DOE/SC-ARM-15-009

The Nocturnal Avian Migration Experiment Final Campaign Report

PM Stepanian
KG Horton

March 2016

DISCLAIMER

Nocturnal Avian Migration Experiment Final Campaign Report

PM Stepanian, University of Oklahoma
KG Horton, University of Oklahoma

March 2016

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Executive Summary

Remote sensing techniques are playing a greater role in ornithology, and radar has proven a valuable tool for high resolution, long-term observations of airborne animals. The major disadvantage in radar remote sensing is the current inability to gain taxonomic information from these measurements. One solution is the incorporation of collocated acoustic monitoring that can provide recordings of species-specific nocturnal flight calls of migrating birds in flight. In addition, by taking multichannel recordings of these calls, the position of the calling bird can be calculated and linked to collocated radar measurements.

The Nocturnal Avian Migration Experiment (NAME) took place at the Atmospheric Radiation Measurement Climate Research Facility's Southern Great Plains (SGP) site from March 20 through May 20, 2014. During this period an acoustic recording array was deployed alongside the vertically pointing remote sensors at the SGP Central Facility, providing nightly audio surveillance of the airspace above the site. The purpose of this experiment was two-fold. First the campaign provided taxonomic information for the serendipitous bird measurements that are regularly captured by the surrounding radars (e.g., KAZR, Ka/W-SACR, and KVNX). The ability to characterize these radar measurements with respect to the underlying scatterers can add value to future bird measurements that do not have collocated audio (i.e., beyond the duration of the experiment). Second, the combined data set of acoustic, radar, lidar, and meteorological observations is, in itself, valuable for aeroecology research on the movement and behavior of migrating birds in connection to atmospheric features and conditions. From these measurements, we should be able to describe what species of birds are moving, what altitudes at which they are flying, and how winds, turbulence, cloud cover, or other factors influence these choices.

At present, several layers of data analysis are ongoing. High winds at the site contributed to enhanced acoustic noise that has complicated automated bird call detection, requiring manual data screening that is currently in progress. Additional analyses using KAZR and Doppler lidar observations are underway and awaiting acoustic localization retrievals. An overview of the acoustic array, including preliminary results from NAME, is in preparation for submission to *Methods in Ecology and Evolution.*

Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
KAZR	Ka-band ARM Zenith-pointing Radar
KVNX	NEXRAD Weather Surveillance Radar at Vance Air Force Base
NAME	Nocturnal Avian Migration Experiment
NEXRAD	Next Generation Radar Network
NFC	nocturnal flight calls
SGP	Southern Great Plains
TDOA	time difference of arrival

Contents

Figures

1.0 Background

The atmosphere is home to a host of airborne organisms including birds, bats, and insects, many of which spend significant portions of their lives in flight. Just as terrestrial animals are dependent on the landscape features that make up their habitat, volant animals are inherently tied to their atmospheric ecosystem (Diehl 2013). Aeroecology is the branch of science studying life in the atmosphere, and its connection to underlying atmospheric processes (Kunz et al. 2008). Radar is an important tool for observing these organisms aloft, but generally cannot provide the species of observed animals.

Many species of birds utter unique Nocturnal Flight Calls (NFCs) while engaging in migratory movements (Farnsworth 2005). Audio recordings of NFCs can indicate the presence and identity of migrating birds passing overhead, and are sometimes used as proxies of animal abundance (Evans and Mellinger 1999). A disadvantage to this method is that calling rate can vary with weather conditions and by species, and that call detectability can vary with atmospheric conditions (Horton et al. 2015b). Current efforts are underway to link radar measurements (such as those provided by NEXRAD) with acoustic NFC recordings to provide a complete picture of bird migration (Farnsworth et al. 2004; Horton et al. 2015b). It is generally the case, however, that a recorded call cannot be directly attributed to a specific animal in radar observations. For example, a flight call may be recorded while several birds are observed flying overhead, but it is unclear which bird uttered the call.

Acoustic localization is the process of using multiple time-synchronized audio recordings to retrieve the source position of a sound. This technique has the ability to explicitly link a NFC to the location associated with another measurement. For example, the localization retrieval can tell whether a NFC was uttered by a bird in the vertically pointing radar beam, or if it was uttered by a bird perched on the ground. If the former, we can link the radar measurement to the corresponding bird species. Prior to this experiment, localization of NFCs within the airspace has never been attempted.

The Nocturnal Avian Migration Experiment was organized by Phillip Stepanian and Kyle Horton of the University of Oklahoma's Advanced Radar Research Center. This collaboration within the Advanced Radar Research Center represents a cross-disciplinary approach to biological remote sensing, combining atmospheric science (Stepanian) and ecology (Horton) for a unique product of radio and acoustic measurements. From March 20 through May 20, 2014, an acoustic recording array was deployed alongside the vertically pointing remote sensors at the Atmospheric Radiation Measurement (ARM) Climate Research Facility's Southern Great Plains (SGP) site (Figure 1). This time span encompassed much of the northward spring migration over the SGP site. The acoustic array provided nightly audio surveillance of the airspace above the central facility, recording any NFCs within the range of the microphones.

The purpose of the Nocturnal Avian Migration Experiment was twofold. First, the campaign provided taxonomic information for the serendipitous bird measurements that are regularly captured by the surrounding radars (e.g., KAZR, Ka/W-SACR, and KVNX). The ability to characterize these radar measurements with respect to the underlying scatterers can add value to future bird measurements that do not have collocated audio (i.e., after the duration of the experiment). Second, the combined data set of acoustic, radar, lidar, and meteorological observations is, in itself, valuable for aeroecology research on the movement and behavior of migrating birds in connection to atmospheric features and conditions.

From these measurements, we should be able to describe what species of birds are moving, what altitudes they are using, and how winds, turbulence, cloud cover, or other factors influence these choices.

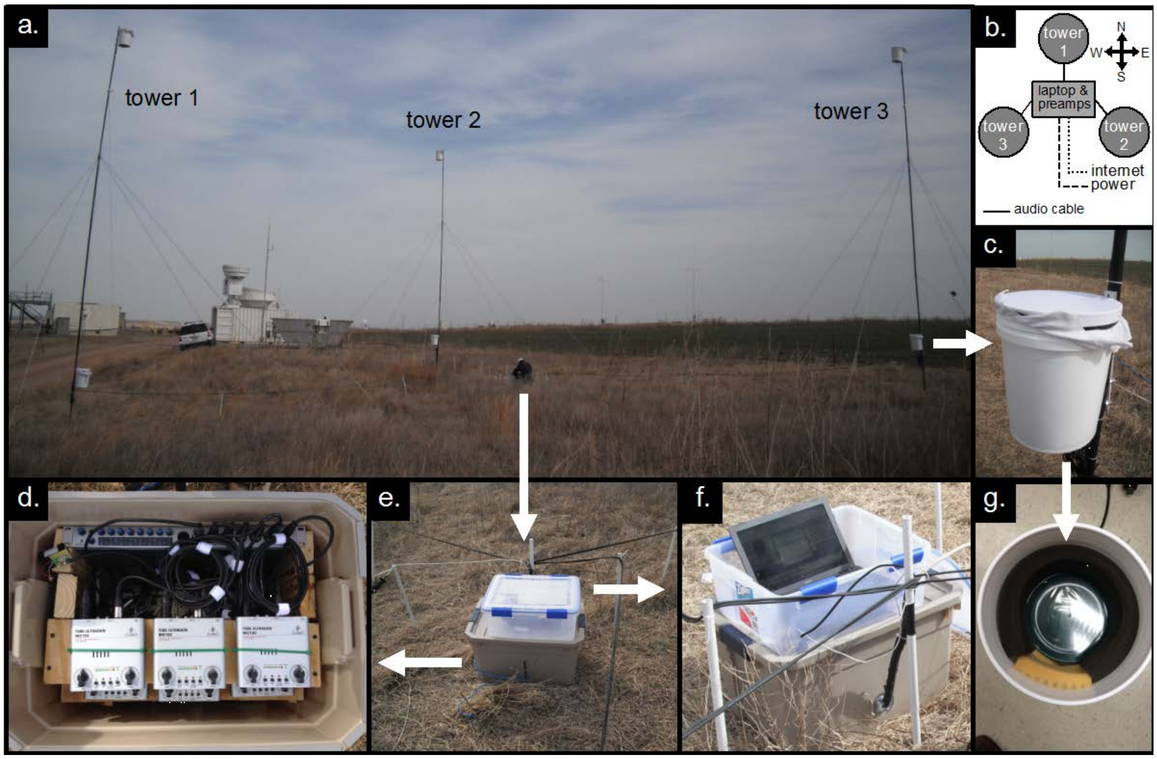

Figure 1. Acoustic Array Setup and Components for the Nocturnal Avian Migration Experiment at the ARM SGP Site in Spring 2014. (a) Photo of array deployment beside radars and lidar. (b) Schematic of array layout. (c) Closeup on one microphone enclosure with protective cloth cover. (d) Inside of amplification enclosure. (e) Central enclosures holding amplifiers (bottom) and laptop (top). (f) Laptop for data acquisition and storage. (g) Inside of microphone enclosure revealing foam baffling surrounding flowerpot microphone.

Presently, several layers of data analysis from the Nocturnal Avian Migration Experiment are ongoing. Currently, Kyle Horton is in the process of extracting NFCs from the >700 hours of audio that was collected during the experiment. Phil Stepanian has downloaded the KAZR, Doppler lidar, and KVNX data associated with the experiment for comparisons with NFC localization results. In addition, Charlotte Wainwright is beginning to compare migratory height utilization (via KAZR) with respect to the low-level jet (via Doppler lidar winds).

2.0 Notable Events

We had anticipated using a vertically pointing thermal imaging camera as an additional validation technique; however, the camera was not deployed during the experiment. The thermal imaging camera is quite delicate and sensitive to moisture and dust. As a result, it must be constantly attended to ensure that it can be covered in the case of rain. Coupled with the constant blowing dust, the risk of damaging the instrument seem too great to rationalize its field deployment.

3.0 Lessons Learned

The major obstacle during the experiment—and the subsequent audio analysis—was the high winds at the SGP site. During periods of strong winds that persisted through much of the first half of the experiment, a loose cable flapped against the microphone array support poles. The impact of the cable with the poles creating a loud clanging sound that was within the typical frequency range of bird calls. This effect has resulted in an incredibly high false alarm rate in our automated call detectors, necessitating manual audio screening. This problem was remedied in mid-April, yielding better recordings, but the constant winds still resulted in relatively poor audio signal-to-noise ratios.

4.0 Results

While the process of data analysis is still ongoing, some initial test cases have been generated.
The SGP site is home to a large number of Killdeer (*Charadrius vociferus*), which is a medium-sized plover that produces distinct and long-lasting strings of calls as they move around the site during the day (Figure 2). While these are not NFCs, they do serve as good validation sets for ensuring localization retrievals are producing physically realistic results (i.e., smooth, spatially continuous flight tracks). Figure 2 shows a single channel for one case in which a Killdeer flew over the array while continuously calling. The calls are faint at the start of the segment; they increase in amplitude, and then decrease again. This pattern suggests that the bird was moving toward and then away from the array (i.e., flying over or past). These Killdeer flyovers were quite common through the daylight portions of the experiment. Figure 3 shows a short clip of two consecutive Killdeer calls as recorded on the six microphone channels. The birdcall wave front initially arrived at microphones 5 and 6 (times denoted by red lines) followed by the other channels. Qualitatively, this means that the Killdeer is located closest to Tower #1, and closer to Tower #3 than Tower #2. Applying the localization algorithm to the six channels, each call can be localized to a source in three-dimensional space. Because calls occur at a subsecond frequency, their retrieval locations provide the continuous flight track of the Killdeer over the site. Naturally, these Killdeer are not engaging in migratory movements, but the ability to form coherent flight tracks is a good quality check for the retrieval technique. The process of localizing additional Killdeer calls is underway, as is the larger task of identifying and screening night flight calls.

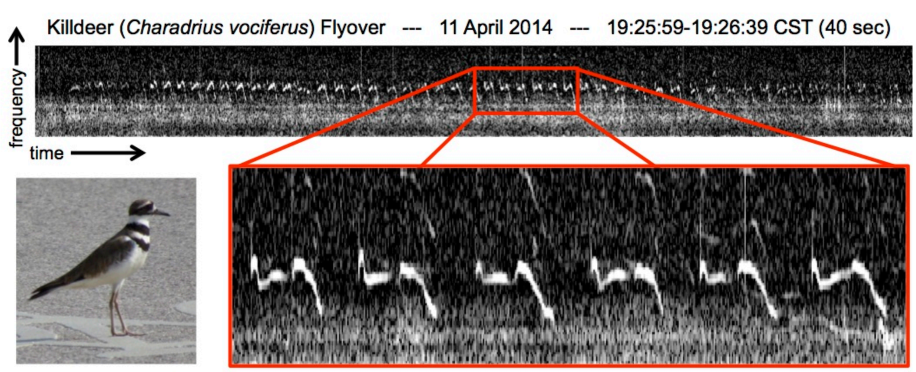

Figure 2. A 40-s Audio Spectrogram of a Killdeer (*Charadrius vociferus*, pictured) Calling Continuously while Flying Past the Acoustic Recording Array Location on April 11, 2014. Brighter shades denote louder acoustic amplitudes. The zoomed region spans approximately seven seconds, and shows six successive Killdeer calls.

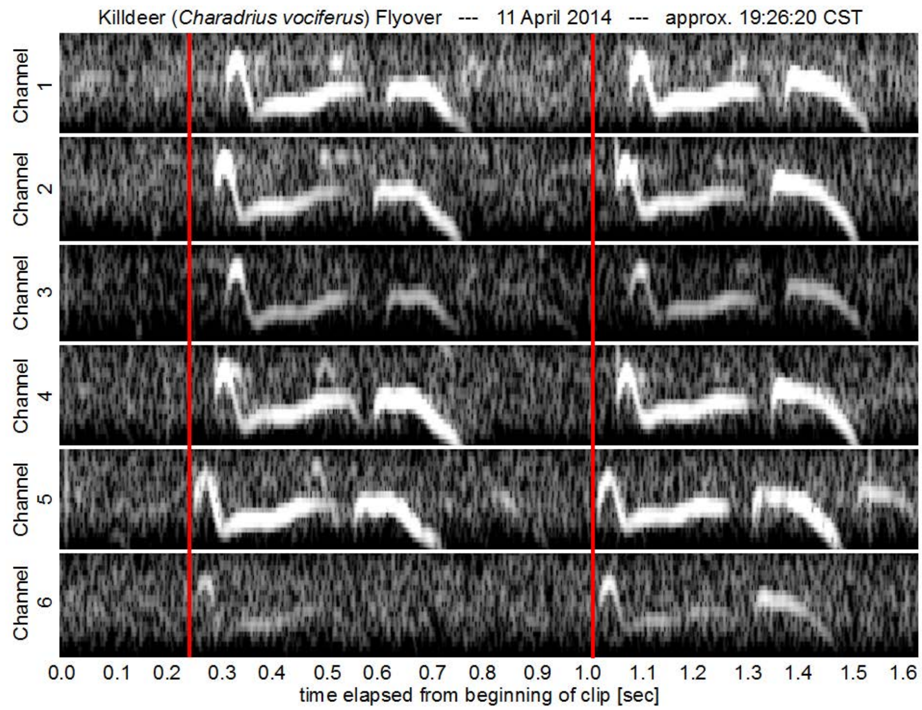

Figure 3. Sample of 1.6-s Audio Spectrograms from the Six Recording Channels of Two Killdeer Calls, Illustrating Call Lags. Brighter shades denote louder acoustic amplitudes. Vertical red lines reference time of first call detection (channels 5 and 6).

5.0 Public Outreach

The campaign website can be found at http://www.arm.gov/campaigns/sgp2014name.

6.0 Nocturnal Avian Migration Experiment Publications

Stepanian, PM, KG Horton, DC Hille, CE Wainwright, and JF Kelly. “Extending Bioacoustic Monitoring of Nocturnally Migrating Birds through Flight Call Localization,” *Methods in Ecology and Evolution* (in preparation).

Wainwright, Charlotte E., Phillip M. Stepanian, and Kyle G. Horton. "The role of the US Great Plains low-level jet in nocturnal migrant behavior." *International Journal of Biometeorology* (2016): 1-12. doi:10.1007/s00484-016-1144-9.

7.0 References

Diehl, RH. 2013. "The airspace is habitat." *Trends in Ecology and Evolution* 28(7):377–379, doi:10.1016/j.tree.2013.02.015.

Farnsworth, A. 2005. "Flight calls and their value for future ornithological studies and conservation research." *The Auk* 122(3):733–746, doi:10.1642/0004-8038.

Farnsworth, A, SA Gauthreaux, Jr., and DE Van Blaricom. 2004. "A comparison of nocturnal call counts of migrating birds and reflectivity measurements on Doppler radar." *Journal of Avian Biology* 35(4):365–369, doi:10.1111/j.0908-8857.2004.03180.x.

Kunz, TH, Thomas H. Kunz, Sidney A. Gauthreaux, Jr, Nickolay I. Hristov, Jason W. Horn, Gareth Jones, Elisabeth K. V. Kalko, Ronald P. Larkin, Gary F. McCracken, Sharon M. Swartz, Robert B. Srygley, Robert Dudley, John K. Westbrook, and Martin Wikelski. 2008. "Aeroecology: probing and modeling the aerosphere." *Integrative and Comparative Biology* 48(1):1–11, doi:10.1093/icb/icn037.

Evans, WR And DK Mellinger. 1999. "Monitoring grassland birds in nocturnal migration." *Studies in Avian Biology* 19:219-229. Available at http://www.oldbird.org/pubs/Grassland.pdf.

Horton, KG, WG Shriver, and J Buler. 2015a. "A comparison of traffic estimates of nocturnal flying animals using radar, thermal imaging, and acoustic recording." Ecological Applications 25(2):300–401, doi:10.1890/14-0279.1.

Horton, KG, PM Stepanian, CE Wainwright, and AK Tegeler. 2015b. "Influence of atmospheric properties on detection of wood-warbler nocturnal flight calls." *International Journal of Biometeorology*, doi:10.1007/s00484-014-0948-8.

ARM

CLIMATE RESEARCH FACILITY

www.arm.gov

U.S. DEPARTMENT OF ENERGY

Office of Science