Acoustic technologies for monitoring birds: past, present, and future

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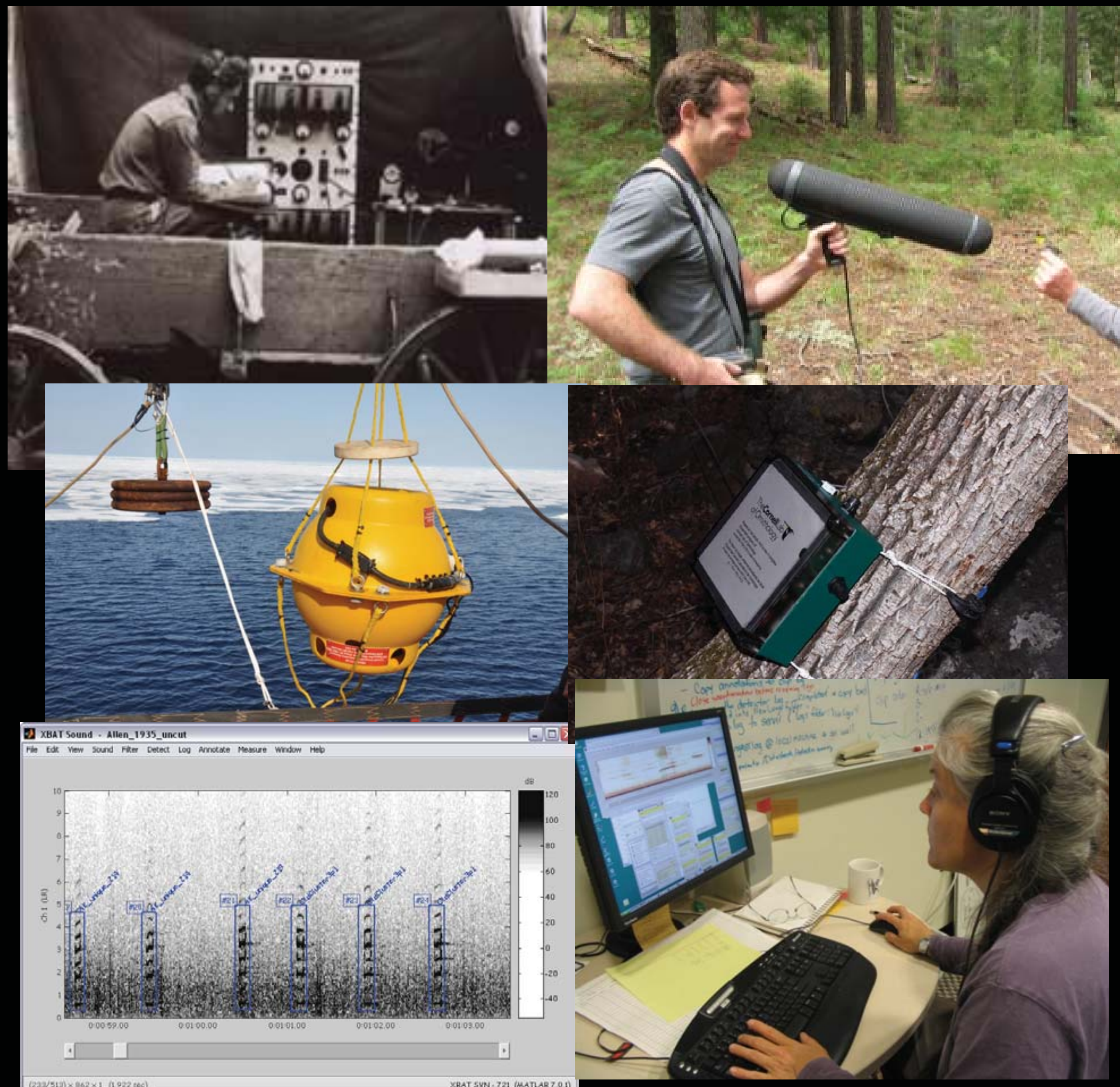
L. Grove, D. Cusano, K. Rosenberg, R. Rohrbaugh

The Cornell Lab of Ornithology

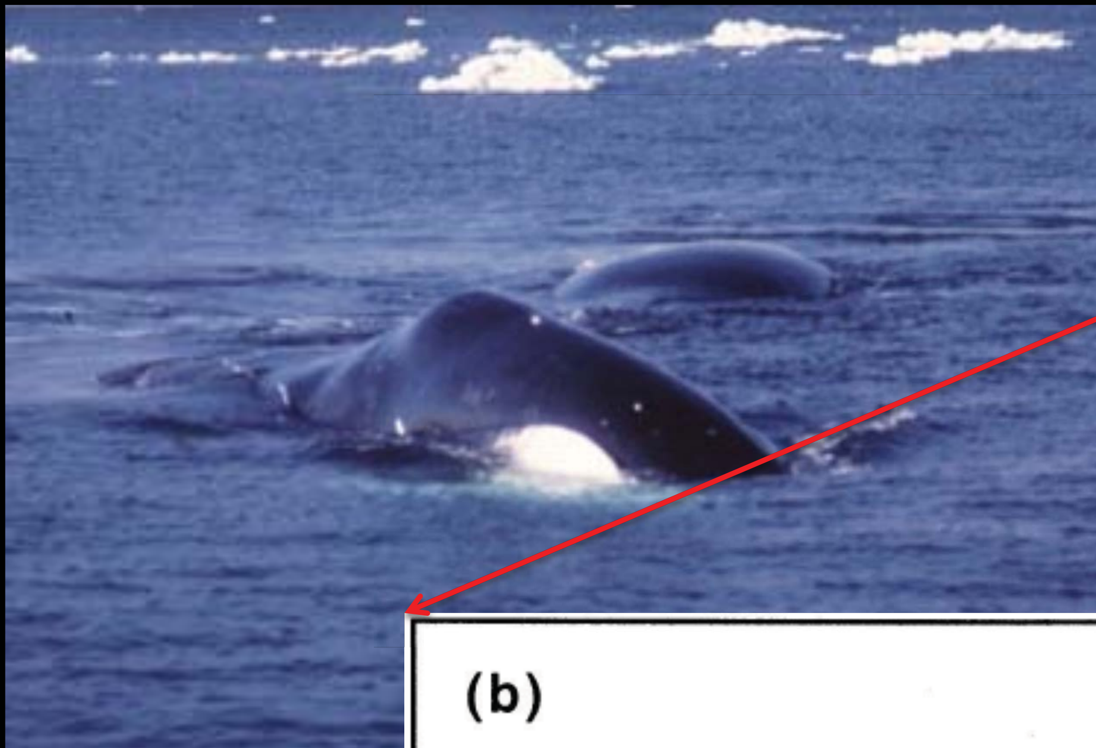
DEPARTMENT OF DEFENSE LEGACY PROGRAM

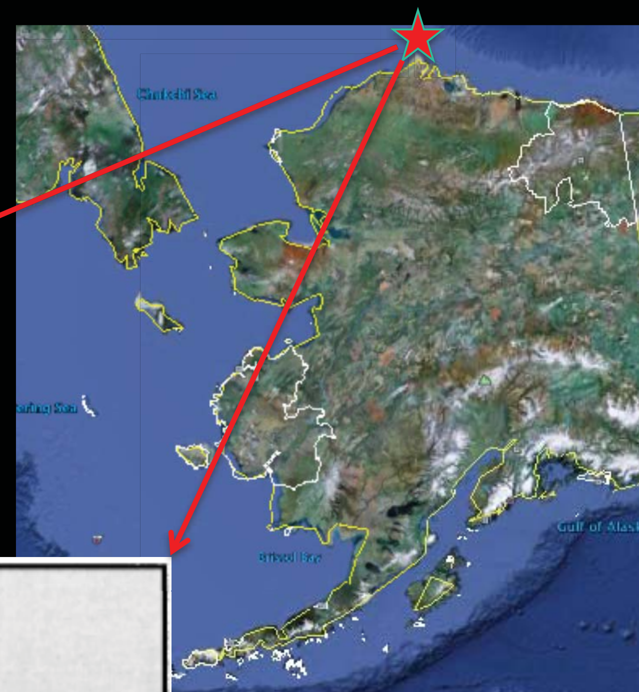
A brief history of acoustic monitoring at Cornell

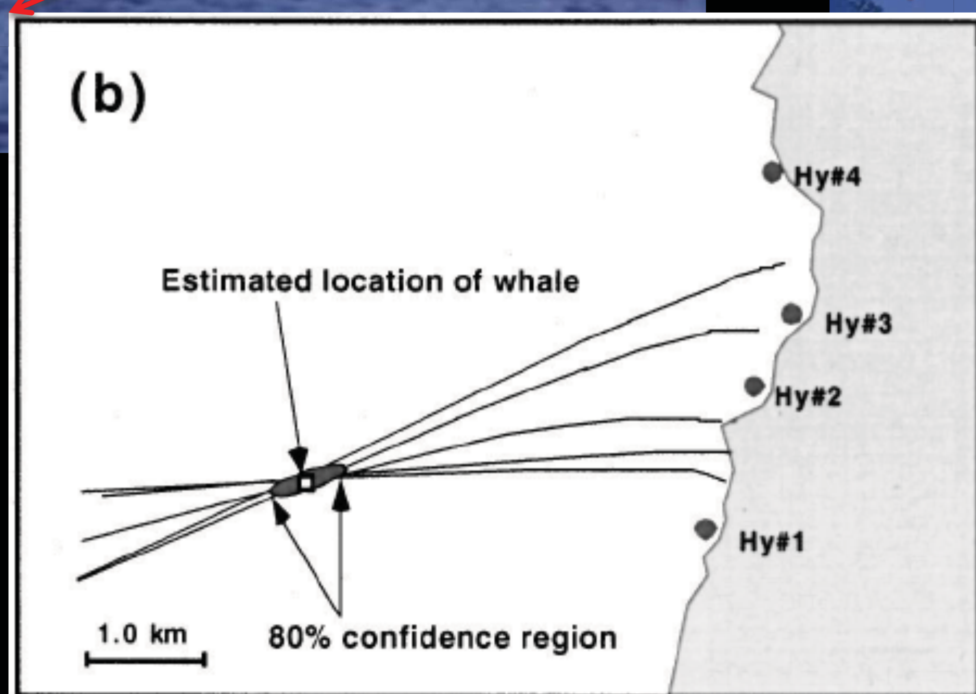


Building the archive

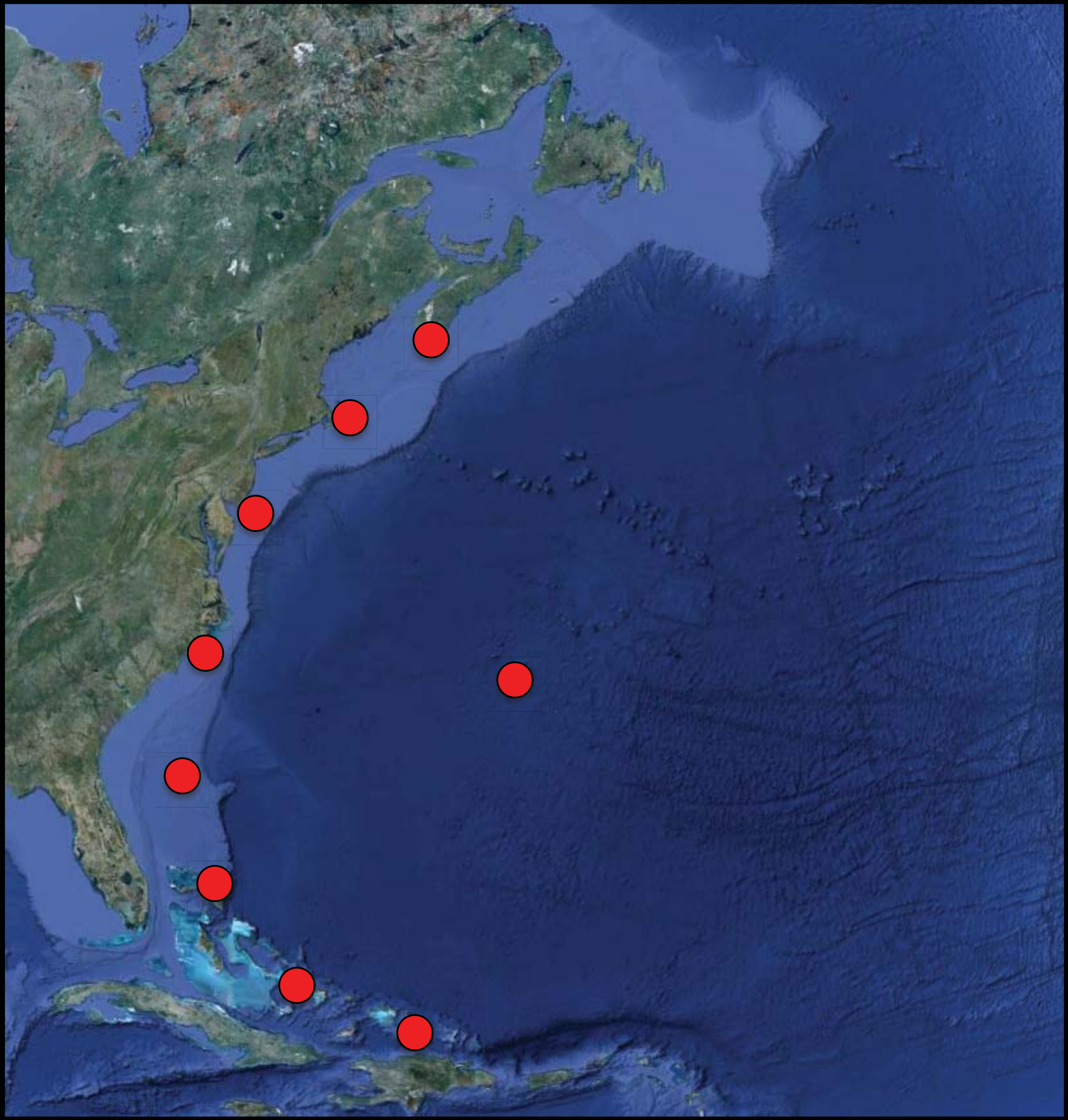
Monitoring migration



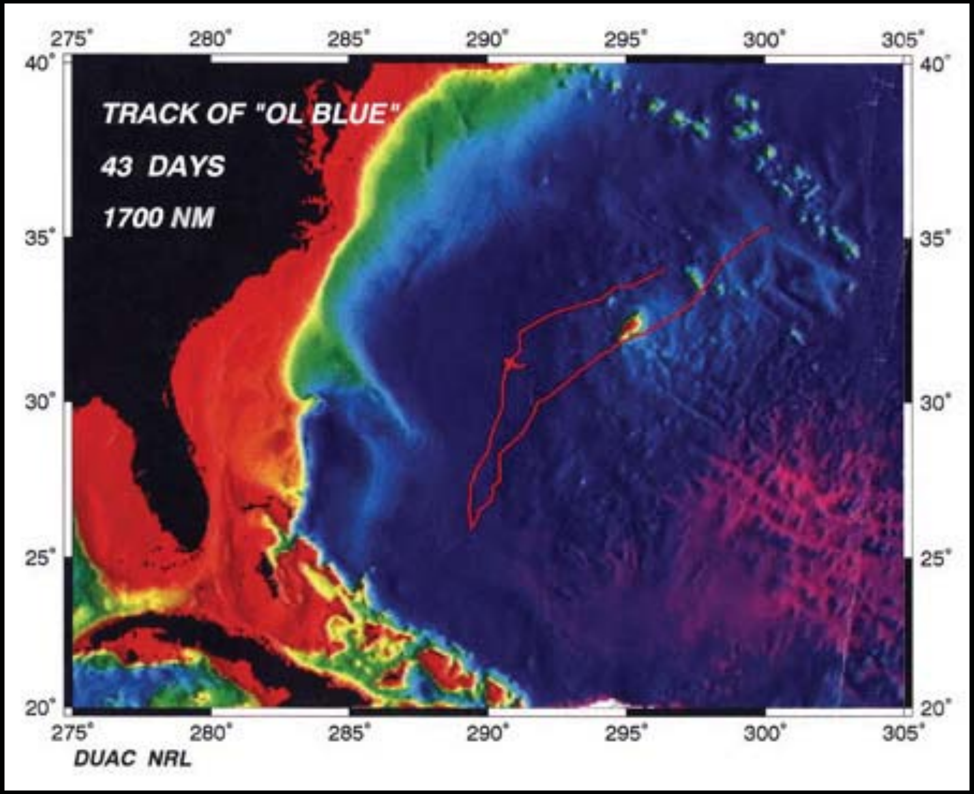


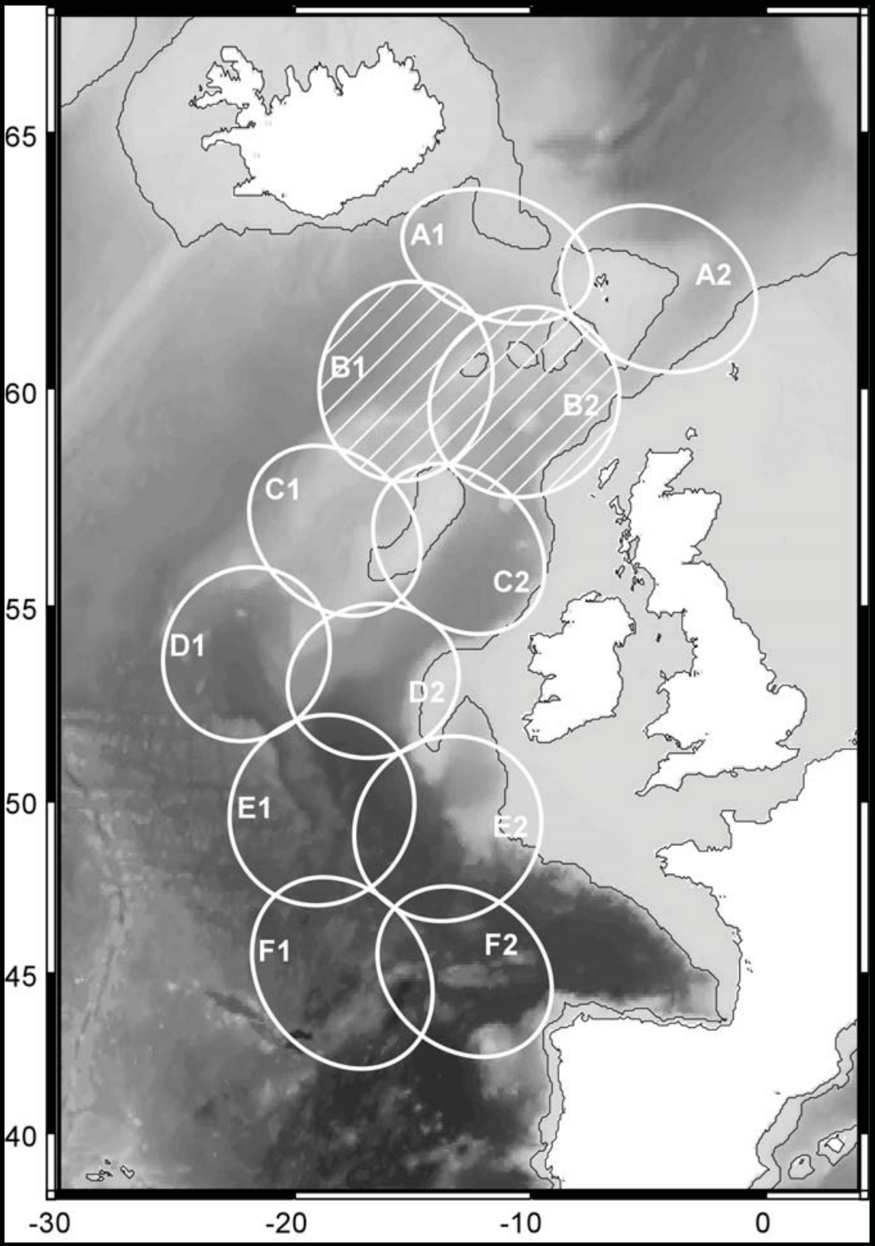


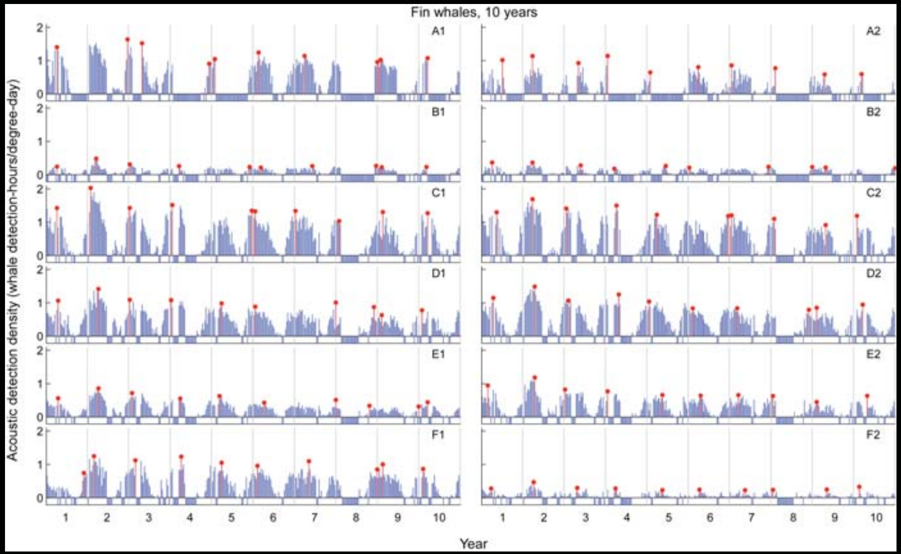
Large-scale monitoring of individuals & populations



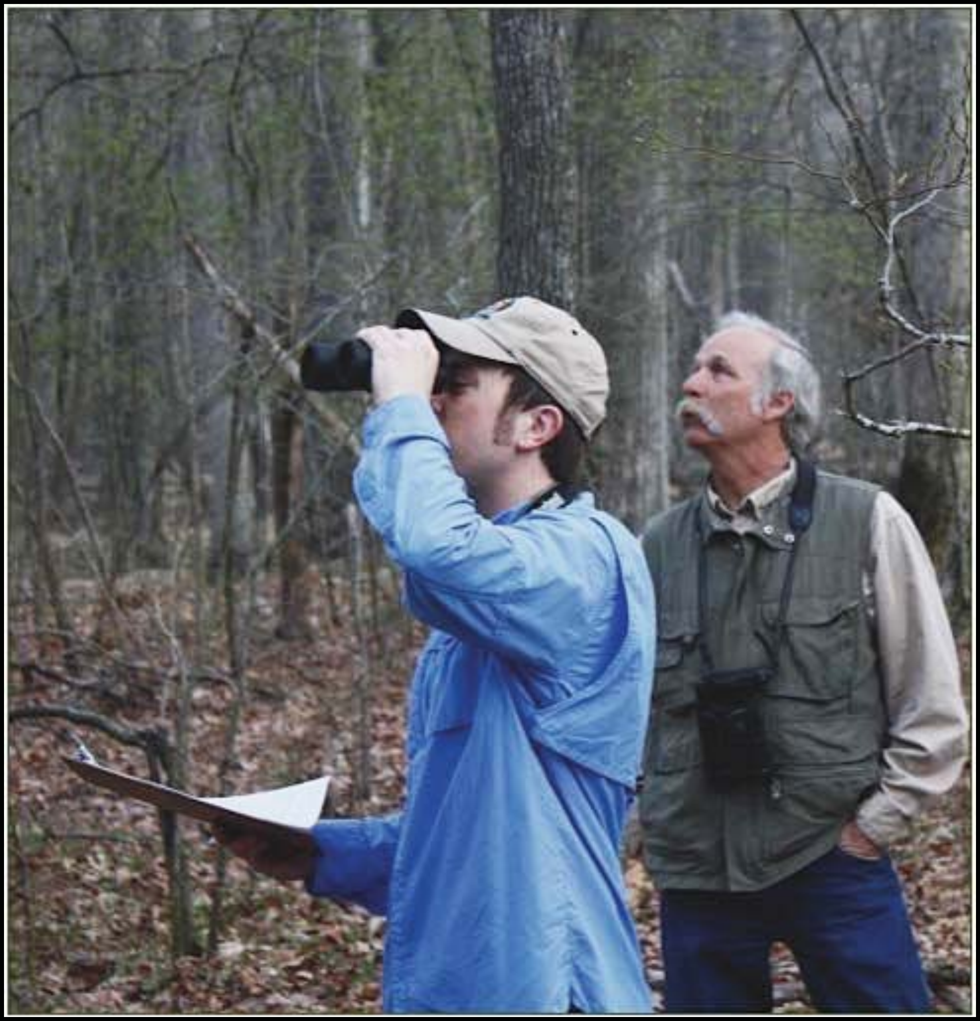
Large-scale monitoring of individuals & populations







Acoustic monitoring of bird populations



Acoustic monitoring of bird populations

<u>Traditional use of acoustics</u>

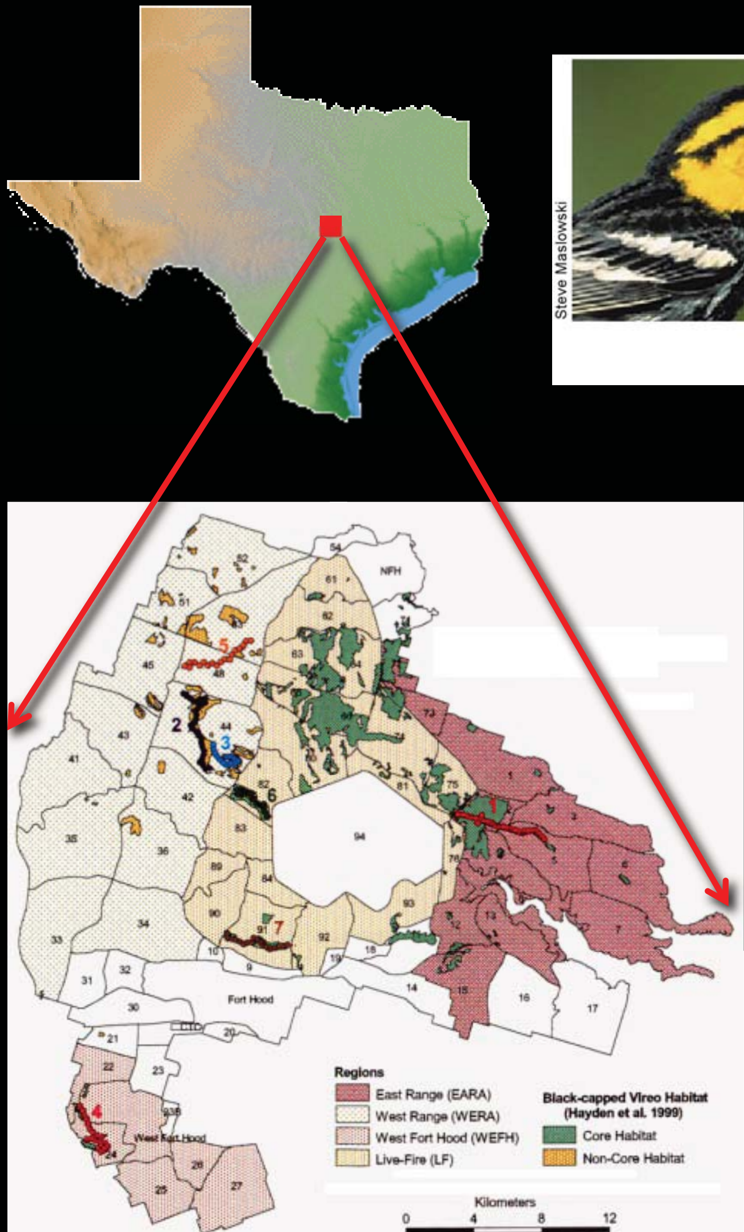
- Biological experts in the field
- Restricted season for expert interpretation
- Data not verifiable
- Problematic for species that vocalize infrequently or at night
- Expensive to cover large area or long time

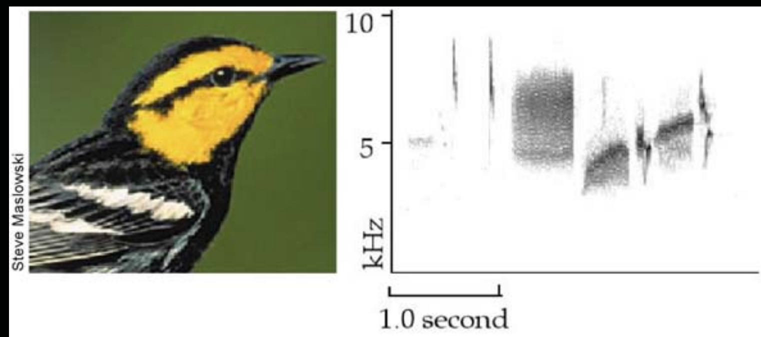
gviamazon.blogspot.com

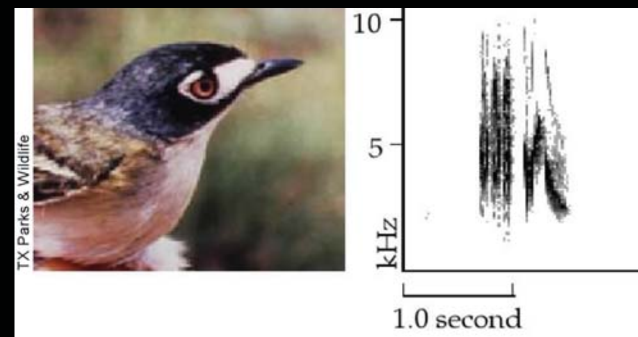
<u>Autonomous recorders</u>

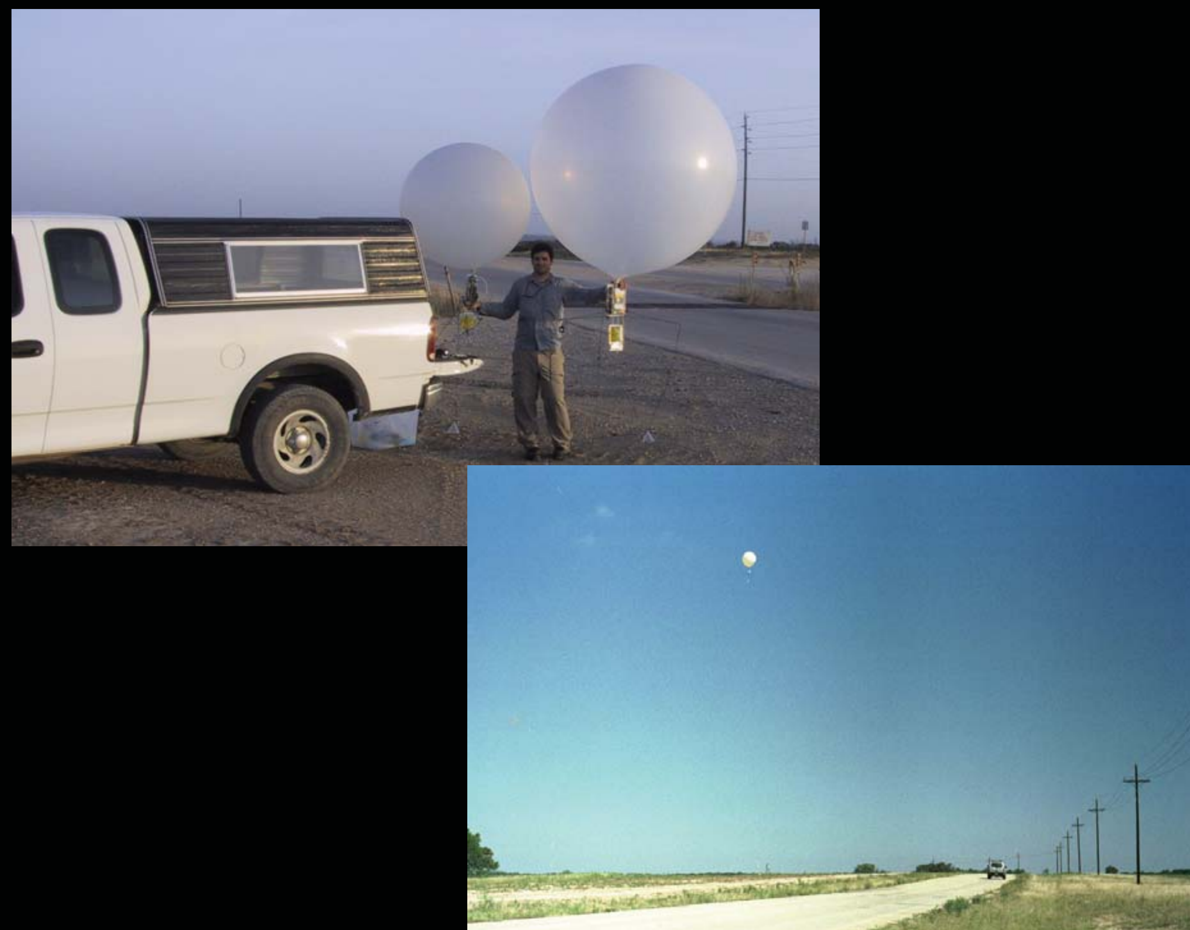
- Digital recording systems in the field; no special skills needed for field staff
- Unlimited season for expert interpretation
- Permanent verifiable record
- Captures infrequent vocalizations, any time of day
- Experts can cover larger area at low cost

Monitoring in inaccessible areas

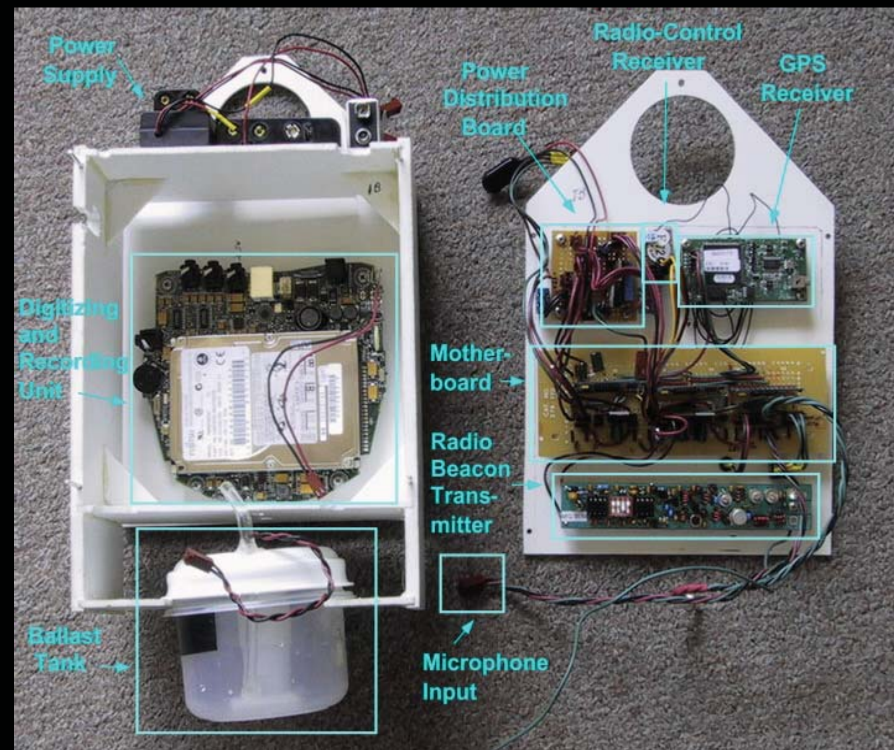


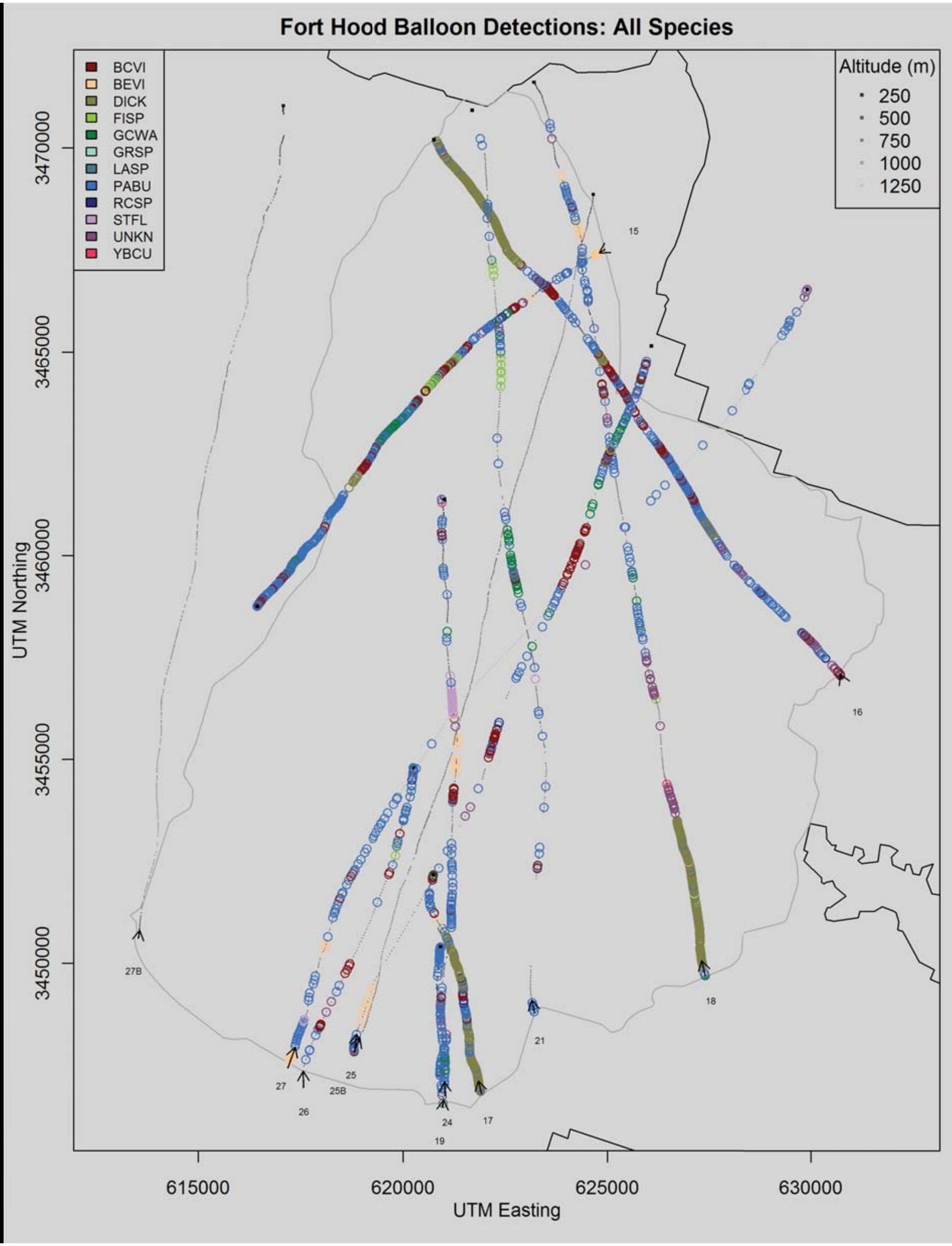




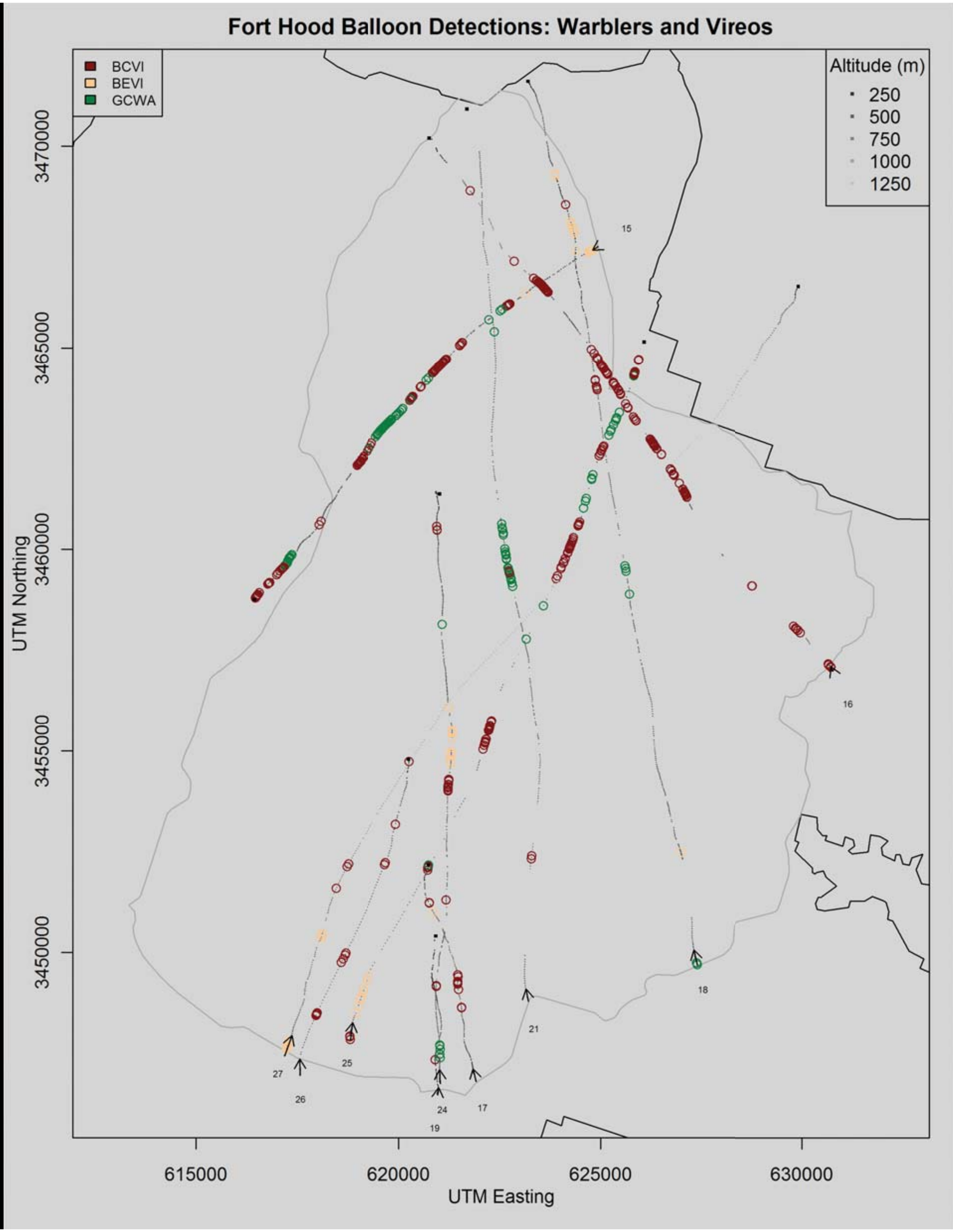


Balloon recording system payload



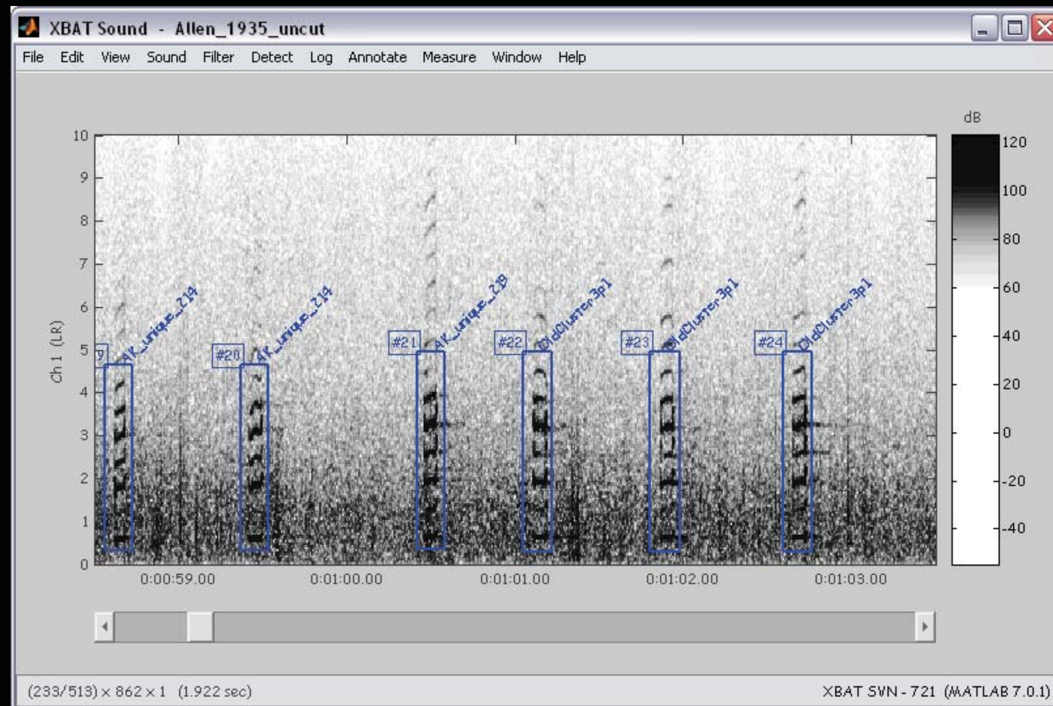


Fort Hood Balloon Detections: All Species
BCVI
BEVI
DICK
FISP
GCWA
GRSP
LASP
PABU
RCSP
STFL
UNKN
YBCU
Altitude (m)
250
500
750
1000
1250
UTM Northing
UTM Easting
3470000
3465000
3460000
3455000
3450000
615000
620000
625000
630000
15
16
18
21
17
24
19
25
25B
26
27
27B



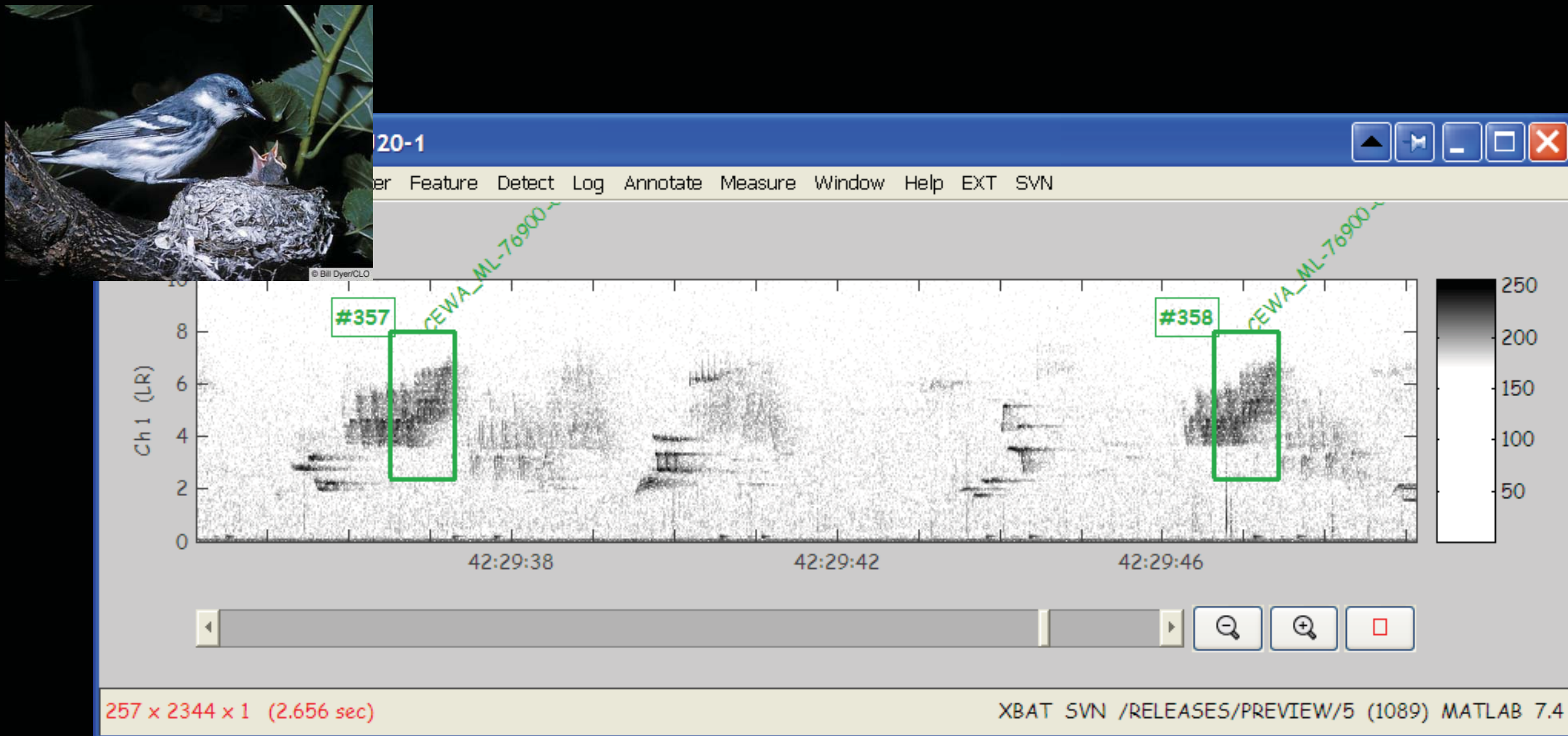
Fort Hood Balloon Detections: Warblers and Vireos
BCVI
BEVI
GCWA
Altitude (m)
250
500
750
1000
1250
UTM Northing
3470000
3465000
3460000
3455000
3450000
UTM Easting
615000
620000
625000
630000
15
16
18
21
27
26
25
24
19
17

Searching for target species



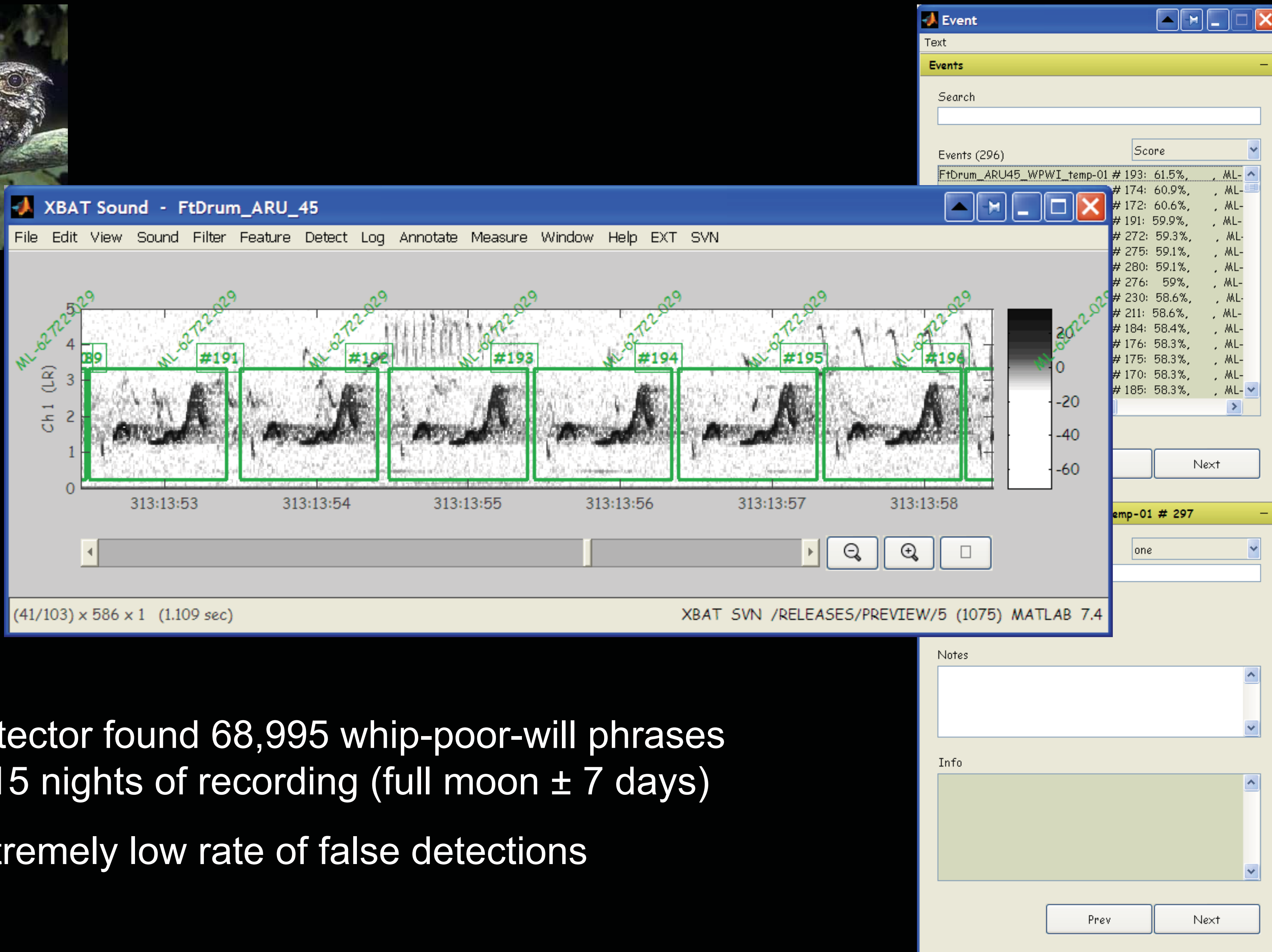
- Typical data rate from Arkansas → CLO in 2004-05 : 900 hours (37.5 days) per week!
- Using data template detector, analysts reviewed 20 – 50 recording hours per hour.

Searching for target species



- ARUs deployed at 4 occupied + 7 unoccupied sites
- Detector found CERW songs at all occupied sites
- Using archived training data only: many false detections at all sites
- Using local training data: performance greatly improved

Searching for target species



- Detector found 68,995 whip-poor-will phrases in 15 nights of recording (full moon ± 7 days)
- Extremely low rate of false detections

Acoustic monitoring of bird populations

The Dream

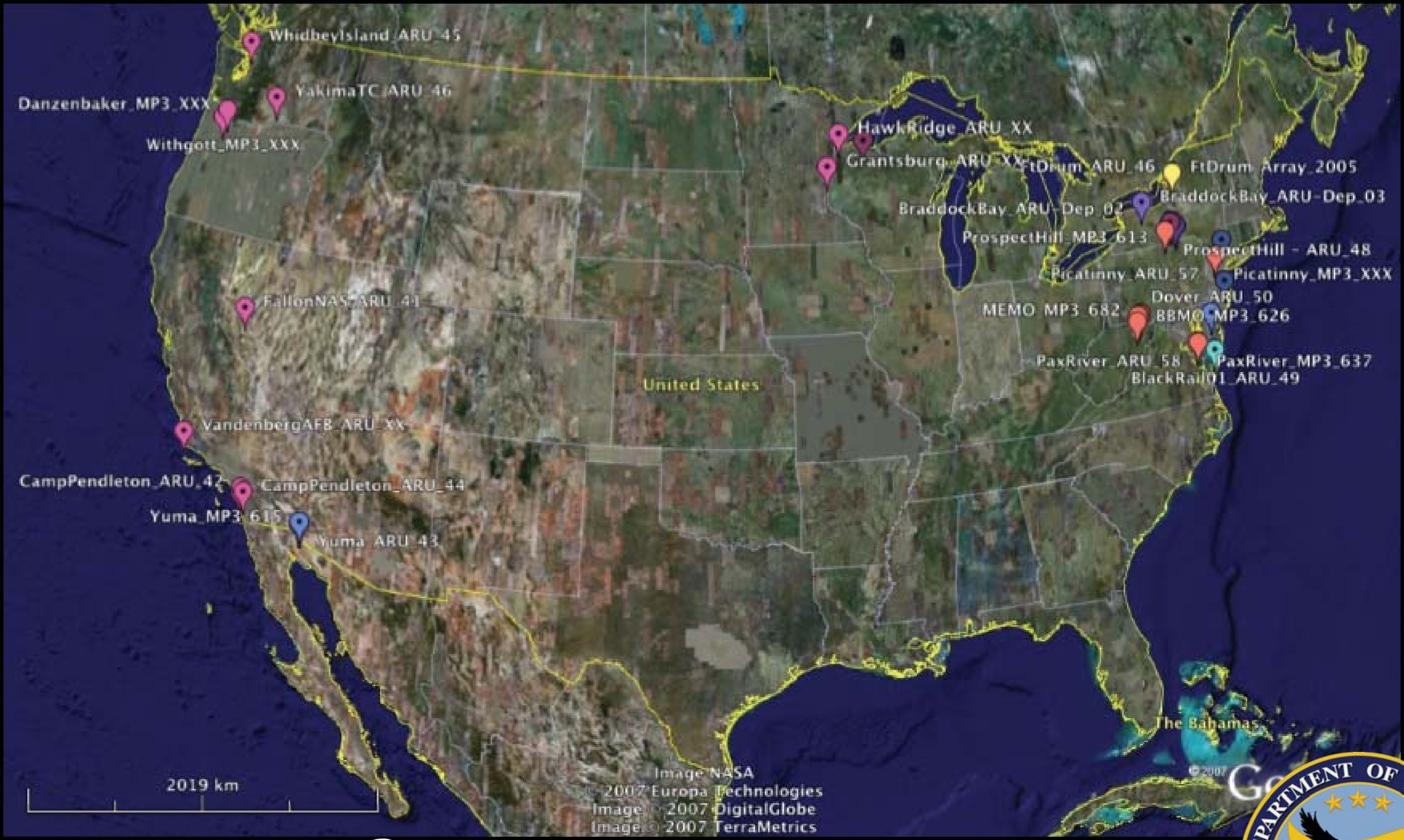
- Artificial Intelligence (AI): complete automation
- detection and classification of many overlapping species: parsing the dawn chorus
- highly and consistently reliable

Acoustic monitoring of bird populations

Where we are now

- Intelligence Amplification (IA): partial automation
- detection of target species
- reliability depends on species and context
- speed, usability, and performance of software tools continually improving

DoD Legacy Program Sites



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Brief summary: acoustic monitoring of target species and nocturnal migration

- 150+ species recorded from ~30 different deployment sites, including: Least Bittern, Yuma Clapper Rail, Upland Sandpiper, Caspian Tern, Eastern and Mexican Whip-poor-wills, Mexican Spotted Owl, Yellow-billed Cuckoo, Willow Flycatcher, Bicknell's Thrush, Canada and Connecticut Warblers, Dickcissel, and Henslow's Sparrow.

- Species composition of nocturnal migration is similar to that observed during diurnal fallouts and ground surveys; however, large numbers of certain species detected by voice were not necessarily detected in diurnal observations.

- Current monitoring protocols (e.g. EWPW, SPOW) can be improved by applying knowledge from automated acoustic monitoring.

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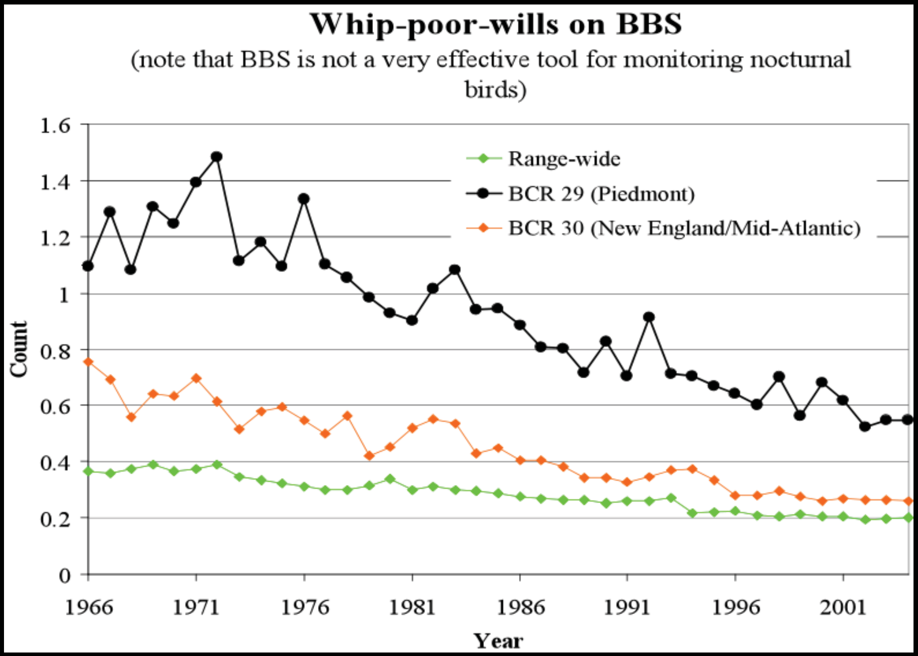
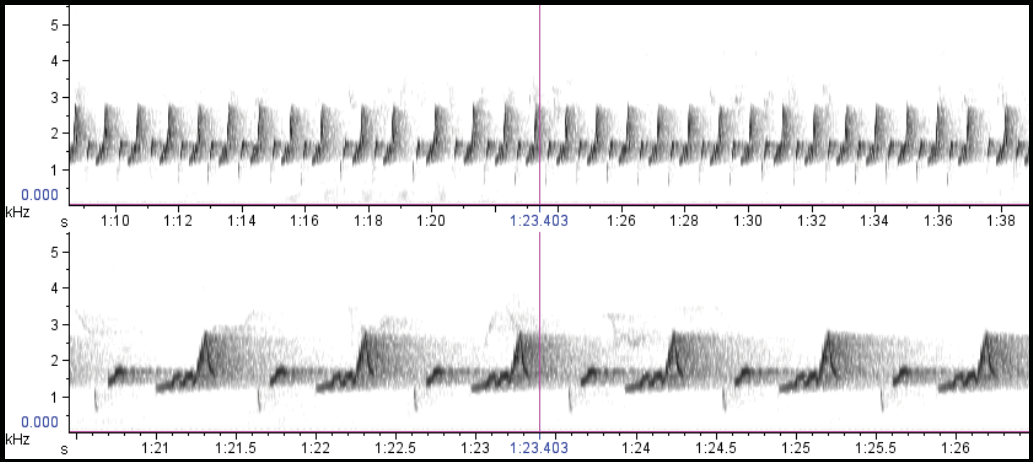
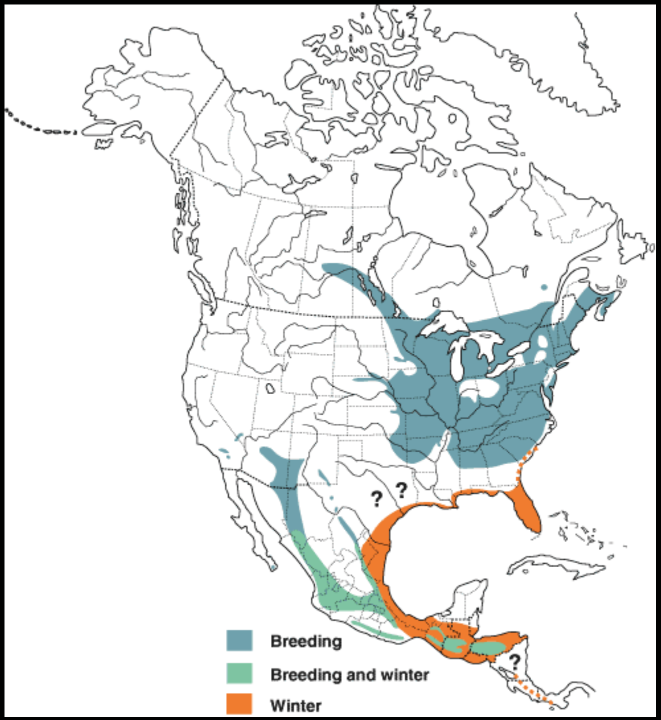
Eastern Whip-poor-will

Caprimulgus vociferus





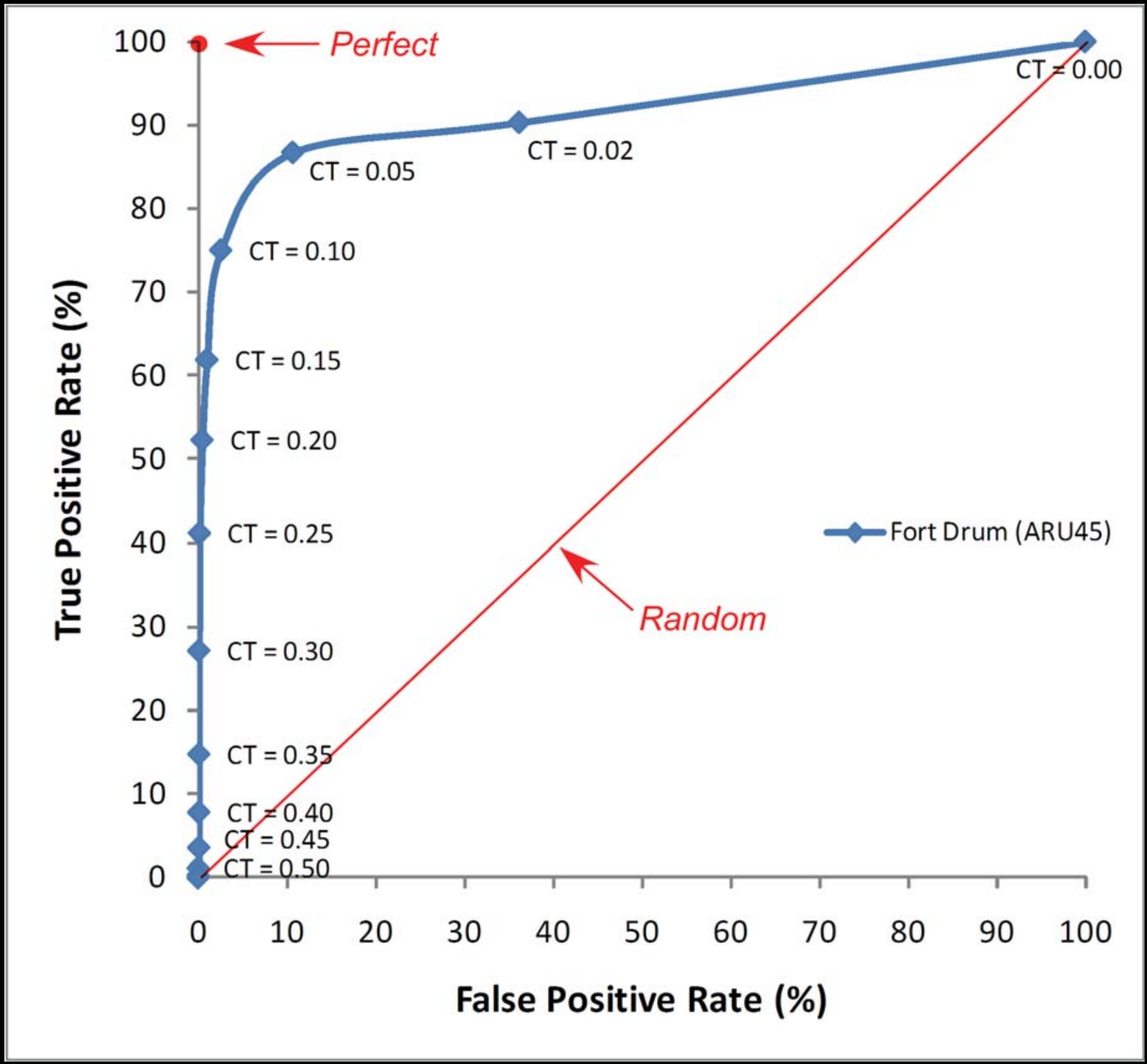


Eastern Whip-poor-will vocal phenology

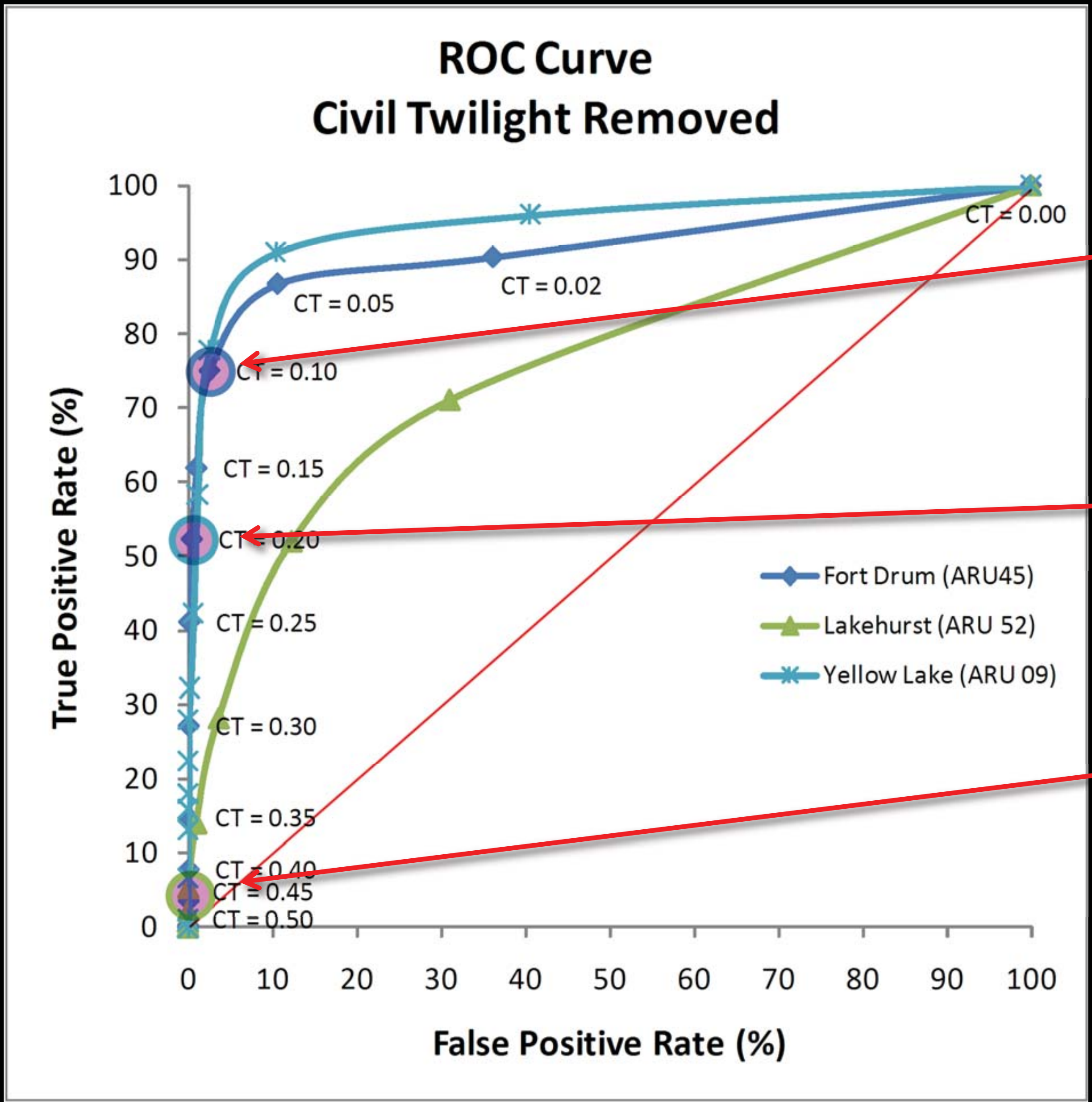
Evaluating detector performance:
Receiver Operating Characteristic (ROC) curve

Summarizes the tradeoff between sensitivity and specificity

- **True positive rate (sensitivity):** Actual positives correctly identified: what % of the targets are reported?
- **False positive rate (specificity):** Actual negatives incorrectly identified: what % of non-targets are reported?



Eastern Whip-poor-will vocal phenology



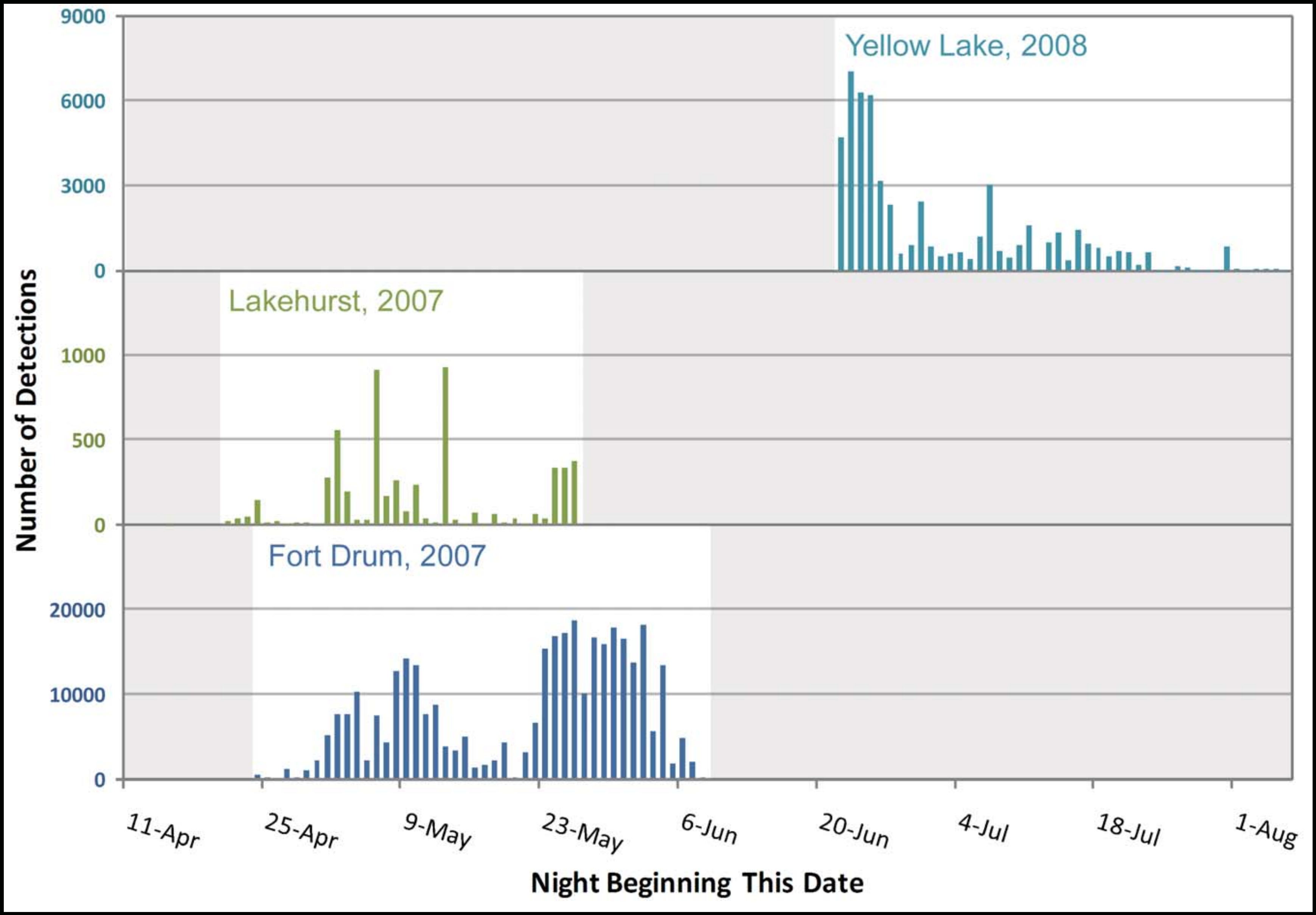
Detector performance

Fort Drum:
- 97% of detections TRUE
- 75% sensitivity

Yellow Lake:
- 96% of detections TRUE
- 42% sensitivity

Lakehurst:
- 96% of detections TRUE
- 2% sensitivity

Eastern Whip-poor-will vocal phenology

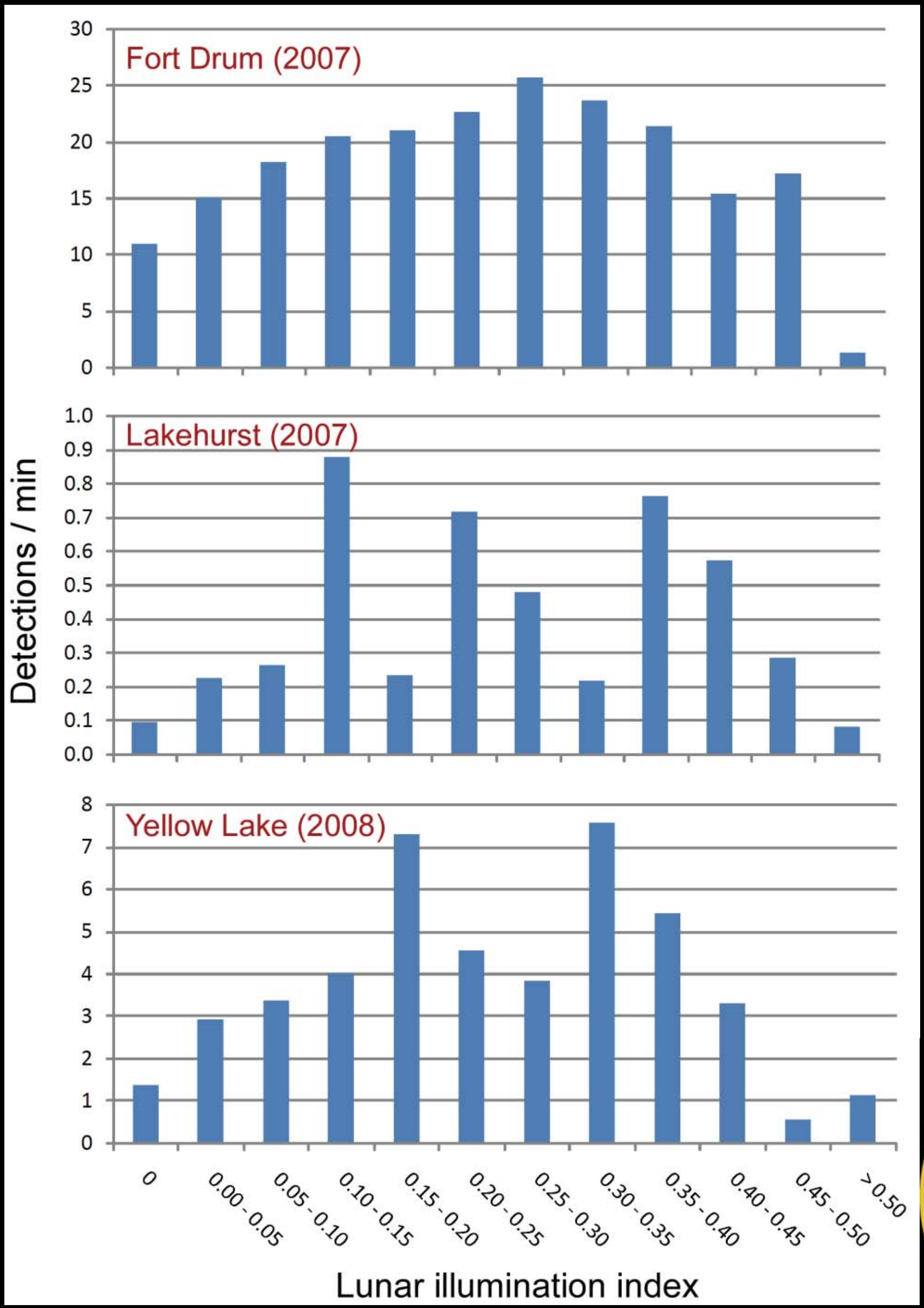


Lakehurst has a low detection rate: false detections from frogs + birds' distance = estimated sensitivity of ~2%!

Even estimating that we miss 98% of EWPW calls (Lakehurst), we have detections almost every night

Eastern Whip-poor-will vocal phenology

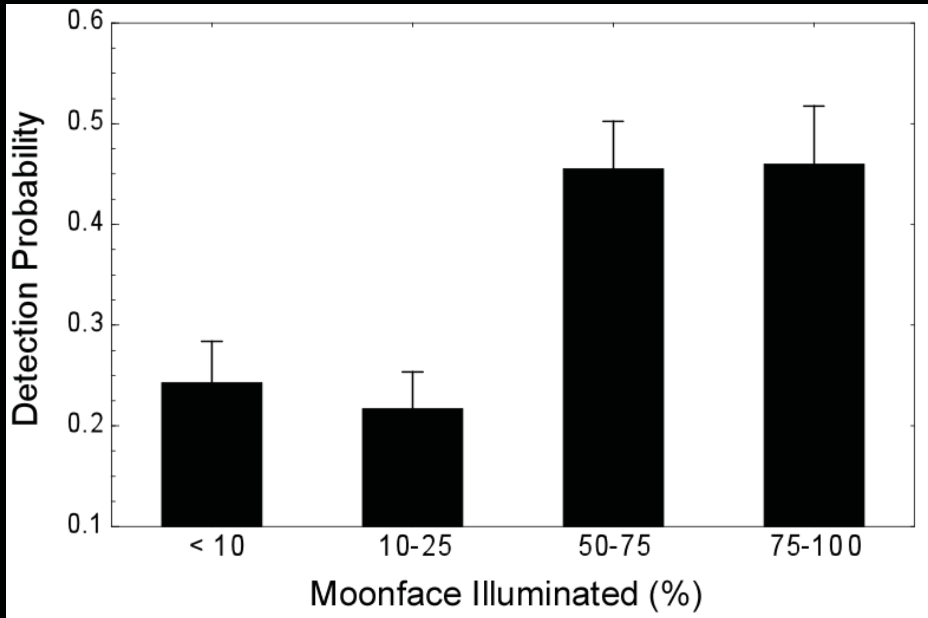
Song rate and lunar illumination index: such a thing as too much moonlight!



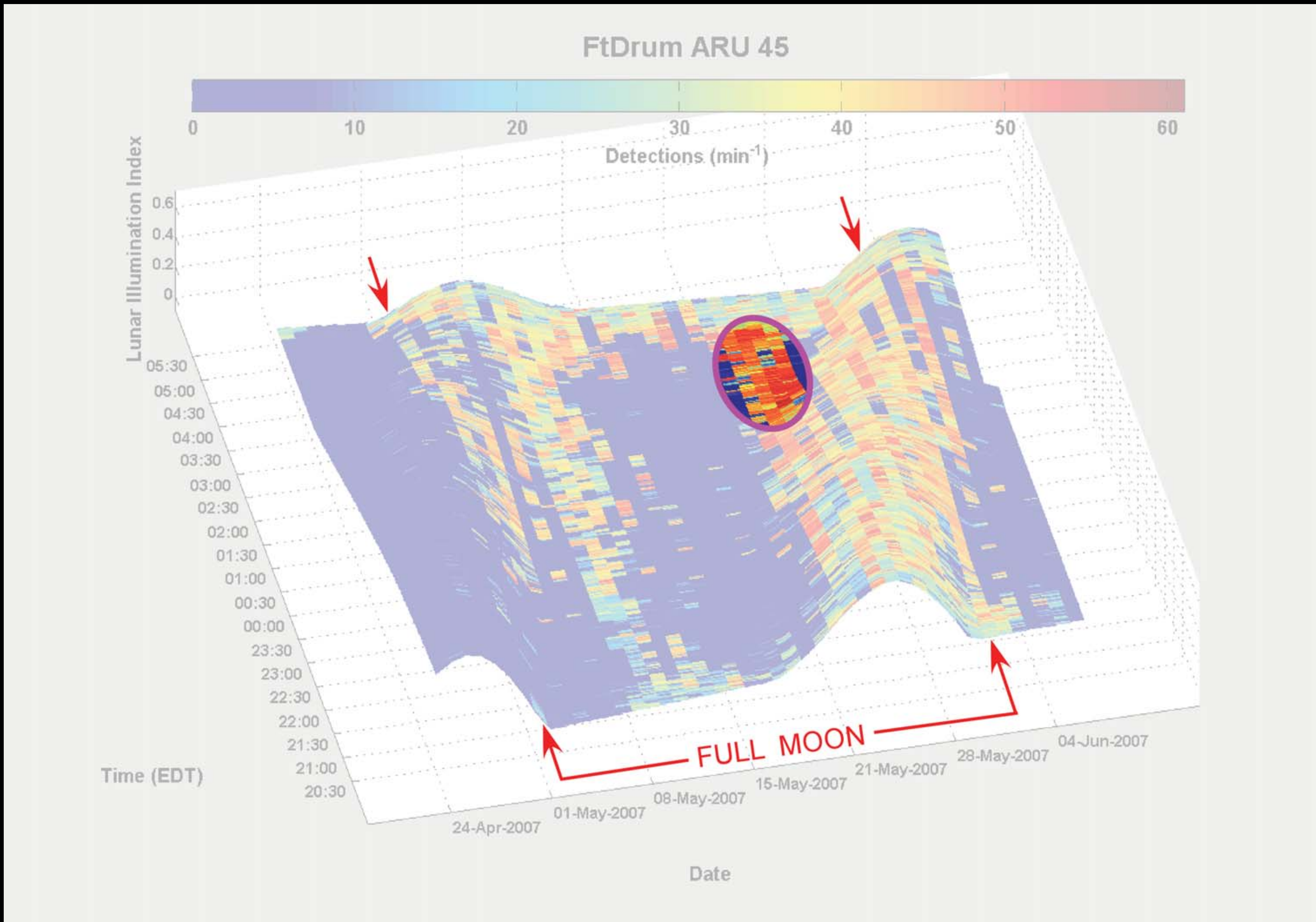
Eastern Whip-poor-will vocal phenology

Standard survey protocol

- Survey only during two-week period centered on full moon
- Listen for 6 minutes at each site



From Wilson, MD and BD Watts. 2006. Effect of moonlight on detection of Whip-poor-wills: implications for long-term monitoring strategies. *J. Field Ornithol.* 77(2):207–211.


FtDrum ARU 45
0
10
20
30
40
50
60
Detections (min^{-1})
Lunar Illumination Index
0.6
0.4
0.2
0
05:30
05:00
04:30
04:00
03:30
03:00
02:30
02:00
01:30
01:00
00:30
00:00
23:30
23:00
22:30
22:00
21:30
21:00
20:30
Time (EDT)
FULL MOON
24-Apr-2007
01-May-2007
08-May-2007
15-May-2007
21-May-2007
28-May-2007
04-Jun-2007
Date

(Mexican) Spotted Owl at Ft. Huachuca

- Threatened species in Mexico and US; FWS released "Mexican Spotted Owl Survey Protocol"
- Well-known home to Mexican Spotted Owl (11 PACs)
- Acoustic monitoring is useful for several reasons, including owls' nocturnal habits, dangerous terrain, difficulty in reaching sites, and limited resources.

(Mexican) Spotted Owl at Ft. Huachuca

Study Plan

1. Three ARUs deployed at known nesting site
2. Two units deployed in little known site
3. Three units to "roam"

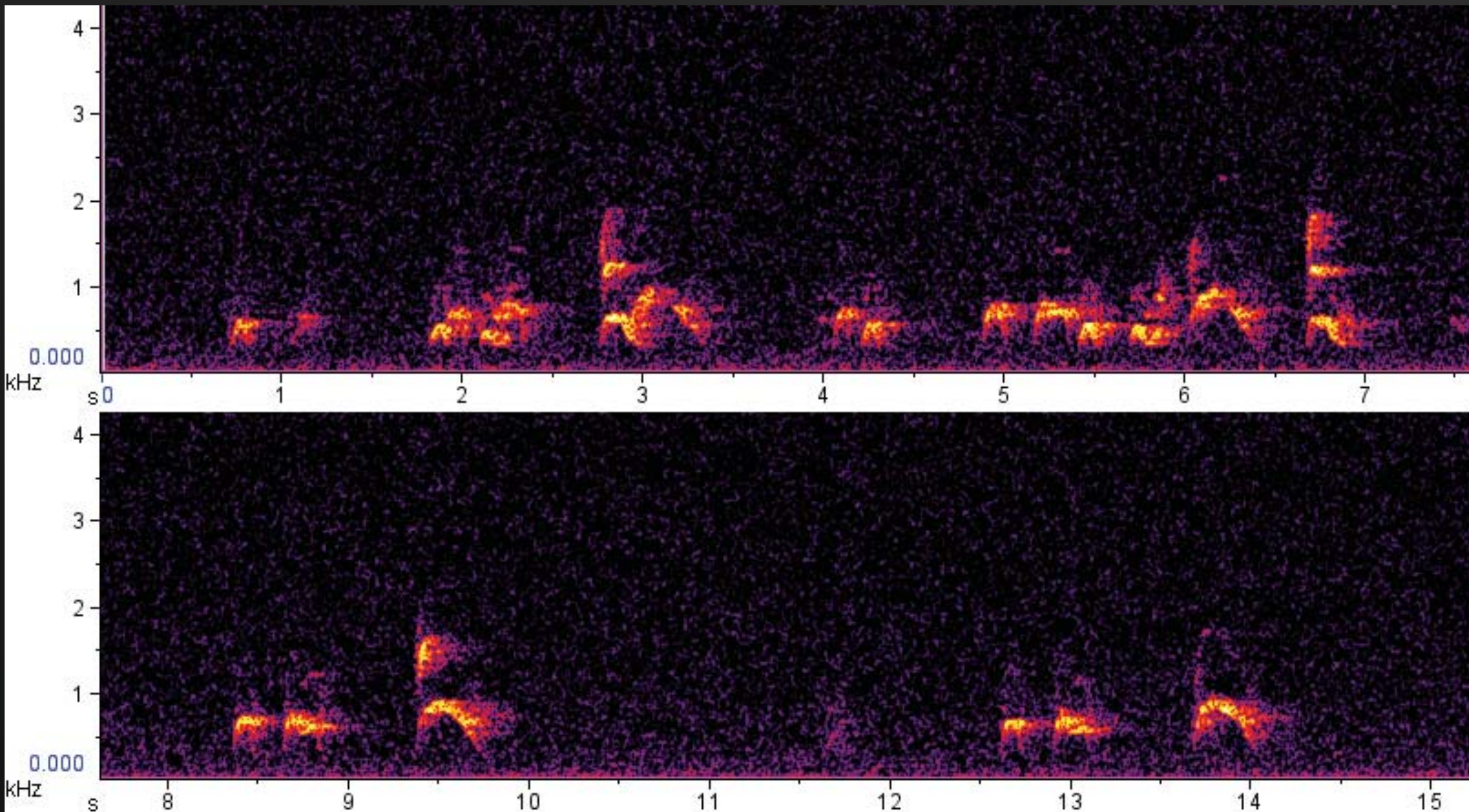
Deployment Plan

1. Three units to "roam" 3 units in Lower Huachuca Canyon
2. 2 units in Scheelite Canyon
3. 2 units in Rock Springs Canyon

Recording protocol

1. Record from local sunset to local sunrise
2. Once/week, batteries changed, cards collected

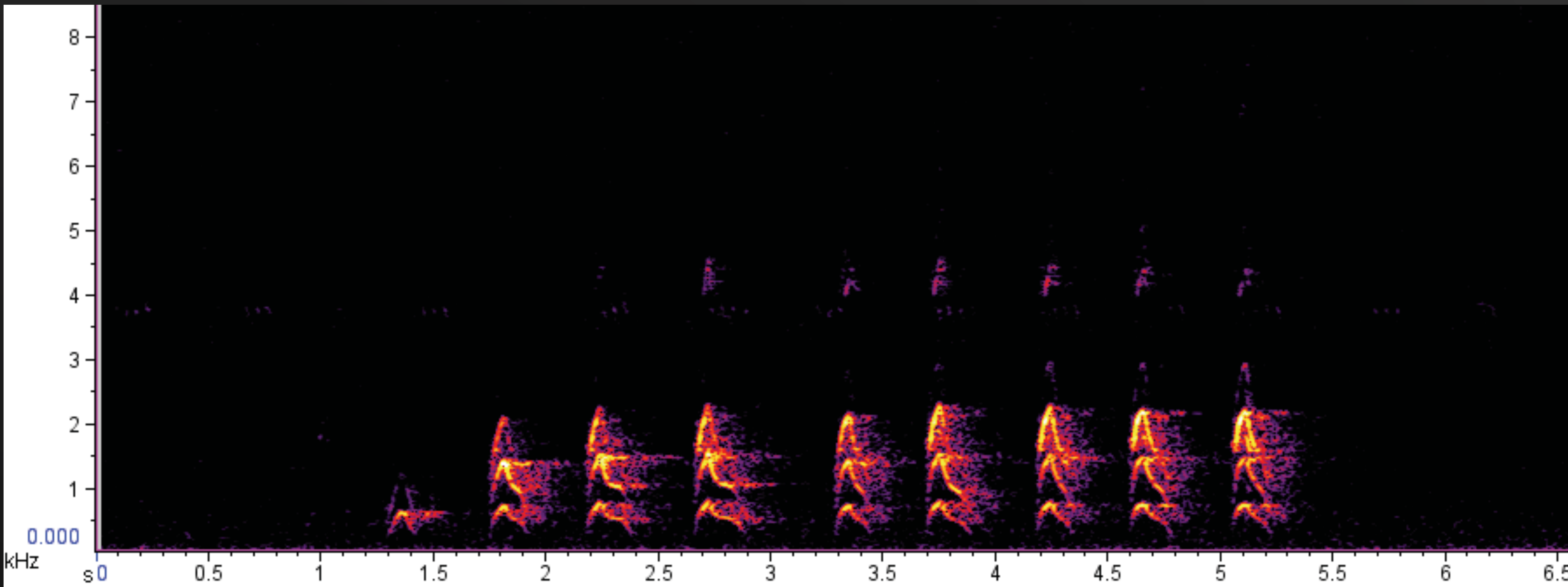
(Mexican) Spotted Owl at Ft. Huachuca



Four-note Location Calls male and female

10 March 2011 03:21:20

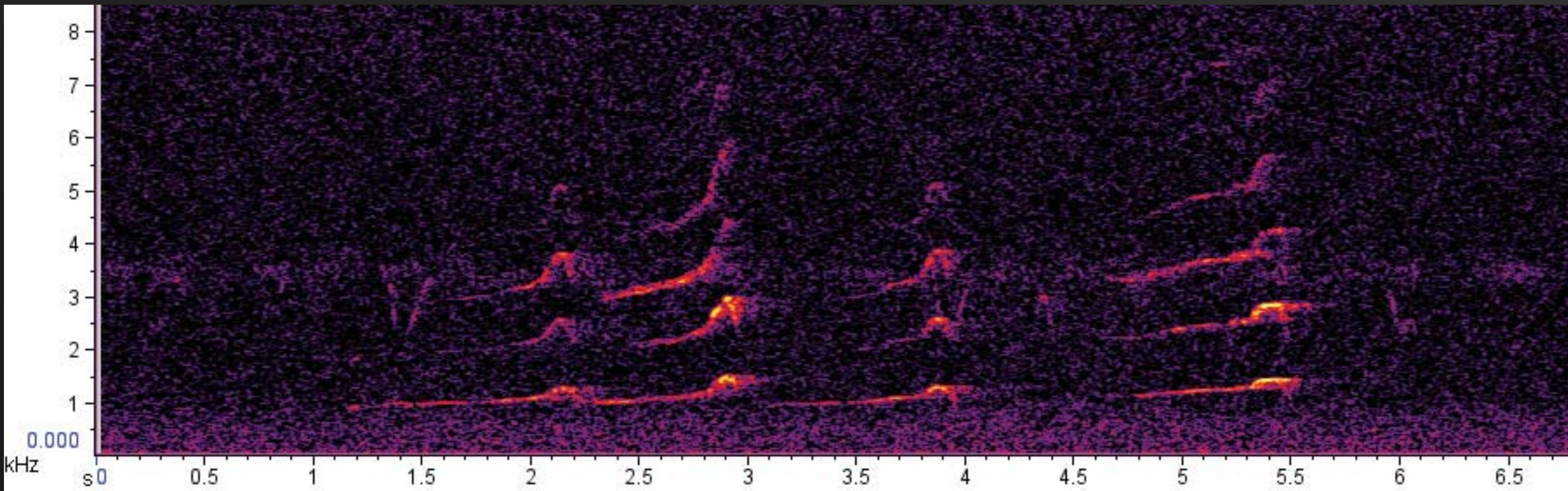
(Mexican) Spotted Owl at Ft. Huachuca



Bark Series

4 June 2011
Ft Huachuca AZ

(Mexican) Spotted Owl at Ft. Huachuca



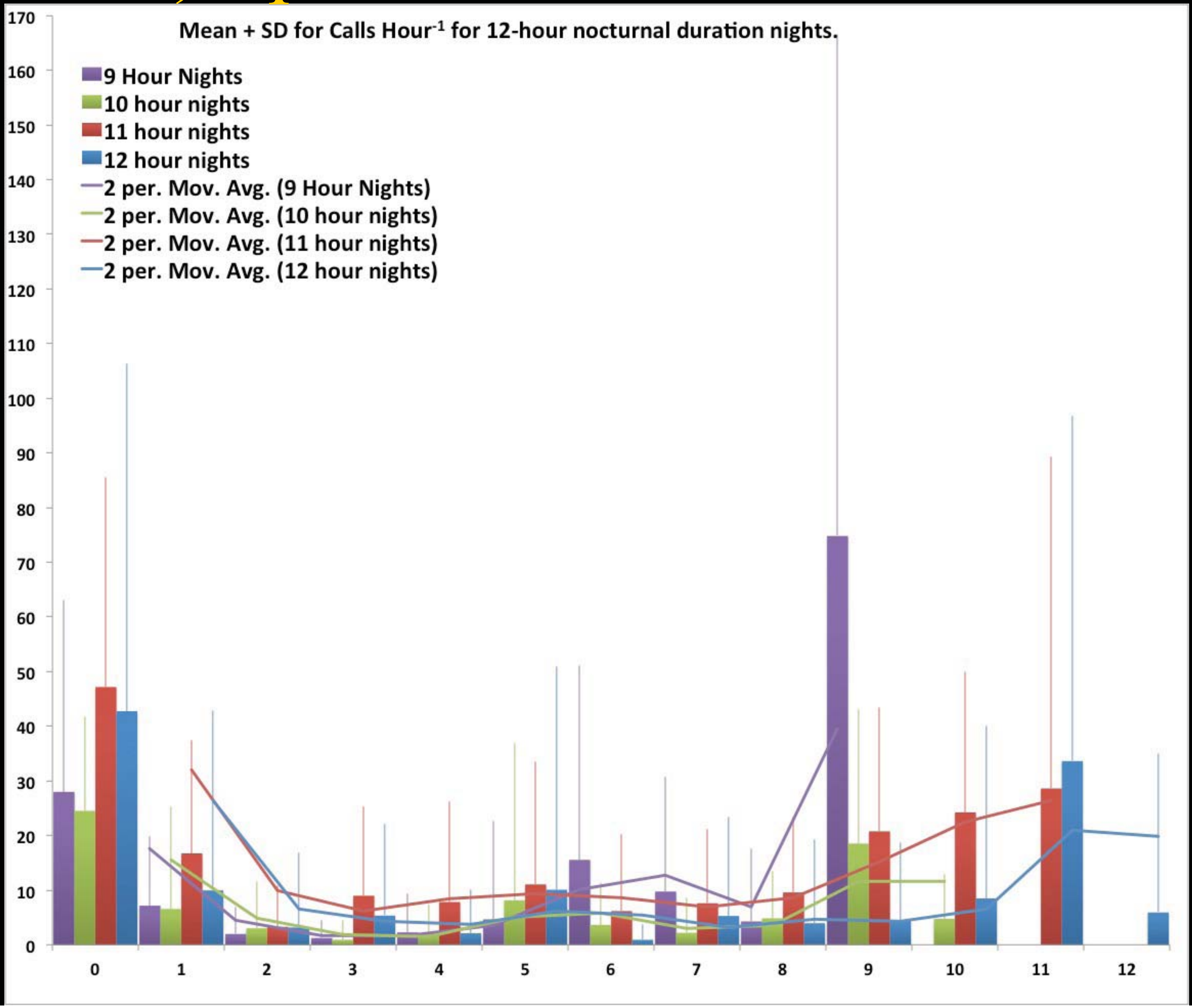
Contact Calls

2 owls vocalizing

11 June 2011 05:11:09

Ft Huachuca AZ

(Mexican) Spotted Owl at Ft. Huachuca



Many species produce flight calls: unique signals given presumably for communication in social, migratory contexts (e.g. in sustained flight).


Dickcissel


Bobolink


Black-billed Cuckoo

White-throated Sparrow


Red-breasted Nuthatch


Swainson’s Thrush


Upland Sandpiper


American Bittern


Caspian Tern


Scarlet Tanager

Rosetta Stone to the Warblers

The Cornell Lab of Ornithology

Ovenbird (*Seiurus aurocapilla*)

Worm-eating Warbler (*Helmitheros vermivorum*)

Louisiana Waterthrush (*Parkesia motacilla*)

Northern Waterthrush (*Parkesia noveboracensis*)

Golden-winged Warbler (*Vermivora chrysoptera*)

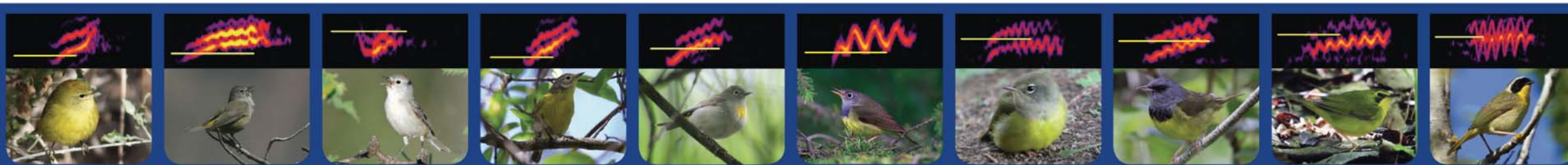
Blue-winged Warbler (*Vermivora cyanoptera*)

Black-and-white Warbler (*Mniotilta varia*)

Prothonotary Warbler (*Protonotaria citrea*)

Swainson's Warbler (*Limnothlypis swainsonii*)

Tennessee Warbler (*Oreothlypis peregrina*)



Orange-crowned Warbler (*Oreothlypis celata*)

Colima Warbler (*Oreothlypis crissalis*)

Lucy's Warbler (*Oreothlypis luciae*)

Nashville Warbler (*Oreothlypis ruficapilla*)

Virginia's Warbler (*Oreothlypis virginiae*)

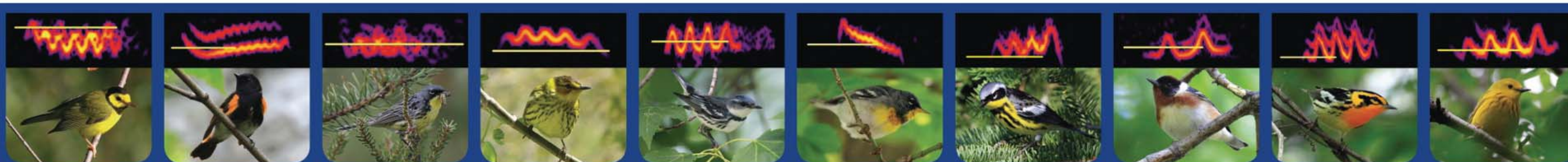
Connecticut Warbler (*Oporornis agilis*)

MacGillivray's Warbler (*Oporornis tolmiei*)

Mourning Warbler (*Oporornis philadelphia*)

Kentucky Warbler (*Oporornis formosus*)

Common Yellowthroat (*Geothlypis trichas*)



Hooded Warbler (*Wilsonia citrina*)

American Redstart (*Setophaga ruticilla*)

Kirtland's Warbler (*Dendroica kirtlandii*)

Cape May Warbler (*Dendroica tigrina*)

Cerulean Warbler (*Dendroica cerulea*)

Northern Parula (*Parula americana*)

Magnolia Warbler (*Dendroica magnolia*)

Bay-breasted Warbler (*Dendroica castanea*)

Blackburnian Warbler (*Dendroica fusca*)

Yellow Warbler (*Dendroica petechia*)

Chestnut-sided Warbler (*Dendroica pensylvanica*)

Blackpoll Warbler (*Dendroica striata*)

Black-throated Blue Warbler (*Dendroica caerulescens*)

Palm Warbler (*Dendroica palmarum*)

Pine Warbler (*Dendroica pinus*)

Yellow-rumped Warbler (*Dendroica coronata*)

Yellow-throated Warbler (*Dendroica dominica*)

Prairie Warbler (*Dendroica discolor*)

Grace's Warbler *Dendroica graciae*

Black-throated Gray Warbler (*Dendroica nigrescens*)

Townsend's Warbler (*Dendroica townsendi*)

Hermit Warbler (*Dendroica occidentalis*)

Golden-cheeked Warbler (*Dendroica chrysoparia*)

Black-throated Green Warbler (*Dendroica virens*)

Canada Warbler (*Wilsonia canadensis*)

Wilson's Warbler (*Wilsonia pusilla*)

Red-faced Warbler (*Cardellina rubrifrons*)

Painted Redstart (*Myioborus pictus*)

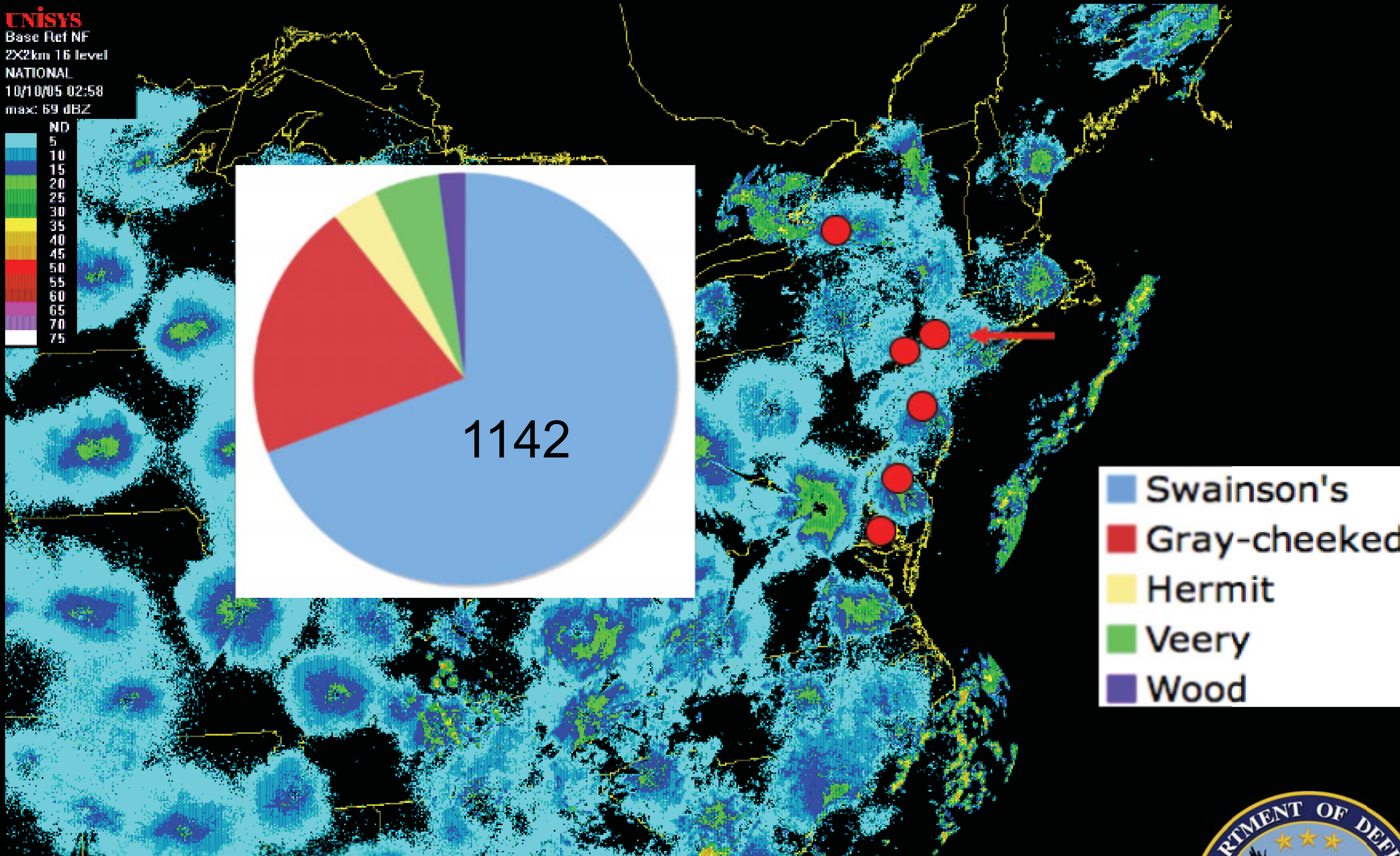
Spectrograms and photographs of 48 species of North American migrant warblers in phylogenetic sequence.

Scale lines = 7 kHz, 50 msec

The Rosetta Stone to the Warblers was compiled by Andrew Farnsworth, Cornell Lab of Ornithology, in collaboration with Michael Lanzone, Cellular Tracking Technologies, Michael O'Brien, and William R. Evans, Oldbird, Inc. Some calls courtesy of Evans, W. R. and O'Brien, M. 2002. Flight calls of migratory birds: eastern North American landbirds. CD-ROM. Oldbird, Inc., Ithaca NY. Taxonomy follows Lovette *et al.* 2010. *Molecular Phylogenetics and Evolution* 57:753–770.

Photos courtesy of Danny Bales, Sarah Beckwith NPS, Roy Brown, Herbert Clark, David Cree, Gerry Dewaghe, Bill Dyer, Laura Erickson, Joan Gellatly, Michael J. Hopiak, Craig Kern, Lois Manowitz, Mike McDowell, David McNicholas, Sharon Richards, Cameron Rognan, Ed Schneider, Van Truan

Thrushes: 9 October, 2005 – West Point USMA



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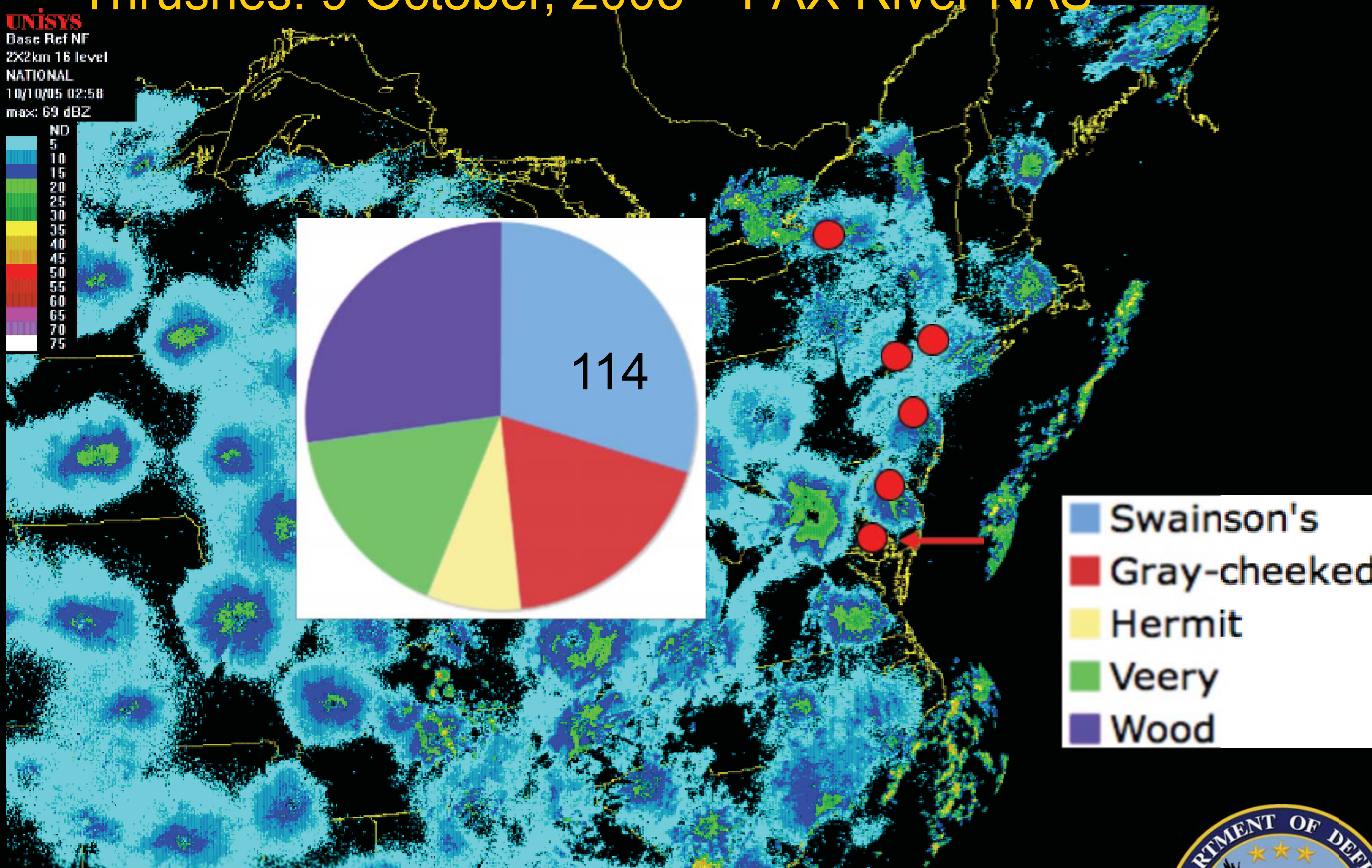
Thrushes: 9 October, 2005 – PAX River NAS



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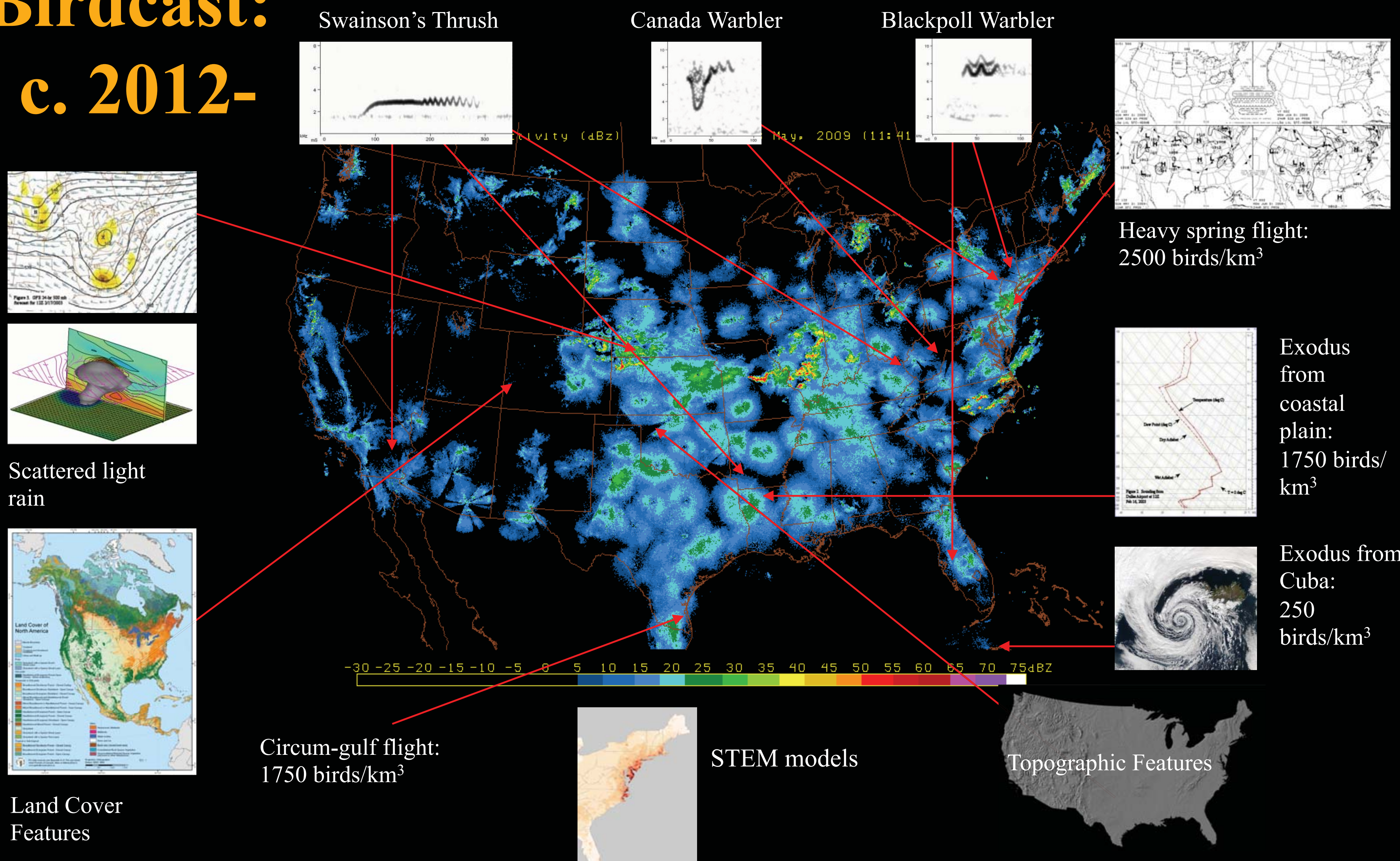
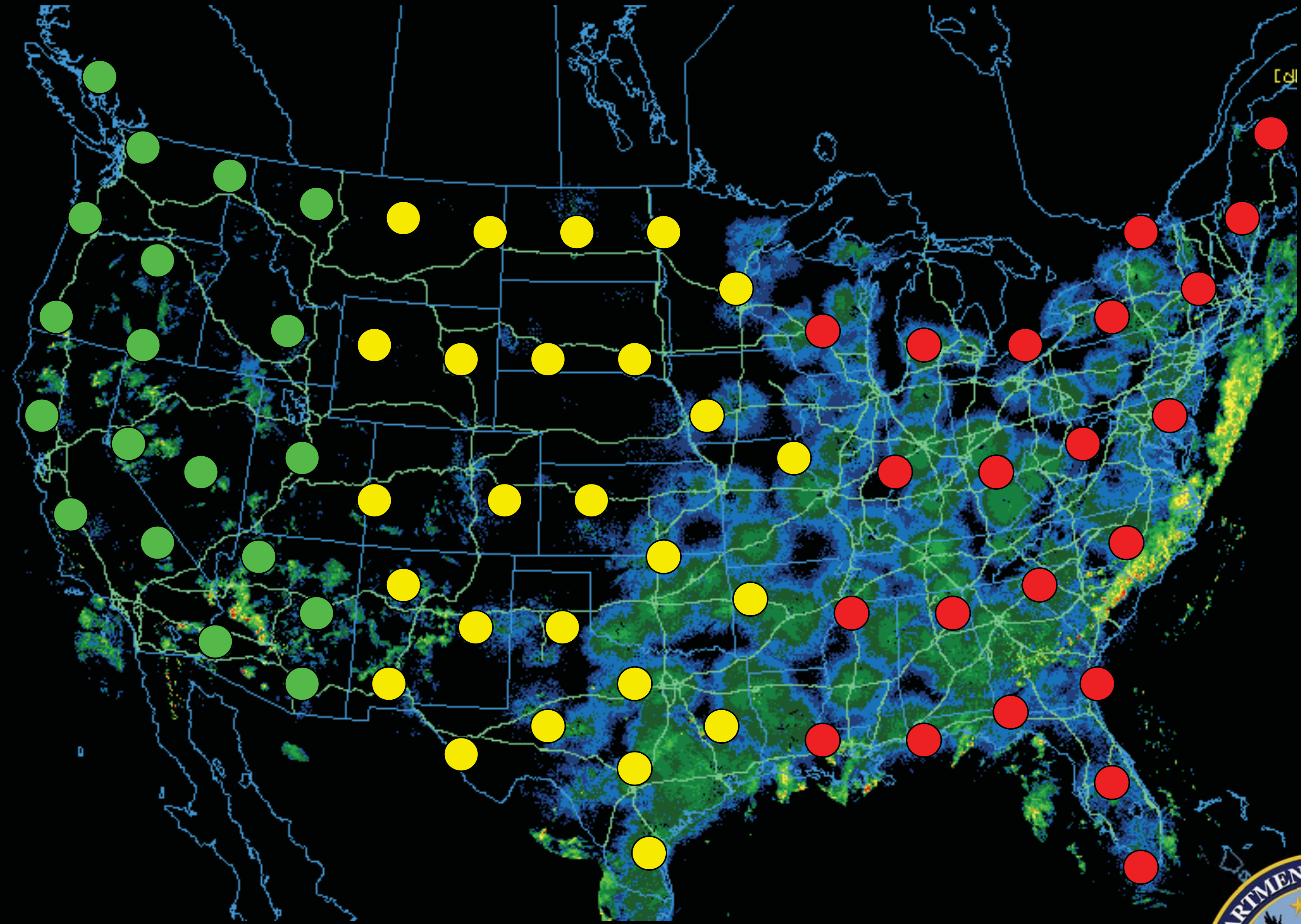
BirdCast: Novel Machine Learning Methods for Understanding Continent-Scale Bird Migration

- real-time predictions: when, where and how far birds migrate
- provide timely information for aviation safety and strike hazards
- aid decisions for placement of wind turbines
- identify nights on which lighting of tall buildings could be reduced
- broad application for basic research
    - to understand behavioral aspects of migration
    - how migration timing and pathways respond to climatic variation
    - whether linkages exist between annual variation in migration timing and subsequent inter-annual changes in population size

Birdcast: c. 2012-



Future plans for conserving migrants: integration



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Acknowledgments and Support

- DoD Legacy Program (05-245, 06-245, 07-245, 10-245); C. Eberly, R. Fischer, J. Hautzenroder, J. Mallory, P. Morales, and a cast of DoD site contacts including K. Rambo, J. Joyce, J. van de Venter, R. Benner, C. Pray, C. Dobony, E. Kershner, C. Leingang, M. Klope, R. Evans, G. Cottle, S. Stone, J. Bolsinger, R. Rainbolt

- Special thanks: W. Evans, M. O'Brien, M. Lanzone; P. Ryan, T. Krein, Bioacoustics Research and Conservation Science Programs, Wisconsin DNR, College of William and Mary, USGS; and field crews from CLO, Powdermill Avian Research Center, Mogollon Rim, Yuma