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RESERVA CLOUDBRIDGE NATURE RESERVE

EFFECTS OF AN ARTIFICIAL FEEDER ON THE BEHAVIOUR OF HUMMINGBIRDS

Cloudbridge nature reserve, Costa Rica

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Abstract

This research was conducted to determine if an artificial feeder alters the behaviour of hummingbirds in Cloudbridge nature reserve, Costa Rica. Hummingbirds were observed three time a day over a time period of 40 days in a pre-determined study area. Out of the 40 survey days, 20 took place without feeder and 20 with a feeder present.

Data on perching-, foraging- and territorial behaviour was recorded during both set-ups, this data was then analysed and compared. There was an overall decline in foraging behaviour at flowers, while perching was increased when the feeder was present.

However, the effects a feeder has on the behaviour strongly varies depending on the species. The Violet Sabrewing appeared to be the species most susceptible to changes in behaviour caused by the artificial feeder, with a highly significant increase in time spend perching. This increase in presence of the Violet Sabrewing seemingly deterred other hummingbirds from visiting the study area.

The use of a feeder alters hummingbird behaviour, this may lead to an overall decrease in foraging behaviour. This decrease in foraging may lead to a decline in pollination of certain plant and tree species, which could lead to a change in forest composition.

Acknowledgement

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1. Introduction

Hummingbirds (Trochilidae) are often considered to be the jewels of the sky, due to their bright and diverse coloration. Out of all homeothermic animals, Hummingbirds have the highest energy expenditure (Bryner, 2006). Nectar plays an important role in fulfilling hummingbird's energy requirements, evolutionary adaptations allow hummingbirds to foraging on flowers in search of nectar. The types of flowers a specific species forages on often depend on the length and the shape of its beak (Pearce Stevens, 2019). Another possibility which allows hummingbirds to fulfil their energy needs is an artificial feeder. A feeder can store a solution of sugar water, which can be used by hummingbirds as an alternative food source. This is a popular way for humans to observe hummingbirds from a close distance while they forage.

The usage of feeders is somewhat controversial since it is believed to have an impact on the behaviour of hummingbirds. The introduction of a feeder will result in an unlimited resource of food. This could change the foraging behaviour of hummingbirds.

Research done on flower visitations indicates that flower visitations increase when a feeder is present. The increase in visitations was noticeable nearby feeders, whilst visitations in plots further away from the feeder remained the same (Brockmeyer & Schaefer, 2012; Sonne et al., 2015). McCaffrey and Wethington (2008) show that the feeders were less likely to be used if nectar from flowers was abundant. This implicates that hummingbirds use feeders when flower resources are low. However, research done in Mexico city contradicts these outcomes indicating a reduction in the visitation rate of hummingbirds to native plants in the plots where a feeder was present. This resulted in lower seed production by the native plants (Arizmendi et al., 2007).

One of the issue that could also be caused by the feeder is the possibility for any hummingbird to use its resources. The evolutionary traits of hummingbirds make it so that each species has different preferred flowers to forage on. Because of these differences species occupy different niches within a habitat or occupy a completely different habitats. The introduction of a feeder might result in conflict between species that would normally never be in contact with each other (Raley, 2016).

A study performed on the Blue-throated hummingbird suggests that an increased food supply affects territorial behaviour. With an unlimited food supply, Blue-throated hummingbirds would become more aggressive towards other Blue-throated hummingbirds however and less aggressive towards hummingbirds of different species (Powers & McKee,1994). Research done in a Monteverde cloud forest backs this conclusion. An increase in feeders resulted in an increase in intraspecific aggression and a decrease in interspecific conflicts (Sawtelle, 2011).

The feeder could also result in a change in species composition within the area. According to Sawtelle (2011), a change in species composition and sex ratio of the hummingbirds visiting the plot occurred when feeders were introduced.

An artificial feeder may have an impact on the behaviour of hummingbirds in the vicinity. A change in behaviour could affect the overall dynamics in the area since hummingbirds are the main pollinators for certain plants and tree species. This research will determine if the use of artificial feeders has an impact on the foraging-, and perching time of species visiting the plot.

Overall changes in perching time, forage time, and daily visitations will be determined however, changes in perch- and forage time might differs between species. Therefore, statistical analysis has been conducted on each species that visited the plot.
Changes in territorial behaviour by the species inside the plot will also be investigated. This research will answer the following research questions.

- Is there a change in the proportion of the behaviour of the species when a feeder is present?
- Is there an increase in foraging time at flowers when a feeder is present?
- Is there an increase in perching time when a feeder is present?
- Is there an increase in territorial behaviour when a feeder is present?
- Is there a change in daily visitations to forage on flowers?
- Is there a change in daily visitations to perch?

2. Methodology

2.1 Study area

This research was conducted in the Cloudbridge nature reserve in Costa Rica. The reserve is located 76 kilometres southeast of San José. Cloudbridge is situated next to Chirripó national park and serves as a corridor between Chirripó and other smaller reserves and forest areas (figure 1). The reserve consists of 283 hectares, with elevations ranging between 1,550 and 2,600 meters. Most of the reserve (255 hectares) consists of former pasture or cultivated land, which has been reforested (Cloudbridge, 2021). Cloudbridge is home to a rare kind of rainforest, a cloud forest, which makes up 2.5% of all tropical forests (Bubb et al., 2004). This type of forest mainly occurs at altitudes between 500 and 2500 meters (DellaSala & Goldstein, 2020).

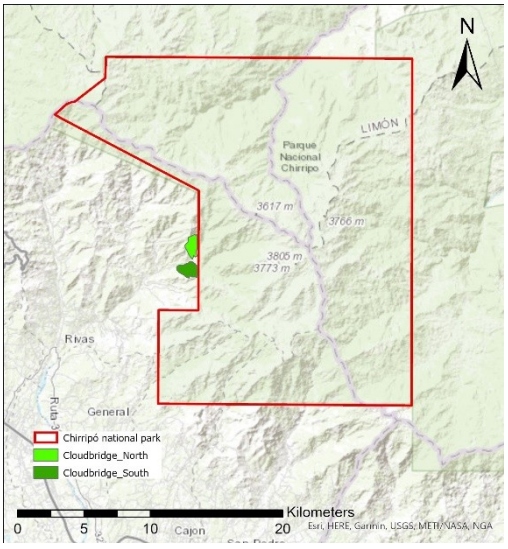


Figure 1: Location Cloudbridge

Within the nature reserve, a study area was appointed to investigate the effects an artificial feeder has on hummingbirds present in the area. The study area was located nearby the basecamp of the reserve (appendix 2). The area is classified as a planted forest on the map with some old-growth forest at the edge. The study area consists of open ground with multiple flowering plants and trees. The openness is optimal for observing the behaviour of hummingbirds. The total surface of the plot is about 135m^2. The feeder was located at the edge of the plot, during the observations with a feeder.
The following flowering trees and plants can be found within the study area; Bomarea costaricensis, Lantana camara, Heliconia wagneria, Heliconia bihai, Impatiens walleriana, Stachytarpheta frantzii, Megaskepasma erythrochlamys Lindau, and the Brugmansia.

Research done during the rainy period in the same area concludes that there is an increase in foraging time when a feeder is present. However, the effects a feeder has on a hummingbird varies per species (Cannon, 2017). This report also states that research should be conducted during the dry period to see if the effects of the feeder will be the same. This research was conducted at the start of the transition from the rainy to the dry season.

2.2 Climate

The area has a tropical climate, With an average temperature of around 20°C. Temperature does not fluctuate a lot during the year, The warmest month being April (21.2°C), and December (19.7°C) being the coldest month (Climate-data, 2021).
The yearly average precipitation is 3853mm, with no dry period. Precipitation is the highest in October (592mm) and the lowest in January (62mm).

2.3 Hummingbird species observed at Cloudbridge

According to Garrigues and Dean (2007), Costa Rica is home to 52 different species of hummingbird, in total 23 out of the 52 species of hummingbirds have been recorded at Cloudbridge nature reserve. The species list is based on observations done by researchers throughout the years. Appendix 1 gives an overview of the different species found at Cloudbridge. However, some of the species on the list are extremely rare or only present during specific months of the year.(R. Dante, personal communication, November 30, 2021).

2.4 Observation

A baseline observation took place between the 22nd of October and the 26th of November. To establish a strong baseline, 20 days of surveys were conducted. During these observations, no artificial feeder was present within the nature reserve. On the 6th of December, an artificial feeder was placed, in total 20 days of observations with feeder took place. Observations with feeder took place until the 31 of January.

Each survey day had three time slots in which observations took place at 7:30, 9:00, and 11:00. Observations would last 30 minutes, and all observations stopped once the timer reached the 30 minutes mark. Any ongoing observation that started before the 30 minutes mark was reached were clocked off at the 30 minutes mark.
The three time slots were selected to minimize any anomalies that might occur due to unfavourable weather conditions. Unfavourable weather conditions are difficult to predict in a cloud forest, however, the highest chance for sunny conditions are between 6:00 and 12:00.

Two observers were present during the surveys to ensure all hummingbirds and their behaviour were recorded. The behaviour of every hummingbird that entered the plot was recorded on a field form (appendix 3) during these observations. The species, behaviour, gender and duration of the behaviour were written down in a notebook. The following behaviours were recorded; foraging, perching, and territorial.

Foraging
The time in which a hummingbird is drinking nectar from a flower, or the substance from the artificial feeder. When the bill of the hummingbird entered the flower or the feeder, a timer was started. When the hummingbird leaves the feeder or plant it was feeding on, the timer was stopped and the duration was recorded. In the case of a hummingbird foraging at a flower, the time is not stopped until the hummingbird leaves the patch of flowers. Since the hummingbird might feed on multiple flowers during one foraging session. If a hummingbird sits still on a flower as it feeds the behaviour will be classed as foraging, not perching. A distinction will be made for feeding on a flower or on a feeder during the observations where an artificial feeder is present.

Perching
Behaviour was classified as perching when a hummingbird landed on an object. The timer was started when the hummingbird landed, the timer was stopped once the hummingbird flew away from the spot it was perching in. The timer would not be stopped if a hummingbird moved position or change perch location.

Territorial
Both vocal and physical forms of territorial behaviour were noted on the field forms. The following traits were classed as territorial behaviours;
- Fast and loud chirping sound
- Raising crown feathers
- Flaring trail
- Spreading or raising wings
- Hovering in front of another animal
- Chasing another animal
- Fighting another animal

Whenever a hummingbird displayed one of the territorial traits, the following data was noted on the field form; species displaying territorial behaviour, type of territorial behaviour, and species at which the behaviour was aimed.
Territorial behaviour was not timed, only the type of behaviour was noted on the field form.

2.5 Material

2.5.1 feeder

Figure 2: Model of feeder used during surveys with a feeder

A feeder similar to the model shown in figure 2 was used during the surveys. Other models proved to be successful in different areas of the reserve, however, these models were not used by hummingbirds when testing them in the plot. The location of the feeder is also of importance, therefore multiple locations within the plot were tested. Data obtained during the testing phase is not included or used in the report.
Foraging behaviour at the feeder was only observed when the feeder was placed underneath branches at the edge of the plot. The artificial feeder was filled with a combination of sugar and water to attract hummingbirds, at a ratio of one part sugar to water five parts water. This ratio was chosen since it is in compliance with guidelines present at Cloudbridge on how to use a feeder.

The feeder was removed at the end of each third day, after sunset to have as minimal disturbance to the plot as possible. The feeder was cleaned to prevent the development of mold inside the feeder (Wetlands & Wildlife Care Center, n.d.). After the feeder was cleaned, it was replenished and replaced in the same evening.

2.5.2 Timer

The mobile app “Multi Timer Stopwatch” was used to track the time of the different behaviours (Multi Timer StopWatch, 2013). The app allows running multiple timers at the same time and naming the different timers. Naming was used to have separate timers for the different species that visited the plot.

2.5.3 Field forms

A field form similar to appendix 3 was used to record the observed behaviours. Abbreviations were used to describe species and behaviours.

3. Results

The result section of the report will be separated into two parts. The first part will discuss and compare the overall results obtained during observation with and without a feeder. The second part will discuss the behaviour of the dominant species that were observed within the plot during the observations.

3.1 Overall results

3.1.1 Count of overall displayed behaviour

In total 1.229 counts of behavioural traits were observed during 60 observations of 30 minutes without a feeder (table 1). Foraging was observed the most during these observations (590), followed by perching (367). In total 236 instances of territorial behaviour were recorded. The majority of territorial behaviour consisted of chasing (272). Chirping (21), hovering (14) and fighting (1) only made up for a small portion of the displayed territorial behaviour.

During the 60 observation with feeder 763 counts of behavioural traits were observed. Foraging was observed the most, with 355 total counts. Perching was observed 265 times, and 143 counts of territorial behaviour were displayed.

Table 1: Count of behavioural traits

	Feeder Absent	**Feeder present**
Count of foraging behaviour	590	355
Count of perching behaviour	367	265
Count of territorial behaviour	272	143
Total behavioural traits	1.229	763

3.1.2 Changes in proportion of overall displayed behaviour

There were some changes in the proportion of overall displayed behaviour (figure 3). The proportion of overall foraging changed slightly, with a 1,5% decrease when the feeder was present.

The proportion of overall Territorial behaviour decreased as well with the presence of a feeder, with a total decline of 3,4%.

The largest change was in overall perching behaviour. The overall proportion of perching behaviour seemed to increase by 4,8% when a feeder was present.

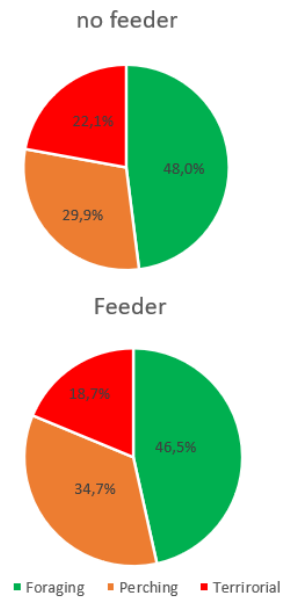


Figure 3: Proportion of overall displayed behaviour

3.1.3 Durations and count of the behavioural traits

Table 2 shows the differences in overall time for the different behavioural trait. Table 2 also shows the difference in average time spend foraging and perching per species.

Table 2: Differences in behaviour during observation with and without feeder

Species	Artificial feeder	Total foraging time (in seconds)		Average time spend foraging (in seconds)	Total perching time (in seconds)	Average time spend perching (in seconds)	Count of territorial behaviour
		Flower	Feeder				
Green hermit	Absent	565	-	47	5	5	1
	Present	0	0	0	0	0	0
White-throated Mountain-gem	Absent	3,559	-	42.88	6,666	99.49	36
	Present	841	0	44.26	532	88.67	5
Green-crowned Brilliant	Absent	2,660	-	41.56	11,976	148	45
	Present	0	0	0	0	0	0
Lesser Violetear	Absent	15	-	15	0	0	0
	Present	0	0	0	0	0	0
Magenta-throated Woodstar	Absent	111	-	111	0	0	0
	Present	24	0	24	0	0	0
Purple-crowned fairy	Absent	29	-	0	0	0	0
	Present	0	0	0	0	0	0
Stripe-tailed hummingbird	Absent	7,276	-	33.22	3,248	45.75	14
	Present	2,430	347	30.38	1,273	55.64	2
Violet Sabrewing	Absent	5,626	-	27.05	6,894	46.90	176
	Present	3,526	2,184	25.74	33,423	144.06	136
Stripe-throated Hermit	Absent	0	-	0	0	0	0
	Present	48	0	24	0	0	0
Rufous-tailed Hummingbird	Absent	0	-	0	0	0	0
	Present	15	0	15	0	0	0
Talamanca Hummingbird	Absent	0	-	0	0	0	0
	Present	30	0	30	0	0	0
Snowy-bellied Hummingbird	Absent	0	-	0	0	0	0
	Present	0	0	0	7	7	0

Overall foraging time on flowers was 19,812 seconds during the surveys without feeder. The Stripe-tailed hummingbird made up for the highest foraging time (7,276) followed by the Violet Sabrewing (5,626), and the White-throated Mountain-gem (3,559). With 2,660 seconds of forage time, the Green-crowned Brilliant accounted for a relatively low percentage of the total foraging time (13%).

With a feeder in place a total of 9,445 seconds of foraging occurred, for these surveys the foraging has been separated into foraging on flowers and foraging on the feeder. The time spent foraging on flowers is the main focus of this research. During the surveys with a feeder, the Violet Sabrewing became the most dominant forager. The total forage time on flowers by the Violet Sabrewing was 3,526 seconds, followed by the Strip-tailed hummingbird (2,430), and the White-throated Mountain-gem (841). The Green-crowned Brilliant was not observed during the surveys with a feeder.

When the feeder was absent the Green-crowned Brilliant was responsible for a large portion of the overall perching time (41%) with a total of 11,967 seconds. The Violet Sabrewing (6,894) and the White-throated Mountain-gem (6,666) both accounted for about 23% of the overall perching time. Even though the Stripe-tailed hummingbird being the most dominant forager, it has one of the lowest overall perching time (3,248) during these surveys. In total 28,789 seconds of perching occurred during the surveys without a feeder.

The Violet Sabrewing became the most dominant species for perching during the observations in which a feeder was present. With a total of 33,423 seconds the Violet Sabrewing had a share of almost 95% of the total perch time. The Stripe-tailed hummingbird (1,273) and the White-throated Mountain-gem (532) make up for a small portion of the overall perch time, during the surveys with a feeder in place.

Most territorial behaviour during observations without a feeder was displayed by the Violet Sabrewing with a total count of 176. The violet Sabrewing also had the highest contribution to territorial behaviour during the observations with feeder. Being responsible for 136 counts out of the total 143 counts of territorial behaviour.

3.1.4 Significant difference of the overall behavioural traits

To determine if there is a significant difference in foraging and perching behaviour during the survey with and without a feeder, a two-sample T-test was used assuming unequal variance. An Alfa level of 0.05 was used as a threshold ($\alpha = 0.05$).

The difference in overall average time spend foraging at a flower without feeder (Mean = 33.62; SD = 31.42) and with feeder (Mean = 28.57; SD = 27.40) was significant ($t(510) = 2.3$; $p = 0.02$) (table3).

Table 3:difference overall average time spend foraging per forage session

Feeder	Mean	St.dev	P-value
Absent	33.62	31.42	0.02
Present	28.57	27.40	

There was also a significant difference ($t(357) = -3,7$; $p = 0.0003$) between the overall average perching time during observations without feeder (Mean = 78.4; SD = 109.95) and observations with feeder (Mean = 28.57; SD = 222.97) (table 4).

Table 4: Difference overall average time spend perching per perching session

Feeder	Mean	St.dev	P-value
Absent	78.4	109.95	0.0003
Present	28.57	222.97	

A two-proportion z-test was performed to determine if there was a significant difference in overall territorial behaviour during the surveys with and without a feeder. The alpha level used as threshold was 0.05 ($\alpha = 0.05$).

Table 5: Proportion of territorial behaviour

Feeder	**n territorial behaviour**	**n overall behaviour**	**Proportion of territorial behaviour**	**P-value**
Absent	272	1,229	0.22	0.07
Present	143	763	0.19	

The P-value (0.07) delivered from the two proportion z-test indicates that there was no significant difference in overall territorial behaviour during both observations (table 5).

3.2 Results per species

This section of the report will only discuss the species that had a dominant presence during the surveys. Most species mentioned in tables 1 are classed as anomalies since they had one or two entrances in the dataset. These species will not be discussed in this section since there is a lack of data to perform any statistical tests. The species that will be discussed are Violet Sabrewing, Stripe-tailed hummingbird, and the White-throated Mountain-gem. The Green-crowned Brilliant will also not be analysed further in this section. Since there was no data recorded on this species during the observations in which the feeder was present.

3.2.1 Changes in proportional behaviour per species

This section will discuss proportional changes in behaviour of the Violet Sabrewing, White-throated Mountain-gem, and the Stripe-tailed Hummingbird. A description of changes in behaviour during both observations will be given. After these descriptions, each behaviour of each species will be statistically analysed.

3.2.1.1 Violet Sabrewing

Foraging consisted of the largest proportion (39%) of displayed behaviour for the Violet Sabrewing During the observations in which the feeder was absent (figure 4). The proportion of foraging remained the same during the observations in which a feeder was present. Foraging was still the main displayed behavioural trait however, there was a change in the proportion of perching and territorial behaviour. Displayed territorial behaviour dropped down from 33% to 23% during observations where a feeder was present. The opposite happened to the proportion of displayed perching behaviour. Perching went up from 28% to 38% during the observations in which a feeder was present.

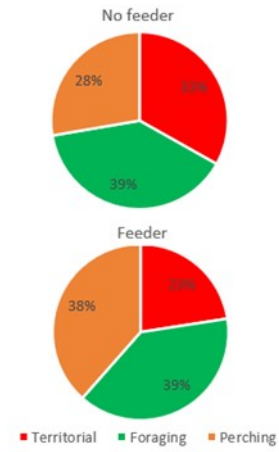


Figure 4: Proportion of behavioural traits Violet Sabrewing

3.2.1.2 White-throated Mountain-gem

Foraging was also the main proportion behavioural trait displayed by the White-throated Mountain-gem, during both observations with and without feeder

(figure 5). However, the proportion of foraging increased by 18% when a feeder was present. Perching declined by 16%, dropping from 36% (feeder absent) to 20% (feeder present). Change in proportion of territorial behaviour was limited, with a drop of 2% during observations in which the feeder was present.

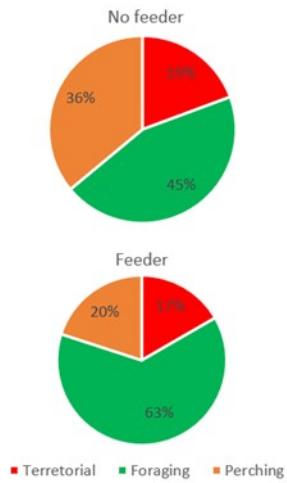


Figure 5: proportion of behavioural traits White-throated Mountain-gem

3.2.1.3 *Stripe-tailed hummingbird*

The Stripe-tailed hummingbird also displayed foraging as its largest proportion of behavioural traits. The proportion of foraging increased by 6% when a feeder was present. Both the proportion of perching and territorial behaviour declined by 3% when the feeder was present (figure 6).

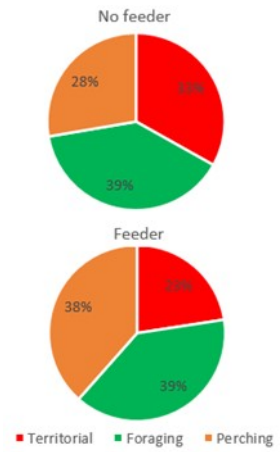


Figure 6:Porportion of behavioural traits Stripe-tailed hummingbird

3.2.2 Foraging

To determine if there is a significant difference in foraging on flowers and perching time a two-sample T-test was used assuming unequal variance was used. An alfa level of 0.05 was set to be the threshold ($\alpha = 0.05$). A significant difference in territorial behaviour was determined using a two-proportion z-test.

The violet Sabrewing did not show a significant difference ($t(289) = 0.48$; $p = 0.63$) during the observations in which a feeder was absent (Mean = 27.05; SD = 24.73), and during observations in which a feeder was present (Mean = 25.74; SD = 25.02). The difference in foraging time at flowers for the White-throated Mountain-gem without a feeder (Mean = 42.88; SD = 35.41) and with feeder (Mean = 44.26; SD = 50.23) was not significant ($t(22) = -0.11$; $p = 0.91$). The stripe-tailed Hummingbird did also not show a significant difference ($t(200) = 0.82$; $p = 0.41$) in foraging time during the observations without (Mean = 33.22; SD = 33.48) and with feeder (Mean = 30.38; SD = 23.47). Table 6 shows the results on average foraging time at flowers per foraging session for each of the analysed species.

Table 6: Results foraging time

Species	Absent			Present			
	Mean	**St.dev**	**n**	**Mean**	**St.dev**	**n**	**P-value**
Violet Sabrewing	27.05	24.73	208	25.74	25.02	137	0.63
White-throated Mountain-gem	42.88	35.41	83	44.26	50.23	19	0.91
Stripe-tailed Hummingbird	33.22	33.48	219	30.38	23.47	80	0.41

Statistical tests were also performed to test if there is a significant difference in daily visitations to the plot to forage on flowers (table 7). The violet Sabrewing did lower these daily visitations when comparing the observations without feeder (Mean = 10.4; SD = 9.10) to those with a feeder (Mean = 6.85; SD = 7.30). However, the Violet Sabrewing was the only hummingbird that did not show a significant difference in visitation during both set-ups ($t(36) = 1.36$; $p = 0.18$). The White-throated Mountain-gem did show a highly significant difference ($t(24) = 4.15$; $p = 0.0003$) with a decrease in visitations during the observations with feeder (Mean = 0.95; SD = 1.19) compared to those without (Mean = 4.15; SD = 3.23). The Daily visitations to forage on flowers for the Stripe-tailed Hummingbird also showed a highly significant difference ($t(22) = 3.70$; $p = 0.001$). With a decreased number of daily visitations during observations with a feeder present (Mean = 4.25; SD = 2.24) compared to those without (Mean = 10.95; SD = 7.78).

Table 7: Daily visitations foraging on flowers

Species	Absent			Present			
	Mean	**St.dev**	**n**	**Mean**	**St.dev**	**n**	**P-value**
Violet Sabrewing	10.4	9.10	20	6.85	7.30	20	0.18
White-throated Mountain-gem	4.15	3.23	20	0.95	1.19	20	0.0003
Stripe-tailed Hummingbird	10.95	7.78	20	4.25	2.24	20	0.001

3.2.3 Perching

The Violet Sabrewing had a highly significant (t (275) = -6.0; p = $6.18*10^{-9}$) increase in perching time when a feeder was present (Mean =144.06; SD = 235.14), compared to the surveys in which a feeder was absent (Mean = 46.90 ; SD = 59.24). The white-throated Mountain-gem did not show a significant difference (t (7) = 0.25; p = 0.81) in perch time during observations without (Mean = 99.49; SD = 143.20) and with feeder (Mean = 88.67; SD = 95.17). The difference in perching time for the Stripe-tailed Hummingbird during observation with the feeder absent (Mean = 45.75; SD = 49.99), and present (Mean = 50.92; SD = 55.64). Therefore the stripe-tailed hummingbird did also not show a significant difference (t (39) = -0.41; p = 0.68) in perch time (table 8).

Table 8: Results perching time

Species	Absent			Present			
	Mean	**St.dev**	**n**	**Mean**	**St.dev**	**n**	**P-value**
Violet Sabrewing	46.90	59.24	147	144.06	235.14	232	$6.18*10^{-9}$
White-throated Mountain-gem	99.49	143.20	67	88.67	95.17	6	0.81
Stripe-tailed Hummingbird	45.75	49.99	71	50.92	55.64	25	0.68

Changes in daily visitations to the plot to perch where also statistically analysed (table 9). The Violet Sabrewing had an increase in daily visitations to perch during observations in which the feeder was present (Mean = 11.6; SD = 6.78), compared to those in which it was absent (Mean = 7.35; SD = 12.36). This increase however was not significant (t (29) = -1.35; p = 0.19). Both the White-throated Mountain-gem (t (20) = 2.81; p = 0.01) and the Stripe-tailed Hummingbird (t (34) = 2.47; p = 0.02) did showed a significant difference in visitations. Both species of hummingbirds had a decrease in daily visitations to perch.

Table 9: Average daily visitations

Species	Absent			Present			
	Mean	**St.dev**	**n**	**Mean**	**St.dev**	**n**	**P-value**
Violet Sabrewing	7.35	12.36	20	11.6	6.78	20	0.19
White-throated Mountain-gem	3.35	4.77	20	0.3	0.80	20	0.01
Stripe-tailed Hummingbird	3.55	3.41	20	1.25	2.38	20	0.02

3.2.4 Territorial behaviour

Changes in territorial behaviour will be based on changes in the proportion of territorial behaviour compared to the overall behaviour. Both the White-throated Mountain-gem (p = 0.73) and the Stripe-tailed Hummingbird (p = 0.15) did not show a significant difference in proportion of territorial behaviour. The Violet Sabrewing does show a highly significant (6.74*10-5) decrease in the proportion of territorial behaviour when the feeder was present (table 10).

Table 10: results on territorial behaviour

Species	Feeder	Proportion of aggressive behaviour	n	P-value
Violet Sabrewing	Absent	33%	531	$6.74*10^{-5}$
	Present	23%	603	
White-throated Mountain-gem	Absent	19%	186	0.73
	Present	17%	30	
Stripe-tailed Hummingbird	Absent	0.04%	304	0.15
	Present	0.02%	122	

4. Discussion

4.1 Interpretation results

The usage of artificial feeders is a very popular method to attract hummingbirds however, the side effects these feeders have on the behaviour of the hummingbirds are often overlooked. The main focus of the study was to determine if an artificial feeder changes the behaviour of hummingbirds present in the area. This research mainly looked at changes in proportional behaviour, time spend foraging, time spend perching, territorial behaviour, and visitations to the plot.

The results indicate that the effect an artificial feeders has on the behaviour of hummingbirds strongly varies per species. Time spend foraging at flowers per foraging session decreases for the Violet Sabrewing and the Stripe-tailed hummingbird, The White-throated Mountain-gem showed an increase with the presence of a feeder. None of these changes were statistically significant however. The daily visitations to forage also showed a decline for both the Stripe-tailed hummingbird and the White-throated Mountain-gem.

There was a significant increase in time spent perching for the Violet Sabrewing. The Stripe-tailed showed an increase in time spend perching, the White-throated mountain-gem a decrease however, both species did not show a significant difference. Daily visitations to perch declined significantly for the Stripe-tailed hummingbird and the White-throated Mountain-gem.

There was a decrease in territorial behaviour for all three species, when the feeder was present. The Violet Sabrewing was the only species that showed a significant decrease in territorial behaviour.

When looking at the overall results it becomes clear that the Violet Sabrewing's presence in the area becomes a lot more dominant. This is not caused by an increase in overall foraging time, since overall foraging time during both set-ups is quite similar.
The presence of an artificial feeder seems to mainly affect the overall perch time of the Violet Sabrewing, with the overall perch time being almost five times higher in the presence of a feeder.

The decrease in perch time of the White-throated Mountain-gem is also noticeable. During the observations in which a feeder was in place the White-throated Mountain-gem showed a strong decline in perching time.

The different changes in perching behaviour of both species suggests that each species reacts differently to the present of a feeder. Since both species showed very similar perching times during the observations where the feeder was absent. Therefore the introduction of the feeder seemed to directly or indirectly have impacted the perching behaviour of these hummingbird species.

The change in most dominant forager in the area is also noticeable. During observations where the feeder was absent, the Stripe-tailed had the largest share in foraging time. This changed when a feeder was present, during these observation the Violet Sabrewing became the most dominant forager in the area.

The decline in overall foraging time during observations with feeder is mainly caused by the decline in foraging of the Stripe-tailed hummingbird, the White-throated Mountain-gem, and the absence of the Green-crowned Brilliant.

All hummingbird species that were analysed showed a decline in the proportion of territorial behaviour during observations where the feeder was present. This decline was significant for the Violet Sabrewing.

The decline in territorial behaviour, however, did not seem to result in an increase in time spent foraging by any of the species analysed. Since the average time spend foraging at flowers during a foraging session does not seem to be affected by the presence of an artificial feeder. This contradicts the results obtained by Cannon (2017) in the same area. This research showed a decrease in foraging time by the Stripe-tailed hummingbird and the White-throated Mountain-gem and an increase by the Violet Sabrewing when a feeder was present.

Both Stripe-tailed hummingbird and the White-throated Mountain-gem showed a significant decline in visitations to the plot when an artificial feeder was present. This result is contractionary to other research done on visitation rates by Brockmeyer and Schaefer (2012) where the presence of a feeder did not affect visitation rates of hummingbirds. Research that was done in Cloudbridge nature reserve during the rainy season shows an increase in foraging visitations by the Stripe-tailed hummingbird and the Violet Sabrewing, and no change in visitations by the White-throated Mountain-gem (Cannon, 2017). This also contradicts the results found during this research.
The results on visitation rates found during this study are partially in line with research done in Mexico City, where a feeder resulted in a decline in flower visitations (Arizmendi et al., 2007). However, Arizmendi et al. (2007) also state that the hummingbirds preferred foraging on the feeder instead of foraging on flowers. This is contradictory to results obtained during this study since none of the analysed species show a higher amount of foraging time on the feeder. All of the analysed species still seem to spend more time foraging on flowers than on the feeder.

The decline in foraging visitations seems to be an indirect effect, caused by the presence of the artificial feeder. Since both the Stripe-tailed hummingbird and the White-throated Mountain-gem both did not seem to value the feeder as a food source. The Stripe-tailed hummingbird has a relatively low foraging time on the feeder, the White-throated Mountain-gem was not observed foraging at the feeder during any of the observations. Even though both species had limited to no interest in the feeder, both did show changes in their behaviour.

These changes in behaviour are most likely caused by the effect the feeder has on another species, the Violet Sabrewing. The increase in presence of the Violet Sabrewing, due to a highly significant increase in perch time seems to deter other hummingbird species from entering the area.

This effect of an increase in perch time of the Violet Sabrewing was not observed during the research of Cannon (2017), where perch time did not seem to be affected by a feeder. The reason why the perching behaviour of the Violet Sabrewing shows such different results in both studies is unknown.
However, this difference in perch time of the Violet Sabrewing could explain why both studies have different results in visitation rates for the other species.

The main objective for most humans when placing an artificial feeder is to lure as many hummingbirds as possible to an area. This research shows that this is highly effective for some species, while it might have opposite effects for other species. However, the implications of this research reach a lot further than just the increase or decrease in presence of certain species.

The presence of a feeder could result in a decrease in overall foraging behaviour by hummingbirds in the area. Hummingbirds are the main pollinators of certain plants and trees in the tropics, with some flowers especially adapted to perfectly suit the hummingbird's beak. A decline in visitation by certain species as a cause of an artificial feeder could lead to a decrease in pollination.

Research done on flower preference of different species indicate that flower preference varies per species (Maglianesi et al., 2014). The decrease of visitation by certain species could lead to a decrease in the pollination of specific plant and tree species. Less pollination of these plant and tree species might eventually lead to a change in forest composition.

Limitations

This research was conducted during the transition period from rainy- to dry season. This affected some of the results of this research.

One of the effects of this transition was the abandonment of the area by certain species, most noticeably the Green-crowned Brilliant. The Green-crowned Brilliant was the most dominant species in the area during the first 10 days of surveys without a feeder. After these 10 days, it completely left the area. The departure of the Green-crowned Brilliant led to a different hierarchy between the species that remained. Which could have resulted in differences between the first 10 days and the remaining surveys.

The change in seasonality seemingly altered the availability of nectar of certain plants, most noticeably the Brazilian red cloak. Since this transition was a gradual process, the nectar resources of certain flowers also seemed to gradually decline. The Brazilian red cloak was the preferred food source of the Violet Sabrewing throughout the observations. Lower nectar availability could have resulted in different behaviour by hummingbirds, namely the Violet Sabrewing. Not only change in nectar resources, but also the change in temperature, rainfall, and other climatic conditions might have altered the results of this research.

Research done in the same area during the rainy season suggested that follow-up research should be conducted in a different season. This follow-up research was meant to determine if the same results would be obtained in a different season. This research was conducted in the transition period from rainy to dry season, and it shows different outcomes. Comparing both studies shows that hummingbirds reacted differently to the feeder during different seasons. However, it does not tell anything about the exact reasons for these differences.

One methodical choice has also caused some limitations in the data. This was noticed after some data had already been obtained, therefore changing the methodology was no longer possible. Territorial behaviour was counted instead of timed. This was unavoidable due to the rapid speed at which some territorial behaviours occur, such as chasing and hovering. However, some territorial displays could have been counted, which would have led to more insight into changes in territorial behaviour. Namely, the change in the duration of vocalization of certain species of hummingbirds should have been timed.

Only one type of feeder was used since other models of feeders seemed to be ineffective in the study area. These other models were also tested in other locations in the reserve, where they instantly attracted hummingbirds. It is unclear in the type of model used also impacted the behaviour of the hummingbird species. The location of the feeder within the plot might also have impacted the behaviour of certain hummingbird species.

4.2 Recommendations

As mentioned in the discussion, both studies performed in the same area showed different results for some species. This could have been due to the difference in seasonality, and thus, a difference in nectar resources, temperature, rainfall, etc.
Studies should be conducted to determine which factor, caused by the change in seasonality, caused the observed differences.

For example, neither of the performed studies investigated the availability of nectar in the flowers that are present in the area. Therefore, it is recommended to conduct research to determine if changes in the amount of available nectar in flowers alter the reaction of hummingbirds to the presence of a feeder.

5. Conclusion

The use of artificial feeders is a popular method in to attract hummingbirds. Feeders are often placed in clear sight so that humans can enjoy the spectacular species of hummingbirds that visit them. Most often feeders perfectly fur full their purpose however, the usage of such feeders might also have other, less favourable, effects. Since it could alter the behaviour of the hummingbird species in the vicinity.

The effect an artificial feeder has on hummingbirds was determined by observing the behaviour of hummingbirds with and without a feeder. The results show that the impact a feeder has on the behaviour of hummingbirds varies depending on the species.

All analysed species showed a decrease in the proportion of territorial behaviour, this decrease was highly significant for the Violet Sabrewing.

Furthermore, the Violet Sabrewing showed a highly significant increase in average perch time. However, the Violet Sabrewing showed no significant change in visitations to forage or perch. The time spend foraging on flowers per forage session did also not show a significant difference for the Violet Sabrewing.

The White-throated Mountain-gem did not show a significant change in time spent foraging on flowers per forage session either. The visitations to the study area to forage on flowers did show a significant decline when the feeder was present. Daily perching visitations also declined when the feeder was present, the average time spend perching did not change.

The Stripe-tailed hummingbird showed a similar pattern as the White-throated Mountain-gem. It also had no significant difference in time spent foraging per session, but did show a decline in daily visitations to forage. The same results were found for perching, where there was no significant change in average perch time but there was a significant decline in daily perch visitations.

It seems as if the decline in visitations by both the White-throated Mountain-gem and the Stripe-tailed hummingbird was caused by an indirect effect of the feeder. Since both White-throated Mountain-gem and the Stripe-tailed hummingbird did not or rarely use the feeder as a food source. The decline in visitations seems more likely to be caused by the increase in presence of the Violet Sabrewing.

This decline in visitations could eventually lead to a decline in the pollination of specific plant or tree species. Since hummingbirds differ in their preferences of flowers to forage on. This decline in pollination could lead to a change in species composition in the area.

The results obtained during this research are not in line with research done in the same area during the rainy season. Therefore, it is suggested further research should be done to determine what caused the different results between both studies.

6. References

Arizmendi, M. D. C., Constanza, M. S., Lourdes, J., Ivonne, F. M., & Edgar, L. S. (2007). Effect of the presence of nectar feeders on the breeding success of Salvia mexicana and Salvia fulgens in a suburban park near México City. *Biological Conservation*, *136*(1), 155–158. https://doi.org/10.1016/j.biocon.2006.11.016

Brockmeyer, T., & Schaefer, H. M. (2012). Do nectar feeders in Andean nature reserves affect flower visitation by hummingbirds? *Basic and Applied Ecology*, *13*(3), 294–300. https://doi.org/10.1016/j.baae.2012.02.005

Bryner, J. (2006, October 9). *The Secret to Hummingbirds' Amazing Energy*. Livescience.Com. Retrieved 19 October 2021, from https://www.livescience.com/1072-secret-hummingbirds-amazing-energy.html

Bubb, P., UNEP World Conservation Monitoring Centre, Mountain Cloud Forest Initiative, IUCN Commission on Ecosystem Management, & Unesco. Programme on Man and the Biosphere. (2004). *Cloud Forest Agenda*. UNEP World Conservation Monitoring Centre.

Cannon, L. (2017). *The effect of an artifical feeder on hummingbird behaviour* (No. 1). University of Salford Manchester. http://www.cloudbridge.org/wp-content/uploads/2011/09/2017-The-effect-of-an-artificial-feeder-on-hummingbird-behaviour-L-Cannon-Final-Report-Abridged-19_7.pdf

Climate-data. (2021). *Rivas*. https://nl.climate-data.org/. Retrieved 30 November 2021, from https://nl.climate-data.org/noord-ameika/costa-rica/san-jose/rivas-653940/

Cloudbridge. (2021). *Welcome to Cloudbridge!* Cloudbridge Nature Reserve. Retrieved 19 October 2021, from http://www.cloudbridge.org/

DellaSala, D. A., & Goldstein, M. (2020). *Encyclopedia of the World's Biomes* (1st ed., Vol. 2020). Elsevier Gezondheidszorg.

Garrigues, R., & Dean, R. (2007). *The Birds of Costa Rica: A Field Guide (Zona Tropical Publications)* (1st ed.). Cornell University Press.

Maglianesi, M. A., Böhning-Gaese, K., & Schleuning, M. (2014). Different foraging preferences of hummingbirds on artificial and natural flowers reveal mechanisms structuring plant-pollinator interactions. *Journal of Animal Ecology*, *84*(3), 655–664. https://doi.org/10.1111/1365-2656.12319

McCaffrey, R. E., & Wethington, S. M. (2008). *How the presence of feeders affects the use of local floral resources by hummingbirds: a case study from southern Ar* (No. 1). The Condor. https://academic.oup.com/condor/article-abstract/110/4/786/5152365

Multi Timer StopWatch (2.8.7). (2013). [Mobile app]. LemonClip. https://play.google.com/store/apps/details?id=com.jee.timer&hl=nl&gl=US

Pearce Stevens, A. (2019, December 6). *Some male hummingbirds wield their bills as weapons*. Science News for Students. Retrieved 19 October 2021, from https://www.sciencenewsforstudents.org/article/some-male-hummingbirds-wield-their-bills-weapons

Powers, D. R., & McKee, T. (1994). The Effect of Food Availability on Time and Energy Expenditures of Territorial and Non-Territorial Hummingbirds. *The Condor*, *96*(4), 1064–1075. https://doi.org/10.2307/1369115

Sawtelle, S. (2011, May). *Food Resource Density and Territorial Behavior of Monteverde Cloud Forest Hummingbirds* (No. 1). Department of Biology and Environmental Studies. https://digital.lib.usf.edu/content/SF/S0/00/14/08/00001/M39-00239-Sawtelle_Sarah_Territorial_behavior_of_hummingbirds_CIEE_Spring_2011.pdf

Sonne, J., Kyvsgaard, P., Maruyama, P. K., Vizentin-Bugoni, J., Ollerton, J., Sazima, M., Rahbek, C., & Dalsgaard, B. (2015). Spatial effects of artificial feeders on hummingbird abundance, floral visitation and pollen deposition. *Journal of Ornithology*, *157*(2), 573–581. https://doi.org/10.1007/s10336-015-1287-1

Wetlands & Wildlife Care Center. (n.d.). *How to care for hummingbird feeders*. Https://Www.Seaandsageaudubon.Org/. Retrieved 18 October 2021, from https://www.seaandsageaudubon.org/BirdInfo/HummingbirdFeeders.pdf

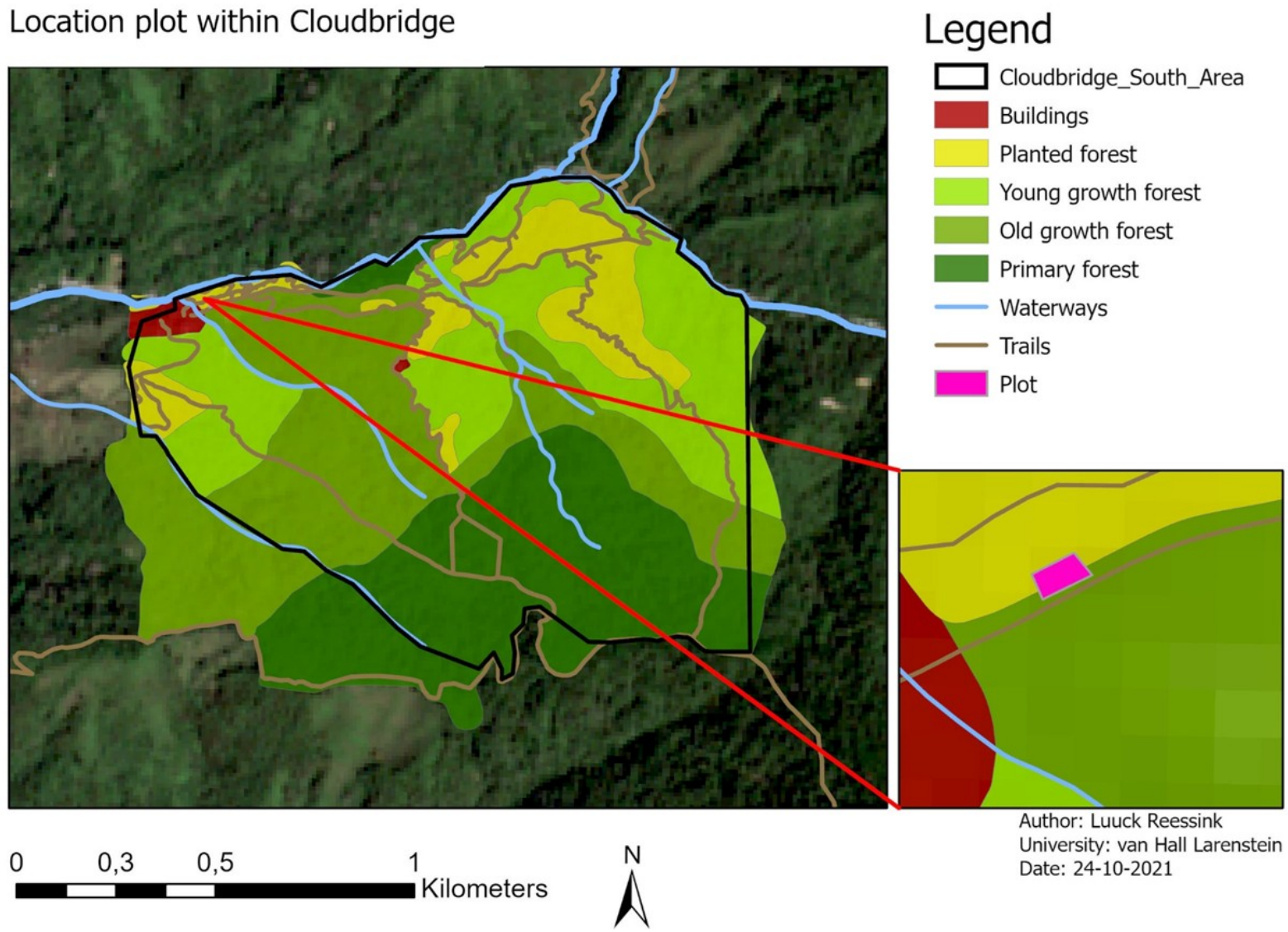
7. Appendices

7.1 Appendix 1: hummingbirds present in Cloudbridge nature reserve

Common name	**Scientific name**
Green Hermit	Phaethornis guy
Stripe-throated Hermit	Phaethornis striigularis
Long-billed Hermit	Phaethornis longirostris
Bronzy Hermit	Glaucis aeneus
Violet Sabrewing	Campylopterus hemileucurus
Fiery-throated hummingbird	Panterpe insignis
Green-crowned Brilliant	Heliodoxa jacula
Scaly-breasted hummingbird	Phaeochroa cuvierii
Purple-crowned fairy	Heliothryx barroti
White-necked Jacobin	Florisuga mellivora
Rufous-tailed hummingbird	Amazilia tzacatl
Brown Violet-ear	Colibri delphinae
Lesser Violet-ear	Colibri cyanotus
Snowy-bellied hummingbird	Amazilia edward
Stripe-tailed hummingbird	Eupherusa eximia
White-tailed emerald	Elvira chionura
Long-billed Starthroat	Heliomaster longirostris
Green-fronted Lancebill	Doryfera ludovicae
White-throated Mountain-gem	Lampornis castaneoventris
Violet-headed hummingbird	Klais guimeti
Magenta-throated Woodstar	Calliphlox bryantae
Scintillant hummingbird	Selasphorus scintilla
Volcano hummingbird	Selasphorus flammula

7.2

7.3 Appendix 2: location of plot within Cloudbridge nature reserve



7.4 Appendix 3: Field form

Time slot: 7:30-8:00/9:00-9:30/11:00-11:30				Date: Observers:	
Basic information				**Specifics territorial behaviour**	
Species	Male/female	Behaviour	Duration	Specific behaviour	Towards which species