RESERVA CLOUDBRIDGE NATURE RESERVE

Hummingbird behavioural study

07 August – 08 December 2023

Cloudbridge Nature Reserve, Costa Rica

Fergus Jackson

Nottingham Trent University

NOTTINGHAM TRENT UNIVERSITY

Contents

1. Introduction

Hummingbirds (*Trochilidae)* are one of the most unique and highly adapted families in the animal kingdom renowned for their unmatched aerial prowess. They provide vital ecosystem services such as pollination and biological control of pests. Hummingbirds will naturally spend 85-90% of their foraging time finding and consuming nectar (Barney, 2019). Having co-evolved with many species of nectar-producing plants, hummingbirds are well suited as pollinators, with over 1000 floral species relying on them for reproduction (Reddish & Attenborough, 2012). Their varied morphological, physiological and behavioural adaptations make them extremely adept in locating and exploiting nectar resources (Rodrigues & Araujo, 2011). However, some species of hummingbird are at risk due to habitat fragmentation and loss (NAPPC, 2008). One cause of this is from non-native plant species being introduced as alternate food sources, which often favour generalist species. Climate change is also predicted to have a detrimental effect, particularly on specialised species with small ranges (NAPPC, 2008).

Hummingbird communities are often defined by floral availability; therefore a country like Costa Rica, where there is an abundance of both naturally growing and planted species of nectar producing flowers, is a suitable place to research hummingbird foraging behaviour preference. Many of these flowering species are ornithophilous plants (pollinated by birds) which depend on hummingbirds for pollination (Fogden & Fogden, 2006). Making up 2-15% of angiosperm species, ornithophilous plants are a vital component in neo-tropical communities (Rodrigues & Araujo, 2011). With a rarity of other bird species such as sunbirds and honey creepers, some of these plants have evolved to only be pollinated and fed from by the *Phaethornis* genus. This hummingbird genus, commonly referred to as hermits, have long, curved bills capable of retrieving nectar from these ornithophilous plants (Feinsinger & Colwell, 1978). The Violet Sabrewing (*Campylopterus hemileucurus)* is one of the few species not in the *Phaethornis* genus that, alongside the hermits, is also capable of feeding from the ornithophilous species. As the *Trochilinae* subfamily typically have shorter, straighter bills, they are more generalist species, feeding from a wide variety of flowering plants which are less rich in nectar. These generalist species share pollination of these plants with bats and insects (Martén-Rodríguez et al., 2009).

While there is adequate research on hummingbirds, very little focuses on the impact of human disturbance on behaviours and natural habits. Mendiola-Islas et al. (2023) outlines how human presence reduces activity of Broad-tailed hummingbirds (*Selasphorus platycercus)* on agricultural land in Mexico. Similar agricultural land use has occurred throughout Central America, and specifically in Costa Rica there has been a focus in reforesting previously deforested land. One example of restorative land use practices from pasture land to reforested land is Cloudbridge Nature Reserve located in the Talamanca mountain range of Costa Rica. The tropical montane cloud forest present in the reserve can be found in varying stages of planted or natural regrowth. The reserve is located at an altitude of 1500m, up to 1900m where it meets the Chirripó national park. Multiple studies have been conducted in the past at Cloudbridge on how feeders can affect hummingbirds and feeding habits (Rabone & Staunton, 2015). However none have investigated human disturbance over several sites with comparisons to natural feeding sites. A species list completed for Cloudbridge Nature Reserve in November 2019 shows evidence of 27 species of hummingbird having been sighted and recorded (Powell et al., 2019). This shows evidence of a variety of food sources being available year-round to be exploited. Due to the high species and plant variability, the aim of this research project is to investigate behaviour and interactions of species of hummingbird present in Cloudbridge Nature Reserve. Specifically, the study looks to compare how behaviour and feeding habits change around areas affected by human activity. Hummingbirds have been widely researched on the reserve, providing valuable baseline knowledge of species and food sources.

2. Methodology

2.1 Site selection

16 sites were selected to be surveyed over the course of six months, 8 of which are based in the protected forest of the nature reserve where primarily natural influences will affect hummingbird behaviour, shown in figure 1. The remaining 8 sites are located in and around areas of human disturbance, as seen in figure 3. These human disturbed feeding sites are made up mostly of planted flower species and are within 10m of buildings. There is at least one natural break or human barrier, such as buildings, separating each of the sites influenced by human activity. The sites with no human influence are separated by natural breaks in food sources and a distance of at minimum 100m.

The sites were chosen for suitability; each site is required to have an abundance of flowering plants to make it a viable feeding territory for hummingbird species. Areas with few flowering plants will likely not attract many birds as the energy spent is not worth the reward (Pyke, 1978).

After two months, all sites were reviewed for continuing suitability due to the varied species of feeding flora and geographic location causing blooms at varying times of the year. After 8 weeks, Jilguero site 2 was deemed no longer a suitable site due to limited nectar availability. Therefore, a new site on Sentinel trail was selected, as shown in figure 2.

2.2 Study sites

2.2.1 Un-disturbed sites (07/08/2023 – 30/09/2023)

- Jilguero 1: 1790m
- Jilguero 2: 1730m
- Rio 1: 1660m
- Rio 2: 1630m
- Gavilan 1: 1830m
- Gavilan 2: 1700m
- Los quetzals 1: 1820m
- Los quetzals 2: 1760m

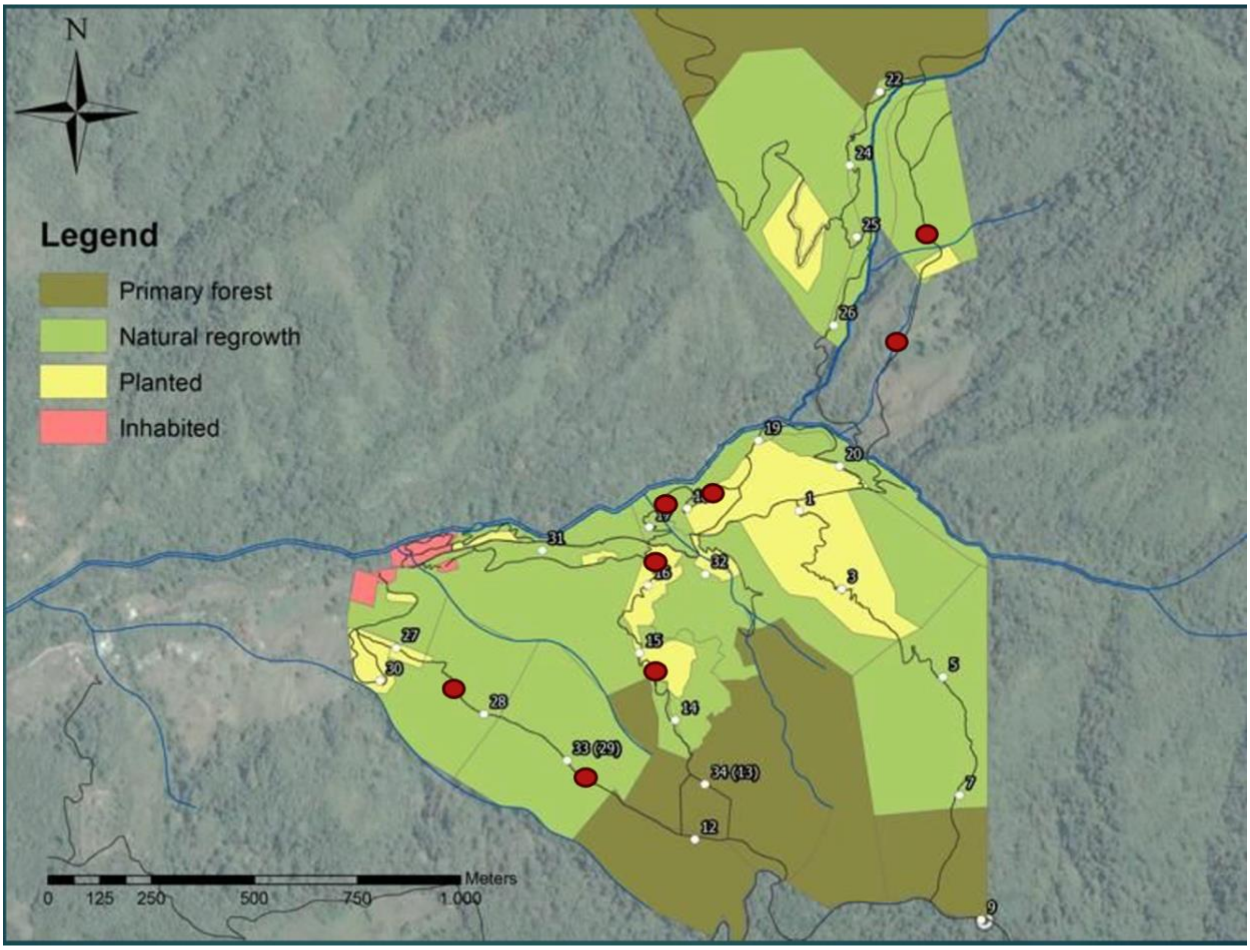

Figure 1: A map showing the main research trails of Cloudbridge nature reserve. Non-disturbed survey sites are indicated by each red point before 2 month review.

2.2.2 Un-disturbed sites (17/10/2023 – 08/12/2023)

- Jilguero 1: 1790m
- Sentinal 1: 1750m
- Rio 1: 1660m
- Rio 2: 1630m
- Gavilan 1: 1830m
- Gavilan 2: 1700m
- Los quetzals 1: 1820m
- Los quetzals 2: 1760m

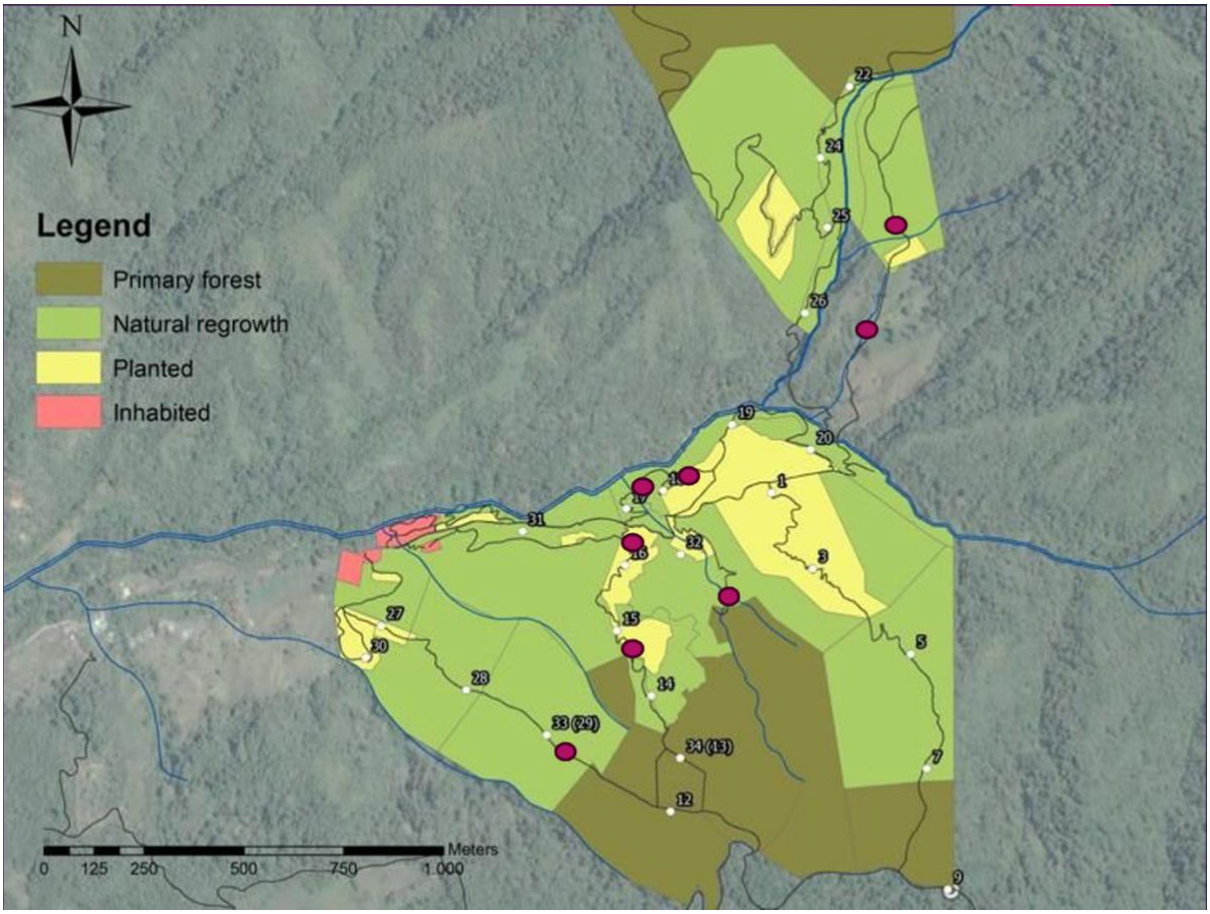

Figure 2: A map showing the main research trails of Cloudbridge nature reserve. Non-disturbed survey sites are indicated by each red point after 2 month review and one implemented site change.

2.2.3 Disturbed sites

- Visitor car park – 1540m
- Lab site – 1560m
- Classroom site – 1560m
- Memorial garden – 1550m
- Private trail – 1550m
- Bird Café – 1510m
- Casita Gavilan 1 – 1790m
- Casita Gavilan 2 – 1790m

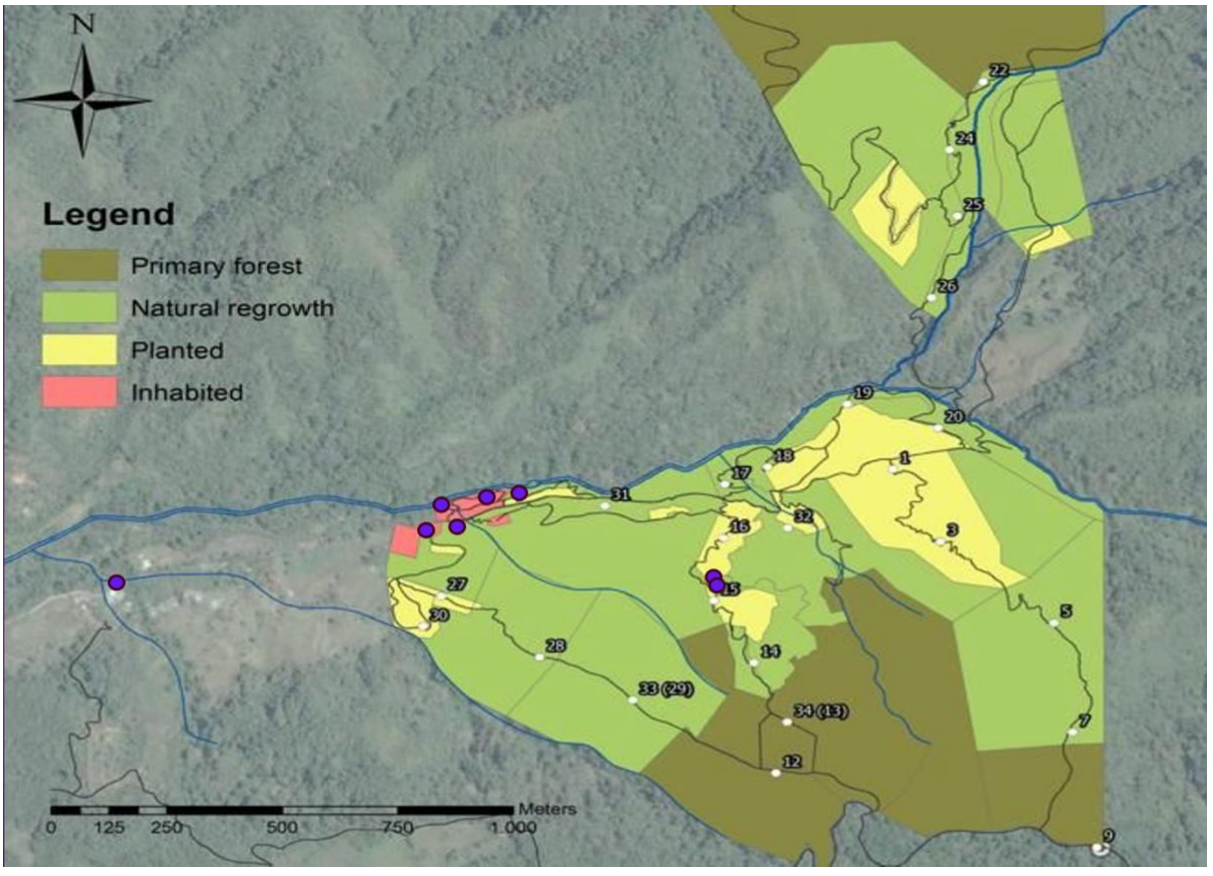

Figure 3: A map showing the main research trails of Cloudbridge nature reserve. Disturbed survey sites are indicated by each purple point.

2.3 Observation method

Each site observation was undertaken for one hour beginning at 7:00am, followed by a second site observation at a different location beginning at 9:00am. One disturbed site and one undisturbed site were surveyed per day, four days a week, over a schedule of 2 weeks. To ensure all sites were visited equally, the starting time of each site changed every 2 weeks so all sites were surveyed at 7:00am and 9:00am equally. Weather conditions and other impactful disturbances were made note of.

Every species seen or heard at the site were recorded. A table of all behaviours was drawn up before each survey point, shown in table 1. When a behaviour was observed, a record was taken in a tally. If a behaviour continued for any duration, until a new behaviour is exhibited, it was recorded as one observation. Male and female individuals, if discernible, were also recorded. If multiple individuals are recorded of different species, all interaction behaviours were recorded for all species involved. Species were identified using the Garrigues & Deans (2014) field guide and the Cornell lab Merlin bird ID app. Plant species being foraged from were noted, when known, shown in table 2. Pictures of the listed plant species can be seen in Appendix A.

2.4 Table 1: Behaviours to be recorded

• Perching – Sitting stationary (can include scanning local environment).
• Bill cleaning – Brushing/wiping bill on branch or stem while perched.
• Grooming – Manipulating and cleaning feathers with bill and feet.
• Feeding – Feeding on nectar from flowers while hovering or perching.
• Catching insects – Rapid erratic flight in pursuit of insects as alternative food source or to remove from territory.
• Defending territory – Aggressive behaviour to remove other individuals/species from a feeding territory.
• Being chased – Fleeing territory while being pursued by another individual.
• Vocalising – Making vocal sounds in alarm or communication
• Locomotion flying – flying through a site with no interaction with feeding flowers or other birds (can include vocalizing).

2.5 Table 2: Most common observed feeding sources:

• Blue porterweed - *Stachytarpheta jamaicensis*
• Lobster claw heliconia - *Heliconia bihai*
• Yellow Jabobinia - *Justicia aurea*
• *Palicourea padifolia*
• *Costus wilsonii*
• West Indian Lantana - *Lantana camara*
• Viola Orchid – *Cochliostema odoratissimum*
• Confederate rose - *Hibiscus mutabilis*
• Bolivian Fuchsia – *Fuchsia boliviana*
• Brazilian red-cloaks – *Megaskepasma erythrochlamys*
• *Besleria solanoides*
• *Phaseolus vulgaris*
• *Etlingera elatior*
• *Rasizea spicata*

3. Results

3.1 Total species encounters

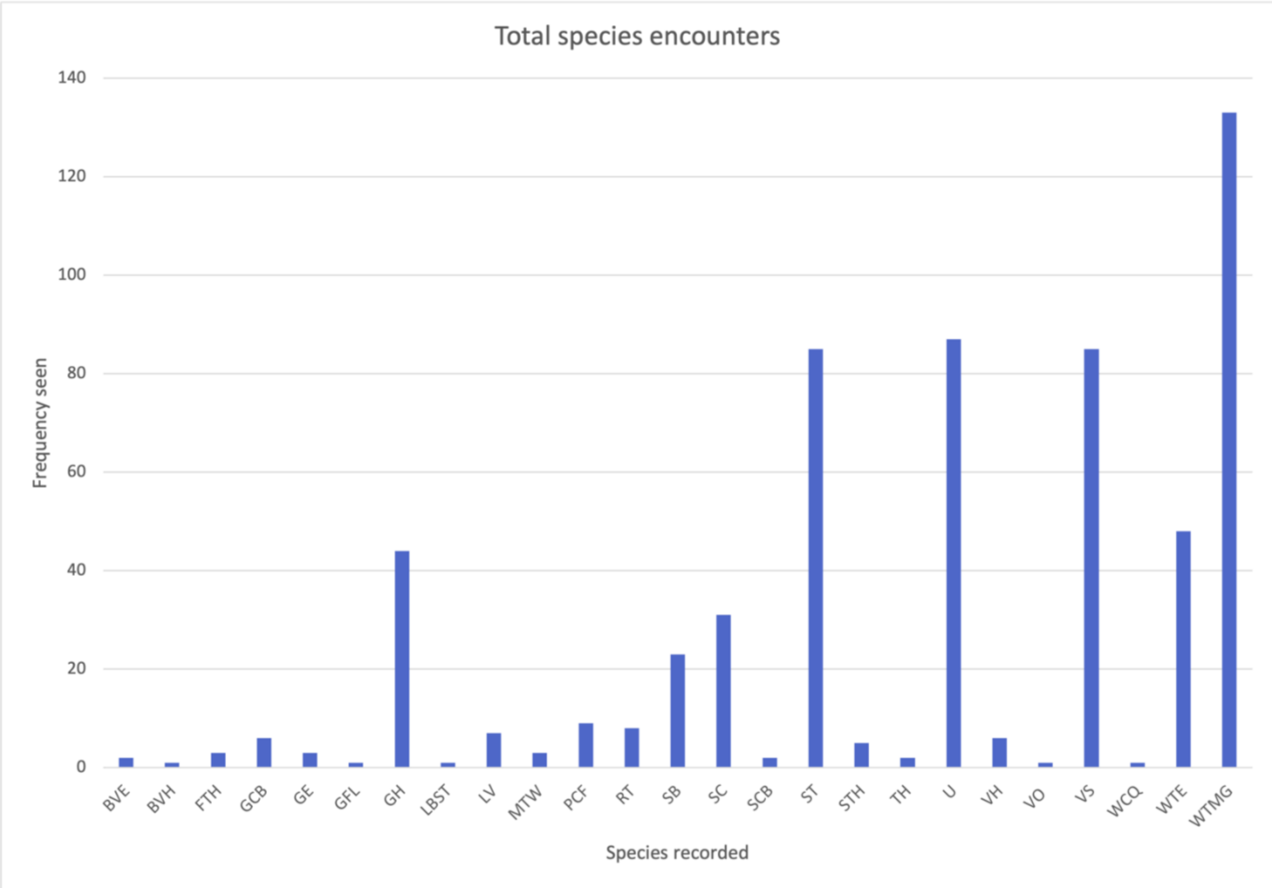

Figure 4: A graph showing the total count of each species of hummingbirds encountered (See Appendix B, Table 1 for species codes).

3.2 Total behaviours recorded

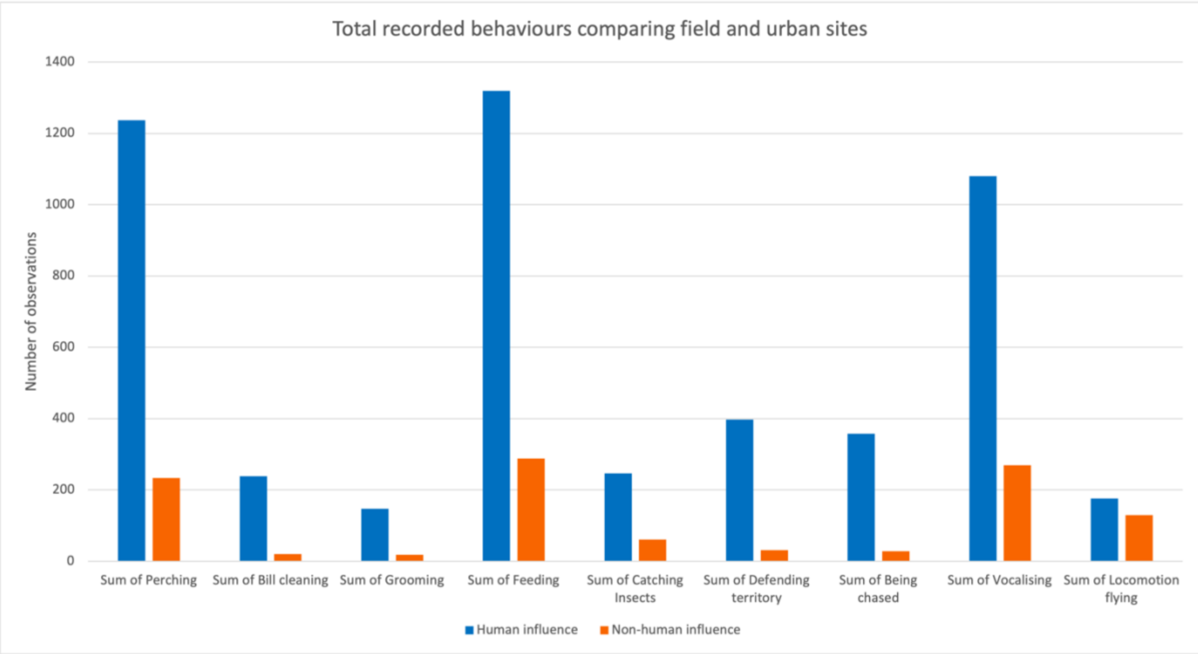

Figure 5: A graph showing a comparison of the total recorded values for each behaviour by site influence.

A Shapiro-Wilk Test for normality generated a p value of 0.067. Therefore, the data does not follow a normal distribution ($p>0.05$). (see Appendix C, figure 24)

A Wilcoxon signed-rank test was undertaken to test the difference between human and non-human influence as paired, count data was used (non-normal distribution). The p value = 0.004. This means there is a significant difference between the amount of recorded behaviours at different site types. ($p<0.05$) (see Appendix C, figure 24)

3.3 Species encountered per time of day

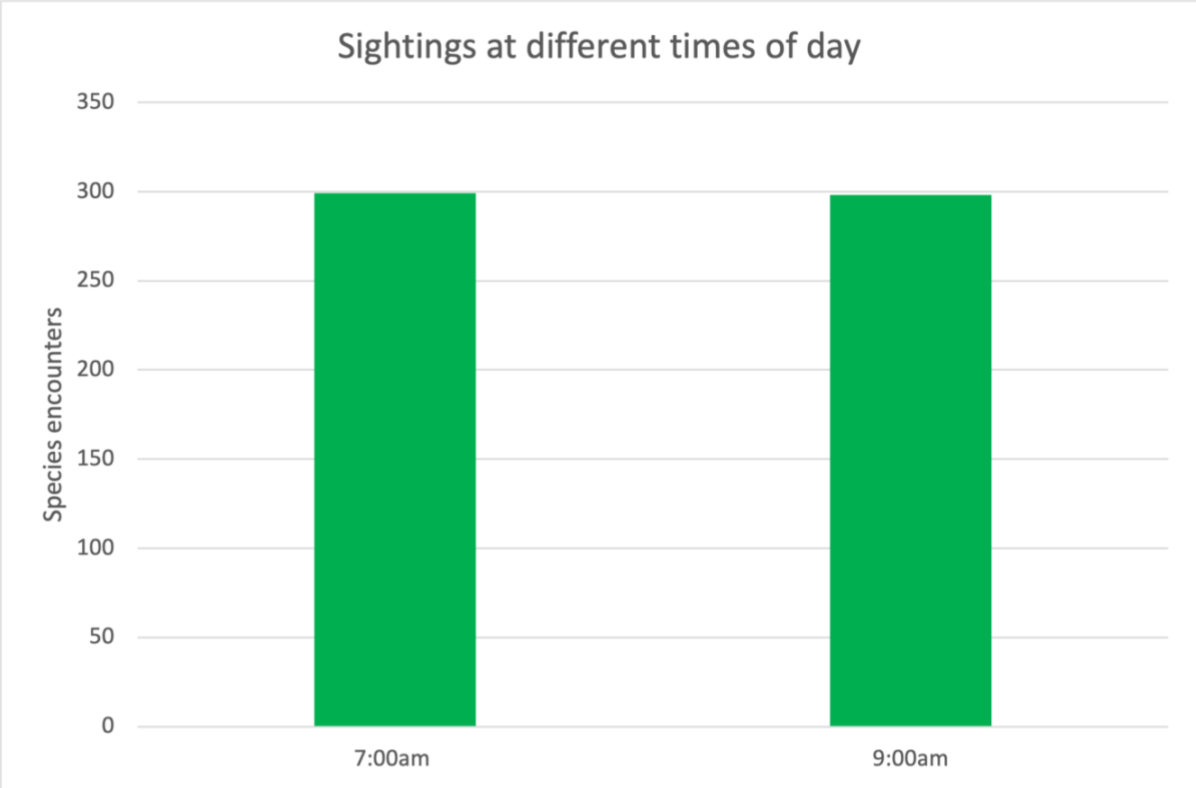

Figure 6: A graph showing the total species encounters for 7:00am and 9:00am. 7:00am value = 299 encounters, 9:00am value = 298 encounters.

Shapiro-Wilk test for normality generated a p = 0.165. This suggests deviation from normal data distribution (p>0.05).

A Wilcoxon signed rank test was undertaken. A p value of 0.816 means that there is no significant difference in hummingbird encounters between time of day. (See Appendix D, figure 25)

3.4 Hummingbird encounters per weather type

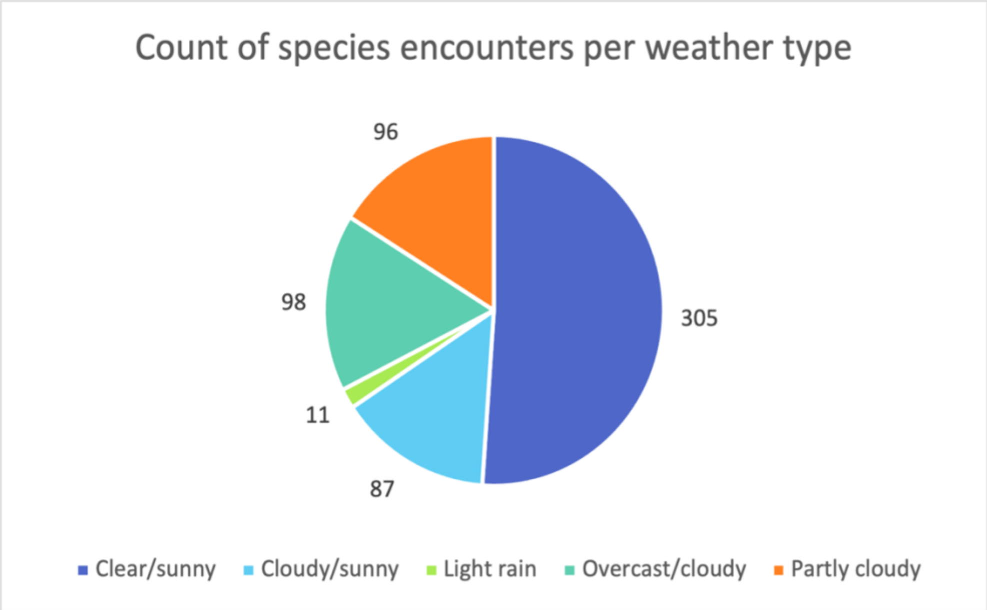

Figure 7: A pie chart to show the amount of hummingbird encounters per weather type.

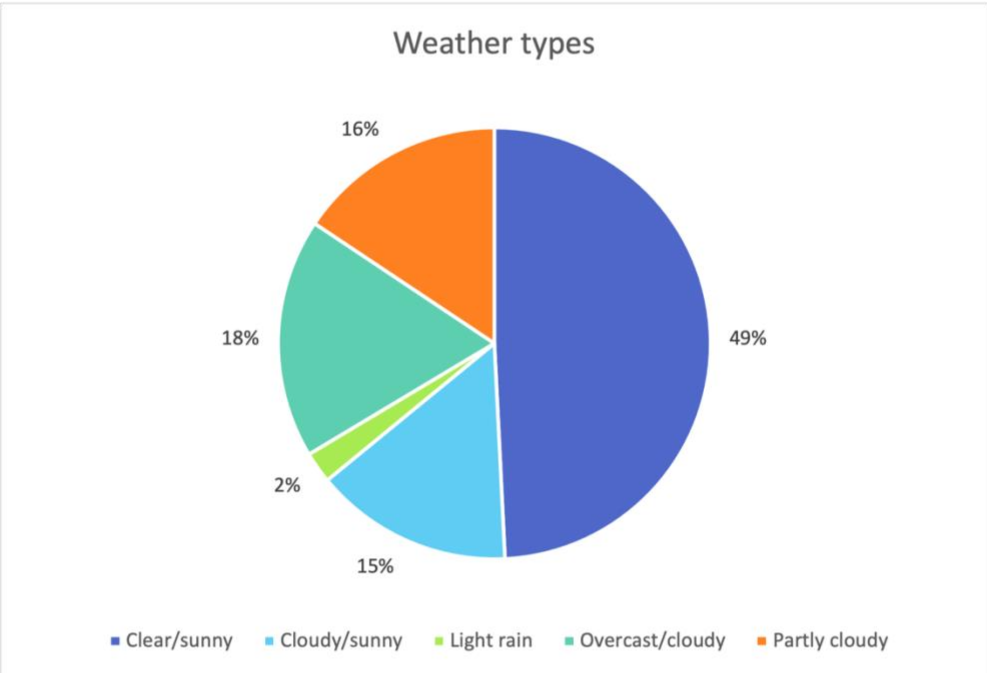

Figure 8: A pie chart to show the percentage of weather types encountered throughout the study period.

To investigate whether there was a significant relationship with weather type and hummingbird encounters, a Linear regression test was conducted. The resulting p value of 0.670 showed no significant relationship between hummingbird encounters and weather type. (See Appendix E, figure 26)

4. Discussion

The majority of feeding sites with high human disturbance were all within relatively close vicinity to buildings and manmade structures. These areas had sparse natural canopy cover, inducing a number of factors to affect hummingbird abundance and behaviour. The opposing effects of canopy cover were seen in natural feeding sites. Dense forest areas provide more cover for camouflage and instigate less natural competition through visual displays. Sexual competition through ornamentation will be more prominent in areas with sparse canopy cover and greater visibility. As a major factor influencing evolution through sexual selection, these areas would be preferable for both sexes, providing a greater prospect of reproduction (Falk et al., 2021).

Areas of non-native planted flowers were frequently larger than areas of naturally occurring native species due to increased access to sunlight. Jiménez et al., (2012) finds that there is a positive correlation between feeding patch size and hummingbird activity. Larger patches also induce more competition between individuals. This supports the results found in this study with sites of planted flowers playing host to significantly more observed hummingbird behaviours (as shown in figure 5).

The flashing of iridescent feathers is a common behaviour exhibited for courtship, warning, aggressive behaviours and territorial displays (Girlado et al., 2021). Areas with more light and exposed branches for perching and showing plumage will encourage more of the behaviour, like the human disturbed areas in this study at Cloudbridge. Maruyama et al. (2019) finds that hummingbirds are highly adaptable towards feeding in urban environments. This includes changing feeding sources to artificial feeders and adjusting territories to encompass alien (non-native) floral species. Urbanised areas have been shown to induce more generalised interactions between avian pollinators and nectar producing plants in comparison to natural undisturbed habitats (Maruyama et al., 2019). Hummingbirds are presumably more acclimatised to human presence in sites with regular human influence, therefore will show less fear when observers are present. In a study by Mendiola-Islas et al., (2023), the opposite was also observed, with species being less likely to remain in a natural un-disturbed feeding site or territory when influenced by human presence. This was clearly observed in this study, with hummingbirds being significantly more active in areas of human influence, despite the increases competition for resources and increased disruption from humans. These factors also induce natural competition which certain species e.g. *Lampornis castaneoventris* are drawn to. Sites of human influence also were recorded to accommodate a wider range of species than those seen in natural feeding sites.

However, there was no significant difference in hummingbird abundance with varying weather conditions (Fig 7,8). Behavioural intensity was also unaffected. Due to the high energy demands of their anatomy, hummingbirds have no choice but to be active and forage in all weather conditions. Lawrence and Hazlehurst (2023) find that hummingbirds will, when necessary, show behavioural techniques for thermoregulation, such as panting and wing spreading.

Barney (2019) outlines how the greatest indicator of hummingbird abundance on a local level is floral richness and diversity. Non-native plant species such as the Blue porterweed (*Stachytarpheta jamaicensis)* flower consistently throughout the year, making it a reliable and plentiful energy source at Cloudbridge. Many of the native species observed in the reserve flower yearly or bi-yearly (Berlin et al., 2000). *Moussonia deppeana,* a naturally occurring species in the Talamanca region, was in bloom for the first 6 weeks of the survey period, however the commencing rainy season caused withering until no flowers could be observed. Hummingbirds relying on this as a food source are subsequently forced to relocate, establishing new food sources and territories. Overall energy efficiency, a defining factor of hummingbird behaviour, favours the site in perpetual efflorescence (Pyke, 1978), like the planted flowers in the disturbed sites at Cloudbridge.

There was no significant variation in hummingbird sightings between different times of day (Fig 6). Reddish and Attenborough (2012) illustrated how high energy requirement means regular feeding is essential, and will therefore not vary throughout the diurnal cycle. Increases in temperature has been found to directly influence nectar production, therefore the superior impact of solar warmth in cleared areas will lead to a higher volume of readily available nutriment (Plos et al., 2023). For example, Nicolson et al. (2013) finds that honeybees will favour warmer, less viscous nectar when foraging, therefore it's possible this is also true for avian pollinators. Thus areas with higher levels of sunlight and reduced canopy cover will provide more accessible nectar sources will therefore see a higher rate of pollination events. This factor among many shows why hummingbirds favour areas with higher levels of human influence.

5. Limitations

As with the majority of studies, the design of the current study is subject to limitations. For example, the number of individuals is not accounted for in this study. With the frequency of activity and sightings of different species, no effective way of discerning individual birds was apparent. The length of time each behaviour was observed for was not taken into account due to the speed and frequency of which hummingbirds display behaviours, making time recording unachievable.

During the rainy season due to high levels of precipitation being experienced and making terrain slippery and dangerous, two survey dates were changed to accommodate. Hummingbirds, due to their high energy demands will remain active during periods of heavy rain, therefore this along with observational errors and lack of experience may have influenced final results of this study.

In following the definitions of expected behaviours, there were certain areas of overlap causing difficulty in distinguishing clear observations e.g. The behaviour of chasing and physically attacking insects with the intention of defending a nectar source and catching insects as a food source were often indistinct.

6. Conclusion

Hummingbirds, being such intensely active birds, flourish in environments that encourage competition over territory and food resources. Preference of large feeding sites with open areas is apparent in this study, which heavily favours sites with human disturbance and influence. Feeding sites, encompassing both floral availability and disturbance, also seem to be the most influential natural factor in hummingbird abundance and behaviours displayed.

In the future, however, this behaviour may have a greater impact on native plant communities. With the continuing expansion of human infrastructure, planting of non-native species, and the use of artificial feeders, many ornithophilous plants may be heavily affected. Maintaining healthy habitats for these vulnerable avian pollinators is of extreme importance, both for hummingbirds and native floral species in this region.

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8. Appendices

8.1 Appendix A – Flower index

Figure 9: Blue porterweed – *Stachytarpheta jamaicensis*

Figure 10: Giant lobster claw - *Heliconia wagneriana*

Figure 11 : Yellow Jabobinia - *Justicia aurea*

Figure 12 : Palicourea padifolia

Figure 13 : Costus wilsonii

Figure 14 : West Indian Lantana - *Lantana camara*

Figure 15: Confederate rose - *Hibiscus mutabilis*

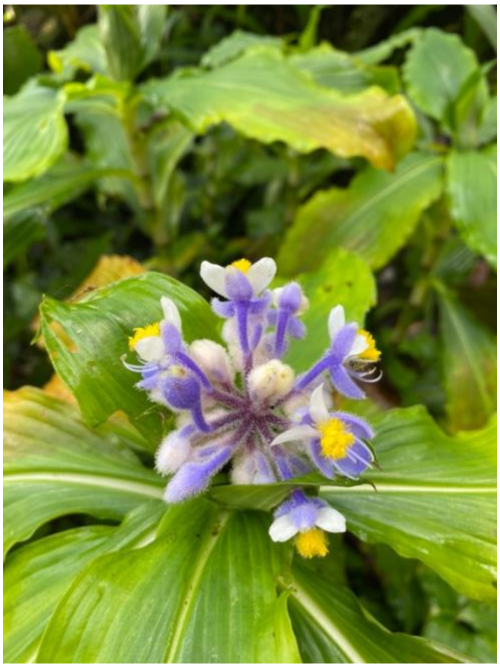

Figure 16: Viola Orchid – *Cochliostema odoratissimum*

Figure 17: Bolivian Fuchsia – *Fuchsia boliviana*

Figure 18: Brazilian red-cloaks – *Megaskepasma erythrochlamys*

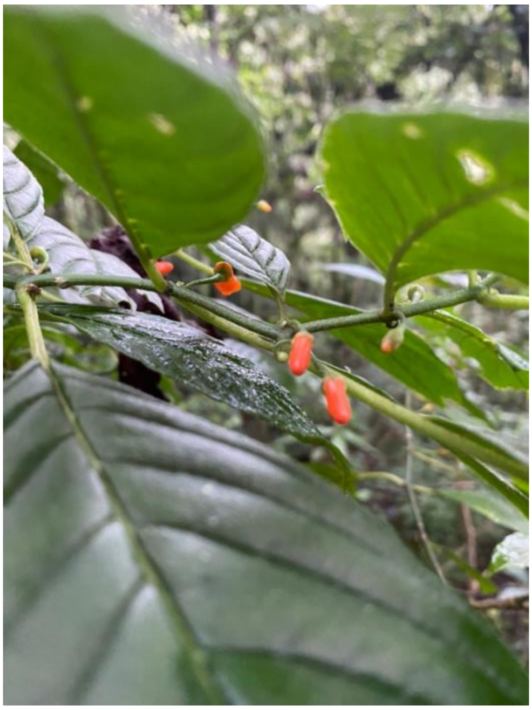

Figure 19: Besleria solanoides vulgaris

Figure 20: Phaseolus

Figure 21: Etlingera elatior

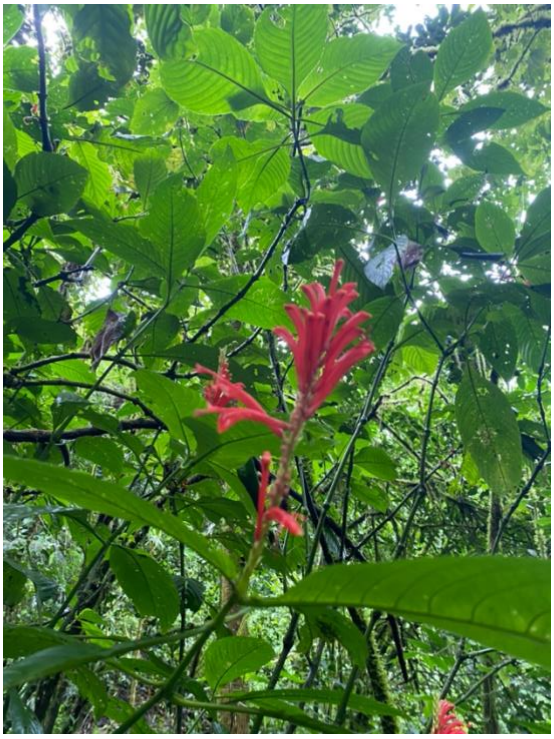

Figure 22: Rasizea spicata

Figure 23: Moussonia deppeana

8.2 Appendix B

Table 1: Species codes

BVE = Brown violetear *(Colibri delphinae)*
BVH = Blue-vented hummingbird (*Saucerottia hoffmanni)*
FTH = Fiery-throated hummingbird *(Panterpe insignis)*
GCB = Green crowned brilliant *(Heliodoxa jacula)*
GE = Garden emerald (*Chlorostilbon assimilis)*
GFL = Green-fronted lancebill *(Doryfera ludovicae)*
GH = Green hermit *(Phaethornis guy)*
LBST = Long-billed star-throat *(Heliomaster longirostris)*
LV = Lesser violetear (*Colibri cyanotus)*
MTW = Magenta-throated woodstar *(Calliphlox bryantae)*
PCF = Purple crowned fairy *(Heliothryx barroti)*
RT = Rufous-tailed hummingbird *(Amazilia tzacatl*)
SB = Snowy bellied hummingbird *(Amazilia edward*)
SC = Scintillant hummingbird (*Selasphorus scintilla)*
SCB = Scaly-breasted hummingbird *(Phaeochroa cuvierii*)
ST = Stripe tailed hummingbird (*Eupherusa eximia)*
STH = Stripe-throated hermit (*Phaethornis striigularis)*
TH = Talamanca hummingbird *(Eugenes spectabilis*)
U = Unidentified
VH = Violet headed hummingbird *(Klais guimeti)*
VO = Volcano hummingbird *(Selasphorus flammula)*
VS = Violet sabrewing *(Campylopterus hemileucurus)*
WCQ = White-crested coquette *(Lophornis adorabilis)*
WTE = White tailed emerald *(Elvira chionura)*
WTMG = White throated mountain gem *(Lampornis castaneoventris)*.

8.3 Appendix C

Paired Samples T-Test ▼

Paired Samples T-Test

Measure 1		Measure 2	W	z	df	p
Human influence	-	Non human influence	45.000	2.666		0.004

Note. Wilcoxon signed-rank test.

Assumption Checks ▼

Test of Normality (Shapiro-Wilk)

			W	p
Human influence	-	Non human influence	0.846	0.067

Note. Significant results suggest a deviation from normality.

Figure 24: Wilcoxon signed-rank test and Shapiro-Wilk test for narmality on total recorded behaviours recorded comparing field and urban sites

8.4 Appendix D

Paired Samples T-Test ▼

Paired Samples T-Test

Measure 1		Measure 2	W	z	df	p
7:00am	-	9:00am	63.000	−0.259		0.816

Note. Wilcoxon signed-rank test.

Assumption Checks ▼

Test of Normality (Shapiro-Wilk)

			W	p
7:00am	-	9:00am	0.919	0.165

Note. Significant results suggest a deviation from normality.

Figure 25: Wilcoxon signed-rank test and Shapiro-Wilk test for narmality on sightings at different times of day.

8.5 Appendix E

Linear Regression ▼

Model Summary - Column 4

Model	R	R^2	Adjusted R^2	RMSE
H_0	0.000	0.000	0.000	18.320
H_1	0.073	0.005	−0.003	18.347

ANOVA ▼

Model		Sum of Squares	df	Mean Square	F	p
H_1	Regression	1074.577	5	214.915	0.638	0.670
	Residual	198946.552	591	336.627		
	Total	200021.129	596			

Note. The intercept model is omitted, as no meaningful information can be shown.

Coefficients

Model		Unstandardized	Standard Error	Standardized[a]	t	p
H_0	(Intercept)	10.514	0.750		14.023	< .001
H_1	(Intercept)	2.000	18.347		0.109	0.913
	Weather (Clear/sunny)	8.102	18.378		0.441	0.659
	Weather (Cloudy/sunny)	11.632	18.453		0.630	0.529
	Weather (Light rain)	7.636	19.163		0.398	0.690
	Weather (Overcast/cloudy)	8.102	18.441		0.439	0.661
	Weather (Partly cloudy)	7.604	18.443		0.412	0.680

[a] Standardized coefficients can only be computed for continuous predictors.

Figure 26: Linear regression model between weather type and hummingbird encounters.