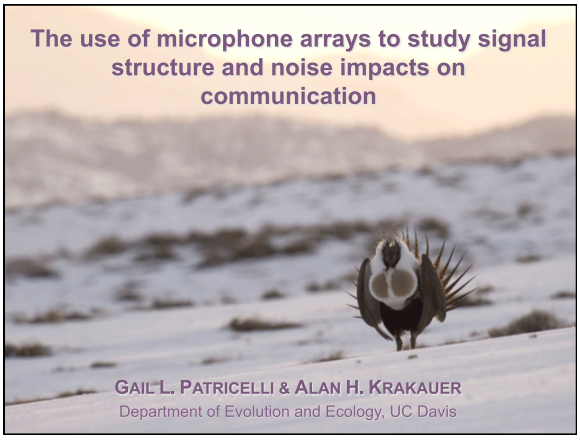
The use of microphone arrays to study signal structure and noise impacts on communication



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Overview of research with arrays

We've used both small and large microphone arrays for studies of animal communication:

- **Small arrays** allow detailed measurements of the spatial component of signal structure
- **Large arrays** allow an examination of signaling interactions within neighborhoods of individuals

Overview of research with arrays

We have used arrays to address three topics:

I. Directionality in songbird vocalizations
II. Directionality & sexual selection in sage-grouse
III. Noise impacts on sage-grouse

Directionality in songbird vocalizations

A vocalization is considered **directional** if radiating sound waves have different amplitudes around the animal

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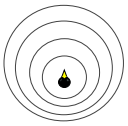


We tested the hypothesis that directionality is adapted to signaling context

Previous Studies of directionality

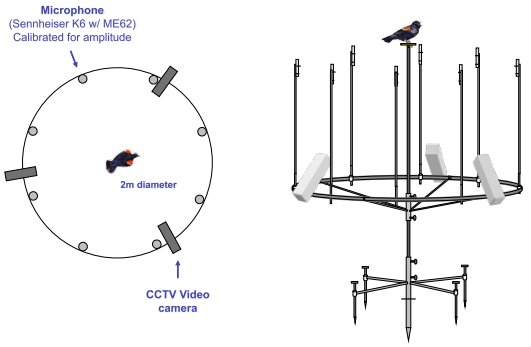
Previous methods:

- Measurements from captive or dead birds in anechoic chambers
- In the field, microphones or sound level meters repositioned around calling animals

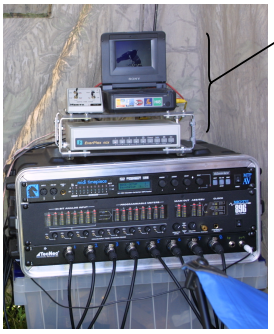
Microphone arrays:

- Allow detailed measures of amplitude and directionality
- Adapted from the methods of Dantzker, Deane & Bradbury (Journal of Experimental Biology, 1999)

Songbird Directionality Array



Songbird Directionality Array



Video deck, multiplexer and window dub inserter (Horita): records 4 channels of video with time code embedded in image

Time code generator (MOTU Midi Timepiece AV): Allows sync with video

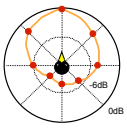
8-channel digitizing preamp (MOTU 896) & laptop: Audio recorded on a Mac running Digital Performer

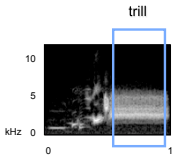
Audio processed using custom Matlab algorithms

Directionality of the "oak-a-lee" song (trill only)

Male 1

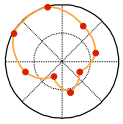
Directivity Index (DI) = 4.0
Difference in dB = 8.6





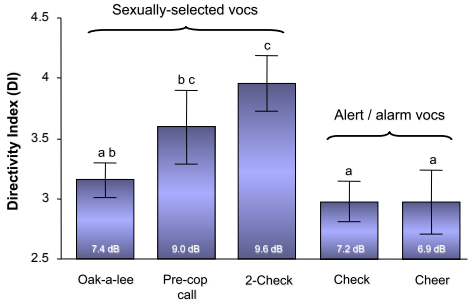
Male 2

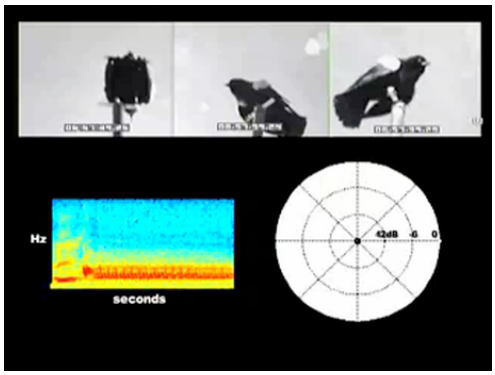
Directivity Index (DI) = 3.3
Difference in dB = 8.3



Mean directionality by vocalization type

There are significant differences in directionality among call types





Overview of current and future research

We have used arrays to address three topics:

I. Directionality in songbird vocalizations

II. Directionality & Sexual selection in sage-grouse

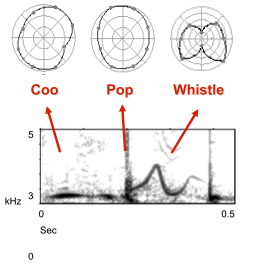
III. Noise impacts on sage-grouse

Sexual selection in sage-grouse

- Sage-grouse are a model system for studies of sexual selection and lek evolution
- Sound is central to female choice
- Male signals are highly directional

(Gibson & Bradbury 1985; Dantzker et al. 1999)

Sexual selection in sage-grouse



(Dantzker et al., 1999)

Methods: Fembot

Robotic female grouse

- Allows us to measure male display from a female's perspective
- Creates a controlled female stimulus
- In combination with the array, allows us to measure "aim"

Methods: 24-Microphone Array

- 24-mic array
- Measure Radiation Patterns
- Mic close to many males
- Acoustic Localization

Methods: 24-Microphone Array

ACOUSTIC DATA

Array Recording

Methods: 24-Microphone Array

ACOUSTIC DATA

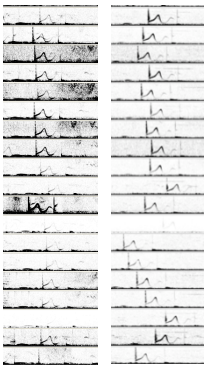
Array Recording

↓

Spectrogram Annotation — *Syrinx (John Burt)*

↓

Acoustic Localization — *ArrayBatchGUI*
Accuracy ≈ 0.5m



Methods: 24-Microphone Array

FIELD OBS & VIDEO

Field IDs, mapping

Video

↓

Time and Location of individual behaviors

Methods: 24-Microphone Array

ACOUSTIC DATA

Array Recording

↓

Spectrogram Annotation

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Acoustic Localization

FIELD OBS & VIDEO

Field IDs, mapping

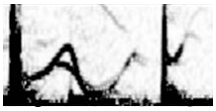
Video

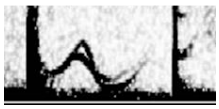
↓

Time and Location of individual behaviors

Localized, Identified Vocalization → **Measurements (e.g. DI, dB SPL)** ***Ongoing...***

Double-Whistles





In 2006, we discovered that males can produce two independent sounds simultaneously

Without arrays, previous researchers dismissed these sounds as overlapping vocalizations

We're now investigating the mechanism and function

Overview of research with arrays

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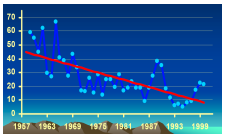
The effects of noise on sage-grouse

Sage-grouse populations are declining across the West

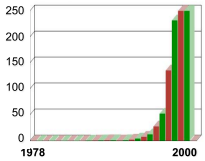
Natural gas development is increasing exponentially; sage-grouse decline in development areas

Our goal is to determine whether noise from gas development is contributing to declines
(with Jessica Blickley)

www.skytruth.org



Wyoming coalbed methane production (millions of cubic feet)



Experimental introduction of noise

In an undisturbed area, we compared attendance and behaviors between control leks and leks with experimental noise

- In 2006: Establish baseline attendance on leks
- In 2007-2008: 8 noise leks (4 road, 2 drilling) & 8 control leks

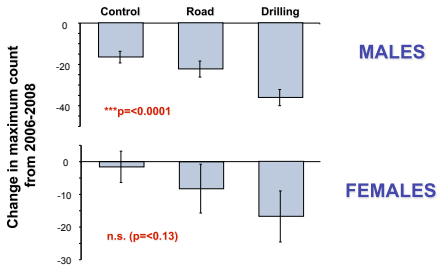
Noise was broadcast at 70dBF SPL at 16 meters from 4 rock-shaped speakers on treatment leks

Dummy speakers on control leks

Spend equal time visiting dummy and real speakers

The effects of noise on sage-grouse

Preliminary Results: Attendance dropped on noise leks compared to controls



The effects of noise on signaling

Do male sage-grouse adjust characteristics of their vocalizations in response to background noise?

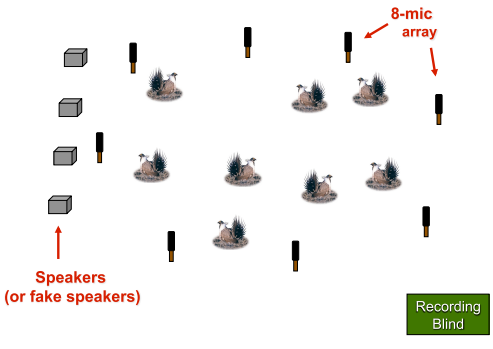
- Increase amplitude
- Shift frequencies
- Shift timing of vocalization
- Increase redundancy

Why use an array?

Use of a microphone array allows recording of multiple individuals simultaneously
- Lots of data on male signal structure & timing

Localization adds spatial information
- Determine whether males avoid speakers
- Estimate noise level that an individual bird is experiencing

Array Design



Conclusions

Arrays can be used to answer many types of questions in behavioral ecology, sometimes simultaneously

Arrays can be even more powerful when combined with video data to relate signal structure and behaviors

The extraction and integration of multiple layers of data present major challenges and are currently labor intensive

ACKNOWLEDGEMENTS:

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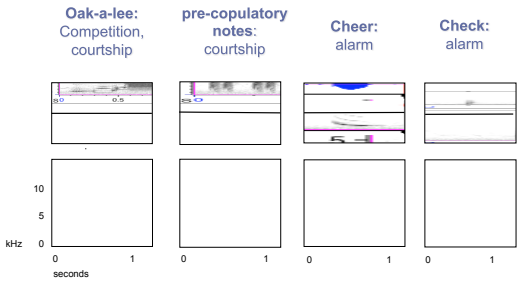
Grouse Photos: Neil Losin
www.neillosin.com

Red-winged blackbird vocalizations



The effects of directionality

Active space:

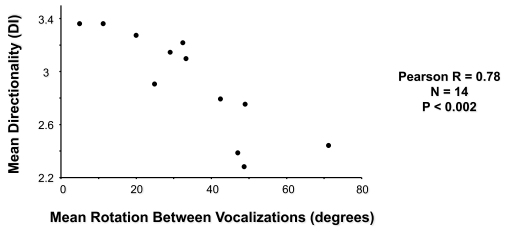
- Signal transmission – amplitude differences as small as 3 dB can translate to a 40% difference in transmission distance
- Number of receivers – omnidirectional radiation may maximize receivers, directional radiation may minimize eavesdropping

Assessing the sender:

- When amplitude *per se* is assessed during communication, e.g. as an indicator of male size or condition

I. Directionality in songbird vocalizations

The amount of male rotation on the perch when singing is inversely related to the directionality of the song



Integrating with video: Directionality and behavior