Estimating Bird Counts with Bioacoustics

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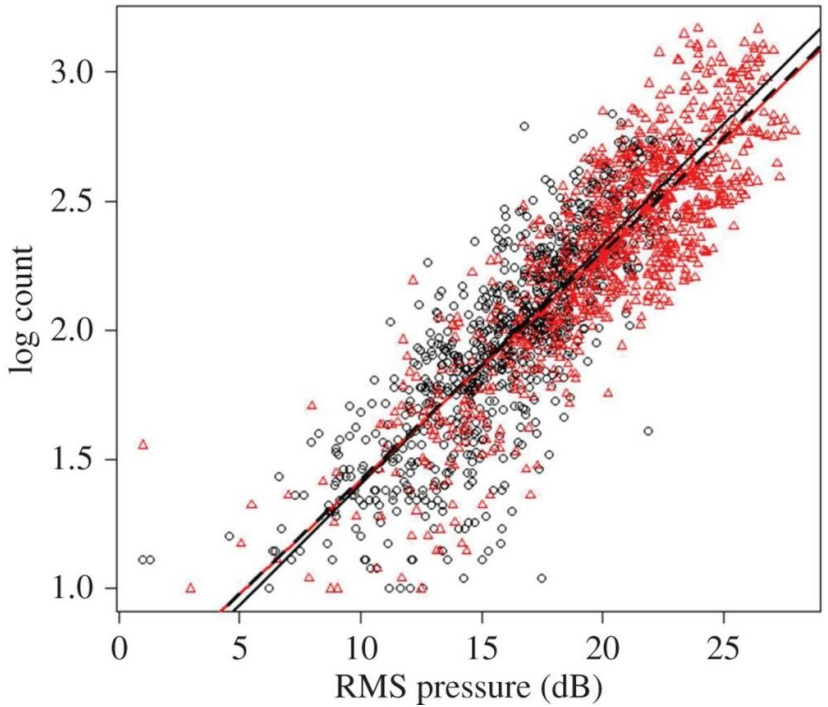
Introduction

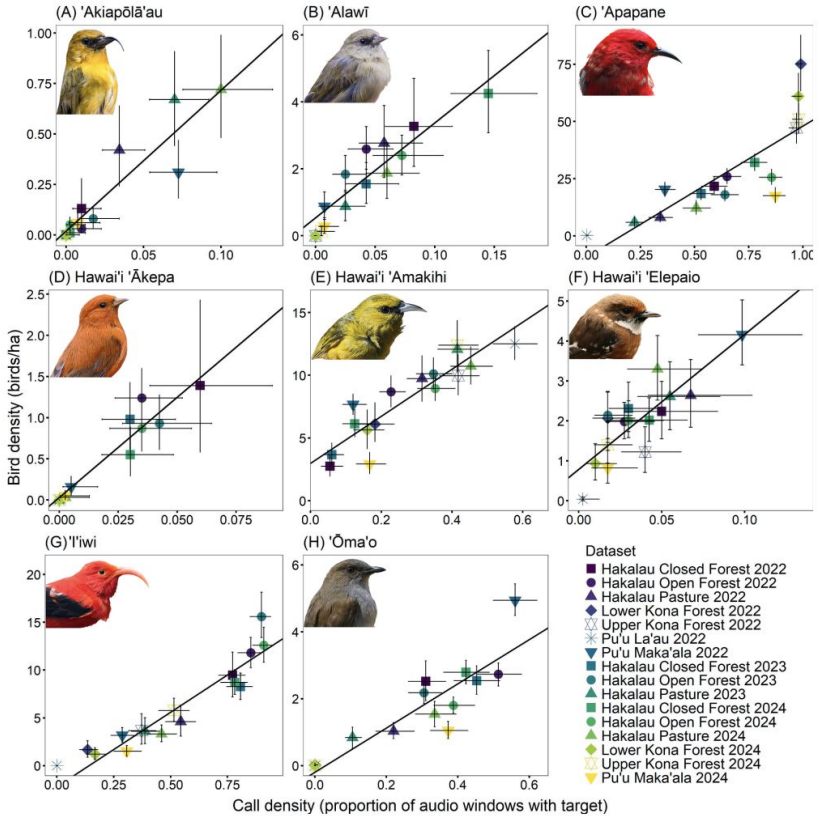
- Why estimate population size?
  - Track trends in populations of endangered species
  - Understand how populations in an area are impacted by environmental changes
  - Make informed conservation decisions

- Manual methods
  - Distance sampling along point or line transects, mark-recapture & quadrat methods
- Passive acoustic monitoring (PAM)
  - Typically used for occupancy models
  - Triangulation using time of detection, direction of arrival
  - Distance estimation based on pressure
  - Vocal activity rates, detection rates

- Estimating colony sizes of emerging bats using acoustic recordings (2016)
  - Every 10 seconds, a video frame and corresponding 1-sec. audio file were extracted
  - Pressure and energy calculated for each clip, and bat counts extracted from video frames
  - Linear correlation modeling predicts bat counts well



- Counting the chorus: A bioacoustic indicator of population density (2024)
  - Sorted audio windows into bins based on their confidence scores
  - In each bin, manually checked windows to see how many had the call
    - Finds likelihood of an actual call in each range of confidence scores
  - Estimate call density based on confidence scores of audio windows
  - Strong predictive power for bird density



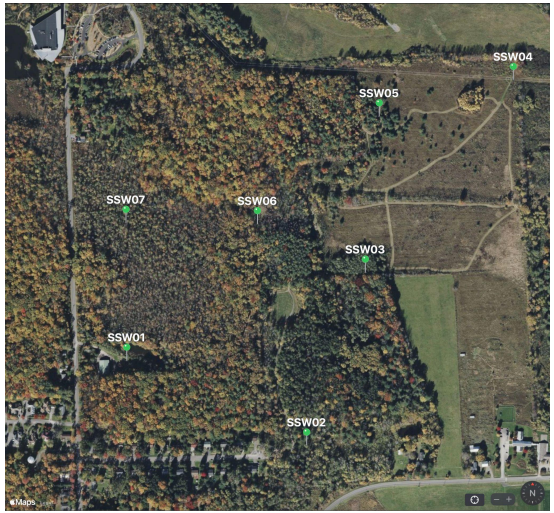
Goals

- Use PAM data to estimate bird population
- Investigate efficacy of methods such as call rate and direction of arrival

Methods

- 26 total PAM recordings paired with point counts
  - 21 from Sapsucker Woods (Ithaca, NY)
  - 5 from Sibley Regional Preserve (Oakland, CA)
  - 5-10 min per recording

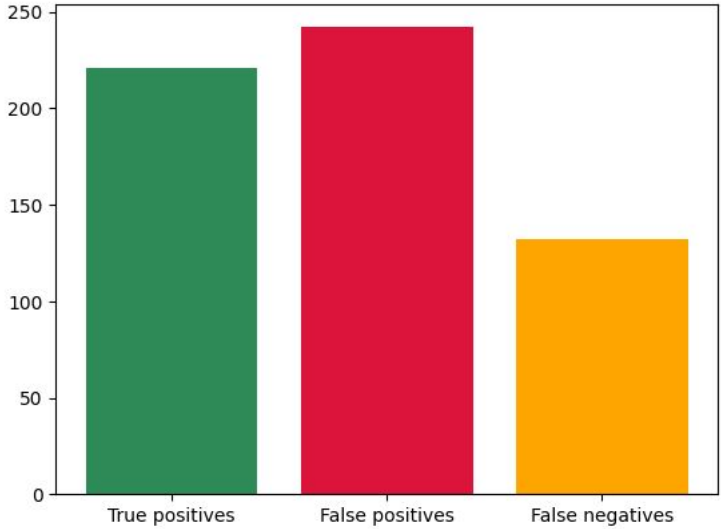
- 7 tetrahedral recordings
  - One from each of 7 sites in Sapsucker Woods
  - 10 min per recording
  - An array of 4 closely spaced microphones
    - Can calculate direction of arrival based on the time delay of the sound picked up by each microphone

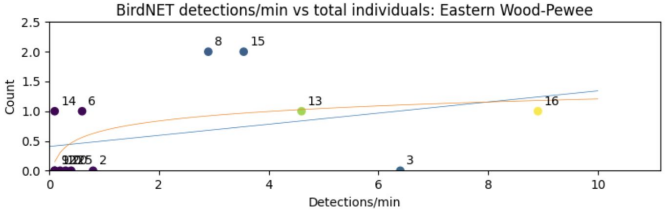


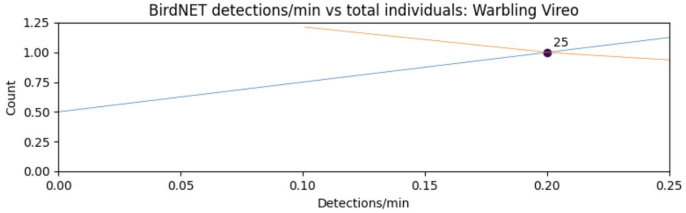
Call rate

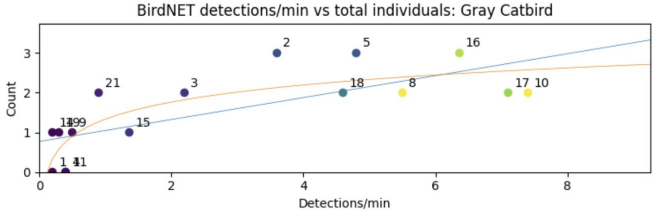
- Call rate of a species = # detections per min / # individuals identified in point count
- # individuals of a species = # detections per min / known call rate
- Theoretically use the second equation to obtain the population size of a species based on automated classifier outputs of future recordings

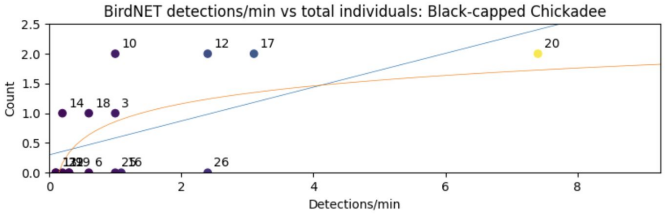
- Sensitive to variable animal behavior
- Sensitive to classifier errors (high rate of false positives)
- Weak correlation between detections and point counts
  - Pearson r = 0.001 (strength of linear relationship)
  - Spearman r = 0.208 (strength of increasing relationship)

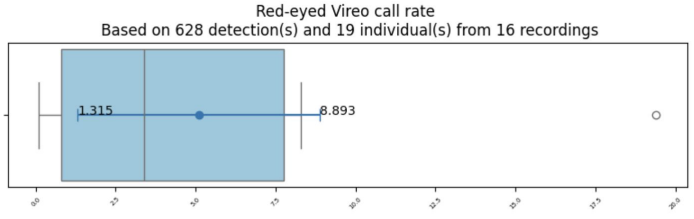


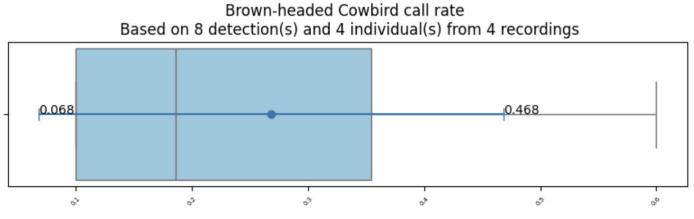

BirdNET detections/min vs total individuals: Eastern Wood-Pewee
Count
Detections/min

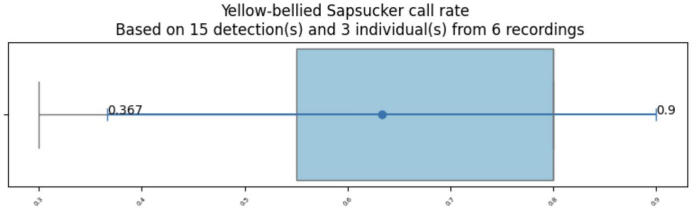

BirdNET detections/min vs total individuals: Warbling Vireo
Count
Detections/min

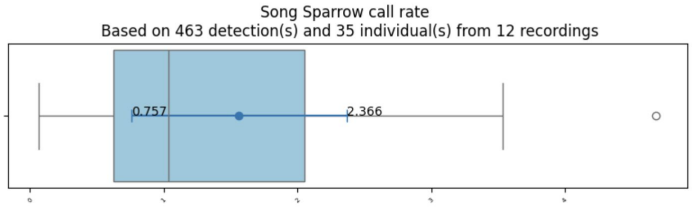

BirdNET detections/min vs total individuals: Gray Catbird
Count
Detections/min

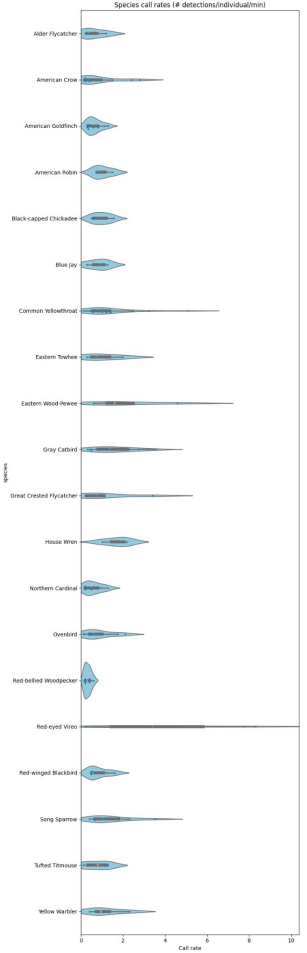

BirdNET detections/min vs total individuals: Black-capped Chickadee
Count
Detections/min


Red-eyed Vireo call rate
Based on 628 detection(s) and 19 individual(s) from 16 recordings
1.315
8.893


Brown-headed Cowbird call rate
Based on 8 detection(s) and 4 individual(s) from 4 recordings
0.068
0.468

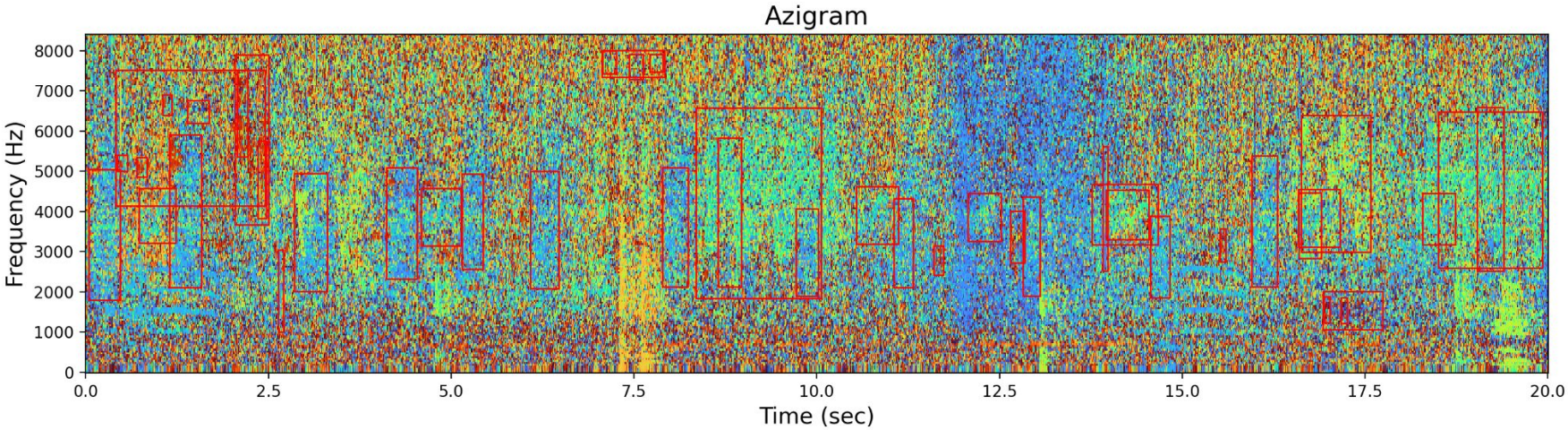

Yellow-bellied Sapsucker call rate
Based on 15 detection(s) and 3 individual(s) from 6 recordings
0.367
0.9


Song Sparrow call rate
Based on 463 detection(s) and 35 individual(s) from 12 recordings
0.757
2.366


Species call rates (# detections/individual/min)
Alder Flycatcher
American Crow
American Goldfinch
American Robin
Black-capped Chickadee
Blue Jay
Common Yellowthroat
Eastern Towhee
Eastern Wood-Pewee
Gray Catbird
Great Crested Flycatcher
House Wren
Northern Cardinal
Ovenbird
Red-bellied Woodpecker
Red-eyed Vireo
Red-winged Blackbird
Song Sparrow
Tufted Titmouse
Yellow Warbler
Species
Call rate

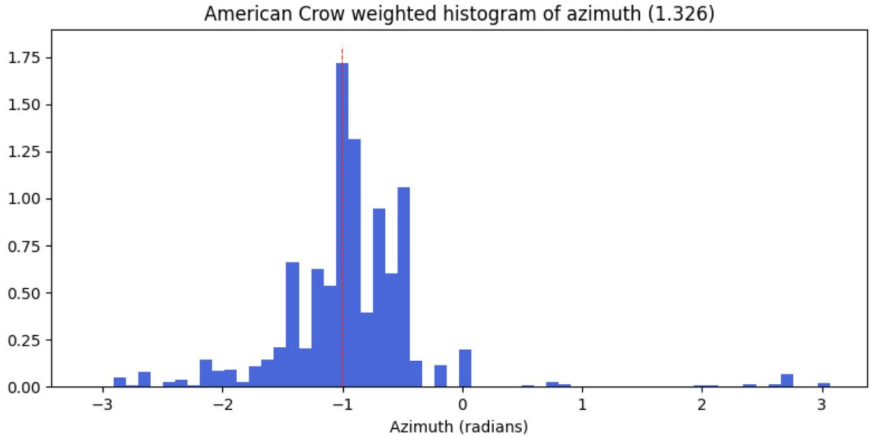
Direction of arrival

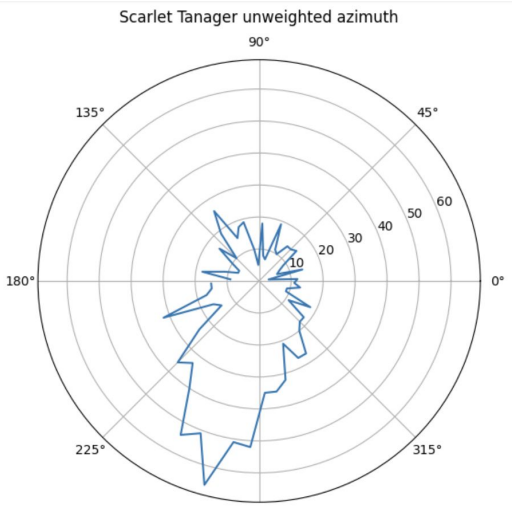
- Calculate direction of arrival (azimuth) of pixels on a spectrogram
- Each vocalization contains many azimuths - extract to determine the direction the sound came from



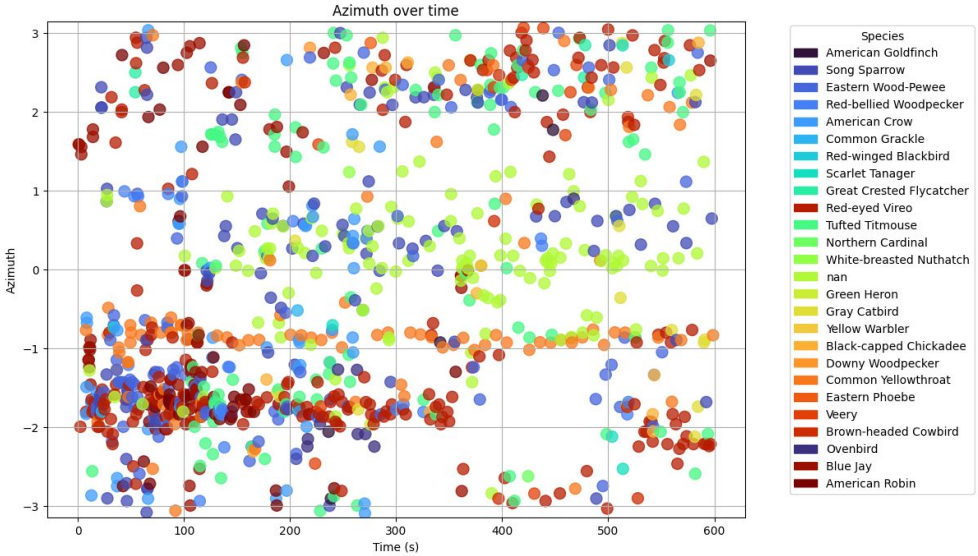
Finding directions

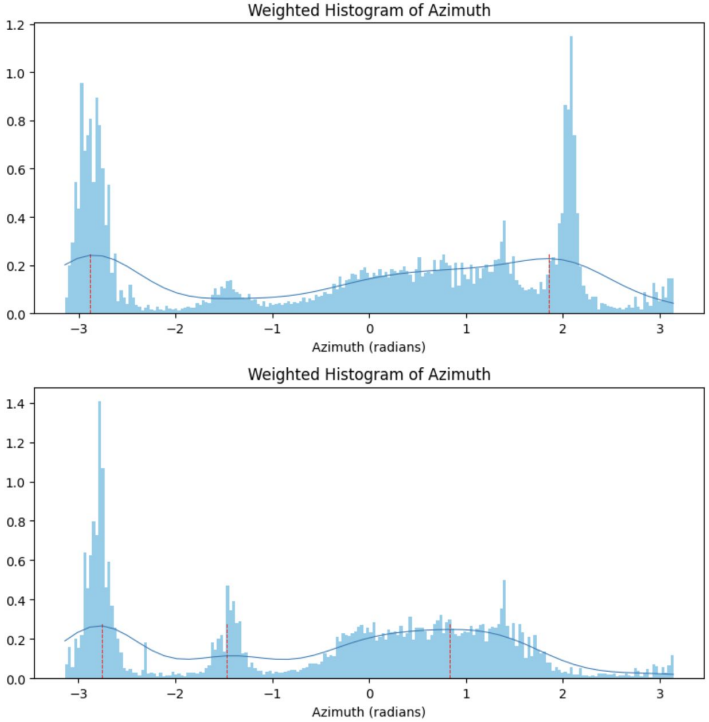
- Create histograms representing the directions calculated from a call
- Extract peaks from histograms to determine likely direction of arrival, then plot time against direction





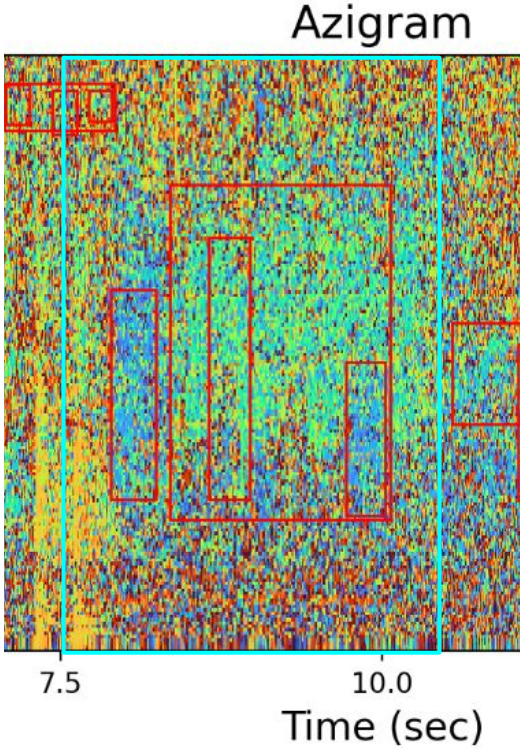
- Distant and overlapping sounds can be challenging



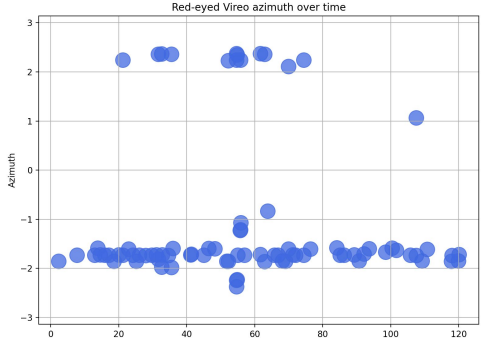


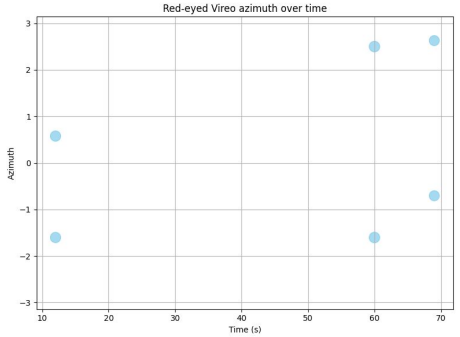
Using annotations

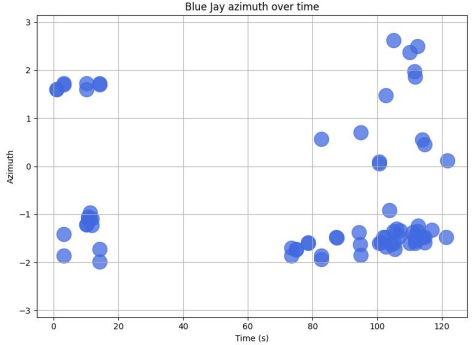
- Avoids automated detection errors
- Tighter boxes around calls on spectrogram
  - More exact time range
  - Allows us to filter out frequencies outside the call

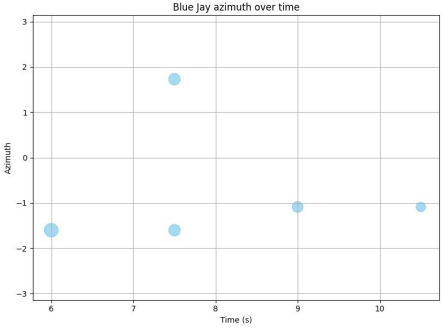


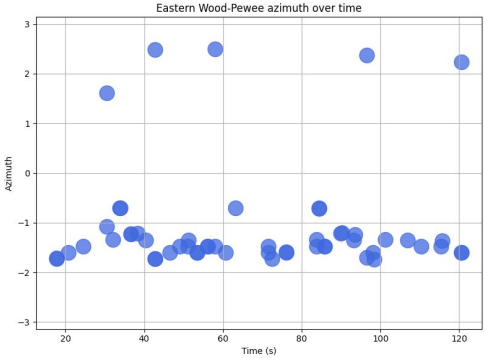
Annotations vs. detections

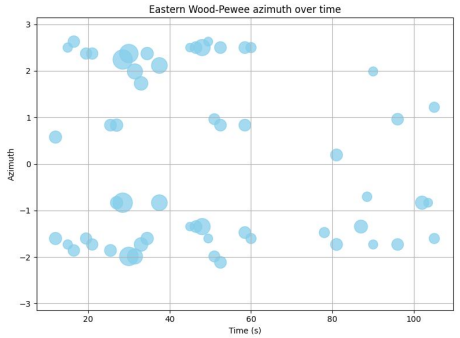


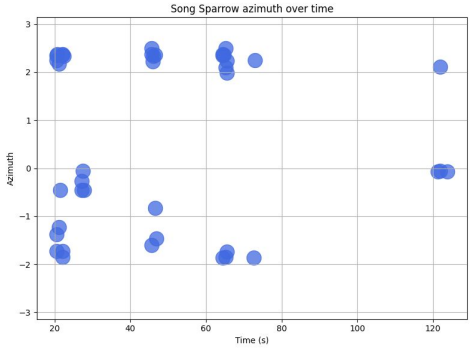


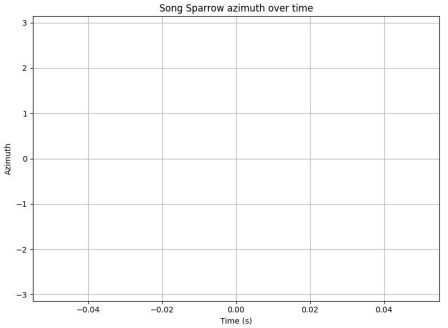






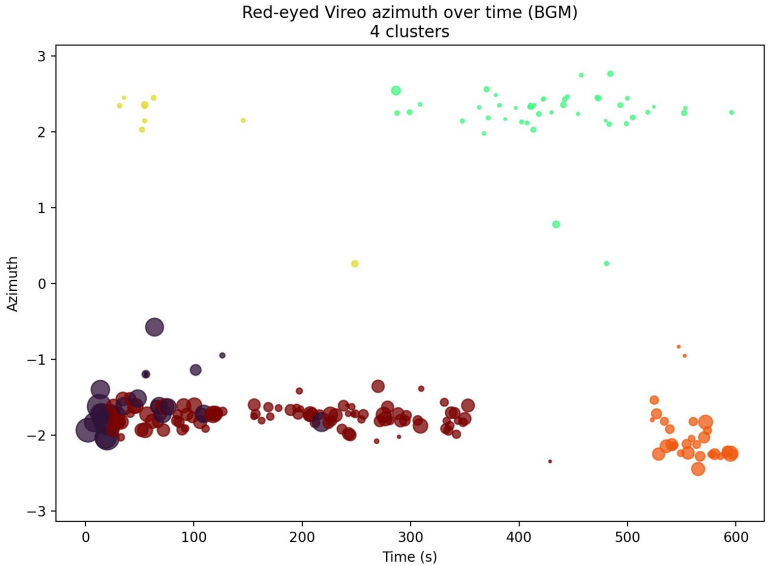


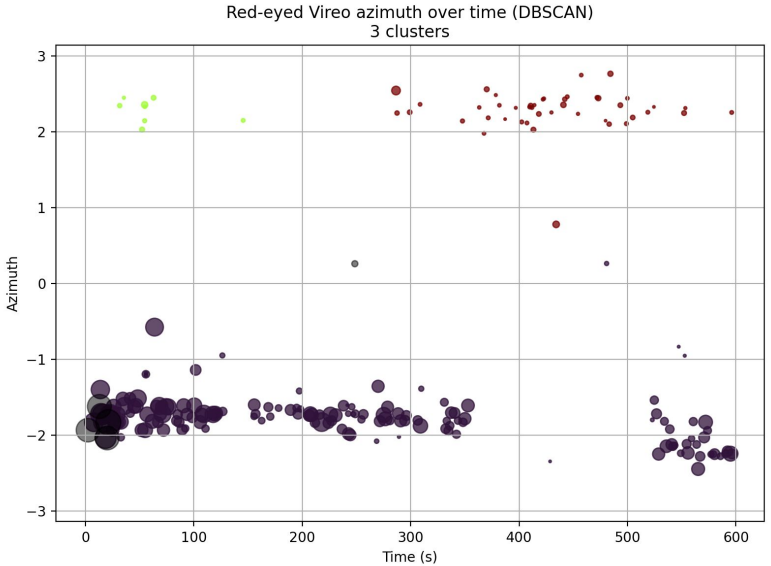




Clustering

- Clustered using Scikit-Learn DBSCAN and Bayesian Gaussian Mixture to produce population estimate





Conclusions

- Simple call rate obtained from # of detections is not necessarily a reliable method of determining population size
- Clustering based on time, azimuth, and amplitude appears promising
- Next step: Automate direction of arrival method

Acknowledgements

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