Comparison of the bird diversity in old, young secondary and planted Tropical Mountain Cloud Forest with focus on the migratory birds

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Abstract

Tropical Mountain Cloud Forests are one of the most endangered, unique and species-rich ecosystems in the world. Cloudbridge Nature Reserve in the Talamanca Mountains in Costa Rica was a previous agriculture land and now reforested to the original cloud forest is home to a rich avian community. This study searched for differences in the bird species diversity between different forest succession stages with focus on the nearctic-neotropical migratory birds. Therefore, birds were counted for 40 minutes each at ten line transects in planted, young regrowth, old regrowth and primary forest for twelve weeks in the rainy season. In total 2022 individuals out of 97 species and 24 families were counted. There are no significant differences of the diversity and distribution between the forest successions. But the young regenerated forest shows the highest diversity and species richness and the primary forest shows significant more individuals per survey than the planted forest ($p = 0,01$, $r = 0,45$). 13 migratory species were seen since the beginning of September. They prefer young forest, while resident birds prefer old forest. Significant more individuals of the resident birds per survey were seen in the primary forest than in the young regenerated ($p = 0,014$, $r = 0,44$) and planted forest ($p = 0,026$, $r = 0,41$). The study shows the importance of mountain cloud forest, as a rich habitat for bird species in all succession stages. Further reforestation and protection of cloud forests is essential for species preservation and as habitats for resident and migratory species.

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1 Introduction

By the 1990's, it was clear that Tropical Mountain Cloud Forests were among the most endangered terrestrial ecosystems in the world, especially because of anthropogenic factors like deforestation, conversion to agriculture land and interruption of the area for infrastructure (Bruijnzeel et al., 2010; Scatena et al., 2010). Tropical Mountain Cloud Forests (TMCF) are tropical forests that exist in areas with permanent or regular ground-level cloud cover or fog (Grubb, 1977; Bruijnzeel & Proctor, 1995). These are found between 30 °N and 30 °S at altitudes between 220 to 5005 m. In contrast to tropical rainforests, cloud forests are more coastal, have a wider range of average temperatures and are mainly found in cooler areas (Jarvis & Mulligan, 2010). Due to the permanent cloud cover, they are wetter than other rainforests (Jarvis & Mulligan, 2010). The interplay of abiotic conditions makes the ecosystem unique, causing endemic and endangered species to be concentrated here. Covering only ~0.4 % of the terrestrial land cloud forests provide habitat for 15 % of all bird species worldwide (Karger et al., 2021).

Cloudbridge Nature Reserve is a private reserve in the Talamanca Mountains of Costa Rica. Since 2002, agriculture land and primary forest has been purchased to regenerate and protect what was originally Tropical Mountain Cloud Forest. Now it has four different stages of forest succession, from primary and old to young secondary and planted areas. With the regeneration, Cloudbridge is protecting a unique ecosystem and working against habitat destruction. Another goal of the reserve is to do research about the flora and fauna and help understand how the ecosystem functions. For example, all six of the cat species that live in Costa Rica can be found at Cloudbridge and it is famous for the richness of birds (Cloudbridge Nature Reserve, n.d. a). 304 different bird species have been seen in the reserve (Cloudbridge Nature Reserve, 2020). Next to the richness of resident birds, the cloud forests of the Talamanca regions are special because many migratory birds come from South America from April to September, and the other way around birds from North America migrate here from September to April. So next to the numerous resident birds, many migratory birds also find their home at Cloudbridge for some time throughout the year. Due to the richness and uniqueness of avian life in this reserve, it's important to conduct continuous studies to monitor the health of the migrant species populations. This study will record and compare the bird diversity in different forest successions with a focus on the migratory birds.

Even if the birds are a topic studied often at Cloudbridge, until now there has been no focus on the difference between the migratory and resident birds. In addition, previous studies showed diverse results about the bird diversity when it comes to preferred habitat. While Kane et al. (2017) showed that the diversity of the birds was the highest in old secondary forest and the lowest in young secondary forest, Van Riesen (2021) showed that bird species richness and diversity was the highest in young secondary forests. Also, different methods were used, but what was most commonly used was the point count method. However, in this study the line transect method is used, because a previous study from this year showed that with line transects a higher abundance was found than by the point count method (Tover Heid, 2023).

The two central aims of this research are:

1) To build a bird species list for Cloudbridge.

2) To analyse differences in the species diversity between the different forest successions as habitats.

In addition, there is a focus on the changes when the migratory birds from North America arrive. Therefore, following questions are discussed:

- When can the migratory birds be found in Cloudbridge?
- Which forest types do the migratory birds prefer and which one do the resident birds prefer?
- Do the migratory birds also join the mixed species flocks?

Following Hypotheses are put forward:

A) H_0: There is no difference in the species diversity between the forest successions.

   H_1: There is a difference in the species diversity between the forest successions.

B) H_0: There is no difference between migratory and resident birds when it comes to preferred habitat.

   H_1: There is a difference between migratory and resident birds when it comes to preferred habitat.

The questions of the research are answered by an empirical study design.

2 Study area

2.1 Cloudbridge Nature Reserve

This study took place at Cloudbridge Nature Reserve, which is located at the pacific side of the Talamanca mountains in the Pérez Zeledón region in Costa Rica, sharing a border with Chirripó National Park. It is a private nature reserve with a total area of around 283 hectares and located at an altitude of 1550 m to 2600 m (Cloudbridge Nature Reserve, n.d. a). At the reserve you can find four forest succession stages of cloud forest, due to former agricultural use of the area and subsequent reforestation or natural regeneration since 2002. Especially in the higher elevation areas you can find primary forest and old secondary forest. There is also young secondary forest, which has been regenerating since 2002. The last forest type is the youngest where the trees were planted after agriculture use (Cloudbridge Nature Reserve, n.d. a). All the forest types will be included in this study.

2.2 Trails and description of the forest

Four trails at Cloudbridge were selected, which include old secondary, young secondary and planted forest: Montaña, Jilguero and Rio together with Heliconia (fig. 1). On these trails the birds were counted by the method of line transect (LT). For every forest type there were in total three line transects (fig. 1). In addition, a line transect in the primary forest at the top of Montaña trail until 30 m into the Chirripó trail were added, to have a comparison with the younger forest.

The following paragraphs are a general description of the different forest successions, where the line transects are found. The values are estimations and not measured.

The Jilguero trail is close to the living area and is quite steep. It contains a main trail and a Jungle loop. The loop and the first section of the main trail are planted forest (LT1), where the trees are up to 30 cm in diameter and up to 20 m high and it has a lot of undergrowth vegetation, especially small trees. The second section is young secondary naturally regrown forest (LT2), where the trees are a bit smaller up to 15 m, but thicker in diameter up to 150 cm. The last section is older secondary forest (LT3), with higher trees, more moss cover and more epiphytes on the trees. Therefore, it contains less undergrowth.

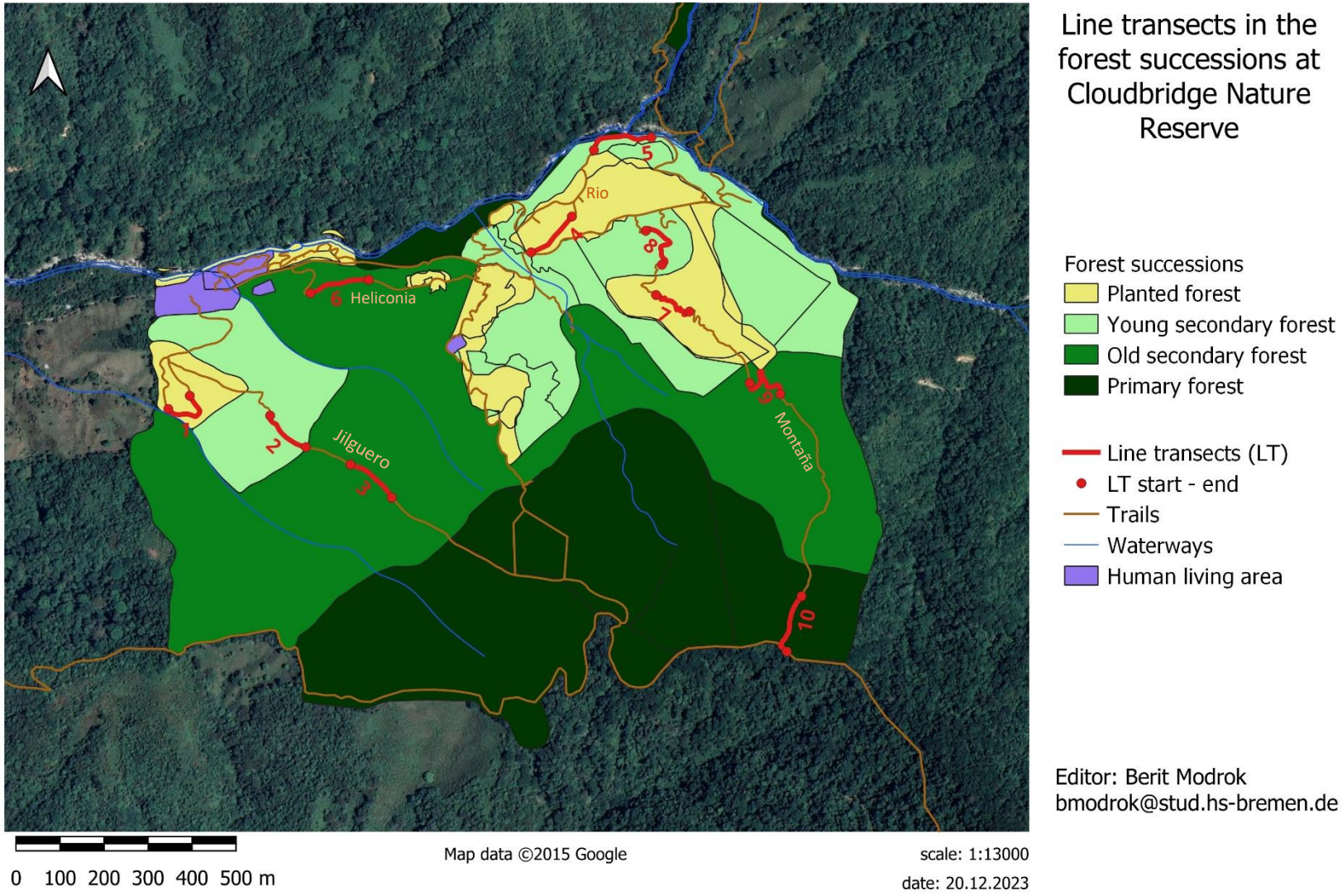

Figure 1: Forest successions and line transects at Cloudbridge Nature Reserve.

The trails Heliconia and Rio are combined for one survey trail with a total of three line transects. At Heliconia you can find old growth forest (LT6), where the trees are up to 50 cm in diameter and 35 m high. The area contains a dense undergrowth with small trees and shrubs. Epiphytes can only be found on some trees, while most of the trees are covered by moss. At Rio you can find planted forest (LT4), where the trees are thinner than in the old forest. Between the larger trees there is a lot of undergrowth with many small trees and also shrubs. The young secondary forest (LT5) is very close to the river, which makes it difficult to listen to birds. Here you can find a lower tree density, but also taller trees, which have a height up to 35 m. In all three forest types you can find a lot of bamboo. In addition, the trails are not close to each other and both trails are easy to hike.

Montaña is one of the longest trails at Cloudbridge, connecting the reserve with the Chirripó trail. At this trail you can find all four different forest successions. At the planted area (LT7) the trees are mostly planted in one line with around 1-2 m in between. Most of the trees are the same height around 10 m and 10 cm in diameter. The canopy cover is 80 – 90 %, which allows only a little bit of sun to reach the ground, where only small parts of undergrowth is present. In the young regenerated forest (LT8) there are trees with a height up to 20 m and 40 cm in diameter. You can find differences in the undergrowth, from some areas with only a few small trees and shrubs to some areas with a dense undergrowth. The old regenerated forest (LT9) borders on the planted forest, where you can see a big difference. The trees are a lot higher reaching 30 m and 70 cm in diameter. The undergrowth is dense with a lot of young trees and shrubs. 80 % of the trees contain moss and epiphytes. The primary forest (LT10) can be found at the top of the Montaña trail and at the Chirripó trail. The trails are still different in their appearance. There are two canopy layers, one up to 35 m and the next one up to 20 m high. 70 % of the trees contain epiphytes and moss. The undergrowth is very dense with a lot of young trees. The trees at Montaña are close to each other with a canopy cover of 60 %. The trees at the Chirripó trail are a lot more spread apart, which is caused by a wider trail, and the canopy coverage is around 40 %.

3 Methodology

3.1 Materials

The following materials were used in this study:

- Binoculars (Eden XP 10x42 114m/1000m)
- GPS tracker (Garmin GPSMAP 64sx)
- Measuring tape 30 m
- Marking bands
- Pencil
- Notebook
- Identification literature: The Birds of Costa Rica, A Field Guide (Garrigues & Dean, 2014)
- The CornellLab: Merlin Bird ID, version 3.0.3 (148 – 2022)
- Microsoft®Office 365 (Excel®)
- IBM: SPSS Statistics, version 28.0.1.0 (142)
- QGIS Development Team: QGIS, version 3.34 Prizren

3.2 Data collection

The data collection took place in the time of 28th August 2023 to 26th November 2023, with 12 survey weeks in total.

3.2.1 Line transects

The birds were counted by the method of line transect. Lines were 150 m long and marked along the way. Therefore, the trails were selected and examined to see which part fits best. The GPS data was collected by using a GPS tracker (tab. 1, fig. 1)

Table 1: GPS coordinates of the line transects. *Measured with Garmin GPSMAP 64sx.*

Line Transect	START Latitude-Longitude		END Latitude- Longitude		Range Elevation (m)	Trail	Forest Type
1	09°28.184'	83°34.721'	09°28.199'	83°34.695'	1617 - 1667	Jilguero	planted
2	09°28.175'	83°34.594'	09°28.136'	83°34.549'	1752 - 1800	Jilguero	young
3	09°28.119'	83°34.494'	09°28.075'	83°34.445'	1833 - 1873	Jilguero	old
4	09°28.374'	83°34.274'	09°28.425'	83°34.224'	1714 - 1703	Rio	planted
5	09°28.499'	83°34.194'	09°28.517'	83°34.123'	1686 - 1697	Rio	young
6	09°28.324'	83°34.546'	09°28.340'	83°34.474'	1616 - 1636	Heliconia	old
7	09°28.322'	83°34.115'	09°28.303'	83°34.076'	1850 - 1873	Montaña	planted
8	09°28.402'	83°34.130'	09°28.356'	83°34.109'	1768 - 1799	Montaña	young
9	09°28.213'	83°34.007'	09°28.200'	83°33.965'	1960 - 1995	Montaña	old
10	09°27.951'	83°33.927'	09°27.888'	83°33.951'	2128 - 2167	Montaña	primary

The line transects were walked at a slow pace for 40 minutes and every few steps there was a pause to look around and listen for birds. If the distance was done before the 40 minutes ended, the transect was walked again in the other direction.

3.2.2 Timetable

The time was divided in two time periods: early from 6am - 8am and late from 8am - 10am, which was again divided in four survey times: 6:20-7:00, 7:20-8:00, 8:20-9:00, 9:20-10:00. Between the time spots were 20 minutes to go to the next line transect and prepare for the next survey. Every transect was surveyed in every survey time slot three times. Therefore, a timetable was created (tab. A1). For the first four weeks, there was only a 15-minute break in between the surveys. After every trail was surveyed in each time slot, the decision was made to expand the break to 20 minutes.

3.2.3 Birding

Before the actual study started, the birds were studied with a pdf about the most 50 common birds at Cloudbridge and bird walks took place every Monday to begin bird identifying skills.

The birds were identified observationally with the help of binoculars and listening. For the identification of unknown birds, the app Merlin was used by comparing them with the pictures or by sound. In addition, the book “The birds of Costa Rica” by Richard Garrigues and Robert Dean (2014) was used for the identification.

3.2.4 Weather

In addition, the weather conditions and the temperature were noted before and after every survey. The temperature data was taken from The Weather channel (n.d.) and the actual

weather conditions were written down. In addition, at every trail it was noted in which survey time slot the sun hits the area in the morning and if it was very misty or cloudy during the survey, which makes the identification more difficult.

3.3 Data analysis

The data analysis was done with excel and the software SPSS. The Shannon-Wiener Index was used to describe the diversity of the bird species. For the quality analysis, the Kruskal-Wallis-test and Mann-Whitney-U-test were used, if the data was not normally distributed, tested by Shapiro-Wilk-test.

In addition to the main research questions, it was analysed if the time affects the abundance. Next to the migratory birds, it was analysed which birds are endangered or endemic to the Talamanca region.

4 Results

In total 2022 individual birds are counted which include 550 unidentified birds, which are not identified due to rapid movement or because of difficult weather conditions. Some individuals are only identified to the family level. Excluding the unidentified birds there are 1472 bird individuals counted which belong to 97 species, 24 bird families and 9 orders (tab. A2).

4.1 Distribution of the birds

80,98 % of the birds belong to the order of Passeriformes. The next biggest order is Apodiformes with 7,61 % (fig. 2). The most common family is Parulidae (32,88 %) followed by Troglodytidae (12,09 %) (tab. 2)

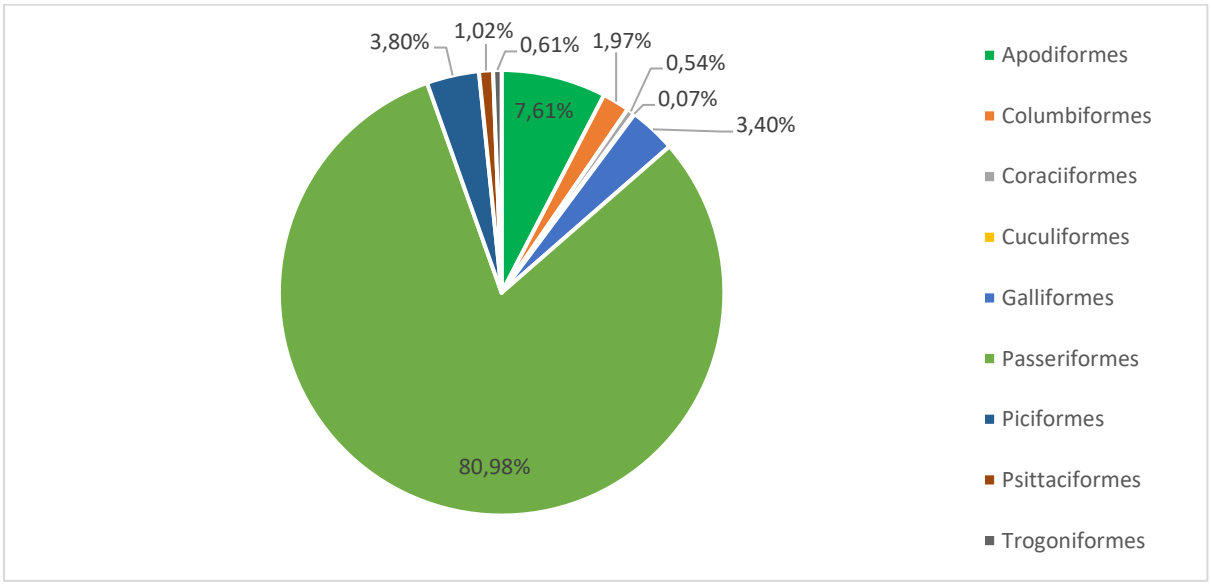

Figure 2: Distribution of the birds by order. Unidentified individuals excluded, N = 1472.

Table 2: Distribution of the families. *Unidentified individuals excluded,* N = 1472.

family	abundance	Percentage in %	order
Parulidae	484	32,88	Passeriformes
Troglodytidae	178	12,09	Passeriformes
Passerellidae	127	8,63	Passeriformes
Trochilidae	112	7,61	Apodiformes
Tyrannidae	106	7,20	Passeriformes
Turdidae	89	6,05	Passeriformes
Furnariidae	72	4,89	Passeriformes
Thraupidae	65	4,42	Passeriformes
Ramphastidae	37	2,51	Piciformes
Columbidae	29	1,97	Columbiformes
Emberizidae	29	1,97	Passeriformes
Cracidae	27	1,83	Galliformes
Vireonidae	25	1,70	Passeriformes
Odontophoridae	23	1,56	Galliformes
Capitonidae	15	1,02	Piciformes
Psittacidae	15	1,02	Psittaciformes
Trogonidae	9	0,61	Trogoniformes
Momotidae	8	0,54	Coraciiformes
Fringillidae	5	0,34	Passeriformes
Ptilogonatidae	5	0,34	Passeriformes
Corvidae	4	0,27	Passeriformes
Picidae	4	0,27	Piciformes
Cuculidae	1	0,07	Cuculiformes
Cardinalidae	1	0,07	Passeriformes
Thamnophilidae	1	0,07	Passeriformes
Icteridea	1	0,07	Passeriformes
total	**1472**	**100,00**	

The most common species (abundance over 15 individuals in 12 weeks) are the Slate-throated Redstart (n = 165), Common Chlorospingus (n = 127) and Gray-breasted Wood-Wren (n = 123) (fig. 3). The Gray-breasted Wood-Wren is one of the birds which are mostly identified by their song. Fig. 4 shows the most common birds with an adjusted graph which do not contain the unidentified birds, identified birds until family level or birds heard by song. The most common birds are still the Slate-throated Redstart (n = 160) and Common Chlorospingus (n = 125) followed by three migratory birds, the Wilson's Warbler (n = 71), Blackburnian Warbler (n = 42) and the Black-and-white Warbler (n = 41).

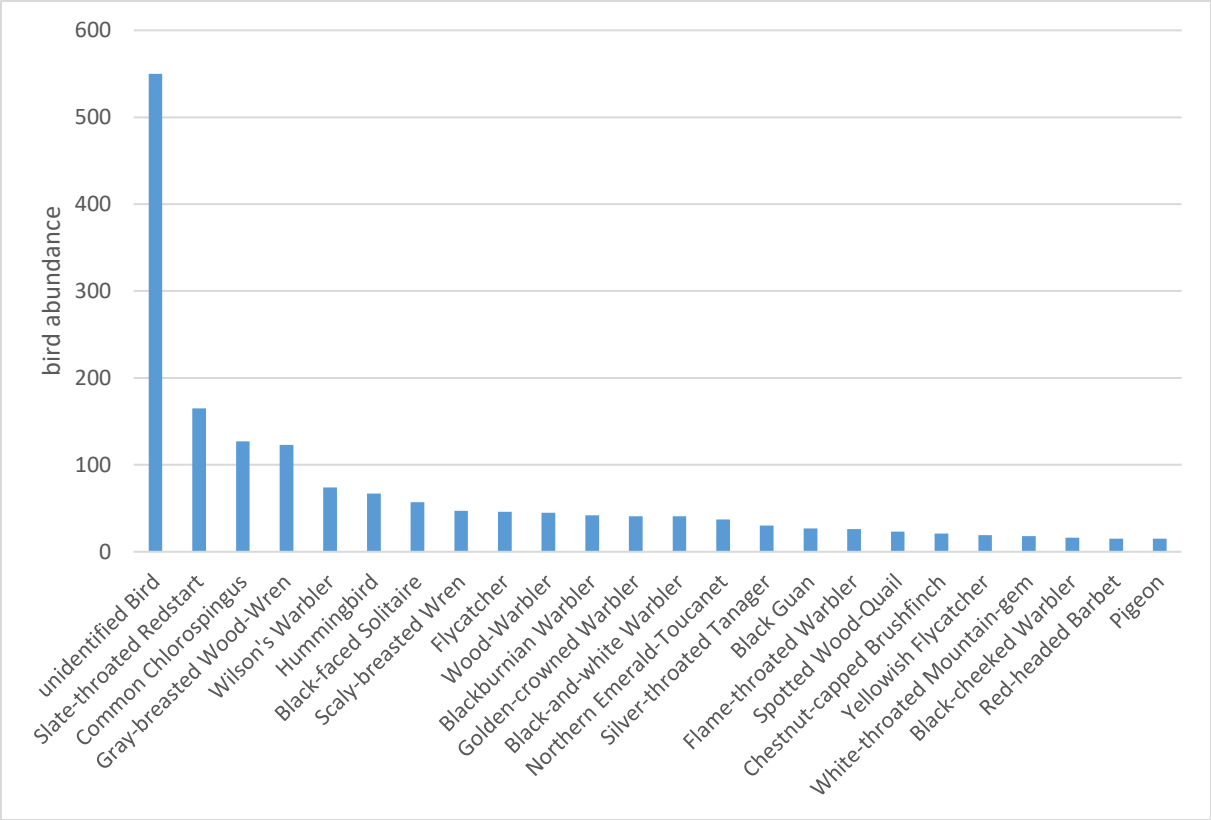

*Figure 3: Most common bird species, including all seen individuals with an a*bundance > 15. N = 2022.

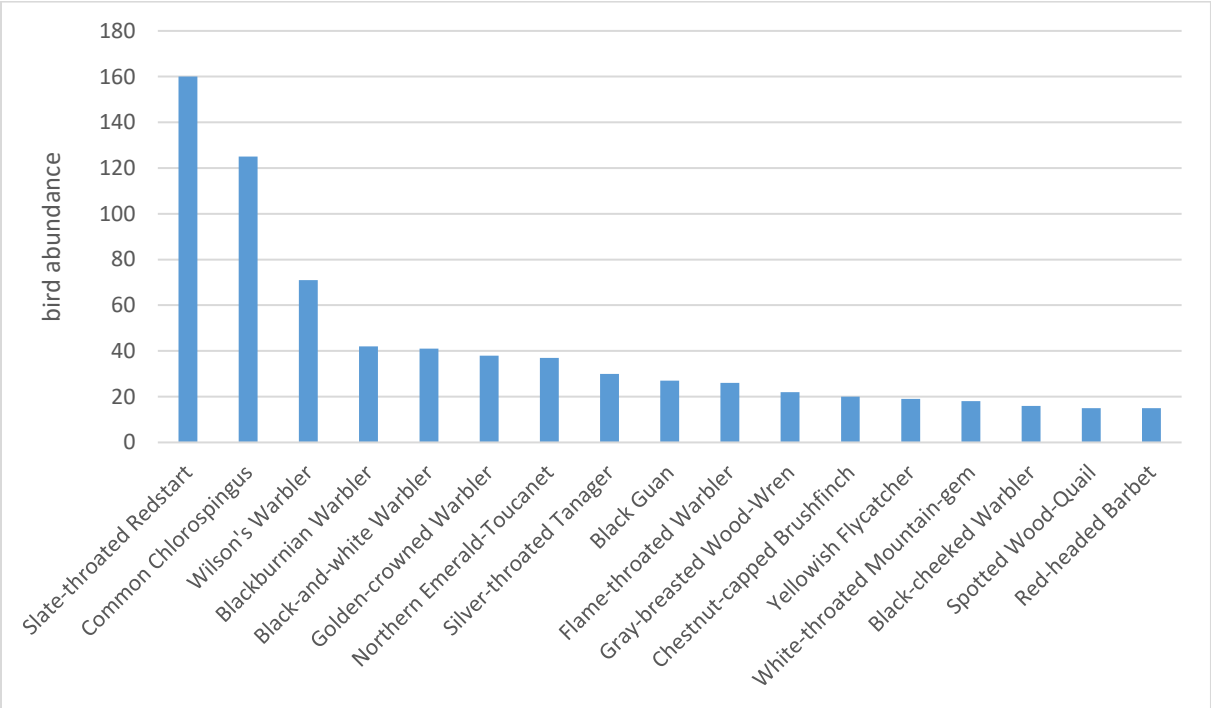

Figure 4: Adjusted most common bird species. Excluded unidentified birds, identified birds until family level, birds heard by song. Abundance > 15. N = 1005.

4.2 Distribution among the forest succession stages

The total number of bird individuals (N = 2022) divided by forest type is 30,56 % in old, 28,19 % in young, 26,26 % in planted and 14,99 % in primary forest (fig. 5a). Without counting the birds at primary forest, the order is the same and there are no statistical differences (Kruskal-Wallis-Test H(2) = 2,000; p = 0,368) between the succession stages (fig. 5b).

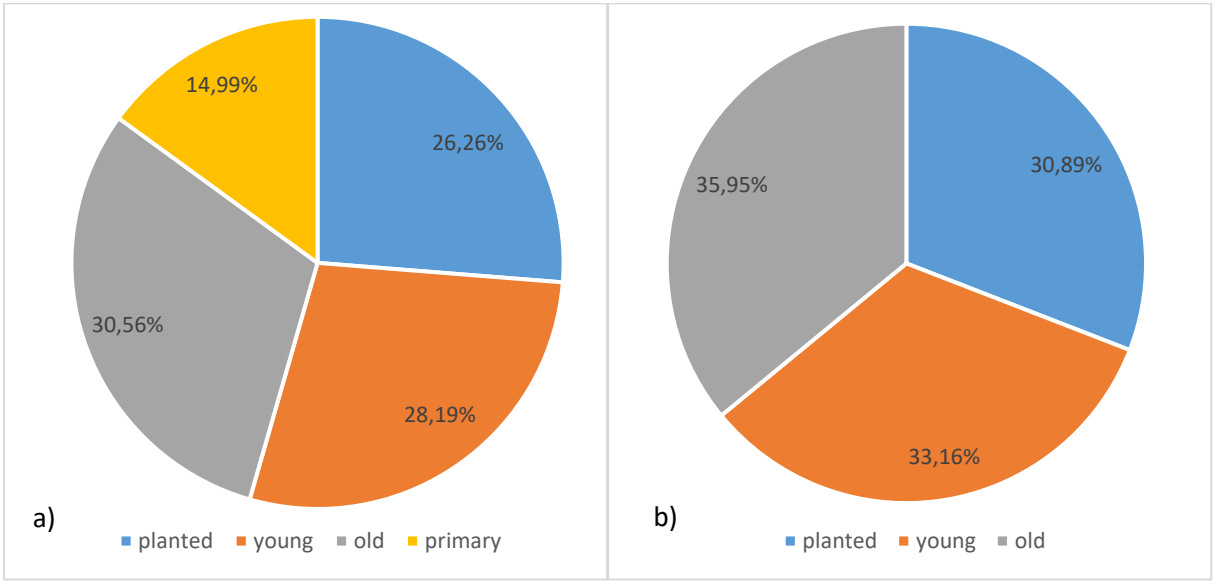

Figure 5: Distribution among the forest succession stages. a) with LT 10 as primary forest, N = 2022, b) without LT 10 (primary forest), N = 1719.

On average the most bird individuals per survey are found in the primary forest (M = 25,25, SD = 11,608), while in the old (M = 17,17, SD = 6,648), young (M = 15,83, SD = 7,485) and the planted forest (M = 14,75, SD = 8,272) less individuals are seen (fig. 6). There is a statistical difference between the forest successions (H(3) = 10,475; p = 0,015). The planted forest ($\tilde{x}$ = 12,50) shows statistically significant less bird individuals per survey than the primary forest ($\tilde{x}$ = 25,50) (p = 0,01, r = 0,45).

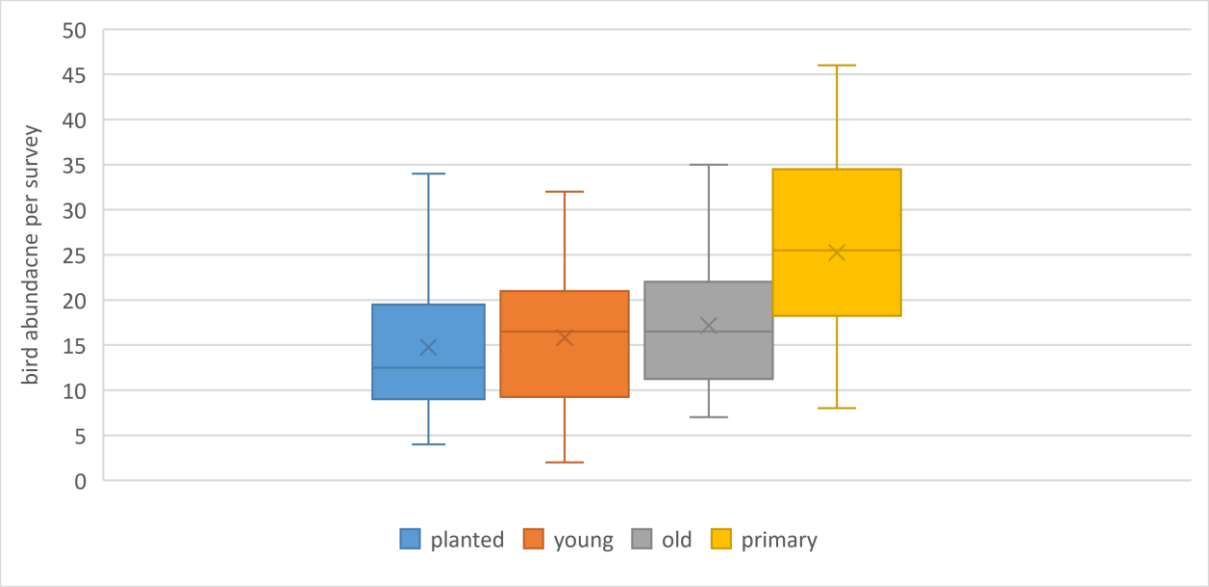

Figure 6: Counted birds per survey divided in the forest succession stages. N = 2022.

In the planted area the most birds are found at the fourth time slot (9:20-10:00am). The young forest counts the most birds at the fourth time slot as well. In the old and primary forest the most birds are counted at the second time slot (7:20-8:00am) (fig. 7). There are no statistically differences between the bird abundance at the forest successions regarding the different times (p>0,068) and early (6:00-8:00am) and late (8:00-10:00am) in the morning (p>0,103). In total, 543 individuals are counted in the third time slot.

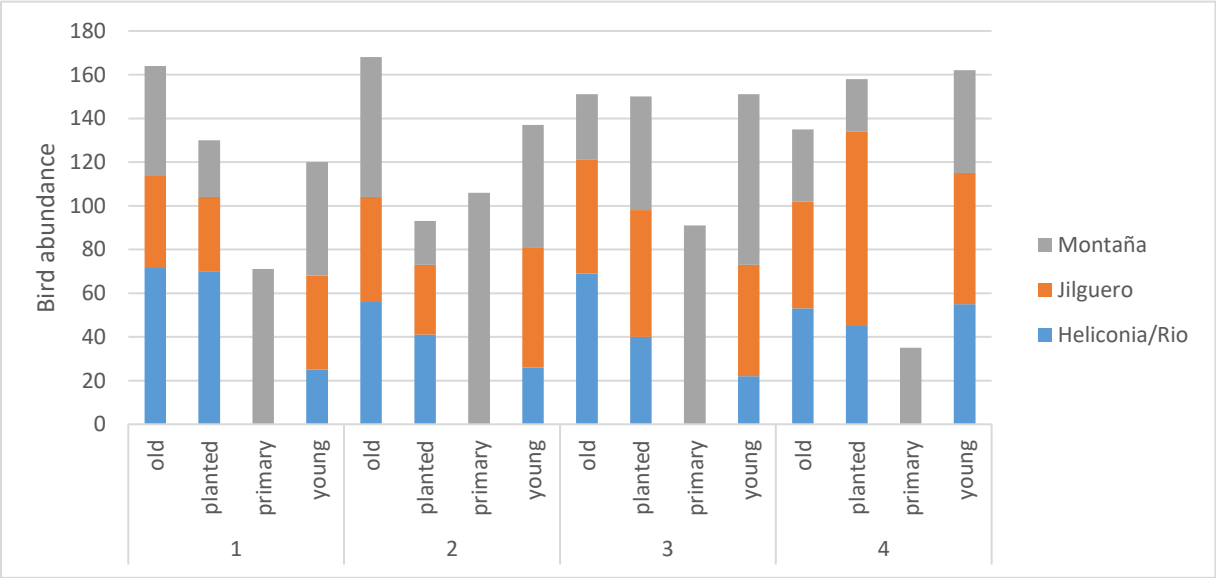

Figure 7: Abundance of the birds in the forest succession stages per time slot. 1 = 6:20-7:00 am, n = 485, 2 = 7:20-8:00 am, n = 504, 3 = 8:20-9:00 am, n = 543, 4 = 9:20-10:00 am, n = 490. N = 2022.

4.3 Distribution among the line transects

The highest number of bird individuals are found at LT10 (n = 303), followed by LT6 (n = 250) and LT8 (n = 233). LT7 shows the lowest number of counted birds (n = 122) (fig. 8).

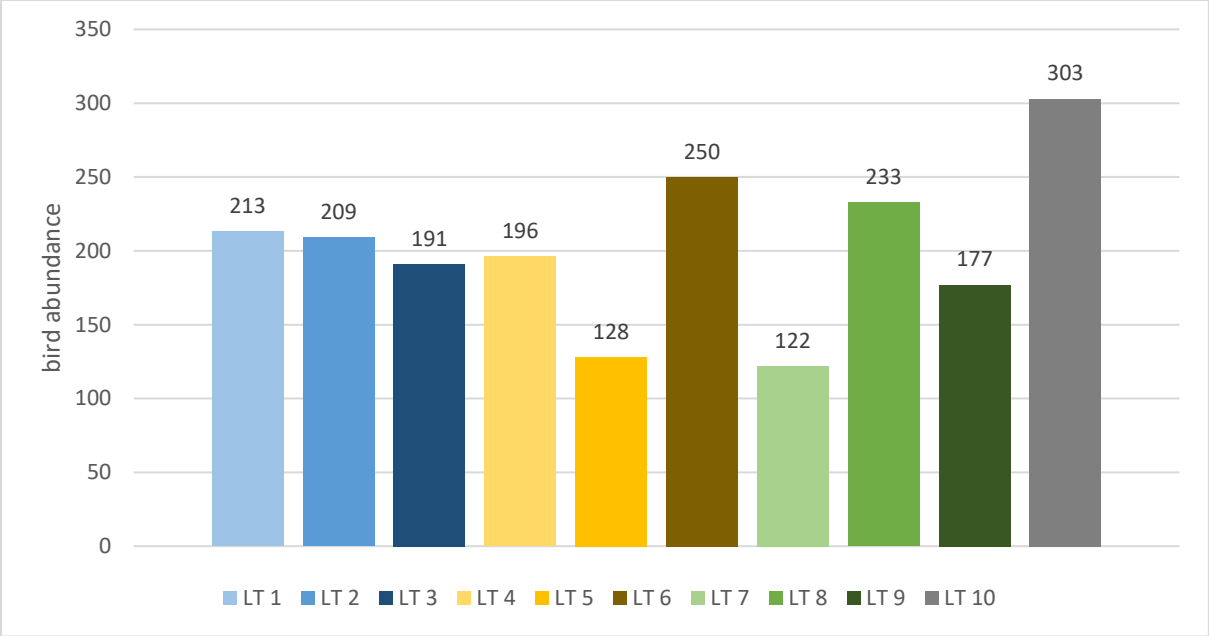

Figure 8: Distribution of the birds per line transect. N = 2022.

When calculating how many birds are counted per survey (fig. 9), Kruskal-Wallis-Test shows significance in bird individuals seen between the line transects ($H(9) = 29{,}795$; $p<0{,}001$). LT7 ($\tilde{x} = 9{,}5$) has significantly less individuals per survey than LT6 ($\tilde{x} = 20{,}0$) ($p = 0{,}017$, $r = 0{,}73$) and LT10 ($\tilde{x} = 25{,}5$) ($p = 0{,}02$, $r = 0{,}82$). Also, at LT5 ($\tilde{x} = 9{,}5$) there are significantly less birds per survey than at LT10 ($\tilde{x} = 25{,}5$) ($p = 0{,}01$, $r = 0{,}75$).

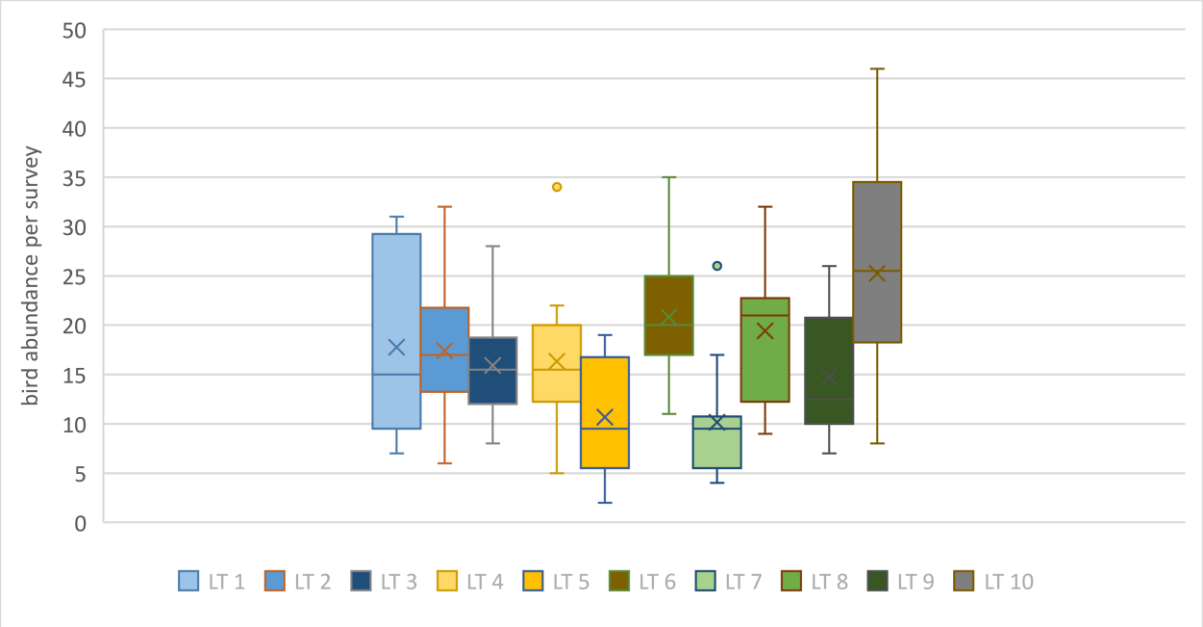

Figure 9: Counted birds per survey per line transects. N = 2022.

While the distribution of the individuals per forest succession hasn't shown a difference in the different time slots, there is a statistical difference between the line transects. LT1 shows significantly more birds later in the morning (8:00-10:00; $\tilde{x} = 28,5$) than in the early morning hours (6am-8am, $\tilde{x} = 10,0$) (H(1) = 6,226, p = 0,013, r = 1,79) and LT9 shows significantly more individuals in the early morning ($\tilde{x}$ = 19,5) than in the late morning ($\tilde{x}$ = 10,5) (H(1) = 5,097, p = 0,024, r = 1,47) (fig. 10).

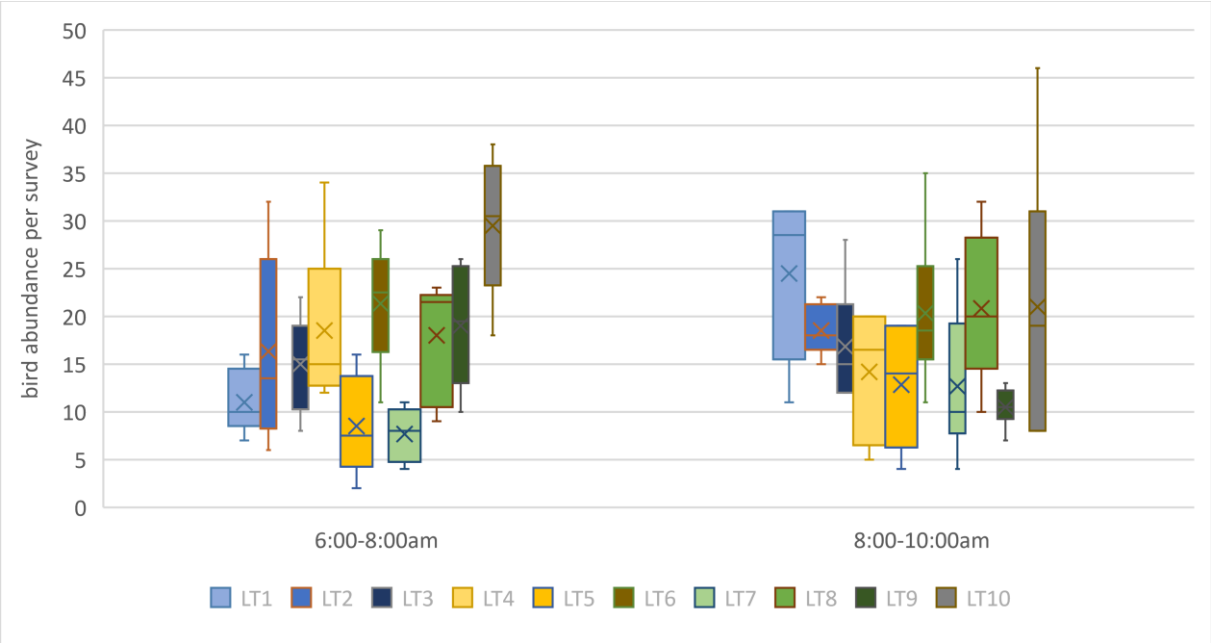

Figure 10: Distribution of the bird abundance per line transect in the early and late morning. N = 2022.

4.4 Diversity

The total diversity by Shannon-Wiener-Index (H) is investigated by forest type, line transect and trail. The young growth forest shows the highest species diversity (H = 3,622) and the highest species richness (n = 76), while the old forest shows the lowest diversity (H = 3,468) and species richness (n = 63) (tab. 3). There is no statistical difference in diversity between the forest succession stages and H0 will be accepted (H(2) = 4,368; p = 0,113). The primary forest shows a Shannon-Index from 3,325, but there is only one line transect in the primary forest.

LT2 (H = 3,416) and afterwards LT10 (H = 3,325) show the highest diversity and LT7 the lowest (H = 2,893) (tab. 4).

Looking at the different trails Jilguero has the highest diversity (H = 3,698), followed by Montaña including the primary forest (LT10), Heliconia/Rio and lastly Montaña, excluding LT10 (tab. 5). There are no significant differences in diversity between the line transects (H(9) = 9,000; p = 0,437) and the trails (H(3) = 3,000; p = 0,392).

***Table 3: Shannon-Index per forest types**. N = 1472.*

forest type	planted	young	old	primary
counted species	73	76	63	43
Shannon-Index	3,492	3,622	3,468	3,325

***Table 4: Shannon-Index per line transect**. N = 1472.*

line transect	1	2	3	4	5	6	7	8	9	10
counted species	44	46	42	42	33	40	29	42	32	43
Shannon-Index	3,296	3,416	3,278	3,114	3,060	3,192	2,893	3,122	3,144	3,325

***Table 5: Shannon-Index per trail.** N = 1472.*

trail	Jilguero	Heliconia/Rio	Montaña	Montaña (without LT10)
counted species	78	64	71	58
Shannon-Index	3,698	3,374	3,536	3,365

4.5 Endangered and endemic birds

According to the IUCN Red List of threatened species (n.d.) 94 species are considered “Least concern”. For the Costa Rican Warbler the data is deficient. The Golden-winged Warbler and the Resplendent Quetzal are near threatened.

21 out of the 97 species found in this study are endemic to the Talamanca mountains in Costa Rica and Panamá (tab. 6). 12 species are seen in the old forest, 11 in young and 10 in planted and primary forest. The highest abundance with 70 individuals each is found in the old and primary forest. While the Black Guan is seen frequently and the Black-faced Solitaire is heard often, there are some birds which are only seen once or twice, for example the Black-capped Flycatcher, Collared Redstart, Dark Pewee, Magenta-throated Woodstar, Sooty Thrush, Streak-headed Treehunter and White-tailed Emerald. The Collared Restart, the Long-tailed Silky-Flycatcher and the Black-cheeked Warbler are only seen in the primary forest.

Table 6: Distribution of the endemic bird species in the forest succession stages. *N = 212.*

Species / forest type	planted	young	old	primary	total
Black Guan	16	4	6	1	27
Black-capped Flycatcher		1			1
Black-cheeked Warbler				16	16
Black-faced Solitaire	7	14	26	10	57
Collared Redstart				2	2
Collared Trogon		1	5	2	8
Costa Rican Warbler	3	1	5		9
Dark Pewee		1			1
Flame-throated Warbler		1	3	22	26
Golden-bellied Flycatcher		2	4		6
Long-tailed Silky-Flycatcher				5	5
Magenta-throated Woodstar	2				2
Ruddy Treerunner			1	7	8
Snowy-bellied Hummingbird	2	2			4
Sooty Thrush	1				1
Spangle-cheeked Tanager			1	3	4
Streak-breasted Treehunter	1		1		2
Sulphur-winged Parakeet			9		9
White-tailed Emerald	1	1			2
White-throated Mountain-gem	4	5	7	2	18
Yellow-thighed Brushfinch	2		2		4
total	**39**	**33**	**70**	**70**	**212**

4.6 Migratory birds

There are 13 nearctic-neotropical migratory species recorded, which are breeding in North America and have their winter habitat in the tropics. The Black-and-white Warbler was the first migratory bird who arrived in the reserve and it was followed by Wilson's Warbler and Yellow-bellied Flycatcher (tab. 7).

Table 7: Distribution of the migratory birds over time. *N = 198. week 1-7 from 28.08.23 to 15.10.23, week 8-12 from 23.10.23 to 26.11.23.*

Species /week	1	2	3	4	5	6	7	8	9	10	11	12	total
Wilson's Warbler		1		4	3	6	10	10	9	14	8	9	74
Blackburnian Warbler			1	8	6	2	2	4	3	9	3	4	42
Black-and-white Warbler		3	4	4	4	2	3	8	3	1	8	1	41
Golden-winged Warbler					1		1		1	3	3	2	11
Summer Tanager									7	1			8
Yellow-bellied Flycatcher		1		1		3					1		6
Swainson's Trush						1	2					2	5
Black-throated Green Warbler										2	1		3
Yellow-throated Vireo						1					2		3
Yellow-rumped Warbler				1			1						2
Eastern Wood-Pewee					1								1
Magnolia Warbler				1									1
Western Wood-Pewee							1						1
total	**0**	**5**	**5**	**19**	**15**	**15**	**20**	**22**	**23**	**30**	**26**	**18**	**198**

The Wilson's Warbler is the most common migratory bird (n = 74), followed by the Blackburnian Warbler (n = 42), the Black-and-White Warbler (n = 41) and Golden-winged Warbler (n = 11). These four species are seen in all four forest successional stages. None of the other migratory birds are seen in the primary forest. The Black-throated Green Warbler and Western Wood-Pewee are only seen in the young forest, while the Magnolia Warbler is only seen in the old forest (fig. 11).

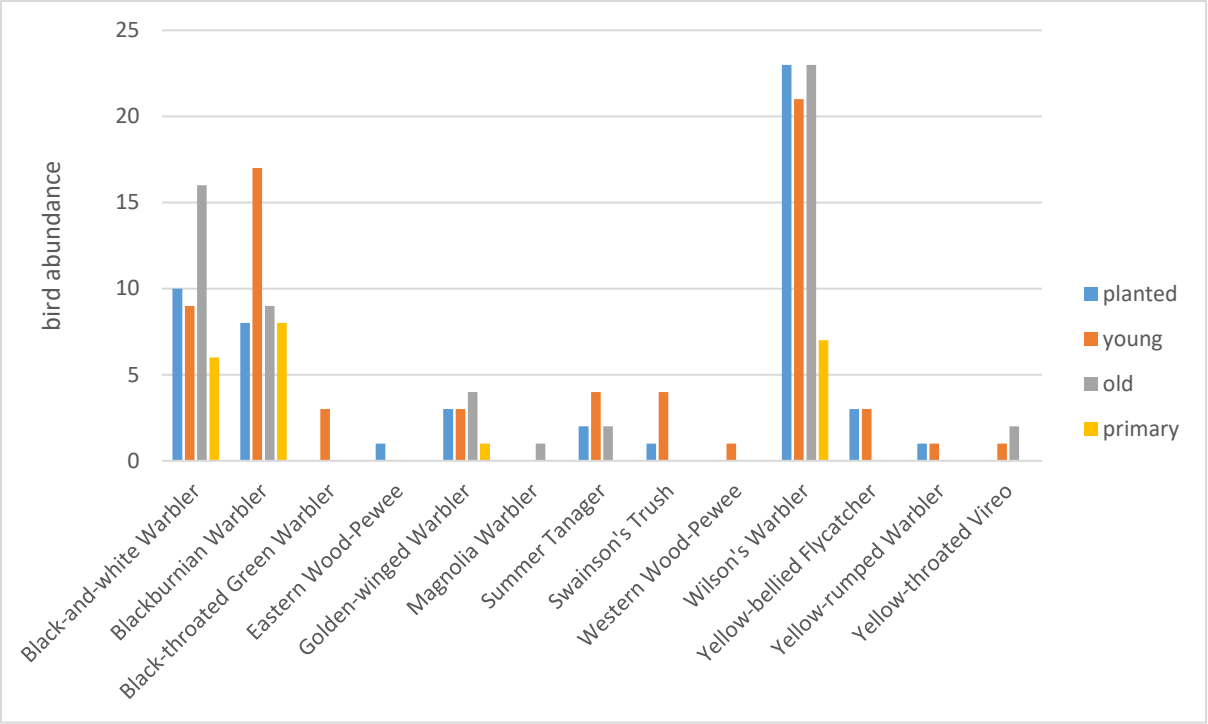

Figure 11: Distribution of the migratory bird species in the forest succession stages. N = 198.

The migratory birds prefer the young forest (33,84 %), while the resident birds prefer the old forest (28,79 %). Both groups are seen up to 26-27 % in the planted areas and under 17 % in the primary forest (fig. 12). Therefore, it's important to keep in mind that only one transect is in the primary forest. In comparison of the percentage of resident and migratory birds, there are no statistical differences between the distribution at the forest types (U>476,000, Z>1004,000, p>0,218). The H0 is accepted.

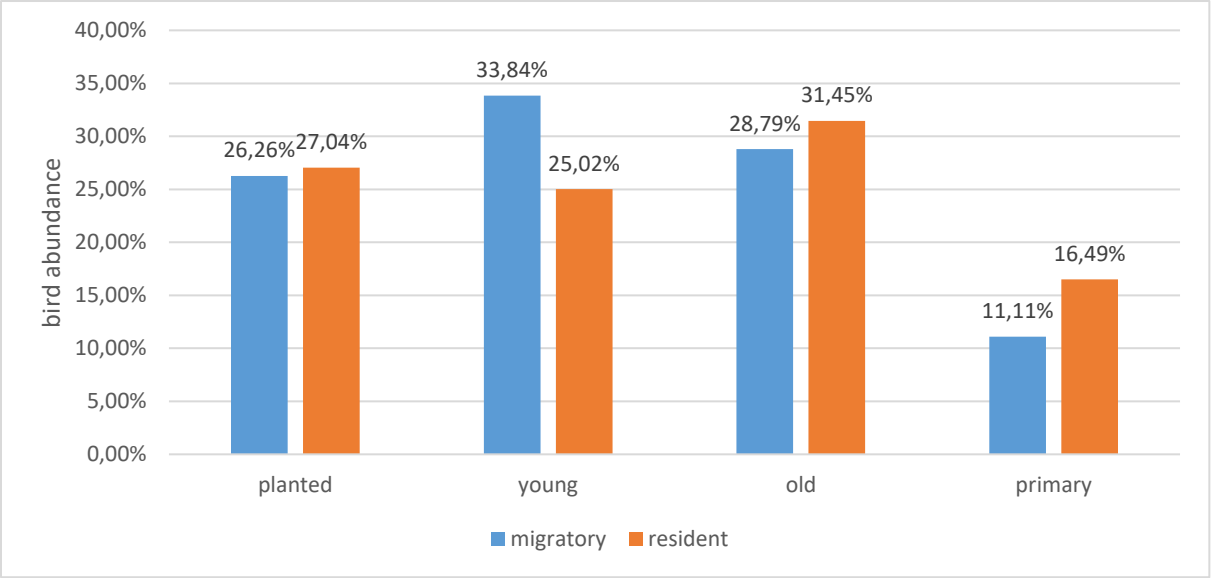

Figure 12: Comparison of the distribution of the migratory and resident birds in the forest succession stages. N = 1241.

The distribution of the migratory birds in the forest types per survey is not statistically significant (H(3) = 0,789; p = 0,852). But there is a statistical difference for the resident birds (H(3) = 12,198, p = (0,007). The primary forest ($\tilde{x}$ = 16,5) shows significantly more individuals than the planted forest ($\tilde{x}$ = 7,0) (p = 0,026, r = 0,41) and the young forest ($\tilde{x}$ = 6,5) (p = 0,014, r = 0,44). There are no statistically significant differences between the other forest types.

4.7 Mixed species flocks

923 from 2022 individuals are seen in 64 mixed species flocks. 603 individuals are identified to species level which belong to 59 species. The most common species who joined the mixed species flocks are the Slate-throated Redstart, Common Chlorospingus and Wilson's Warbler (fig. 13). 11 out of 13 migratory species joined the mixed species flocks, with a total of 125 out of 198 individuals. Only Yellow-bellied Flycatcher and Yellow-rumped Warbler did not join the flocks. Black-throated Green Warbler, Eastern Wood-Pewee, Golden-winged Warbler, Magnolia Warbler, Summer Tanager, Swainson's Thrush and Western Wood-Pewee are only seen in mixed flocks and not individually. There is no significant difference seen between the distribution of the flocks at the different forest successions (H(3) = 6,074, p = 0,108). 7 out of 12 times a mixed species flock is in the primary forest with an average of 21,43 (SD = 9,307) individuals per flock. At the other forest successions there are 16 to 21 times a mixed species flock seen, with an average of 12 individuals (SD = 5,867) in old to 15 (SD = 8,363) individuals per flock in planted forest.

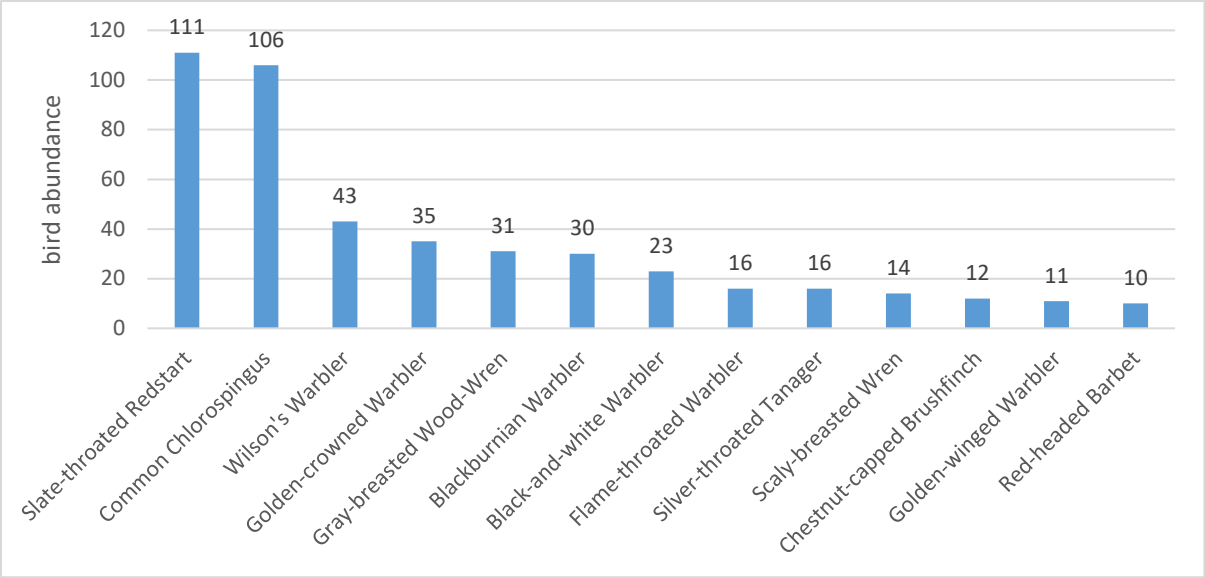

Figure 13: Most common bird species joining the mixed species flocks. Abundance > 10, N = 603.

4.8 Weather

The study took place during the rainy season. In the mornings most of the time it was sunny or cloudy, while in the late morning or afternoon it started to rain. The temperature range during the survey period was from 12°C to 22°C, with a mean temperature before the survey of 15,4°C and 19,1°C after the survey (tab. A3). In most transects the sun hits the area in the first or second time slot. Only at the planted area at Jilguero (LT1), the sun hits earliest in the third time slot.

5 Discussion

The young regenerated forest shows the highest diversity and highest species richness, while the old regenerated forest shows the lowest diversity. But in total, there are no significant differences between the diversity at all the forest succession stages. The results are showing the importance of mountain cloud forest, no matter if it is primary forest or regenerating forest as rich habitat for bird species. An earlier study at Cloudbridge showed similar results, where the highest diversity and species richness could be found in young regenerated forest too (van Riesen, 2021). Thierry (2016) and Womack (2023) described no effect from habitat type on species richness and diversity in Cloudbridge. While tropical forest birds at north-east Brazilian Amazonas showed higher diversity and species richness in primary forest than regenerated forest, the composition was different from primary to regenerated forest and plantations (Barlow et al., 2007). The reasons for the different results could be from differences in the methods, timeframe or geographical changes. In the present study the resident birds prefer the older forest and most individuals per survey are seen in the primary forest. However, for migratory birds there is no significant habitat preference. In a cloud forest of San Antonio in Colombian Andes the bird community was studied over a 100-year time period and showed the impact of forest deforestation and reforestation. In the first years the forest cover decreased by 45 % and the area lost 33 forest bird species; as the forest recovered 17 species recolonized and populations increased. But forest generalists replaced forest specialists, which often needs old growth (Palacio et al., 2019). In the present study 21 endemic species were found, while the highest abundance was in old growth and primary forest. The Collared Restart, the Long-tailed Silky-Flycatcher and the Black-cheeked Warbler were only seen in the primary forest, for what the higher elevation or primary forest as preferred habitat could be the reason for. A meta-analysis about forest successional stages over the world showed that bird species recovered fast, when reforestation took place (Acevedo-Charry & Aide, 2019). There was a large difference in bird species composition and species richness between open areas and secondary forest stages, where bird species who tolerate open areas were replaced by forest generalists and later specialists. While the species richness and composition of secondary forest stages was close to reference forest (Acevedo-Charry & Aide, 2019).

Looking at the abundance per survey, the primary forest shows significantly more birds than the planted forest. Also, the line transects of the primary forest (LT10) shows the highest bird abundance per survey and is significantly higher than the planted forest in LT7 and young forest in LT5. If more primary transects would be included, then maybe there would be a significant difference between the forest succession stages. Also, the definition of primary forest in this part of Cloudbridge is unclear. The area is somehow influenced by human presence, but it is unclear when and how much the forest was disturbed. The planted area at Montaña (LT7) also shows significantly less birds than LT6, the old forest at Heliconia. Here the forest structure could be the reason for this. In this area of the trail all trees are around the same height and planted in a row with a similar distance in between. Also, there is less undergrowth for hiding. The other planted areas (LT1, LT4) where the trees were planted randomly show a higher abundance and diversity.

The study shows no significant differences between the different times in the morning at the forest types, while at two transects the time plays an important role. Studies on lowland forest in Paraguay and Costa Rica showed a higher abundance in the first three hours after sunrise (Blake, 1992; Esquivel & Peris, 2008). While Esquivel and Peris (2008) saw the highest abundance in the first hour after sunrise, Blake (1992) saw a decline from early to late in the morning, where especially birds of the forest understory declined after the first hour after sunrise, and canopy birds increased from the first to the third hour after sunrise and then declined. While in the lowland it is likely that the sun hits the areas at similar times, this isn't the case at Cloudbridge. It is possible that the time the sun hits the area can explain, why at the planted area at Jilguero (LT1) significantly more birds are seen later in the morning. It is quite cold and dark in the early morning. After 8 am the sun hits the area and it is warmer and sunnier. The other way around there are more birds seen in the early morning at the old forest at Montaña (LT9). The sun is in this area from the first time slot, while later in the morning the first clouds and mist reach the area at high elevations.

Tropical Mountain Cloud Forests of Costa Rica are an important habitat for nearctic-neotropical migratory birds (Chandler & King, 2011; DeGraaf & Rappole, 1995). In the present study 13 migratory species find their winter habitat in Cloudbridge. At the weekly monday birding at Cloudbridge three other migratory species were seen: the Yellow Warbler, Tennesee Warbler and Broad-winged Hawk (Cloudbridge Nature Reserve, n.d. b). Migratory birds are

most seen in the young regenerated forest and only four species are seen in the primary forest. DeGraaf and Rappole (1995) looked at several studies, which showed a decrease from 11 out of the 13 migratory bird species, found at Cloudbridge, even before 1995. Nearly one third of nearctic migratory birds have a decline in population, with migration as the biggest mortality reason (Bayly et al., 2018; Rappole & McDonald, 1994). Beacuse in many regions deforestation takes place, migratory birds lose their winter habitat (DeGraaf &Rappole, 1995). Forest restoration is even more important for migrant wintering habitat (Lindell et al., 2012). Therefore, studies showed that habitat structure and food resources are main selection factors for migration (Wolfe & Ralph, 2014). Wolfe and Ralph (2014) found a relationship between the timing of ripe fruit and migrant arrival from frugivorous migrants (Wolfe & Ralph, 2014), while for insectivorous the habitat was a bigger decision-making factor.

There are two near threatened bird species seen during the survey: the Resplendent Quetzal, which migrate from the lowlands to the highlands for breeding, and the Golden-winged Warbler, a migratory bird from North America. The Golden-winged Warbler has been seen eleven times in all forest types. As a near threatened bird species, it is even more important that it can find a winter habitat. Chandler and King (2011) showed in their study of winter habitats in Costa Rica, that the Golden-winged Warbler has more microhabitat requirements than habitat requirements. Also regenerated forest can offer the specific microhabitat.

Most of the migratory birds joined mixed species flocks. In total, nearly half of the counted individuals have been seen in mixed species flocks. There are more individuals seen per flock than in previous studies at Cloudbridge (Slifkin, 2019). Slifkin (2019) also saw no differences between the forest successional stages.

The total of 2022 counted bird individuals is quite a high number of birds seen in the short study period. Previous studies at Cloudbridge saw less birds while doing point count methods (Thierry, 2016; Womack, 2023). Using line transects seems to be a good alternative to point count methods with a higher chance to see more birds in this study area.

The results could be different if there were more identified individuals. 27 % of the counted individuals stayed unidentified. In general, unidentified birds were counted when the birds were seen, but were too fast to identify or the weather conditions made it difficult. Over the time there was no decrease, more a small increase of unidentified birds per survey. It’s possible that the increase is caused by a better spotting of birds, even without identifying

them. The biggest limitation of the study is human error. The knowledge of the birds could improve further even if it had already. Only some birds could be identified by sound and that could be a large bias. Another limitation is that at Rio (LT5) the river is really near and birds were difficult to hear, which could be the reason for the small individual number seen on LT5.

6 Conclusion

The study shows the importance of mountain cloud forest, no matter if it is primary forest or regenerating forest. All forest stages offer a rich habitat for different bird species and are progress to growing to old forest again. Further reforestation and protection of cloud forests is important for species preservation and as habitats for resident and migratory species.

Ongoing bird monitoring at Cloudbridge is important to have long term data about the status of the resident and migratory birds. Also, further studies are requested. Projects with focus on the species composition in the forest successional stages would be helpful to understand why different forest types are beneficial to avian populations, and what types of trees and shrubs are being used by the bird populations.

7 Bibliography

Acevedo-Charry, O. & Aide, T. M. (2019). Recovery of amphibian, reptile, bird and mammal diversity during secondary forest succession in the tropics. *Oikos, 128*, 1065-1078.

Barlow, J., Mestre, L. A. M., Gardner, T. A. & Peres, C. A. (2007). The value of primary, secondary and plantation forests for Amazonian birds. *Biological Conservation, 136*, 212-231.

Bayly, N. J., Rosenberg, K. V., Easton, W. E., Gómez, C., Carlisle, J., Ewert, D. N., Drake, A. & Goodrich, L. (2018). *Bird Conservation International, 28*, 1-26. Doi: 10.1017/S0959270917000296

Blake, J. G. (1992). Temporal variation in point counts of birds in a lowland wet forest in Costa Rica. *The Condor, 95*, 265-275.

Bruijnzeel, L. A., Kapelle, M., Mulligan, M. & Scatena, F. N. (2010). Tropical montane cloud forests: state of knowledge and sustainability perspectives in a changing world. In L. A. Bruijnzeel, F. N. Scatena & L. S. Hamilton (ed.), *Tropical Montane Cloud Forests: Science for Conservation and Management*, 691-740. Cambridge University Press.

Bruijnzeel, L. A. & Proctor, J. (1995). Hydrology and biogeochemistry of tropical montane cloud forests: What do we really know? In L. S. Hamilton, J. O. Juvik & F. N. Scatena (ed.), *Tropical Montane Cloud Forests,* 38–78. Springer-Verlag.

Chandler, R. B. & King, D. I. (2011). Habitat quality and habitat selection of golden-winged warblers in Costa Rica: an application of hierarchical models for open populations. *Journal of Applied Ecology, 48*, 1038-1047.

DeGraaf, R. M. & Rappole, J. H. (1995). *Neotropical migratory birds*. Cornell University Press.

Esquivel, A. & Peris, S. (2008). Influence of time of day, duration and number of counts in point count sampling on birds in an Atlantic forest of Paraguay. *Ornitologia neotropical, 19*, 229-242.

Garrigues, R. & Dean, R. (2014). *The birds of Costa Rica, a field guide* (2. edition). Cornell University Press.

Grubb, P. J. (1977). Control of forest growth and distribution on wet tropical mountains: with special reference to mineral nutrition. *Annual Review of Ecology and Systematics, 8*, 83–107.

Jarvis, A. J. & Mulligan, M. (2010). The climate of cloud forests. In L. A. Bruijnzeel, F. N. Scatena & L. S. Hamilton (ed.), *Tropical Montane Cloud Forests: Science for Conservation and Management,* 39-56. Cambridge University Press.

Kane, S., Hancart, N. & Powell, J. R. (2017). Bird Monitoring Study Data Report January – February 2017. Cloudbridge Nature Reserve. http://www.cloudbridge.org/wp-content/uploads/2011/09/2017-Bird-Monitoring-Study-Data-Report-Kane-Hancart-Powell.pdf

Karger, D. N., Kessler, M., Lehnert, M. & Jetz, W. (2021). Limited protection and ongoing loss of tropical cloud forest biodiversity and ecosystems worldwide. *Nature ecology & evolution, 5*, 854-862.

Lindell, C. A., Cole, R. J., Holl, K. D. & Zahawi, R. A. (2012). Migratory bird species in young tropical forest restoration sites: effects of vegetation height, planting design, and season. *Bird Conservation International, 22,* 94-105. doi:10.1017/S0959270911000177

Palacio, R. D., Kattan, G. H. & Pimm, S. L. (2019). Bird extirpations and community dynamics in an Andean cloud forest over 100 years of land-use change. *Conservation Biology, 34* (3), 677–687.

Powell, J. R., Slifkin, J. P., Spooner, F. T., Roth, J., Allnatt, L., Andrews, R. & Smokoska, M. (2022). Bird species inventory in secondary tropical montane cloud forest at Cloudbridge Nature Reserve, Talamanca Mountains, Costa Rica. *Check List, 18* (1), 17-65.

Rappole, J. H. & McDonald, M. V. (1994). Cause and effect in population declines of migratory birds. *The Auk, 111* (2), 652-660.

Scatena, F. N., Bruijnzeel, Bubb, P. & Das, S. (2010). Setting the stage. In L. A. Bruijnzeel, F. N. Scatena & L. S. Hamilton (ed.), *Tropical Montane Cloud Forests: Science for Conservation and Management*, 3-13. Cambridge University Press.

Slifkin (2019). Surveys of Mixed Species Feeding Flocks in Cloudbridge Nature Reserve, Costa Rica: A Progress Report. Cloudbridge Nature Reserve. http://www.cloudbridge.org/wp-content/uploads/2019/07/Mixed-Species-Feeding-Flocks-Cloudbridge-Nature-Reserve-12Jul19.pdf

Thierry, M. (2016). The effectiveness of tropical cloud forest restauration on bird community at Cloudbridge nature reserve, Costa Rica. Cloudbridge Nature Reserve. http://www.cloudbridge.org/wp-content/uploads/2016/11/2016-Effectiveness-of-restoration-on-bird-community-M-Thierry.pdf

Tover Heid, M. A. N. (2023). Comparing point counts and line transects as an effective bird survey methodology. Cloudbridge Nature Reserve, unreleased.

Van Riesen, H. (2021). Bird diversity in a montane cloud forest reserve, Costa Rica. Cloudbridge Nature Reserve. http://www.cloudbridge.org/wp-content/uploads/2021/09/Bird-diversity-in-a-montane-cloud-forest-reserve-Costa-Rica.pdf

Wolfe, J., Johnson, M. D. & Ralph, C. J. (2014). Do Birds Select Habitat or Food Resources? Nearctic-Neotropic Migrants in Northeastern Costa Rica. *PLoS ONE, 9* (1), e86221. doi:10.1371/journal.pone.0086221

Womack, B. H. (2023). The effect of forest type and time of day on bird activity and diversity in a cloud forest. Cloudbridge Nature Reserve. https://www.cloudbridge.org/wp-content/uploads/2023/10/The-affect-of-forest-type-and-time-of-day-on-bird-activity-and-bird-diversity-in-a-cloud-forest.pdf

Cloudbridge Nature Reserve. (n.d. a). http://www.cloudbridge.org/

Cloudbridge Nature Reserve. (n.d. b). Monday birding list. Unreleasaed.

Cloudbridge Nature Reserve. (2020). Aves (Bird) Species List. http://www.cloudbridge.org/wp-content/uploads/2020/04/Bird-Species-List-Costa-Rica-13-April-2020.pdf

IUCN. (n.d.). The IUCN Red List of threatened species. https://www.iucnredlist.org/

The Weather Channel. (n.d.). Hourly Weather, Rivas, San José, Costa Rica. https://weather.com/weather/hourbyhour/l/0fd943752567d02369ad9e8f8b901b9c72feecf420949b2ddf19df18a0e38f87 [2023]

8 Appendix

Table A1: Timetable for the surveys. Week 1-7 from 28.08.23 to 15.10.23, week 8-12 from 23.10.23 to 26.11.23.

Week	Time				Trail
	6:20-7:00	7:20-8:00	8:20-9:00	9:20-10:00	
1	LT2	LT3		LT1	Jilguero
2	LT3	LT2	LT1		Jilguero
3	LT1		LT3	LT2	Jilguero
4		LT1	LT2	LT3	Jilguero
5	LT2	LT3		LT1	Jilguero
6	LT3	LT2	LT1		Jilguero
7	LT1		LT3	LT2	Jilguero
8		LT1	LT2	LT3	Jilguero
9	LT2	LT3		LT1	Jilguero
10	LT3	LT2	LT1		Jilguero
11	LT1		LT3	LT2	Jilguero
12		LT1	LT2	LT3	Jilguero
1	LT6		LT5	LT4	Rio/Heliconia
2		LT6	LT4	LT5	Rio/Heliconia
3	LT5	LT4	LT6		Rio/Heliconia
4	LT4	LT5		LT6	Rio/Heliconia
5	LT6		LT5	LT4	Rio/Heliconia
6		LT6	LT4	LT5	Rio/Heliconia
7	LT5	LT4	LT6		Rio/Heliconia
8	LT4	LT5		LT6	Rio/Heliconia
9	LT6		LT5	LT4	Rio/Heliconia
10		LT6	LT4	LT5	Rio/Heliconia
11	LT5	LT4	LT6		Rio/Heliconia
12	LT4	LT5		LT6	Rio/Heliconia
1	LT7	LT8	LT9	LT10	Montaña
2	LT8	LT7	LT10	LT9	Montaña
3	LT10	LT9	LT8	LT7	Montaña
4	LT9	LT10	TL7	LT8	Montaña
5	LT7	LT8	LT9	LT10	Montaña
6	LT8	LT7	LT10	LT9	Montaña
7	LT10	LT9	LT8	LT7	Montaña
8	LT9	LT10	TL7	LT8	Montaña
9	LT7	LT8	LT9	LT10	Montaña
10	LT8	LT7	LT10	LT9	Montaña
11	LT10	LT9	LT8	LT7	Montaña
12	LT9	LT10	TL7	LT8	Montaña

Table A2: Bird species list. Species seen from 30.08.23 to 23.11.23 using line transects. Endangered and endemic status taken from IUCN (n.d.).

species	scientific name	family	order	migratory	endemic	endangered	abundance
Acorn Woodpecker	*Melanerpes formicivorus*	Picidae	Piciformes	no	no	LC	1
Band-tailed Pigeon	*Patagioenas fasciata*	Columbidae	Columbiformes	no	no	LC	3
Bay-headed Tanager	*Tangara gyrola*	Thraupidae	Passeriformes	no	no	LC	1
Black Guan	*Chamaepetes unicolor*	Cracidae	Galliformes	no	yes	LC	27
Black-and-white Warbler	*Mniotilta varia*	Parulidae	Passeriformes	yes	no	LC	41
Blackburnian Warbler	*Setophaga fusca*	Parulidae	Passeriformes	yes	no	LC	42
Black-capped Flycatcher	*Empidonax atriceps*	Tyrannidae	Passeriformes	no	yes	LC	1
Black-cheeked Warbler	*Basileuterus melanogenys*	Parulidae	Passeriformes	no	yes	LC	16
Black-faced Solitaire	*Myadestes melanops*	Turdidae	Passeriformes	no	yes	LC	57
Black-throated Green Warbler	*Dendroica virens*	Parulidae	Passeriformes	yes	no	LC	3
Blue Dacnis	*Dacnis cayana*	Thraupidae	Passeriformes	no	no	LC	2
Blue-gray Tanager	*Thraupis episcopus*	Thraupidae	Passeriformes	no	no	LC	1
Boat-billed Flycatcher	*Megarynchus pitangua*	Tyrannidae	Passeriformes	no	no	LC	5
Brown Jay	*Cyanocorax morio*	Corvidae	Passeriformes	no	no	LC	4
Brown-capped Vireo	*Vireo leucophrys*	Vireonidae	Passeriformes	no	no	LC	4
Brushfinch		Emberizidae	Passeriformes				2
Buff-throated Saltator	*Saltator maximus*	Cardinalidae	Passeriformes	no	no	LC	1
Chestnut-capped Brushfinch	*Arremon brunneinucha*	Emberizidae	Passeriformes	no	no	LC	21
Clay-colored Trush	*Turdus grayi*	Turdidae	Passeriformes	no	no	LC	4
Collared Redstart	*Myioborus torquatus*	Parulidae	Passeriformes	no	yes	LC	2
Collared Trogon	*Trogon collaris*	Trogonidae	Trogoniformes	no	yes	LC	8
Common Chlorospingus	*Chlorospingus flavopectus*	Passerellidae	Passeriformes	no	no	LC	127
Costa Rican Warbler	*Basileuterus melanotis*	Parulidae	Passeriformes	no	yes	DD	9
Dark Pewee	*Contopus lugubris*	Tyrannidae	Passeriformes	no	yes	LC	1
Dusky-capped Flycatcher	*Myiarchus tuberculifer*	Tyrannidae	Passeriformes	no	no	LC	8
Eastern Wood-Pewee	*Contopus virens*	Tyrannidae	Passeriformes	yes	no	LC	1
Elegant Euphonia	*Chlorophonia elegantissima*	Fringillidae	Passeriformes	no	no	LC	4
Euphonia		Fringillidae	Passeriformes				1
Eye-ringed Flatbill	*Rhynchocyclus brevirostris*	Tyrannidae	Passeriformes	no	no	LC	2

Continuation of table A2: Bird species list.

Flame-colored Tanager	*Piranga bidentata*	Thraupidae	Passeriformes	no	no	LC	1
Flame-throated Warbler	*Oreothlypis gutturalis*	Parulidae	Passeriformes	no	yes	LC	26
Flycatcher		Tyrannidae	Passeriformes				46
Golden-bellied Flycatcher	*Myiodynastes hemichrysus*	Tyrannidae	Passeriformes	no	yes	LC	6
Golden-crowned Warbler	*Basileuterus culicivorus*	Parulidae	Passeriformes	no	no	LC	41
Golden-winged Warbler	*Vermivora chrysoptera*	Parulidae	Passeriformes	yes	no	NT	11
Gray-breasted Wood-Wren	*Henicorhina leucophrys*	Troglodytidae	Passeriformes	no	no	LC	123
Green Hermit	*Phaethornis guy*	Trochilidae	Apodiformes	no	no	LC	1
Green-crowned Brilliant	*Heliodoxa jacula*	Trochilidae	Apodiformes	no	no	LC	4
Hairy Woodpecker	*Dryobates villosus*	Picidae	Piciformes	no	no	LC	1
Hummingbird		Trochilidae	Apodiformes				67
Lesser Greenlet	*Pachysylvia decurtata*	Vireonidae	Passeriformes	no	no	LC	6
Lesson's Motmot	*Momotus lessonii*	Momotidae	Coraciiformes	no	no	LC	8
Long-billed Hermit	*Phaethornis longirostris*	Trochilidae	Apodiformes	no	no	LC	1
Long-tailed Silky-Flycatcher	*Ptilogonys caudatus*	Ptilogonatidae	Passeriformes	no	yes	LC	5
Magenta-throated Woodstar	*Philodice bryantae*	Trochilidae	Apodiformes	no	yes	LC	2
Magnolia Warbler	*Setophaga magnolia*	Parulidae	Passeriformes	yes	no	LC	1
Mountain Elaenia	*Elaenia frantzii*	Tyrannidae	Passeriformes	no	no	LC	5
Mountain Thrush	*Turdus plebejus*	Turdidae	Passeriformes	no	no	LC	3
Northern Emerald-Toucanet	*Aulacorhynchus prasinus*	Ramphastidae	Piciformes	no	no	LC	37
Olivaceous Woodcreeper	*Sittasomus griseicapillus*	Furnariidae	Passeriformes	no	no	LC	1
Olive-striped Flycatcher	*Mionectes galbinus*	Tyrannidae	Passeriformes	no	no	LC	1
Orange-billed Nightingale-Thrush	*Catharus aurantiirostris*	Turdidae	Passeriformes	no	no	LC	1
Ovenbirds & Woodcreeper		Furnariidae	Passeriformes				5
Parakeet		Psittacidae	Psittaciformes				6
Pigeon		Columbidae	Columbiformes				15
Plain Xenops	*Xenops genibarbis*	Furnariidae	Passeriformes	no	no	LC	6
Purple-crowned Fairy	*Heliothryx barroti*	Trochilidae	Apodiformes	no	no	LC	1
Red-faced Spinetail	*Cranioleuca erythrops*	Furnariidae	Passeriformes	no	no	LC	11

Continuation of table A2: Bird species list.

Red-headed Barbet	*Eubucco bourcierii*	Capitonidae	Piciformes	no	no	LC	15
Resplendent Quetzal	*Pharomachrus mocinno*	Trogonidae	Trogoniformes	no	no	NT	1
Ruddy Pigeon	*Patagioenas subvinacea*	Columbidae	Columbiformes	no	no	LC	11
Ruddy Treerunner	*Margarornis rubiginosus*	Furnariidae	Passeriformes	no	yes	LC	8
Ruddy-capped Nightingale-Thrush	*Catharus frantzii*	Turdidae	Passeriformes	no	no	LC	4
Rufous-browed Peppershrike	*Cyclarhis gujanensis*	Vireonidae	Passeriformes	no	no	LC	4
Rufous-tailed Hummingbird	*Amazilia tzacatl*	Trochilidae	Apodiformes	no	no	LC	1
Scaly-breasted Wren	*Microcerculus marginatus*	Troglodytidae	Passeriformes	no	no	LC	47
Scarlet-thighed Dacnis	*Dacnis venusta*	Thraupidae	Passeriformes	no	no	LC	4
Silver-throated Tanager	*Tangara icterocephala*	Thraupidae	Passeriformes	no	no	LC	30
Slate-throated Redstart	*Myioborus miniatus*	Parulidae	Passeriformes	no	no	LC	165
Slaty Antwren	*Myrmotherula schisticolor*	Thamnophilidae	Passeriformes	no	no	LC	1
Slaty-backed Nightingale-Trush	*Catharus fuscater*	Turdidae	Passeriformes	no	no	LC	5
Slaty-capped Flycatcher	*Leptopogon superciliaris*	Tyrannidae	Passeriformes	no	no	LC	2
Snowy-bellied Hummingbird	*Saucerottia edward*	Trochilidae	Apodiformes	no	yes	LC	4
Social Flycatcher	*Myiozetetes similis*	Tyrannidae	Passeriformes	no	no	LC	2
Sooty Thrush	*Turdus nigrescens*	Turdidae	Passeriformes	no	yes	LC	1
Spangle-cheeked Tanager	*Tachyphonus luctuosus*	Thraupidae	Passeriformes	no	yes	LC	4
Speckled Tanager	*Ixothraupis guttata*	Thraupidae	Passeriformes	no	no	LC	7
Spot-crowned Woodcreeper	*Lepidocolaptes affinis*	Furnariidae	Passeriformes	no	no	LC	9
Spotted Barbtail	*Premnoplex brunnescens*	Furnariidae	Passeriformes	no	no	LC	2
Spotted Woodcreeper	*Xiphorhynchus erythropygius*	Furnariidae	Passeriformes	no	no	LC	3
Spotted Wood-Quail	*Odontophorus guttatus*	Odontophoridae	Galliformes	no	no	LC	23
Squirrel Cuckoo	*Piaya cayana*	Cuculidae	Cuculiformes	no	no	LC	1
Streak-breasted Treehunter	*Thripadectes rufobrunneus*	Furnariidae	Passeriformes	no	yes	LC	2
Streak-headed Woodcreeper	*Lepidocolaptes souleyetii*	Furnariidae	Passeriformes	no	no	LC	11
Stripe-tailed Hummingbird	*Eupherusa eximia*	Trochilidae	Apodiformes	no	no	LC	2
Sulphur-winged Parakeet	*Pyrrhura hoffmanni*	Psittacidae	Psittaciformes	no	yes	LC	9

Continuation of table A2: Bird species list.

Summer Tanager	*Piranga rubra*	Thraupidae	Passeriformes	yes	no	LC	8
Swainson's Trush	*Catharus ustulatus*	Turdidae	Passeriformes	yes	no	LC	5
Tanager		Thraupidae	Passeriformes				4
Thrush		Turdidae	Passeriformes				9
Tropical Parula	*Setophaga pitiayumi*	Parulidae	Passeriformes	no	no	LC	6
unidentified Bird		unident. family	unident. order				550
Violet Sabrewing	*Campylopterus hemileucurus*	Trochilidae	Apodiformes	no	no	LC	7
Violet-headed Hummingbird	*Klais guimeti*	Trochilidae	Apodiformes	no	no	LC	2
Vireo		Vireonidae	Passeriformes				7
Western Wood-Pewee	*Contopus sordidulus*	Tyrannidae	Passeriformes	yes	no	LC	1
White-naped Brushfinch	*Atlapetes albinucha*	Emberizidae	Passeriformes	no	no	LC	2
White-tailed Emerald	*Microchera chionura*	Trochilidae	Apodiformes	no	yes	LC	2
White-throated Mountain-gem	*Lampornis castaneoventris*	Trochilidae	Apodiformes	no	yes	LC	18
White-winged Tanager	*Piranga leucoptera*	Thraupidae	Passeriformes	no	no	LC	3
Wilson's Warbler	*Cardellina pusilla*	Parulidae	Passeriformes	yes	no	LC	74
Woodcreeper		Furnariidae	Passeriformes				14
Woodpecker		Picidae	Piciformes				2
Wood-Warbler		Parulidae	Passeriformes				45
Wren		Troglodytidae	Passeriformes				8
Yellow-bellied Flycatcher	*Empidonax flaviventris*	Tyrannidae	Passeriformes	yes	no	LC	6
Yellow-billed Cacique	*Amblycercus holoaweiceus*	Icteridea	Passeriformes	no	no	LC	1
Yellow-green Vireo	*Vireo olivaceus*	Vireonidae	Passeriformes	no	no	LC	1
Yellowish Flycatcher	*Empidonax flavescens*	Tyrannidae	Passeriformes	no	no	LC	19
Yellow-rumped Warbler	*Setophaga coronata*	Parulidae	Passeriformes	yes	no	LC	2
Yellow-thighed Brushfinch	*Atlapetes tibialis*	Emberizidae	Passeriformes	no	yes	LC	4
Yellow-throated Vireo	*Vireo flavifrons*	Vireonidae	Passeriformes	yes	no	LC	3

Table A3: Weather data from the survey days. Temperatures taken from The Weather Channel (n.d.). Temperatures from 30.08.23 until 05.09.23 are probably falsified, due to incorrect localisation.

Date	Temperatur in °C		Weather		Trail
	pre survey	post survey	pre survey	post survey	
30.08.2023	10	16	cloudy, partly sunny	cloudy	Jilguero
31.08.2023	9	14	cloudy	cloudy	Heliconia/Rio
01.09.2023	9	14	partly cloudy, blue sky	cloudy	Montaña
05.09.2023	11	14	sonny	sonny	Heliconia/Rio
07.09.2023	17	19	cloudy	partly cloudy, sunny	Jilguero
08.09.2023	17	20	partly cloudy, sunny	cloudy	Montaña
12.09.2023	16	21	sunny	sunny	Montaña
14.09.2023	16	21	blue sky, partly cloudy	sunny	Heliconia/Rio
15.09.2023	16	21	cloudy	cloudy	Jilguero
19.09.2023	17	17	blue sky, sunny	cloudy, misty	Jilguero
20.09.2023	17	20	blue sky	sunny	Montaña
22.09.2023	17	22	sunny	sunny	Heliconia/Rio
25.09.2023	17	22	sunny	cloudy	Montaña
26.09.2023	16	22	cloudy	cloudy	Heliconia/Rio
28.09.2023	16	19	cloudy	cloudy	Jilguero
03.10.2023	17	19	cloudy	cloudy	Heliconia/Rio
05.10.2023	17	20	cloudy	cloudy	Jilguero
06.10.2023	16	21	blue sky, sunny	cloudy	Montaña
10.10.2023	17	18	partly cloudy, sunny	cloudy	Jilguero
11.10.2023	16	19	partly cloudy, sunny	cloudy	Montaña
13.10.2023	18	22	cloudy	sunny	Heliconia/Rio
24.10.2023	16	19	cloudy	coudy	Jilguero
26.10.2023	12	17	cloudy	cloudy	Montaña
28.10.2023	14	16	cloudy	cloudy	Heliconia/Rio
03.11.2023	12	17	sunny	cloudy	Montaña
04.11.2023	14	18	cloudy	rainy	Heliconia/Rio
05.11.2023	14	18	cloudy	sunny	Jilguero
07.11.2023	16	19	sunny	sunny	Heliconia/Rio
09.11.2023	14	19	sunny	sunny	Jilguero
10.11.2023	14	21	blue sky	sunny	Montaña
14.11.2023	14	19	sunny	sunny	Jilguero
16.11.2023	13	16	blue sky/ sunny	cloudy	Montaña
17.11.2023	13	14	rainy	rainy	Heliconia/Rio
21.11.2023	16	21	blue sky	sunny	Montaña
22.11.2023	14	17	sunny	sunny	Heliconia/Rio
23.11.2023	14	18	sunny	cloudy	Jilguero
average	**15,41**	**19,12**			