Acoustic Monitoring of Emerald Ash Borer Larvae in Ash Tree Saplings

Cameron Arkesteyn, Victor Croitoru, Becca McCue,
Gabe Iorgulescu, Eric Otrusina

Sponsor: Morton Arboretum
Advisors: Dr. Jason Streeter, Dr. Gaj Sivandran

1 Introduction

The Emerald Ash Borer (EAB), an invasive boring beetle native to north-eastern Asia, was discovered in 2002 in Michigan and, since then, has been eliminating ash trees throughout North America, as shown in Figure 1. EAB enters ash trees and consumes away the cambium layer of the tree, or its living layer. This cambium layer is what trees use to facilitate the movement of water and food thus as EAB eats away this layer, it hinder the tree's ability to sustain itself. Certain ash trees, known as lingering ash for their ability to resist destruction from the EAB, have been shown to deter some of the EAB effects and protect the trees from these beetles. Because of EAB's destructive nature, many are trying to learn more about the lingering ash's resistive capabilities. One of these groups is the Morton Arboretum (MA) in Lisle, Illinois. The MA and USDA Forest Service would like to perform experiments on several ash tree saplings to learn more about the lifecycle of EAB larvae. This data would reveal vital information about the lives and actions of EAB, and how they specifically destroy ash trees.

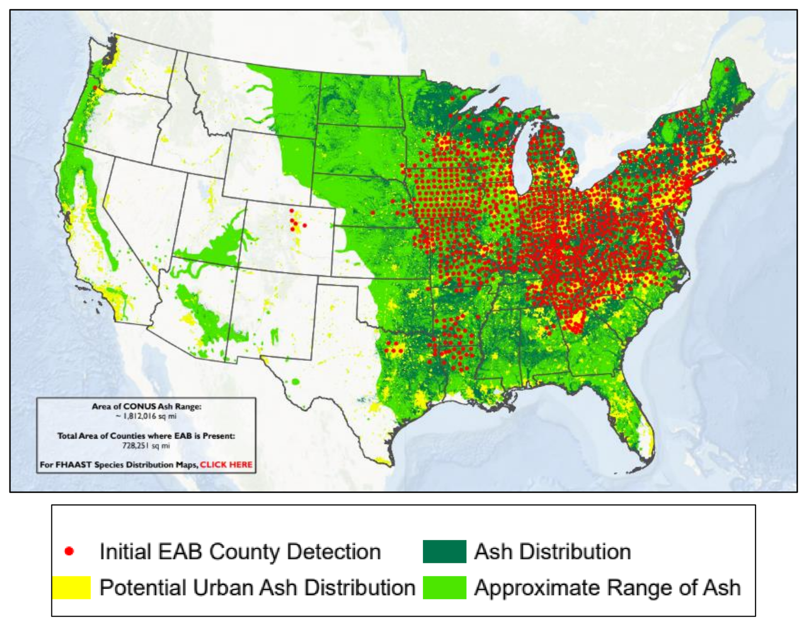

Figure 1: Map showing EAB affected counties across the United States, green denoting where ash trees grow and red dots indicating counties with EAB detections [Source: USDA APHIS, Map from January 2021]

2 Purpose/Scope

Researchers are interested in learning about the lingering ash sapling. Current methods involve taking a sample from the sapling after a predetermined amount of time. This, however, does not guarantee a fresh sample thus a device is required to improve the timing of these samples. The aim of this project is to develop a system using acoustics to monitor the presence and activity of EAB larvae in lingering ash saplings. The finished device will detect the timeframe that an EAB larva dies in a lingering ash sapling. This information allows researchers to know when to graft samples of the inner bark tissue of that sapling to reveal phenotypic information about the lingering ash sapling. The functionality of the device will improve the accuracy of the experimental results and help determine the certain trait expressed within the sapling stage that deters EAB Larvae. An image of our system diagram is included below in Figure 2.

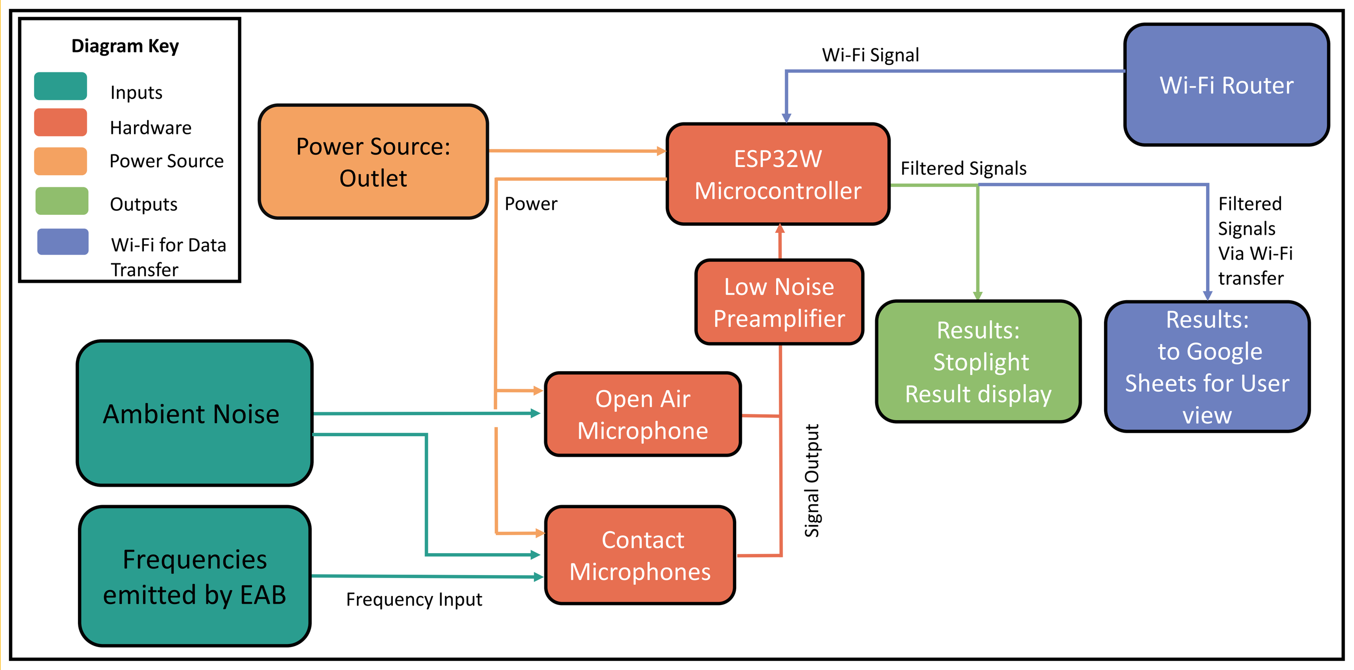

Figure 2: Overall system diagram showing different components of our system including inputs, hardware, power, Wi-Fi, and outputs. Ambient Noise and EAB frequencies will be transmitted through open air and contact microphones to the ESP32W for processing then transferred via Wi-Fi to a Google Sheets for the user to view collected data.

3 Materials and Methods

Microcontroller

The ESP32W (Figure 3) is multi-faceted microcontroller unit with onboard Wi-Fi and Bluetooth capabilities. The device uses a few Arduino-based sensors and onboard software to convert input signals into output frequencies. It will connect to the Wi-Fi at the Arboretum which will allow for the microcontroller to transfer data directly to a Google Sheet that can be viewed from any computer connected to the internet.

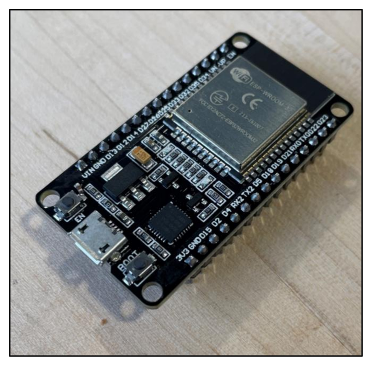

Figure 3: ESP32W Microcontroller

Contact Microphone and 805M1-0020 Accelerometer

Piezoelectric disc contact microphones and the 805M1-0020 Accelerometer are the sensors that will be attached to the sapling to detect frequencies made by EAB chewing (Figure 4,5). Both will be connected to an aluminum bracket that will be screwed into the tree and serve as a sound conduction medium. Contact microphones will be wired into the ESP32W via a potentiometer that will amplify the input signal.

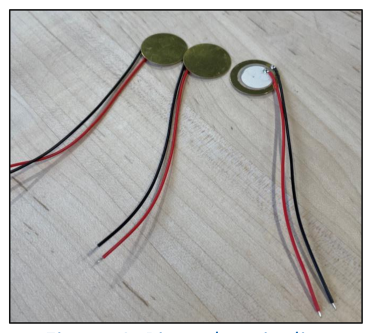

Figure 4: Piezoelectric disc contact microphones

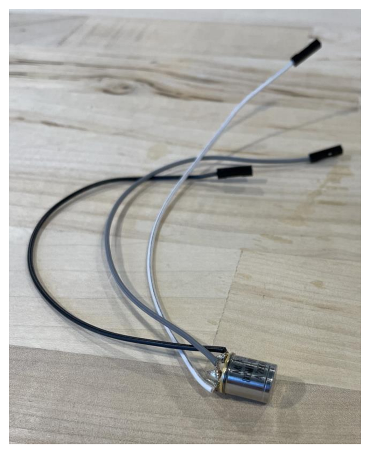

Figure 5: 805M1-0020 Accelerometer

3-D Printed Protective Housing

The ESP32 and other hardware components must be housed in a protective casing to shield them from any damage (Figure 6). The housing must be watertight, lightweight, able to fasten to the sapling, and have a removable top layer to assist in setup and maintenance. Ultimately, we decided to design our casings on SolidWorks and 3D print the designs with an ASA filament, providing optimal layer adhesion. The top layer will be secured by screws with silicon paste for waterproofing as well as being fitted with notches for the fasteners to secure the hardware to the sapling.

Figure 6: 3-D Printed Protective Housing for ESP32W Microcontroller showing latches for fastening, lid, and screw

Silicone Cable Tie Fasteners

We will be utilizing adjustable silicone zip ties (Figure 7) to secure the hardware and housing to the sapling during lab testing. These silicone zip ties fit our needs because they are reusable, causing minimal harm to the sapling, will not interfere with acoustic data, and will be compatible with our 3-D printed housing designs.

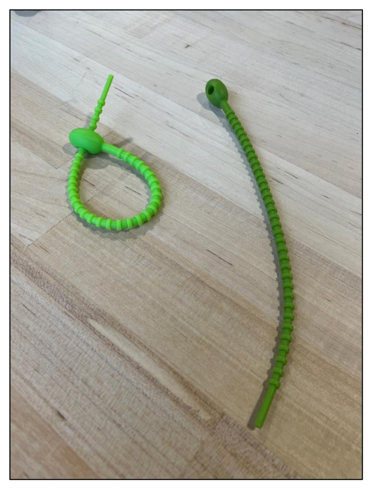

Figure 7: Adjustable Silicone Zip Ties for fastening

Stoplight Results Display

There will be two methods for visualizing the results, one of which is through an LED stoplight board shown in Figure 8. This will be displayed close to the ESP32W Microcontroller and show researchers when EAB are active, passive, or no longer alive. A green light signifies that the setup is currently hearing live EAB, a yellow light signifies that it recently heard EAB activity, and red light signifies that the EAB are dead and that it is time to sample.

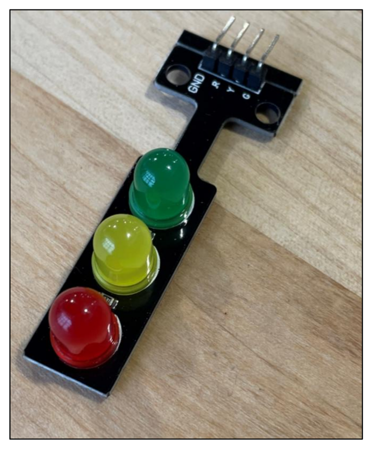

Figure 8: LED Stoplight board

Filtering

To circumvent any noise constraints, a 7th order Butterworth bandpass filter is implemented with a range of 1200 – 1800 Hz as, through our research, this is the frequency for EAB.

Data Transfer

The ESP32W, while connected to Wi-Fi, calls a certain URL that interacts with a Google Script. The script takes certain values in the URL and puts them into a color-coded Google Spreadsheet, also automatically adding them into a bar graph for visualization of data.

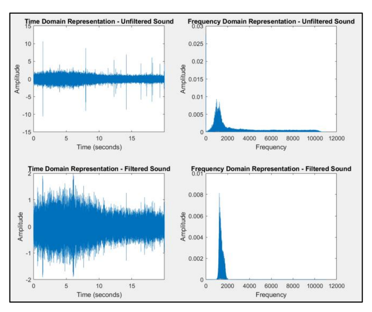

Figure 9: Example of our audio filtering in MATLAB with original signals on the left-hand side and filtered signals on the right

4 Results

Utilizing these materials, the final system includes contact microphones and an ambient microphone all attached to the sapling with the silicone cable tie fasteners. These hardware components will transfer data via wires to ESP32W where the processing and data analysis will occur. A sketch of our system is below in Figure 10. After processing within the ESP32W, frequency data will be transferred with Wi-Fi to a separate Google Sheets document and put into separate columns, one for each component of data acquisition. This Google Sheets document will serve as a way for the user to view the data in any location with internet connection. The document is programmed to create a graph for visualization alongside the data as well as color-coding the frequency values based on our knowledge of EAB activity frequency. Like the stoplight results display, green signifies values in our desired range of EAB activity, yellow signifies values that are close to this range, and red signifies values that are not close to our range. An image of this Google Sheets is below in Figure 11.

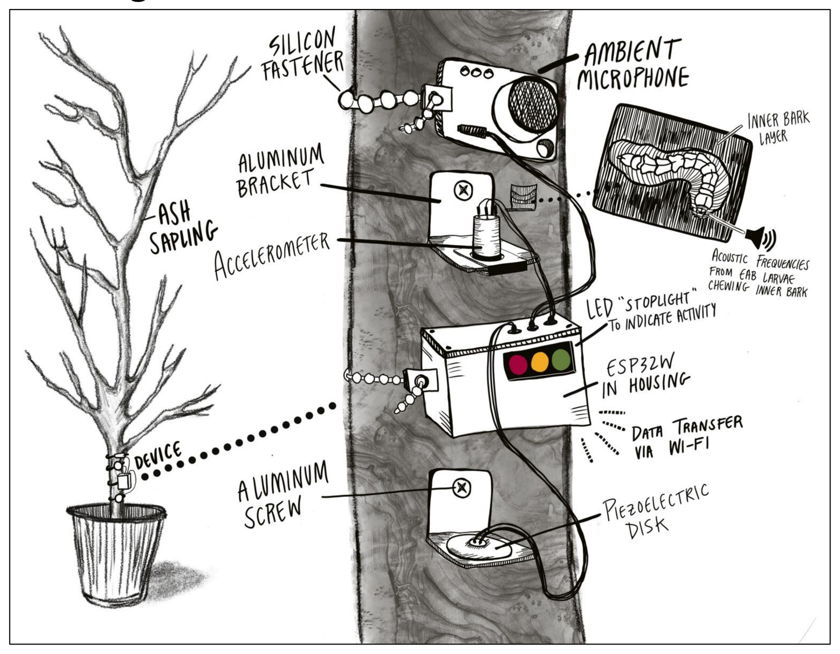

Figure 10: Drawing of system as a whole [Drawn by Becca McCue]

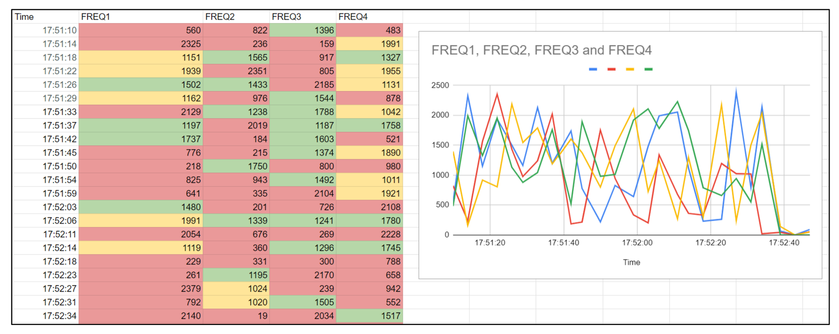

Figure 11: Google Sheets to display data acquired by device and transferred via Wi-Fi

5 Conclusion

In conclusion, our system will help researchers in learning about lingering ash saplings to protect future generations of ash trees. Researchers will have a better idea of when to take samples to ensure freshness for phenotyping trials, and accuracy in their results. Due to an inability to test our device on live larvae, we believe there is still room to improve on this project. Next steps could include advancements in the sensitivity of existing contact microphone set ups and ensuring EAB signals can be picked up with the hardware in use. Further research into signal amplification may be beneficial. Ultimately, we are excited to have worked on this project and hopeful that our device can help researchers learn about the EAB and help slow the spread of this invasive species. In the future, by using the user's manual, it would be possible for the Arboretum to implement our system for other studies to have larger study groups and a greater efficiency.

6 Acknowledgements

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