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Examining Avian Species Diversity in Various Forest Types at La Selva Biological Research Station

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Abstract

Rainforest degradation due to urbanization and land use changes can significantly impact tropical ecosystems, creating various forest types. This research explored avian species diversity in response to forest type within the protected land of La Selva Biological Research Station in northeastern Costa Rica. We hypothesized that the avian species diversity would be greater in old growth forests compared to successional plots between 1-4 years old and developed areas. Visual surveys were conducted daily in both habitat types throughout the ten-day research period, with audio sampling in old growth forests. Audio sampling was not conducted in the successional or developed areas due to their proximity to old growth forests. The sampling occurred in two-hour periods during the morning and afternoon for each forest type, alternating the starting forest type each day. Statistical analysis with a chi-squared test showed significantly higher bird species diversity in old growth forests compared to successional plots and developed forests ($p < 0.05$). In total we recorded 87 bird species, with 72 species found in old growth forests and 35 found in the successional and developed areas. These results illustrate the inverse relationship between avian diversity and forest disturbance, emphasizing the critical importance of protecting old growth rainforest habitats from human-induced degradation and development.

Keywords: Avian diversity; Forest succession; Habitat disturbance; Old growth forest; Tropical rainforest.

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1. Introduction

Tropical rainforests are experiencing forest fragmentation which decreases tropical avian species diversity [1]. Land use changes such as clearing forest for agriculture or urbanization threaten avian ecological niches [2]. Forest types including old, successional, secondary, and developed growth provide different habitats and resources for various birds. Secondary forests may not have as many critical resources as old growth forests [3]. As forest types continue to change due to increased development and disturbances, it is necessary to understand how these changes will affect neotropical rainforests and neotropical avian species.

Expansion of land clearing for development and agriculture into forested land disturbs the ecological roles of bird species [2]. As urbanization and human development continue to spread, forested areas are at risk of fragmentation and degradation. One study shows that avian species react differently to fragmentation, so it is important to understand how specific species are affected to cultivate effective conservation management plans [1]. In Afrotropical regions, one study found that urbanized areas have less taxonomic diversity compared to un-urbanized areas [4]. Urbanization has negative impacts on avian richness as it leads to habitat loss, less genetic diversity, and resource depletion, emphasizing the importance of understanding how human actions influence ecosystems.

La Selva Biological Research Station is a protected neotropical rainforest in northeastern Costa Rica [5]. When this land was initially purchased, it consisted of old growth forest with surrounding agricultural plantations. It has a fragment size of 1611 hectares and supports 250 known bird species as of 2010 [1]. La Selva experienced changes in avian diversity due to anthropogenic land-use changes in the past as it underwent deforestation in the 1970s, but began regrowth by the 1980s, creating vast secondary forests [1,5]. Previous avian studies in La Selva indicate that while some species increased between 1989-2011, many species decreased at rates exceeding increase rates [5]. The area surrounding La Selva has developed and become more inhabited over time, which introduces additional sources of disturbance to the protected area including air and noise pollution.

Recent research conducted in Costa Rica explores how habitat fragmentation affects bird diversity. It is known that tropical birds exhibit specific traits that make them vulnerable to human degradation including specific habitat requirements and unique diets [5]. One study conducted in La Selva found that generalist birds increased within protected land and that birds in need of non-forest habitats decreased due to the increase of secondary growth in La Selva [5]. Another study determined that mixed-species flocks and forest birds decreased in La Selva due to habitat fragmentation while edge species increased due to the surrounding plantations and secondary forests [1]. It has been determined that avian richness and abundance are influenced by old-growth, mid-successional, and early successional forests in Southern Chile, with more avian abundance in old-growth forests [3]. In support of previous studies, research in Ethiopia determined there is a positive relationship between forest age and bird species diversity [2]. Older forests, due to their age and resource availability provide desired habitat to various avian species.

Current research focuses on the impacts of urbanization and forest proximity to development. Bird species diversity in relation to forest successional stage and urbanization has been studied in separate locations.

Examination of previous studies revealed little research describes how forest structure in one plot of a larger area of protected land affects avian species in surrounding forest environments. One gap in current research is the lack of data examining how forest dynamics in one protected area change between old growth, intentional successional plots, and developmental areas while remaining in protected "forested" land. At La Selva, there are manmade structures including cabins, a kitchen, and buildings where bird sightings are frequently observed. Additionally, within the dense vegetation and old growth, La Selva cleared multiple successional plots that were cut to monitor successional forest growth. These unique "new growth" habitats and landscapes attract diverse neotropical birds.

This study explores how various forest types including old growth and disturbed growth (successional plots between 1-4 years old and maintained areas with man-made development) influence avian diversity in La Selva Biological Research Station. Exploring these forest types while remaining in the protected land of La Selva is important to understand how small-scale developmental features and land maintenance affect bird species diversity. We hypothesized that old growth forests would have greater avian diversity compared to disturbed growth.

2. Methods

Study Site

La Selva Biological Research Station is a neotropical rainforest in northeastern Costa Rica owned by the Organization for Tropical Studies (OTS) that consists of 1611 ha of tropical forest [5,7]. An average of 3962 mm of precipitation falls in La Selva annually and the average temperature of the rainforest is between 24.7°C – 27.1°C [5]. The rainforest connects with the Braulio Carrillo National Park and Barva Volcano while La Selva is known to have 250 bird species as of 2010 [6,1].

Old growth forests are prominent in La Selva which provide habitat and resources to numerous species. Old growth locations surveyed at La Selva consisted of the Main Bridge, the bridge on the SAZ trail, and the bridge on the trail on the way to the river station, with one hour of data collected at the arboretum on ARB off SUR (Figure 1). These locations were accessible by small bridges along trails that overlooked dense undisturbed forests and provided open focal ranges.

Successional plots were purposefully cut within the tropical rainforest to examine regrowth and succession of secondary forests off the SOR trail. Between the parcels were grass and dirt trails that surrounded the perimeter of each parcel and were accessible to the surveyors. La Selva had multiple successional plots, but this research only examined parcels 1-4, which were randomly selected as the closest parcels to the SOR trail. Parcel 1 was 4-5 years old; parcel 2: 0-1 years old; parcel 3: 1-2 years old; parcel 4: 2-3 years old. The parcels were between dense old growth forests and were adjacent to a river on its eastern border. The developed areas studied in this research included the kitchen and garden. The kitchen facility consisted of landscaped grass, large manmade structures including a patio for seating, a visitor center, cabins, gravel roads and parking lots. The garden location included maintained and mowed lawns, cabins, research buildings, and paved paths with heavy foot

traffic. These locations were selected for representation of developed spaces due to prominent human presence and the resources humans provide to areas including food, planted species, and maintenance.

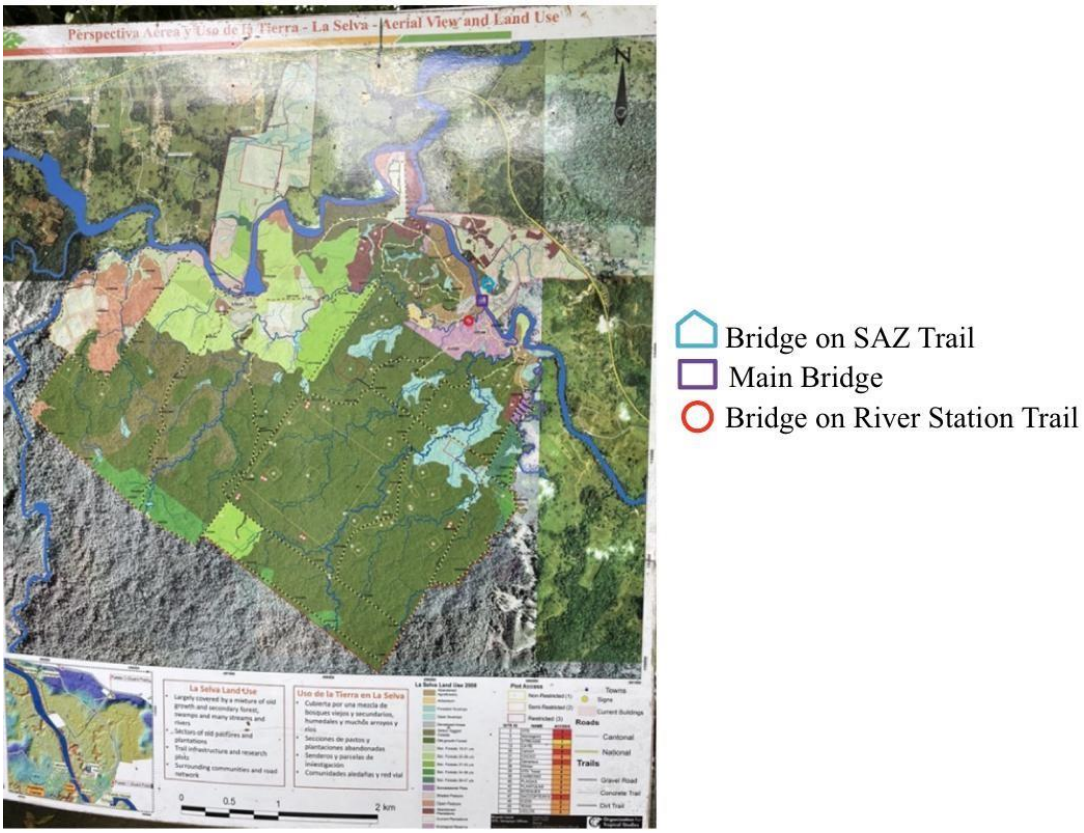

Figure 1: Map of La Selva Biological Station – blue pentagon: bridge on SAZ trail, purple box: main bridge, red circle: bridge on river station trail. Photo by Anna Varholak on January 3, 2025.

3. Sampling Methods

This study was conducted to examine tropical bird species diversity in northeastern Costa Rica. Research occurred in various locations in La Selva Biological Research Station to record avian species richness in the northeast corner of the station in accordance with Figure 1. The old growth was identified based on the structure and density of the forest with larger, non-planted trees that did not appear to be disturbed. The successional plots were in either early or midsuccession as they were regrowing from anthropogenic disturbance for varied amounts of time. Each day, approximately four hours of sampling occurred, two hours in the old growth forest and two hours in the disturbed growth. During surveys, locations changed within the forest type, so two sites were examined for each forest type in each survey (excluding day one). This design was used to reduce biases or errors of surveying one spot that may not be the most indicative of bird presence in that growth type. The first two hours of collection were conducted in the morning (00:00 - 12:00) and the second two hours were conducted in the afternoon (12:01 - 24:00) with approximately one hour of data collection at each site. The observation periods were not always continuous: an hour observation would occur around sunrise (6:00) and then another hour in the late morning a few hours later, as well as general “passing time” between one site to the next. In addition, surveying could have been interrupted by the rain in which surveying was stopped and

resumed when conditions improved.

The starting forest type alternated each day - if old growth was surveyed in the morning on day one, it was sampled in the afternoon on day two alternating from January 4, 2025 – January 11, 2025. The alternating design between days was included to neutralize any biases or errors that could have been introduced based on surveying time. Additionally, old growth surveys were taken for about 20 minutes in the morning of January 12, 2025, but no new species were observed during this collection period. One important distinction to note is that on January 7, 2025, only old growth data was collected (afternoon collection) and on January 9, 2025, only developed data was collected (morning collection) which created one full day of data collection. Research concluded with 7 total days of complete data collection. Day one of research collection began with 1 hour of old growth surveying in the morning with 1 hour of surveying in disturbed areas in the afternoon.

4. Data Collection

The forest type, location, time, method of observation (audio, visual, or both (a/v)), number of individuals (for visual observations), species identification, and weather conditions were recorded during each survey at each site. In old growth locations, visual and audio observations were recorded. For visual observations, binoculars were used, and bird descriptions were compared to known species in Costa Rica found in *The Birds of Costa Rica: A Field Guide (Second Edition)* by Richard Garrigues and Robert Dean. Visual bird identifications were made based on visual bird characteristics, prominent locations, and online identification. For online identification, pictures of an individual were uploaded to the Merlin Bird ID App run by CornellLab and results were provided based on location and visual appearance. If there was no picture of the individual, the “Step by Step” feature on the Merlin Bird ID App run by CornellLab was used. In addition to visual observations, audio observations were recorded in old growth forests. Audio identification was performed with the 3.5(190-2024) version of the Merlin Bird ID App and 1-3 cellular devices were used for collection. In old growth sites, visual and audio methods of observation occurred simultaneously. Audio data was collected in old growth sites because the locations were far enough away from disturbed growth, creating little concern that the birds heard by the app were outside of the old growth forest.

The disturbed growth data collection was split between successional plots and developed growth. In the successional plots, visual surveys were conducted. Parcels 1, 2, 3, and 4 were examined a total of three times across the seven-day research period. The parcels were squares, so researchers walked down one path between two parcels or around the perimeter of the parcels, for example between parcel 1-2, parcel 2-3, and parcel 3-4. Developed locations surveyed at La Selva included the areas around the kitchen facility and the garden on the other side of the main bridge when entering the rainforest. Surveyors conducted visual surveys using the same methods described in old growth visual observations including the use of binoculars, online identification and the utilization of the field guide. Audio surveys were not conducted in the disturbed growth.

The successional plots existed in the middle of the old growth forest, surrounded by dense growth on all sides. The proximity of the disturbed sites to old growth made it difficult to determine if an audio identification was from within the parcels, disturbed locations, or dense old growth areas surrounding the disturbed locations.

Additionally, the identification app did not have a specific range limit, and the dense growth made it difficult to see every bird that was observed by audio recordings.

5. Tools and Limitations

Tools used for this research included binoculars, the Merlin Bird ID App by CornellLab, and *The Birds of Costa Rica: A Field Guide (Second Edition)* by Richard Garrigues and Robert Dean. Limitations to this research could include improper identification by the surveyors as identification skills were learned in the field, as well as by the Merlin Bird ID App if there was an unknown incorrect audio or visual observation. There was no way to ensure the same bird was not counted more than once if their audio and visual observations were recorded at different times. This could affect the results of the study since there may not have been as many individual species observations as indicated by the data if the same bird was counted multiple times. Additionally, there was no known observational distinction between the Great Kiskadee and the Social Flycatcher until the first morning survey of January 8, 2025. Lastly, not all species observed were identified. The researchers made their best effort to identify the birds, but numerous birds were deemed unidentifiable due to lack of individual surveyor experience or poor observations.

6. Data Analysis

A chi-squared test was conducted in RStudio comparing old growth forest avian species diversity to that in disturbed growth areas. A chi-square test was used due to the categorical nature of both variables, forest type and species. The test provided an X^2 value and p-value to determine if the diversity between locations was statistically significant. Additionally, bar graphs were used to visualize the difference in species diversity between forest types and compare the unique species found in both disturbed and old growth.

7. Results

A chi-squared test was performed and determined there was a significant difference in avian species diversity between forest types ($X^2 = 353.52$, df = 86, $p < 2.2x10^{-16}$). There were 87 species observed at La Selva using varied methods. Of the 87 birds observed, 54 species were identified by audio-only observations, 59 by visual-only observations, and 13 were identified with both methods. Distribution among the observed species revealed 72 species were recorded in old growth forests while 35 species were seen in disturbed forests (Figure 2). As seen in Figure 3, from the 72 species recorded in old growth forests, the Yellow-throated Toucan (n = 43), Keel-billed Toucan (n = 15), and Montezuma Oropendola (n = 12), had the highest recorded observations in old growth forests. The Scarlet-rumped Tanager (n = 69), Great Kiskadee (n = 30), and Rufous-tailed Hummingbird (n = 20) had the highest recorded observations out of the 35 species identified within disturbed forests as presented in Figure 4. There are unidentified species, referred to as “unknown,” recorded in both the old growth and disturbed forests (n = 24, 39 respectively, Figure 3 and Figure 4). These birds were unidentifiable to the species level based on visual observation in both forest types. While some were identified to the genus or family level, the specific species remained unknown.

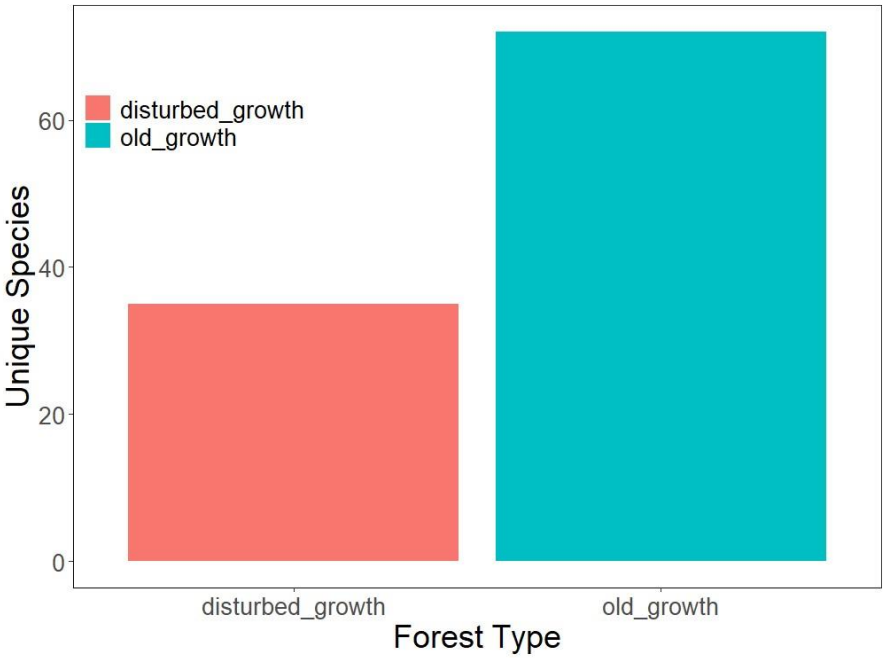

Figure 2: Old growth forests had more avian species recorded than disturbed forests (n = 72, 35 respectively, $p < 0.05$).

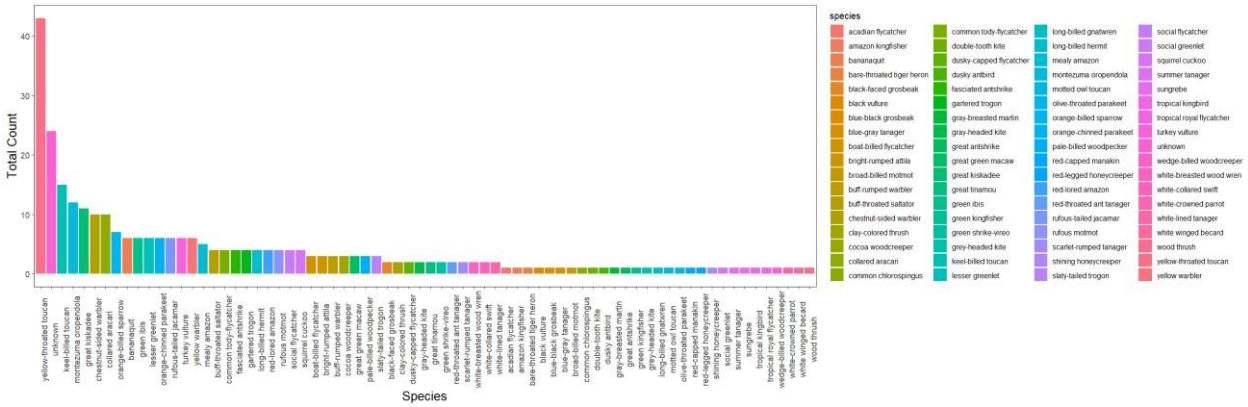

Figure 3: Frequency of avian species recorded in old growth locations. In old growth, the Yellow-throated Toucan, Keel-billed Toucan, and Montezuma Oropendola have the greatest frequency (n= 43, 15, 12).

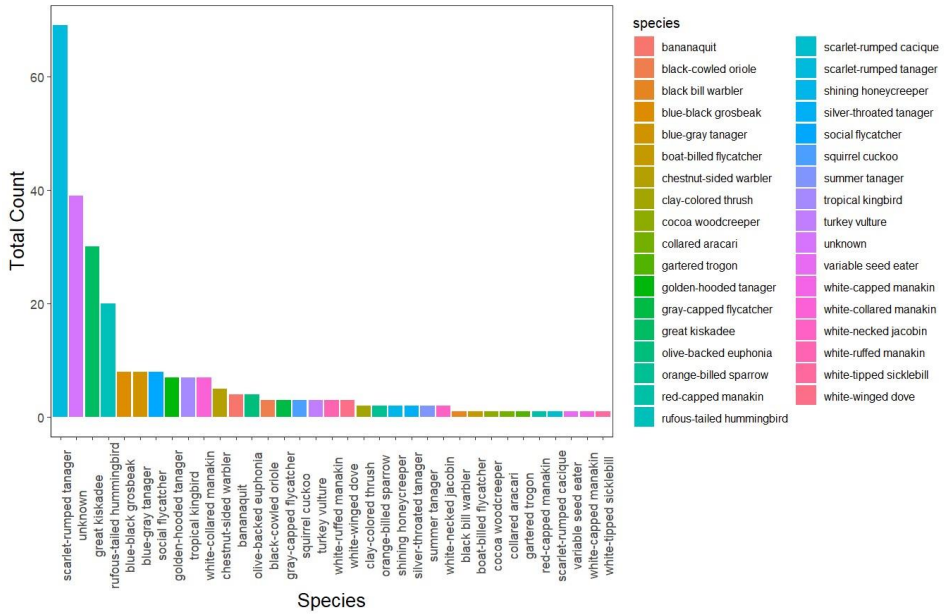

Figure 4: Frequency of avian species recorded in disturbed growth locations. In disturbed growth, the Scarlet-rumped Tanager, Great Kiskadee, and Rufous-tailed Hummingbird have the greatest frequency (n = 69, 30, 20).

Temporal analysis determined how the date and time influenced avian species richness in both forest types. The timing of the survey was split into two distinct time periods: morning (00:00 - 12:00) and afternoon (12:01 - 24:00). As seen in Figure 5, there were greater unique species observations in the morning than in the afternoon (n = 71, 48 respectively). In Figure 5, it should be noted that N/A consisted of 4 observations that were all recorded in the afternoon, but without a specific time. Figure 6 portrays the daily data that was plotted to determine what day had the greatest number of observations, which was January 6, 2025.

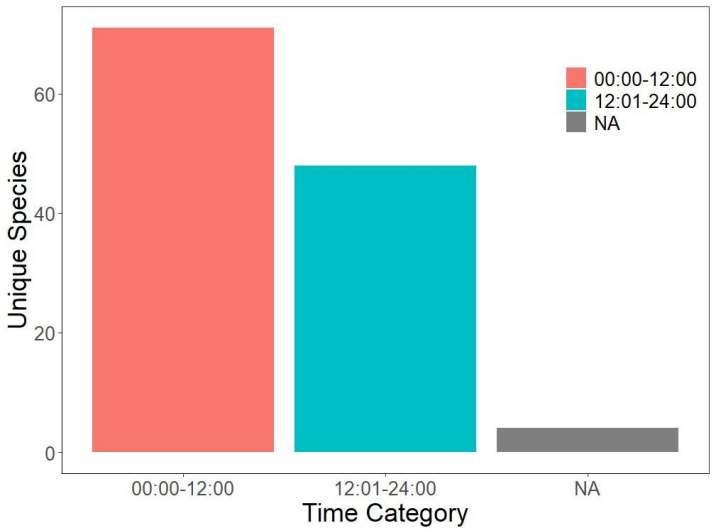

Figure 5: More unique species were observed in the morning (00:00 - 12:00) than in the afternoon (12:01 - 24:00). N/A has 4 observations from the afternoon time block, but no exact time was recorded.

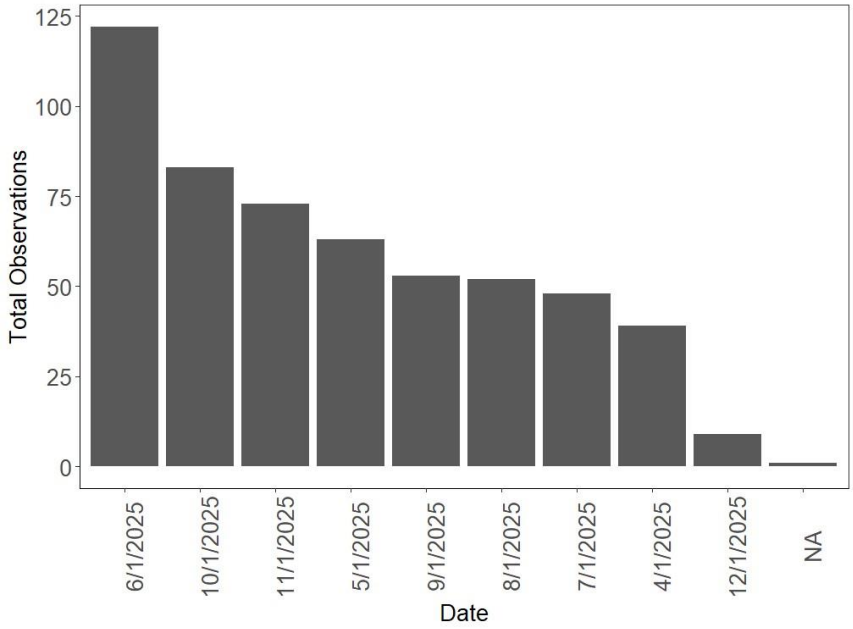

Figure 6: Count of total observations per day. January 7, 2025, and January 9, 2025, had either morning or afternoon surveying. January 6, 2025, had the greatest number of total observations.

Greater avian species diversity was observed in old growth forests compared to disturbed forests, and morning surveys promoted higher species richness than afternoon surveys. The results of this study suggest that habitat type and development status as well as time of day affected bird diversity observations at La Selva, emphasizing the importance of protecting old growth forest and optimizing survey timing for accurate observations.

8. Discussion

Our research found that avian diversity is affected by forest type and time of day at La Selva Biological Research Station. Bird species diversity in old growth forests is significantly greater than in disturbed growth at La Selva. There were 37 more bird species observed in old growth compared to disturbed growth. The p-value from the chi-squared test comparing bird diversity between forest types was less than $2.2x10^{-16}$ which is less than the alpha value of 0.05, proving that there is a statistically significant difference in bird diversity between forest types. This low p-value allows us to reject the null hypothesis and supports our hypothesis that old growth forests have more bird species diversity than areas of disturbed growth. This hypothesis was formulated based on the belief that old growth forests have more resources such as space, food, and habitat to support a larger variety of avian species. It was predicted that fewer bird species would be supported in disturbed areas since there is not as much biodiversity to provide specialized food and resources. These results indicate that there may be more resources such as food, shelter, and habitat in the old growth forest compared to disturbed growth. The avian preference for old growth forests is in cooperation with prior findings that secondary forests may have fewer critical resources than old growth forests [3].

Bird species diversity changed in relation to forest type within La Selva. The results of this research are in accordance with a study conducted in Afrotropical regions which found that urbanized areas have less

taxonomic diversity than un-urbanized areas [4]. Previous research suggested that tropical bird species had traits such as their diets and habitat requirements that made them vulnerable to human destruction [5] which supports why certain species would be better suited in old growth forests. Our findings indicate that anthropogenic actions such as development and deforestation led to the change in forest type which then led to the change in avian species richness. This is not a new issue in La Selva as anthropogenic land-use changes in La Selva led to deforestation in the 1970s which caused change in avian diversity [1,5].

In our study, the decrease in avian diversity in disturbed areas can also be explained by the disturbance of the avian ecological roles caused by land clearance for development and agriculture [2]. A portion of the land in the disturbed growth areas of La Selva were clearcut. The successional plots grow back under observation, but the rest of the developed land is landscaped and maintained. Buildings and man-made structures were built which disturbed the ecological niche of the bird species present in that ecosystem. One study found that "bird daily activity patterns may be directly affected by daily variations in forest microclimate conditions and indirectly affected by [changes] in resource availability, which may be affecting their ecological interactions" [8]. Microhabitat and available resources, such as space and food, can result in changes in bird behavior in terms of nesting, foraging, competition, and reproduction. Our study found that there was a difference between bird observations by day and time, which can indicate behavior preferences. Further research can determine if there was a preferred time for activity in each forest type to better understand bird behavior in regard to disturbed versus old growth.

Research findings conclude that greater avian species diversity was observed in the morning than in the afternoon and on January 6, 2025, than any other day. The temporal data implies that birds are more active in the morning which may indicate preferred foraging time or times of increased productivity. While this was not an initial aspect of our research question, the broad examination of both temporal and spatial influences provides a deeper understanding of avian tropical ecology and behavior norms. Temporal and spatial factors reveal a more wholistic view of how birds exist and interact within their ecosystems. This data can also reveal trends in resource availability or microhabitat preference. These results can be used to further determine how timing and weather conditions influence bird observation success in both old and disturbed growth in La Selva.

At La Selva, development and forest degradation have detrimental impacts on bird species diversity. While it is known that degradation and habitat destruction are detrimental to species diversity, our study examines a specific type of disturbed growth including intentionally cut successional plots and maintained areas with man-made structures. Other research examines more developed areas such as towns or cities, but our research is unique in its classification of disturbed growth. Our research combines both successional plots that are disturbed by clearcutting and land that has been slightly developed, but not to the extent of a town. Additionally, our disturbed growth area is within the same protected land, La Selva, as the old growth forests. This is not common in other research as there are usually two or more separate sites used for avian observation [1]. Our research can be useful to determine how much disturbance will allow for and support a diverse avian population and how much disturbance would be detrimental to bird communities and their ecological functions.

Findings from this research can be used to guide conservation efforts in Costa Rica and similar tropical

rainforest ecosystems. Development has detrimental consequences, even at a very minimal level, but can have cascading effects on biodiversity. This study supports increased establishments of protected land such as La Selva. La Selva cannot undergo extreme development or clearcutting because of its protected status. The decrease in avian species diversity at La Selva in disturbed areas emphasizes the necessity for more rainforests to become protected land where it is forbidden to clearcut or develop and disturb land beyond a certain extent.

Limitations to this research included identification abilities, inconsistencies in individual audio and visual observations, and differences in methods between forest types. One limitation was the lack of ability to identify each bird visually observed. There were numerous birds observed in both old and disturbed growth where birds were unidentifiable based on the observation and identification resources in the field. Observations were either too brief or not detailed enough to confidently identify individual birds while in both old and disturbed growth. The large amount of unidentifiable individual birds could skew the unique species data as there could be more unique species seen during observation at La Selva. It should be noted that the Social Flycatcher was not identified as a unique species until January 8, 2025. The Social Flycatcher and the Great Kiskadee have very similar features, the main differences are that the Social Flycatcher has a slightly shorter beak and is generally smaller than the Great Kiskadee. However, identification based on size is difficult to use to distinguish between the two species because there could have been a smaller Great Kiskadee or a larger Social Flycatcher.

Additionally, until the differences in beak sizes were noticed, it was hard to determine the species of the bird. This suggests that there may be observations where the Great Kiskadee and Social Flycatcher were mis-identified until January 8, 2025.

Inconsistencies in audio and visual observations could have caused additional skews in the data. In the field it was difficult to determine when the Merlin Bird ID app was recording a previously recorded individual bird when calls from the same species were heard a few minutes apart. This could have led to inconsistencies in how many individual birds were observed but should not have a large impact on the number of species observed.

Additionally, methods for data collection differed between forest types. Most of the disturbed growth sites observed were within close proximity to old growth forests which led to the exclusion of audio collection in disturbed growth areas. It was difficult to determine if the sound recorded by the Merlin Bird ID app was coming from within the successional plots and developed areas or within the old growth trees on the perimeter of the disturbed growth. The exclusion of audio collection can have a large impact on the data. It is likely there were species in disturbed growth areas that our group members could not identify visually, where at old growth sites, the audio collection led to new recorded species that were never visually observed. Although this can cause inconsistencies, the decision to exclude audio surveying more accurately described the visually seen species in the less dense, more developed areas.

One factor that was uncontrollable during this research was the weather, which was variable throughout the 10-day collection period. While weather conditions, such as rain, were recorded in the field, sampling observations may have been influenced by the past, present, or future weather at the time of the observation. If temperatures were too high, this could have affected the foraging strategies and activity of the birds. In addition, in the

presence of heavy rainfall, birds would look to take shelter, rather than continuing with their regular activities, which could influence the number of unique species observed in a given location.

A potential source of error was using multiple names for the same species across various platforms. The Yellow-Throated Toucan, the most updated name of the species, was referred to as the Black-Mandibled Toucan in the field guide. The same occurred for the Scarlet-Rumped Tanager, which was referred to as the Passerini Tanager in the field guide. Corrections were later made to the dataset to identify all birds of the same species with one name, but this could have led to inconsistencies between audio and visual field observations.

Further research can be done by examining weather conditions to determine how weather conditions influence avian species diversity and observation success. Rain and wet conditions could potentially influence the observed bird species richness if birds decide to stay under cover from the rain. In addition, dry and warm conditions could affect the observed species diversity of birds if the temperature is outside the optimal range of most species. Another suggestion to further this research is to examine bird species diversity at additional sites with various levels of disturbance. Areas with more development, such as towns or cities would have different, potentially greater impacts on avian species richness compared to minimally disturbed areas and successional plots. A final further research suggestion is to examine the types of avian species in each forest type. Based on personal observations, larger birds and sometimes more rare species were observed in old growth forests compared to disturbed growth. Categorizing common birds based on size and determining how avian size varies among forest types could lead to further understandings of ecosystem interactions and required resources.

The results from this study conducted at La Selva can be used to prevent old growth forest degradation and habitat destruction as the desire for development increases. These findings encourage greater habitat conservation and can be used to advocate for additional protected areas like La Selva to combat the ongoing expansion of development and to protect avian species diversity.

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