Discerning Behavioral Habits of Echolocating Bats Using Acoustical and Computational Methods

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Overview

1) **Why are we monitoring bats?**
    - What are bioindicators?
    - What makes bats good bioindicators?
2) **How do we gather data on bats?**
    - Tools, location, and target species.
    - Passive Acoustic Monitoring
3) **What tool will help us understand our data?**
    - Diving into the Bat Detective computational package.
    - Applying Bat Detective on our data.
    - Testing Bat Detective's precision and reliability.
    - Demonstrating where Bat Detective can be improved upon.
4) **How can we use this tool to understand bat behavior?**
    - What kind of information can we learn using Bat Detective?
    - What are our next steps to understanding our bats?

Assessing Ecosystems using Bioindicators

Bioindicators:
A type of organism whose unique traits allow ecosystems to be qualitatively studied.

Changes in ecosystem ⇒ Change in:

1) Population Numbers
2) Behaviors
3) Feeding/Breeding Grounds

Valuable to study ecosystems cost-effectively.

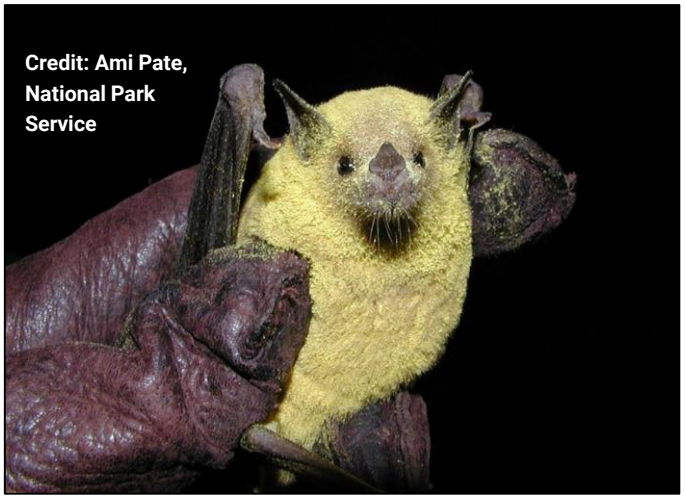
Species:	Salamanders[7]
Unique trait:	Absorbent skin.
Used to study:	Water quality.

Why are we monitoring bats?

Bats are excellent bioindicators.

- They have important environmental roles:
  - Pollinators
  - Natural Insecticides
- Bats are also present around the world.
- Bats share a unique ability to produce ultrasonic echolocation calls when active.

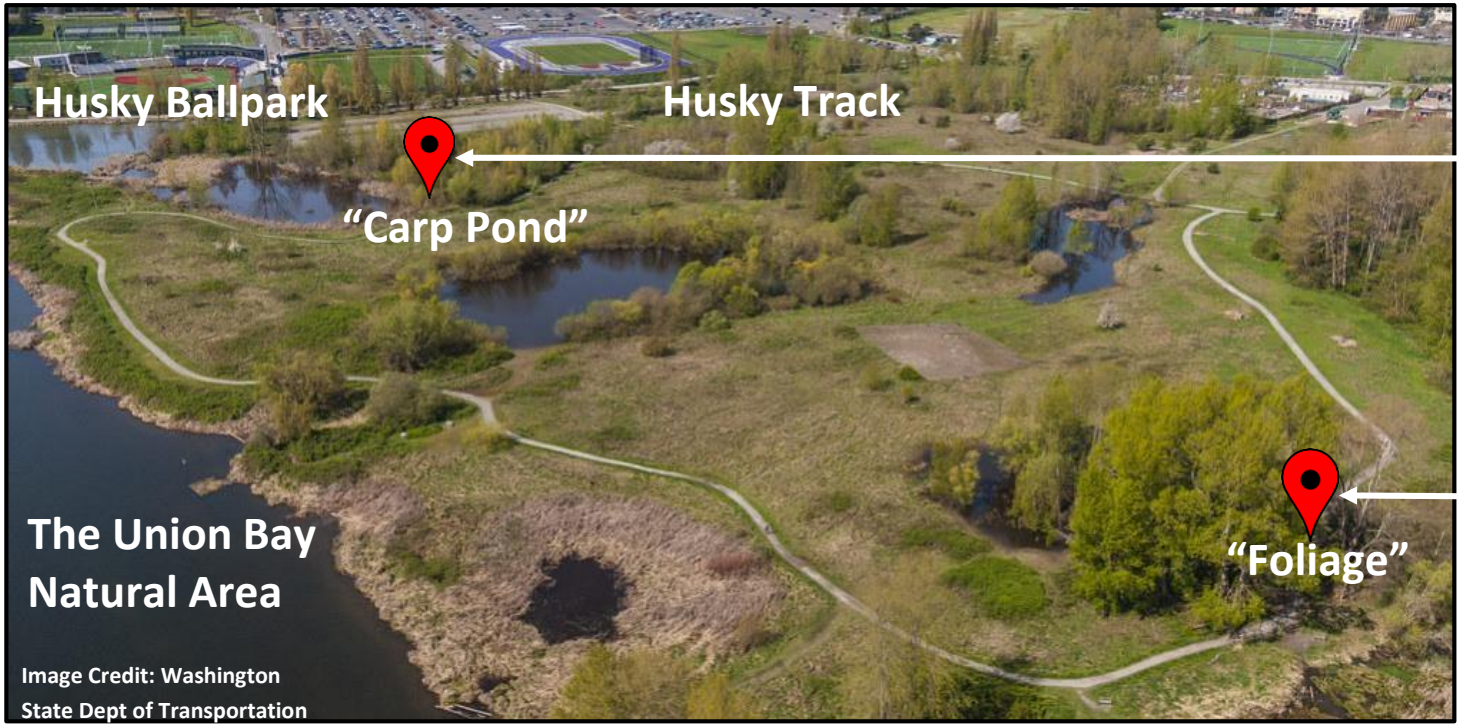
*Humans cannot hear sounds in the ultrasonic frequency range so all played bat calls are slowed down by 80% to be **audible**.



This lesser long-nosed bat is covered in pollen from feeding on nectar all night.

(Russo, 2021)

Our Devices and Location



Audiomoths

(Backus, 2019)

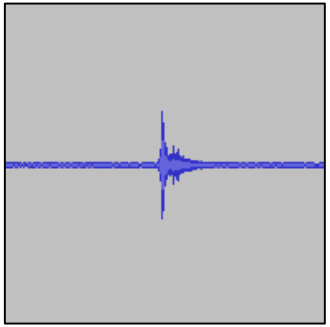
Target Species of Union Bay Natural Area

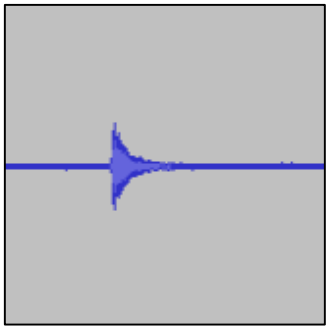
Known Bat Species

Big Brown Bat (Eptesicus fuscus)

Little Brown Bat (Myotis lucifugus)

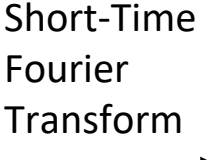
Waveform audio



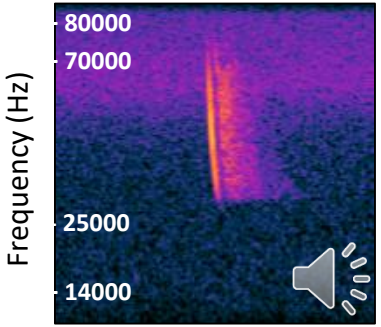


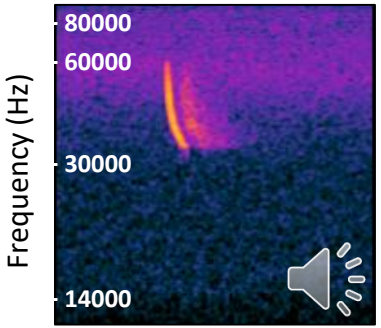
Time (ms)

Short-Time Fourier Transform



Spectrogram





Time (ms)

Image Credit: U.S. Fish and Wildlife Service Headquarters

(Backus, 2019)

Passive Acoustic Monitoring

Monitoring by listening.

Intention:

Monitor animals whose auditory cues are more valuable than their visual cues.

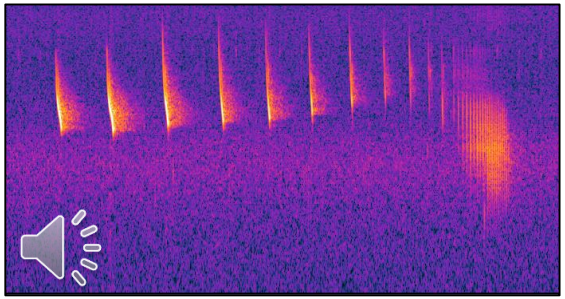
Analysis:

Signal Processing → Machine Learning

Chosen computational package:
Bat Detective by Aodha et al.[4]

A bat hunting and feeding in the night

Visual



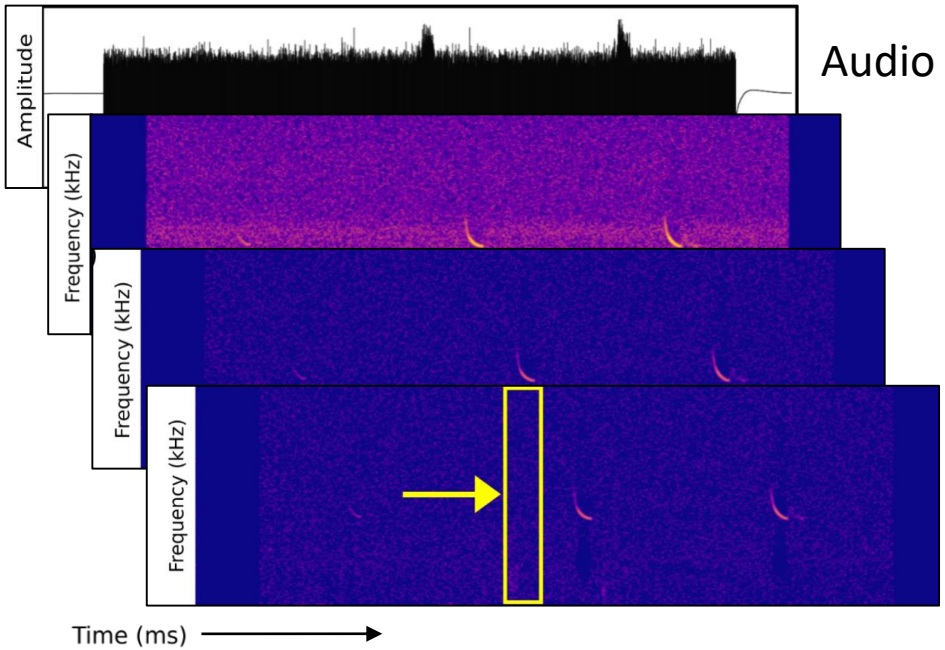
Acoustical

(Surlykke, 2014), (Sugai, 2019) , (Rannisto, 2020)

Research Question:

Could we take Bat Detective, which was developed on bats call recordings taken from Romania and Bulgaria, and use it to detect the number of calls recorded from our UBNA recordings?

Bat Detective under-the-hood



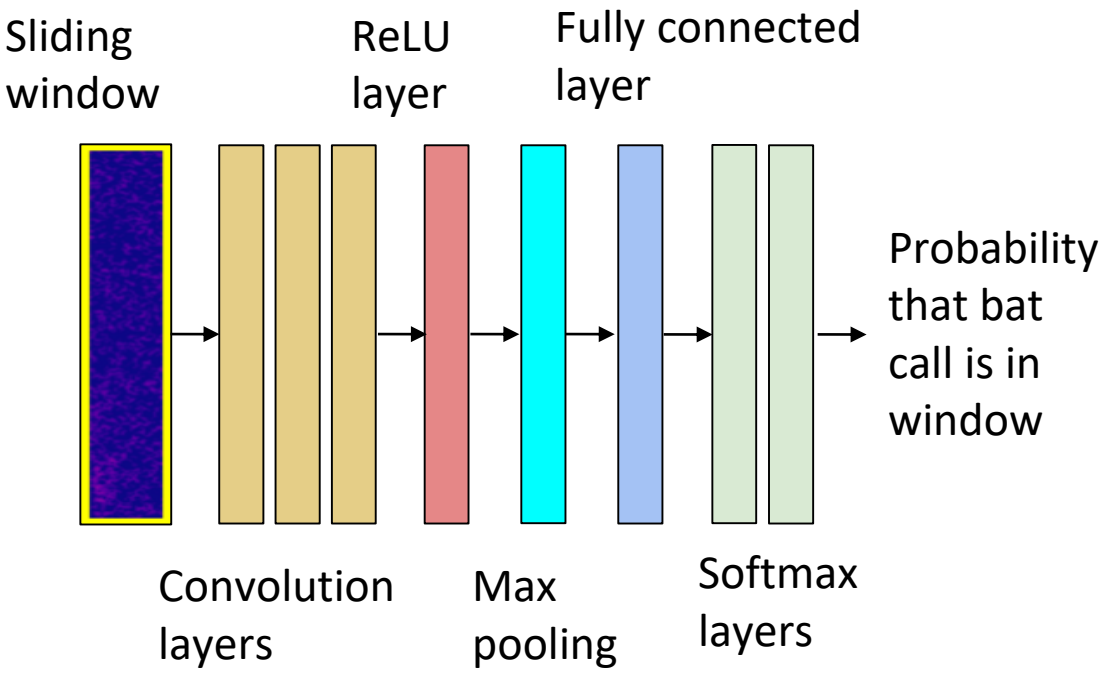
Audio Signals

- Reduce low-frequency background noise
- Easier to detect calls visually

Spectrograms

(Aodha, 2018)

Bat Detective under-the-hood

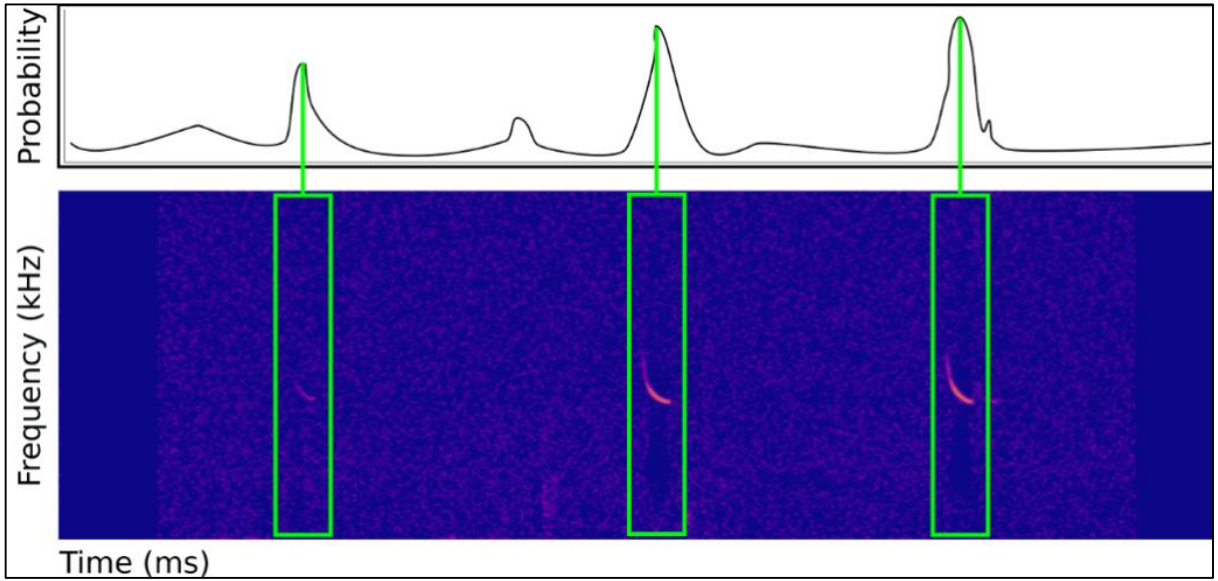


Convolutional Neural Network:

- **Input**:
  Window of Spectrogram
- **Output**:
  Detector's predicted probability that bat call exists in given window

(Aodha, 2018)

Bat Detective under-the-hood



Sliding window ⇒
Probability Curve

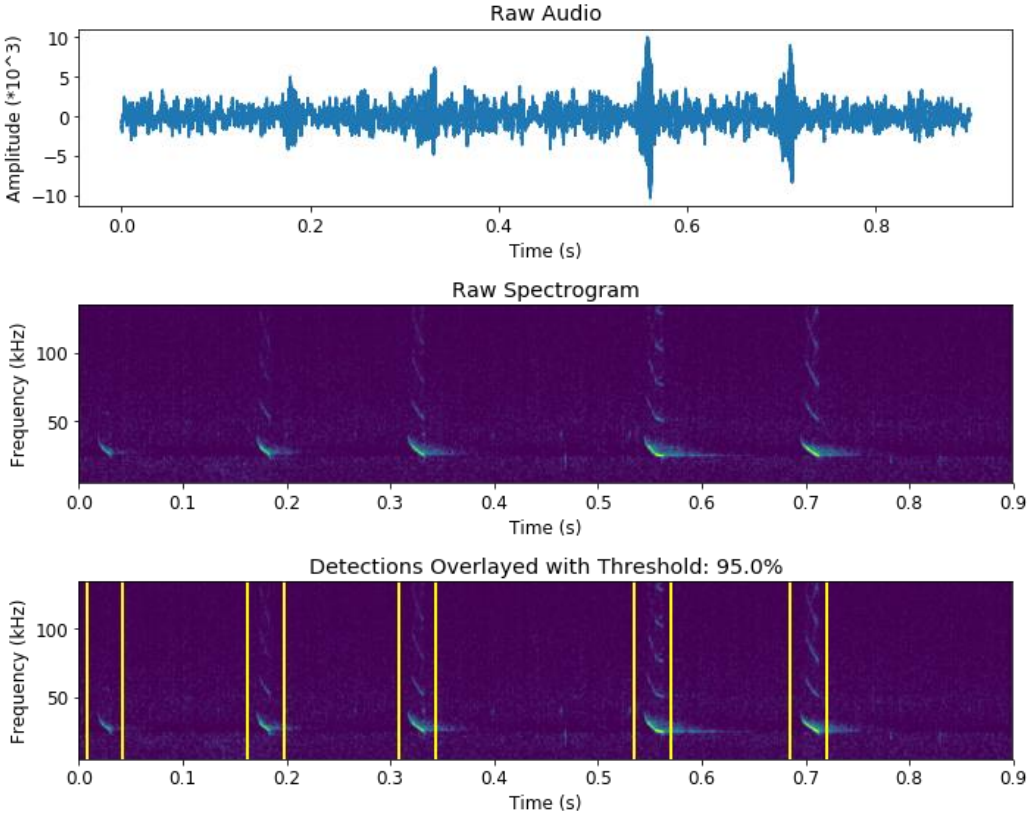
Probability Peaks ⇒
Predicted Bat Calls

User Control:

- Probability Threshold

(Aodha, 2018)

Using Bat Detective



Default Probability Threshold: 95%

Noteworthy points:

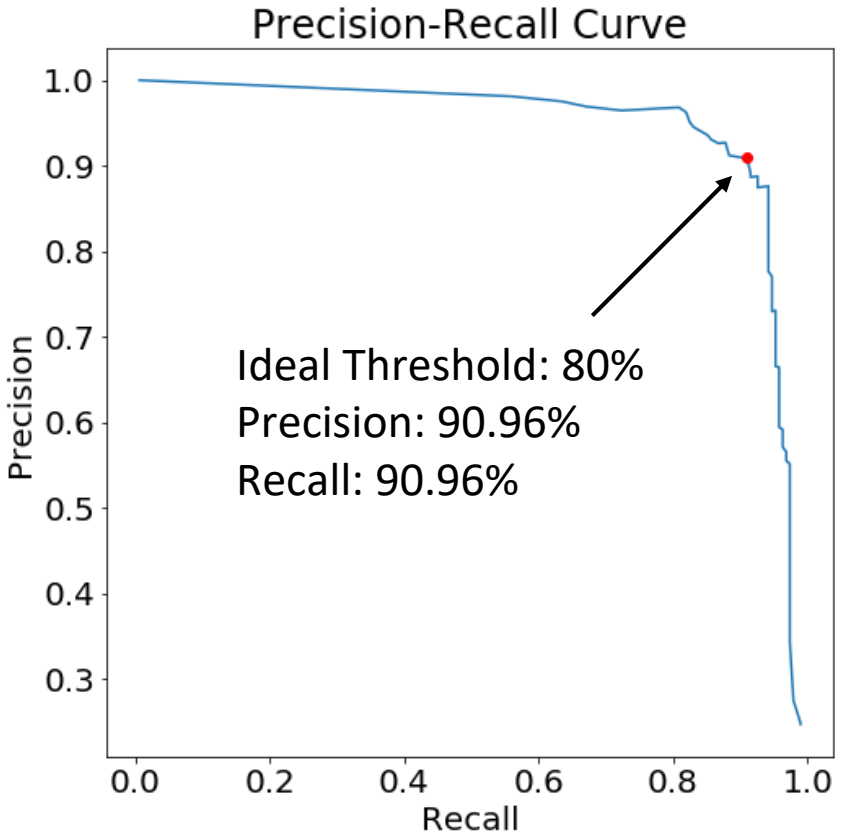
- Bat Detective works on our data even with default settings.
- Bats are a globally monitorable species.

Testing Bat Detective's Results

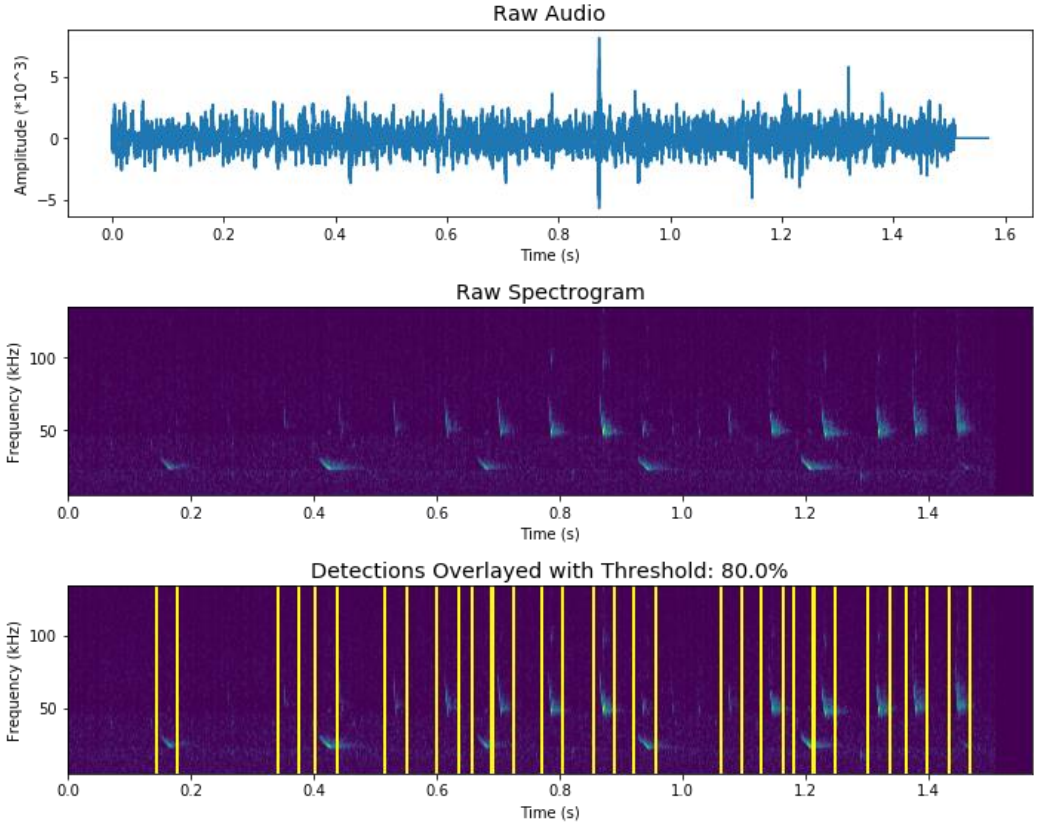
1) Compare results to manual detections done by-hand.
   - False Positive: Incorrect Detections
   - False Negative: Missed Detections
   - True Positive: Correct Detections
2) Generate a Precision-Recall curve.

$$\text{Precision} = \frac{True\ Positive}{True\ Positive + False\ Positive}$$

$$\text{Recall} = \frac{True\ Positive}{True\ Positive + False\ Negative}$$



Next step: Improve Bat Detective to include species classification



- Time-stamps do not help differentiate species.

Discussion + Future Steps

Record more data and use Bat Detective on UBNA recordings to measure:

- **Activity:**
  - Periods of most bat calls.
  - Start and end times of bat activity.
  - Fluctuation of times.
- **Species Differentiation:**
  - Difference between high frequency activity and lower frequency activity?
- **Environmental Factors:**
  - Collect environmental data to draw correlations to bat activity.

Time (UTC)	Foliage 2021/09/09	Foliage 2021/10/16
0:00:00		
0:30:00		
1:00:00		
1:30:00		LF = HF
2:00:00		LF < HF
2:30:00	HF	LF = HF
3:00:00	LF > HF	HF
3:30:00	LF > HF	LF < HF
4:00:00	LF	HF
4:30:00	LF > HF	LF = HF
5:00:00	LF > HF*	
5:30:00	LF	HF*
6:00:00	LF > HF	
6:30:00	LF > HF	HF
7:00:00	LF	HF
7:30:00	HF*	HF

Color Key	
	-> No Data
	-> No Calls Found (Checked)
*	-> *Very Few* Calls Annotated
LF	-> LF calls only
HF	-> HF calls only
LF > HF	-> More LF calls than HF calls
LF = HF	-> Data well-populated with both types of calls
LF < HF	-> More HF calls than LF calls

Any Questions?

References

1) Ecological Restoration Project Planning In the Union Bay Natural Area by Jon Backus (2019). Retrieved from: https://depts.washington.edu/uwbg/research/theses/Jon_Backus_MEH_2019.pdf
2) Biosonar (2014) by Annemarie Surlykke, Paul E. Nachtigall, Richard R. Fay, Arthur N. Popper. ISBN: 978-1-4614-9146-0
3) Russo, D.; Salinas-Ramos, V.B.; Cistrone, L.; Smeraldo, S.; Bosso, L.; Ancillotto, L. Do We Need to Use Bats as Bioindicators? Biology 2021, 10, 693. https://doi.org/10.3390/biology10080693
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5) Larissa Sayuri Moreira Sugai, Thiago Sanna Freire Silva, José Wagner Ribeiro, Jr, Diego Llusia, Terrestrial Passive Acoustic Monitoring: Review and Perspectives, BioScience, Volume 69, Issue 1, January 2019, Pages 15–25, https://doi.org/10.1093/biosci/biy147
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7) "Saving Salamanders: Vital to Ecosystem Health." United States Geological Survey.