNAL FLIGHT CALLS: A TREASURE HUNT FOR UNDERSTANDING BIRD MIGRATION IN ARIZONA

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ABSTRACT: I explored the avian nocturnal flight call phenomenon near Nogales, Arizona from mid-August through October 2015 and found a surprisingly heavy calling rate. My analysis of the 6-10 kHz audio frequency band revealed nearly 21,000 warbler and sparrow calls, 17,629 of which were loud enough to present well for classifying to a species category. Preliminary results suggest 82% involve 7 species of migratory sparrows, 12% are of undetermined species ID, and the rest from an assortment of warblers, other sparrow species, and *Passerina* buntings. Artificial light was minimal at the recording site and is not suspected to have significantly impacted the calling rate of individual birds or caused aggregation behavior. The high calling total may reflect channeling of night migrants in the lower atmosphere, perhaps due to concentration dynamics from regional montane terrain.

The intriguing behavior of avian nocturnal migration became a focus of research for ornithologists during the latter half of the 20th century. New study methodologies shed light on many aspects including the geographic scope and unexpectedly large numbers involved (Gauthreaux 1996). Only one study of birds in active nocturnal migration was reported during this period in Arizona—presumed night migrating birds were observed with telescopes crossing the disc of the moon in early October 1951 from Tucson for 2 nights and Flagstaff for 4 nights (Lowery and Newman 1966). Nocturnal migration remains understudied in Arizona as I am aware of just a few publications on the topic from the past 20 years. Felix et al. (2008) published an analysis of nocturnal bird migration direction and altitude using 2005 and 2006 NEXRAD weather radar data from Tucson and Flagstaff and an expanded analysis using the same NEXRAD dataset was reported by Ruth et al. (2010). What we can generally gather from these studies and infer from others across the continent is that birds are regularly on the move across the Arizona landscape at night during migration periods.

Many species of birds vocalize while migrating at night, and monitoring such calling is the oldest method for studying nocturnal migration. Aboriginal people living in the vicinity of the lower Colorado River in Arizona likely heard and thereby were able to follow the seasonal flight direction and general quantities of calling of night migrating waterfowl and other species. Gauthreaux (1996) noted limitations of the acoustic study method for modern day studies of nocturnal migration because of evidence that calling rates may vary with environmental conditions, and that some species apparently do not call regularly. But monitoring these calls currently provides the only direct means we have to acquire detailed information about the species in active nocturnal migration over a site. Applications for such information have been noted (Evans and Rosenberg 2000, Farnsworth 2005) and microphones have been popping up on the rooftops of birders, but the potential of monitoring avian nocturnal flight calls remains largely untapped.

The first I recall hearing about avian nocturnal flight calls west of the Rocky Mountains was from Joe Marshall, former zoologist and curator of birds at the University of Arizona. He shared with me his memory of hearing flights of Swainson's Thrush (*Catharus ustulatus*) on the West Coast in the 1940s. The nocturnal flight call (nfc) of Swainson's Thrush is distinctive and one of the first songbird nfcs many people learn in North America. This species likely can be heard regularly in migration across most of Arizona, especially in the hour or 2 before sunrise when they are descending from migratory flight. In early June 1997, I recall being surprised to hear a light but steady passage of northbound Swainson's Thrush while I was camped along the Arizona border with Mexico in Cabeza Prieta National Wildlife Refuge.

The dictum I have persistently heard through the years is that while one can hear calls of night migrants in the West, the phenomenon is of a much smaller scale compared to eastern North America. Hearing a big flight in the East can

be an extraordinary experience—one can hear hundreds of calls an hour from a continuous stream of calling birds passing over in the darkness. For example, **https://soundcloud.com/user-830174402/big-migration-night**.

A prevailing theory for the perceived lower calling rate in the West is simply that there are fewer birds aloft, which can be regularly seen in NEXRAD weather surveillance data. For example, **https://www.pauljhurtado.com/US_Composite_Radar/2015-9-11/**. Another factor in much of the West is the relatively dry climate and lack of low cloud ceiling nights. Where weather conditions create lower cloud layers, migrants concentrate closer to the ground. In conjunction with low cloud and light rain, artificial light can disorient night migrating songbirds, causing individuals to increase their calling rate and triggering them to repeatedly fly around in a lighted airspace instead of making migration progress. These behavioral changes can lead to greatly elevated numbers of calls detected by a listener or acoustic monitoring station on the ground (Evans and Conway 2021, Evans et al. 2007).

Figure 1. Microphone atop administration building at Ajo High School, April 2012. Photo by W. R. Evans

My nfc investigations in Arizona began in spring 1995 with a monitoring station at Montezuma Castle National Monument, north of Phoenix. In 2012 I operated a semiautomated acoustic monitoring station at Ajo High School in Ajo, the nfc data from which was posted online for public access each morning (Figure 1). The results from these 2 stations fit my expectation that the calling rate would be much lower than that I had been accustomed to recording in the East.

But in 2015, while investigating the possibility of establishing a new nfc monitoring station in the Nogales area, I contacted Alan Schmierer. He lived nearby toward Patagonia Lake and being an avid birder was happy to host a nfc monitoring station. The recording equipment operated atop a small pumphouse at his residence in spring and fall migration 2015 and spring migration 2016. The following report presents the unexpected results from this nfc monitoring station in the fall 2015 migration period.

Figure 2a. Residential lighting as seen from the nfc monitoring site looking east toward Patagonia Mountains, June 2021. Photo by W. R. Evans

METHODS

A nfc recording station was installed at 78 Circulo Montana Road, Nogales (31.4655, -110.8575) in April 2015. The location is a single-family residence approximately 10 km southwest of Patagonia at 1,250 m above sea level. It is about 3 km south of Patagonia Lake and 5 km north of the terminal at Nogales International Airport. It is in an isolated residential development with about 3 dozen widely spaced homes scattered across 8 km^2. In 2015, there were no unusually bright sources of artificial light within 5 km of the recording site and generally just sparse residential lighting, if any, for 10 km in all directions (e.g., Figure 2a). The glow and city lights from the Nogales municipal area was visible ~12 km to the southwest (Figure 2b).

Figure 2b. Light from the Nogales (Arizona and Sonora) municipal area as seen from the nfc monitoring site, June 2021. Photo by W. R. Evans

I positioned an Old Bird 21c (v2010) microphone (Old Bird, Ithaca NY) on the roof of a small pumphouse south of the residence (Figure 3). The aperture of the microphone was aimed skyward, tilted ~15 degrees from the zenith toward the west to help dispel rainwater. This microphone has a hypercardioid sensitivity pattern and is designed to have acute directional sensitivity in the 2-10 kHz frequency range—the effect is a ~60-degree cone of enhanced sensitivity expanding upward above the station. I have estimated the microphone is able to detect many warbler and sparrow nfcs up to ~300 m above ground, but this varies with species, weather dynamics, and environmental noise.

Figure 3. Looking toward west northwest at microphone atop 78 Circulo Montana pumphouse, February 2021. A similar microphone position on the pumphouse was used in 2015. Photo by David Christiana

I used ~30 m of cable to transfer the audio signal from the microphone to a Turtle Beach Amigo II sound card, which was connected to a PC running Windows 7. Audio was automatically recorded to the PC nightly with Easy HiQ software at 22050 Hz sampling rate and 16-bit resolution in WAV file format. Nightly recordings were made from 20:00-06:00 MST (UTC-7) with a goal of acquiring a large sample of the period between astronomical twilight at sunset and astronomical twilight at sunrise.

My analysis targeted calls in the 6-10 kHz frequency range. This band contains nfcs of warblers, sparrows, and *Passerina* buntings, and was nearly free of insect song at the recording site. To extract nfcs from the all-night recordings, I ran Tseep software (Old Bird, Ithaca, NY) on the 10-hour audio files. This software detects short transient peaks of sound energy relative to the average background sound in and near the 6-10 kHz frequency band. Species with calls around 5 kHz or below were not extracted due to competing insect song in that range.

I analyzed 10-hour recordings (20:00-06:00 MST) from the nights of 18-19 August through 29-30 October. The night of 29-30 August was missed due to a power outage. The entire period from the beginning of astronomical twilight at sunset to the end of astronomical twilight at sunrise was recorded on the first night of recording, 18-19 August. This gradually declined to 85 percent by the night of 29-30 October. All nightly recordings extended through the astronomical twilight period at sunrise.

Nfcs were classified to species categories by visually analyzing spectrograms using GlassOFire software (**http://www.oldbird.org/glassofire.htm**) and Vesper software (**https://github.com/HaroldMills/Vesper**). Preliminary species classification is based on Evans and O'Brien (2002), my personal diurnal flight call recordings and, in 2 cases, deductions supported by contributors to the Xeno-Canto and Macaulay Library sound archives. Using these resources, I placed the extracted nfcs into major categories that have at least 1% of the season's total calling. For species categories with less than 1%, the total number of their calls is reported. Spectrographic examples of each species category using calls from the study are provided in the Appendix. The spectrograms show audio frequency on the y-axis from 0-11 kHz (calls are in the 5-11 kHz range) and time on the x-axis.

RESULTS

From the 72 nights recorded, my preliminary analysis documented a total of 20,994 passerine nfcs in the 6-10 kHz frequency band. Figure 4 shows the nightly totals.

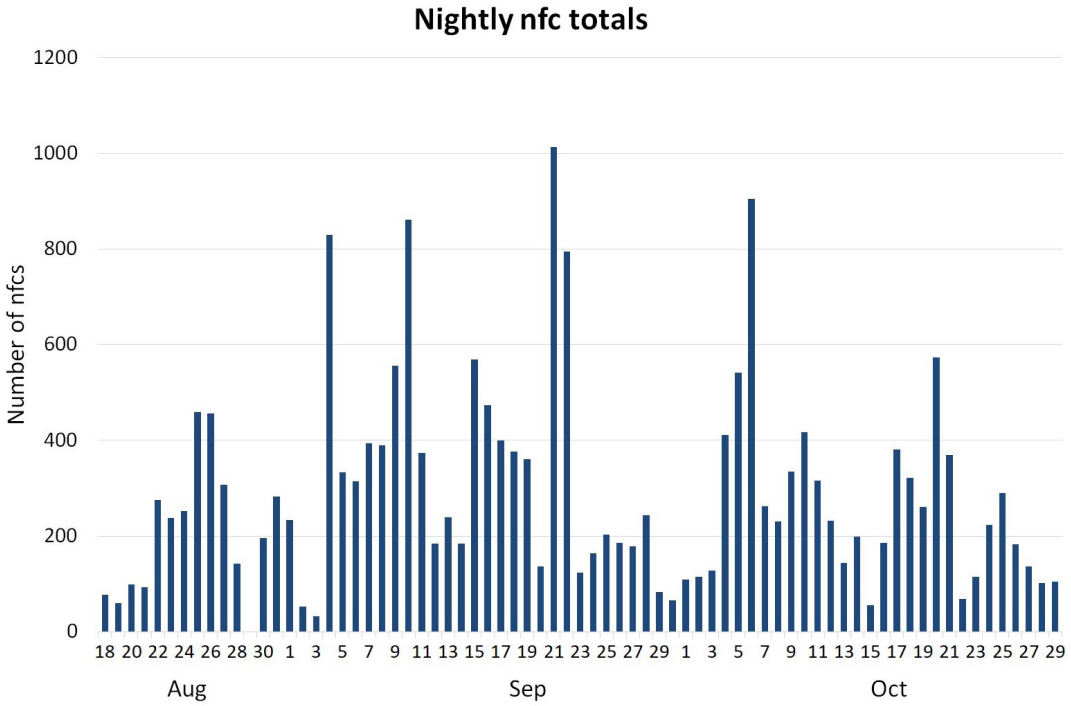

Figure 4. Nightly nfc totals extracted from the evening of 18 August to the morning of 30 October, 20:00 to 06:00 MST. No data for the night of 29-30 August.

Of the 20,994 high frequency calls recorded, 17,629 were loud enough to reveal distinguishing features in spectrograms for species category classification. Eighty-two percent of these were tentatively classified as one of 7 species of migratory sparrows, 12% uncertain species, and the rest from an assortment of warblers, other species of sparrows, and *Passerina* buntings. Wilson's Warbler comprised 1.0% and Yellow Warbler 1.2% (assuming all "zeeps" are from this species). Preliminary call classification categories for species and species complexes with 1% or more of all small passerine nfcs documented in the study are noted below. The season-total percentages and call totals for each are presented in Figure 5.

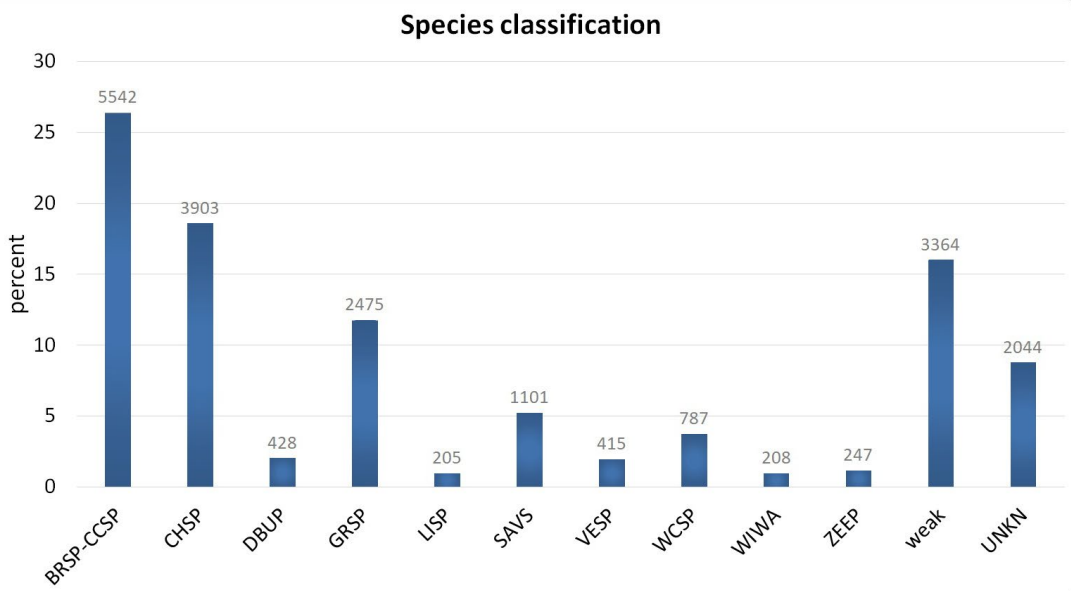

Figure 5. Bars indicate the percentage of fall-season nfcs classified to a particular species or species complex. Number atop each bar is the total number of calls in the respective category.

Species/Species complexes (see spectrographic examples in Appendix)

- BRSP-CCSP = calls presumed to be from either Brewer's Sparrow (*Spizella breweri*) or Clay-colored Sparrow (*Spizella pallida*).
- CHSP = calls presumed to be from Chipping Sparrow (*Spizella passerina*).
- DBUP = This category lumps a group of species that have similar nfcs, generally short calls (< 60 mS) with 2 contemporaneous rising tracks. Species potentially include Orange-crowned Warbler (*Leiothlypis celata*), Lucy's Warbler (*L. luciae*), Nashville Warbler (*L. ruficapilla*), Virginia's Warbler (*L. virginiae*), Black-throated Gray Warbler (*Setaphaga nigrescens*), Townsend's Warbler (*S. townsendi*), and Hermit Warbler (*S. occidentalis*). Variants of several other species may be included here.
- GRSP = calls presumed to be from Grasshopper Sparrow (*Ammodramus savannarum*).
- LISP = calls presumed to be primarily from Lincoln's Sparrow (*Melospiza lincolnii*). The similar nfc of Swamp Sparrow (*M. georgiana*) currently cannot be ruled out except with respect to its much lower abundance in Arizona.
- SAVS = calls presumed to be from Savannah Sparrow (*Passerculus sandwichensis*).
- VESP = calls presumed to be from Vesper Sparrow (*Pooecetes gramineus*).
- WCSP = calls presumed to be from White-crowned Sparrow (*Zonotrichia leuophrys*).
- WIWA = calls presumed to be from Wilson's Warbler (*Wilsonia pusilla*).
- ZEEP = short (< 60 mS) modulated calls from a complex of species; presumably the vast majority in this study are from Yellow Warbler (*Setophaga petechia*).
- Weak = calls with too low an amplitude to be able to be classified in a species category.
- UNKN = calls not classified to a species category. Many are likely variants of other species categories, and some may be from species whose calls are not known.

The following species were detected in smaller numbers (each < 1% of the total nfcs). They are listed here in order of most to least detected with the total number of their calls noted: *Passerina* bunting complex 75; Lark Sparrow (*Chondestes grammacus*) 58; MacGillivray's Warbler (*Geothlypis tolmiei*) 50; Black-chinned Sparrow (*Spizella atrogularis*) 16; Common Yellowthroat (*Geothlypis trichas*) 4; Northern Waterthrush (*Parkesia noveboracensis*) 3; American Redstart (*Setophaga ruticilla*) 2.

The URL below leads to a ~6-hour (~21:00-03:00 MST) segment of audio from the 10-hour recording the night of 22-23 September 2015. This audio segment contains more than 650 of the small passerine nocturnal flight calls that were extracted from this night, mostly migrating sparrows. **https://soundcloud.com/user-830174402/nogales**

DISCUSSION

Documentation of ~21,000 small passerine nfcs at the Nogales acoustic monitoring station far exceeded my expectation based on my previous monitoring in Arizona. The Nogales area recording site had no bright sources of artificial light that might induce higher calling rates in individual birds or cause aggregation behavior. While the

number of calls detected at a recording site is affected by microphone design, environmental noise, and method of analysis, the high calling rate detected at Nogales is like that which I have documented at nfc monitoring stations in dark terrain in the interior of east-central North America using similar monitoring equipment and analysis protocol. I can find no reason undermining a conclusion that relatively large numbers of birds (of species that are vociferous in nocturnal migration) flew over the recording site from mid-August through October 2015.

An interesting question is whether the high calling rate is a general characteristic of southeastern Arizona or perhaps is due to concentration dynamics involving local topography. The Santa Rita Mountains lie directly north of the monitoring site and the Patagonia Mountains directly east. The Sonoita Valley, which runs northeast to southwest, bisects these 2 ranges and the nfc monitoring station was in the extension of the Sonoita Valley as it passes to the west of the mountains (Figure 6). Perhaps the Sonoita Valley concentrates a low altitude stratum of night migrating passerines passing between these ranges. Perhaps there are concentration dynamics of southeasterly-bound migrants caused by the west side of Santa Rita range. These are interesting questions for further study.

Figure 6. Map of south-central Arizona from Google Maps showing location of nfc monitoring station (red marker).

The species classifications are reasonably solid for comparison with data from similar monitoring efforts that may take place in the region, especially regarding species proportions. For example, I note that calls from the Brewer's/Clay-colored Sparrow complex were more than twice as common as Grasshopper Sparrow; Grasshopper more than twice as common as Savannah; Savannah more than twice as common as Vesper; and Vesper more than twice as common as Lincoln's. Of course, such ratios do not necessarily transfer to actual proportions of species moving over the recording site because species may have different calling rates. But presuming the tendency of a species to call in nocturnal migration is somewhat constant, then intra- and interstation ratios could be compared.

While some species are relatively distinctive, others are less so and have zones of overlap with one or more other species. For example, it might be surprising that there can be a question of whether a call is from MacGillivray's Warbler or Vesper Sparrow, and that there is potential overlap between some nfcs of Wilson's Warbler and Lark Sparrow. As more is understood about the variability of a species' nfc, calls currently classified as "unknown" may be shifted to species categories, and perhaps some calls currently in a species category will be moved to "unknown" or a different species category. Such changes are likely to involve relatively small numbers of calls and should not affect the general ratios of the major classification categories presented here.

Regardless of the uncertainty in nfc species identification, the old dictum for nfcs in the West needs to be revised. The evidence presented here indicates to me that there are locations in the West where the nfc phenomenon is on par with that in interior east-central North America. Whether local topography played a role in concentrating birds over the recording site is unknown, but the complex montane geography in Arizona and western North America in general probably fractures broad front continuities and channelizes nocturnal bird migration. Networked arrays of nfc

monitoring stations have the potential to be a major tool for mapping such dynamics. An exciting prospect is finding locations where concentration dynamics of active avian night migrants occur, and the real treasure—places where 2 concentrated streams of active night migration meet.

Further information related to this study can be found at **http://www.oldbird.org/pubs.htm**

ACKNOWLEDGMENTS

Cynthia L. Fleming provided a basecamp in Phoenix, material support, and steadfast encouragement. Robert Dooley, superintendent of the Ajo Unified School District, did not hesitate in supporting a nfc monitoring station at Ajo High School, including making room for a data collecting computer in his office. John Grahame facilitated the early nfc monitoring effort at Montezuma Castle National Monument. And in Nogales, many thanks to Alan and Anna Schmierer for hosting the nfc monitoring station that led to the remarkable discovery reported here. Finally, I thank Ken Able, Gary Rosenberg, David Vander Pluym, and Kerrie Anne Loyd for helpful comments that improved the accuracy, organization, and clarity of this manuscript.

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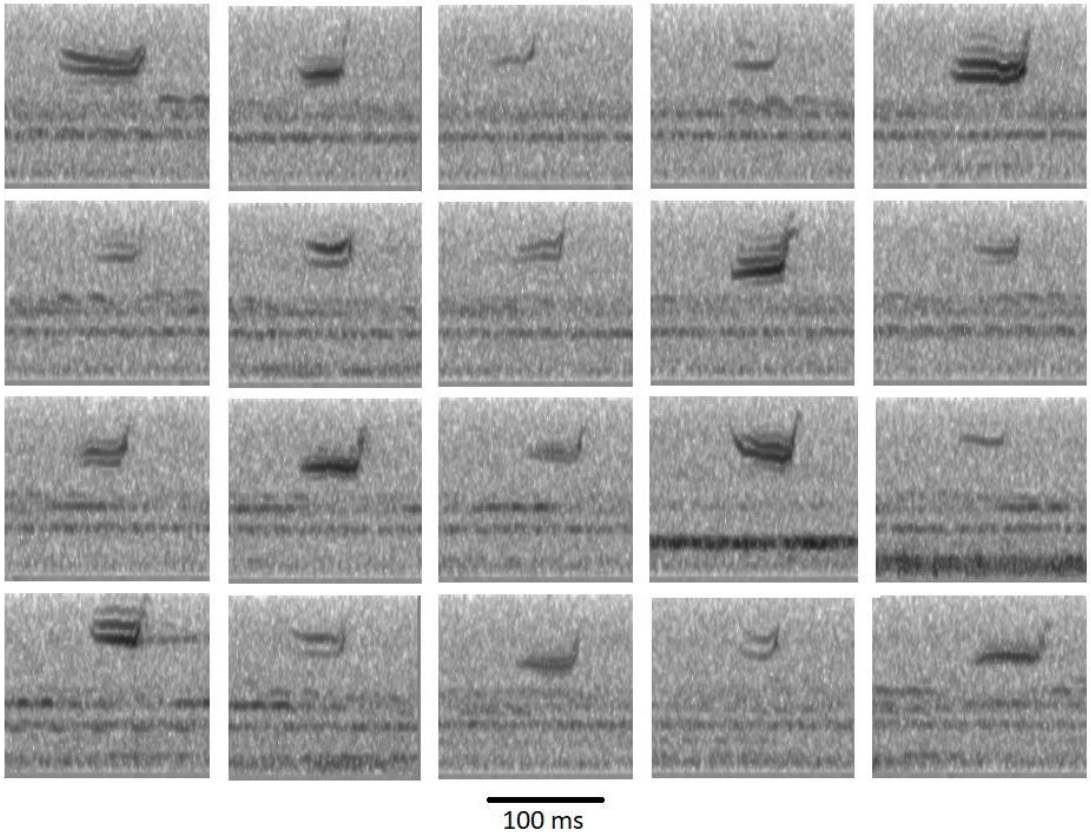
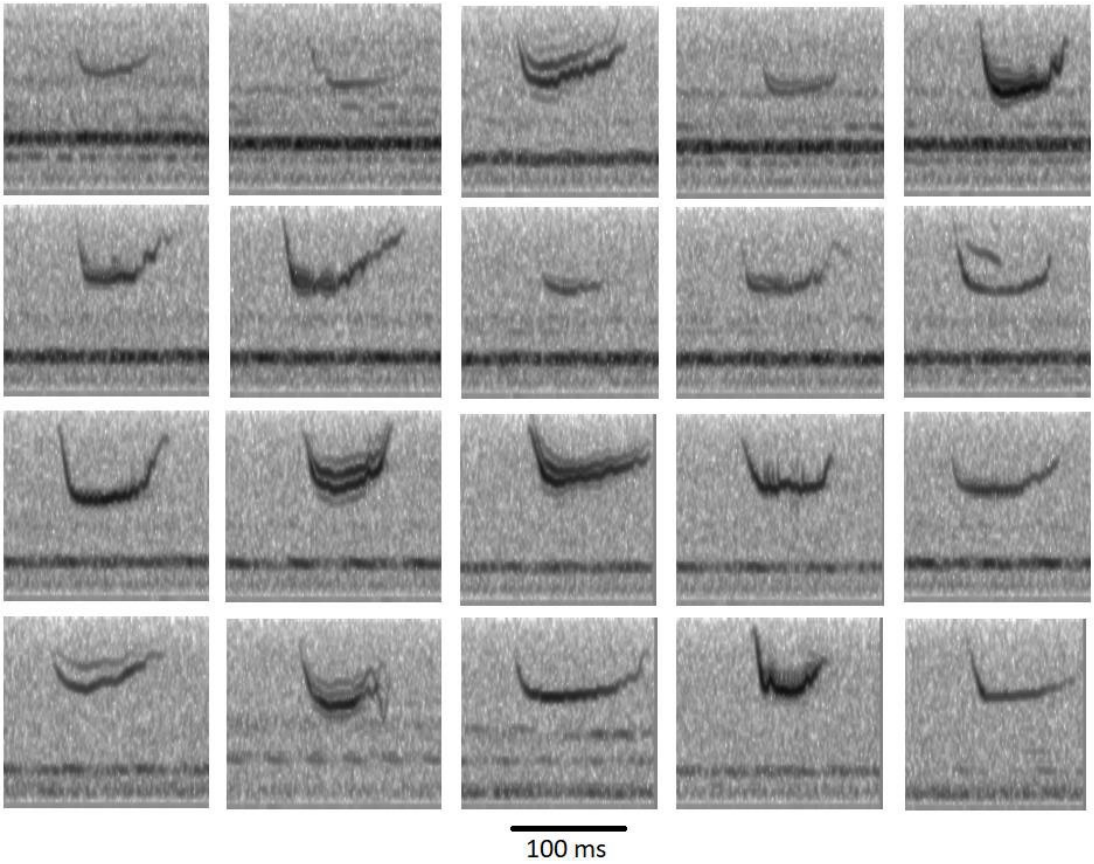
APPENDIX

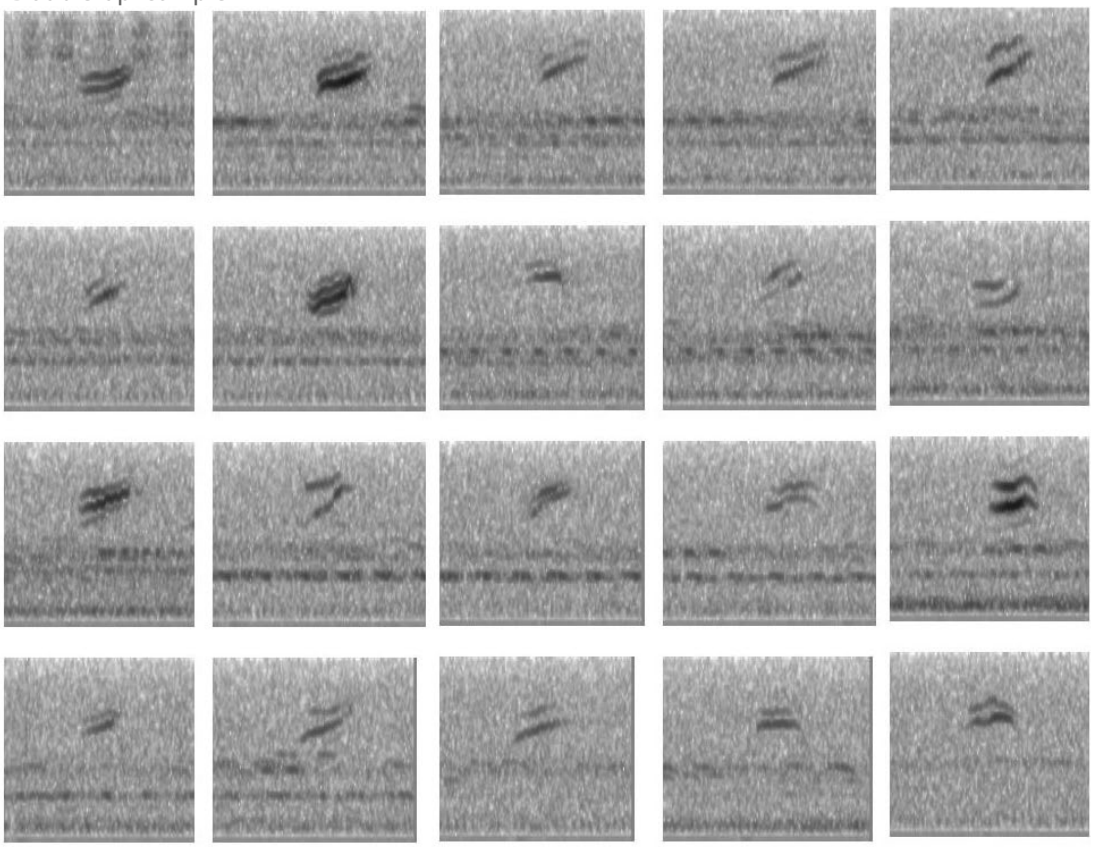
Brewer's/Clay-colored Sparrow complex



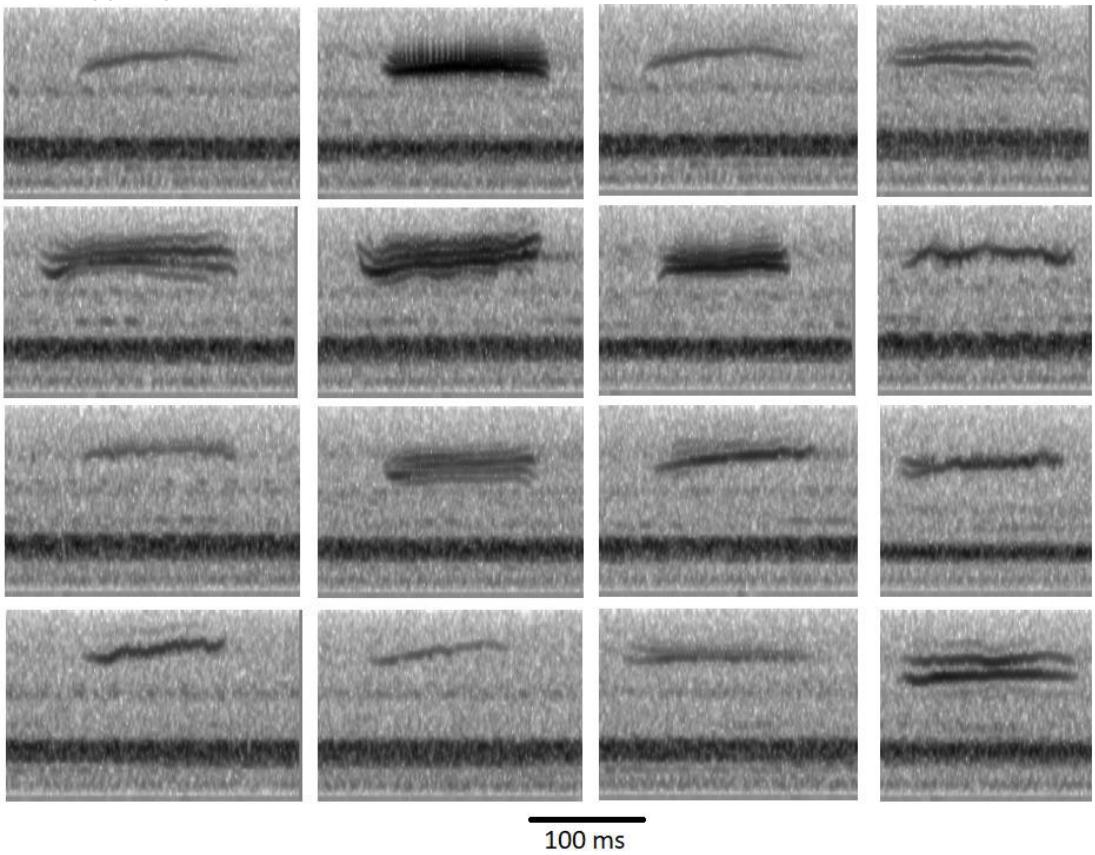
Chipping Sparrow



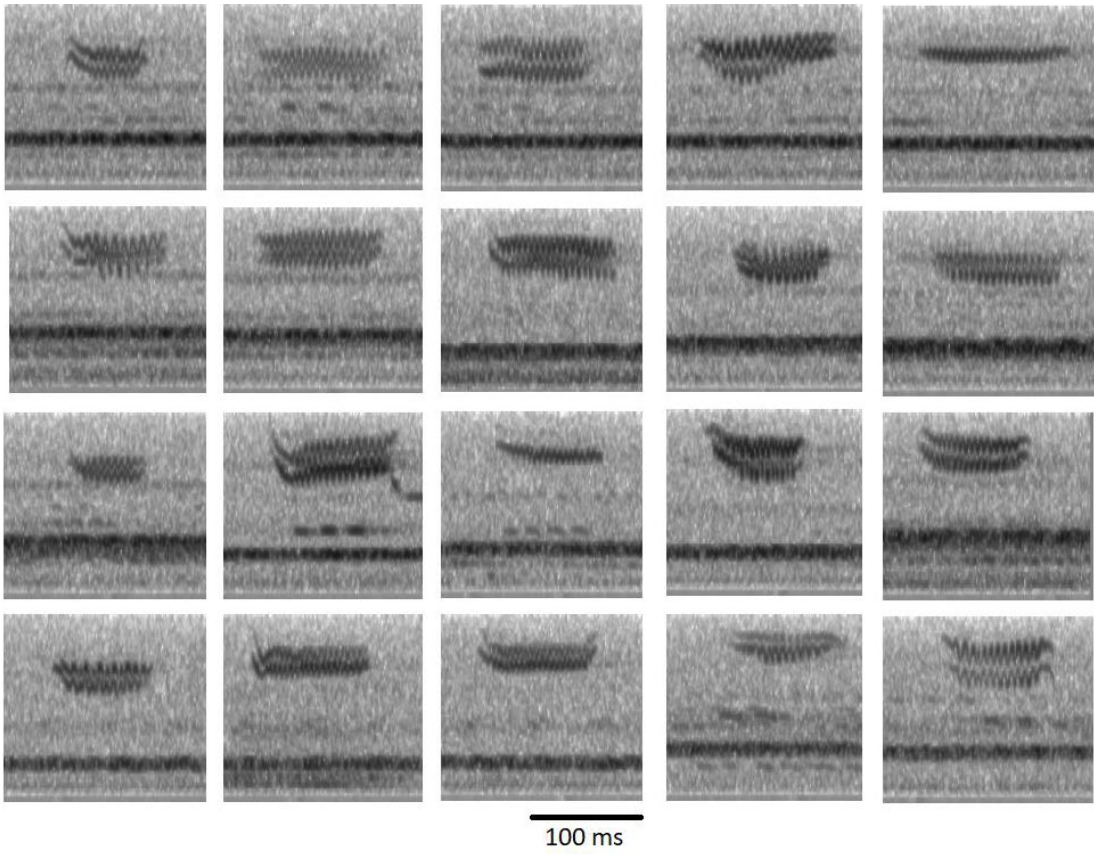
"Double-up" complex



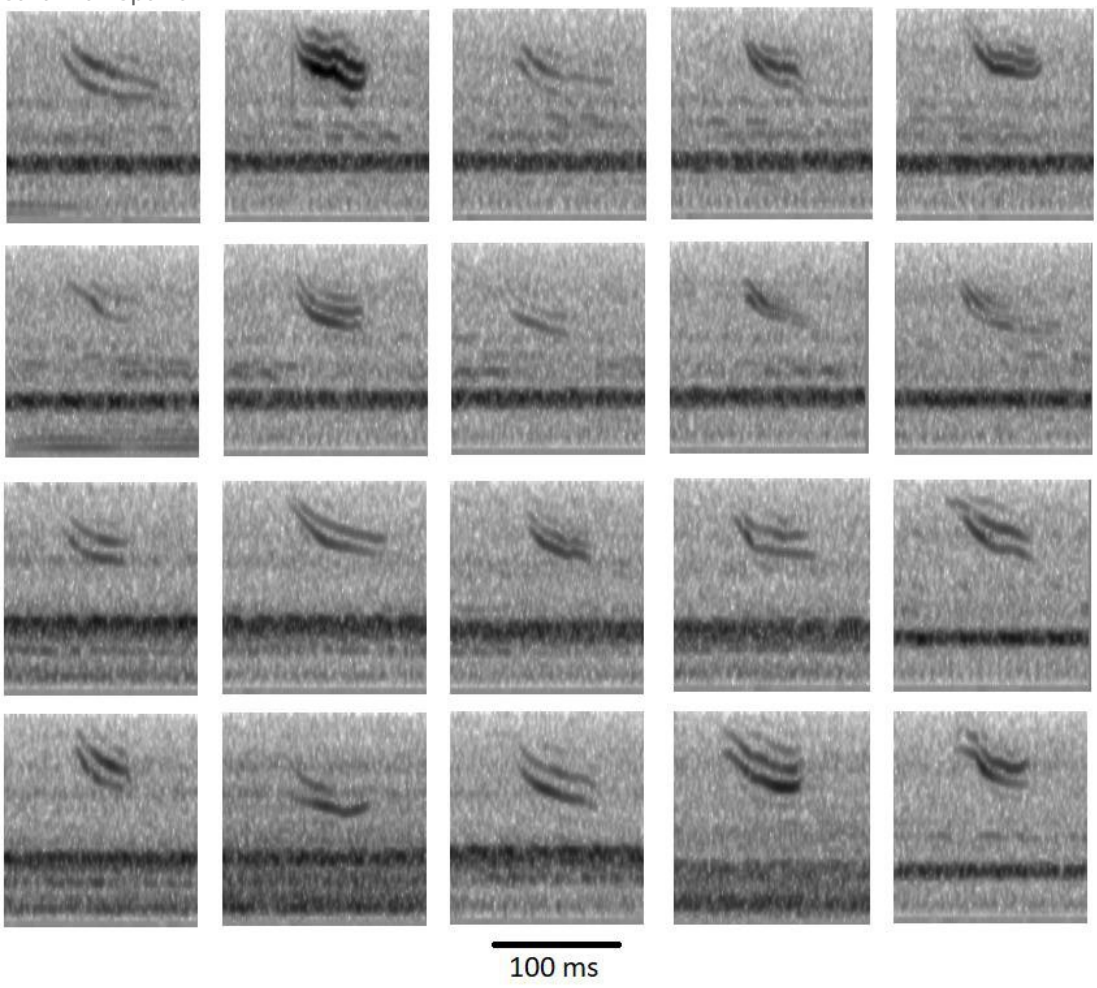
Grasshopper Sparrow



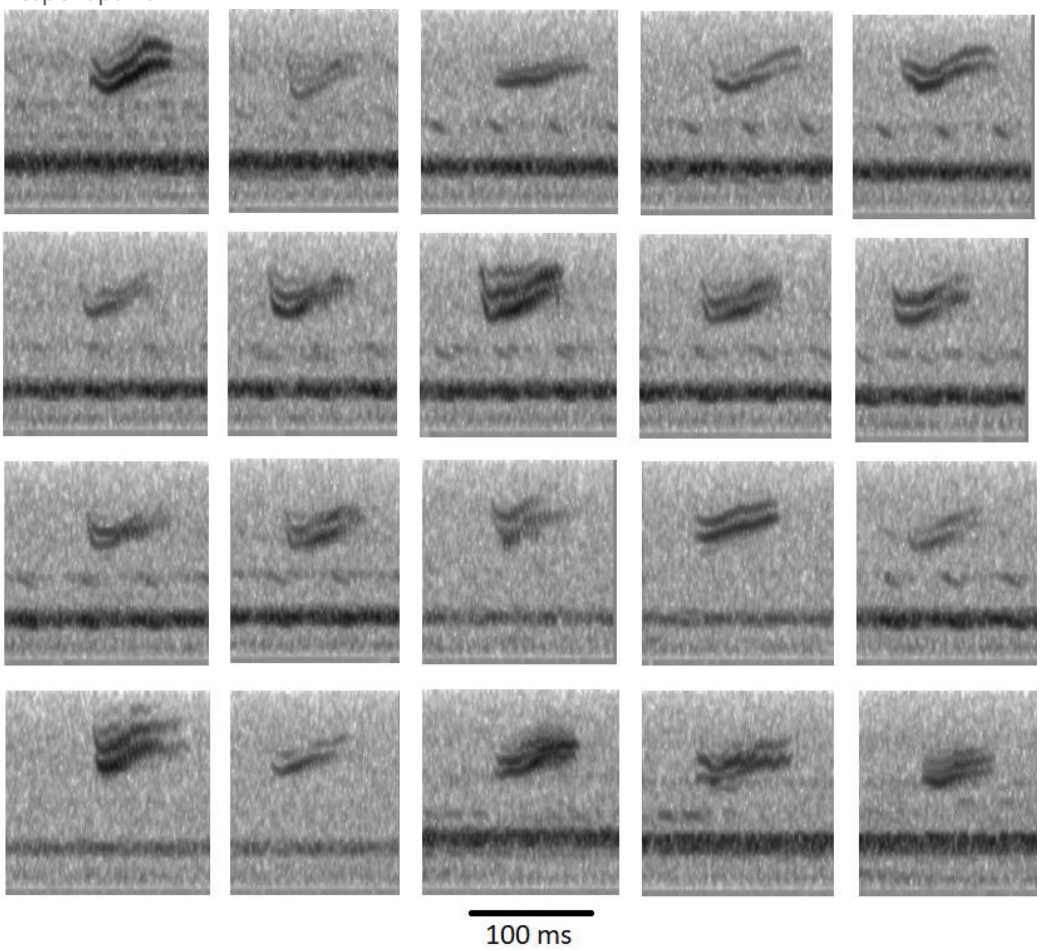
Lincoln's/Swamp Sparrow complex



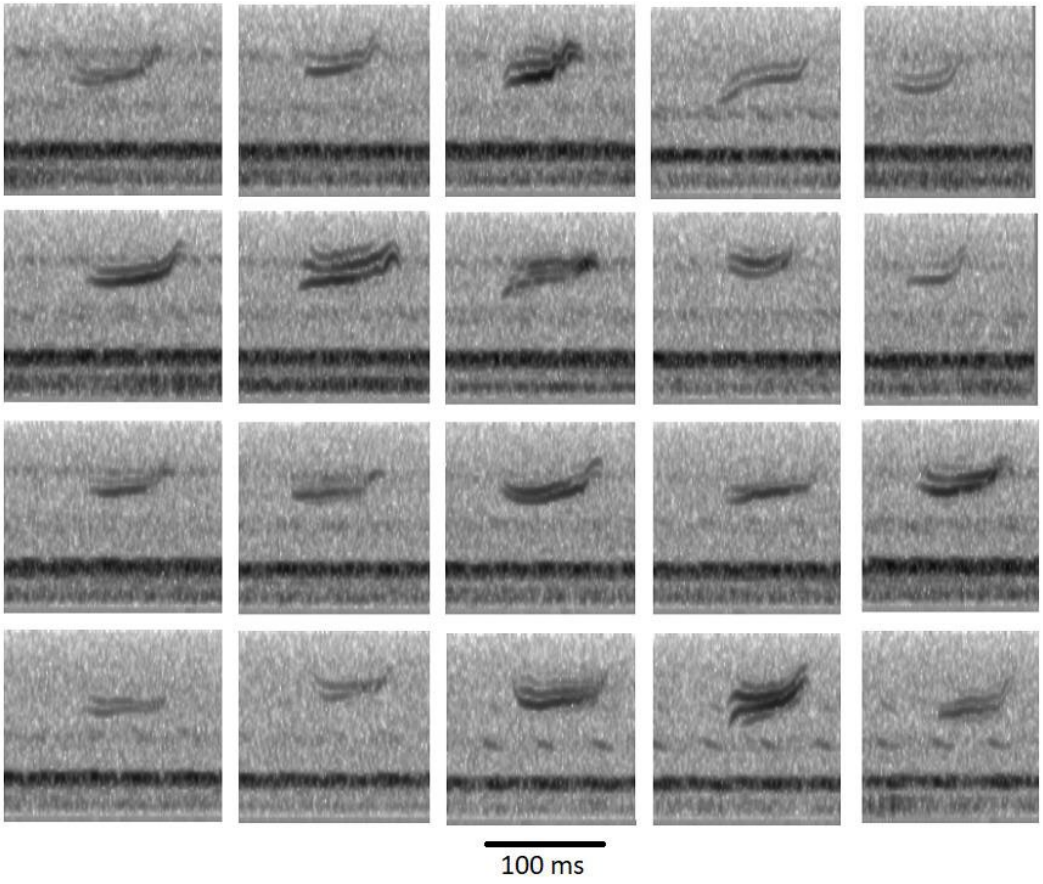
Savannah Sparrow



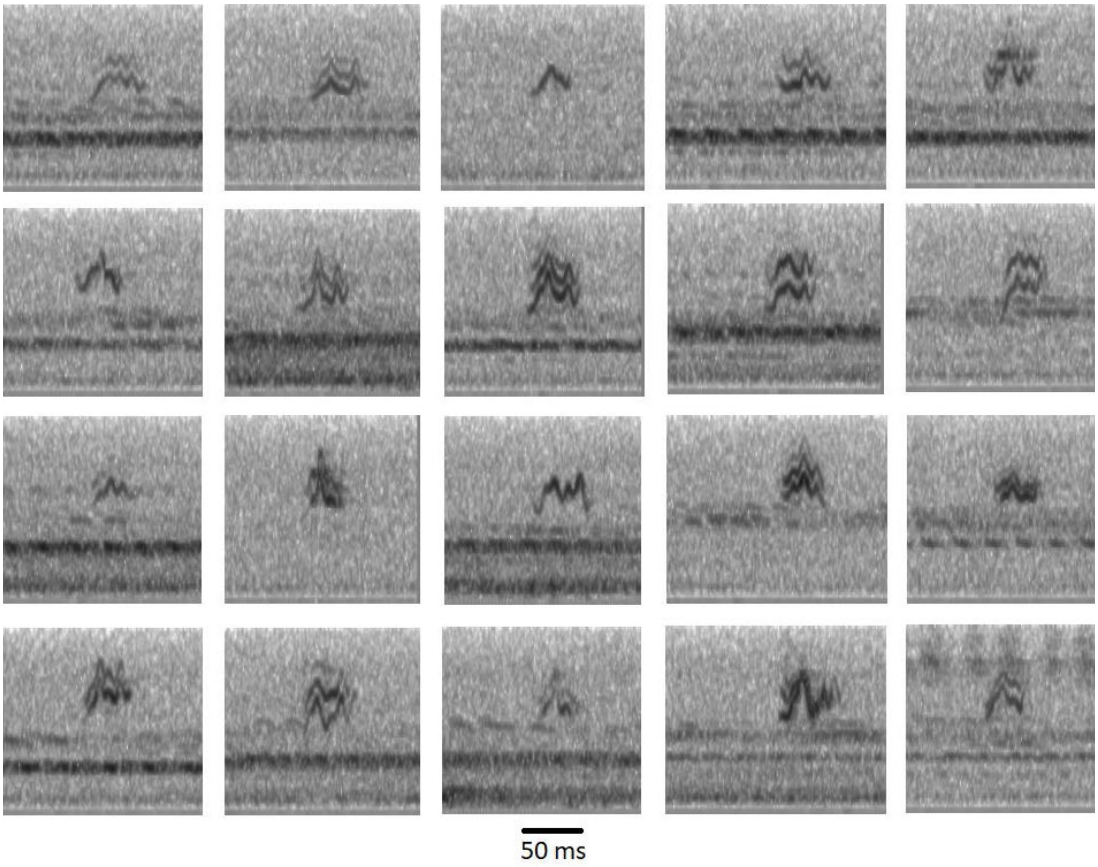
Vesper Sparrow



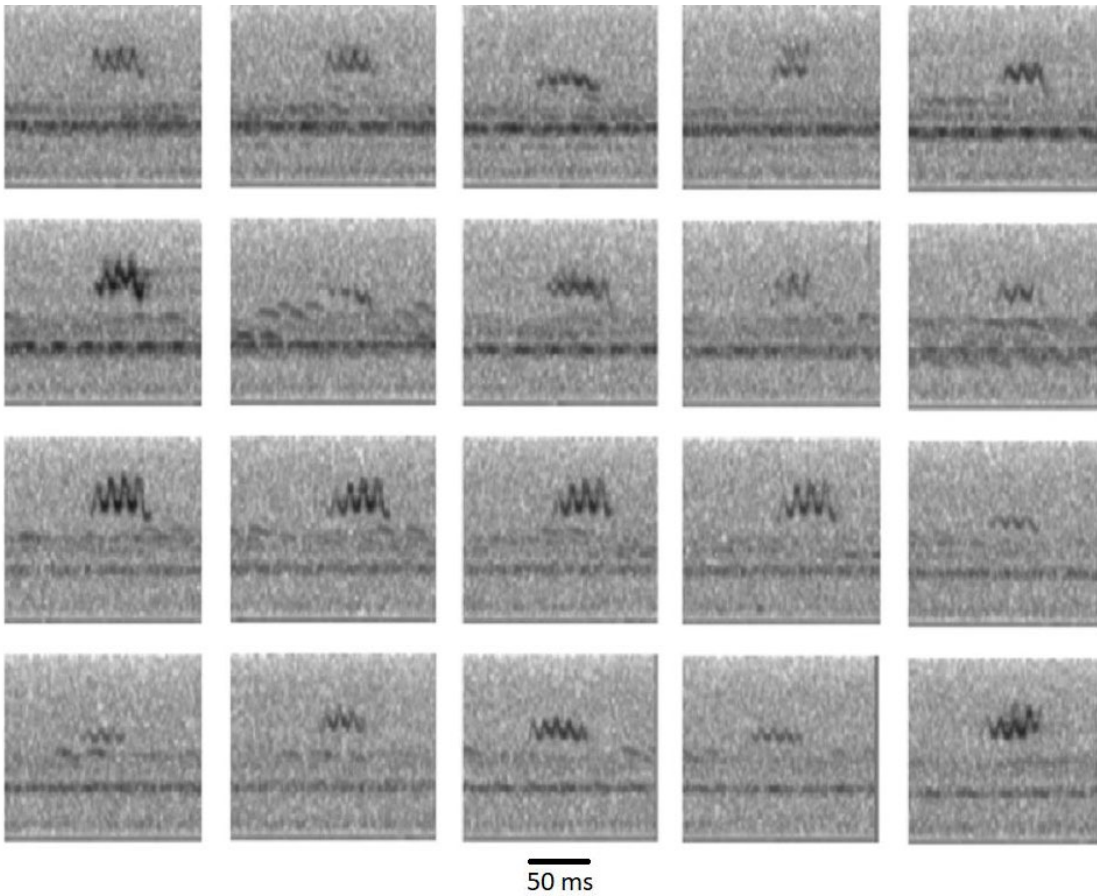
White-crowned Sparrow



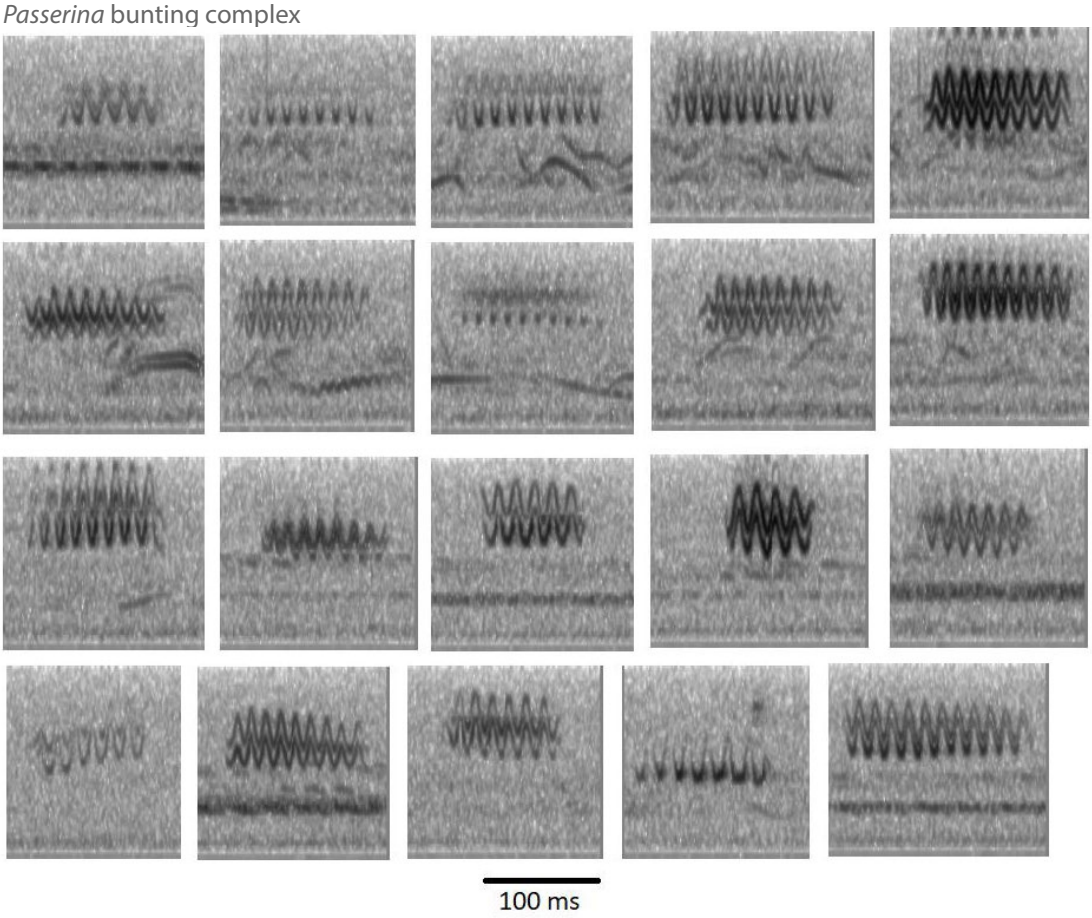
Wilson's Warbler (western)



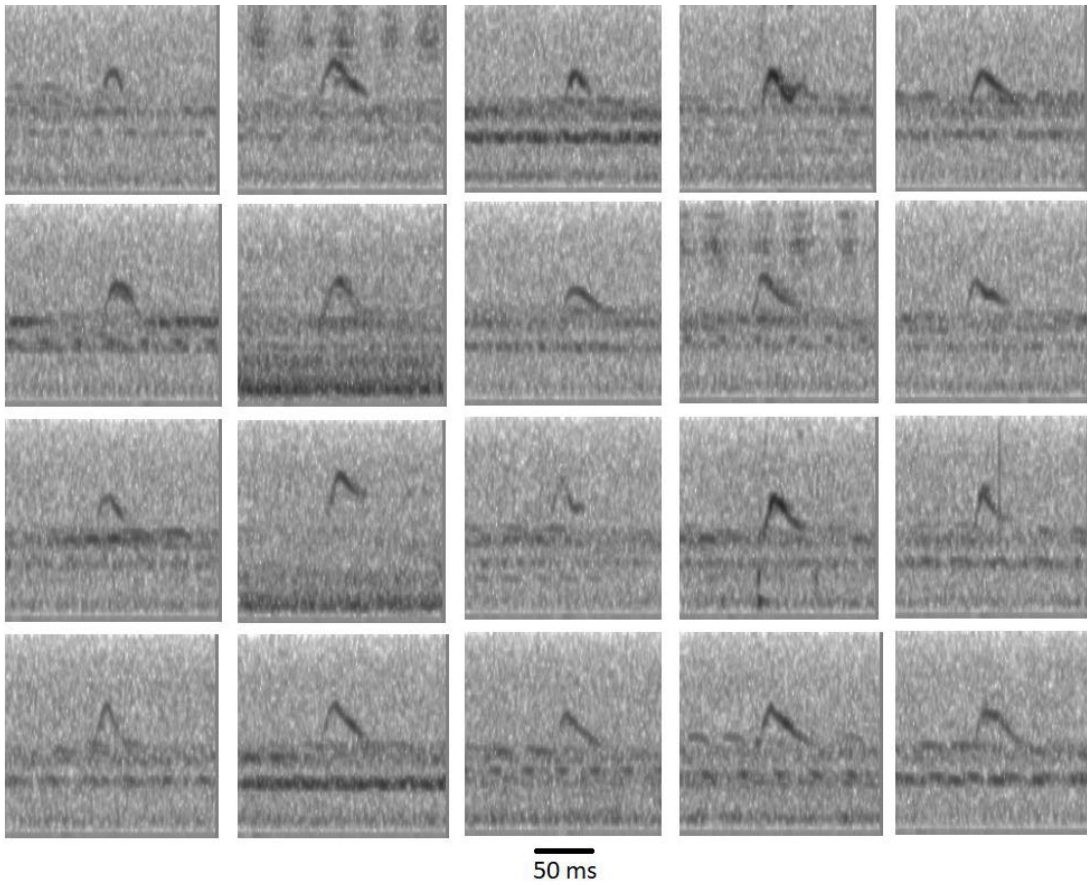
"Zeep" complex



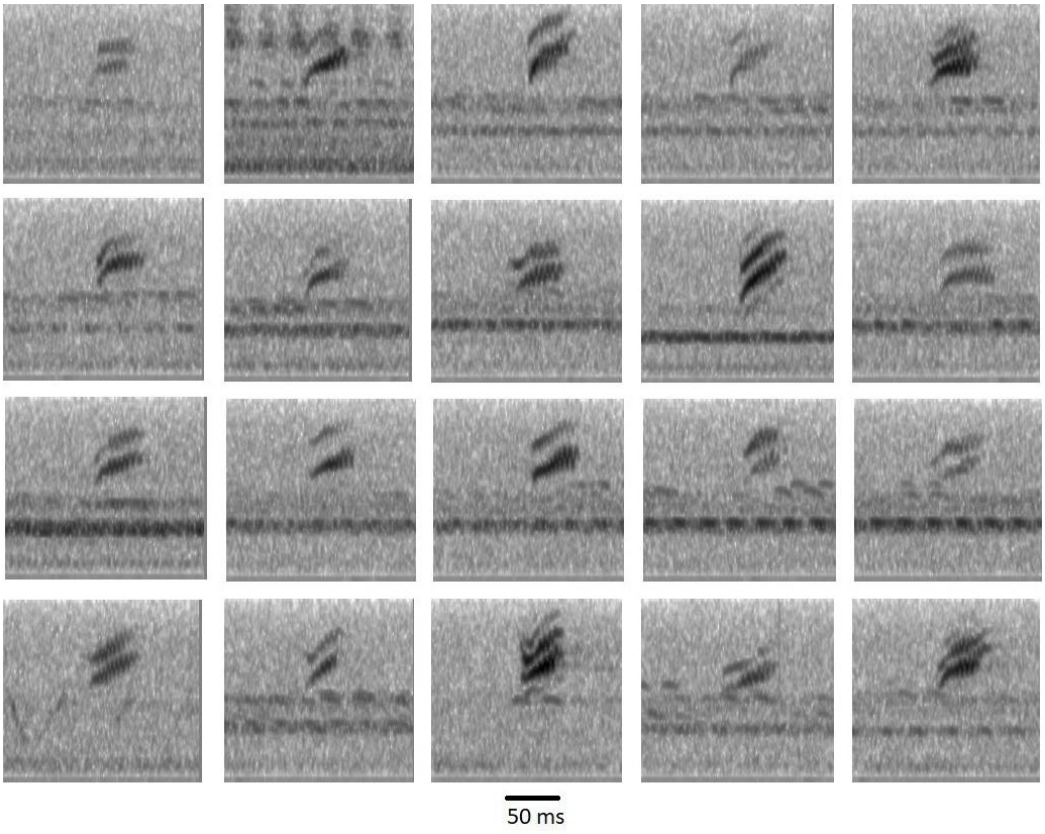
Passerina bunting complex



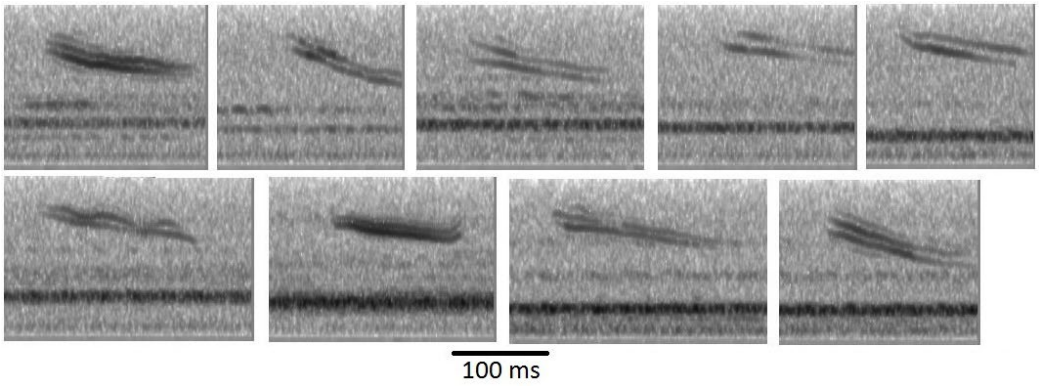
Lark Sparrow



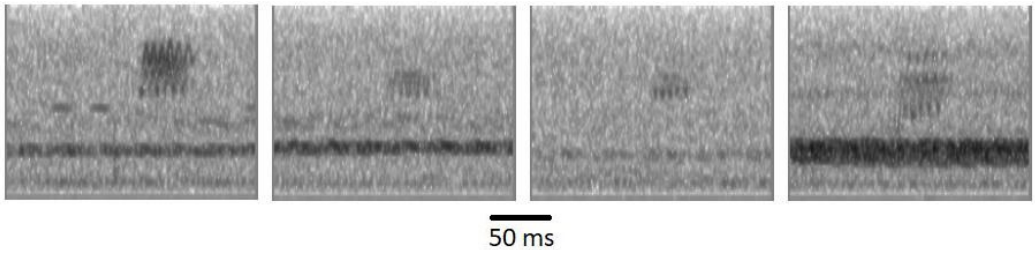
MacGillivray's Warbler



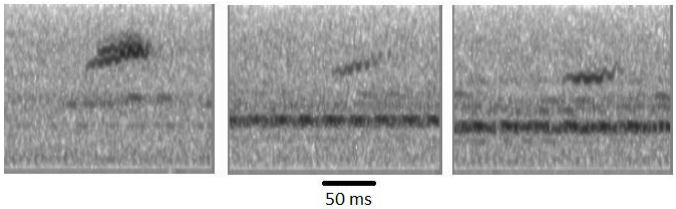
Black-chinned Sparrow



Common Yellowthroat



Northern Waterthrush



American Redstart