Soundscapes to Landscapes (S2L)

Monitoring Bird Diversity from Space Using Citizen Scientists

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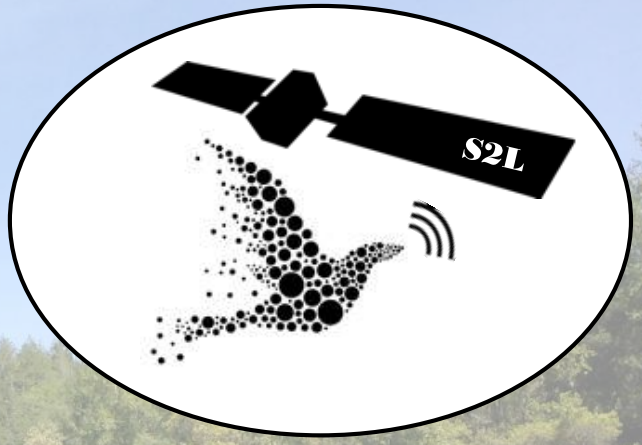
Steven Hancock (University of Edinburgh)



Funding: NASA's Citizen Science for Earth Systems Program (16-CSESP 2016-0009)

Soundscapes to Landscapes (S2L)

Advance bird diversity monitoring from next-generation and existing Earth-observing satellites

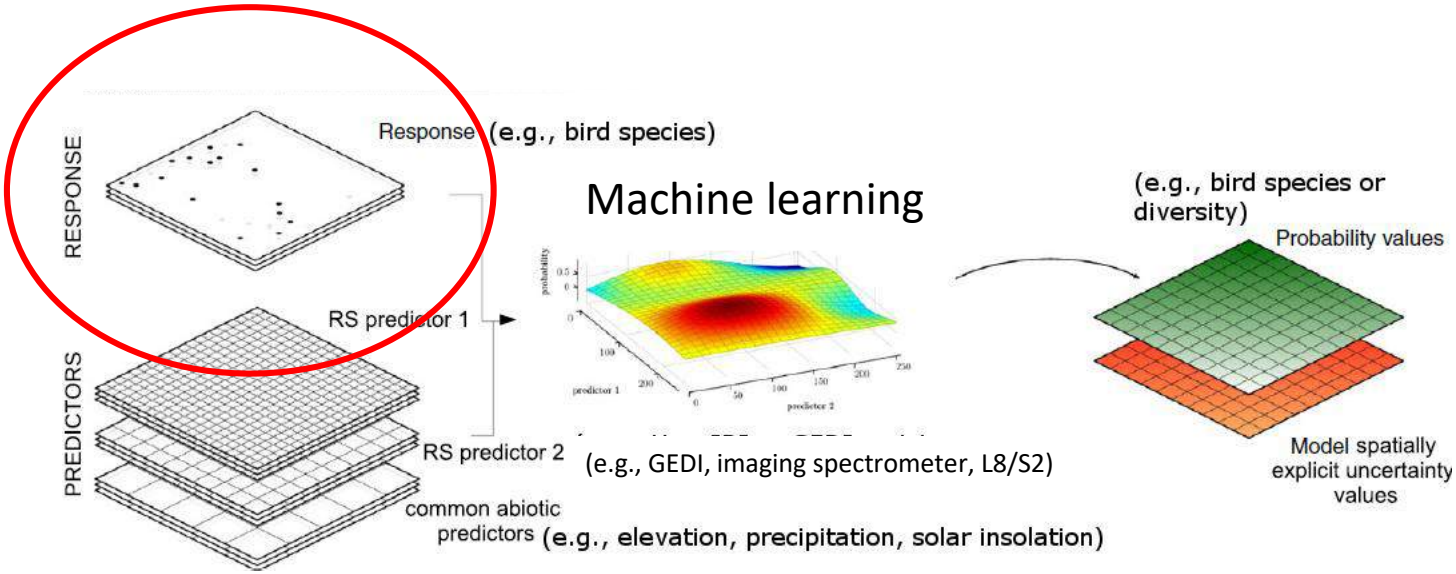
NASA-funded, 3-year Implementation Phase, Sonoma County, California

<u>Approach</u>

1. Citizen scientists collect sound recordings
2. Bioacoustic analysis used to detect birds at sites by their calls
3. Bird species distribution modeling (SDM) with remote sensing predictors (spaceborne lidar, hyperspectral, multispectral)
4. Use SDM maps for biodiversity monitoring and conservation
5. Explore relationship between soundscapes, biodiversity and forest structure (i.e., GEDI)

Species Distribution Modeling (SDM)

Need *in situ* data



Remote sensing predictors → vegetation structure, chemistry, & phenology related to habitat

Adapted from He et al., 2015

In situ animal diversity data through soundscape analysis

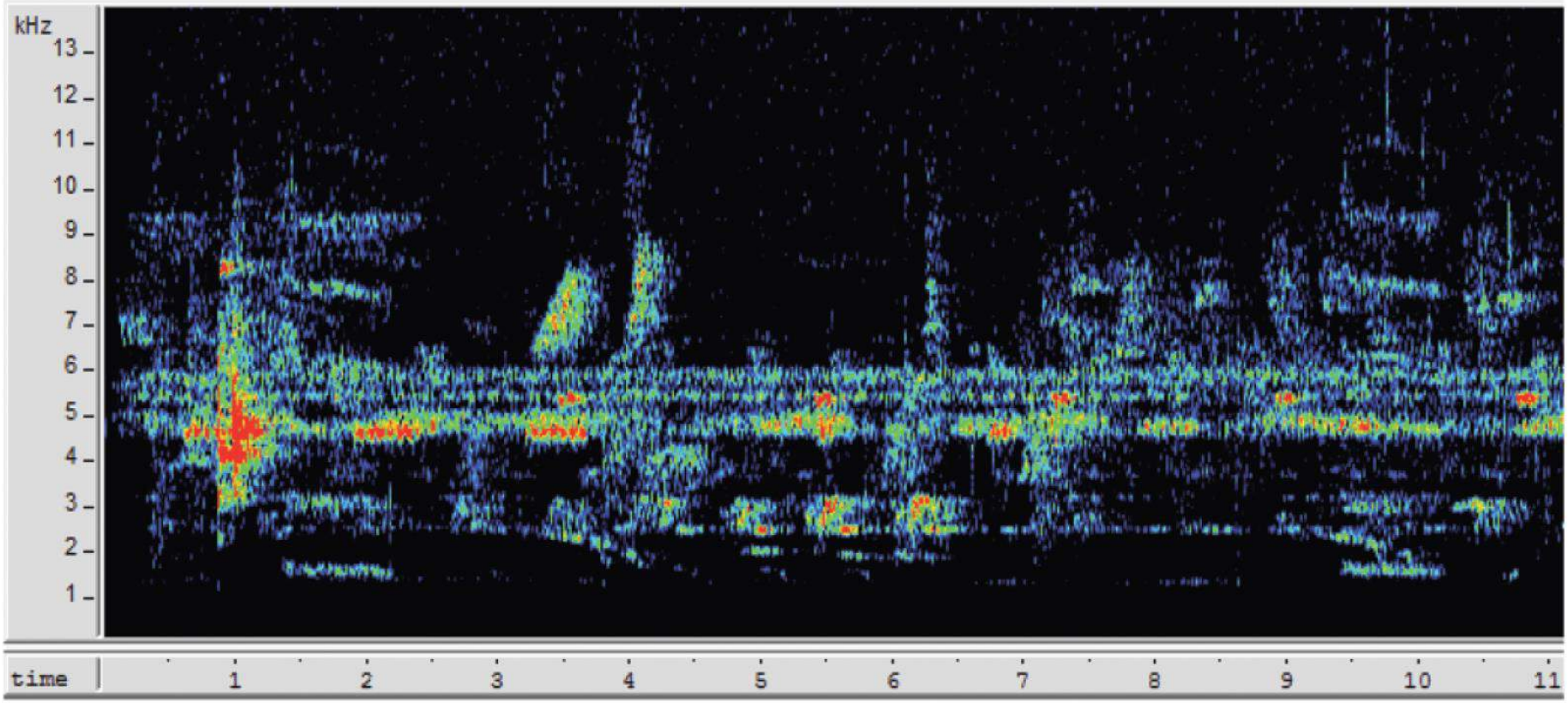


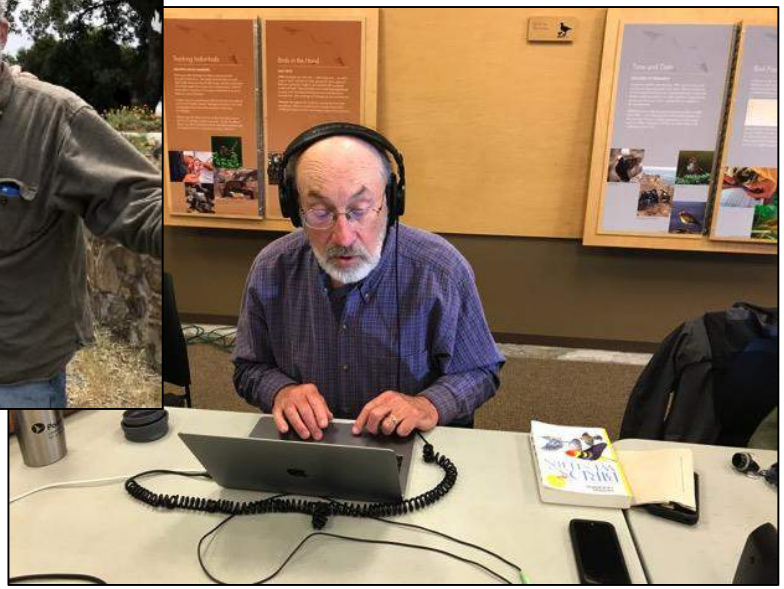
Figure 2. Spectrogram of an 11-second recording of the dawn chorus at the La Selva Biological Station, Costa Rica. Birds and insects are creating a variety of sounds from 1 kilohertz (kHz) to some even above 12 kHz. There is considerable biophonic activity between 4 and 6 kHz, with the loudest sounds occurring 1 second into this recording. Crickets are stridulating at 4.7, 5.3, and 6.0 kHz. Note that raindrops falling from the tropical canopy can be heard (sounds below 2 kHz), an example of geophony.

Pijanowski et al., BioScience 2011

Citizen Scientists

Students & volunteers

Landowners



Birders

Recording Soundscapes

Methods in Ecology and Evolution
BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE | Open Access

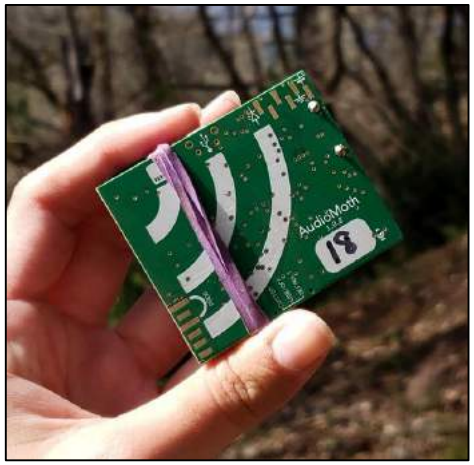
AudioMoth: Evaluation of a smart open acoustic device for monitoring biodiversity and the environment

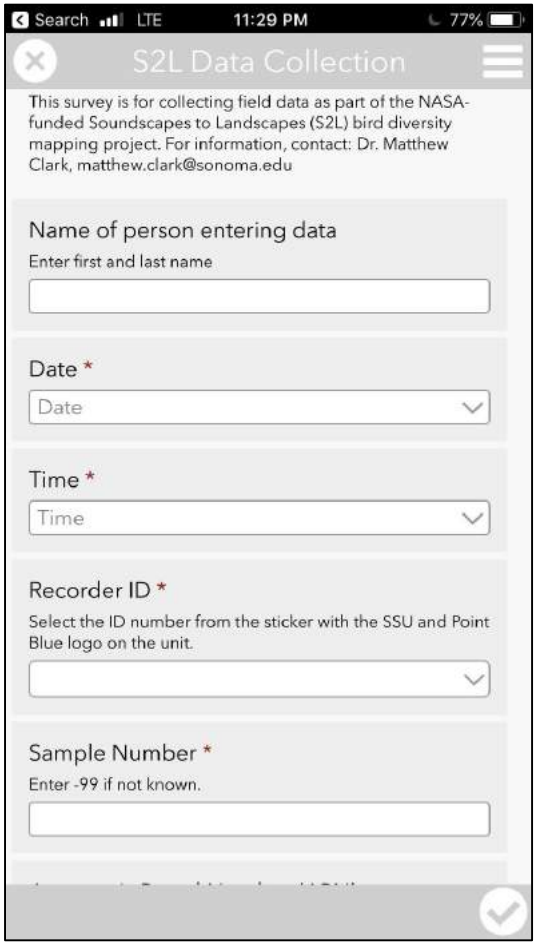
Andrew P. Hill, Peter Prince, Evelyn Piña Covarrubias, C. Patrick Doncaster, Jake L. Snaddon, Alex Rogers

First published: 13 December 2017 | https://doi.org/10.1111/2041-210X.12955 | Cited by: 1

Each site: 3-4 days, with 1-minute recording every 10 minutes

- AudioMoth is < $80
- Programmable
- Uses 3 x AA batteries
- Size is 58 x 48 x 15 mm
- Simple on/off switch





Field Campaigns - March to June

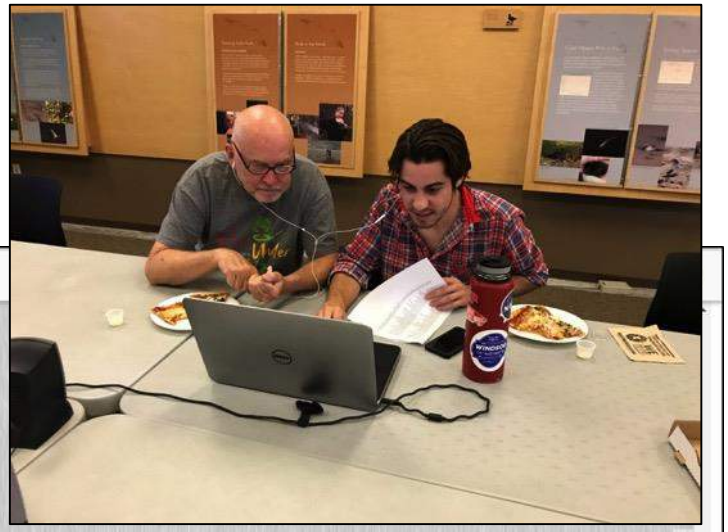
To date, we have collected over 206,000 minutes of recordings (~3,433 hours)

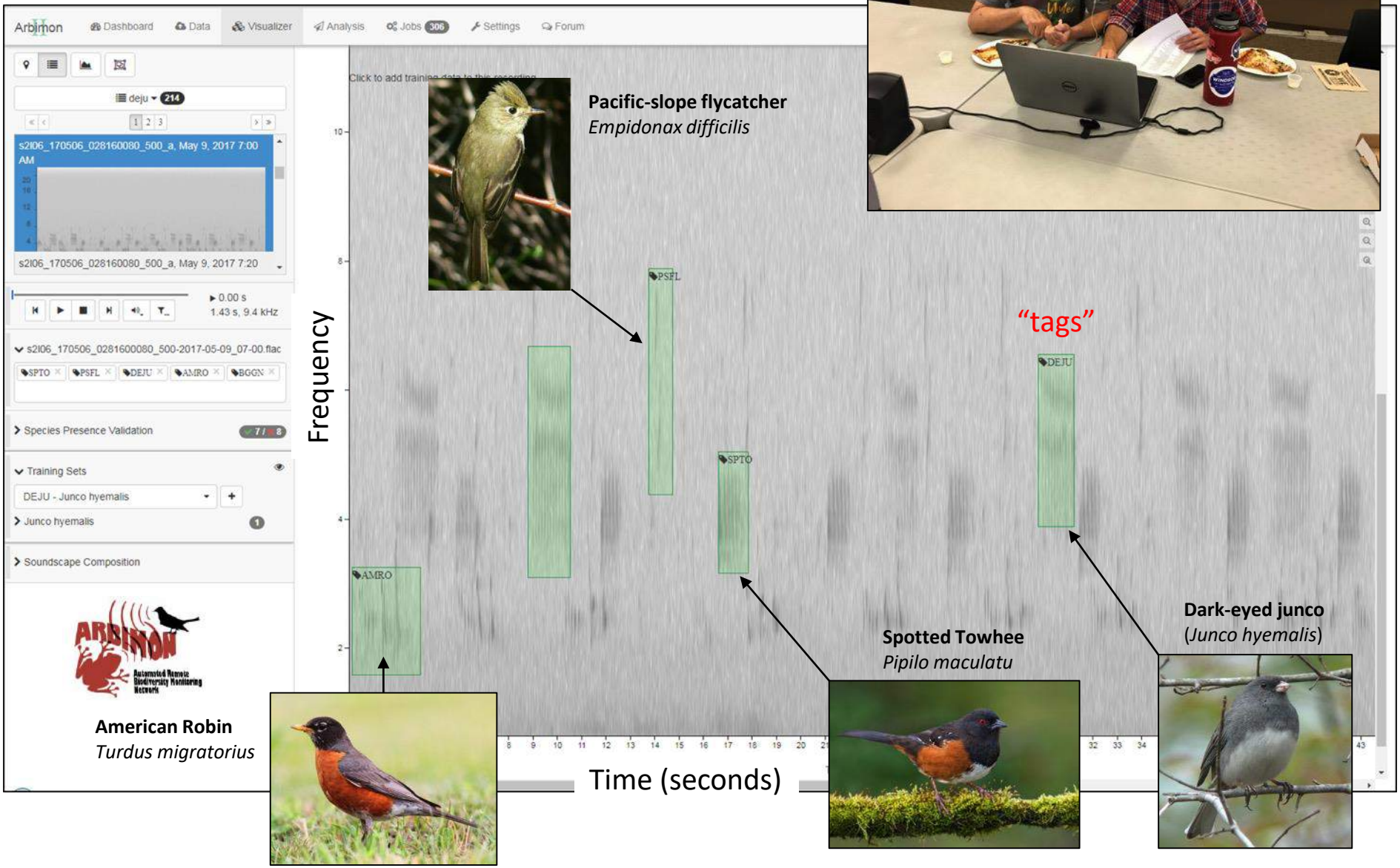
2019 Field Season (as of 5/15/2019)	Project Total (since 3/01/2017)
190 unique sites visited	401 unique sites visited
555 CS field work hours ($13,387)	1329 CS field work hours ($32,082)

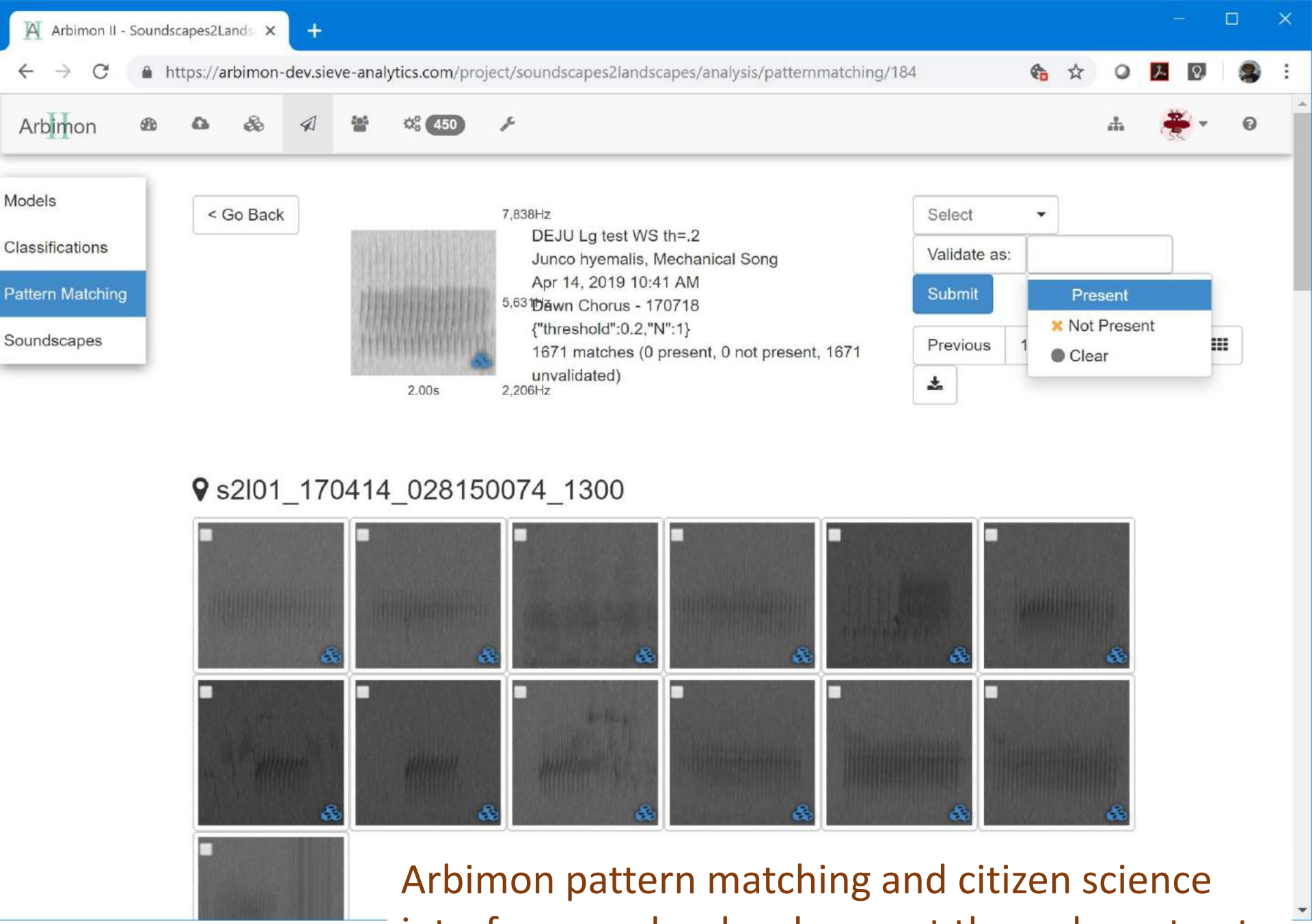
Public lands
AudioMoth deployment mostly done by student interns & community volunteers

Private lands
- Mail Deploy
- Classroom Deploy
- Cluster Deploy

Web-based Bioacoustics Analysis





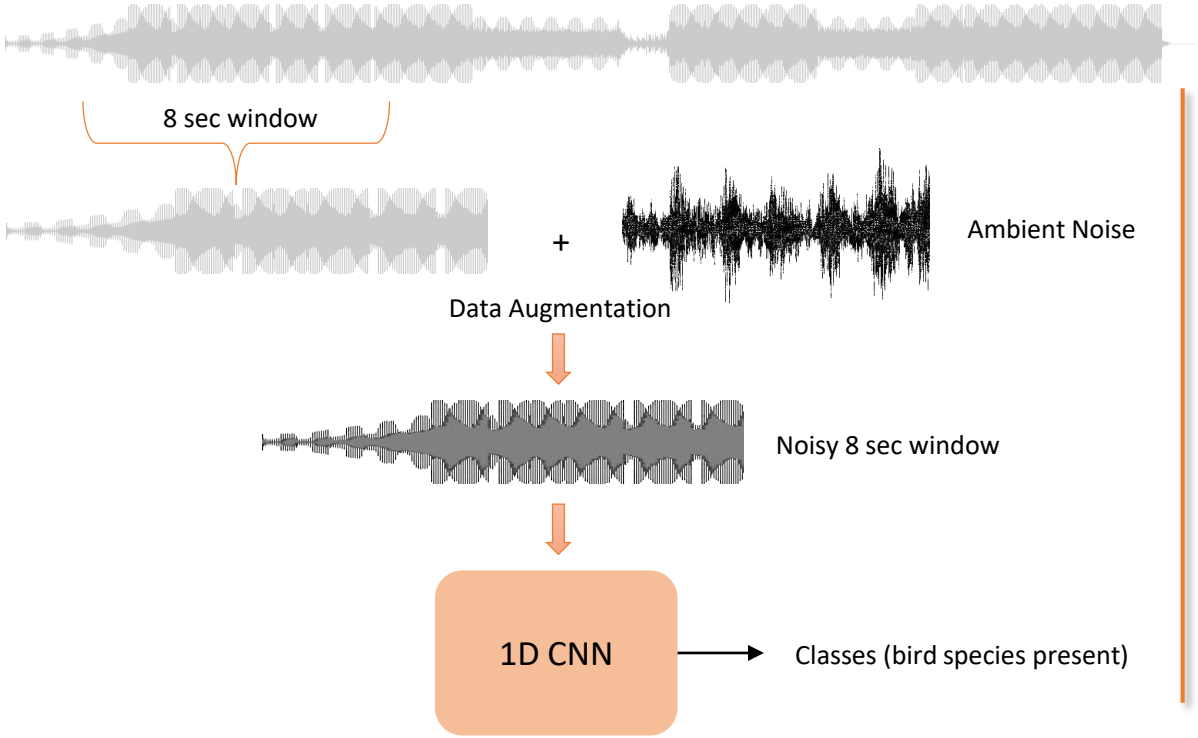


Arbimon pattern matching and citizen science interface - under development through contract

Bird Call Classification

Deep learning using Convolutional Neural Networks (CNN)

Recordings analyzed as waveforms



- Deep learning needs a large training datasets (i.e., labeled bird calls)
- Collected clean audio data from Xeno-Canto
- Data augmentation
  - Adding noise
  - Speed audio up/down
  - Overlay multiple bird calls
- Data augmentation is critical for generalization and robustness

Shrishail Baligar & Dr. Shawn Newsam, UC Merced

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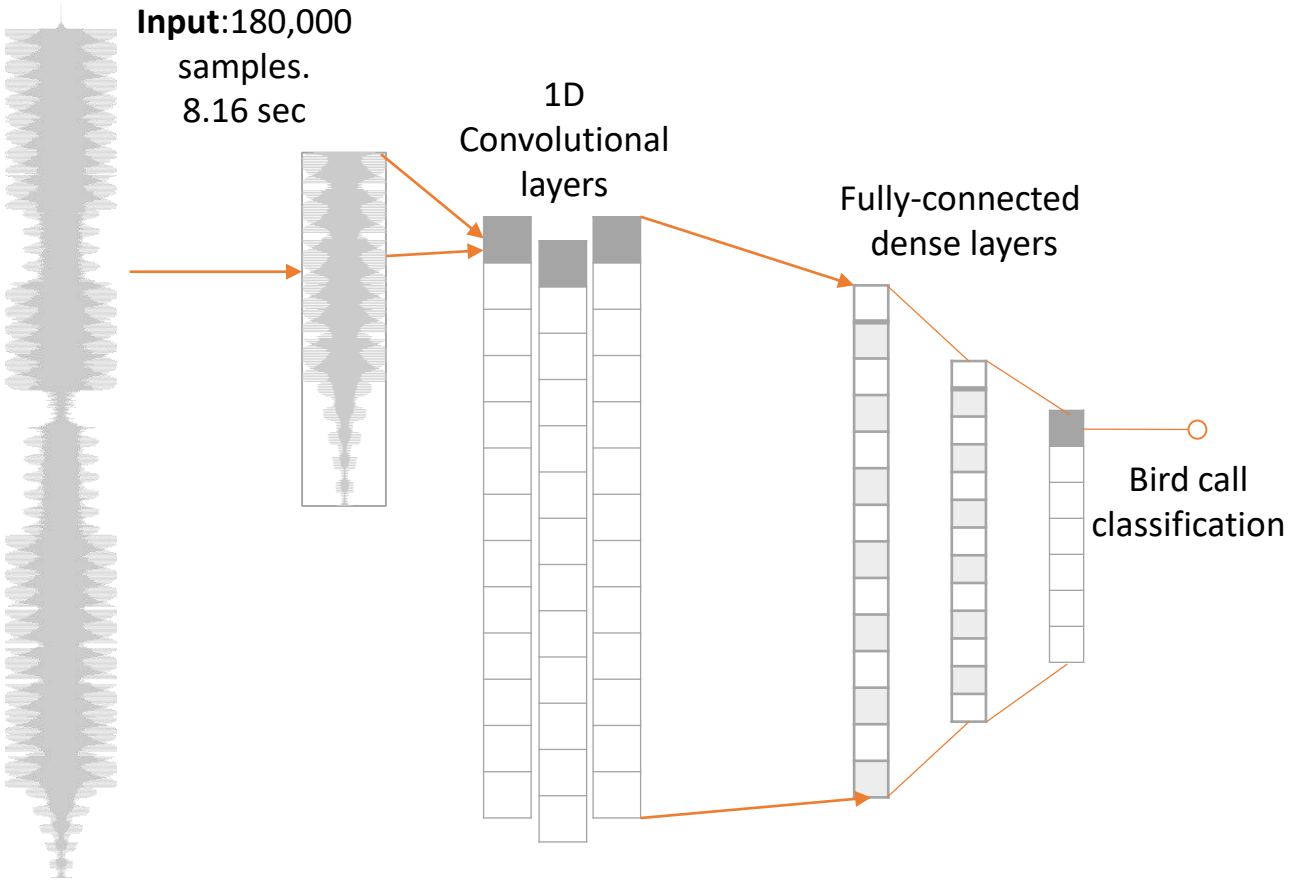
CNN Model Details and Evaluation



Evaluation

- **Initial results:** 84% accuracy for 10 bird species classes
- Now training for 30 bird species using over 33 hours of augmented audio
- S2L soundscape data will be used for tuning the model

Shrishail Baligar & Dr. Shawn Newsam, UC Merced

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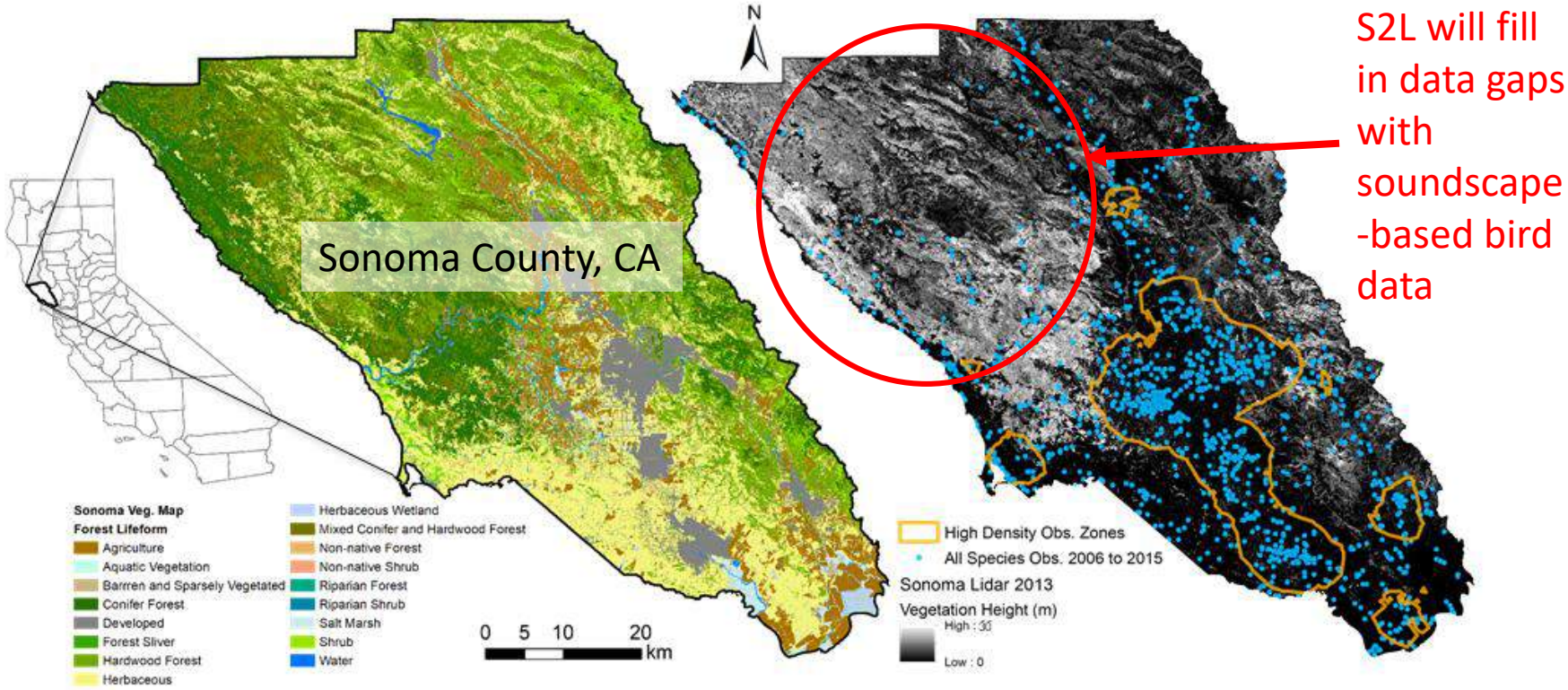
SDM Using Existing Bird Diversity *In Situ* Data

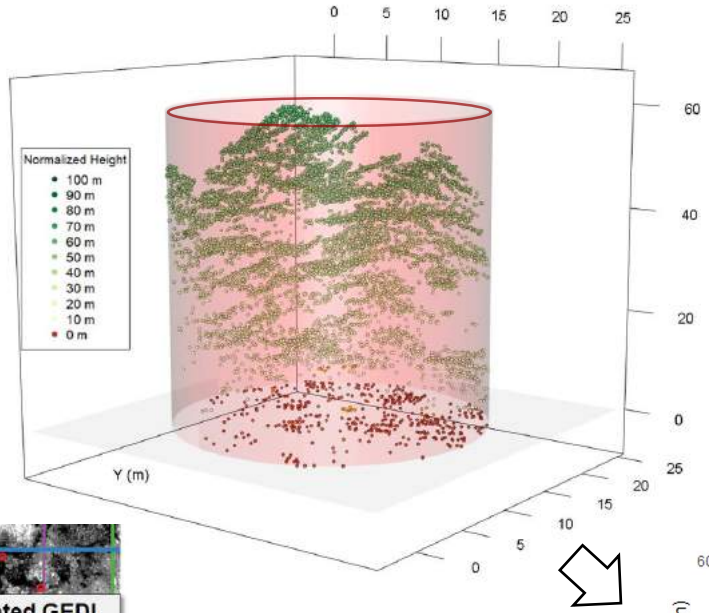
Collaborators: Dr. Leo Salas (Point Blue Conservation Science); Pat Burns, Dr. Scott Goetz (Northern Arizona Univ.); Dr. Steve Hancock (Edinburgh), David Leeland, Wendy Schackwitz (Citizen Scientists)



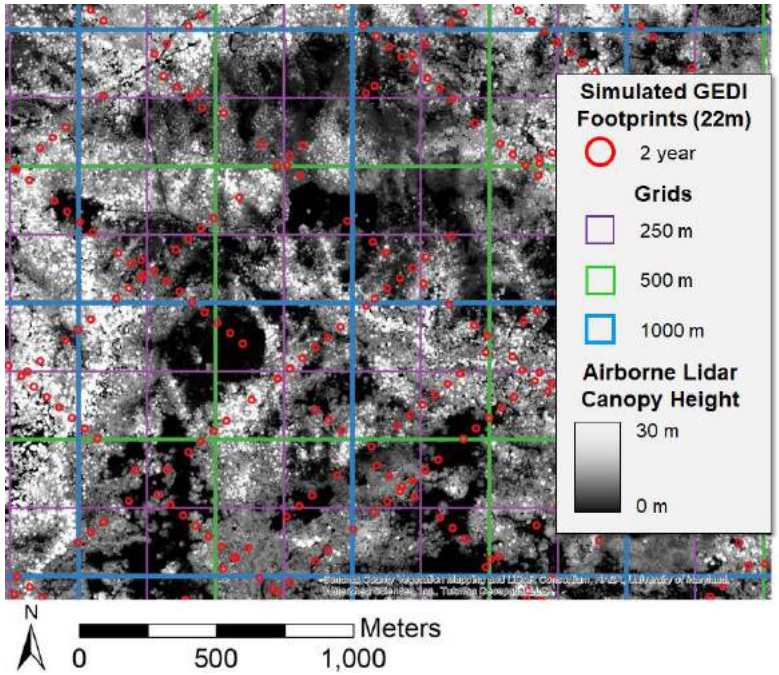
- Bird data compiled from California Avian Data Center by Point Blue Conservation Science for water years 2006 to 2015
  - Point Blue, Breeding Bird Survey (BBS), & eBird
  - Avg. 174 presence, 538 absences per species
- SDMs predict probability of occurrence for 25 bird species from different habitat associations (oak woodlands, conifer forest, riparian, grassland, urban, generalist)

Canopy Structure from Simulated GEDI Metrics

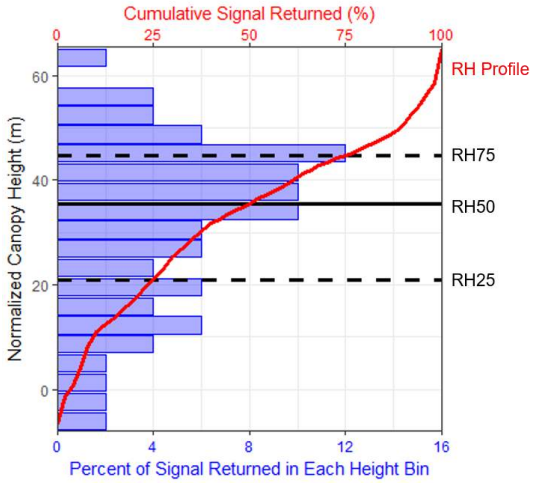
Simulation of GEDI L2 product waveforms from airborne lidar data (Hancock et al., 2019)



Airborne Lidar Point Cloud



Moving Window Kriging used to interpolate surfaces for each structure metric (250, 500, 1000 m)

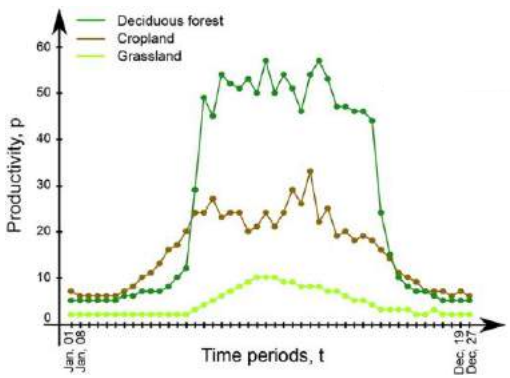


Simulated GEDI waveform and canopy structure metrics

Other Predictor Data

Phenology Metrics

- MODIS NDVI Dynamic Habitat Indices (DHI): cumulative, minimum, variance
- Additional MODIS NDVI metrics: seasonal difference, median, maximum
- Used Google Earth Engine
- Aggregated all to 250, 500, and 1000 m grids



http://silvis.forest.wisc.edu/data/DHIs

Equations

DHI Cum = $\sum p_t$

DHI Min = $min(p_t)$

DHI Med = $med(p_t)$

DHI Max = $max(p_t)$

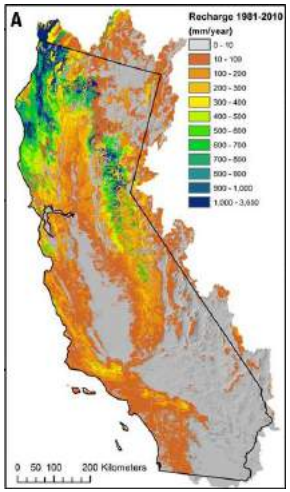
DHI Var = $var(p_t)$

DHI seasDiff = $med(p_{june}) - med(p_{nov})$

Similar to Radeloff et al., RSE 2019

USGS Basin Characterization Model (BCM)

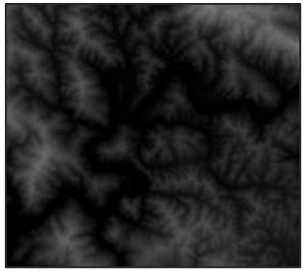
- Hydro-climate data for California, 270 m (Flint et al., 2013)
- Tmin, Tmax, precipitation, actual evapotranspiration, climate water deficit



https://ca.water.usgs.gov/projects/reg_hydro/basin-characterization-model.html

Auxiliary variables

- Elevation
- Distance to stream/river
- Distance to coastline
- Distance to road

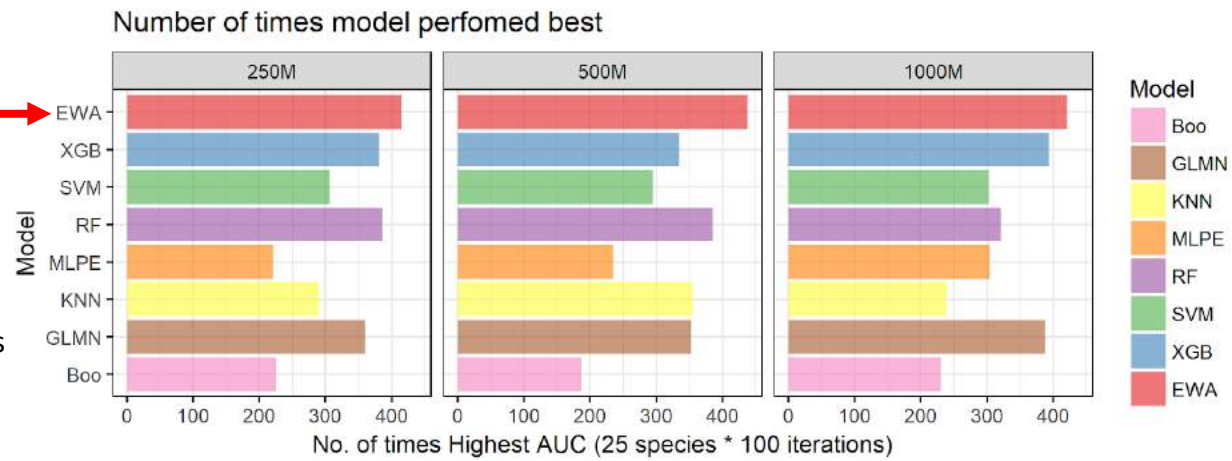


Variance Inflation Factor (VIF) used to remove correlated variables before SDM

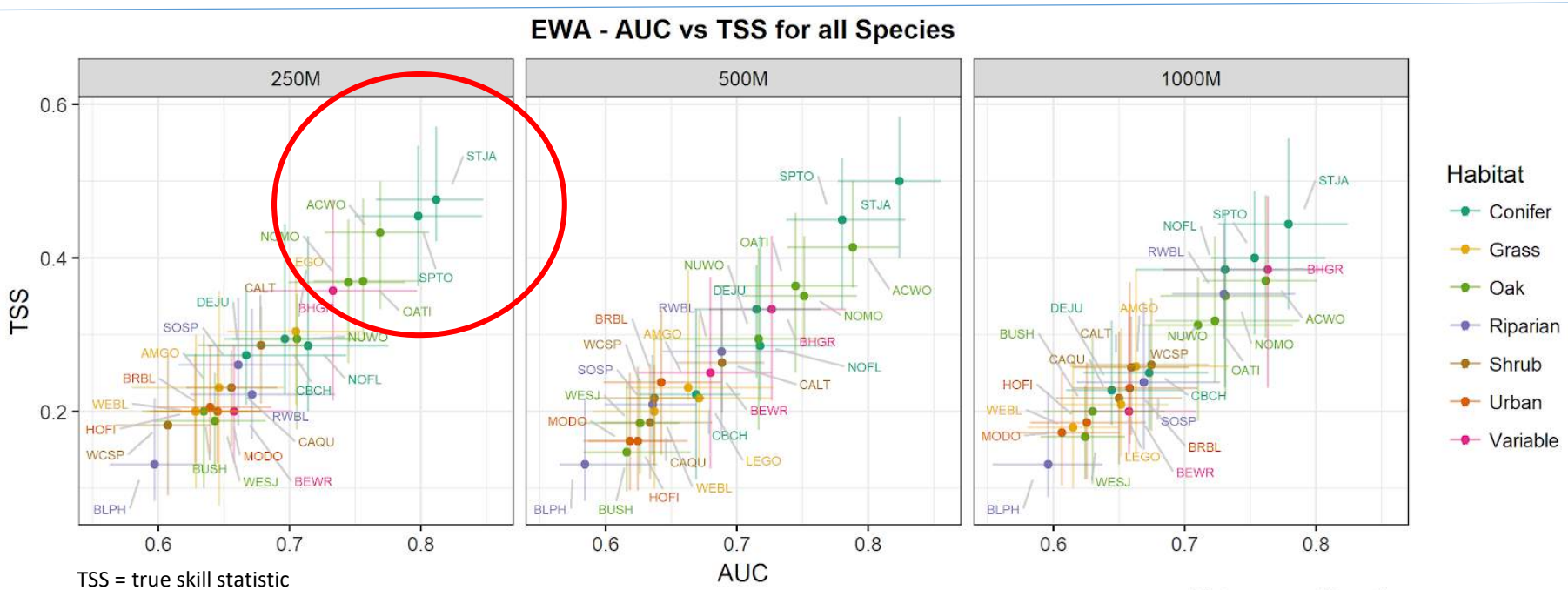
55 variables → 23 variables

SDM Performance

EWA - Ensemble Weighted Average
XGB - Extreme Gradient Boosting
SVM -Support Vector Machine
RF - Random Forest
MLPE - Multilayer Perceptron Ensemble
KNN - K-nearest neighbor
GLMN - Elastic-Net Reg. Gen. Linear Models
Boo - AdaBoost M.1



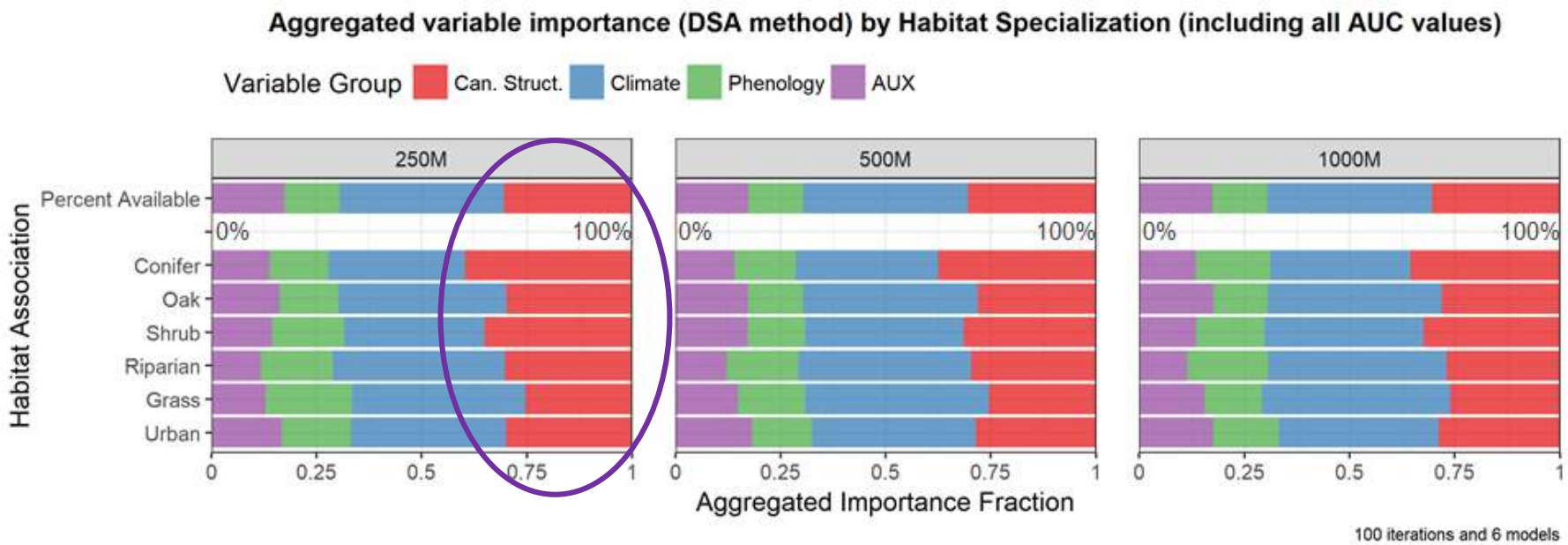
For all species and bootstrap iterations the number of times an individual model was the best performer based on AUC



TSS = true skill statistic
AUC = Area Under the Curve

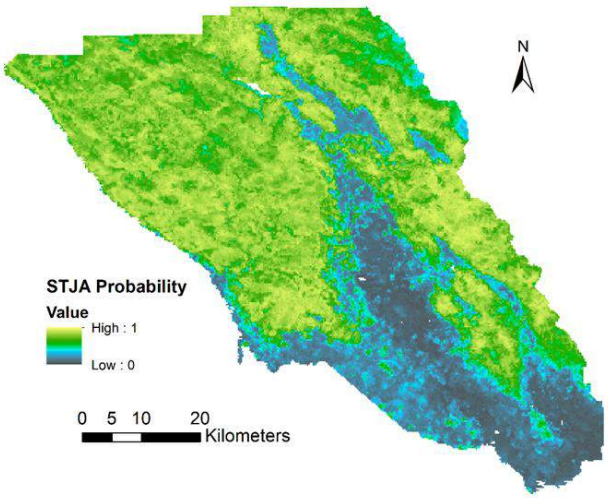
Points correspond to median
Bars correspond to Interquartile Range

Variable Importance

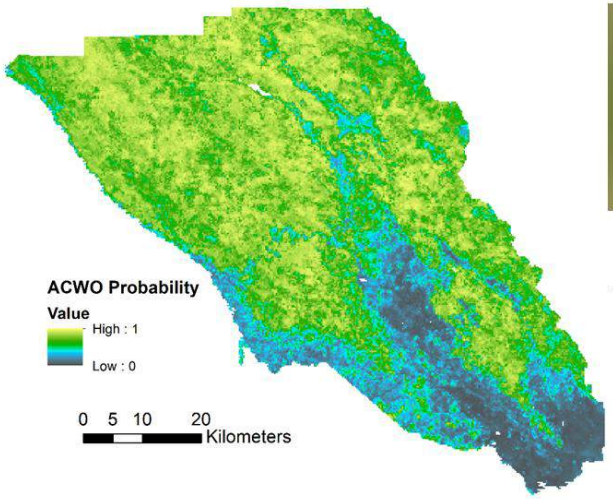


Aggregated variable importance (DSA method from *rminer*) by predictor variable group and bird species habitat specialization. Percent Available is percentage of variables available from a group (Canopy Structure, Climate, Phenology, Auxiliary) relative to the total number of variables after Variance Inflation Factor filtering (n=23)

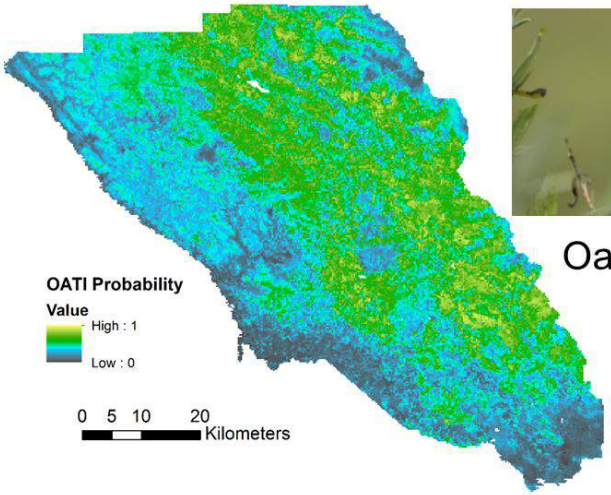
Example maps from SDM



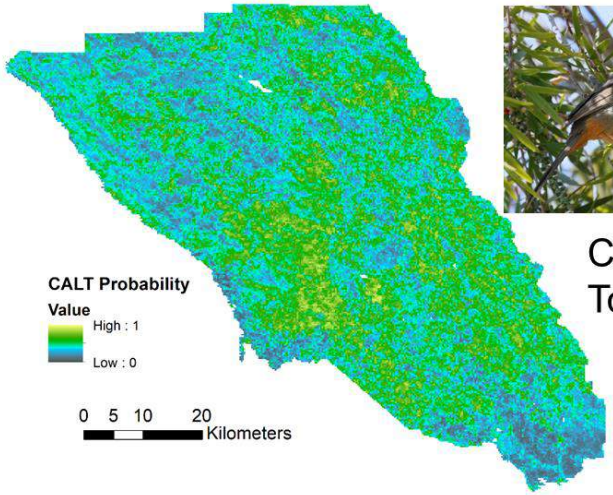
Steller's Jay



Acorn Woodpecker



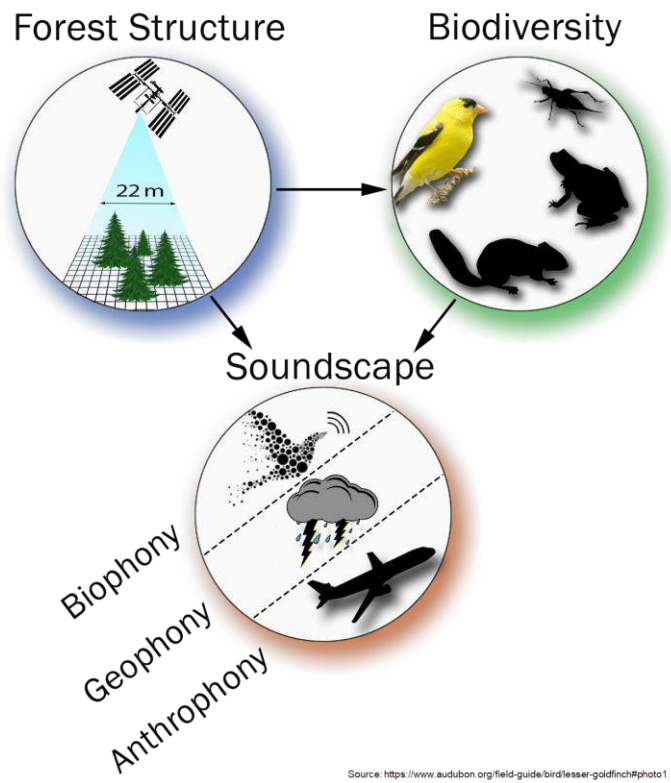
Oak titmouse



California Tohwee

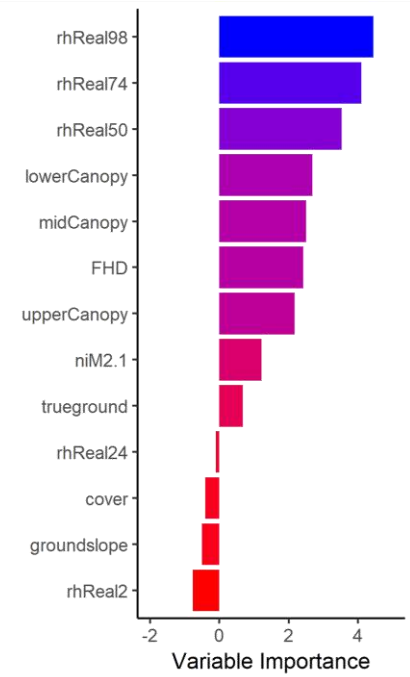
Example SDM outputs of probability of occurrence from 2 years of simulated GEDI at 250 m spatial resolution. Bird data were from existing eBird. Breeding Bird Survey, and Point Blue data.

Soundscapes, Avian Diversity and Forest Structure

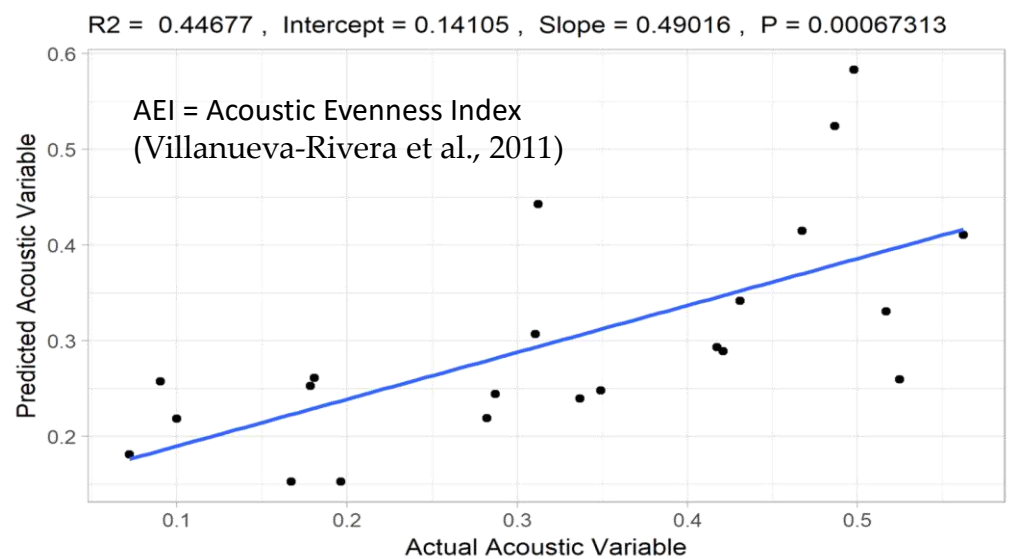


Modeling the relationship of forest structure and soundscapes (acoustic indices) to understand biodiversity

Initial results suggest GEDI simulated forest structure can be used to predict certain acoustic indices. These indices have been shown to reflect biodiversity. We can map GEDI-modelled acoustic indices to understand avian biodiversity across Sonoma County.



Predicted Average AEI using Random Forests and GEDI metrics



Collin Quinn, Northern Arizona University - see poster!

Thank you

nature
International journal of science

IN FOCUS NEWS

Habitats such as coral reefs have been hit hard by pollution and climate change.

BIODIVERSITY

One million species face extinction

Landmark United Nations report finds that human activities threaten ecosystems around the world.

2019 Global Assessment by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

Species at risk

More than **40%** of **amphibian species**

Almost **33%** of **reef-forming corals**

More than a **1/3** of all **marine mammals**

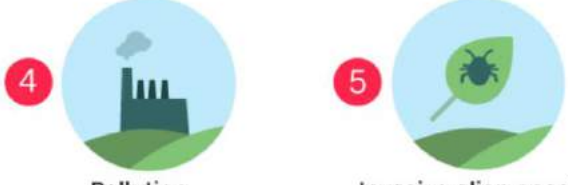
Source: IPBES Report
Graphic: Wafaa Ayish, CNN

5 main drivers of species loss

1 **Changes in land and sea use**
Humans have altered **75%** of land and **66%** of marine environments since pre-industrial times.

2 **Direct exploitation of organisms**
In 2015, a **third** of marine stocks were being fished at unsustainable levels.

3 **Climate change**
Global warming has already impacted almost **half** of threatened mammals and **one quarter** of birds.



4 **Pollution**
Marine plastic pollution has increased tenfold since 1980, with an average **300-400M** tons of waste dumped annually into the world's waters.

5 **Invasive alien species**
The numbers of invasive alien species per country have risen by about **70%** since 1970.

Source: IPBES Report
Graphic: Wafaa Ayish, CNN