A Descriptive Analysis of Avian diversity at the ephemeral pools in the lowland Peruvian Amazon

Ella Newins

Corresponding emails: ellanewins@rocket.com & info@sustainableamazon.org

Abstract

The degradation of the Amazon rainforest has led to major changes to its climatic and hydrological cycles, resulting in increased incidence and intensity of droughts. The water-energy hypothesis predicts that periods of drought throughout the dry season can have major consequences on biodiversity. Birds are vital for the Amazon to survive through the abundance of services they provide. However they rely on these hydrological cycles to survive. Ephemeral pools are temporary seasonal pools of water that solely rely on precipitation. The presence of ephemeral pools during the dry season could be detrimental to the survival and diversity of Avians. Bird observations, along with camera traps and sound identification, were used to collect an inventory of the Avian species present at these pools. A comparison study was also conducted at a site on the forest floor to determine the pools diversity value. Two surveys, morning and evening, were conducted twice at each site. Statistical analysis showed that there was no significant difference between the species richness observed at the ephemeral pools in comparison to the forest floor. However, there was a significant difference observed in total abundances and the species compositions at these sites. The ephemeral pools observed a great number of Trochilidae and Thamnophilidae that weren't observed at the forest floor, meanwhile it had far more ground-dwelling birds than that of the ephemeral pools. The differences in species composition can be explained by nectar and flowering plant availability at the ephemeral pools. Additionally, the increase in insect diversity that is supported at the pools, and consequently the presence of mixed-species bird flocks that increased overall abundances. In summary, although the ephemeral pools did not have a significant impact on diversity, it clearly supported different species compositions. Although this study provides some great insight into an unexplored area, it primarily acts as a starting point for further research. Additional sampling with prolonged data collection time period and further research into habitat structure are necessary to test this hypothesis at a local level.

Introduction

The consequences of deforestation and increasing carbon emissions on ecosystems and their biodiversity has been researched widely around the world. While these remain a top priority, the changes in frequency of extreme weather events which come as a result of increasing global temperatures may have equally disturbing implications on the environment.

The Amazon rainforest is the world's richest biome, and plays a vital role in providing key ecological services benefiting both human well-being and biodiversity (Sanchez-Cuevo et al. 2020). The tropical region also holds great conservation value due to its rich cultural diversity. However, the Amazon is currently facing large expanses on degradation occurring at alarming rates, with deforestation posing the biggest threat to the Amazon Rainforest and all its inhabitants. With immediate impact deforestation destroys several habitats, displacing and endangering the species that previously coincided there, resulting in deforestation being listed as a main threat to around 85% of all species on the IUCN's Red List (World Wildlife Fund 2020). As a result of large-scale deforestation in the Amazon, the biome is gradually converting from a carbon sink to a major carbon source. A Brazilian researcher has estimated that the Amazon releases roughly three hundred million tonnes of carbon annually into the atmosphere (Gatti 2021). Specific to the Madre De Dios region, the establishment of the 'Interoceanic Highway,' a transcontinental highway running through Peru to Brazil, saw rapid increases in population and local economy due to the formation of several small-scale agriculture and mining sites (Sanchez-Cuevo et al. 2020). Of the total deforestation that occurred during 1999-2005 in Peru, 19% was conducted in close proximity to the Highway (Gallice et al. 2017).

As a result of increasing carbon emissions, the hydrological cycles occurring in the Amazon basin will intensify. Therefore, Southern America will experience increased volume and duration of flooding during the wet seasons and increased periods of drought during the dry season. These climatic fluctuations can have further detrimental impacts on the ecosystem and its inhabitants. A study conducted by Lapola et al. (2023) discovered that drought alone affected 2,740,647km of the Amazon, equating to 41.1% of the remaining Amazon forest cover (Figure 1). Furthermore, periods of drought drastically increase the frequency and intensity of forest fires, roughly between two to four times greater than that of non-drought years (Lapola et al. 2023). Often resulting in mass destruction of the forests and wildlife habitats, threatening the abundance of species that coincide there, which contributes to reductions in species diversity.

There are several hypotheses used to explain spatial variation in species diversity, one of which being the water-energy hypothesis. It is based on the premise that energy and water availability are key drivers in explaining species richness, with higher precipitation leading to higher species richness. Many species populations rely on the hydrological cycles of river water for their survival. Therefore, major fluctuations in water levels through periods of intense flooding followed by prolonged droughts can cause shifts in these wildlife populations, while also impacting their relative abundances (Bodmer et al. 2018). Many non-aquatic species require a reliable supply of water within their habitat for regular ingestion (Hilden 1965). Additionally, precipitation is key for vegetation productivity, resulting in large abundances of flowers, fruits, seeds and insects, which act as the main sources of food for several species, more specifically avians.

In periods of drought birds suffer increased mortality of adults due to reductions in available food source and the additional stress of finding alternative habitats (Albright et al. 2010). Studies have found that during these extreme events birds often carry out reduced breeding attempts, and of those attempts they are far less successful in producing fertile offspring (Li and Brown 1999). The overall impact of droughts on avian species is unclear as responses vary among different avian species with varying ancestry and characteristics. For example, species that rely on human subsidies may

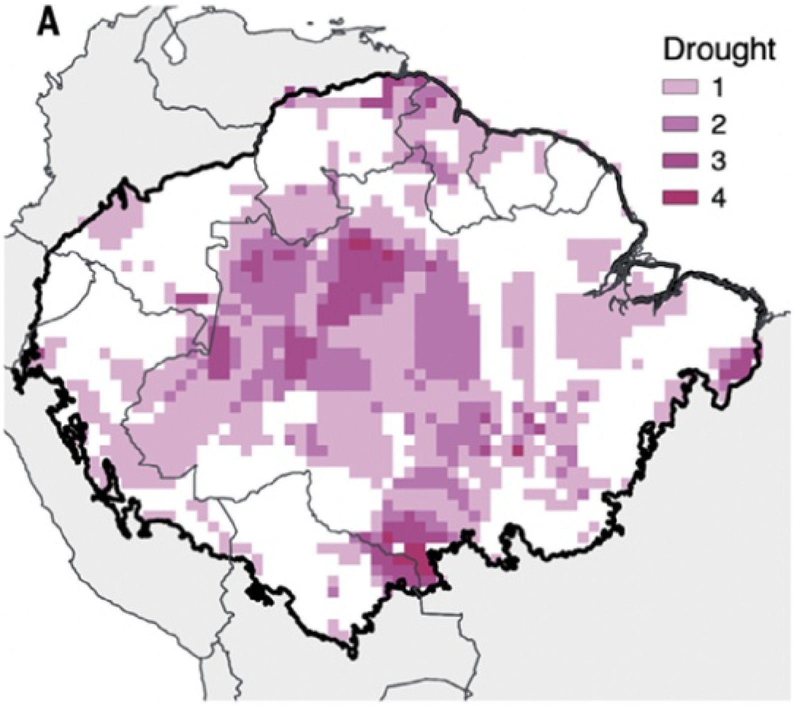


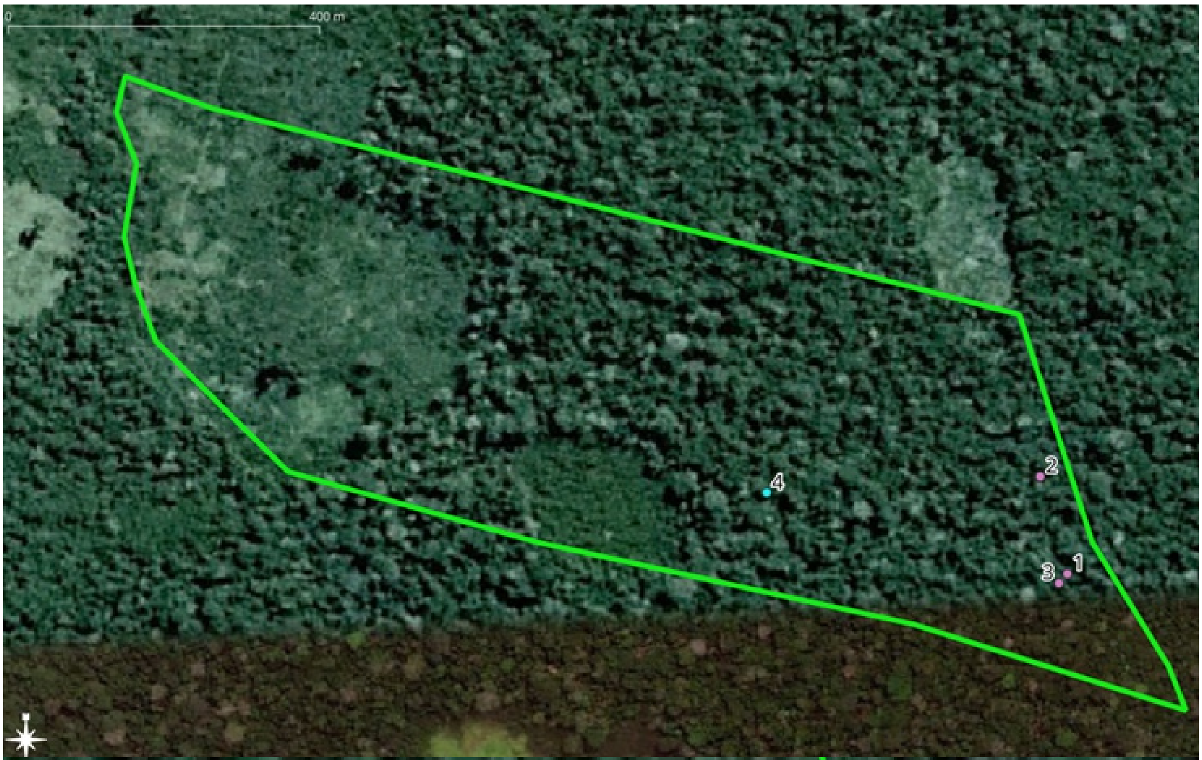
Figure 1. Current spatial distribution (2001-2018) of the occurrence of extreme drought in the Amazon rainforest, excluding deforestation and savannah areas. Lapola et al. (2023)

react adversely to those that require high moisture levels within their habitat. Furthermore, we cannot expect that permanent resident birds will be affected similarly to neotropical or even mid-distant migrants.

A highly diverse community of Avians is essential for the conservation of the Amazon rainforest for several reasons as they provide a wide range of ecosystem services. Through their insectivorous diet they act as pest controllers and maintain their populations, which in turn has substantial benefits for plant survival rates. Around 50% of bird species are predominantly insectivores, and almost 75% eat invertebrates occasionally (Wenny et al. 2011). Possibly the most important ecosystem service avians provide to the rainforest is seed dispersal. Almost 33% of bird species carry out seed dispersal, mainly through fruit consumption, however scatter-hoarding is also conducted (Wenny et al. 2011). It is difficult to quantify exactly how many plant species have avian dispersed fruit, however an estimate of 30-50% has been proposed by several researchers, equating to roughly 80,000 to 140,000 species (Wenny et al. 2011). Seed dispersal benefits plant species in several ways, including: gene flow; open site colonisation; escape from predators; and enhanced germination (Wenny et al. 2011). Another example of avian ecosystem services is the importance of scavenging. Devault et al. (2003) discovered that vultures, along with other vertebrate scavengers, consume most available carcasses in terrestrial habitats. Through scavenging, these vertebrates contribute to waste removal, disease regulation, and nutrient cycling (Houston 1979). The final ecosystem service of avians that will be discussed is their contribution to the structure of the community and their role as 'ecosystem engineers'. Most bird species construct nests within their habitat, these vary greatly in structure, size and material dependent on the species. Once abandoned, these nests are later used by several other organisms, mostly smaller animals, supporting their lifestyle and survival.

Avians can also be used as indicators for the wider biodiversity of the community, as often the resources required to survey biodiversity directly have limited accessibility. Bioindicators are organisms used to monitor the health of the environment, such as pollution levels, and most importantly the successfulness of conservation efforts and sustainability on biodiversity (Mekonen 2017). Birds are the most widely monitored taxonomic group, as they are easy to detect and identify through several different methods. It is well known that avian diversity and faunal health is highly correlated, additionally, avians tend to be located towards the top of the food chain, and therefore become impacted by changes towards the lower trophic levels (Friezedas et al. 2020). There is abundant research using birds as bioindicators for varying reasons, including: biodiversity and species richness; environmental contamination by pollutants; condition of ecosystems; and ecosystem responses to disturbances (Mekonen 2017). Birds are also flagships for nature, of interest by both the public and decision makers. They act as nature's 'ambassadors' playing a key role in raising conservation funds and awareness of biodiversity conservation (Wang et al. 2023). Additionally, as described above, birds are economically important through processes such as pest control, pollination and seed dispersal, therefore they are directly linked to the survival of several other species (Mekonen 2017). However, in 2011, Eglington et al. discovered that "19% of the variation in total species richness in other taxa was explained by species richness in birds." Although this percentage isn't that high, it can still give some great insight into population dynamics, and avians were found to still be better at reflecting species richness in mammals than any other taxa (Eglington 2011). However, the ecosystem in which birds are used as bioindicators can result in varying levels of effectiveness.

Ephemeral pools, otherwise known as vernal pools, are seasonal pools of water that are isolated, with no inlet or outlet. They are defined as "episaturated seasonal wetlands that are characterised by a unique assemblage of vegetation and soils" (Huertos 2020). Due to lack of water flow they rely almost entirely on precipitation levels unlike most water sources, therefore their characteristics vary greatly throughout the seasons. This variability provides unique services that differentiates them from other habitats. Furthermore, as a result of deforestation, in combination with warming global temperatures, the Amazon rainforest is recording extremely high levels of drought, threatening an abundance of species. Ephemeral pools could provide a solution to this issue, acting as an alternative water source and habitat to these threatened species that would have relied on other water sources. Currently, there is limited research investigating ephemeral pools in the Amazon Rainforest as most studies are located within Northern America. Additionally, as of yet there is no research looking into the interactions of Avians with ephemeral pools in tropical areas, therefore, this study acts as a crucial starting point to further our understanding of Avian distribution.



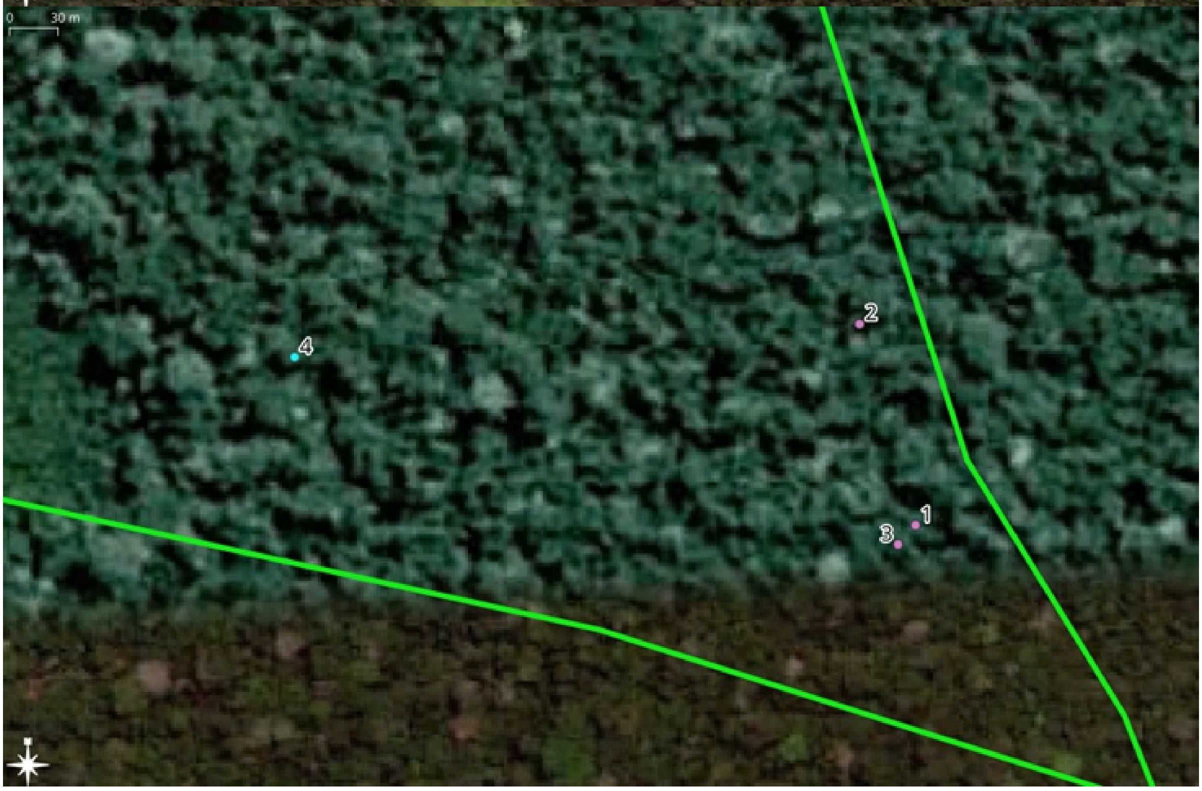


Figure 2. and 3. Using QGIS, a map of the Finca Las Piedras property (outlined in green), along with the three ephemeral pool sample sites: site 1, site 2, and site 3 (pink dots), and the forest floor site 4 (light blue dots) (QGIS 2023).

Understanding the correlation between water availability and avian biodiversity can have several applications for the wider community. Firstly, if a positive correlation is found between ephemeral pools and increased species diversity this can massively improve conservation efforts. Individuals or organisations that have acquired land within the Amazon rainforest and aim to support conservation of wildlife can artificially produce ephemeral pools during periods of drought. Additionally this information can be used to support arguments regarding carbon emissions' contribution with fluctuating climates and biodiversity decline to educate and persuade large carbon emitters to reduce their output.

The aim of this paper is to develop a descriptive analysis of Avian species diversity observed at ephemeral pools in the lowland region of the Peruvian Amazon, and to compare this to the species identified at a site far from the ephemeral pools. To do this, observations of Avians at the ephemeral pools and deep within the forest will be recorded. From which, the species will be identified along with relative abundances. Using this data, statistical analyses will be carried out to develop a thorough descriptive analysis of Avian species diversity. Following this, conclusions will be made involving relevant data regarding each species life history along with characteristics to understand any visible correlations.

Methodology

Study site

The study site encompassed Finca Las Piedras, located in the Madre De Dios region, Peru. The study was conducted in three ephemeral pools located along the Eastern edge of the primary forest within the Finca Las Piedras plot. Due to it currently being the dry season for the Finca Las Piedras region, all data-recording locations were selected based on the presence of an ephemeral pool. In addition to the ephemeral pool, a 'forest floor' site was also included to allow comparisons between the two. All the studied sites were georeferenced using a GPS tracking app.

Site	Longitude (*W)	Latitude (*S)
1	-69.10733	-12.22876
2	-69.10754	-12.22785
3	-69.10723	-12.22891
Far	-69.11068	-12.22784

Table 1. Table displaying the GPS location (including longitude and latitude) of the three ephemeral pool sampling sites and the one far forest floor site, using GPS tracks digital software.

The weather is highly seasonal, experiencing both 'wet' and 'dry' seasons, with the dry season runs from June to September. Researchers suggest that rainfall drops by around 50% from the wet to the dry season (NASA 2021). This study was conducted from the 28th August 2023 to the 8th September 2023. In the days leading up to this study starting from the 1st August 2023, the average maximum temperature was recorded at 29.81oc, meanwhile the average minimum temperature was 21.75oc degrees (ASA 2023). It is important to note that midway through the data collection period, the Madre De Dios region experienced a friaje, in which precipitation levels reached 59mm. If throughout the data collection period the results show significant differences between diversity observed while in the aftermath of a friaje, this will be taken into account during data analysis.

Experimental design

Bird Observations:

A thorough bird species list had been

provided by ASA, recording all 355 bird species that have been observed, specific to Fincas Las Piedras. From this, a list was produced comprised of all the most commonly observed birds within the region. Any species identified that was not included on this list were also noted down and recorded, and remained on the list for further data collection periods. In addition to identifying the species, the actions presented by each of the birds was also noted to increase our information regarding the interactions between avians and ephemeral pools.

Sounds and Calls:

Due to the minimal amount of birds observed during the preliminary study, a decision was made to include bird sounds and calls to increase our data pool. However, due to lack of experience identifying Amazonian bird species via sounds, a digital software app launched by eBird and Cornell University named 'Merlin ID' was used to analyse and classify the surrounding bird calls (The Cornell Lab 2023). The software has sound data for 1,054 species of birds globally, 602 of which belong to the neotropics. This data was kept separate from the bird observations so that independent statistical analysis could be conducted.

Ephemeral Pools:

The characteristics of each ephemeral pool was recorded after each data collection session with the intention to not disturb the environment prior to collection and confound the results. These characteristics include the maximum depth and the surface area, which was measured using a tape measure. These were recorded at each recording session as these ephemeral pools have variable water levels subject to precipitation and evaporation rates.

Camera Traps:

In addition to in-person observations, camera traps will be utilised to further our understanding of avian species interactions at the ephemeral pools. One camera trap will be set up at each ephemeral pool in a way that disturbances from pedestrians will be minimalised. The camera traps used are Browning BTC-5HDX which use a passive infrared sensor that captures videos in response to subject movement light. It's detection range is 80 feet, equating to roughly 25m, and the video detection systems results in cameras continuing to record for as long as subjects continue to move for up to 30 seconds. The delay between two recordings has been set to 1 second to minimise the likelihood of missing new individuals. Due to the short delay time it is very likely that some individuals will be repeated if they remain in front of the camera for more than 30 seconds, in which case, this will be noted and only one sighting will be noted. The sightings captured with these camera traps will be recorded separately to those collected in-person, so that separate analysis can be conducted.

Data collection

Due to increased bird activity during the early hours in the tropics, data was collected at each site between the hours of 5:45am and 6:45am during the first light of sunrise. However, in hopes not to introduce any bias, an additional data collection period was carried out at each site between the hours of 4:15pm and 5:15pm, just prior to the sun setting. The recording period was fixed to 1 hour, as longer periods could result in the observer working at less than full effort. The data collection method used was the listing method, in which each species observed is noted down, and any further individuals belonging to the same species are further noted. For unidentifiable birds that were observed a photograph was taken to allow for further identification after the data collection period had ended. The study was conducted over eight days, equating to two data-collection days at each site, meaning two morning sessions and two afternoon sessions at each site. However, to reduce the possible confounding effect of temperature changes, two different sites were sampled in one day, for example, Site One in the morning and Site Two in the evening. Two days were also spent collecting data at a site far from the ephemeral pools, both in the morning and the afternoon.

Statistical Analysis

All the collected data was implemented into respective data sheets on Excel, which were later analysed using R software. The previously mentioned ASA species list was used to determine the Families and Orders of all the observed species, this way it could be determined which families were most prevalent. A phylogenetic tree was produced using this data to accurately display these relationships in a easy to interpret figure. Using R software, Shannon's diversity index was calculated for all the observed data in addition to each data recording session to be used for later analysis. Boxplots were produced to investigate the differences observed between the three ephemeral pool sites, allowing comparison between means, range and standard deviation. For both species richness and total abundance. Scattergraphs were made to understand the relationship between the richness and abundance of avian species with the measured characteristics of the pool. Spearmans rank correlation coefficients were conducted to determine whether a correlation was present between these variables. A pie chart was produced in Excel to clearly show the proportions of different pool usage activities that were carried out by each individual at time of observation. Similarly to site differences, box plots were also produced to compare the differences in observations between the morning and evening data collection sessions.

Results

Summary data

Over the data collection period a total of 29 different species were observed at the ephemeral sites (Table 2), excluding two individuals that were left unidentified and three individuals who were identified down to group level ('Antbird sp.,' 'Hermit sp.'). These species are sub-categorised into fifteen different Families within seven different Orders. Passeriformes had the highest species richness with 17, meanwhile Apodiformes had the highest observed abundance with 98 individuals.

Species List		
Red-headed manakin	Black-faced antbird	Russet-backed oropendola
Great billed hermit	Ruddy quail dove	Black-faced antthrush
American pygmy kingfisher	Rufous breasted hermit	Thrush-like wren
Chestnut-breasted wren	Fork-tailed woodnymph	Screaming piha
Spot-winged antbird	Undulated tinamou	Blue headed parrot
Buff-throated foliage gleaner	Spix's guan	Red crowned ant-tanager
Moustached wren	Ruddy ground dove	Dwarfed tyrant manakin
Blue capped manakin	White throated antbird	Reddish hermit
Sooty antbird	White bearded hermit	Plumbeous pigeon
Buff-throated saltator	Buff-throated woodcreeper	

Table 2. Full list of avian species, using their common name, observed at the three ephemeral sites over the six days of data collection

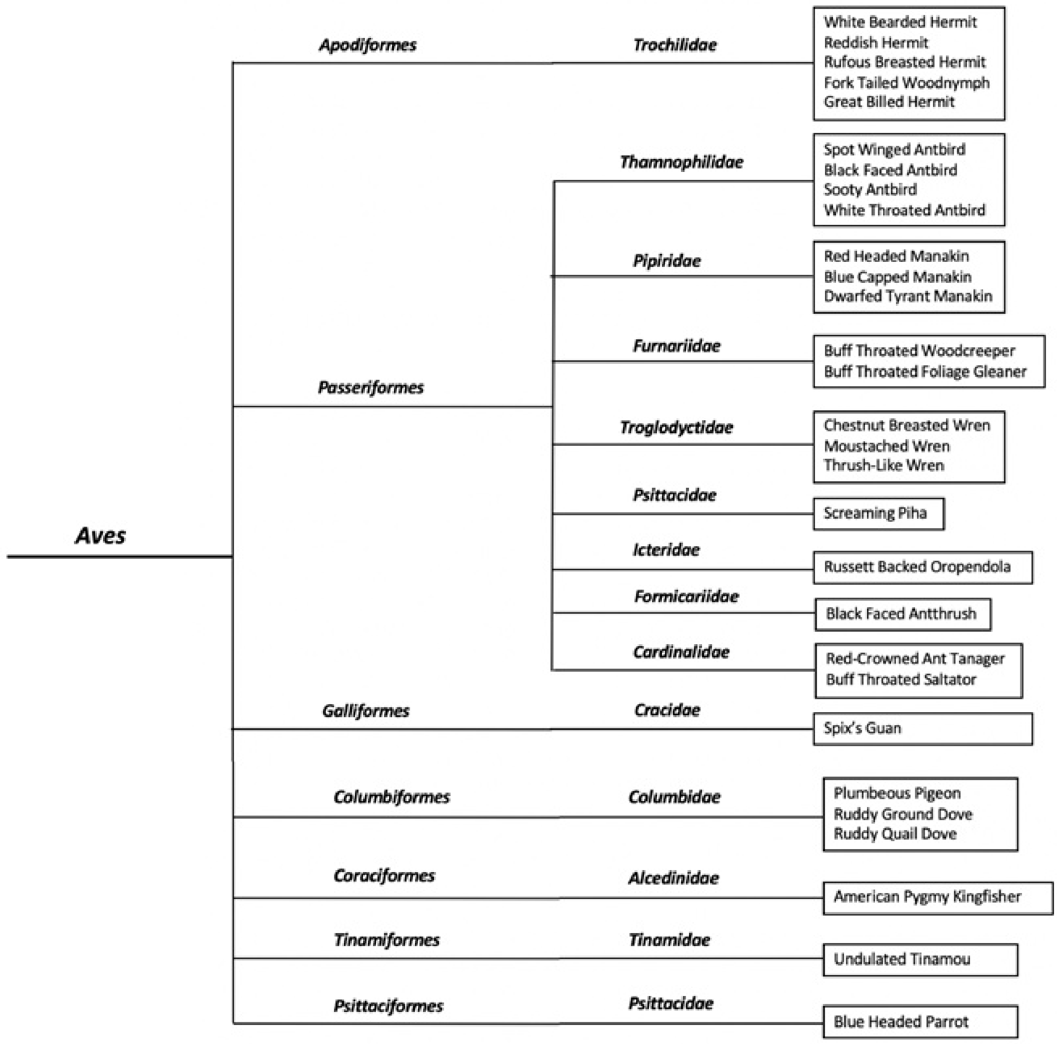


Figure 4. Phylogenetic Tree displaying all observed species categorised into their Family and Orders to show their evolutionary relationships

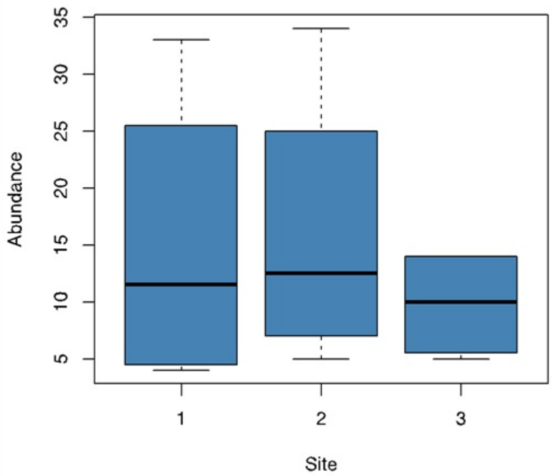


Figure 5. Boxplot displaying the abundances (total number of individuals) observed at each observation session at the ephemeral pool sites (1, 2 and 3).

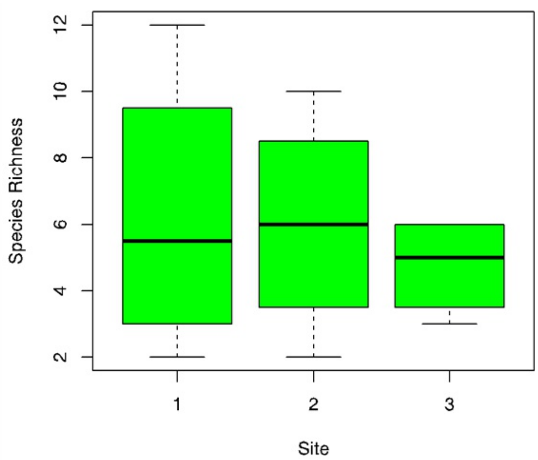


Figure 6. Boxplot displaying the species richness (number of different species) observed at each ephemeral pool site (1, 2 and 3).

Using Shannon's Diversity Index the overall diversity was calculated to be 2.66 (3sf.), which included data collected during every observation session at all three ephemeral pools.
Through Merlin sound ID software, 46 species were recorded, 34 of which were new species that hadn't been observed at any sites. Screaming piha was the most recorded species through sound, being identified at 11 out of 12 data collection sessions, closely followed by great tinamou with 7 recordings. The most species recorded within one session was nineteen, meanwhile the minimum was three. In regards to abundance, a total of 163 individuals were observed at the ephemeral pool sites, meanwhile 113 individuals were identified through sound.

Site differences
For Site One, Site Two and Site Three the number of species recorded was 20, 17 and 10 respectively, meanwhile the total abundances were 60, 64 and 39 respectively. There were only four species that were present at all three sites; great-billed hermit; rufous breasted hermit; black faced antbird; and the fork-tailed woodnymph.
The means remained relatively consistent between all three sites for both abundance and species richness. The ranges for both variables at Site 3 were much smaller than those observed at the remaining two sites. The standard deviation bars regarding abundance for site one and site two are very similar, meanwhile for species richness at site two it becomes less prevalent.

Forest Floor Site
A total of 34 individuals were observed at the forest floor site over the two days of data collection, belonging to 15 different species, seven of these species were not observed at the ephemeral pool sites (Table 3). These species belong to eleven different families and six different orders. The Passeriformes were the most frequently observed Order with a total abundance of fifteen individuals within six different species. Psarocolius angustifrons (russet-backed oropendola) was the most abundant species with 8 individual sightings. Two of the six orders observed had not been previously observed during the ephemeral pool samples: Piciformes, with families Picidae and Ramphastidae; and Cuculiformes, with family Cuculidae.
Meanwhile using Sound ID software, 27 different species were recorded, six of which hadn't been recorded at any ephemeral pool site: blue-and-yellow macaw; purple-throated euphonia; house wren; great antshrike; barred antshrike; and squirrel cuckoo. The Shannon's diversity index score for the far site was 2.450863.

New Species		
Violaceous jay	Little Tinamou	Great Tinamou
Yellow tufted woodpecker	Channel billed toucan	Squirrel cuckoo
Brown tinamou		

Table 3. List of species that were observed during data collection at the forest floor site that hadn't been observed at the ephemeral pool sites.

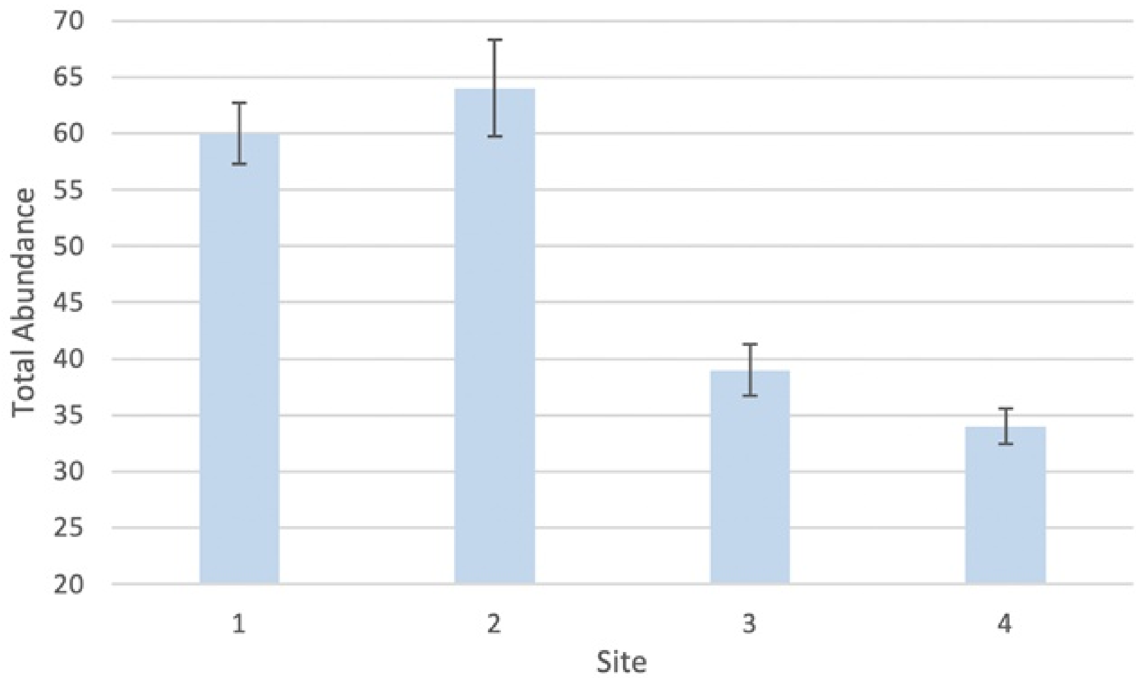


Figure 7. Bar chart displaying the total abundances observed at each ephemeral pool site (1, 2 and 3), and the forest floor site (4), including their standard deviation bars.

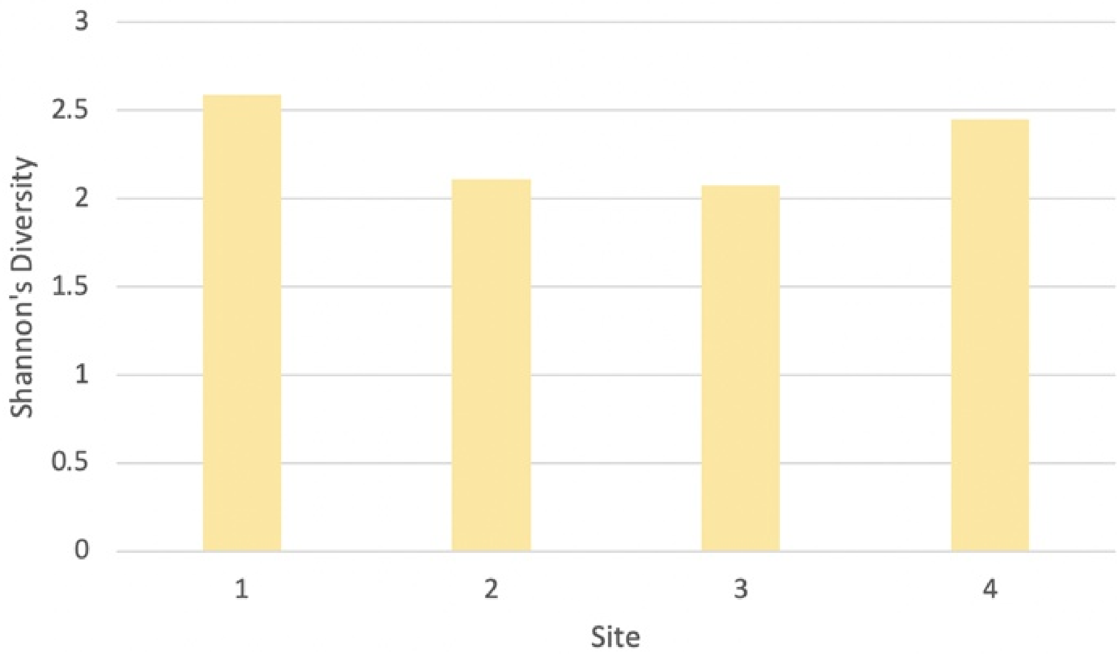


Figure 8. Bar chart displaying the calculated Shannon's Diversity index at the ephemeral pool sites (1, 2 and 3), and the forest floor site (4).

Effect of Ephemeral Pool Size

The highest abundance of birds at one sample was 34, with the ephemeral pool area equating to 7068 cm2 and its depth equal to 80mm. The largest ephemeral pool in regards to area was measured at 137444 cm2 with 18 individuals being observed. Meanwhile, the deepest pool was measured at 480 mm and 6 individuals were observed at this site. Through creating a histogram and conducting a Shapiro Test on R software it was discovered that none of these variables displayed a normal distribution, therefore lines of best fit could not be created, proving no present significant correlation.

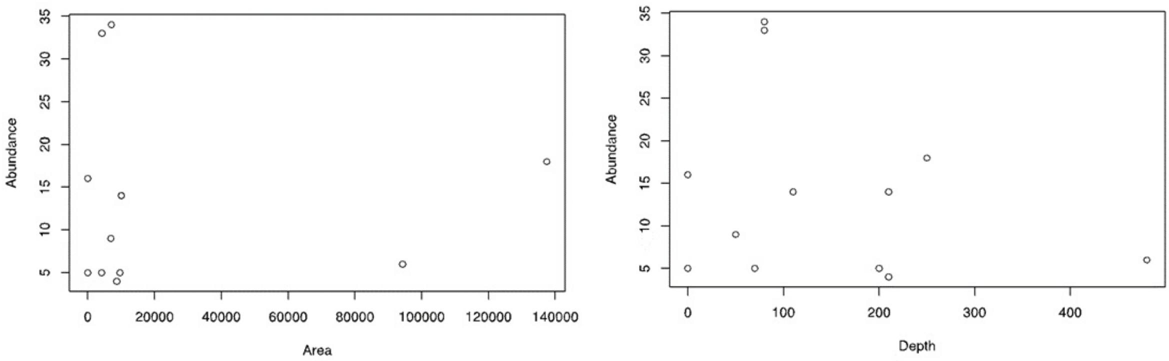


Figure 9. Scattergraph displaying relative abundance of avian individuals compared to the calculated area (left) and depth (right)

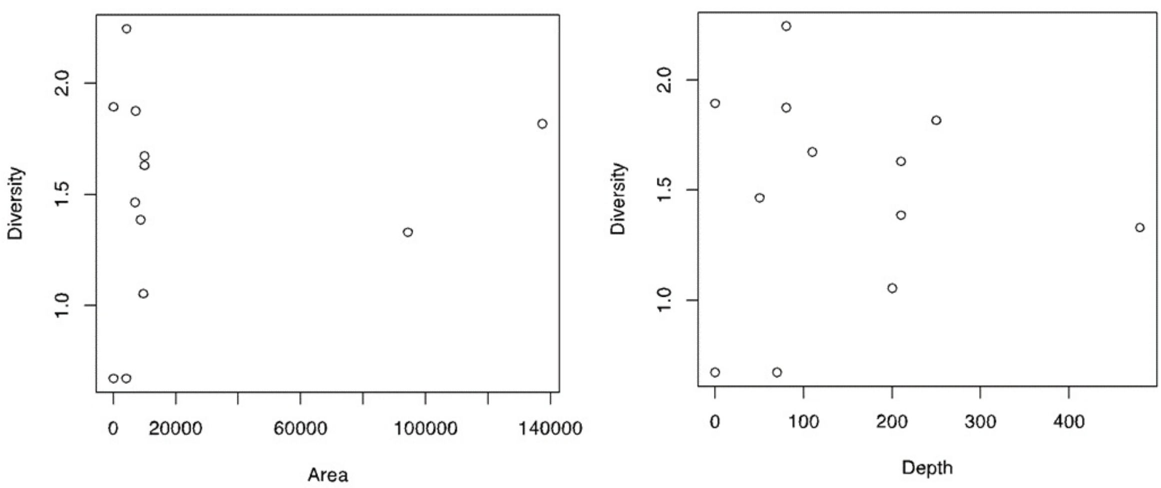


Figure 10. Scattergraphs displaying relative species diversity of avian species compared to the calculated area (left) and depth (right) of each ephemeral pool at the time of data collection.

Species interactions

Each interaction observed was listed into one of seven categories: flying; foraging; territorial; perched; ground; and submerging. Due to difficulty distinguishing individuals drinking from those foraging these were all grouped into the 'foraging in pool' subcategory. Of these activities foraging was the most recorded, being performed by 53 individuals, meanwhile ground-dwelling individuals was least recorded, with only 4 incidences.

10 individuals were recorded fully submersing themselves into the ephemeral pools, 8 of which were performed by species belonging to the Thamnophilidae family (Black-faced antbird, Spot-winged antbird, and Sooty Antbird). Of the 53 individuals displaying foraging within the ephemeral pool, 72% (38 individuals) were observed by either 'Great-billed hermits' or 'Fork-tailed woodnymphs,' with 19 individuals of each species.

Time differences

During the morning data samples, a total of 34 individuals were recorded, belong to 10 different species, meanwhile in the afternoon samples 129 individuals were observed belonging to 26 different species. 7 of these species were observed during both the morning and afternoon sessions, 6 of which were observed more frequently during the afternoon sample, with one exception being the buff-throated saltator. At all three sites more individuals were observed during both the afternoon sessions when compared to the respective morning sessions.

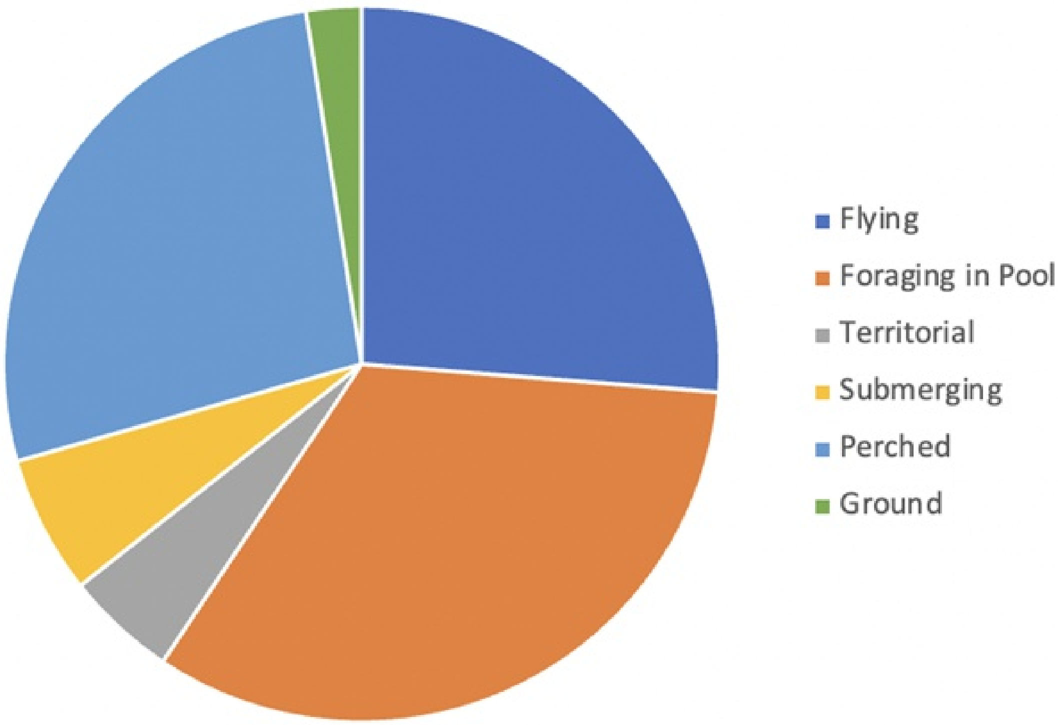


Figure 11. Pie chart displaying the frequency of the seven species interactions (flying, foraging in pool, territorial, perched, ground; and submerging) observed at the three ephemeral pool sites over the data collection period

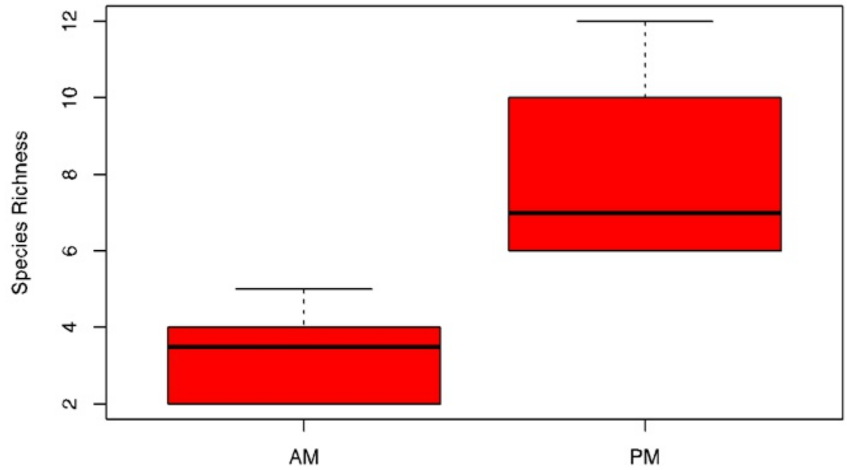


Figure 12. Boxplot displaying observed species richness for the morning (AM) session, and the afternoon (PM) session at the ephemeral pool sites.

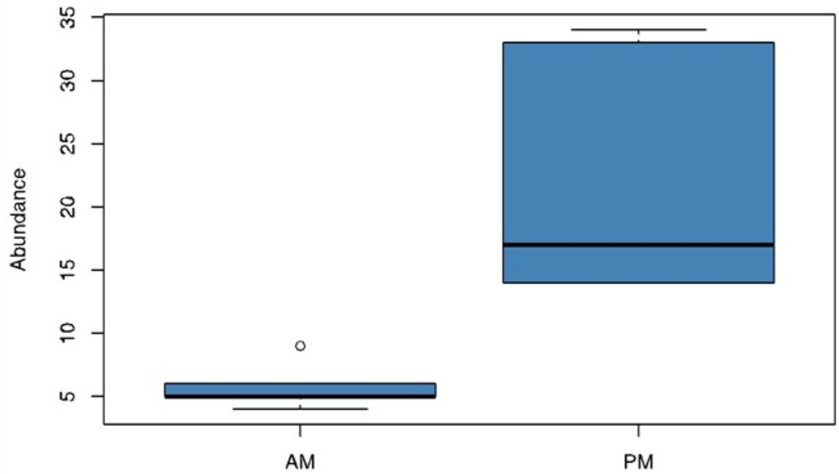


Figure 13. Boxplot displaying the observed abundance for the morning (AM) session, and the afternoon (PM) session at the ephemeral pool sites.

Camera Traps

A total of 127 avian individuals were captured through these camera traps, belonging to 33 different identifiable species (Table 4). There were only 4 found species that were present among all three sites being: lined forest falcon; sooty antbird; pectoral sparrow; and white throated antbird. The most frequently observed species was the white throated antbird, with 12 sightings, closely followed by the sooty antbird with 11 sightings. Site 1 had the highest Shannon's Diversity Index along with the highest species richness, as shown in Table … Site 1 and 3 had the highest total abundance with 45 individual observations (SD ± 1.72353945 for Site 1, SD ± 3.77964473 for Site 3).

Site	Abundance	Species Richness	Shannon's Diversity
1	45	18	2.667616
2	37	16	2.548172
3	45	15	2.254708

Table 4. Presenting the abundance, species richness, and Shannon's diversity index that was calculated from the avian sightings through the three camera traps that were set up at each ephemeral pool (Site 1, Site 2 and Site 3).

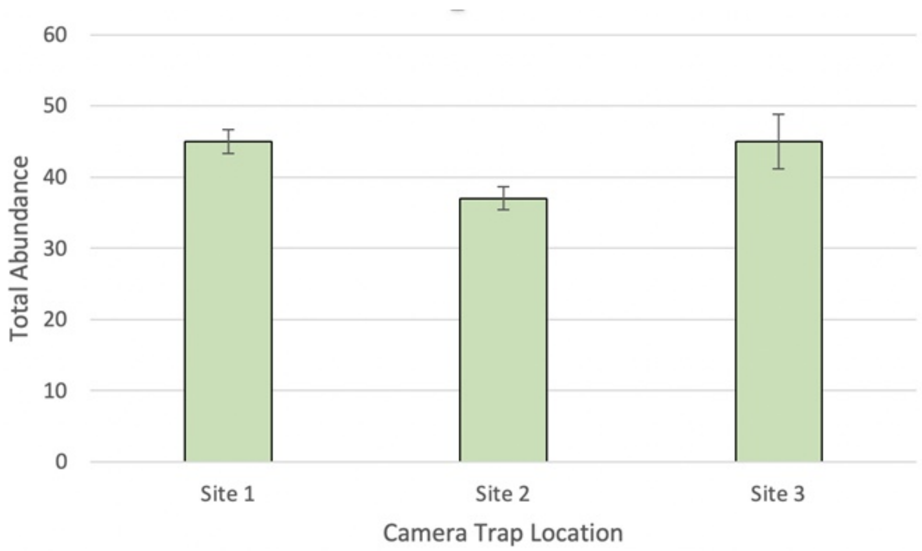


Figure 14. Bar chart displaying the total abundance for each of three sites including their standard deviations.

Discussion

Ephemeral Pool Diversity

It is clear from Figure 5 and 6 that there no significant differences between the abundances and species richness' observed at each data collection session at the three ephemeral pool sites. Total abundance however was significantly lower for site three, at thirty-nine, than site one and two, with sixty and sixty-four respectively, as shown in Figure 7. There are no clear indications as to why this result occurred as species composition remained relatively consistent throughout the ephemeral pool observations, simply that there were fewer of each species at site three.

The species richness of certain families, such as the hummingbirds (Trochilidae) and the antbird (Thamnophilidae), was disproportionally high at the ephemeral pool sites. There were five different species of Trochilidae, the abundance of which reached ninety-nine individuals across all three sites. The territorial behaviour conducted by the hummingbirds at the ephemeral pools leads us to believe that these sites have a great number of nectar producing flowering plants (see Section 4.5. Species Interactions). Hummingbirds feed on floral nectar and small arthropods, therefore, as the ephemeral pool sites presented an area with many nectar sources this can explain the high abundance of hummingbird individuals. In addition to this, hummingbirds have sedentary habits to reduce their energy expenditure, so its movements are restricted to small areas, resulting in their continued increased abundance throughout the ephemeral pool samples (Calvino-cancela 2005).

There were four observed species belonging to Thamnophilidae, with a total abundance of 28 individuals across all three ephemeral pool sites. In addition to this, two species of Furnariidae were also observed at the site: buff-throated foliage gleaner; and buff-throated woodcreeper. Some Thamnophilidae (antbirds) along with all the Furnariidae are primarily live-leaf gleaners, bark gleaners or dead-leaf gleaners (Martinez et al. 2016). Martinez and Zenil (2012) suggested that insectivorous birds that feed by gleaning experience a higher predation risk than those birds that search from afar. Risk of predation often results in prey species altering behavioural responses to reduce this risk, however more often this comes at an expense to foraging opportunities. Therefore, within a shared environment, members experiencing similar risks will gather relevant information from each other to minimise the effects on foraging (Seppanen et al. 2007). Mixed-species bird flocks are an outcome of this, in which species will respond to alarm calls presented by other species to minimise predation risk and increase survival rates (Martinez et al. 2016).

Clerke and Williamson (1992) discovered that some species of ants prey on newly metamorphosed cane toads at natural ponds in Queensland, Australia. Cane toads are also native to South America primarily located in the Amazon rainforest. A high abundance of cane toad eggs and toadlets at the ephemeral pools could give rise to an increase in ant populations. As the name suggests, antbirds are obligate ant followers, foraging almost exclusively on ant swarms (Martinez et al. 2018). Therefore, an increase in ant abundance surrounding ephemeral pools can explain the increase in antbird abundance in comparison to that observed at the forest floor site.

Size differences

Figures 9 and 10 clearly show the lack of correlation between both the ephemeral pool area and depth, compared to the abundance and overall diversity of avian species present. Therefore, we can accept the null hypothesis that the size of the pool has no significant impact on avian species presence. This could be explained by the simultaneous size changes experienced at all three sites after a friaje and increased precipitation. Additionally, the variation in area and depth may not have been great enough to have a significant impact of avian diversity. However, Pizarro-Araya et al. (2023) investigated insect populations at ephemeral pools in Chile, they discovered a negative correlation between the area of the pools and the species richness and abundance. They also discovered no significant correlation between the depth and the species richness and abundance.

Time differences

Figure 12 and Figure 13 suggest the afternoon (PM) session as being higher in both abundance and species richness than the morning (AM) session. Robbins (1981) found hummingbird abundances to increase each hour after sunrise, however there is no information regarding tropical bird activity in the later hours of the day. As hummingbirds presented the vast majority of the data collected at the ephemeral sites this can explain the drastic increase in abundance observed in the afternoon sessions. Meanwhile, the study also found wrens and doves to be most active within the first hour after sunrise and found a negative correlation for the hours thereafter (Robbins 1981). However, very few wrens were observed throughout this study resulting in no significant impact on the time-abundance data.

Forest Floor

Figure 7 shows that the forest floor site has a significantly lower abundance than those observed at the ephemeral pool sites, however, the calculated Shannon's diversity index for this site was actually greater than the equivalent at site two and site 3. Although fewer individuals were recorded at the forest floor site there was a greater variety of species to compensate for that. Differences in species identities between the forest floor and the ephemeral pools are shown by differing richness and abundance values, along with different species compositions, suggesting different

mechanisms structuring the communities (Robinson et al. 2021).
In comparison to the ephemeral sites, the proportion of observed avian species with a larger body size was greater at the forest floor site. Martinez et al. (2016) discovered that birds with a small body size have variable flocking levels, meanwhile larger birds have consistently low flocking levels. Therefore, this could explain the significant reduction in total avian abundance recorded at the forest floor site as these individuals tend to be more solitary species.

Species Interactions
Five percent of all observed birds were presenting 'territorial' behaviour, all of which were performed by hummingbirds (Trochilidae). This behaviour was displayed by high speed chases throughout the mid canopy. Territoriality is a common behaviour for hummingbirds that is believed to be strongly influenced by local energy sources, particularly feeding sources (Nunes-Rosas et al. 2017). The main food source for hummingbirds is nectar, therefore, males defend territories that are characterised by a variable number of flowering plants (Nunes-Rosas et al. 2017). Males that possess these territories have advantages over intruding males when it comes to mate-selection.
Other than birds there were several other species clearly interacting with the ephemeral pools that were either observed during the in-person data collections or seen from the camera trap videos. Through camera trap footage there was evidence of fish within these ponds, which can explain the presence of the American pygmy kingfisher. Another video captured by these camera traps depicted a Cuniculus paca hunting for fish within these ponds which is a behaviour that has never previously been documented. As the ephemeral pools have proven to be an area of high avian populations through both the camera traps and the observations, in turn it could also result in an increase in species that predate on birds. In one instance, a Nasua nasua was observed to be hunting on plumbeous pigeons that were on the bank of the pools.

Limitations
Due to time constraints, data collection was only conducted for 8 days, with 6 days spent collecting data at the ephemeral pool sites. Therefore, data at the forest floor site was only conducted over 2 days, meaning an overall comparison between forest floor and ephemeral pools could not be conducted as the data pools are unequal, resulting in invalid results. To overcome this, the forest floor data was analysed in comparison to each ephemeral pool site separately as each the data collection periods were equal at two days, resulting in comparable data.
Throughout conducting the observation surveys it was clear that bird identification skills improved over the duration of the study, which could introduce some bias. This was overcome by mixing the sites that were observed on each day, so each site was repeated further into the study when identification skills had already improved.
Alongside in-person observations, Merlin ID software was used to collect data regarding bird calls. An issue discovered while using this software was the lack of information regarding the abundance of each species present, therefore the maximum each species could be recorded as was one individual. This led to some individuals, particularly those of flock species, being missed from our data collection, reducing the accuracy of our results. In addition to this, there was no information present regarding the distance from the sites as the recordings were completely dependent on volume of noise rather than proximity to the pool. Some

species are much more vocal than others, for example 'screaming piha,' resulting in more frequent recordings than those that are less vocal. However, these limitations were overcome by analysing this data separate to that of the observations to eliminate the confounding effect it could've had.

The addition of camera traps provided some great information regarding bird activity at these ephemeral pools during times when in-person data collection was not conducted. One limitation to utilising camera traps for recording activity is that due to the speed at which certain species travel, for example hermits, it may be difficult for camera traps to capture these individuals, resulting in a reduction in recorded bird diversity. Additionally, due to the high abundance of lepidopteral individuals that were also setting off these camera traps, some target individuals could've been missed, decreasing the accuracy of our results. To overcome both these limitations the camera trap data was recorded and analysed separately to that of the in-person observational data so that any confounding effects of the camera traps were eradicated and didn't impact the overall validity of the study. Upon analysis of the camera trap data it was noted that Chiroptera were very active at the ephemeral pools during the night, which led to draining of the battery, meaning that each camera was only able to capture avian individuals over one to three days.

Future investigations

This study acts as an important starting point for further research investigating avian biodiversity at ephemeral pools showing that different compositions of birds are more frequently present at ephemeral pools in comparison to further forest floor sites. However, further research needs to be conducted to fully understand the differences in species composition and to determine the true biodiversity value of ephemeral pools. Future investigations should be conducted over a greater time period to gather larger data pools at both the ephemeral pools and the forest floor. Additionally, an equal number of sites should be sampled at both comparisons. In 2017 Mekonen suggested that the impacts of environment changes on birds resulted in behavioural and physiological changes in the characteristics of the individual, which resultantly effects birth rate, death rate, and dispersal rate. After some time, changes in these parameters would result in fluctuations in secondary population parameters such as abundances, species richness and breeding populations (Mekonen 2017). Therefore, by studying for a significantly longer duration these effects would become present through observations, and a more quantifiable impact can be calculated. Furthermore, more research could provide important information regarding the structure of the habitat, along with floristic richness, Hexapoda abundance, and other key characteristics, that could explain the structure of the avian community interacting with these environments (Tornero et al., 2016; Heino et al., 2017).

Acknowledgements:

I would like to thank the Alliance for a Sustainable Amazon for providing me the location and all the necessary materials for this project. I'd particularly like to thank Barry Cronin, Academics Programme Coordinator, for his supervision and guidance throughout the duration of this project.

References:

Albright et al. (2010) Effects of drought on avian community structure. Global Change Biology 16:2158-2170

Brasil L., et al. (2018) Net primary productivity and seasonality of temperature and precipitation are predictors of the species richness of the Damselflies in the Amazon. Basic and Applied Ecology 35:45-53

Bodmer R. et al. (2018) Major shifts in Amazon wildlife populations from recent intensification of floods and drought. Conservation biology 32:333-344

Calvino-Cancela M. (2005) Time-activity budgets and behaviour of the amazalia hummingbird. Rev. Biol. Trop 54:873-878.

Clerke R., Williamson I. (1992) A note on the predation of bufo marinus juveniles by the ant iridomyrmes purpureus. Australian Zoologist 28:1-4

DeVault T., Milton S. (2003) The importance of roads and road verges for raptors and crows in the succulent and namakaroo, South Africa. Ostrich 74:181-186.

Eglington S., Noble D., Fuller R. (2011) A meta-analysis of spatial relationships in species richness across taxa: Birds as indicators of wider biodiversity in temperate regions. Journal for Nature Conservation. 20:301-309

Fraizedas S., Linden A., Piha M., Cabeza M., Gregory R., Lehikoinen A. (2020) A state-of-the-art review on birds as indicator of biodiversity: advances, challenges, and future directions. Ecological Indicators. 118

Gallice G., Larrea-Gallegos G., Vazques-Rowe I. (2017) The threat of road expansion in the Peruvian amazon. Fauna and Floral International.

Gatti, L.V., Basso, L.S., Miller, J.B. et al. (2021) Amazonia as a carbon source linked to deforestation and climate change. Nature 595:388–393

Hashimoto et al. (2021) New generation geostationary satellite observations support seasonality in greenness of the Amazon evergreen forests. Nature communications. 12:684.

Heino J., Bini L.M., Andersson J., Bergsten J., Bjelke U. and Johansen F. (2017) Unravelling the correlates of species richness and ecological uniqueness in a metacommunity of urban pond insects. Ecological Indicators 73: 422-431.

Hilden O (1965) Habitat selection in birds. Annales Zoologica Fennici 2:53-75.

Houston D. (1979) The adaptations of scavengers. Dynamics of an Ecosystem 263-286

Huertos M. (2020) The Stage: Typologies of aquatic systems. Ecology and Management of Inland Waters.

Lapola D., et al. (2023) The drivers and impacts of Amazon forest degradation. Science. 379.

Li S., Brown J (1999) Influence of climate on reproductive success in Mexican Jays. Auk 116: 924-936.

Martinez A., Gomez J., Ponciano J., Robinson S. (2016) Functional traits, flocking propensity, and perceived predation risk in an Amazonian understory bird community. The American Naturalist 187: 5

Martinez A., Pollock H., Kelley P., Tarwater C. (2018) Social information cascades influence the formation of mixed-species foraging aggregations of ant-following birds in the neotropics. Animal behaviour 135:25-35.

Martinez A., Zenil R. (2012) Foraging guild influences dependence on heterospecific alarm calls in Amazonian bird flocks. Behavioural Ecology. 23:544-550

Mekonen S. (2017) Birds as biodiversity and environmental indicator. Journal of natural sciences research 7:28-34

NASA Earth Observatory (2021) Satellite senses subtle amazon seasonality. https://earthobservatory.nasa.gov/images/148363/satellite-senses-subtle-amazon-seasonality Accessed: 10th July 2023.

NASA (2021) Dry and wet seasons in the Amazon basin. https://misr.jpl.nasa.gov/gallery/dry-and-wet-seasons-amazon-basin/ Accessed: 10th July 2023.

Nunes-Rosas L., Arizmendi M., Cueva del Castilla R., Serrano-Meneses M. (2017) Mating system, male territoriality and agility as predictors of the evolution of sexual dimorphism in hummingbirds (Aves: Trochilidae). Behaviour. 154:1297-1341

Pizarro-Araya J., Alfaro F., Rios-Escalante P. (2023) Insects associated to ephemeral pools in Huentelauquen (Coquimbo region, Chile). Brazilian Journal of Biology. 84

Robbins C. (1981) Effect of time of day on bird activity. Studies in Avian Biology 6:275-286

Robinson W., Errichett D., Pollock H., Martinez A., Stouffer P., Shen F., Blake J. (2021) Big bird plots: benchmarking neotropical bird communities to address questions in ecology and conservation in an era of rapid change. Frontiers in Ecology and Evolution. 9: 697511

Sanchez-Cuervo A., Lima L., Dallmeier F., Garate P., Bravo A., Vanthomme H. (2020) Twenty years of land cover change in the southeastern Peruvian Amazon: Implications for biodiversity conservation. Regional Environmental Change 20:8.

Seppanen J., Forsman J., Monkkonen M., Thomsom R. (2007) Social information use is a process across time, space and ecology, reaching heterospecifics. Ecology 88:1622-1633

The Cornell Lab (2023) Merlin: Identify bird songs and calls with sound ID. https://merlin.allaboutbirds.org/sound-id/ Accessed: 15th September 2023

Tornero I., Sala J., Gascon S., Àvila N., Quintana X.D. and Boix D. (2016) Pond size effect on macrofauna community structure in a highly connected pond network. Limnetica, 2:337-354.

Wang Y., Shi J., Wu Y., Zhang W., Yang X., Lv H., Xia S., Zhao S., Tian J., Cui P., et al. (2023) Selection of

Flagship Species and Their Use as Umbrellas in Bird Conservation: A Case Study in Lishui, Zhejiang Province, China. Animals 13(11):1825.

Wenny D., DeVault T., Johnson M., Sekercioglu, Tomback D., Whelan C. (2011) The need to quantify ecosystem services provided by birds. The American ornithological society. 128:1-14

World Wildlife Fund (2020) Losing their homes because of the growing needs of humans. https://wwf.panda.org/discover/our_focus/wildlife_practice/problems/habitat_loss_degradation/#:~:text=It%20is%20identified%20as%20a,Why%20is%20it%20happening%3F Accessed: 5th July 2023