Bird Diversity at Cloudbridge:
A Preliminary Report

by Nathan Marcy
January 2007

Title
Bird Diversity and Community Composition in Different Habitats in a Costa Rican Cloud Forest

Summary
This study aims to identify the determinants of bird diversity at Cloudbridge. Preliminary results demonstrate that diversity is closely linked to habitat structure, which varies greatly as a result of the transitional nature of vegetation in parts of the Cloudbridge Reserve. Sites only 200 meters apart differ markedly in their bird communities, as do sites with subtle differences in vegetation.

Principal Investigator
Nathan Marcy
ngmarcy@cloudbridge.org

Objectives
This study is designed to document patterns of bird diversity and community composition among the various habitats at Cloudbridge. I have sought to discover which aspects of habitat structure are associated with high levels of diversity. I also want to understand how each of the various habitat types contributes to the overall diversity of birds at Cloudbridge, and how this diversity arises from the reserve's complex habitat mosaic.

Background
As primary forests have been depleted throughout the tropics, much attention has been paid to the resulting decline of species and ecosystem functions. Less well studied are the characteristics of the landscapes that have replaced them (Daily et al, 2001). Like Cloudbridge, these are often a mosaic of habitats that vary widely in vegetation structure and history of human influence. Studies of birds in these landscapes have found that a high proportion of native forest species often persist in secondary habitats. In fact, secondary growth can sometimes support greater bird species richness than primary forests in the same area (Blake and Loiselle, 2001). But all secondary habitats are not equal. Bird communities differ dramatically over short distances, and species richness tends to increases along a gradient of increasing habitat age (Petit et al, 1999). Also, the abundance of birds in some secondary habitats may depend on the proximity of primary forest. And the prevalence of edges in habitat mosaics makes such landscapes unsuitable for species that depend on large forest tracts (Martinez-Morales, 1995). Secondary habitats in the tropics hold great potential for the conservation of birds, but also present great challenges. More study is needed to understand how to implement conservation strategies for different – and sometimes conflicting – priorities.

The Cloudbridge Reserve is an excellent natural laboratory for this kind of study. Its combination of habitats make it a microcosm of much of the tropics. It also occupies a pivotal point on both land use and elevational gradients. Upstream along the Chirripó River, the successional habitats of the reserve blend into the primary forest of Chirripó National Park. Downstream they are replaced by increasingly cultivated landscapes. Within the reserve there is an area of transition where mid-elevation bird species give way to high-elevation specialists. The results of this study will suggest how the reserve can best be managed for the conservation of birds in the area, perhaps by maintaining diverse habitats to promote species richness, or by "softening" the edge of the national park to benefit vulnerable forest species.

Point Count Methods
This report describes the results of point counts conducted in February and August of 2006. Point counts were conducted using a fixed radius method. I recorded all birds seen or heard within 25

meters of the site location. I chose this small radius because of the likelihood that detection probabilities at greater distances would vary among different habitats (i.e. forested sites versus open sites). Each count lasted 10 minutes, which was divided into periods corresponding with the first 3 minutes, the next 2 minutes, and the final 5 minutes. Counts were conducted during the first three hours after sunrise. Each site was counted three times in both February and August.

Point Count Sites
I sought to establish as many sites as possible, in order to encompass the full range of habitats at Cloudbridge. To allow for safe and efficient access, all sites were located on existing trails. Following a protocol designed to ensure the statistical independence of point counts (Ralph et al, 1995), all sites were separated by at least 200 meters. Within these limitations I was able to establish a total of 26 sites.

1-4: Ridge Trail between gate and forest edge; open habitats.
5-8: Ridge Trail, between forest edge and Chirripó Trail; forested habitats.
9-11: Chiripo trail, between park entrance and Gavilán Trail; forested habitats.
12-13: Gavilán Trail, between Chirripó Trail and forest edge; forested habitats.
14-16: Gavilán Trail, between forest edge and main trail; mixed habitats.
17-20: River Trail; mixed habitats.
21-24: Victor's Falls Trail; forested and mixed habitats.
25-26: Cloudbridge North Trail, between Victor's Hut and property line; mixed habitats.

Vegetation Survey Methods
I took a series of measurements to quantify the vegetation at each point count site. I divided the area surrounding each site into four quarters. Within each quarter I measured the distance to the three nearest woody plants with a diameter of at least 1 cm, and measured or estimated their diameter and height. If none had a diameter of at least 10 cm, I repeated these measurements for the nearest tree that did. I also estimated the percent cover of several vegetation types within the 25 m radius point count area. The categories used were primary forest, old secondary forest, young secondary forest, woody shrubs, herbaceous thicket, grass, and other.

Data Analysis Methods
I combined the six point counts done at each site to create a list of all the species observed there. I also tallied the number of times each species was observed. From these lists I generated four statistics: total number of species, total number of individuals, average number of species per count, and maximum number of species per count.

I reduced the vegetation data to a similar set of statistics: average distance to the three nearest trees in each quarter, average distance to the nearest tree in each quarter at least 10 cm in diameter (with a value of 25 meters substituted when there was no such tree within the 25 meter point count radius), and the average diameter and height of the three nearest trees in each quarter. To compare relative tree size among sites, I multiplied the values for height and diameter (height in meters and diameter in centimeters).

To investigate the relationship between bird diversity and habitat structure, I produced a series of scatter graphs that pair the various point count and vegetation statistics of each site (e.g. average number of species per count versus average tree size). To illustrate trends in this data, and to estimate which variables are most strongly correlated, I plotted linear and polynomial trend lines on each graph.

I also grouped the point count sites into four strata based on vegetation data. From A to D, these strata span a gradient of habitats from least to most forested.

A: Sites 1, 2, 3, 4, 17, 18. Mostly open, with some scattered trees.
B: Sites 14, 15, 16, 20, 23, 24, 26. Mixed habitats, usually including a forest edge.
C: Sites 5, 6, 19, 21, 22, 25. Mostly forested, with some clearings and edges.
D: Sites 7, 8, 9, 10, 11, 12, 13. Entirely forested.

Figure 1 shows the relative vegetation characteristics of these strata.

As another means of comparing bird diversity among different habitats, I generated statistics that combine the point count data of all sites within each of the strata. Because the strata contain unequal numbers of sites, I decided that the average total number of species per site was the most useful statistic.

Results

Table 1 displays a list of all species observed during point counts, ranked according to their frequency of observation, as well as separate lists for February and August. In 26 hours of point count time I have recorded a total of 87 species. This represents 61 percent of the 143 species on the official Cloudbridge bird list. In February, 74 species were observed, of which 7 were migrants that breed in North America. In August, 67 species were recorded, none of which were migrants.

Table 2 (not included here, available from author) shows the point count data and point count statistics for each site. The sites varied widely in their diversity of birds. The lowest species total (7) came from Site 3, in a treeless part of the Ridge Trail. The highest total (31) was recorded at Site 16, in a mixed/forest edge habitat just below the shelter on the Gavilán Trail. The average total of all the sites was 19.

Table 3 (not included here, available from author) shows the vegetation data and vegetation statistics for each site.

Figure 2 graphs the average number of species per point count as a function of tree density at each site. **Figure 3** plots the average number of species per count versus tree size. **Figure 4** does the same for percent cover of forest. All three graphs show a positive linear trend. Bird species diversity increases along a habitat gradient from less to more forested. Among the three relationships, tree density is most strongly correlated with bird diversity ($R^2 = 0.287$). However, the graphs also suggest that the correlation is not strictly linear. Polynomial trend lines plotted on each graph show diversity peaking roughly in the middle of the habitat gradient, not at its most forested end. The polynomial curve deviates most sharply from the linear regression in the graph of species versus tree size. It shows the strongest correlation in the graph of species versus tree density.

Figure 5 compares diversity among the four point count strata. The least-forested stratum A had by far the lowest diversity of birds, an average of 11 species per site. stratum B, with vegetation most statistically similar to that of A, had the highest diversity (22.6 species per site). stratum D, composed of entirely forested sites, was nearly as diverse (21.6 species per site). stratum C had an average of 18.3 species.

Figure 6 shows the extent to which the bird communities of the four strata have species in common. Not surprisingly, strata A and D were the most dissimilar. Among all the species observed in these strata combined, only 21 percent were recorded in both. The two most forested strata, C and D, shared the most species (35 percent).

Figure 7 compares how forested and open/mixed habitats contribute to the overall diversity of birds at Cloudbridge. For this comparison I combined strata A and B and strata C and D, thereby dividing the point count sites into two equal halves (with 13 sites in each). The two halves had nearly identical species totals: 63 in the mostly unforested half (A+B), and 65 in the mostly forested half (C+D). These numbers represent 72 and 75 percent of the species total for all sites. The numbers of species unique to each half were also very similar: 21 in A+B, versus 23 in C+D.

Discussion

It is evident that bird diversity at Cloudbridge is closely linked to habitat structure. Point count sites only 200 meters apart vary markedly in their bird communities, as do sites with subtle differences in

vegetation. Because Cloudbridge is a complex patchwork of habitat types, its overall diversity of birds will be determined by the relative areas and spatial arrangement of these patches.

The point counts confirm the presumption that intact forest supports a far greater diversity of birds than does cleared land. However, the results suggest that primary forest is not the most species rich habitat at Cloudbridge. Diversity appears to reach its maximum in young habitats that combine trees and large open spaces. Bird communities in these areas include both open habitat specialists and many species commonly observed in the forest. This is illustrated by the fact that the most forested stratum (D) and most open stratum (A) shared only 26.6 percent of their species, while stratum D had 42.2 percent in common with stratum B (composed of mixed habitats).

It is important to note that the presence of many forest species in mixed habitats likely depends on the proximity of a forest edge. The high diversity of mixed habitats may therefore be misleading. Although they are frequently visited by forest species, they may not be able to support them on their own. The forest interior, on the other hand, supports a level of diversity nearly as high without the benefit of species "crossing over" from other habitats. In fact, the diversity of forested habitats is probably limited by the proximity of open areas, as some forest species are intolerant of edges.

It is likely that the average bird diversity (and perhaps overall bird diversity) of Cloudbridge will increase over time. Through tree plantings and natural succession, the least diverse open habitats will be replaced by the most diverse mixed habitats. These habitats will also be brought into more continuous connection with the forest edges, further increasing their diversity. Succession should "soften" the forest edges, to the benefit of bird communities of the forest interior. A point will be reached, however, after which diversity will decline. As seen in Figure 7, the two most forested strata (C and D) account for only 75 percent of the overall species total. The remaining species were recorded only in open and mixed habitats. When Cloudbridge returns to a forested state, many of these species will likely be displaced. The loss may be offset by the addition of forest species not currently present at Cloudbridge, but there are probably not enough such species indigenous to the area to make up the difference.

Plans for Further Study

This is an ongoing project, with evolving methods and objectives. In February 2007 I will begin its next phase, a mist netting and banding effort. This will complement the point count data, leading to a clearer picture of bird distribution. The banding and recapture of birds may provide evidence of their movement between habitats. Data collected from birds in hand will also allow a comparison of the physical fitness of birds captured in different habitats. Another avenue of study will be permitted by newly acquired aerial photographs of Cloudbridge and surrounding areas. These will make it possible to measure the size and shape of habitat patches, and to measure the distance of each point count site to features such as forest edges. These variables likely play a large role in determining bird diversity, but have not yet been considered in this study.

Literature Cited

Blake, J.G. and Loiselle, B.A. 2001. Bird assemblages in second-growth and old-growth Forests, Costa Rica: Perspectives from mist nets and point counts. The Auk 118(2): 304-326.

Daily, G.C., Ehrlich P.R., and Sanchez-Azofeifa, G.A. 2001. Countryside biogeography: use of human-dominated habitats by the avifauna of southern Costa Rica. Ecological Applications 11(1): 1-13.

Martinez-Morales, M.A. 2005. Landscape patterns influencing bird assemblages in a fragmented neotropical cloud forest. Biological Conservation 121: 117-126.

Petit, L.J., Petit, D.R., Christian, D.G., and Powell, H.D.W. 1999. Bird communities of Natural and modified habitats in Panama. Ecography 22: 292-304.

Ralph, C.J., Sauer, J.R., Droege, S., technical editors. 1995. Monitoring bird populations by point counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, US Department of Agriculture.

Table 1. Species list and count of birds at Cloudbridge

English	Spanish	Scientific	Code	TOTAL	FEB 2006	AUG 2006
Common Bush-tanager	Tangara de Monte Ojeruda	*Chlorospingus opthalmicus*	COBT	260	108	152
Sulfur-winged Parakeet	Perico Aliazufrado	*Pyrrhura hoffmanni*	SWPA	76	31	45
Yellow-thighed Finch	Saltón de Muslos Amarillos	*Pselliophorus tibialis*	YTFI	68	32	36
Silver-throated Tanager	Tangara Dorada	*Tangara icterocephala*	STTA	67	27	40
Slate-throated Redstart	Candelita Pechinegra	*Myioborus miniatus*	STRE	59	33	26
Gray-breasted Wood-Wren	Soterrey de Selva Pechigrís	*Henicorhina leucophrys*	GBWW	52	21	31
Yellow-faced Grassquit	Semillerito Cariamarillo	*Tiaris olivacea*	YFGR	44	30	14
Black-cheeked Warbler	Reinita Carinegra	*Basileuterus melanogenys*	BCWA	43	26	17
Brown-capped Vireo	Vireo Montañero	*Vireo leucophrys*	BCVI	37	12	25
Spotted-crowned Woodcreeper	Trepador Cabecipunteado	*Lepidocolaptes affinis*	SCWO	34	19	15
Rufus-collared Sparrow	Chingolo	*Zonotrichia capensis*	RCSP	33	19	14
Three-striped Warbler	Reinita Cabecilistada	*Basileuterus tristriatus*	TSWA	33	20	13
Spangled-cheeked Tanager	Tangara Vientricastaña	*Tangara dowii*	SCTA	30	16	14
Yellowish Flycatcher	Mosquerito Amarillento	*Empidonax flavescens*	YEFL	29	5	24
Chestnut-capped Brush-Finch	Saltón Cabecicastaño	*Atlapetes brunneinucha*	CCBF	24	10	14
Scintillant Hummingbird	Chispita Gorginaranja	*Selasphorus scintilla*	SCHU	24	13	11
Wilson's Warbler	Reinita Gorrinegra	*Wilsonia pusilla*	WIWA	21	21	0
Collared Redstart	Candelita Collareja	*Myioborus torquatus*	CORE	20	11	9
Gray-tailed Mountain-gem	Colibrí Montañes Coligrís	*Lampornis cinereicauda*	GTMG	19	1	18
House Wren	Soterrey Cucarachero	*Troglodytes aedon*	HOWR	19	8	11
Golden-bellied Flycatcher	Mosquero Vientridorado	*Myiodynastes hemichrysus*	GBFL	18	10	8
Mistletoe Tyrannulet	Mosquerito Cejigrís	*Zimmerius vilissimus*	MITY	17	5	12
Yellow-winged Vireo	Vireo Aliamarillo	*Vireo carmioli*	YWVI	17	9	8
Flame-throated Warbler	Garganta de Fuego	*Parula gutturalis*	FTWA	16	1	15
Ruddy-capped Nightingale-Thrush	Zorzal Gorrirojizo	*Catharus frantzii*	RCNT	16	7	9
Black-faced Solitaire	Solitario Carinegro	*Myadestes melanops*	BFSO	16	9	7
Ochraceous Wren	Soterrey Ocroso	*Troglodytes ochraceus*	OCWR	15	1	14
Green Hermit	Ermitaño Verde	*Phaethornis guy*	GRHE	14	10	4
Emerald Toucanet	Tucancillo Verde	*Aulacorhynchus prasinus*	EMTO	14	12	2
Striped-tailed Hummingbird	Colibrí Colirrayado	*Eupherusa eximia*	STHU	12	7	5
Silver-throated Jay	Urraca Gorgiplateada	*Cyanolyca argentigula*	STJA	10	0	10
Red-headed Barbet	Barbudo Cabecirrojo	*Eubucco bourcierri*	RHBA	10	4	6
Blue-hooded Euphonia	Eufonia Capuchiceleste	*Euphonia elegantissima*	BHEU	10	5	5
Rufus-browed Peppershrike	Vireon Cejirrufo	*Cyclarhis gujanensis*	RBPE	10	5	5
Spotted Wood-Quail	Codorniz Moteada	*Odontophorus guttatus*	SPWQ	10	6	4
Flame-colored Tanager	Tangara Dorsirrayada	*Piranga bidentata*	FCTA	10	7	3
Black-throated Green Warbler	Reinita Cariamarilla	*Dendroica virens*	BTGW	10	10	0
Slaty Flowerpiercer	Pinchaflor Plomizo	*Diglossa plumbea*	SLFL	9	3	6
Red-faced Spinetail	Colaespina Carirroja	*Cranioleuca erythrops*	RFSP	7	3	4
Band-tailed Pigeon	Paloma Collareja	*Columba fasciata*	BTPI	7	7	0
Golden-browed Chlorophonia	Clorofonia Cejidorada	*Chlorophonia callophrys*	GBCH	6	0	6
White-tailed Emerald	Esmeralda Coliblanca	*Elvira chionura*	WTEM	6	0	6
Lineated Foliage-gleaner	Trepamusgo Lineado	*Syndactyla subalaris*	LIFG	6	3	3
Spotted Barbtail	Subepalo Moteado	*Premnoplex brunnescens*	SPBA	6	3	3
Barred Becard	Cabezón Ondeado	*Pachyramphus versicolor*	BABE	6	3	3
Green Violet-ear	Colibrí Orejivioláceo Verde	*Colibri thalassinus*	GRVE	6	3	3
Lesser Goldfinch	Jilguero Minor	*Carduelis psaltria*	LEGO	6	3	3
Snowy-bellied Hummingbird	Amazilia Vientriblanca	*Amazilia edward*	SBHU	6	5	1
Mountain Robin	Mirlo Montañero	*Turdus plebejus*	MORO	6	6	0
Yellow-throated Brush-Finch	Saltón Gargantiamarilla	*Atlapetes gutturalis*	YTBF	6	2	4
Ruddy Pigeon	Paloma Rojiza	*Columba subvinacea*	RUPI	5	0	5
White-winged Tanager	Tangara Aliblanca	*Piranga leucoptera*	WWTA	5	0	5
Tufted Flycatcher	Mosquerito Moñudo	*Mitrephanes phaeocercus*	TUFL	5	1	4
Hairy Woodpecker	Carpintero Serranero	*Picoides villosus*	HAWO	5	2	3
Buff-throated Saltator	Saltator Gorgianteado	*Saltator maximus*	BTSA	5	2	3
Tropical Parula	Parula Tropical	*Parula pitiayumi*	TRPA	5	2	3
Collared Trogon	Trogón Collarejo	*Trogon collaris*	COTR	5	4	1
Slaty Antwren	Hormiguerito Pizarroso	*Myrmotherula schisticolor*	SLAN	4	1	3
Speckled Tanager	Tangara Moteada	*Tangara guttata*	SPTA	4	2	2
Yellow-bellied Siskin	Jilguero Vientriamarillo	*Carduelis xanthogastra*	YBSI	4	4	0
Tennessee Warbler	Reinita Verdilla	*Dendroica peregrina*	TEWA	4	4	0

Figure 1 Relative vegetation characteristics

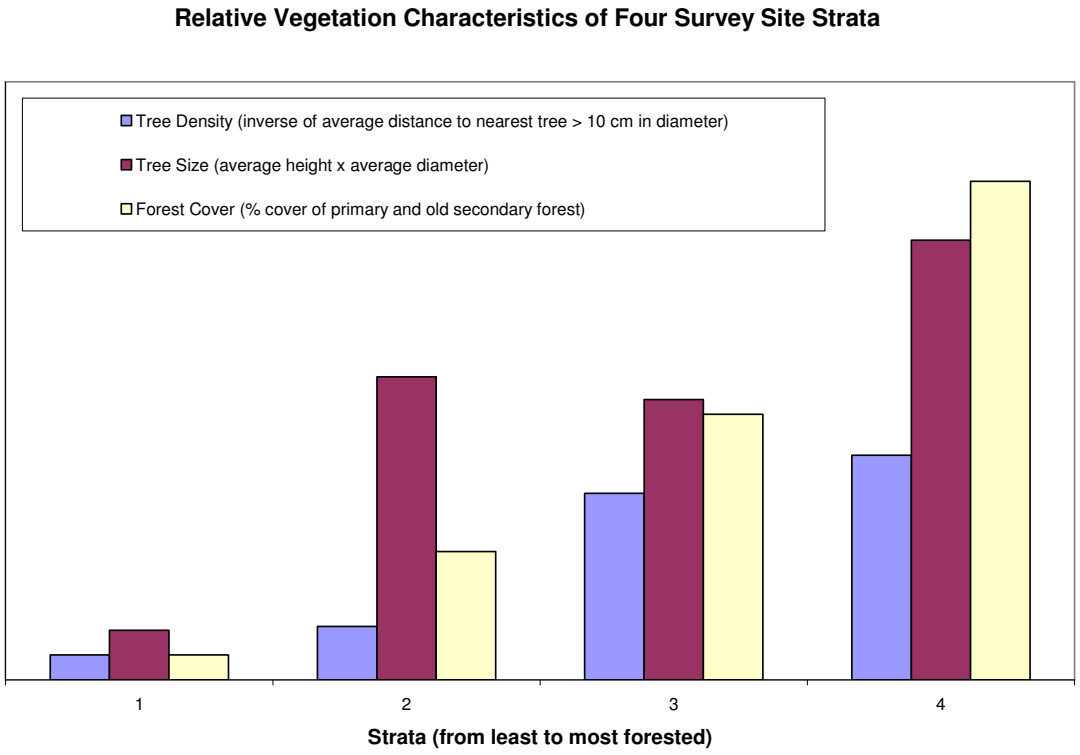

Figure 2 Average number of species as a function of tree density

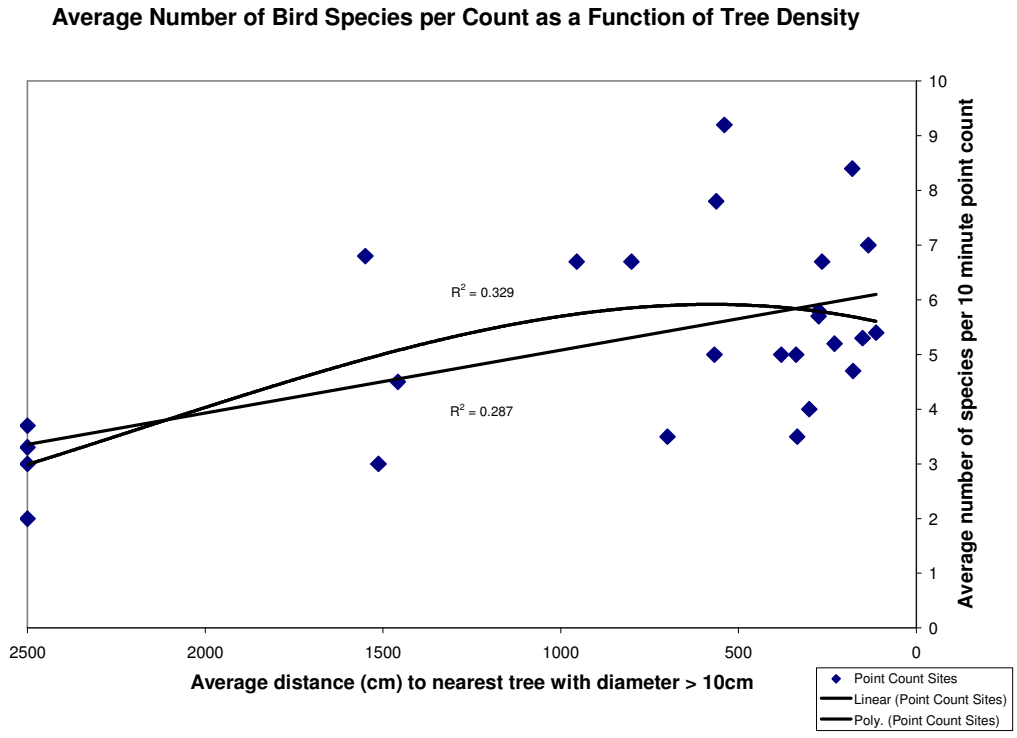

Figure 3 Average number of species versus tree size

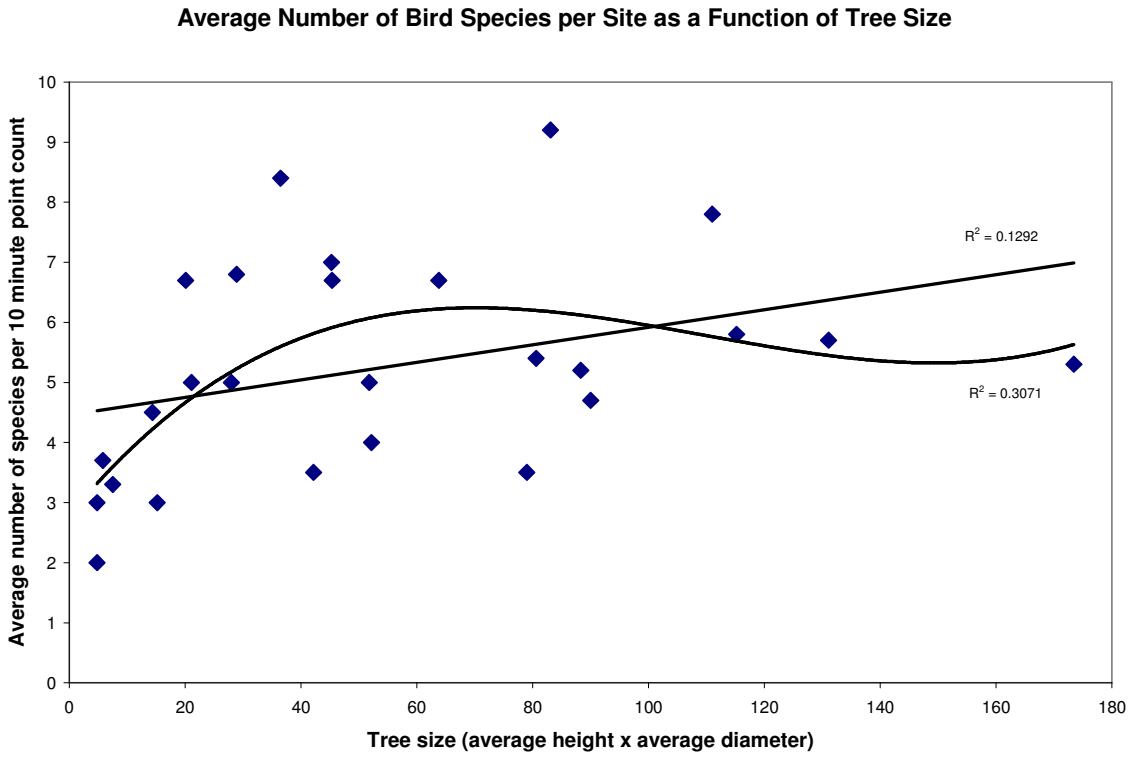

Figure 4 Average number of species versus percent cover of forest

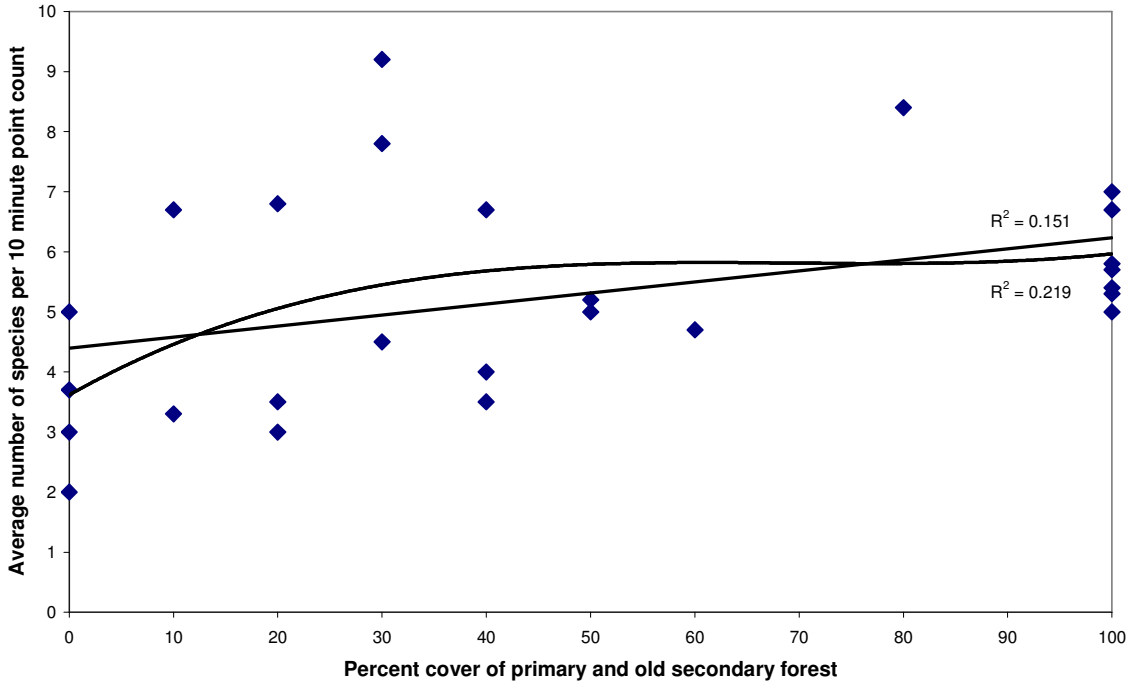

Figure 5 Diversity among the four strata

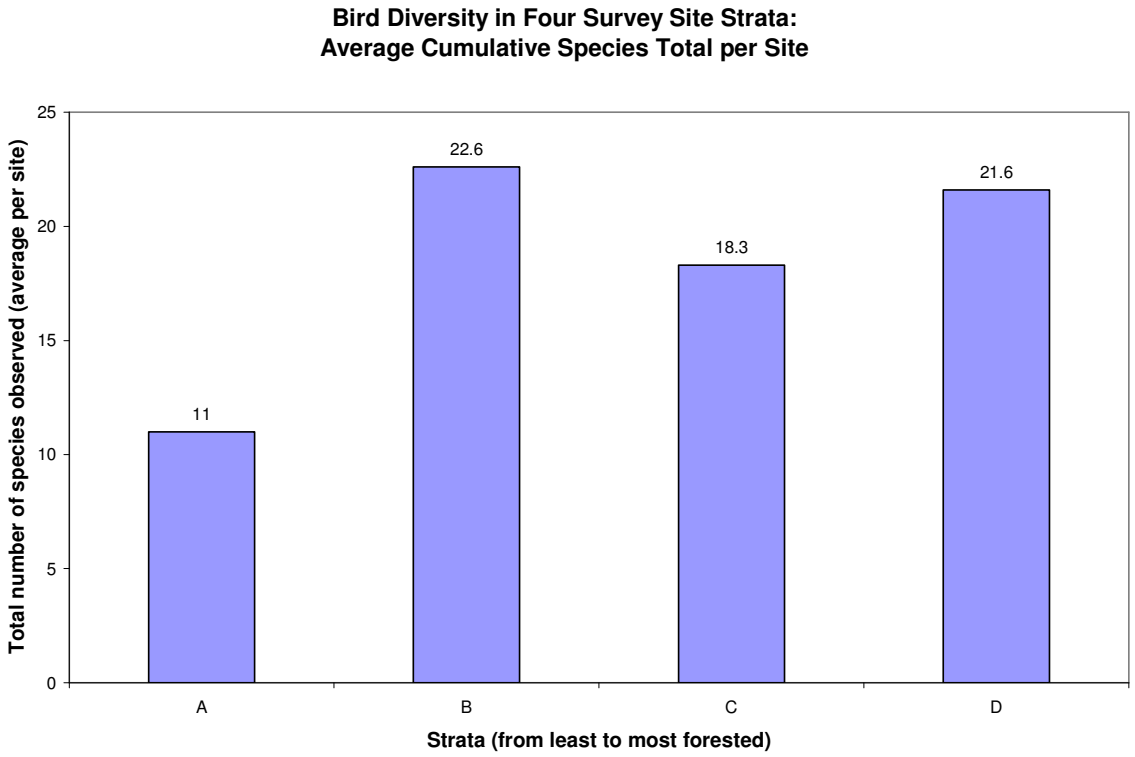

Figure 6 Extent to which the bird communities of the four strata have species in common

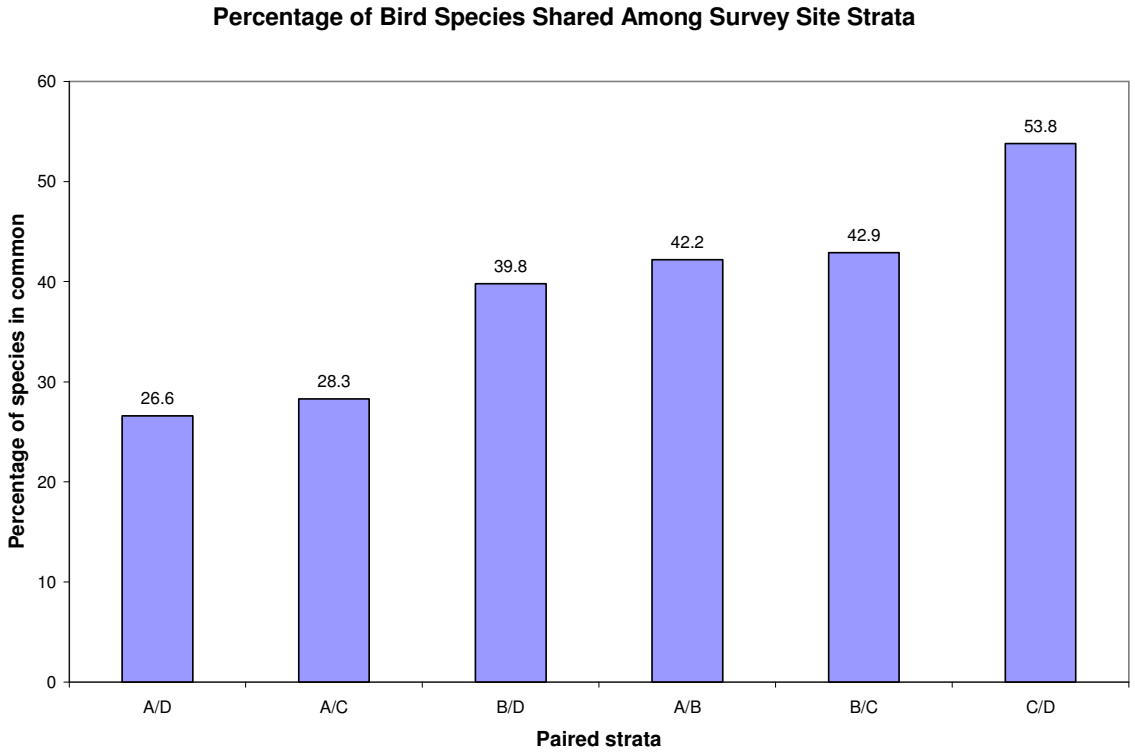

Figure 7 How forested and open/mixed habitats contribute to the overall diversity of birds at Cloudbridge