Bird Species Identification and Population Estimation by Computerized Sound Analysis

Caltrans CFS Number 2045DRI, XB05

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Caltrans

State and federal laws require assessment of project impacts to threatened, endangered, and sensitive species.

- This can accrue high costs because of the specialized personnel required to perform the work.
  - Monitoring of rare species typically demands even greater survey effort to acquire reliable data compared to more common species.
- Long-term monitoring, essential for management, requires consistent and repeatable methodologies.

...a potential solution: acoustic monitoring

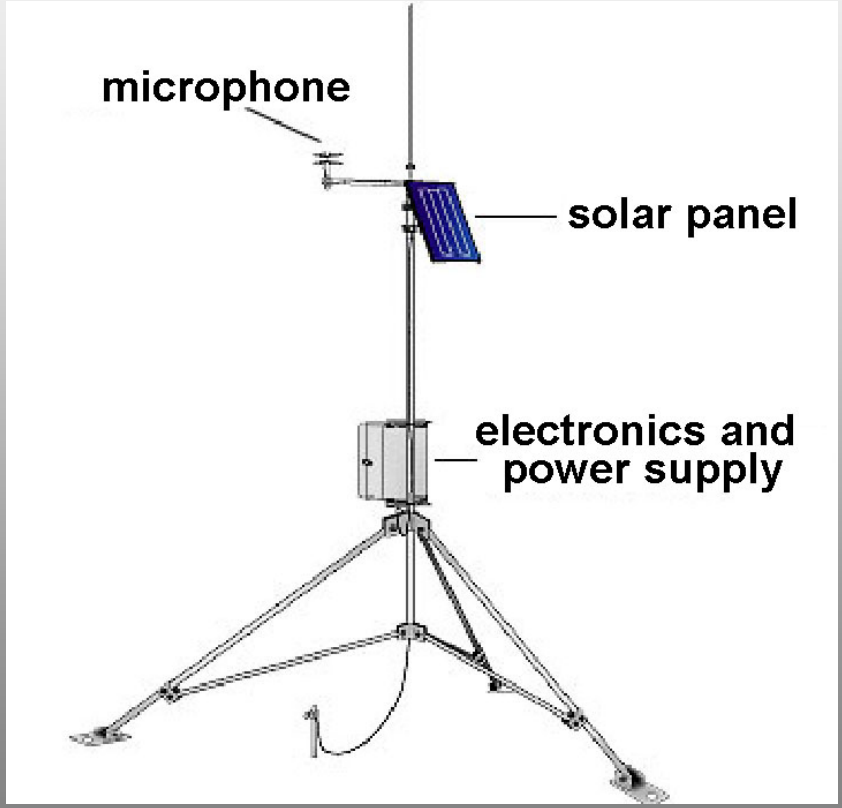
Advantages of acoustic monitoring

- Reduced observer bias
  - more objective
- Can collect data in locations with difficult access
- Contemporaneous data acquisition
  - eliminates temporal bias
- Provide a permanent record of sampling
  - also verifiable

Technical approach:

Develop hardware and software technology to:

- automatically and continuously monitor birds and other acoustic signals (e.g., bats) for weeks or months at a time,
- automatically process field-collected data to confidently assess species presence/absence, population levels, temporal movements, and acoustically-gleaned demographic information.



Automated classification requires a robust library of known species recordings.

Cameron Rognan

Amy Amones

Manual field recording throughout California, 2005–2008.

9,635 recordings of 172 species

State or Fed. listed

- Greater sandhill crane
- Western yellow-billed cuckoo
- Elf owl
- Northern spotted owl
- Great gray owl
- Gila woodpecker
- Gilded northern flicker
- Willow flycatcher
- Southwestern willow flycatcher
- Bank swallow
- Coastal California gnatcatcher
- San Clemente loggerhead shrike
- Arizona Bell's vireo
- Least Bell's vireo
- Inyo California towhee
- San Clemente sage sparrow
- Belding's savannah sparrow

Species of concern

- Bells Sage Sparrow
- California Spotted Owl
- Coopers Hawk
- Le Contes Thrasher
- Loggerhead Shrike
- Long-billed Curlew
- Osprey
- Purple Martin
- Sharp-shinned Hawk
- Summer Tanager
- Yellow Warbler
- Yellow-breasted Chat
- California Gull
- California Horned Lark
- Vaux's Swift
- Eagle Mountain Scrub Jay
- Black-capped Chickadee
- Saltmarsh Common Yellowthroat
- Suisun Song Sparrow
- San Pablo Song Sparrow
- Almaeda Song Sparrow

Recording Hardware

Audio Recorders

Initially, mp3-based recorders seemed the favored recording medium

- **Fast**
- **Available and inexpensive**
  - **Consumer electronics**
- **Large storage capacity**

- **Field units powered by two 12 volt, 12 Ah batteries**
- **Charge maintained by 20 watt solar panel**

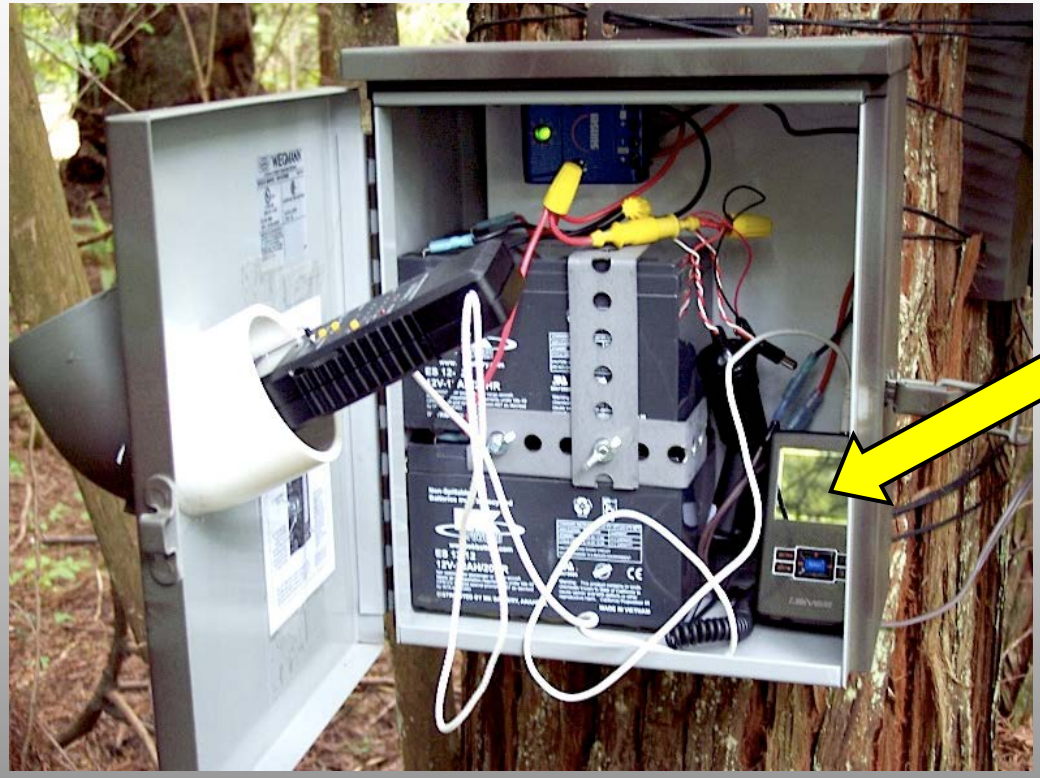
Audio Recorders

RIAA forced mp3-based recorders off the market

- Fast
- ~~Available and inexpensive~~
  - ~~Consumer electronics~~
- Large storage capacity

mp3 licensing arrangement changed to assess decoding

Interim recorders for trial field studies



Open source firmware programmable units

- Fast
- Available and inexpensive
  - Consumer electronics
- Large storage capacity
- wav or wavpak audio formats

Recorder– final product: FR125

Specifications:

Interface:

- One (1) RS-232 console connector
- Two (2) USB 2.0 (high-speed) host ports
- Two (2) Ethernet connectors
- One (1) Stereo Line-In audio jack
- One (1) Stereo headphone audio jack

Compatible Accessories:

- AR125 Utrasonic Receiver
- USB Thumb-drives
- USB Compact Flash writer
- USB enabled external hard drives

Power Requirements : +5V @ 5.0W (typ.)

- ***Programmable***
  - **Daily recording period**
  - **File parameters**
  - **Recording logic, e.g., trigger logic**
  - ***Accommodates bird microphones and ultrasonic bat detector hardware***

- **open storage capacity- *uses any USB device***
  - ***week–months***
- **wav or wavpak audio formats**
- **Open source standards to maintain availability**

Microphones

- Mono mini preamplified microphone
- Frequency sensitivity 20-16000 Hz
- Signal to noise ratio 58 dB
- Horn arrangement
  - Increased microphone gain
  - Rejects low frequency noise
  - Horizontally omnidirectional

Microphone performance

Species (*p*=0.996)

Willow flycatcher: 116m

Wilson's warbler: 115m

Lincoln's sparrow: 117m

Orientation (*p*=0.800)

Facing: 118m

Between: 114m

Vegetation (*p*=0.089)

Sparse: 136m

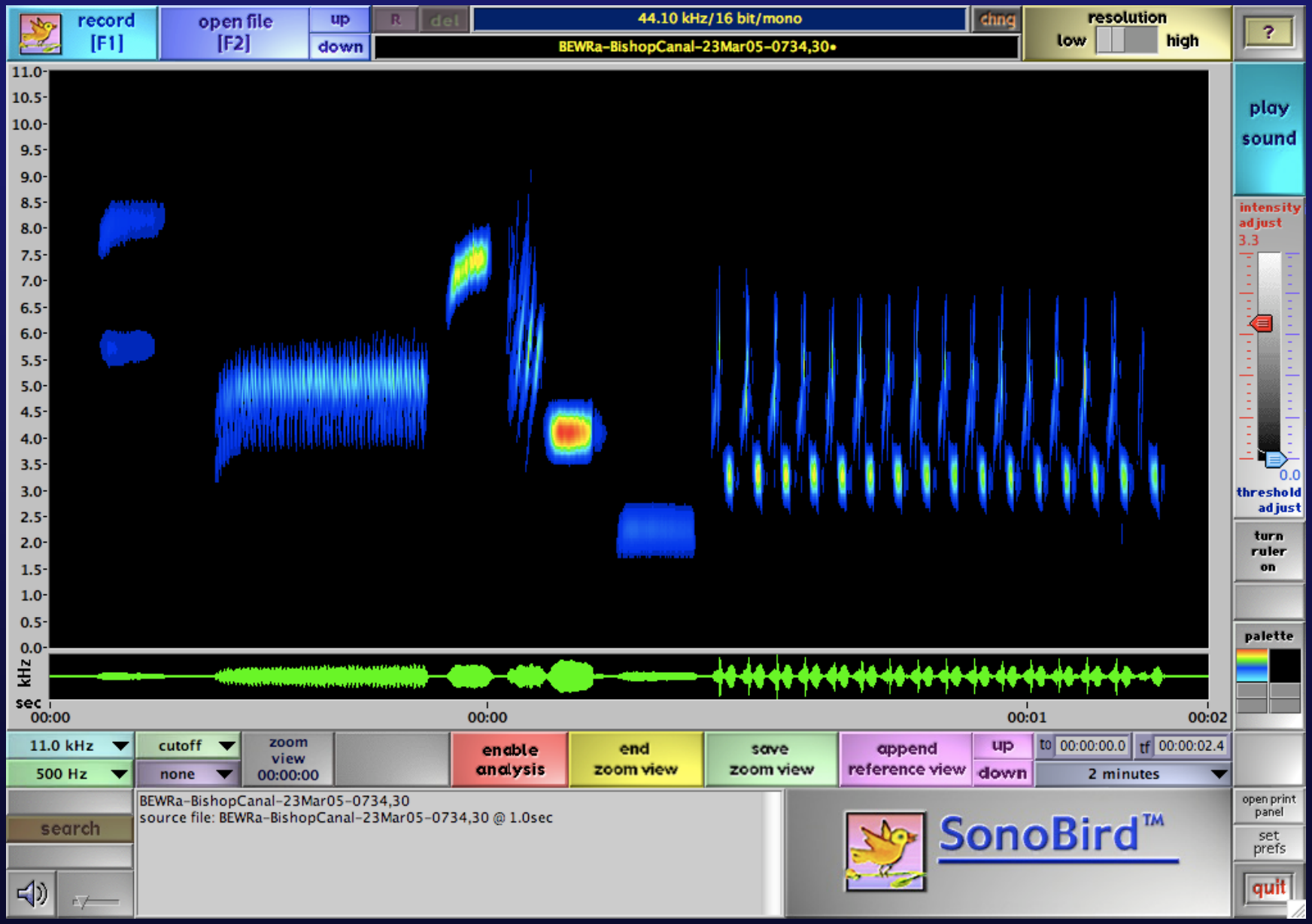
Moderate: 109m

Dense: 104m

No significant difference in performance compared with human listener.

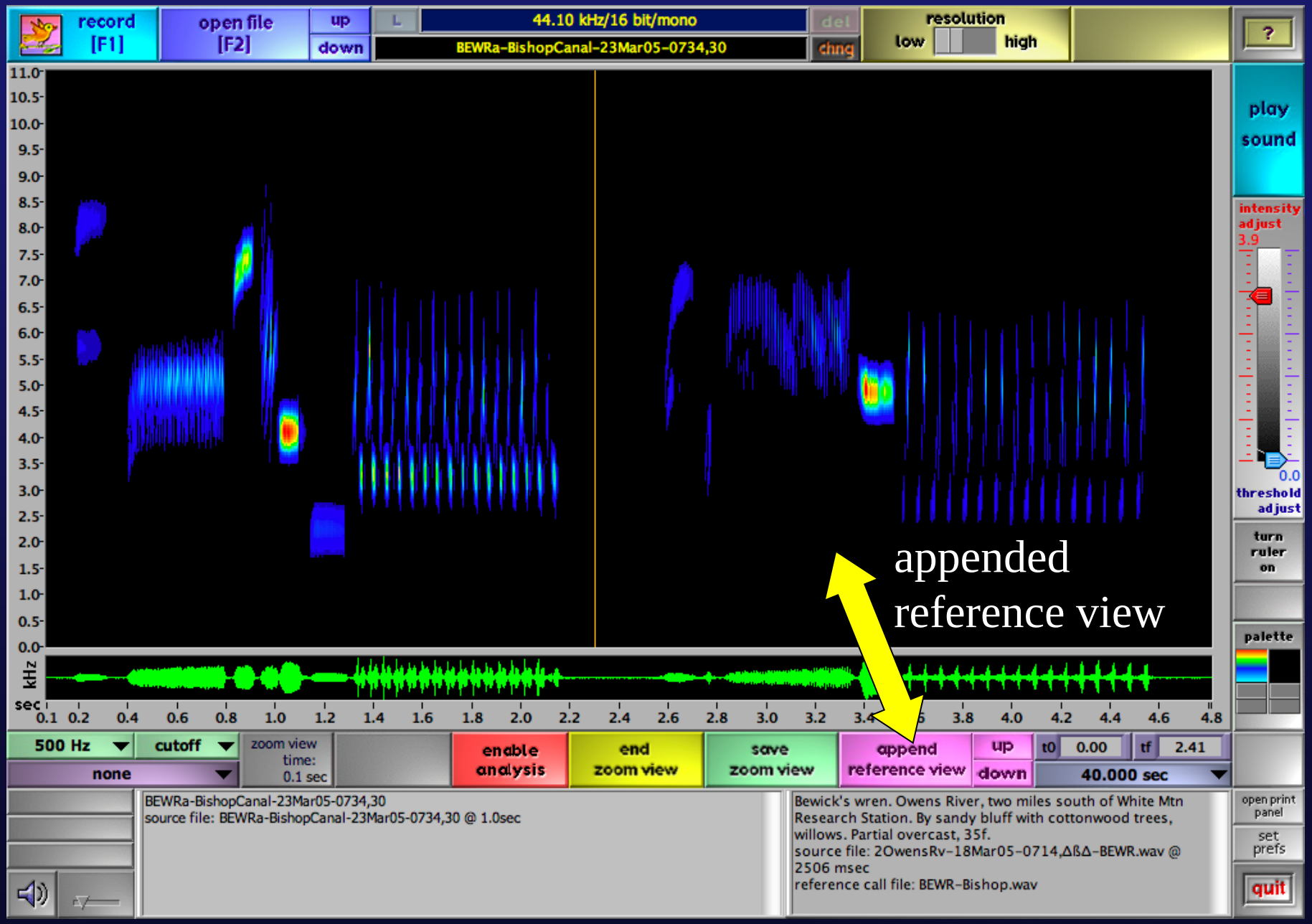
Automated recording station deployed

Automated processing & identification of bird calls



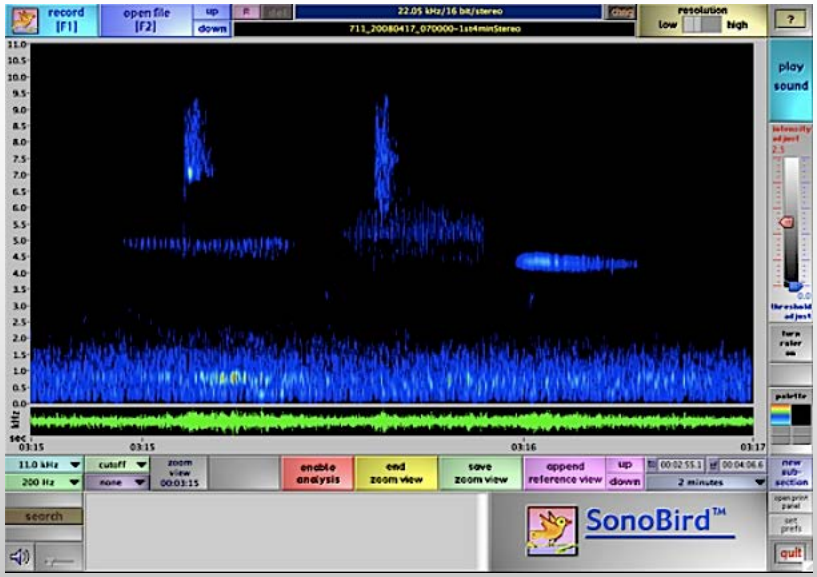
Sonogram of a Bewick's wren song.

Automated processing & identification of bird calls



Automated processing & recognition of bird songs

1. Filter noise (to separate out signal frequencies)
   - ***Especially important near construction and transportation corridors***
2. Two-stage search for candidate signals
   - *Rapid* coarse search followed by high resolution search
3. Pattern matching
   - Time-frequency domain
   - Time-amplitude domain
   - Frequency-power domain



unfiltered

filtered

Overview of SonoBird search software

click search button to initiate a search

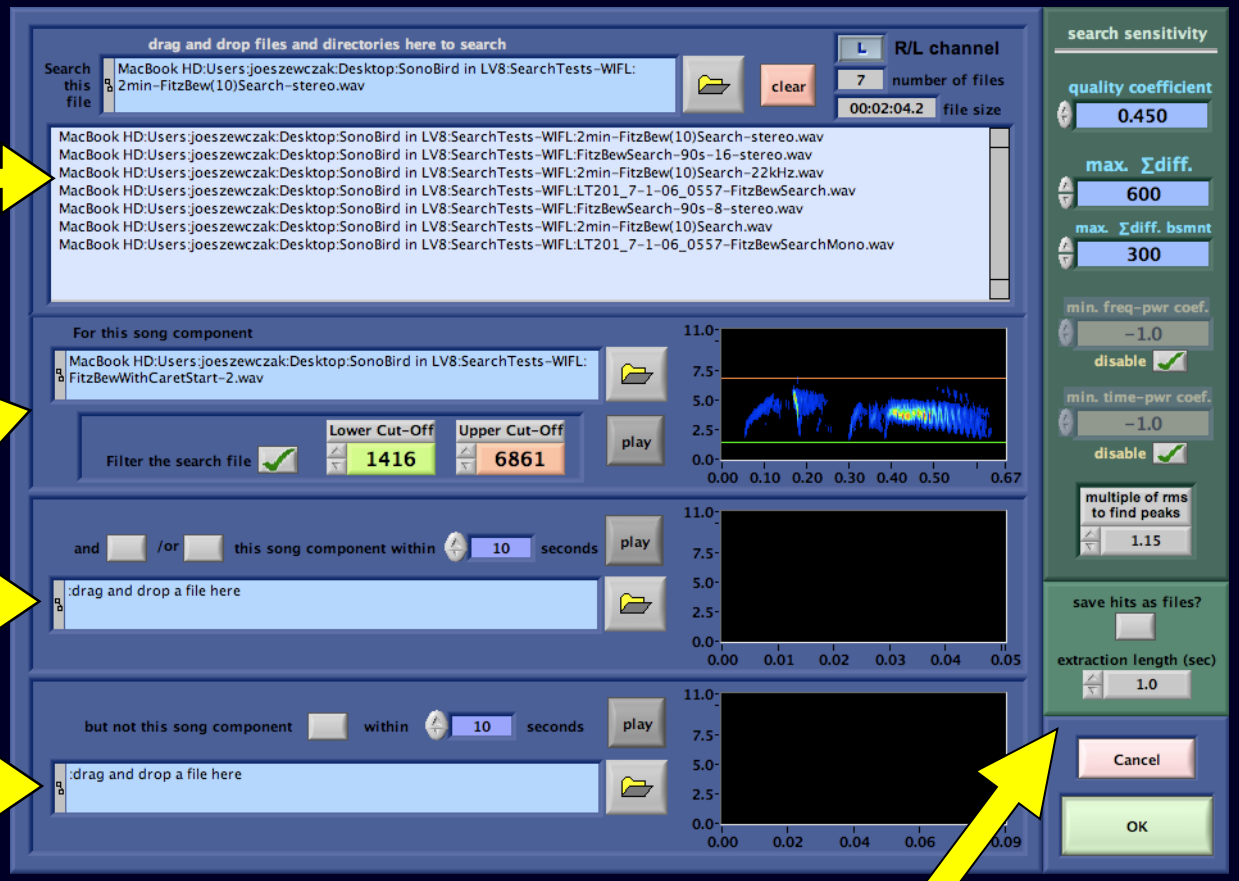
Search preference panel

Batch processing of file directories

Search terms

and

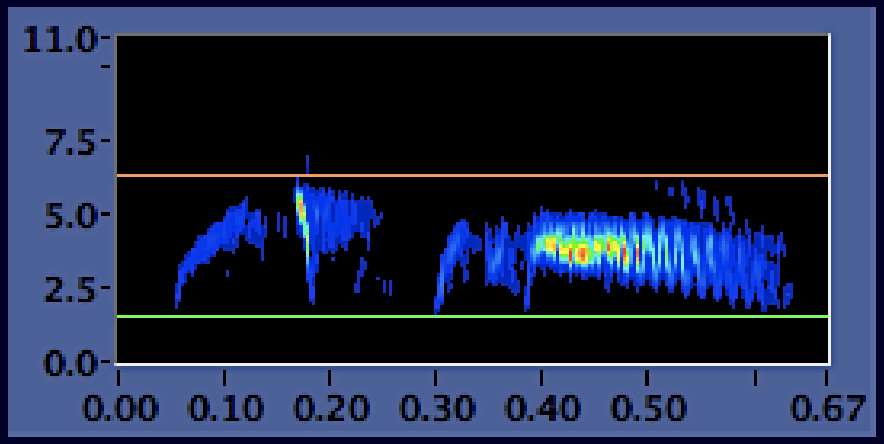
or

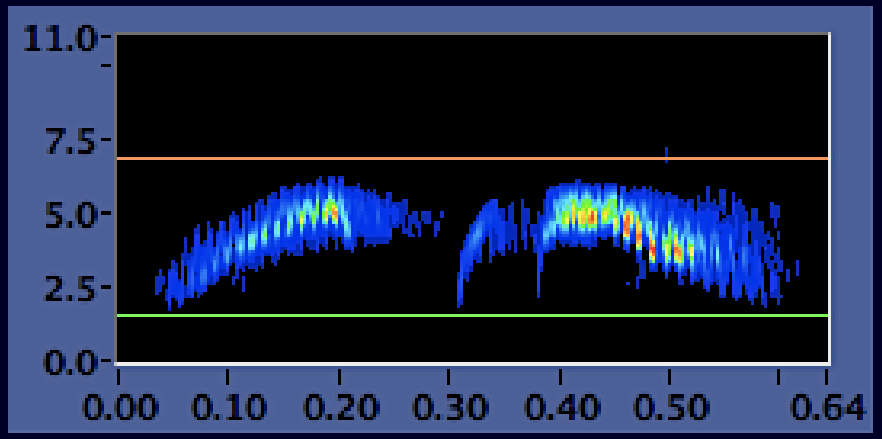


Search sensitivity settings

- Best search terms: representative sections or notes of target songs or calls.
  - from library
  - saved sections from search recordings
- Search success increases with the distinctiveness (and consistency) of the search term
- Specificity of search controllable by pref settings.

Example search terms



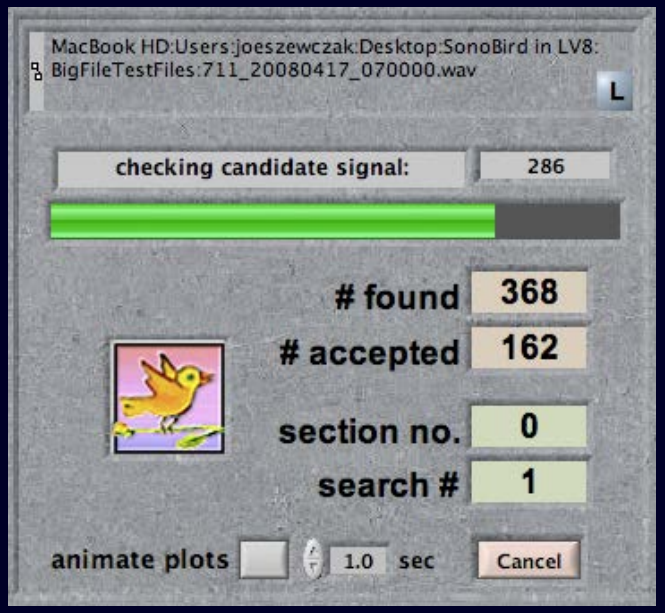


Willow flycatcher
fitzbews

Rapid search algorithm

- Initial coarse search for candidate signals based on frequency band-pass filtering and zero-cross processing.
- Followed by higher resolution acceptance/rejection of candidate signals, i.e., “hits.”

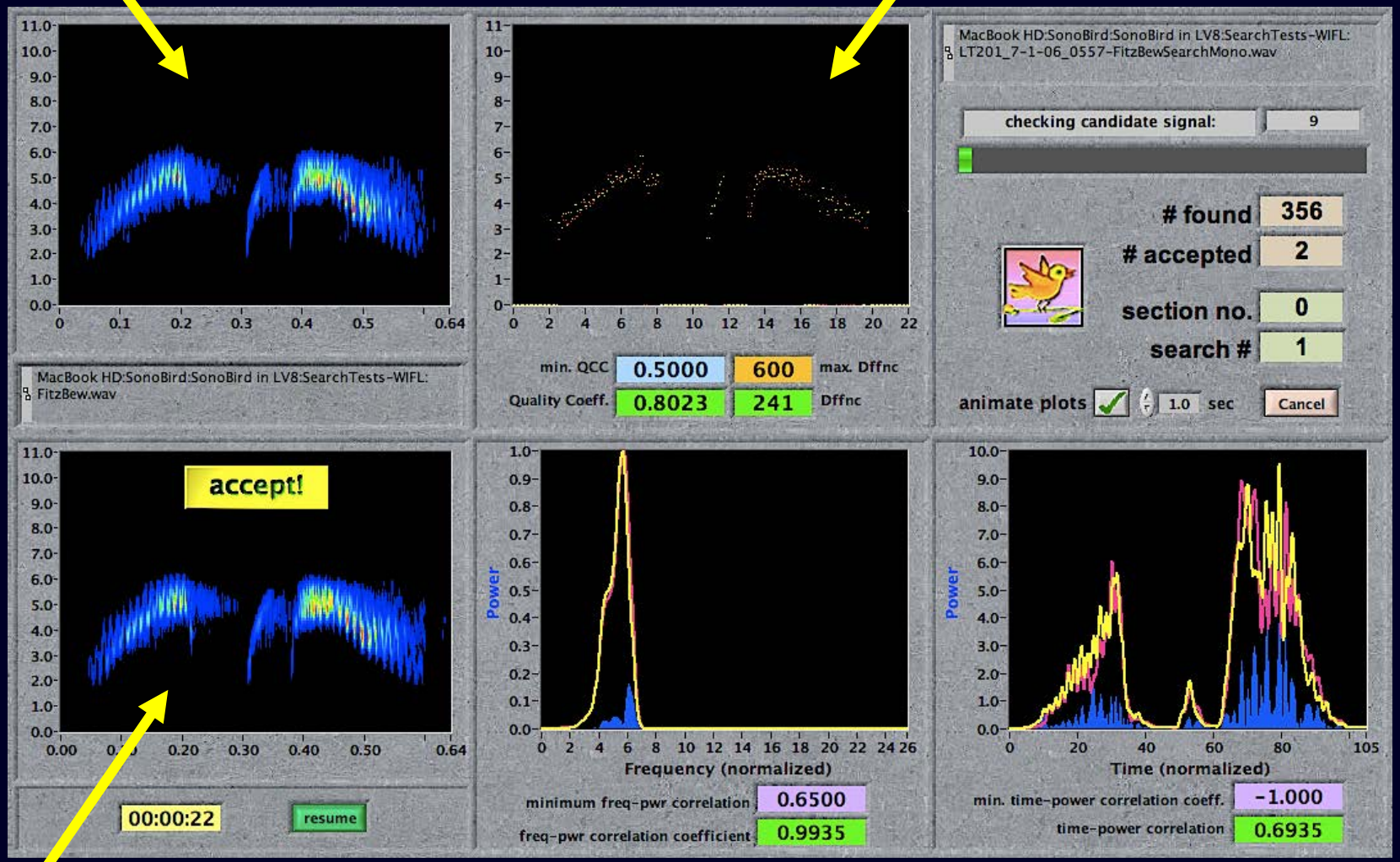
Search and find target signals in a one hour recording in about a minute.



Search progress panel

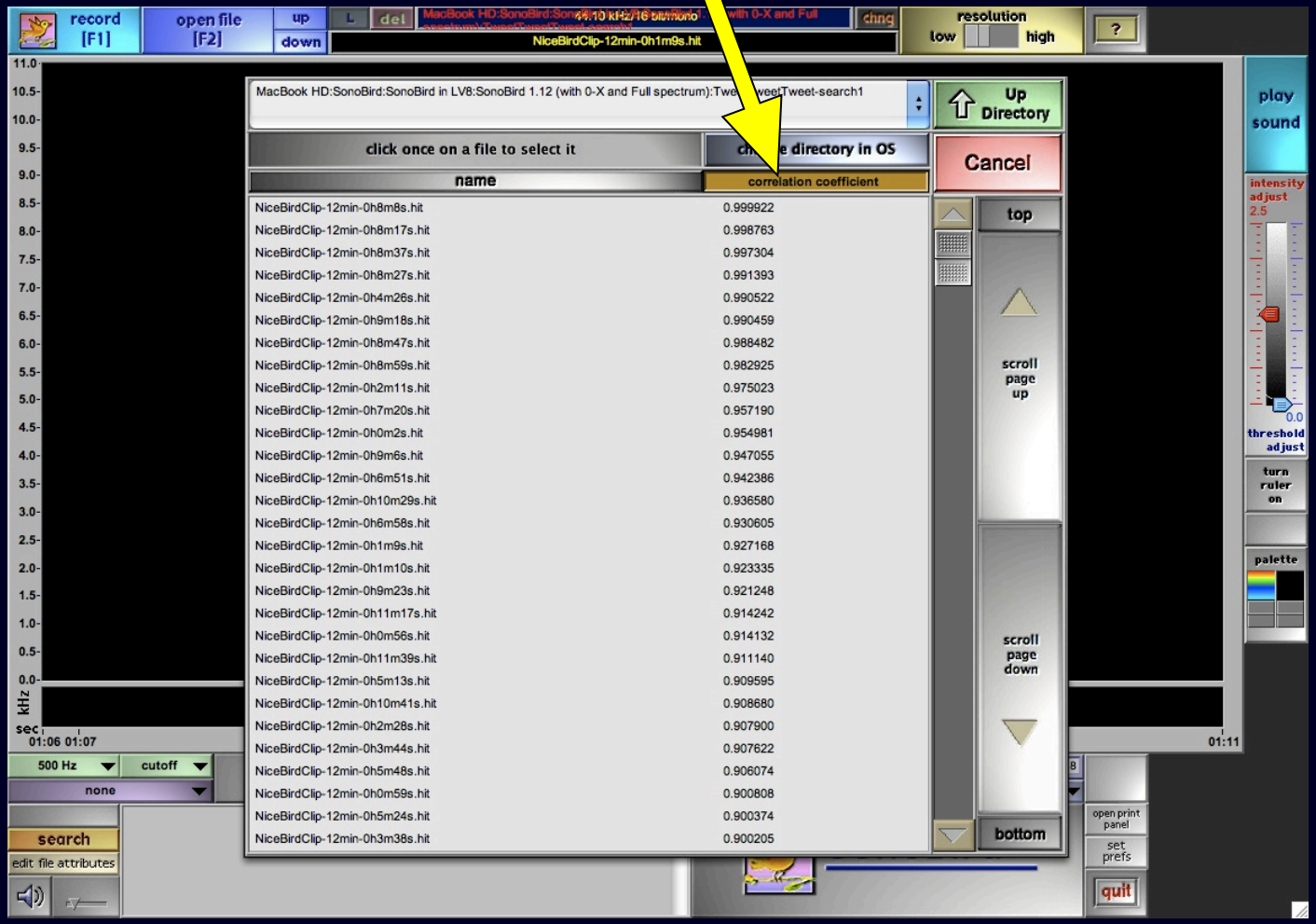
search term

time-frequency comparison plot



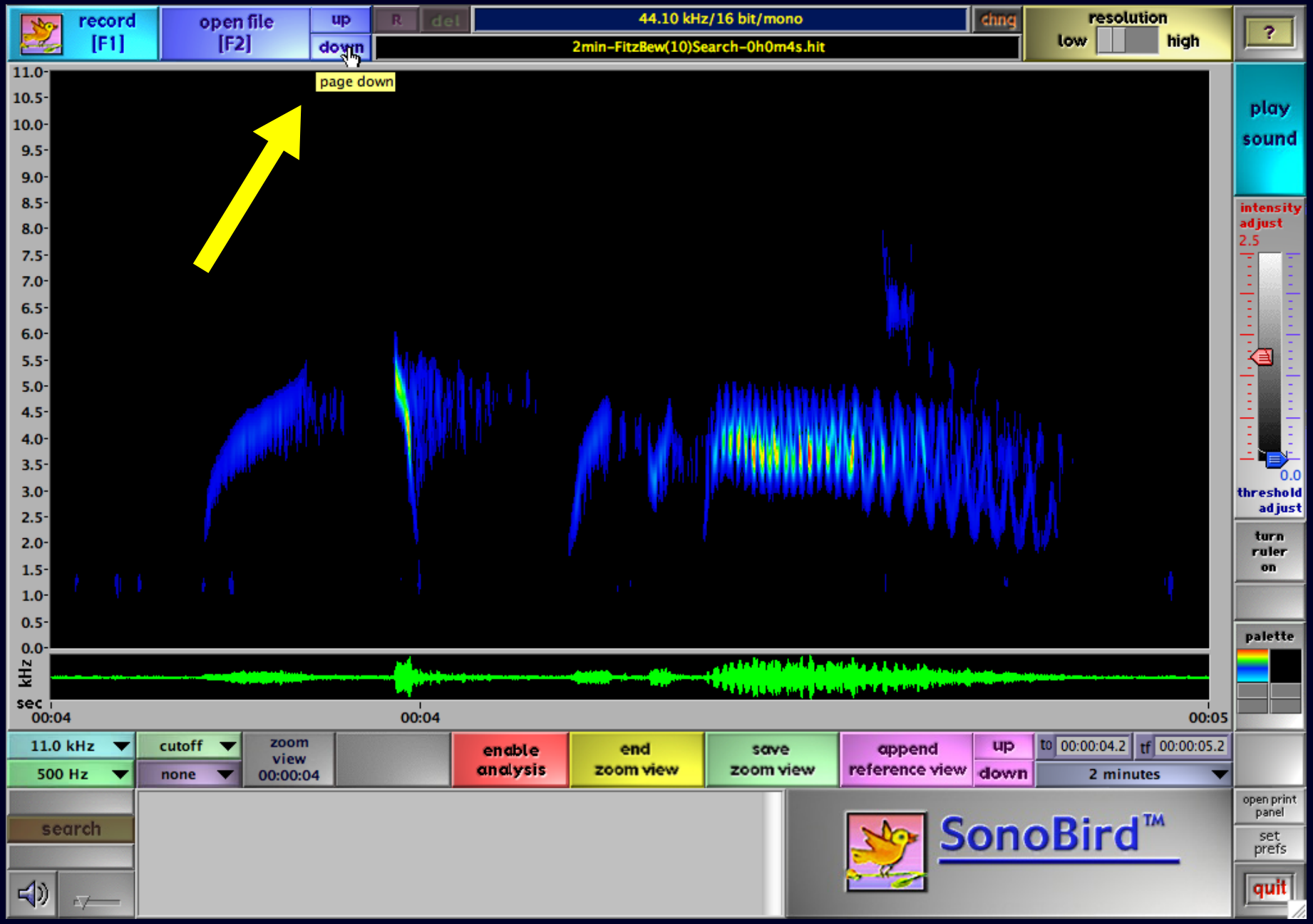
candidate signal

By default, .hit files open sorted by correlation ranking with search component.



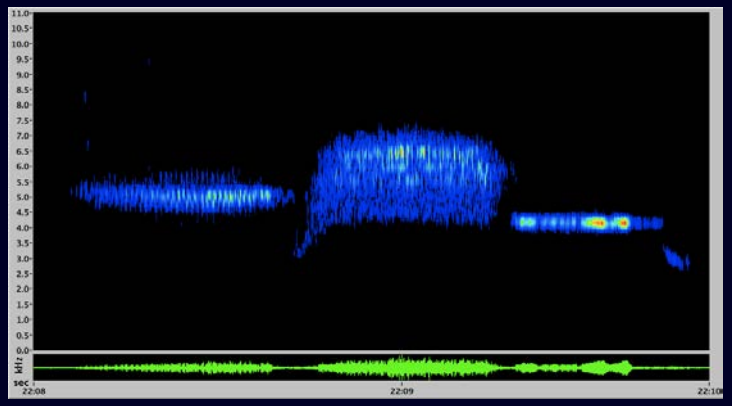
This facilitates presence/absence surveys by minimizing the potential results to inspect for confirmation.

Simply scroll through search results to inspect results.

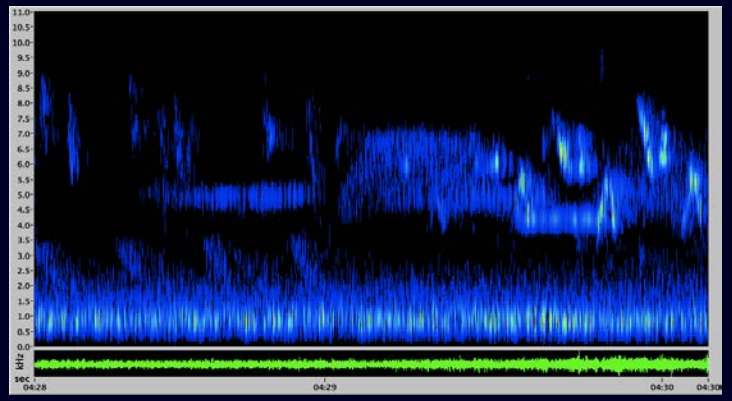


Search performance

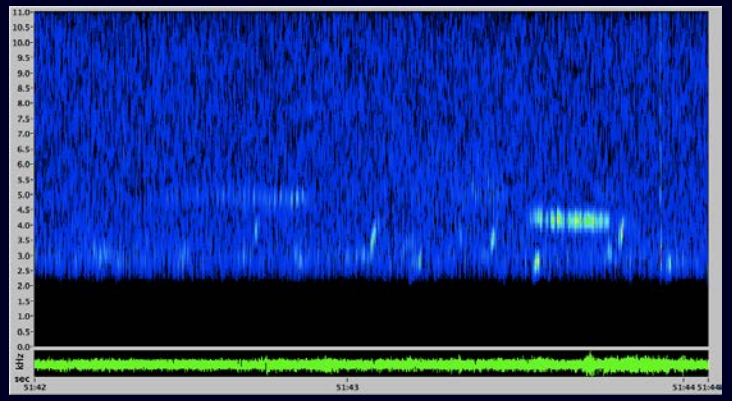
Clean golden-cheeked warbler call found in a four hour recording.



Call found in noise from same recording.

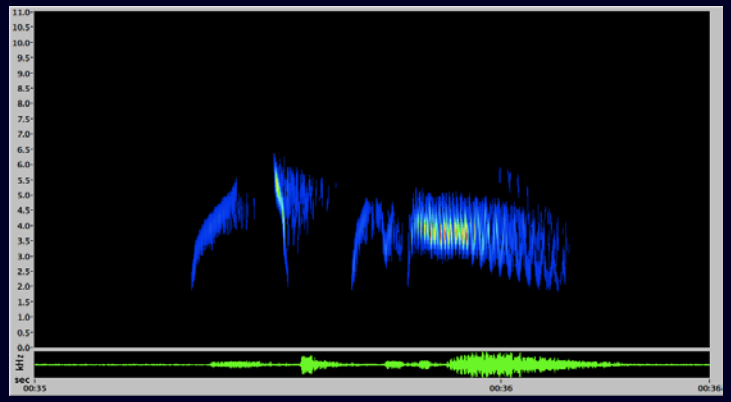


Faint call found in noise from same recording.

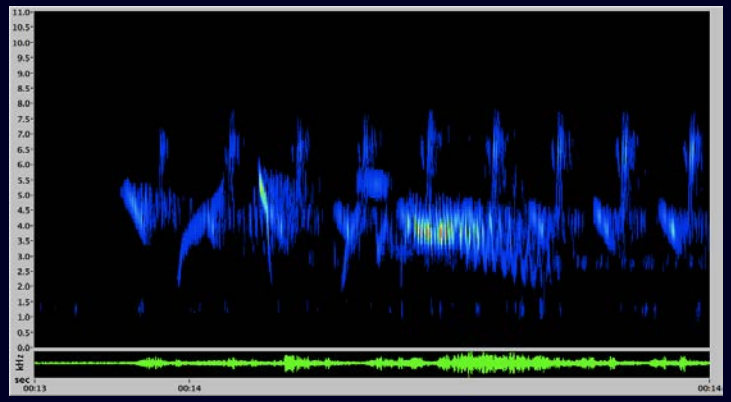


Search performance

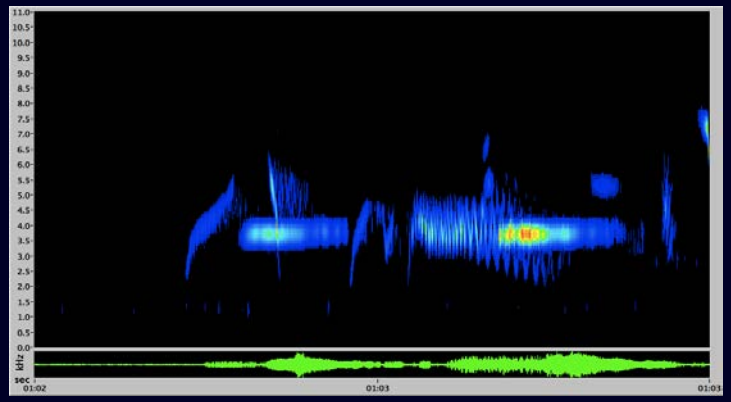
Clean willow flycatcher call found in a four hour recording.



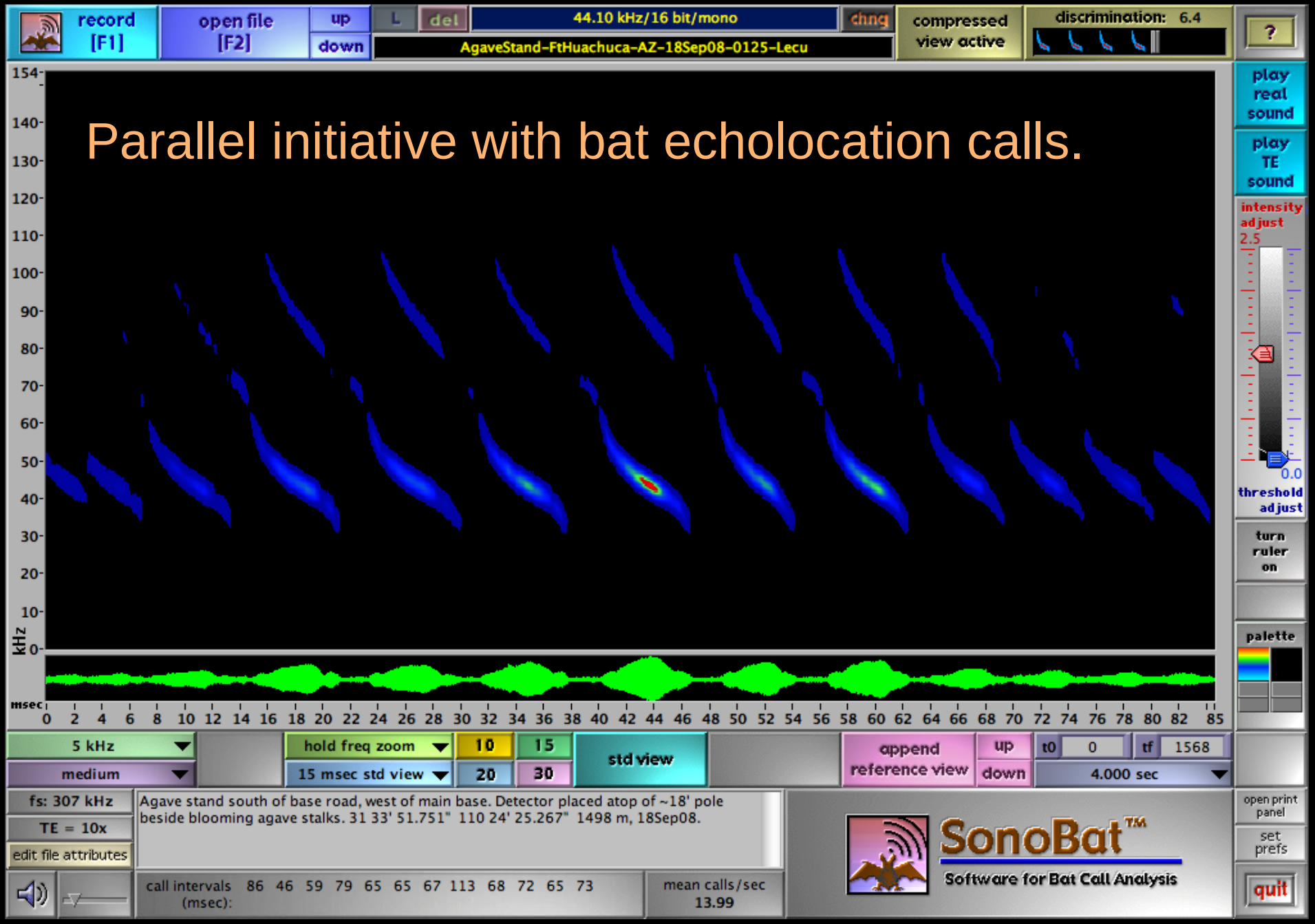
Call found amidst competing song from same recording.

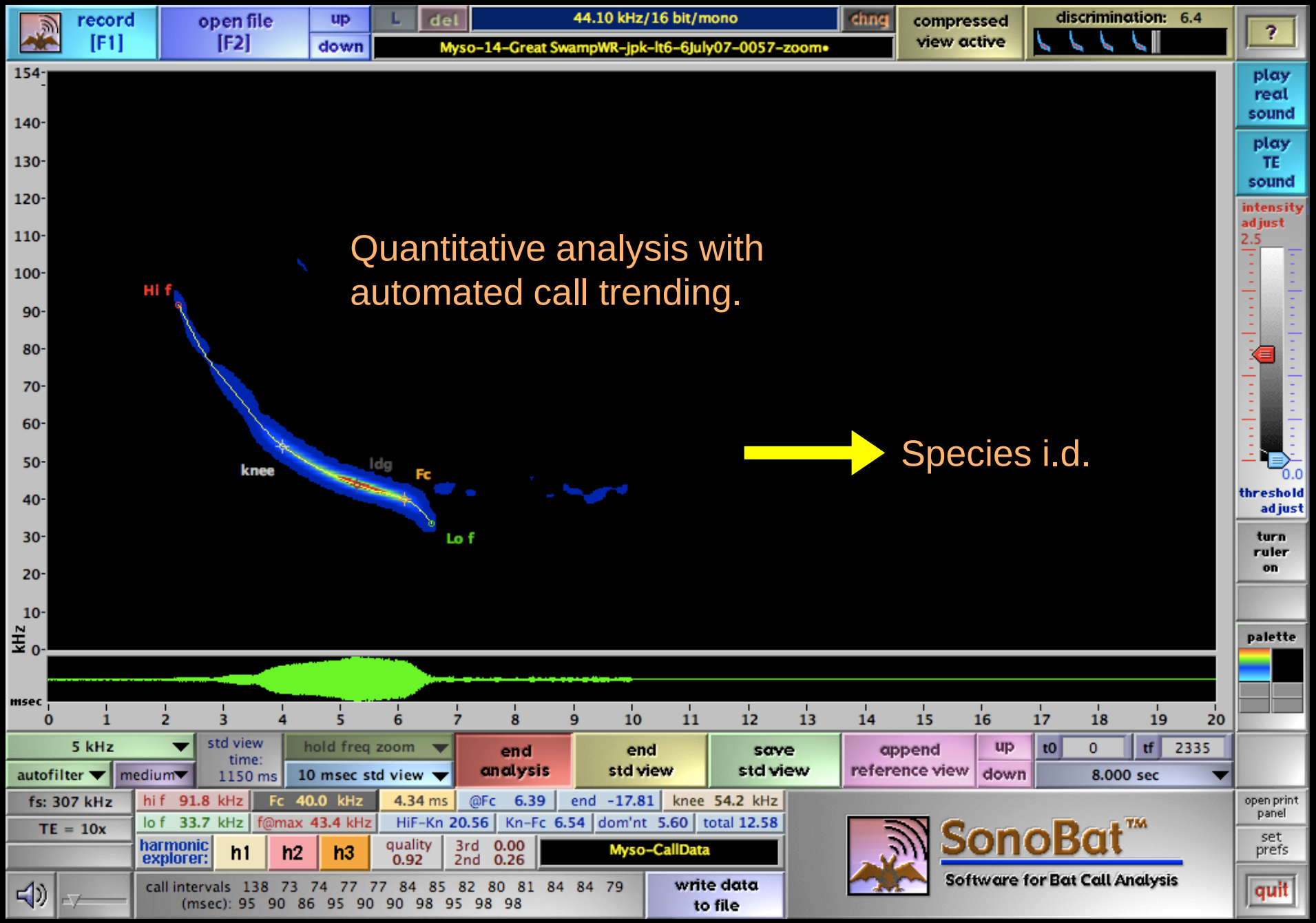


Call found amidst competing song from same recording.



Parallel initiative with bat echolocation calls.

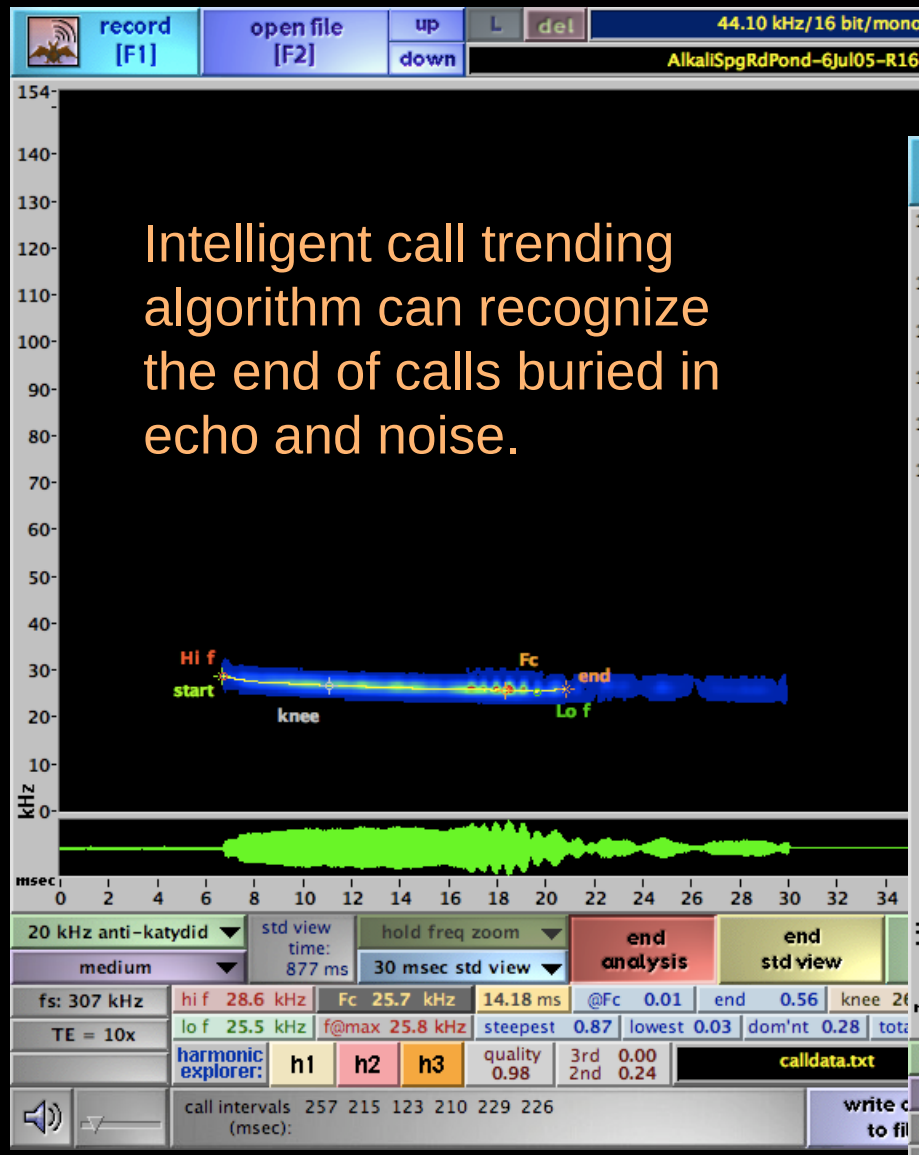


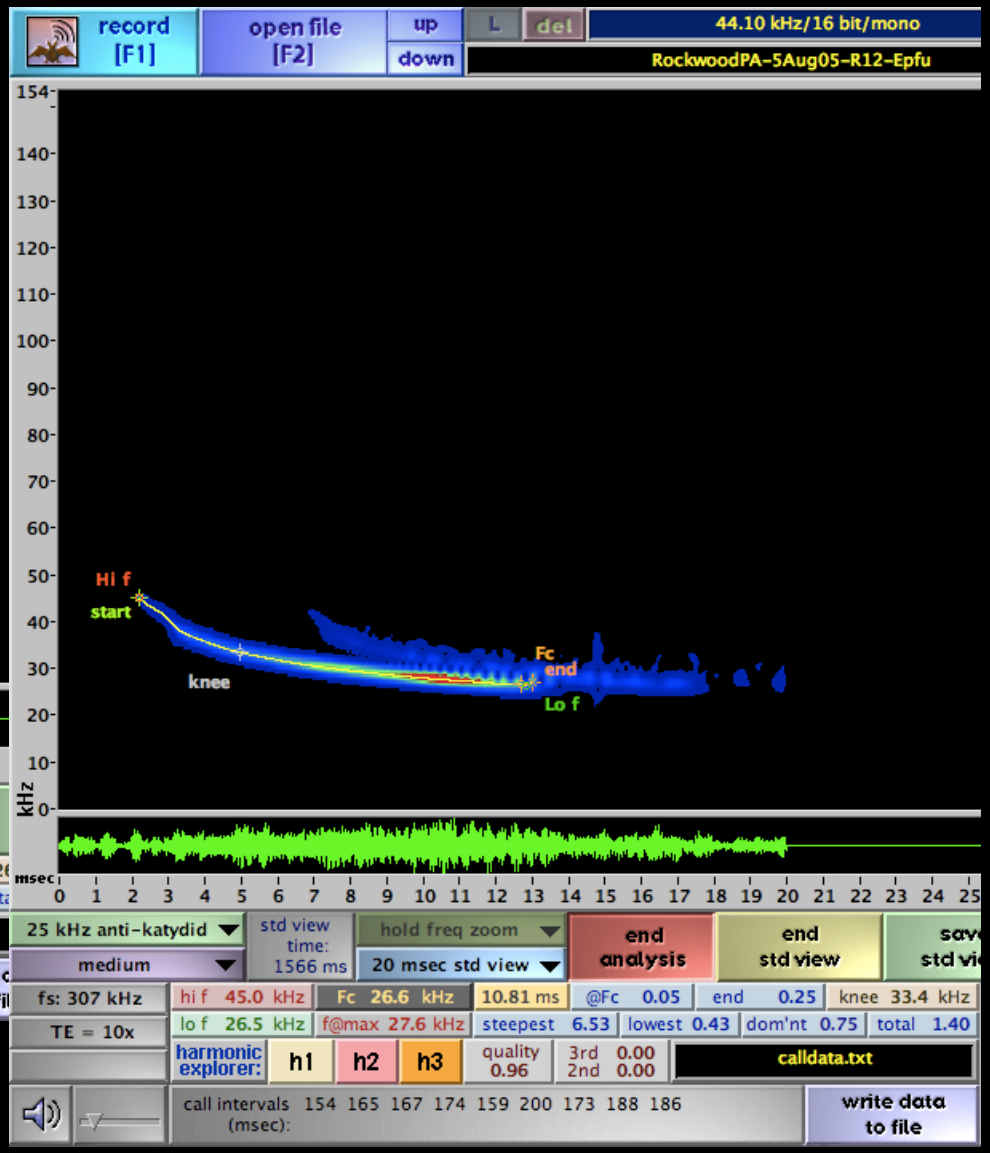


Quantitative analysis with automated call trending.

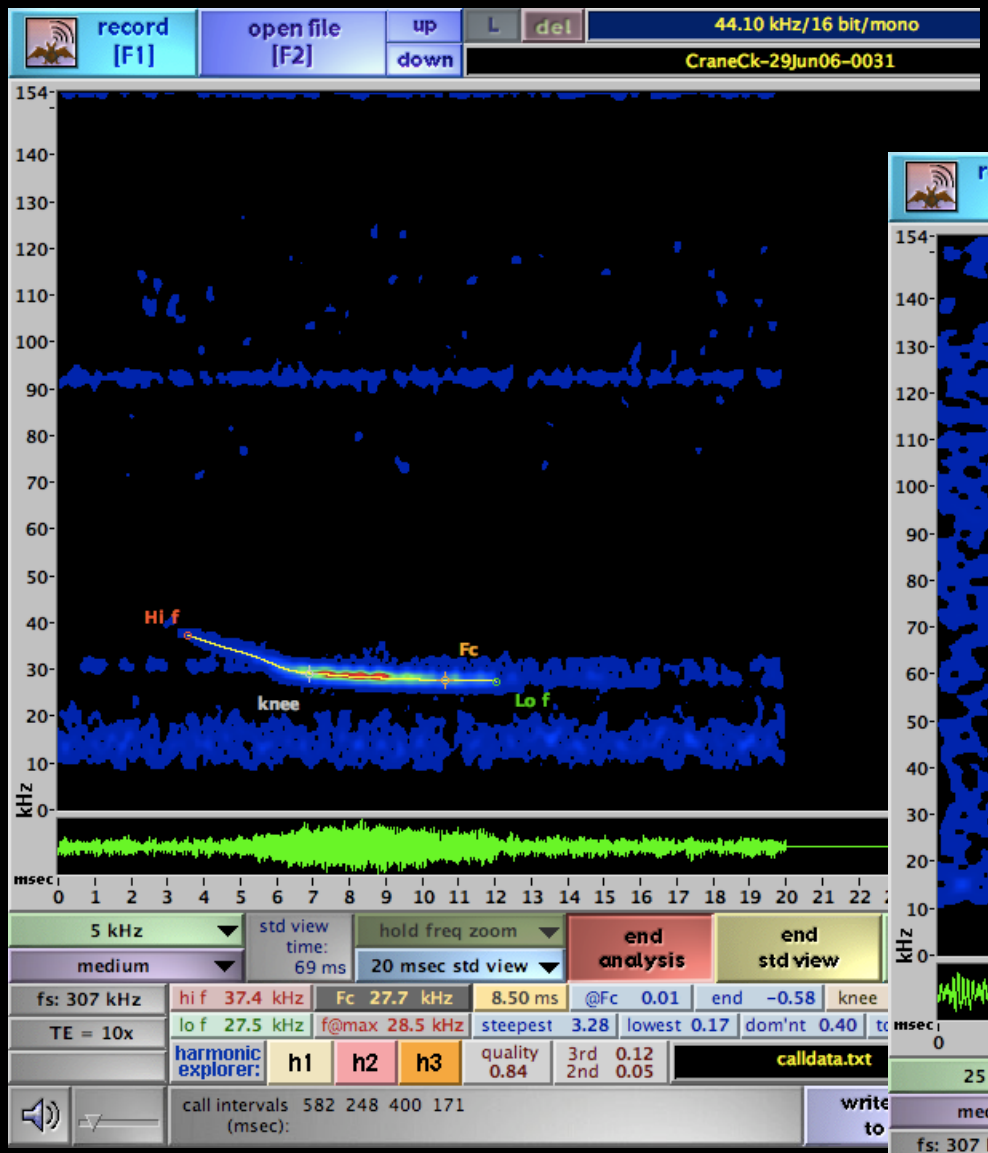
Species i.d.

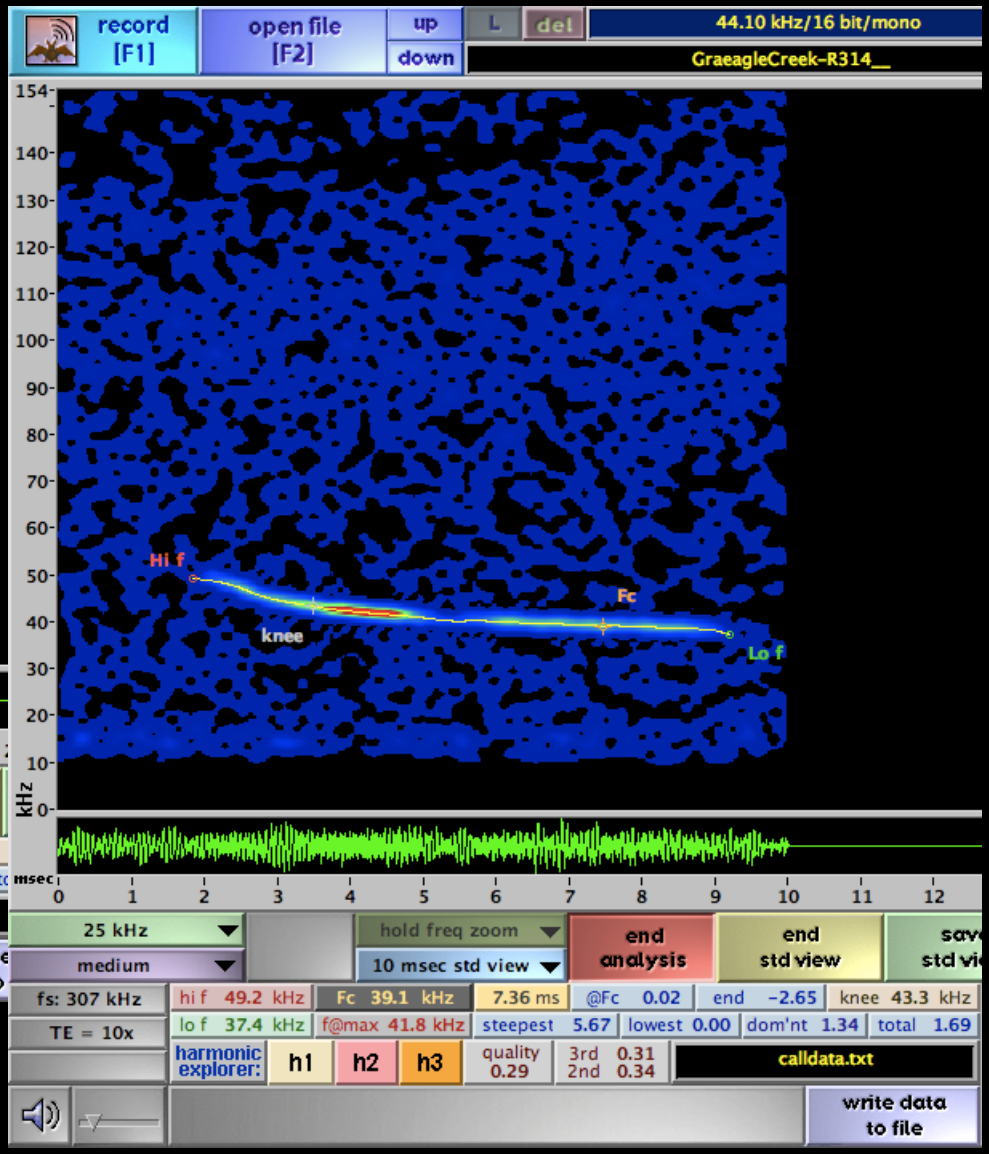
Intelligent call trending algorithm can recognize the end of calls buried in echo and noise.



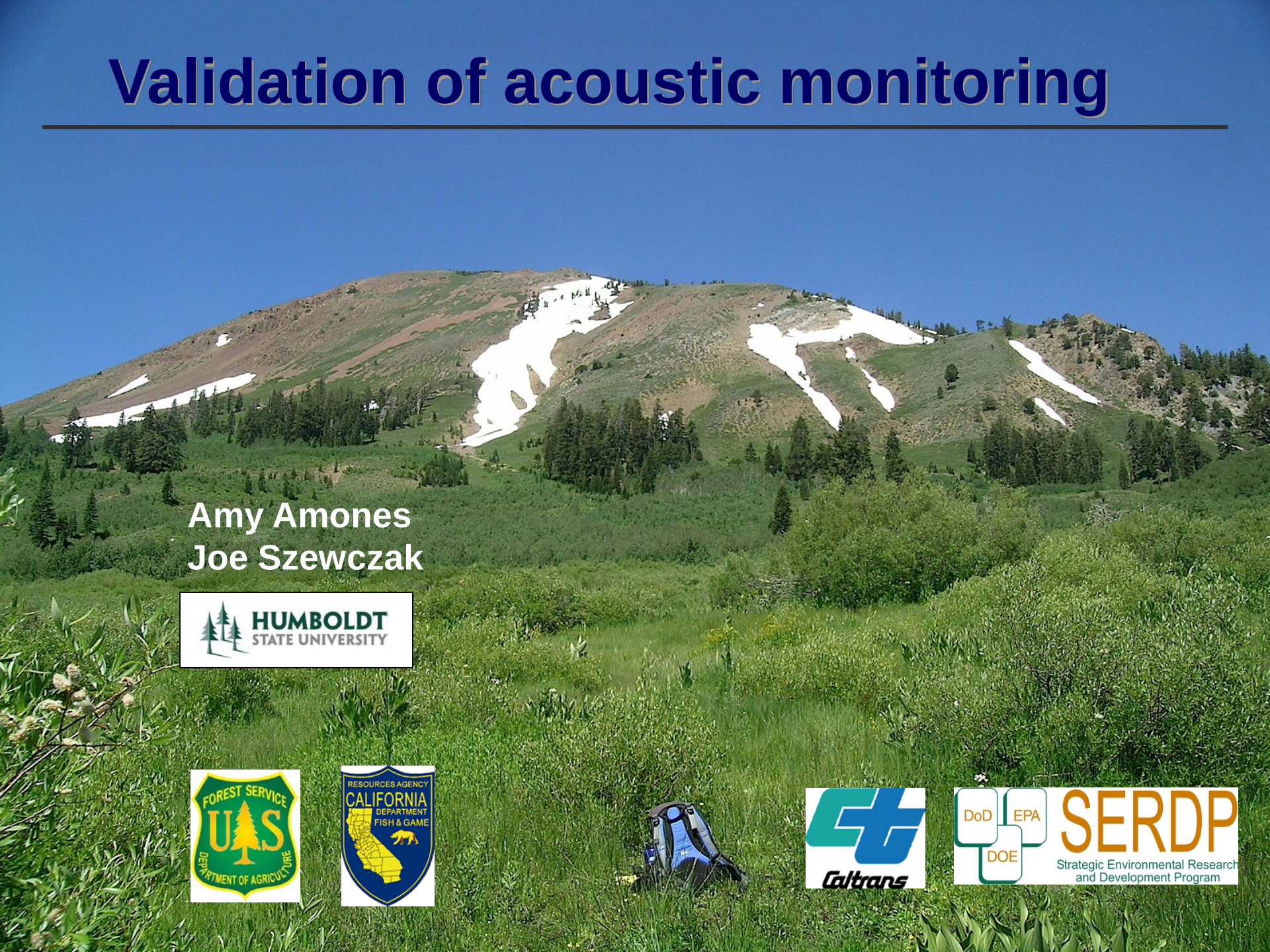


SonoBat can also successfully establish trends through noise and from low power signals.





Validation of acoustic monitoring

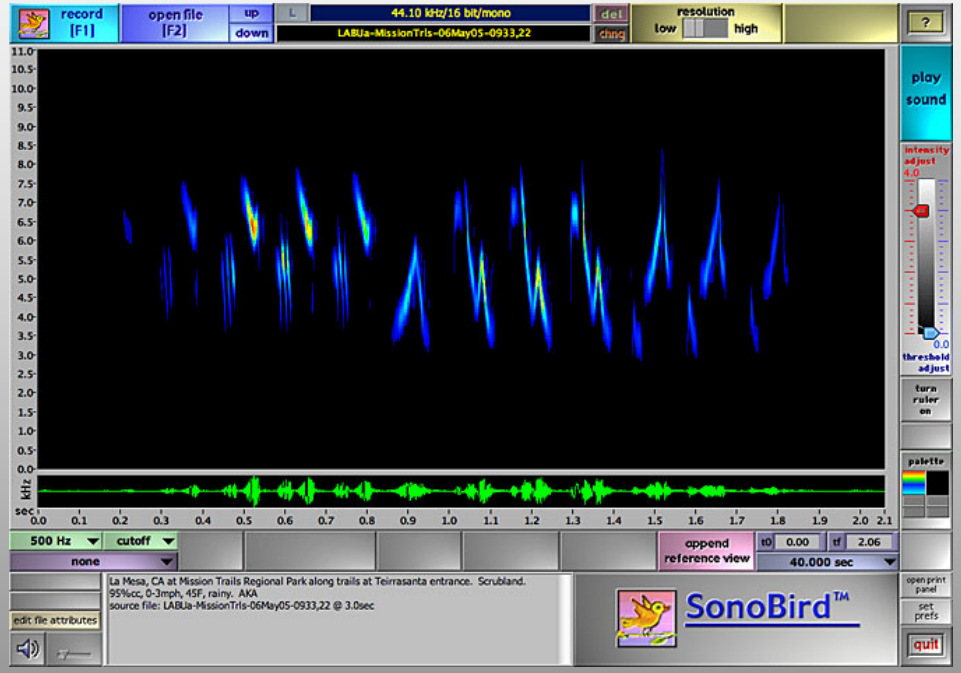


Amy Amones
Joe Szewczak

Validation of methodology

- Calibration and verification of avian acoustic monitoring methodology in collaboration with CA Dept of Fish and Game and US Forest Service.

- 2006, 2007: simultaneous deployment of field recording units at meadows undergoing standard point count surveys.



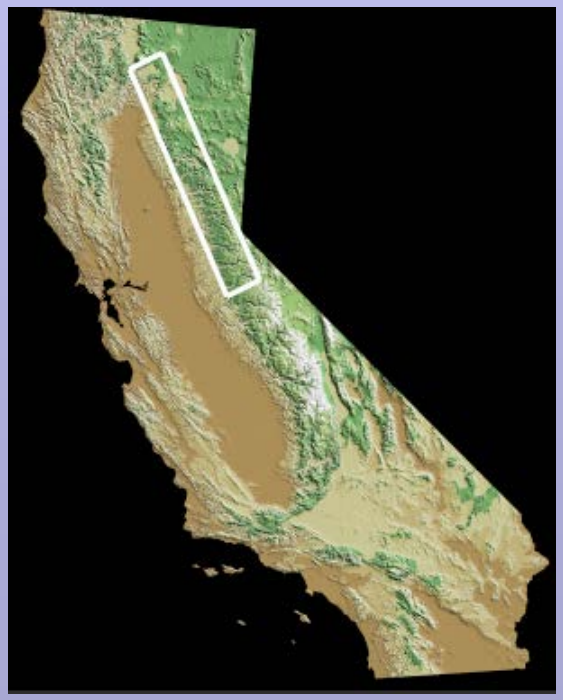
Lazuli bunting, La Mesa, CA, May 2005.

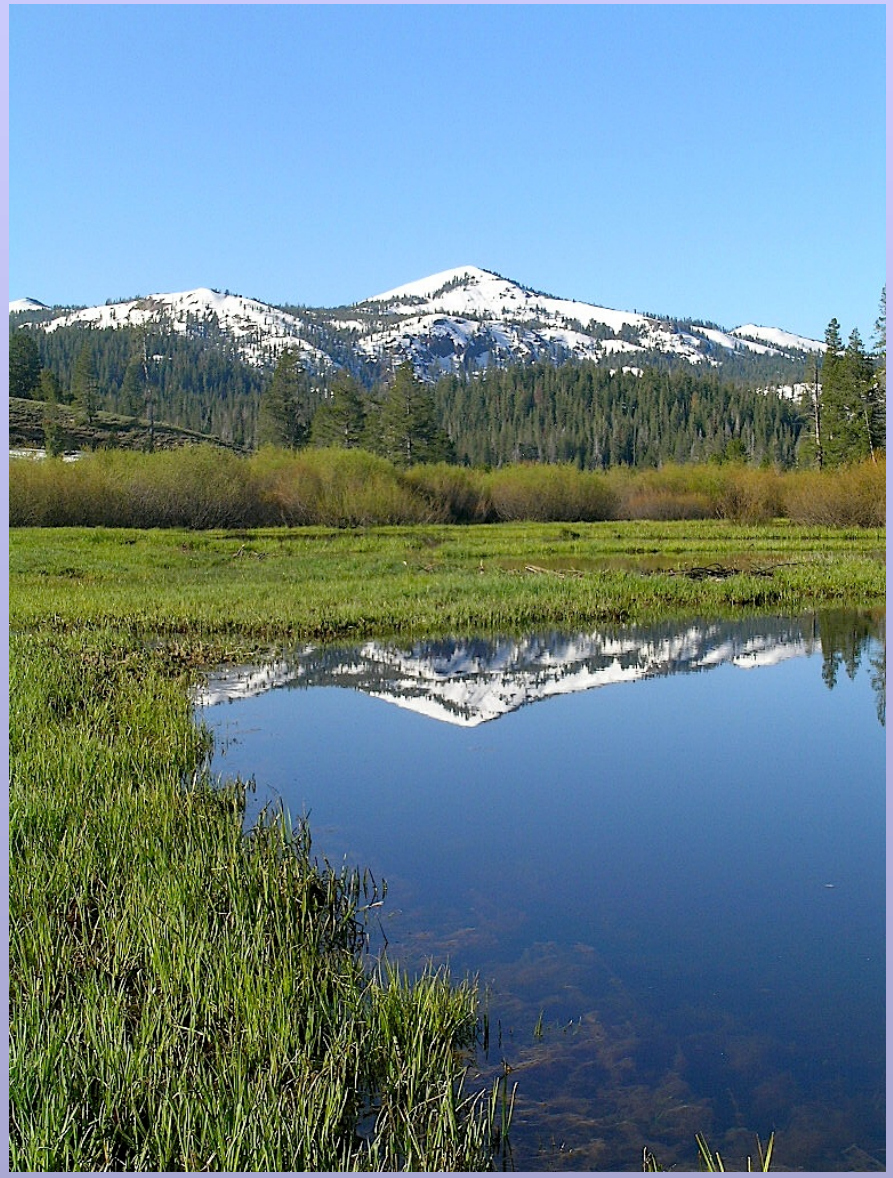
Objectives

1. Compare audio recorders with point count surveys for estimating bird species richness
   - How capable and comparable are audio recorders for species detection?
2. Determine the recording time needed to assess species richness; presence/absence

Study Sites

Thirteen wet montane meadows in the north-central Sierra Nevada and southern Cascade Range.





Methods

Point Counts

- 112 point locations
- 15 minutes per count
- Surveyed every 7-10 days

Audio Recorders

- 48 point locations
- Recorded 5am-10am
- Surveyed 7 consecutive days

Audio Recorders vs. Point Counts

- **Species richness was calculated from two randomly sampled 15 min audio segments and two 15 min surveys from point counts at each point location**
  - ***(before automated search was available)***
- **Meadows were the sampling units, point locations were the replicates**

Audio Recorders *vs.* Point Counts

30 min of randomly selected audio recording *vs.* 30 min point counts **(*p*=0.023)**

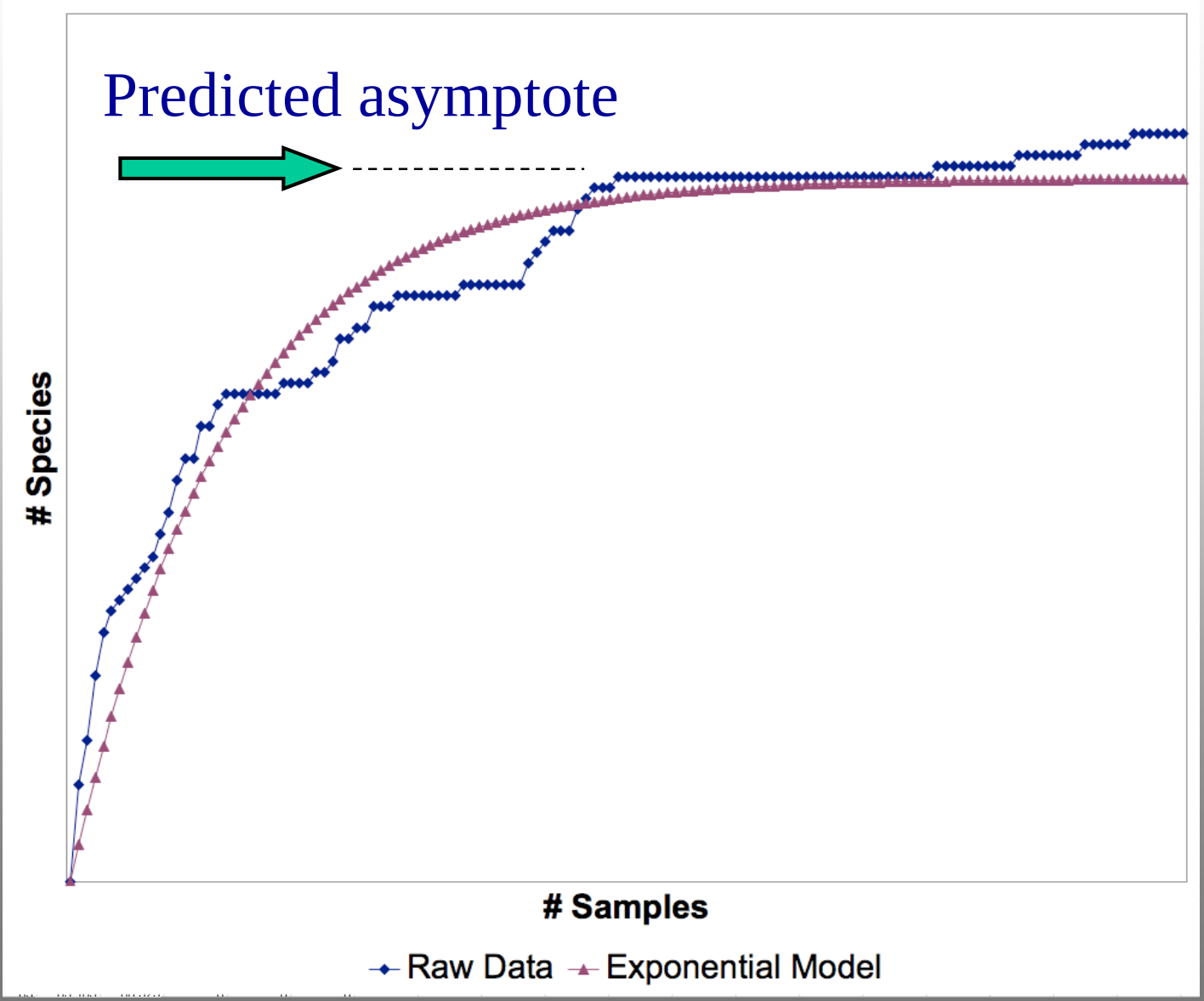
- **Audio recorders: 14.7 species per meadow**
- **Point counts: 15.8 species per meadow**

Audio Recorders *vs.* Point Counts

30 min of randomly selected audio recording *vs.* 30 min point count ***audio*** detections **(*p*=0.718)**

- **Audio recorders: 14.7 species per meadow**
- **Point counts: 14.5 species per meadow**

Exponential Model



Total Species Detected

Point counts

- 69 species
- 18 species were not detected by audio recorders
  - 5 were only detected visually

* Species detected by only one method were detected at 3 or less point locations

Audio recorders

- 57 species (30 min/pt)
- 6 species were not detected by point counts
- When asymptote was reached (~30–100 of ~1200 min):

  7 additional species

  - 5 had been detected by point counts
  - 64 species total

Conclusions

- **Audio recorders can sample more intensively than human-based surveys, with equivalent personnel effort, *and with comparable results***
  - ***Increased confidence of detecting rare and hard to detect species***
  - **Can also provide information about nocturnal species not typically included in point count surveys**

The effects of highway construction noise on golden-cheeked warblers

Michael L. Morrison

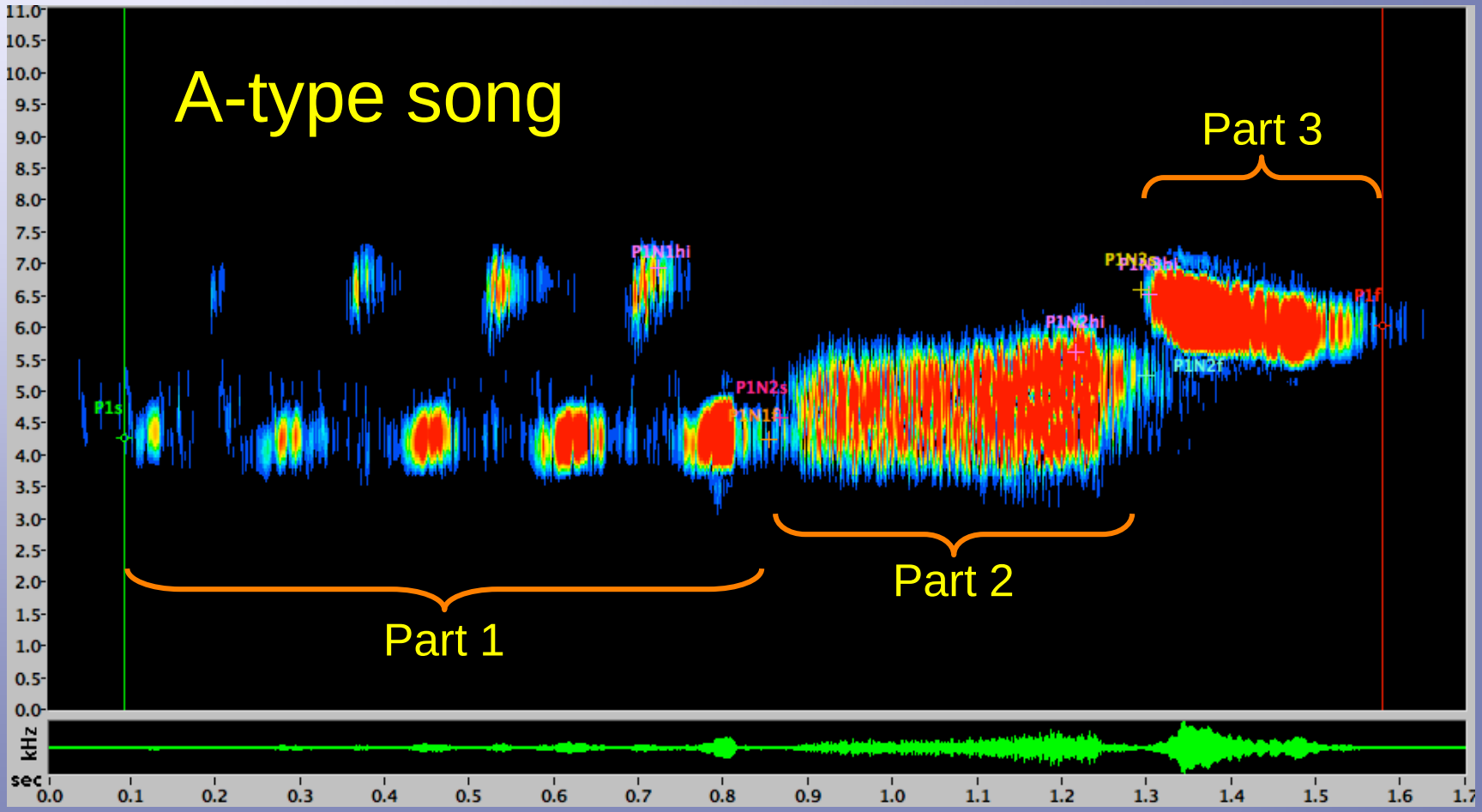
Zachary Loman

Joe Szewczak

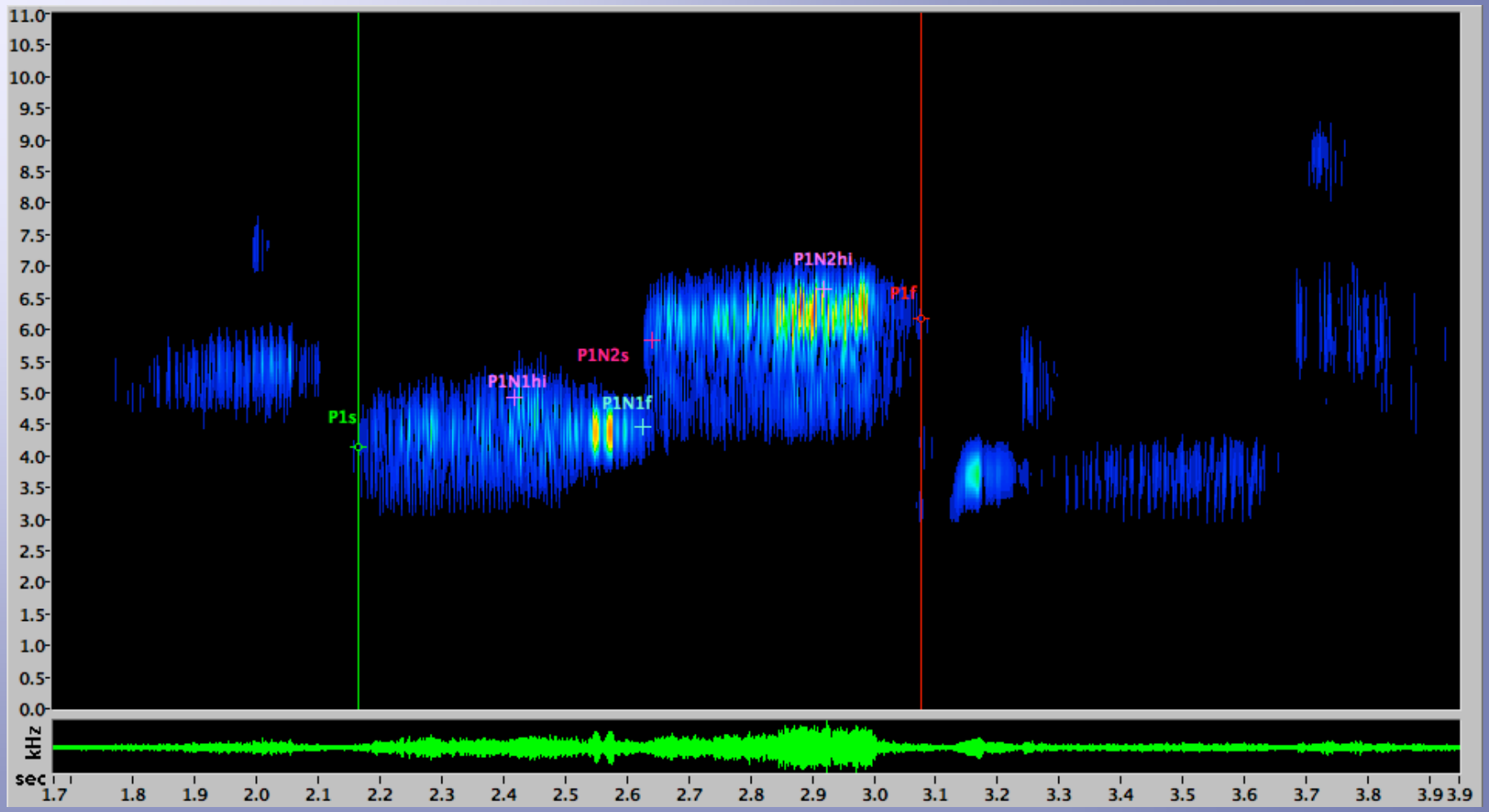
HUMBOLDT STATE UNIVERSITY

Texas Department of Transportation

Golden cheeked warbler (GCWA) A-type song showing the three sections used for measurement.

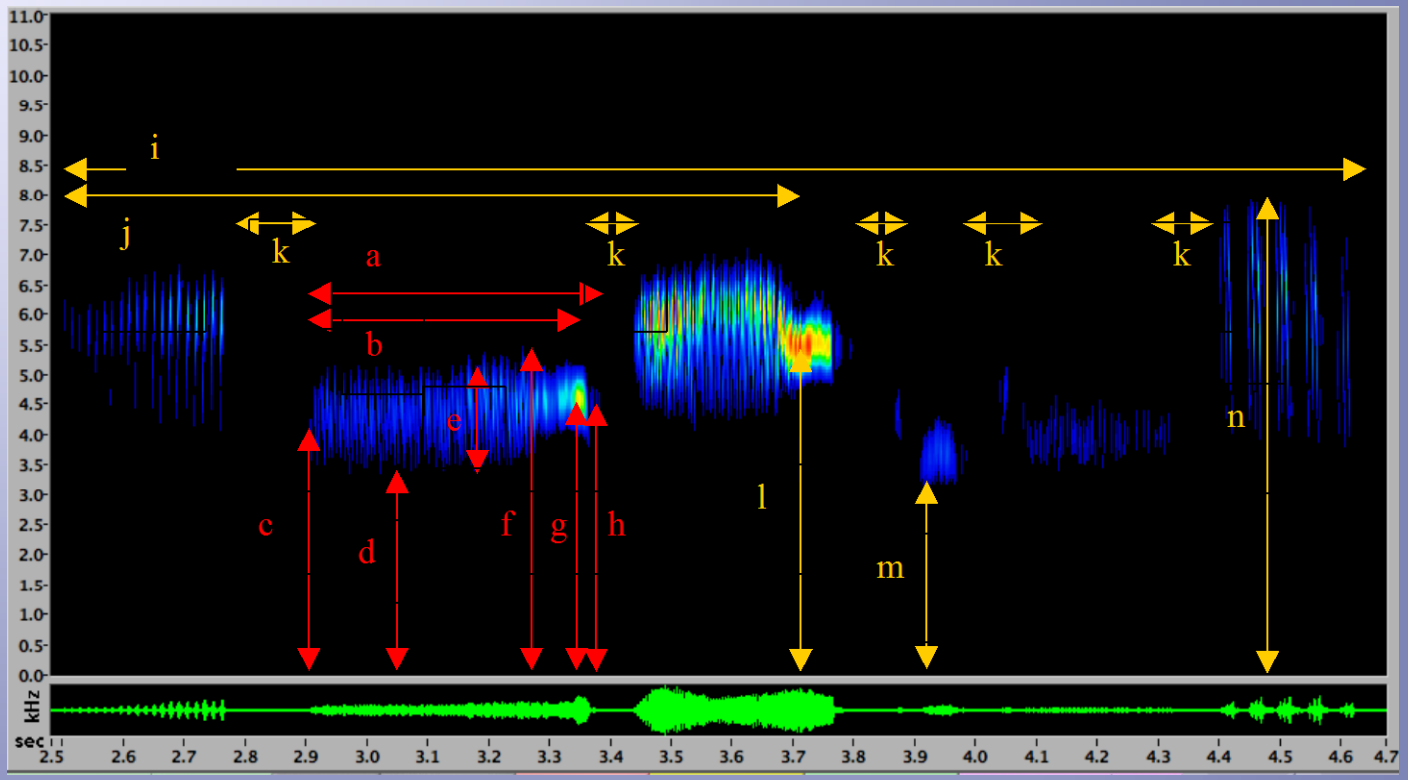


A-type song always presents all three sections, unlike the highly variable B-type song which often adds and subtracts notes.



Typical complete B-type song. Only the two center notes are consistently present in this type. All others may be omitted or rearranged.

Quantifying song parameters



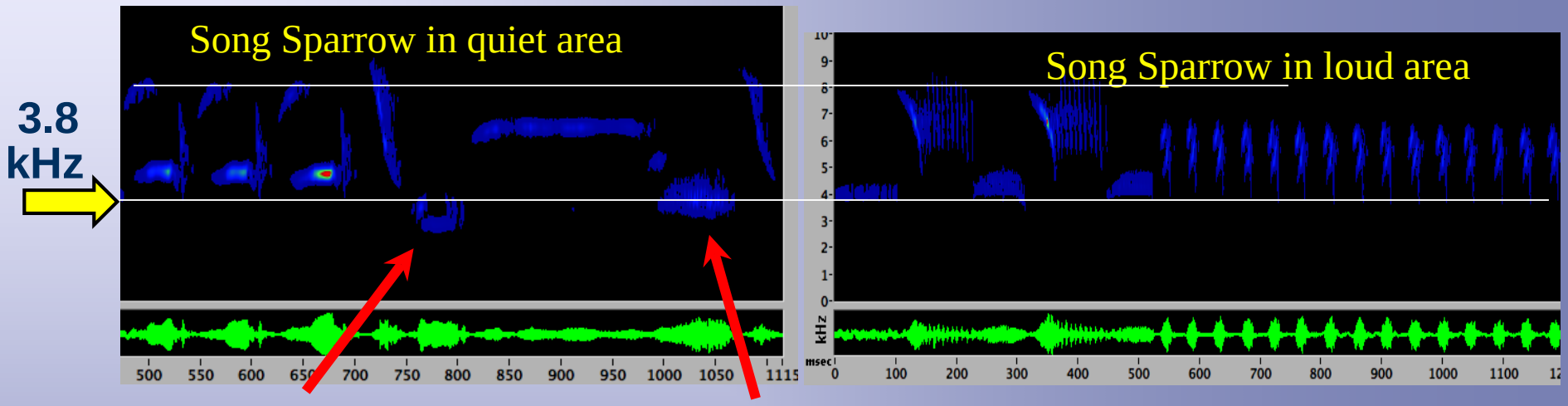
Note specific measurements:

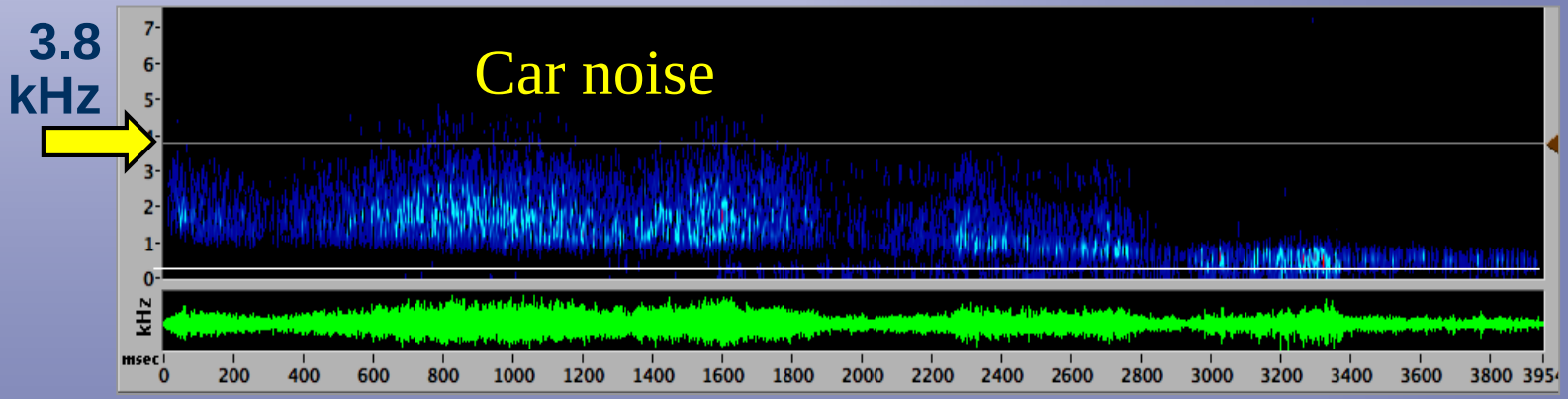
a—note duration, b—time to peak amplitude, c—start frequency, d—minimum frequency, e—bandwidth, f—maximum frequency, g—frequency at peak amplitude, h—end frequency

Song specific measurements:

i—song duration, j—time to peak amplitude, k—time between notes, l—frequency at peak song amplitude, m—minimum song frequency, n-maximum song frequency

Vocal adjustment to noise





Golden cheeked warblers may shift energy to higher frequencies in response to noise, apparently to separate their calls from masking ambient noise.

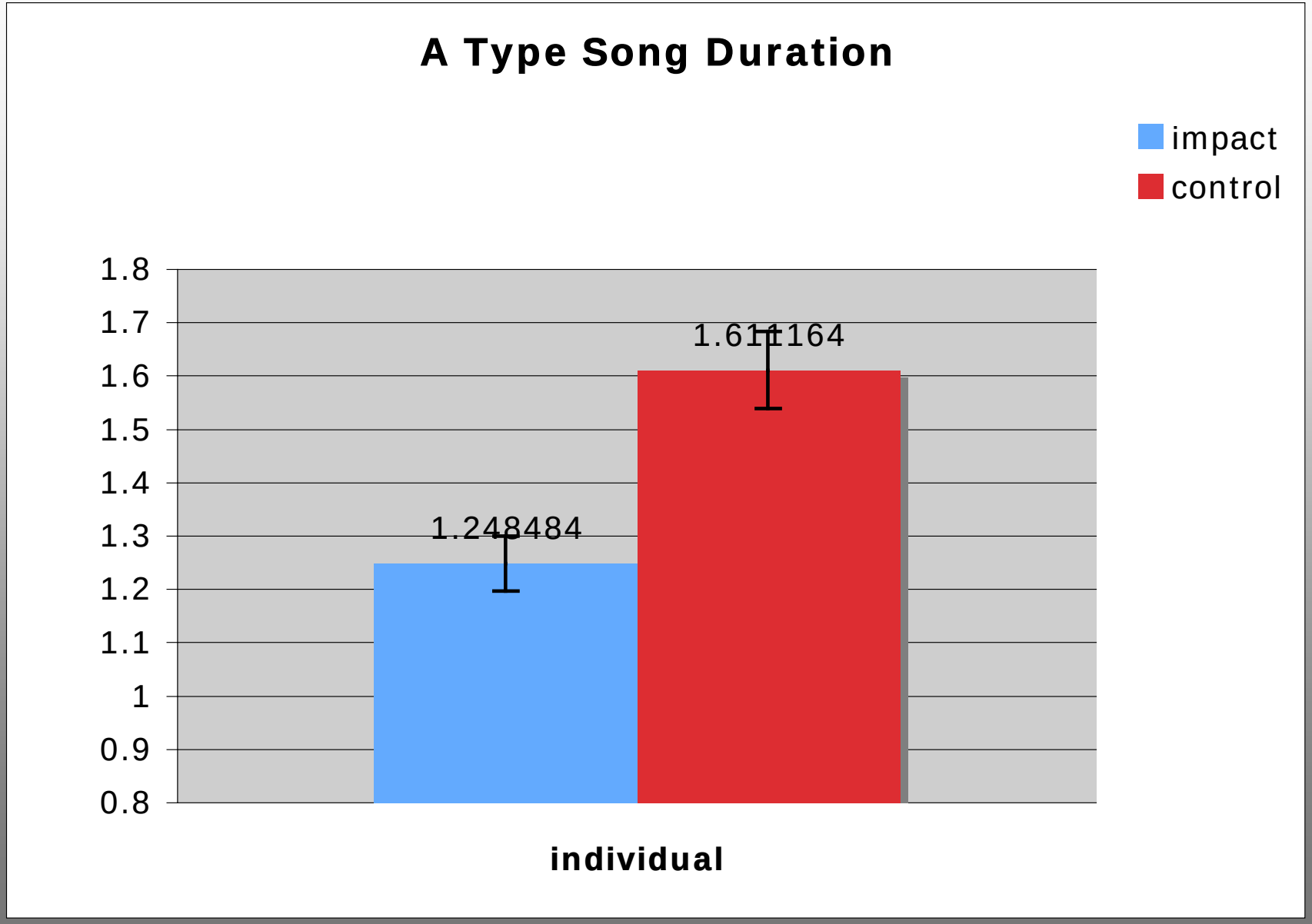
Initial analysis

- Extracted ~30,000 candidate songs from 5 individual warblers. Then using both automated and manual assessments selected ~500 high quality calls for analysis.

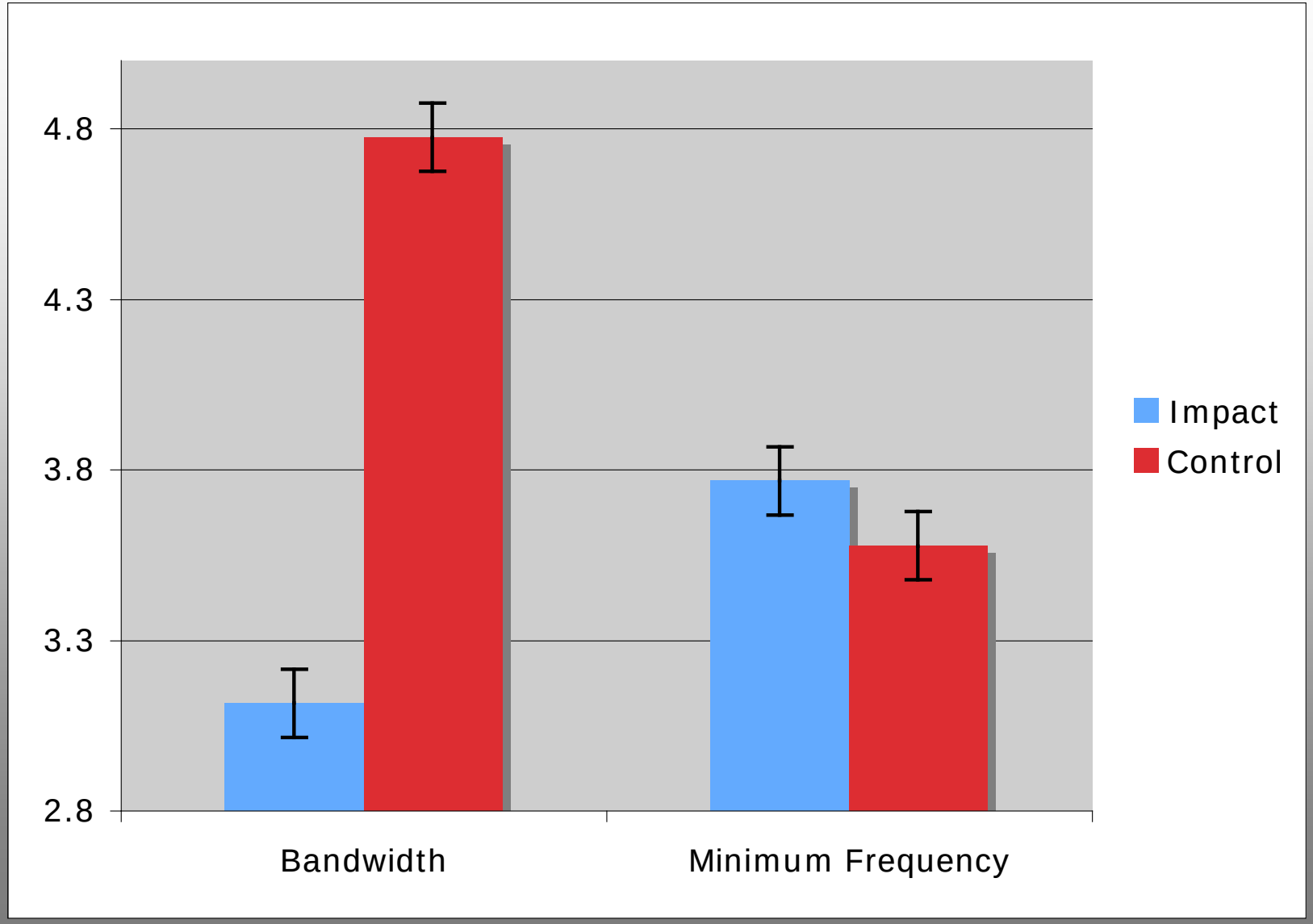
- Used groups of 25 of either all A- or B-type songs from the same individual, but scattered as widely as possible across the breeding season and the day.

- Directly compared song elements across individuals from impact and control sites using ANOVA.

Songs recorded in the loudest territory were consistently shorter ($p < 0.00001$) than songs in the quietest territory.

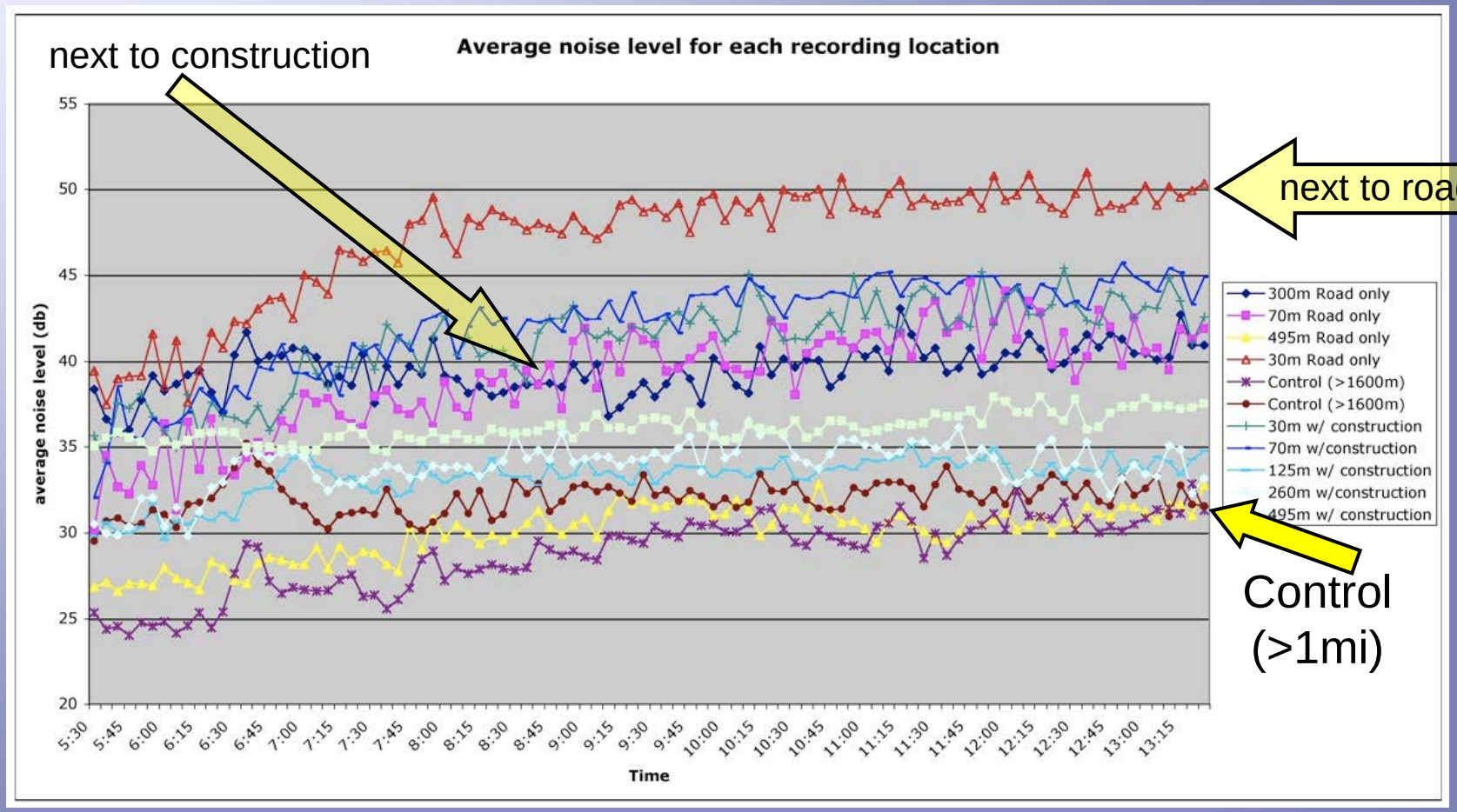


Songs recorded in the loudest territory had components shifted to higher frequencies.



These results support the vocal adjustment hypothesis.

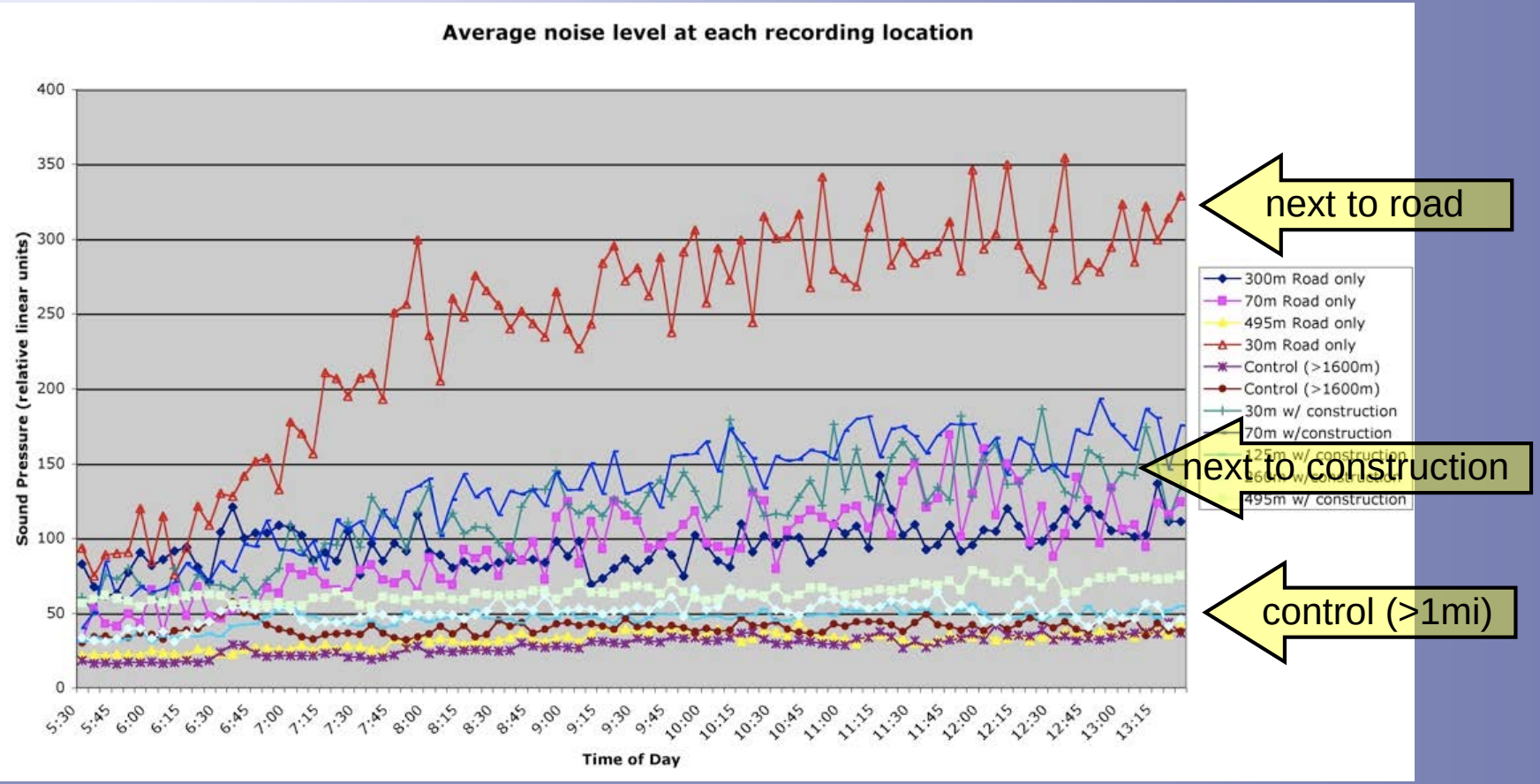
Noise measurements



Birds next to road and construction are subjected to persistent and significantly louder noise throughout the day.

Note decibel units, a logarithmic scale.

Noise measurements



Same data plotted in units of sound pressure to display relative intensity of noise. Construction noise amplitude exceeded 500% of levels in reference areas.

Noise analysis

- Continuous recording facilitates correlating song activity with chronic noise levels and noise levels *prior* to singing bouts.

(*ongoing analysis*)

Excluding bats from bridges prior to construction and maintenance–

A potential new approach

Cappell Creek bridge, CA Hwy 169

American Wind Energy Association

TRF Sustainable Development Fund

National Fish and Wildlife Foundation

Caltrans

Bat Conservation International

Congress Ave, Austin, TX

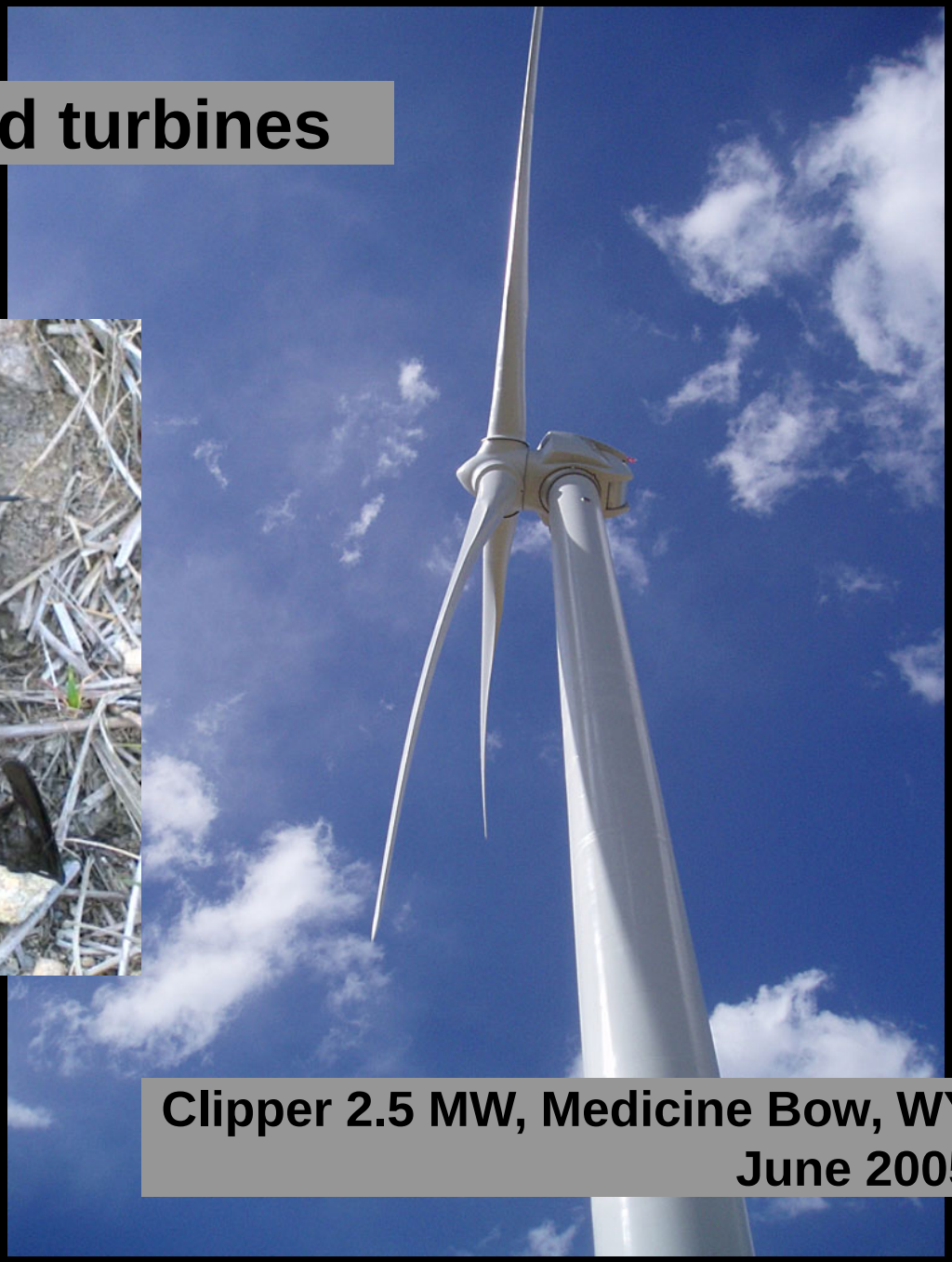
Bats roosting in joints

guano

“Temporary” bridge replacements after 1964 flood on Klamath River.

Bat mortality at wind turbines

Hoary bat, eastern US



Clipper 2.5 MW, Medicine Bow, WY
June 2005

2005
Began initial investigations into possible ultrasonic attraction
Foote Creek, WY June 2005

Can we create a disorienting or uncomfortable airspace around turbines that will deter bats?

Echo return ~45 dB less at 1.5 m
⇒ ~65 dB

~110 dB
(varies by species)

⇒ Sounds greater than ~65 dB may interfere with perception of echoes from targets beyond ~1.5m

No-fly zone.
NEG Micon 1.5 MW, Kimball, NE

Ultrasound broadcast unit

AT800 Prototypes developed by Binary Acoustic Technology

Field testing

Can ultrasound deter bats?

Site selection:

- consistent activity (e.g., pond)
- small enough to concentrate activity
- large enough to provide a choice to use resource out of treatment effect

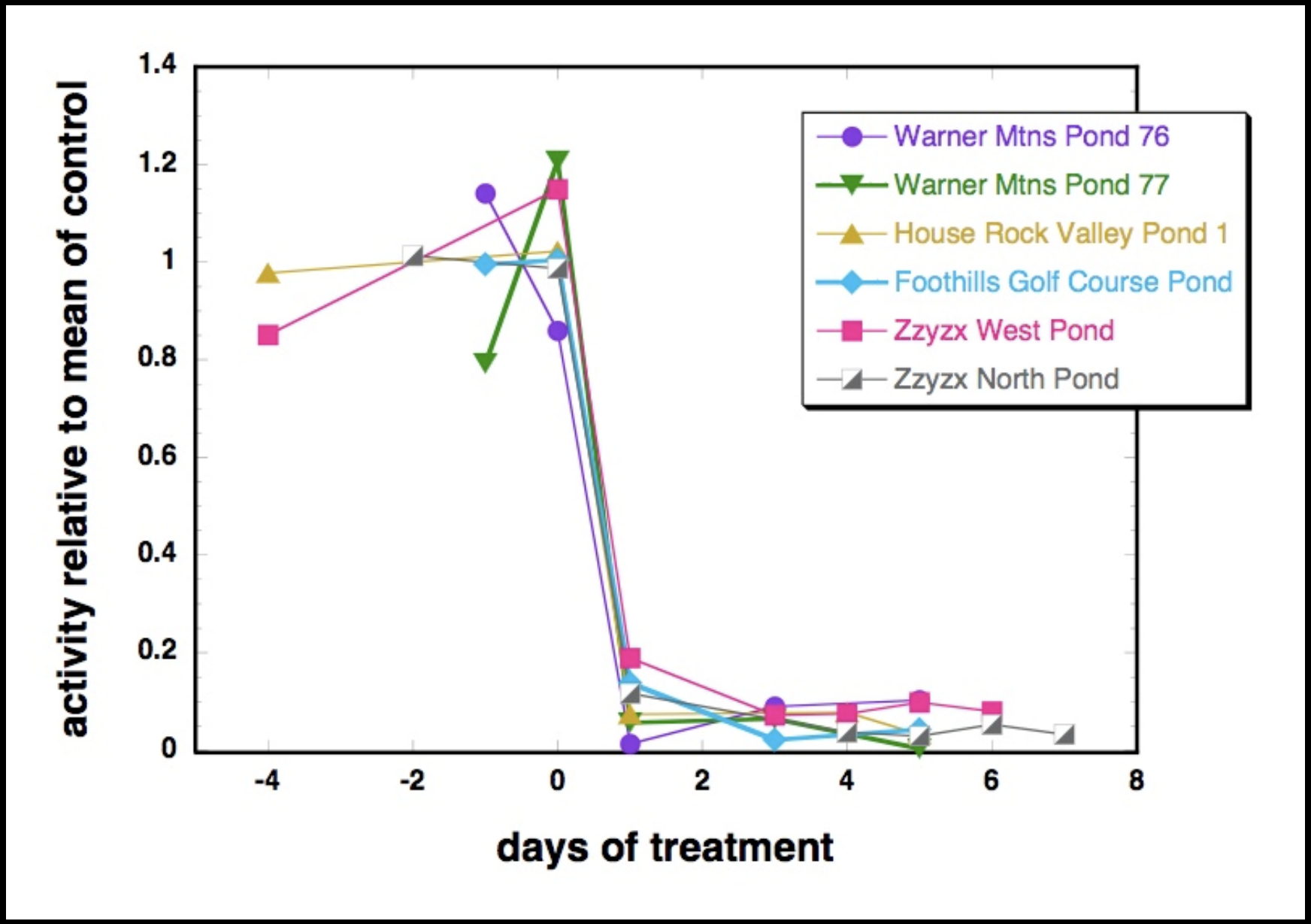
Field testing

- Recorded the *same* scene at the same **one hour** time:
  - two nights of control
  - at least five nights of treatment

control

treatment

Results, normalized to mean of control activity

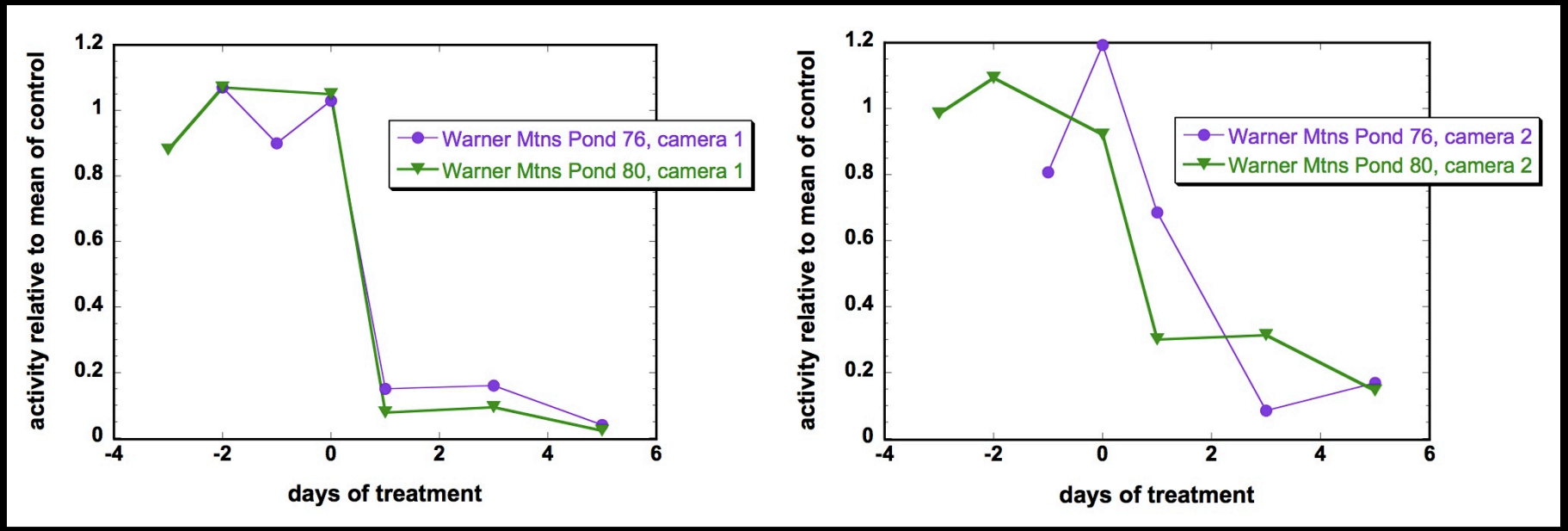


Behavioral deterrent with biological sounds?

- ~~Corvids?~~
- ~~Owls?~~

- Hoary bats...

Results, normalized to mean of control activity



15 m

30 m

Change in bat pass activity at two sites in response to playback of hoary bat social vocalizations. These sites have a prevalence of Myotis and silver-haired bats.

Results

Just ultrasound:

~90% reduction within ~15 m of broadcast

Sustained effect, no indication of habituation

Caveats and limitations

- Limited range of effectiveness due to high attenuation rate of ultrasound in air.
- Limitations on broadcast amplitude.

Collateral effects

- Dispersal of small mammals?
- Dispersal of insects.
- Dispersal of passerines?

But...

Can deploy on bridges without the range limitations of turbines.