Avian Biodiversity and Abundance at the CSU Mountain Campus: An Acoustic Monitoring Study

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CSU University Honors Program, Fall 2024

December 13, 2024

Abstract: The research conducted for this thesis and the overarching project encompassing it measured the biodiversity of avian species present at the CSU Mountain Campus through auditory data collection. We deployed auditory recording devices at the beginning of the summer of 2024 and allowed them to record data on the calls of avian species present across the campus until the end of the summer. We found that the standing forest habitat of mixed conifers had the highest amount of call activity, but the lowest amount of unique calls associated with it. However, the devices deployed in the riparian and the burn stand habitat zones had much higher diversity and unique species despite having a lower volume of recorded calls. Because unique species were found throughout the campus and there was a high number and diversity of calls at each of the three habitat types, we encourage future management and conservation of the CSU Mountain Campus to incorporate all three of these habitat types into land management practices. This is of extreme importance as the campus continues to grow and usage of the trails through these habitat types increases, potentially affecting the avian populations present.

Introduction

Across the globe, there is an increase in recreational trail usage (Bötsch et al. 2018) which we can see mirrored in the increased student presence at the CSU Mountain Campus as more classes become offered at the campus and those classes grow in size. The CSU Mountain Campus provides important educational opportunities for its students. With a growing number of students visiting the Mountain Campus each summer (*Academic Programs*, 2023), we sought to create a more in depth understanding of the avian biodiversity present in the area. Located in the Rocky Mountain Range of northern Colorado, the CSU Mountain Campus primarily consists of a strongly coniferous forest (*Academic Programs*, 2023). This habitat type is known to support high regional biodiversity, especially of birds (Deluca and King, 2014; Martin et al. 2021). However, increased human activity in montane environments has been associated with reduced avian species presence both near and further away from the trail (Bötsch et al. 2018; Deluca and King, 2014). This could be of concern for the biodiversity of the Mountain Campus if proper care and management action of local avian biodiversity is not taken. In the case of a site like the CSU Mountain Campus, management of the local ecosystems could revolve around education of the students, staff, and other visitors that focuses on the species present at the site and gives insight into the negative effects of increases in human presence on bird species and the larger ecosystem as a whole.

Because of the relative high species richness of mountain ecosystems in North America, management that prioritizes the preservation of healthy habitats is key for continuing the positive impacts of these biodiversity hotspots (Deluca and King, 2014; Martin et al. 2021). Conservation of this forest type is important not only to preserve the native biodiversity present, but also to continue offering the fullest possible experience of the Mountain Campus to the students, faculty,

and staff that visit each year. It is important to first know what species are using the habitat and the important resources for them when creating monitoring and management plans for habitat types(Sullivan et al. 2018). Providing reliable estimates of biodiversity, such as occupancy and abundance estimates, requires a sufficient dataset. In our case, we utilized auditory data spanning three months in order to achieve this goal.

Ours is not the first study to use auditory monitoring to develop biodiversity measurement. Previous studies have revealed that the use of acoustic data can be an effective and non-invasive way of measuring the biodiversity of a region (Gasc et al. 2017; McGrann et al. 2022). Acoustic studies have become a reliable and accessible tool for assessing the biodiversity of an area (Gasc et al. 2017; McGrann et al. 2022; Towsey et al. 2014), becoming larger in scope and more complex as technologies have improved (Towsey et al 2014). These developments and previous research into acoustic biodiversity made our project possible to achieve within in the short time frame of a single academic semester.

A number of studies have indicated that acoustic data may be beneficial for gathering species richness for an area, but are less beneficial for gathering biodiversity data for individual incidences (Gasc et al. 2017; Kotian et al. 2024; Towsey et al 2014). This is due to the very nature of audio data. It is difficult to tell one individual from another with this type of data, though distinguishing species from one another is a far more achievable task (Gasc et al. 2017; Kotian et al. 2024). This potential pitfall when using acoustic data ought to be kept in mind for any analyses that utilize it. However, acoustic monitoring data has been successfully implemented for inferring population estimates including occupancy and abundance estimates (Bombaci and Pejchar 2019). If kept within the inherent limitations that present when using acoustic data, it can be a reliable measure of species biodiversity, especially avian species.

Acoustic monitoring has been shown to effectively work for assessing biological diversity of species richness in a variety of habitats including dry tropical forests (Kotain et al. 2024). Acoustic studies in montane ecosystems have been able to monitor specific species for territory shapes and even changes in vocalizations due to various environmental factors (Reid et al. 2022). While this data cannot be used to determine territories or home ranges of individuals, it can also be used to map the extent of species and the habitat exclusivity of some species at the CSU Mountain Campus through the monitoring of calls alone. Similar studies of acoustic diversity have shown that automated, acoustic data can be a useful way to determine species richness over habitat-diverse swaths of land (McGrann et al. 2024). The landscape we measured contains three main habitat types over which we were able to synthesize biodiversity data similar to how estimates of abundance and occupancy were gathered by Bombaci and Pejchar (2019) through auditory data.

Methods and Materials

To assess avian biodiversity as the CSU Mountain Campus, we collected data during crepuscular hours, when birds are most active, in order to collect sufficient data to monitor avian biodiversity. Furthermore, the data for the project as a whole needed to span the entirety of the season so as to get the most holistic understanding of the ecosystem processes taking place at the Mountain Campus. This thesis project captures only a piece of the larger study set to monitor avian biodiversity at the Mountain Campus through long term acoustic collections with the intention of supporting ecological research and education. Even though on a smaller scale, the thesis project presented also required good data that was as accurate as possible at representing

the natural day to day activities of the avian species present was still a necessary component of the research.

We placed a total of 24 small audiomoths, acoustic recording devices that can be programmed to collect auditory data at specific times and for a set amount of time prior to being deployed, around the mountain campus. In the smallest of the three habitat types, the riparian zone habitat, we deployed 6 audio units where we hoped to get a representative amount of bird calls without audio being overpowered by the river or other background noise. In the burn scar habitat, we deployed a total of 8 audiomoths. Our largest section of habitat was the mixed conifer forest present at the CSU Mountain Campus. Here, we deployed a total of 10 audiomoths to best cover the entirety of the habitat type. Preprogrammed to capture data at dawn and dusk each day, the audiomoths were prepared to be collecting data when we found the majority of bird species are active. Each unit was attached to a tree, or some other form of sturdy vegetation when no trees were available and the location marked with a GPS location. This placement was intended to reduce the background audio that could make it difficult to hear and extract bird calls on particularly windy or rainy days. To further reduce human impact on the study, audiomoths were deployed a minimum of 100 meters from the nearest trail or development. This was intended to reduce potential impacts on species presence from trail use. Marking the location of the devices was monumental in finding them later and will be of importance for future deployment and expansion of the project in the future. The devices were left in place after being deployed without human intervention for the summer until their retrieval at the end of the data collection period. The audio units were placed in early June and remained in place until late August when they were collected again. Leaving the devices without any human interaction for this time period minimized the invasiveness of the data collection and encouraged behaviors that would be

expressed with no humans present. After the collection time was completed, we retrieved all of the audiomoths and extracted the audio from them for analysis.

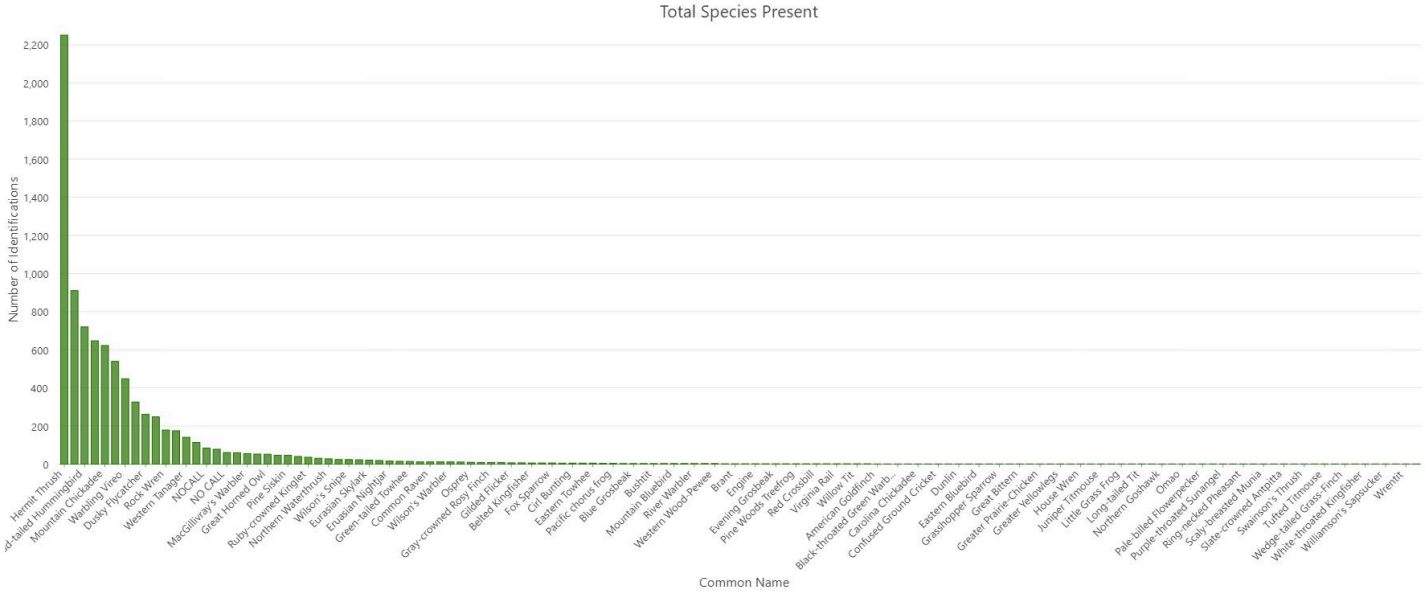
We downloaded all acoustic recordings from each of the audio units and organized and stored the audio files using online cloud storage. For the thesis, the five minute clips from the morning and evening of each day were analyzed by the desktop application BirdNet Analyzer available from the Cornell Lab of Ornithology. The application was tuned to only identify birds present at the latitude and longitude of the CSU Mountain Campus, longitude of -105 and latitude of 40. Each species identified by the application for the individual audio clip was transferred to a text file and included a confidence interval for the identification. Once all of the files for each of the audiomoths were run through the program and the output data compiled into a series of text files, the data was transferred into an Excel spreadsheet correlating the species identified with the auditory unit and the date of the identification. As species were identified and transcribed, a cross examination was performed. This included a comparison of species identified by the BirdNet Analyzer with a compiled list of species identified at the CSU Mountain Campus and uploaded to the open access eBird database. This database, also available through the Cornell Lab of Ornithology, is free to use and relies on citizen science for submissions of birds identified as well as the monitoring of the accuracy of this data. For this reason, we felt confident in the accuracy of these collections as a source of cross referencing sightings and auditory identifications for this thesis and the larger project.

Once the spreadsheet was complete, the data was converted into a .csv file and brought into a map project using ArcGIS Pro 3.2. This table, which also contained the latitude and longitude of each audiomoth, was then used to create the avian diversity map of the mountain campus (*Figure 2*). The locations and labels of the individual audiomoth units were used to

create the different habitat types present that we identified at the beginning of the project. The points associated with the audiomoths and the species found at each one were further used to create the diversity graphs present on the map. Together, the diversity at each audiomoth and the habitat in which the device was placed create the larger image present of species competition based on habitat type at the mountain campus.

Results

Figure 1: A bar graph analysis of each species of bird, as well as several other species recorded, present at the CSU Mountain Campus and the associated number of recorded calls for each species



We identified 133 different sounds across all 24 audiomoth units placed at the CSU Mountain Campus, see Figure 1. The vast majority of these calls were avian, but we were also able to capture several amphibious species and auditory data reflecting the human presence at the Mountain Campus (*Figure 1*). Of these species, 53 were identified a single time out of over 8,000 records spanning the three different habitat types at the Mountain Campus (*Figure 1*). We also recorded 155 instances of no calls being recorded or detected by the BirdNet Analyzer over the 5 minute operating time (*Figure 1*). We deployed 8 audiomoth units in what we identified to be a burn scar from a previous fire, creating what we identified to be “Burn Scar Habitat”

(*Figure 2*). In Figure 2, these "Burn Scar Habitat" units are labeled as 1, 2, 3, 22, 23, 25, 26, and 33 based off of the ARU assigned to them at the beginning of the project. Another 10 of the recording devices, labeled 6, 7, 9, 10, 14, 17, 18, 19, 20 and 31 on the map provided as Figure 2, were located within what we identified as a "Mixed Conifer Forest Habitat" (*Figure 2*). This old growth stand of forest represents the largest habitat type at the Mountain Campus and the surrounding areas. The final 6 auditory recording devices, labeled 8, 12, 13, 15, 27, and 29, were located in the smallest of the habitat types present; we identified this area as the "Riparian Habitat" at the Mountain Campus (*Figure 2*).

While observed variation was found among each habitat type, some species were more prevalent than others, in either raw numbers or in presence across the landscape. The most abundant species by far was the hermit thrush as it was captured a total of 2,250 times (*Figure 1*) with at least one occurrence in all three habitat types (*Figure 3*). The hermit thrush was most abundant in the Mixed Conifer Forest Habitat making up 52.4% of calls identified there (*Figure 3*). While not as commonly heard in the other two habitat types, this species was still present in both (*Figure 3*). Other species were also heard in high abundance and across different habitat types as well, these species include the Lincoln's sparrow and the broad-tailed hummingbird. By being spread across all three habitat types, the adaptability of these species to a wide range of environments and conditions becomes apparent. Similarly, many species had only a few recorded calls and were only captured in specific habitats, demonstrating specificity to a certain habitat type or resource.

Our results show that each of the habitat types are relatively diverse. We recorded 2,509 individual calls being identified in the Riparian habitat, 3,312 individual calls in the Mixed Conifer Forest, and 2,857 individual calls in the Burn Scar habitat (*Figure 3*). Between the

habitat types, it is clear that more avian activity is taking place in the Mixed Conifer Forest sites because of the high number of calls. However, upon further inspection the Mixed Conifer Forest Habitat has the lowest number of species being recorded despite having the highest number of calls (*Figure 3*). There are fewer species that make up over the 2% minimum threshold of the pie graph figure and this habitat type has the lowest percentage of unique species that make up less than 2% of the recordings (*Figure 3*). In contrast, the Riparian Habitat and the Burn Scar Habitat both have more species making up over 2% of the calls and have higher percentages of unique species present (*Figure 3*). Of all of the habitat types the riparian zone of the Mountain Campus appeared to have the highest number of unique species with over 16% of the calls identified being from species making up fewer than 2% of the total.

Each habitat type had at least one species that was captured only within the boundary of the habitat type at the Mountain Campus. These unique species mark the importance of each habitat type to specialized animals reliant upon them for resources or other survival means. We identified 35 unique species to the Burn Scar Habitat (*Figure 1*; *Figure 3*). Another 48 species were identified to be unique to the Riparian Habitat and the Mixed Conifer Forest contained only 7 unique species (*Figure 1*; *Figure 3*). These findings demonstrate that high abundance of animals, such as in the Mixed Conifer Forest Habitat does not necessarily indicate high diversity in occupance. The smallest of our habitat types, the Riparian Habitat, contained the highest number of unique species despite having the smallest amount of space and having the fewest calls associated with it. We can also see through these findings that undisturbed habitat such as an old growth forest may also have reduced niches or resources for high abundance of diverse species such as was recorded in the Burn Scar Habitat of this project.

Figure 2: A map of the audiomoth points associated within the habitat type of their deployment for this study. Audiomoths are labeled by ARU in their associated habitat type. Audiomoth "LLL" represents a future location for ARU 33 that is further from the trail, thus better for data accumulation

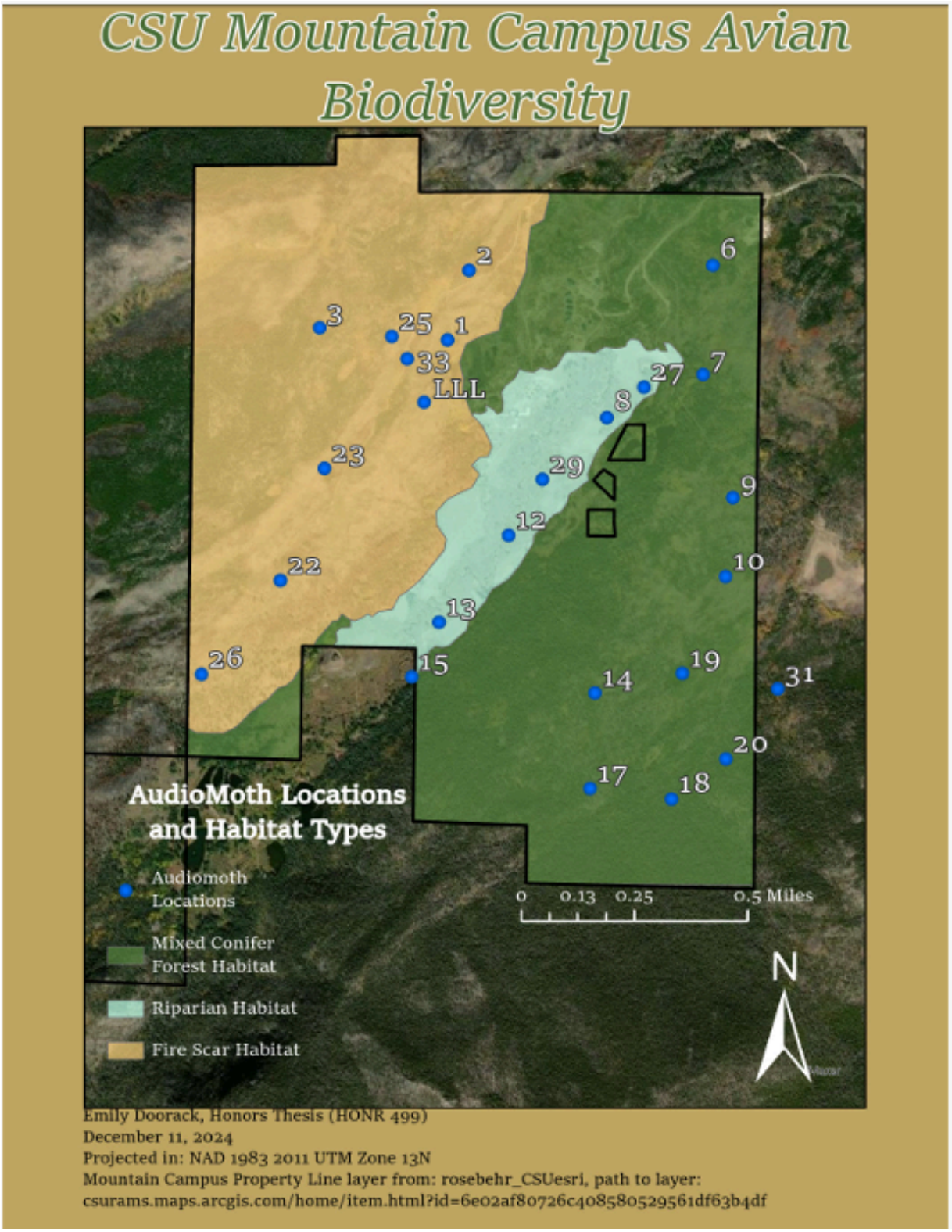
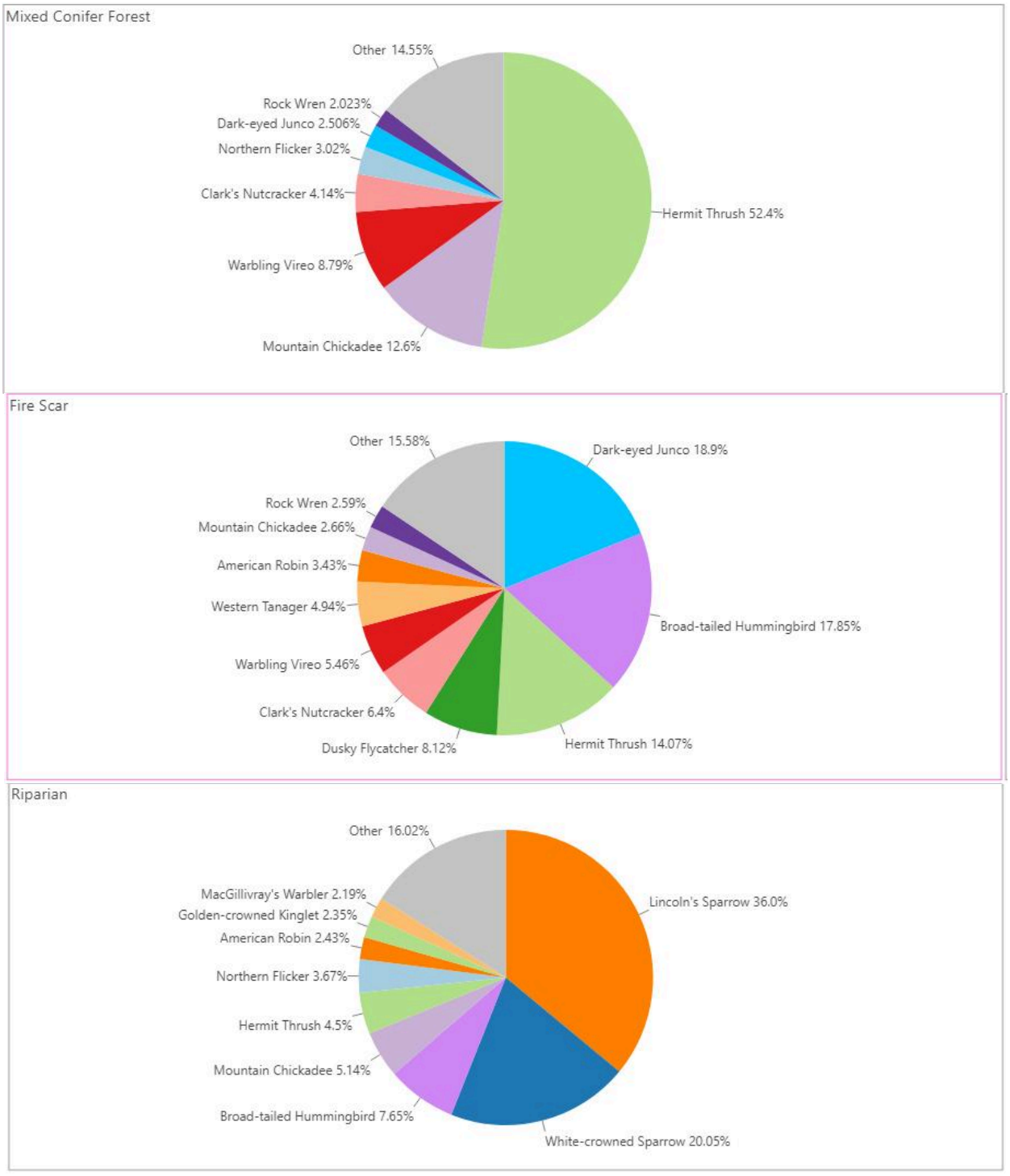


Figure 3: pie charts of the three habitat types present at the CSU Mountain Campus entitled "Mixed Conifer Forest", "Fire Scar", and "Riparian"; Calls of each species present were accumulated and shown with a 2% minimum frequency barrier in place for individual species placement.



Discussion

Despite our findings that the Mixed Conifer Forest habitat types had the highest number of individual calls recorded, we advocate for future use and management of the CSU Mountain Campus that takes all three of the habitat types identified into account. We found that in this research that each of the three major habitat types contained at least one species that was unique to that system in that it was only recorded from audio devices deployed there. Based on this, management of the CSU Mountain Campus ought to incorporate measures for the health of all three of these habitat types to maintain populations of these unique recordings. This is of special import for areas such as the Riparian Habitat that hosts a large range of unique species only found there.

The data collected gives strong management incentives for the conservation of the larger ecosystem of the CSU Mountain Campus. The unique species present as well as the relatively high number of calls at each site show that all parts of the CSU Mountain Campus are important for supporting avian biodiversity. The mature Mixed Conifer Forests are home to high activity of bird species and contain a high number of unique species. In contrast, the Burn Scar habitat appeared to be less active than the Mixed Conifer Forest habitat type, but contained a greater unique species and apparently higher diversity. However, the presence of unique species in an active ecosystem also indicates that fire in the ecosystem may have greater impacts on avian biodiversity than we initially believed. A 2022 study by Jorge et al. found that after a fire in a mixed conifer forest, the diversity and abundance of avian species present can change quite dramatically as new habitat niches open in the altered habitat type. The Jorge et al (2022) study and our findings point to fire regimes being important for different species and guilds of avian species than are found in undisturbed mixed conifer forests.

The Riparian Habitat at the Mountain Campus makes up the smallest of the habitat types, yet it has a wide range of biodiversity in calls and was a site for the greatest number of unique species recorded. This suggests that the riparian zone may be an important site for specialist species unable to live in other areas and may also provide different opportunities in food availability or other resources for species that do cross habitat types. Riparian habitats have been known to act as biodiversity hotspots, offering unique nesting and foraging opportunities for avian species to take advantage of (Campos et al. 2020). This uniqueness of the habitat type may be the root of the high number of unique species heard in the riparian habitat at the Mountain Campus, illustrating the importance of this habitat type for bird biodiversity throughout the site.

As the mountain campus continues to be used for education and housing of students, staff, faculty, and even the general public as a conference site and the host of an event known as "EcoWeek" for grade students across the front range (*Eco Week* 2021), we encourage that research like this thesis project and the larger scale project encompassing it take into account the avian species richness of the different habitats present at the site. The preservation of these habitats and the species present within them is key for the fullest experience of the campus for those that are able to visit it. If this incredible biodiversity were to be lost from unchecked increased human activity at the CSU Mountain Campus, the experience would be without one of the key features that makes the campus so special to the university and to its visitors. Similarly, conservation of species for the continuation of their survival in a world where humans and wildlife are increasingly in contact is important for the sake of protecting the natural resources around us, such as the different avian species that all play a role in a healthy ecosystem.

We acknowledge the inherent shortcomings of this type of data collection for biodiversity studies and the limitations in what can be learned from auditory monitoring alone. Because there

were no visuals on the animals making the calls recorded and no tracking of individuals through other means, our data cannot detect if an individual was recorded more than once at the same location or at separate locations. This means that our data cannot be reliably used to estimate the number of individuals in a given species population at the CSU Mountain Campus. With this in mind, though, we do feel this data and the collection of acoustic data is a reliable method of estimating occupancy and relative abundance of species present as a given site. The collection of data also only pertains to those species active in crepuscular hours. While this is when most species are likely to be present and vocalizing, any non-vocalizing species or those that are diurnal or nocturnal would not be captured by the timing of this monitoring approach. Our data also must account for poor weather conditions. While it is less likely for avian species to be calling under poor conditions like rain and high wind, it is still possible. Our devices were more likely to not capture and calls under such conditions as the wind, rain, and movement of vegetation would mask any potential calls being made. This could lead to potential skews in data in which unique species were not heard and identified or common species were not captured to their full extent. Another potential skew in data could have arisen from the analysis tool utilized for species identification. It is possible that species that have similar calls were misidentified and not captured by the cross examination process. It is also important to keep in mind that the identification of species through an analyzer such as the BirdNet Analyzer is not a guaranteed correct system especially if parameters are not correctly set for season or location of the site. Species that live in different parts of the globe may have similar sounding calls that can skew results if there is no indication of where the data was collected spatially. Complete reliance on computer-driven identification can result in mis-identifications being overlooked and skew data.

It is with this in mind that we strongly urge all future auditory based biodiversity projects to examine and reevaluate the identified species after the analyzer finishes with the auditory data.

In this project, the data from ARU 29, ARU 31, and ARU 33 appears to have too wide of a search range associated with the audio identification. This is due to the apparent presence of endemic Hawiian species such as the Hawaii creeper at the CSU Mountain Campus. Before this data is used for future use in the overarching project, we suggest that these three ARUs be reanalyzed by the BirdNet Analyzer with specific attention paid to the coordinates of the output species and then checked for inaccuracies before updating the final datasets. These audio devices make up a relatively small amount of the data set, though, and are unlikely to impact the overarching findings of this project for the habitat types, biodiversity, and occupancy of the Mountain Campus. Despite these potential errors, we feel that the data presented is largely accurate to the biodiversity present at the CSU Mountain Campus.

This thesis project gives a snapshot of the larger research being done and demonstrates the practical applications of acoustic monitoring for species biodiversity indices at a specific location at a certain time. It also gives information that can be useful for species or ecosystem management at the CSU Mountain Campus. Further, this project can be a model for other students looking for futures in wildlife conservation or wildlife management either in research or in management applications. Here, we demonstrate the use of current acoustic monitoring research methods and give insight into how the information gathered from acoustic monitoring can be practically applied to conservation of a site. We found that the mixed conifer forest habitats contained the greatest abundance of calls, showing high occupancy of the area. Our results also demonstrate the burn scar and the riparian habitats, though often overlooked or smaller in size, have a high number of unique species present that are not found elsewhere.

Understanding the abundance and occupancy of avian species at the CSU Mountain Campus is the first step to designing proper conservation methods. This practical application of the data collected and analyzed can also be a model for future students looking for ways in which their futures can help shape conservation and management of species or habitats. The larger project that encompasses this thesis will also be used to create a lab session for a capstone course of the Fish and Wildlife Conservation Biology major at CSU. This will further the goal set out by this thesis project in management applications and student impact.

Citations

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