The value of acoustic technologies for monitoring bird migration

Andrew Farnsworth, Conservation Science Program

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Monitoring using acoustic technologies

1) Informing traditional auditory monitoring
2) Monitoring species that are difficult to survey.
3) Monitoring migrants by recording flight-calls.
Many species produce flight calls: unique vocalizations, varying in frequency, duration, and pattern; primarily given in sustained flight, presumably for communication.

Dickcissel  Black-billed Cuckoo  Red-breasted Nuthatch

Bobolink  White-throated Sparrow  Swainson’s Thrush

Evans and O’Brien (2002)
Recording flight calls: nocturnal

Recording flight calls: diurnal
Recording flight calls: captive birds

Designed by M. Lanzone (Lanzone and Farnsworth submitted)
Projects:
Recording Locations

Recording Type
- Captive
- Free-flying
- Offshore
- DoD Sites
Traditional analysis

Syllabic measurements

Sweep

Modulation

Spectral and temporal measurements

Bandwidth

Duration

Maximum

Minimum

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New ways of representing flight-calls

- **Spectrogram Cross Correlation**
  - acoustic (particularly “syllabic”) similarity among species
  - identify flight-call “template” for each species that best correlates with remaining calls

- **ACOUSTAT/XBAT**
  - treat spectrogram data as probability distributions
  - characterize using order statistics (e.g. median)
Swainson’s Thrush variation

- Learn the variation in a species you hear often
- Note the differences in trailing modulation, duration, and initial upsweep in these calls
Low frequency, thrush-like calls

- These calls exhibit a wide array of frequencies, degrees of modulation, sweeps, and shapes. However, when heard in passing, these identifications can be challenging.
“Zeep” Complex

- Similarity in duration and “shape” for all of these species; slight differences in frequency ranges, degree and depth of modulation.
Sound Spectrogram Settings
Sound Spectrogram Settings
“The Rosetta Stone...”
### Highlights: Species-pairs

<table>
<thead>
<tr>
<th>Species-pair</th>
<th>Similarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange-crowned Warbler</td>
<td>Vermivora chrysoptera</td>
</tr>
<tr>
<td>Golden-winged Warbler</td>
<td>Vermivora pinus</td>
</tr>
<tr>
<td>Colima Warbler</td>
<td>Vermivora pinus</td>
</tr>
<tr>
<td>Lucy's Warbler</td>
<td>Vermivora pinus</td>
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<tr>
<td>Virginia's Warbler</td>
<td>Vermivora pinus</td>
</tr>
<tr>
<td>Nashville Warbler</td>
<td>Vermivora ruficapilla</td>
</tr>
<tr>
<td>Tennessee Warbler</td>
<td>Vermivora ruficapilla</td>
</tr>
</tbody>
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### Highlights: Convergence?

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<tr>
<td>Golden-winged Warbler</td>
<td>Vermivora pinus</td>
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<tr>
<td>Blue-winged Warbler</td>
<td>Vermivora pinus</td>
</tr>
<tr>
<td>Mourning Warbler</td>
<td>Oporornis philadelphia</td>
</tr>
<tr>
<td>MacGillivray's Warbler</td>
<td>Oporornis tolmei</td>
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</tbody>
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### Highlights: Divergence?

<table>
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<tr>
<td>Painted Whitestart</td>
<td>Myioborus pictus</td>
</tr>
<tr>
<td>Red-faced Warbler</td>
<td>Cardellina rubrifrons</td>
</tr>
<tr>
<td>Canada Warbler</td>
<td>Wilsonia canadensis</td>
</tr>
<tr>
<td>Wilson's Warbler</td>
<td>Wilsonia pusilla</td>
</tr>
<tr>
<td>Kentucky Warbler</td>
<td>Opororhynchus formicivorus</td>
</tr>
</tbody>
</table>

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**Cornell Lab of Ornithology**
Black Rail Surveys in Virginia
Mike Wilson, College of William and Mary

- Threatened species in VA
- Never systematically surveyed, though anecdotal records from remote marshes
- Determine status
- Point count/playback
- ARUs in known territories to record calling rates
- Still analyzing (!): many other rails, nightjars recorded
Monitoring stopover and migration hotspots
Yuma, AZ

PIs: Rich Fischer; Sid Gauthreaux

- Ground truth and radar to index abundance, composition, location, patterns
- Acoustic data for comparison, collected with 6 ARUs in spring 2007
- Knowledge of characteristics, dynamics of migration in SW riparian areas
- Preliminary analyses show correlation between ground truth observations and acoustic recordings in terms of species composition.
- However, some species not detected visually were recorded on ARUs (Yuma Clapper Rail, Swainson’s Thrush, Yellow-billed Cuckoo)
- Data still being analyzed at CLO for planned manuscript
Examples:

2005-2007 highlights: 120+ species detected

- **Waterbirds** - American & Least Bitterns, Great Blue & Green Herons, Snow Goose, “Yuma” Clapper & Virginia Rails, Sora, Greater Yellowlegs, Short-billed Dowitcher, Pectoral Sandpiper, Caspian Tern

- **Owls, Nightjars, and Cuckoos**: Barn Owl, Common Nighthawk, Whip-poor-will, Chuck-will’s-widow, Yellow-billed & Black-billed Cuckoos

- **Thrushes** - Wood, Hermit, Swainson’s, Gray-cheeked, Bicknell’s, Veery

- **Wood-warblers** - 23 spp. including Black-throated Blue, Canada, Connecticut

- **Emberizids and Cardinalids**: Savannah, White-throated, White-crowned, Brewer’s, & Chipping Sparrows, Dickcissel, Blue Grosbeak, Indigo & Lazuli Buntings, Rose-breasted Grosbeak, Scarlet & Western Tanagers

Observations and acoustic recordings correspond in terms of species composition, but some species detected acoustically only (Yuma Clapper Rail, Swainson’s Thrush, Yellow-billed Cuckoo).
MMS 2005-009, MOGP

Farnsworth and Russell 2007

Calls minute-1

Hours after sunset

- Avg calls/minute
- Avg calls/minute w/o 9/10
- Avg calls/minute w/o 9/10, 9/14, 9/29

Interactions Between Migrating Birds and Offshore Oil and Gas Platforms in the Northern Gulf of Mexico
Final Report

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Call Count/Night, 9-14 Oct 2005
Whip-poor-will calling phenology
Variation among species is greater than variation among individuals and ages and between sexes.

Farnsworth and Lanzone in prep.
Flight-calling behavior is **not** limited to migratory periods in warblers.
8-Channel Microphone Array, Oct 2007

Movement
Real-time Auto-detection Network: Boston Shipping Lane

Whales Detected

Last Whale Heard: 2008-01-30 09:08:23 GMT on Buoy DMF1

Current time: 2008-01-30 16:30:25 GMT

Buoys report their status periodically. If they fail to report within 24 hours or have never reported they are considered 'offline.'
Call Location on 19-Channel array – 14 Sept 2007

Location (x,y)
At present, flight call recording represents only reliable method for directly identifying birds migrating at night. Additionally, acoustic technologies facilitate:

- sampling species beyond range of traditional protocols;
- collecting for extended periods at difficult-to-access sites;
- recording secretive species that vocalize infrequently;
- generating permanent record for repeated sampling;
- estimating variation in probabilities of detection.

Why study migrants and migration using acoustic technology?
Monitoring bird migration using radar

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Radar Basics

- Radars detect targets, measuring reflected radio signals.
  - The greater in size and number the targets, the stronger the reflected, scattered signals.
  - Reflectivity magnitude relates to the number and size of the targets encountered.

- Radar determines target location and measure “radial velocity,” the component of target velocity moving toward or away from the radar.
Radar Basics

From NJ Audubon website, after D. Mizrahi and CUROL

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Radar Basics

Distance from NEXRAD

Altitude
Weather Surveillance Radar-88D

- Doppler radar (~150 across the US)
- Antenna elevation angle 0.5°
- Resolution of 1 km x 0.96° beam width
- At 37 km this beam samples an altitudinal band 150-760m above ground level.
**WSR-88D Products**

**Base reflectivity**: relative amount of reflected energy from targets detected in a radar scan.

**Radial velocity**: component of target velocity moving toward or away from the radar.
Precipitation
Sunset
Non-biological, non-meteorological
Chaff – military activities
Non-biological, non-meteorological Strobes and Anomalous Propagation
Non-biological, non-meteorological
Critical station Error
Wind-related products

Vertical wind profile shows the velocity and direction of windborne targets above the radar.

SkewT samples wind speed and direction at specified levels of the atmosphere from a balloon launch.
Insects
Interpretation of bird movements

[Image of radar map showing bird movements with color-coded areas and arrows indicating movement directions.]
Relating bird density and radar reflectivity

Lowery (1951) and Lowery and Newman (1955)

Gauthreaux and Belser (1998, 1999)
Bird Migration on Radar
Bird Migration on Radar

Image at 0500Z Tue 24 Apr 2007
Fronts at 06Z Tue 24 Apr 2007

University of Wyoming

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Movements: Evening 24 April
Movements: Evening 24 April
Bird migration by radar, microphone

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Birds and weather

• Migration and weather
  – Frontal passages provide combinations of atmospheric conditions that facilitate migration

• Interpreting maps
  – Position of pressure centers and frontal boundaries
  – Orientation of isobars
  – Distribution of precipitation
Identifying key stopover habitats
Migration at the local scale

A

B

C

D
Migration at the continental scale
Patterns of bird density and flight call counts exhibit wide variation.

Nightly temporal pattern of bird density and flight-call counts

Frequency distribution of peaks of bird density and flight-call counts

Farnsworth et al. 2004
Why study migration using radar?

Radar provides unique information to quantify the magnitude, direction, speed, and location of migrating birds.

Additionally, radar technologies facilitate:

– sampling at a variety of scales from 10s to 1000s km;
– collecting for extended periods at difficult-to-access sites;
– collecting ancillary data on atmospheric conditions and changes in these conditions;
– collecting data during periods when other methods are unavailable (cloudy conditions, high wind);
– Relating bird densities on radar to habitat features on the ground
Future plans for monitoring migrants

ebird
Why study migrants and migration using acoustic technology?

Survey “boreal-breeders” that winter in Amazonia

Monitor humans activities that create new hazards
Why study migrants and migration using acoustic technology?
Acknowledgments and Support

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Useful Websites

CUROL - www.clemson.edu/birdrad
DuPage – www.weather.cod.edu/analysis/analysis.radar.html
UW - http://weather.uwyo.edu/mapper/
NCAR - http://www.rap.ucar.edu/weather/radar

Bill Evans’ Oldbird, Inc.: www.oldbird.org
Flight calls at Cornell: birds.cornell.edu/birdcalls
PARC: http://www.powdermill.org/bioacoustic.htm
XBAT: www.xbat.org
RAVEN: http://birds.cornell.edu/Raven
GlassoFire: www.oldbird.org/GlassoFire.htm
Clemson Radar Lab: www.clemson.edu/birdrad