# A Reassessment of Avian Assemblages Along the Lakes Corridor in the Atherton Tablelands, North Queensland

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## ABSTRACT

Forest fragmentation is the process by which large areas of continuous forest are replaced by foreign ecosystems that restrict native growth to isolated patches. Biota remaining within these fragmented environments often suffer consequences that stem from reduced forest area. Wildlife corridors—linear patches of habitat that connect remnant fragments—have frequently been proposed to alleviate fragmentation effects by facilitating biotic movement between forest patches. Initiated in 1998, the Lakes Corridor on the Atherton Tablelands in North Queensland, Australia, connects the two formerly isolated sections of Crater Lakes National Park with the goal of promoting wildlife dispersal between them. This study monitored avian assemblages along the corridor to determine its success in providing the habitat necessary for rainforest species utilization. Bird communities were monitored in remnant, regrowth, and planted sites using point counts. Compared with baseline trends, corridor use has consistently increased within bird communities analyzed according to vagility, mobility, and foraging guilds. The greater abundance of sensitive and robust species demonstrates that after ten years of succession the corridor has begun to provide habitats for a variety of rainforest birds and suggests that the Lakes Corridor may help alleviate the effects of isolated fragments in this tropical rainforest system.

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## Acknowledgements

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# 1. INTRODUCTION

## 1.1 Fragmentation

Forest fragmentation is the process by which large areas of continuous forest are replaced by new ecosystems that restrict native growth to isolated patches (Murcia, 1995). Biota remaining within these fragmented environments often suffer consequences that stem from reduced forest area. In particular, organisms living at or near ecosystem boundaries (edges) find themselves exposed to altered environments to which they may not be evolutionarily adapted. Such abiotic effects are especially pronounced in areas of human-created fragmentation where structurally simple environments characterized by low biomass surround forest remnants and create a gradient of differential microclimates that penetrate into the forest edge (Murcia, 1995). The depth of edge-related microclimatic disturbance varies dramatically, and distances have been recorded up to 100 m in tropical forests (Laurance *et al.*, 1997). Microclimatic edge effects vary with matrix use and may be based solely on environmental characteristics such as light availability, soil moisture, humidity, and temperature. In addition, they may also include chemical compounds that have been introduced into the system via fertilizer or pesticide applications. The severity of edge effects may decrease over time if vegetation is allowed to develop in area surrounding a forest fragment (Turton & Freiburger, 1997).

Changing abiotic conditions may influence wildlife directly and indirectly. Fluctuations in solar radiation, temperature, and moisture can alter important biological processes such as photosynthesis, vegetation growth, decomposition, and nutrient cycling (Turton & Freiburger, 1997) that may transform species composition by varying the distribution and abundance of particular organisms. Within the animal community, censuses have shown trends of increased beetle and ant density near forest edges and that the species richness and composition of these populations differs from those found in continuous forest interiors (Didham, 1997). By altering species composition, differential microclimates may also instigate trophic cascades that reshape the dynamics of interspecific biological interactions (Murcia, 1995).

Even without edge effects, fragmentation has several consequences for wildlife on a community-wide level. As reviewed by Turner (2006), populations of certain species can be lost from an area if individuals are not in the vicinity at the time of isolation, and the absence of large or keystone species can destabilize the entire fragment by disrupting important ecological processes such as predation and seed dispersal. Alternatively, large-bodied species may become extirpated if fragments are smaller than their required home ranges, and their disappearances felt across all of the lower trophic levels. Even if a population remains, decreased immigration and emigration rates result in an eventual inbreeding depression that reduces the vigor of the entire population. Genetic effects may be reinforced by skewed sex ratios or age distributions that result from the community's composition when fragmentation occurred. Finally, small, isolated populations are more likely to suffer drastic losses from stochastic events (e.g. cyclones, bushfires, floods, and diseases) than are larger populations housed in continuous habitats.

**1.2 Proposed solution: corridors**

Wildlife corridors have frequently been proposed as a way to alleviate fragmentation effects by facilitating biotic movement between forest fragments (Lamb *et al.*, 1997). Corridors are linear habitat pathways that connect remnant fragments and primarily benefit species that are unable or unwilling to cross open habitats (Lindenmayer & Franklin, 2002). Successful designs promote general biotic movement while sustaining breeding animal populations and enabling the dispersal of their offspring through the corridor (Lindenmayer & Franklin, 2002). They may rescue metapopulations from inbreeding depressions and/or local extinctions by introducing immigrants that diversify the gene pool (Lamb *et al.*, 1997).

Corridors may furthermore help maintain the composition of plant species, support resident populations of many organisms, and encompass diverse habitat types that provide for specialist species (Lindenmayer & Franklin, 2002). Finally, corridors that shade creeks, streams, and rivers may also improve water quality by filtering sediments, limiting run-off, and reducing erosion (Lamb *et al.*, 1997).

However, Lindenmayer and Franklin caution that wildlife corridors are not right for all conservation strategies (2002). They generally fail to promote plant dispersal (Simberloff, 1993), may be avoided by or useless to target species with random dispersal patterns (Lindenmayer & Franklin, 2002), and do not primarily address edge effects. Indeed, even when successfully implemented, corridors do not come without costs. In addition to facilitating species movement, corridors may also promote the spread of harmful phenomena such as wildfires, introduced predators, and diseases (Simberloff & Cox, 1987). Similarly, weedy and opportunistic species may use corridors to invade previously isolated fragments and compete with native biota for resources. Finally, in some cases, corridors may actually bring their users into danger by increasing their exposure to humans, domestic animals, and predators (Soulé & Simberloff, 1986). Long-term monitoring is therefore necessary to uncover the specific interactions with local wildlife that contribute to the successes or failures of wildlife corridors and provide the knowledge required to implement effective conservation policies in fragmented ecosystems.

**1.3 Corridors in the Atherton Tablelands**

Situated in northeastern Queensland and listed as part of the Wet Tropics World Heritage Area, Australia's Atherton Tablelands host some of the world's most renowned rainforests. In the early 1900s, the northeastern section of the Tablelands contained a large, continuous rainforest that was selectively cleared to meet the growing demands for farming and grazing (Laurance, 1997). Two corridor projects have been undertaken within the past

15 years to link the two primary rainforest remnants with continuous forest. Donaghy's Corridor was initiated in 1995 and runs along Toohey's Creek, connecting the Lake Barrine section of Crater Lakes National Park to Gadgarra State Forest (>50,000 ha), while the Lakes Corridor was planted three years later and connects the Lake Eacham section of Crater Lakes National Park with the Lake Barrine section. Although baseline studies have been completed on both corridors (L. Quackenbush, unpubl.; E. Austin, unpubl.), only Donaghy's corridor has since been intensively monitored (Jansen, 2005).

In a study showing promising signs of corridor effectiveness, Jansen (2005) monitored avifaunal communities throughout newly planted plots linking remnant forest patches to mature and regrowth rainforest along Toohey's Creek. Over three years of succession, the abundance of primarily-rainforest species increased in the plantings but not in the corridor gaps, indicating that the new growth trees were responsible for avian dispersal.

**1.4 Project's importance**

Now, ten years after its establishment, the Lakes Corridor needs monitoring to assess its effectiveness in facilitating avifaunal movement between the Lake Eacham and Lake Barrine fragments of Crater Lakes National Park. In particular, three of the species surveyed by E. Austin (unpubl.) have been suggested as indicator species to monitor its success. The Australian Fernwren, which was absent from all corridor sites at the time of baseline assessment, requires a sizeable area of rainforest, perhaps to accommodate its seasonal movements. The Yellow-throated Scrubwren, which was never observed along the corridor, may have similar landscape requirements (E. Austin, unpubl.). The arrival of either of these species into the corridor will therefore indicate the corridor's ability to provide adequate connectivity between the two National Park forest fragments. Finally, evidence exists that the number of groups of Chowchillas living in the Crater Lakes National Park is limited (A. Neuman, unpubl.). Individuals are poor fliers, and as a result relatively non-mobile. As with the Australian Fernwren and Yellow-throated Scrubwren, an increase in the abundance of this species will indicate that the Lakes Corridor has facilitated the movement of sensitive avifauna.

**1.5 General aims**

The goal of this study was therefore to reassess avian assemblages along the Lakes Corridor after ten years of succession. Specifically, this study aimed to (1) investigate species richness and diversity within the corridor, (2) analyze habitat usage according to community composition, and (3) compare current trends with baseline findings. Together, these objectives will allow evaluation of the corridor's success in promoting avian dispersal between the Lake Eacham and Lake Barrine sections of Crater Lakes National Park.

**1.6 Hypothesis**

The frequencies with which species and guilds of differing sensitivities to forest fragmentation are present in the Lakes Corridor should provide an index of its effectiveness in facilitating avian dispersal between the Lake Eacham and Lake Barrine remnants. Specifically, if the corridor is providing adequate cover, habitat, and resources for sensitive rainforest species, these individuals should increase in abundance along the corridor path. If, however, the plantings are still too young to fulfill these requirements, there should be a continuation of the usage patterns recorded when the corridor was established, with sensitive species restricted to the most complex sites and resilient species exploring less developed areas of the corridor.

## 2. METHODOLOGY

### 2.1 The Atherton Tablelands

This study was located on the Atherton Tablelands, which ranges between 600 and 900 m in elevation, receives an average rainfall of 1,438 mm, and has a mean annual temperature of 20°C (Laurance, 1997; Warburton, 1997). These environmental conditions facilitate the growth of complex mesophyll and simple notophyll vine forests on the mosaic of nutrient-rich basaltic and nutrient-poor metamorphic soils, respectively (Laurance, 1997). Much of the original complex forest has been cleared to take advantage of the fertile soil (Lamb *et al.*, 1997); other areas have been logged for red "cedar" (*Toona australis*) (Laurance, 1997).

### 2.2 The Lakes Corridor

The Lakes Corridor (17° 16' S, 145° 38' E) provides a forested pathway reconnecting the Lake Eacham section (~500 ha) of Crater Lakes National Park to the Lake Barrine section (~500 ha) in the north (Figure 1). Beginning in 1998, 14,000 seedlings were planted according to the framework method (Lamb *et al.*, 1997), which uses species that attract seed-dispersing fauna to help accelerate rainforest colonization through seed rain deposition. The 1.5 km corridor has a minimum width of 25 m and winds through a mixture of vegetation types that include remnant, regrowth, and planted plots in different stages of development.

### 2.3 Study sites

The distribution of bird species was assessed at seven sites along the corridor path (Figure 2). Site 1 is located in the 10,100 $m^2$ remnant forest that is separated from the Lake Eacham section of Crater Lakes National Park by Gadgarra Road. The canopy reaches approximately 25 m and is composed of mixed rainforest species typical of complex mesophyll vine forests (Type 1B). Fishtail Lawyer Vines (*Calamus spp*.) and rainforest seedlings dominate the understory, although grassy patches have developed in tree gaps created by Cyclone Larry in 2006.

Sites 2 and 3 are located northwest of the remnant plot and are bordered by three-year-old plantings to the east.  Site 2 is a 1,600 $m^2$ plot of mixed rainforest species that has been well-maintained since its planting in 1992.  Dense canopy cover approximately 20 m in height has eliminated many of the weeds that were prevalent in 1998 (E. Austin, unpubl.); today grass cover is less than 5%, tobacco growth is limited to the western border, and native regeneration has taken over the understory.  Dominant species include *Acacia cincinnata*, Atherton Oak (*Athertonia diversifolia*), Candlenut (*Aleurites moluccanan*), Silver Quandong (*Elaeocarpus grandis*), and Queensland Maple (*Flindersia brayleyana*).  Planted in 1998, Site 3 has been less well maintained.  Although the canopy height reaches 20 m, survivorship is patchy, and despite the presence of large Sarsparilla (*Alphitonia petrei*) and White Cedar trees (*Melia azedarach*), the broken canopy has enabled grasses to take over approximately 70% of the understory.

Continuing north, sites 4 and 5 extend into a 12,940 $m^2$ gully of 30-50 year *Acacia cincinnata* regrowth.  Grasses and weeds are rare, and native flora, including Brown Bolly Gum (*Litsea leefeana*), Grey Bollywood (*Neolitsea dealbata*), Milkwood (*Alstonia muelleriana*), Millaa Millaa Vines (*Eleagnus triflora*), Sarsparilla, and Wait-a-whiles (*Calamus spp.*), are regenerating at both sites.

To the northwest, Site 6 slopes down past a cluster of tree ferns (*Cyathea cooperi*) adjacent to Maroobi Creek.  The 1998 plantings have been largely unsuccessful, and although a few species have grown to 15 m, a majority of the broken canopy is less than 6 m tall.  Grasses cover 90% of the understory, and lantana and bracken dominate the remaining ground.  The most successful species have been Celerywood (*Polyscias elegans*), Flame Trees (*Brachychiton* acerifolious), Silver Quondong, and Sarsparilla.  Finally, Site 7 overlooks the end of the corridor where the regrowth boot of the Lake Barrine section of the National Park meets the creek. The plantings are more successful than at Site 6, with fewer gaps in a canopy that often exceeds 8 m. Grass cover has been reduced to 60%, and lantana is present only in patches. As in Site 3, Sarsparilla and White Cedar trees have been the most successful species within the site.

### 2.4 Study species

Eight target species were surveyed in this study: the Australian Fernwren (*Oreoscopus gutturalis*), the Chowchilla (*Orthonyx spaldingii*), the Eastern Whipbird (*Psophodes olivaceus*), the Grey-headed Robin (*Heteromyias albispecularis*), the Pale-yellow Robin (*Tregellasia capito*), the Spotted Catbird (*Ailuroedus melanotis*), the Victoria's Riflebird (*Ptiloris victoriae*), and the Yellow-throated Scrubwren (*Sericornis citerogularis*). With the exception of the Victoria's Riflebird (a mobile, trunk-gleaning insectivorous species), all species are non-mobile to semi-mobile and/or ground feeders that may be particularly challenged by fragmentation (L. Quackenbush, unpubl.). All species were monitored when the Lakes Corridor was established (E. Austin, unpubl.).

### 2.5 Data collection

Data were collected between 07 April 2008 and 01 May 2008 following the methods of E. Austin (unpubl.). The presence or absence of target species at each study site was determined by visual and/or auditory identification of individuals within a 20 m radius circle. Non-target species were also monitored with the assistance of John Grant. In-circle data were used to calculate visitation frequencies along the corridor, and out-of-circle data were used to obtain complete species lists for each site. Trials were conducted between 0630 and 1030 and lasted for 20 minutes apiece. Each site was surveyed 20 times.

### 2.6 Data analysis

Species richness and diversity indices were calculated for each site to measure the relative abundance and diversity of birds along the corridor. Birds were then assigned to vagility categories, mobility groupings, and foraging guilds that were established during baseline studies for analysis of community composition (Appendices 1-3). Species that were not recorded in previous years were placed into categories with the assistance of John Grant. Vagility is a measure of sensitivity, referring to a species' ability to adapt to new environmental conditions (E. Austin, unpubl). Species are rated between A and E, with E being the most vagile. Mobility groupings are based on species dispersal through habitats with differential canopy cover, while foraging guilds are based on primary foraging strategies (L. Quackenbush, unpubl.).

Kruskal-Wallis and Rank Sum tests were run to determine whether each community type differed in abundance across all sites. Both tests were also run to determine if vagility groups and mobility groups differed in site use; foraging guilds were not included due to time constraints.

Habitat usage by community type was also compared to baseline findings collected from the Lakes Corridor (E. Austin, unpubl.) and from Donaghy's Corridor (L. Quackenbush, unpubl.) when they were first planted. Although the Quackenbush study was conducted on Donaghy's corridor, comparisons between it and the present study are valid since both corridors share similar environmental conditions and contain a mixture of remnant, regrowth, and planted sites. As a result, trends observed by E. Austin and L. Quackenbush were as baselines for community composition at the time of corridor establishment.

## 3. RESULTS

### 3.1 Species richness and diversity indices

Fifty-five species were identified along the corridor during the course of observation (Appendix 4). Fifty-three visited the corridor plantings (sites 2, 3, 6, and 7), compared with 37 in the remnant plot (Site 1) and 27 in the *Acacia* regrowth gully (sites 4 and 5, Table 1). Site 7 was the most species-rich location along the corridor, receiving individuals from 42 species. This trend is consistent with the diversity indices calculated for in-circle observations (Table 2), which ranked the corridor plantings as most diverse, followed by the remnant and regrowth areas.

### 3.2 Vagility categories

In general, the number of corridor sites with in-circle recordings increased with species vagility (Table 3). While Groups A and C were restricted to one and two sites, respectively, Groups D and E utilized all sites along the corridor. Group B, the exception to the aforementioned trend, was observed in four sites.

Observation frequencies also tended to increase with vagility rating (Table 3). Only one individual of Group A was present in-site, and this occurred at Site 1, resulting in a mean remnant frequency of 0.03/day (±0.04 SD) for the least vagile species. Group B was distributed equally throughout sites 1, 4, 6, and 7, where an average of 0.08 (± 0.12 SD) individuals were recorded each day. Group C was most common in Site 1, where daily observation frequencies averaged 0.25 (± 0.35 SD). Although individuals within Group D were present throughout the entire corridor, they were most common in sites 1 and 4, where an average of 0.28 (± 0.20 SD) birds were observed per day. Group E, meanwhile, occurred consistently throughout the entire corridor with an average of 0.96 (± 1.11 SD) individuals recorded daily.

### 3.3 Mobility groupings

Although each mobility grouping was recorded in every site, semi-mobile species were observed most frequently, with an average of 0.34 (± 0.13 SD) individuals recorded in-circle daily, compared with 0.17 (± 0.73 SD) mobile and 0.06 (± 0.46 SD) non-mobile individuals per day (Table 4). Non-mobile species were concentrated primarily in the remnant (Site 1), whereas mobile species were dispersed evenly throughout the corridor. Semi-mobile species were distributed evenly across all sites except Site 3, which was visited less frequently.

### 3.4 Foraging guilds

With the exception of foliage-gleaning insectivores and ground pouncers, foraging guilds were distributed equally throughout the sites that they visited (Table 5). Site 3 supported fewer foliage-gleaning insectivores than any other site, while ground pouncers were most common in the remnant (Site 1). The aerial insectivore, foliage-gleaning insectivore, and nectarivore/insectivore/frugivore guilds were the only groupings to explore all sites along the corridor. Most guilds frequented a combination of remnant, planted, and regrowth areas, although the carnivore/insectivore guild avoided remnant vegetation (Site 1) and the granivore and omnivore guilds avoided regrowth sites 4 and 5 (Table 5).

## 4. DISCUSSION

Compared with baseline trends, corridor usage has increased within bird communities analyzed according to vagility, mobility, and foraging guilds. The greater abundance of sensitive and robust species demonstrates that after ten years of succession the corridor has begun to provide habitat for a variety of rainforest birds and suggests that the Lakes Corridor may help alleviate the effects of isolated fragments in this tropical rainforest system.

### 4.1 Vagility categories

Within the past ten years, vagility groups have increased their utilization of corridor sites and begun exploring new areas within the Lakes Corridor. Group A, which contains the species that are most sensitive to changing environmental conditions and were absent from the corridor path at the time of its establishment, is now a rare visitor to the remnant site. Although this visitation was only manifested once during data collection, it offers promising implications for the effectiveness of the Lakes Corridor by addressing the discontinuity between the corridor and the Lake Eacham section of Crater Lakes National Park created by Gadgarra Road. According to Goosem (1997), contrasting microhabitat climates and environmental disturbances surrounding roads may create barriers that sensitive species are reluctant or unable to cross and consequently limit or prevent wildlife movement. If Group A species are willing and able to transverse Gadgarra Road to utilize the remnant site, the road is unlikely to pose a permanent obstacle to the most sensitive vagility groups as postulated previously (E. Austin, unpubl.).

Group B has increased its corridor usage as well. With the exception of the Orange-footed Scrubfowl, which utilized the remnant (Site 1), this group was absent from the corridor pathway during initial surveys (E. Austin, unpubl.). The Bower's Shrike-thrush and the Spotted Catbird have since joined the Orange-footed Scrubfowl in the corridor, and this group now uses each vegetation type along the pathway. The presence of individuals in sites at the ends and middle of the corridor indicate that the Lakes Corridor now provides enough resources to lure these species away from the Crater Lakes National Park sections where they were restricted to previously.

Although Group C is still limited to two sites along the corridor, individuals have replaced site 7, which overlooks the regrowth boot of the Lake Barrine section of Crater Lakes National Park, with Site 4 in the area of *Acacia* regrowth. This shift in site preference suggests a willingness to travel along the corridor, since Site 4 is located in the middle of the corridor path and consequently accessible only via corridor plantings or cleared agricultural fields.

Groups D and E are the only groups to utilize the entire corridor. Since 1998, Group D has moved into the previously unoccupied planted sites (2 and 6), while Group E has increased in frequency by nearly 54 percent. Once again, this rise in species abundance provides support for appropriate avifaunal habitat within the corridor.

**4.2 Mobility groupings**

In-circle frequencies indicate that all three mobility groups have increased their utilization of corridor sites and/or begun exploring sites located in the middle of the corridor within the past ten years of succession. Whereas non-mobile species were restricted to sites within the areas of continuous and closed canopy cover flanking Donaghy's Corridor, the same species are now present in every site at the Lakes Corridor. Although the non-mobile group was recorded less frequently than any other mobility group, their presence in the corridor indicates that the remnant, regrowth, and planted sites are beginning to provide adequate cover for sensitive avifauna.

Semi-mobile individuals increased in frequency along the corridor as well. In the 1995 census, these species were restricted to either the closed canopy sites bordering the corridor or to the remnant patch in its interior; today the same species are found in all vegetation types along the Lakes Corridor, including planted and regrowth areas. Species were found with equal frequency in every site except for 3, which provides the least amount of canopy cover. The combination of increased dispersal throughout the corridor and general avoidance of Site 3 demonstrates that the majority of the corridor now supplies sufficient cover for species requiring a closed canopy habitat.

Finally, although mobile species were recorded in all sites along the corridor during the 1995 survey, including those with less developed canopies, they were most common at the corridor ends. Today these species are located within all Lakes Corridor sites at equal frequencies, indicating that the entire corridor is now able to support species with more flexible habitat needs.

**4.3 Foraging guilds**

In 1995, closed canopy rainforest and *Acacia* regrowth sites supported a higher frequency of foraging guilds than the open canopy sites along Donaghy's Corridor (L. Quackenbush, unpubl.). Current trends suggest that the 10- and 16-year-old plantings within the Lakes Corridor provide adequate resources for all guilds except ground pouncers, which are still found in the remnant at a higher frequency than in any other vegetation type.

Although foliage-gleaning insectivores were distributed equally throughout planted sites 2, 6, and 7, they were less abundant at planting site 3. This pattern reflects the behavior of semi-mobile species (section 4.2), since in addition to having less canopy cover than the other planting sites, Site 3 likely supports a lower threshold of prey items for members of this guild.

The frugivore, frugivore/granivore, and nectarivore/insectivore/frugivore guilds utilized Site 3 more than any other foraging guild. Graham (2002) discusses a cyclical relationship between fruiting tree and frugivorous bird communities in which each community type supports and relies on the other. The abundance of fruit-eating species at

Site 3 may therefore be attributed to the presence of large, fruiting trees in an otherwise poorly maintained planting. The willingness of these species to utilize less developed habitats provides support for effectiveness of the framework planting method. Strategically planted fruiting trees may help accelerate rainforest restoration by attracting the seed-dispersing species included in the frugivorous foraging guilds to facilitate seed rain deposition. This process is not immediately evident in Site 3, although it may be hidden if understory grasses are out-competing rainforest seedlings—a possibility highlighted by the adjacent Site 2, which attracts frugivorous species but lacks a grassy understory and supports an abundance of rainforest seedlings.

### 4.4 Indicator species

Overall, despite the vast increase in avian abundance along the corridor, the indicator species identified in E. Austin (unpubl.) are still largely absent from the corridor. The Australian Fernwren and the Chowchilla were never seen or heard in any of the study sites, and the Yellow-throated Scrubwren was recorded only once in twenty days of observation. Therefore, all three species should still be monitored to evaluate the corridor's ability to provide connectivity for highly sensitive bird species.

## 5. CONCLUSION

Extensive forest clearing on the Atherton Tablelands in North Queensland has resulted in a mosaic of remnant forest patches isolated amongst agricultural fields. Recently, wildlife corridors have been planted to link these fragmented forests in an effort to provide dispersal pathways for isolated biota. This study aimed to reassess avian assemblages along the Lakes Corridor after ten years of succession by (1) investigating species richness and diversity, (2) analyzing habitat use by communities organized according to vagility, mobility, and foraging groupings, and (3) comparing current trends with baseline findings. Species richness and diversity indices were both highest in planting sites, intermediate in the remnant plot, and lowest in regrowth areas. Compared with baseline trends, corridor use has increased within bird communities. Overall, data indicate that the Lakes Corridor is beginning to provide connectivity between the two sections of Crater Lakes National Park for avifaunal species, and that this connectivity should increase as planted sites continue to develop. These results highlight the importance of providing closed canopy cover to attract avian to restoration plantings and lend support to the framework method of reforestation.

Because the Lakes Corridor is still developing, further studies are necessary to truly evaluate the corridor's ability to provide connectivity for rainforest bird species. Future research should include longitudinal investigations that compare avian assemblages and habitat usage along the corridor during the wet and dry seasons to determine the effect of differential resource abundance and distribution on these factors. Mist-netting can also provide a profile of the ages and sex of corridor users to determine if corridors support viable populations, while banding may help clarify patterns of avian dispersal. Continued monitoring of the wildlife corridors on the Atherton Tablelands will provide valuable insight into the field of restoration ecology that will improve our ability to connect and restore fragmented ecosystems in the years to come.

**FIGURES AND TABLES**

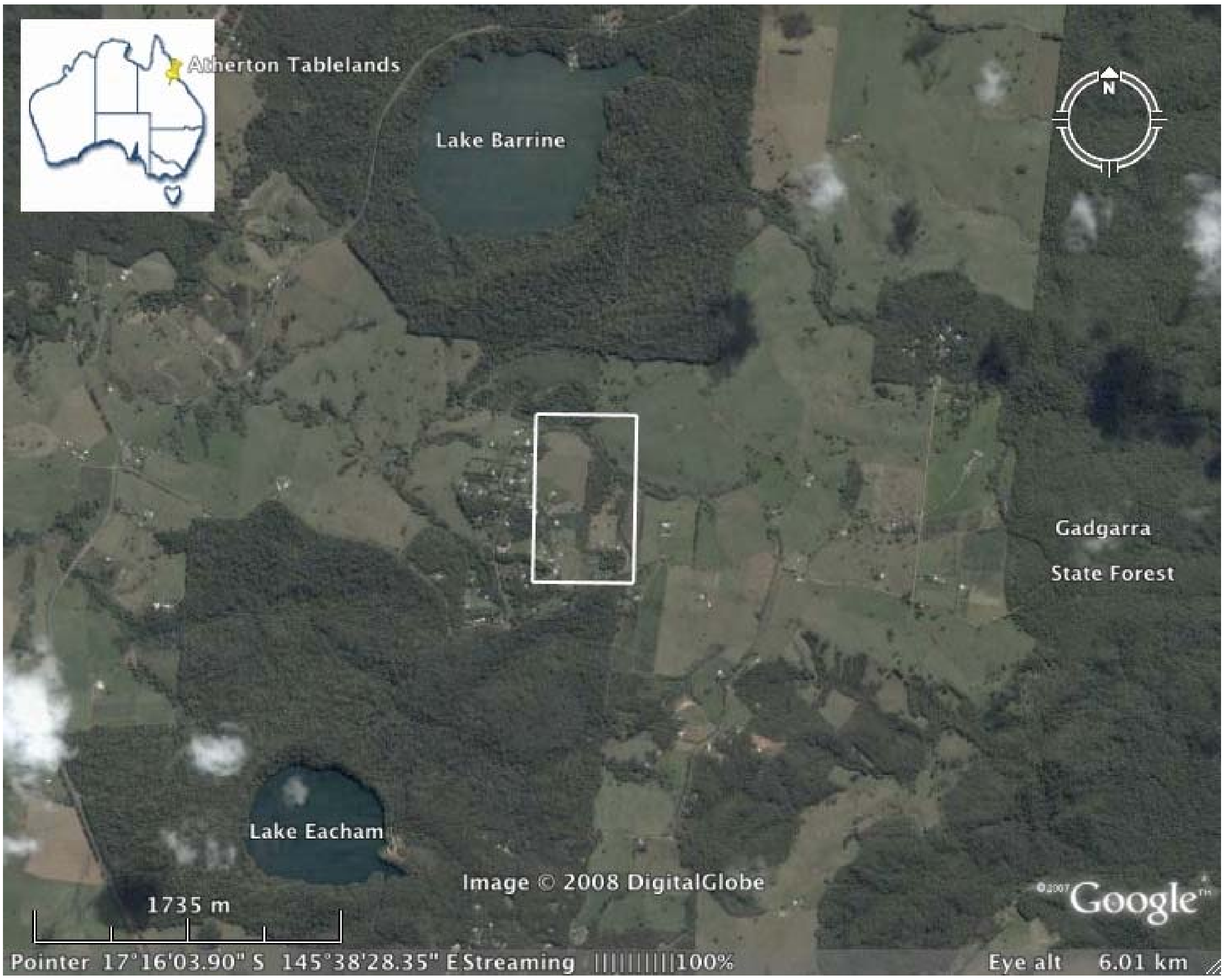


*Photo credit: Google Earth*

**Figure 1.** Aerial view of the study area on the Atherton Tablelands in Northeastern Queensland with the Lakes Corridor highlighted.

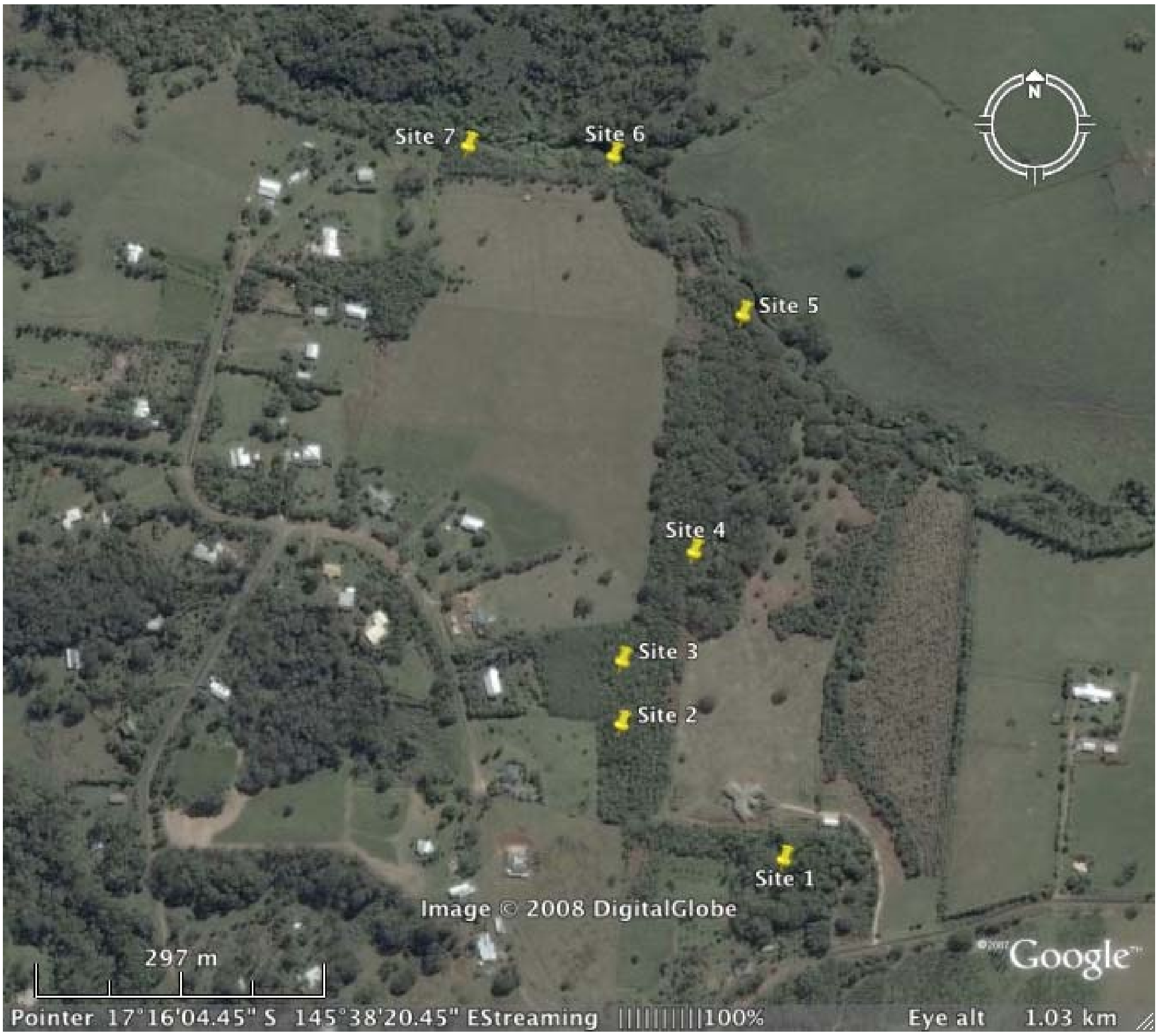


*Photo credit: Google Earth*

**Figure 2.** Aerial view of study sites along the Lakes Corridor**.**

**Table 1.** Number of species observed along the Lakes corridor calculated from in- and outside-circle frequencies.

| Site | Species Richness |
|---|---|
| 1 | 37 |
| 2 | 23 |
| 3 | 27 |
| 4 | 23 |
| 5 | 18 |
| 6 | 20 |
| 7 | 42 |

**Table 2.** Shannon's Diversity Indices calculated from in-circle frequencies along the Lakes Corridor.

| Site | Diversity Index |
|---|---|
| 1 | 2.73 |
| 2 | 2.69 |
| 3 | 2.25 |
| 4 | 0.95 |
| 5 | 1.77 |
| 6 | 2.31 |
| 7 | 2.80 |

**Table 3.** In-circle frequencies of vagility groups at the Lakes Corridor

| | Mean In-Circle Frequency (±SD) | | | | |
|---|---|---|---|---|---|
| Site | A | B | C | D | E |
| 1 | 0.03 (± 0.04) | 0.1 (± 0.14) | 0.25 (± 0.35) | 0.34 (± 0.22) | 1.54 (± 1.46) |
| 2 | 0 (± 0) | 0 (± 0) | 0 (± 0) | 0.08 (± 0.08) | 0.85 (± 0.67) |
| 3 | 0 (± 0) | 0 (± 0) | 0 (± 0) | 0.10 (± 0.10) | 0.29 (± 0.44) |
| 4 | 0 (± 0) | 0.08 (± 0.15) | 0 (± 0) | 0.22 (± 0.19) | 1.13 (± 0.92) |
| 5 | 0 (± 0) | 0 (± 0) | 0.02 (± 0.03) | 0.07 (± 0.06) | 1.42 (± 1.98) |
| 6 | 0 (± 0) | 0.05 (± 0.06) | 0 (± 0) | 0.02 (± 0.03) | 0.77 (± 0.67) |
| 7 | 0 (± 0) | 0.11 (± 0.13) | 0 (± 0) | 0.10 (± 0.17) | 0.69 (±0.91) |

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**Table 4.** In-circle frequencies of mobility groups at the Lakes Corridor

| | Mean In-Circle Frequency (±SD) | | |
|---|---|---|---|
| Site | Non-Mobile | Semi-Mobile | Mobile |
| 1 | 0.24 (± 0.25) | 0.54 (± 1.02) | 0.10 (± 0.22) |
| 2 | 0.04 (± 0.07) | 0.29 (± 0.47) | 0.20 (± 0.39) |
| 3 | 0.02 (± 0.04) | 0.07 (± 0.13) | 0.33 (± 0.77) |
| 4 | 0.03 (± 0.07) | 0.41 (± 0.63) | 0.14 (± 0.41) |
| 5 | 0.01 (± 0.04) | 0.44 (± 1.22) | 0.07 (± 0.23) |
| 6 | 0.01 (± 0.04) | 0.34 (± 0.55) | 0.15 (± 0.55) |
| 7 | 0.07 (± 0.11) | 0.29 (± 0.56) | 0.17 (± 0.36) |

**Table 5.** In-circle frequencies of foraging guilds at the Lakes Corridor

| | Mean InCircle Frequency (±SD) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Aerial Insectivore | Carnivore/ Insectivore | Foliage-Gleaning Insectivore | Frugivore | Frugivore/ Granivore | Granivore | Ground Pouncer | Leaf Litter Insectivore | Nectarivore/ Insectivore/ Frugivore | Omnivore | Trunk-Gleaning Insectivore |
| 1 | 0.17 (±0.15) | 0 (±0) | 0.56 (±1.17) | 0.1 (±0.12) | 0.12 (±0.11) | 0.05 (±0.07) | 0.55 (±0.14) | 0.15 (±0.27) | 0.24 (±0.34) | 0.03 (±0.06) | 0.18 (±0.24) |
| 2 | 0.27 (±0.31) | 0 (±0) | 0.34 (±0.50) | 0.14 (±0.31) | 0.28 (±0.57) | 0.05 (±0.07) | 0.08 (±0.11) | 0 (±0) | 0.22 (±0.45) | 0.13 (±0.15) | 0 (±0) |
| 3 | 0.13 (±0.15) | 0.03 (±0.06) | 0.07 (±0.13) | 0.66 (±1.48) | 0.48 (±0.86) | 0.05 (±0.07) | 0 (±0) | 0.01 (±0.03) | 0.2 (±0.36) | 0.07 (±0.06) | 0.13 (±0.10) |
| 4 | 0.27 (±0.31) | 0.1 (±0.17) | 0.41 (±0.71) | 0.08 (±0.13) | 0 (±0) | 0 (±0) | 0.18 (±0.25) | 0.08 (±0.05) | 0.31 (±0.65) | 0 (±0) | 0.08 (±0.15) |
| 5 | 0.17 (±0.21) | 0 (±0) | 0.5 (±1.38) | 0 (±0) | 0.02 (±0.04) | 0 (±0) | 0.05 (±0.07) | 0.03 (±0.05) | 0.2 (±0.37) | 0 (±0) | 0.04 (±0.05) |
| 6 | 0.17 (±0.15) | 0 (±0) | 0.39 (±0.61) | 0 (±0) | 0 (±0) | 0.2 (±0.28) | 0.03 (±0.04) | 0 (±0) | 0.41 (±0.86) | 0.03 (±0.06) | 0 (±0) |
| 7 | 0.1 (±0.10) | 0.03 (±0.06) | 0.03 (±0.63) | 0.07 (±0.08) | 0.06 (±0.13) | 0.2 (±0) | 0.15 (±0.21) | 0.09 (±0.06) | 0.36 (±0.54) | 0.1 (±0.17) | 0 (±0) |

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Personal Communications

Grant, J. April 2008.

## APPENDICES

**Appendix 1:** Vagility Groups from E. Austin (unpubl.)

Group A
Australian Fernwren
Yellow-throated Scrubwren

Group B
Bower's Shrike-thrush
Chowchilla
Orange-footed Scrubfowl
Spotted Catbird

Group C
Grey-headed Robin
Macleay's Honeyeater
Victoria's Riflebird

Group D
Brush Turkey
Pale-yellow Robin
White-throated Treecreeper

Group E
Brown Gerygone
Eastern Whipbird
Golden Whistler
Large-billed Scurbwren
Lewin's Honeyeater
Little Shrike-thrush

**Appendix 2:** Mobility Groupings of Rainforest Species adapted from L. Quackenbush (unpubl.)

Non-Mobile
Bridled Honeyeater
Eastern Spinebill
Eastern Whipbird
Grey-headed Robin
Orange-footed Scrubfowl
Pied Monarch
White-eared Monarch
Yellow-throated Scrubwren

Semi-Mobile
Black Butcherbird
Bower's Shrike-thrush
Brown Gerygone
Fairy Gerygone
Golden Whistler
Grey Fantail
Large-billed Scrubwren
Little Shrike-thrush
Macleay's Honeyeater
Mistletoebird
Pale-yellow Robin
Rufous Fantail
Shining Bronze Cuckoo
Spectacled Monarch
Spotted Catbird
Superb Fruit Dove
Toothbilled Bowerbird
White-throated Treecreeper
Yellow-breasted Boatbill

Mobile
Black-faced Monarch
Brown Pigeon
Brush Turkey
Cicadabird
Crimson Rosella
Emerald Dove
Figbird
Grey Whistler
Helmeted Friarbird
King Parrot
Laughing Kookaburra
Lewin's Honeyeater
Little Bronze Cuckoo
Little Cuckoo-shrike
Pacifica Baza
Pied Currawong
Rainbow Bee-eater
Silvereye
Sulphur-crested Cockatoo
Varied Triller
Victoria's Riflebird
White-browed Scrubwren
Yellow-bellied Sunbird
Yellow-eyed Cuckoo-shrike

**Appendix 3**: Foraging Guilds adapted from L. Quackenbush (unpubl.)

Aerial Insectivore
Grey Fantail
Rainbow Bee-eater
Rufous Fantail

Carnivore/Insectivore
Black Butcherbird
Laughing Kookaburra
Pacific Baza

Foliage Gleaning Insectivore
Black-faced Monarch
Bower's Shrike-thrush
Brown Gerygone
Cicadabird
Fairy Gerygone
Golden Whistler
Grey Whistler
Large-billed Scrubwren
Little Bronze Cuckoo
Little Cuckoo-shrike
Little Shrike-thrush
Spectacled Monarch
Varied Triller
White-eared Monarch
Yellow-breasted Boatbill

Frugivore
Figbird
Spotted Catbird
Superb Fruit Dove
Toothbilled Bowerbird
Yellow-eyed Cuckoo-shrike

Frugivore/Granivore
Brown Pigeon
Crimson Rosella
Emerald Dove
King Parrot
Sulphur-crested Cockatoo

Granivore
Bar-shouldered Dove
Red-bellied Finch

Ground Pouncer
Grey-headed Robin
Pale-yellow Robin

Leaf Litter Insectivore
Eastern Whipbird
Shining Bronze Cuckoo
White-browed Scrubwren

Nectarivore/Insectivore/Frugivore
Bridled Honeyeater
Eastern Spinebill
Helmeted Friarbird
Lewin's Honeyeater
Macleay's Honeyeater
Mistletoebird
Scarlet Honeyeater
Yellow-bellied Sunbird
Eastern Spinebill
Helmeted Friarbird
Lewin's Honeyeater
Macleay's Honeyeater
Mistletoebird
Scarlet Honeyeater
Yellow-bellied Sunbird

Omnivore
Brush Turkey
Orange-footed Scrubfowl
Pied Currawong

Trunk Gleaning Insectivore
Pied Monarch
Varied Triller
White-throated Gerygone
White-throated Treecreeper

**Appendix 4:** In-circle frequencies. Frequencies represent the average number of times a species was seen or heard in-circle per day and are based on 20 days of observation for target species and 10 days of observation for non-target species.

| **Species** | **Site 1** | **Site 2** | **Site 3** | **Site 4** | **Site 5** | **Site 6** | **Site 7** |
|---|---|---|---|---|---|---|---|
| Bar-shouldered Dove | 0.10 | 0.10 | 0.10 | 0 | 0 | 0 | 0.20 |
| Black Butcherbird | 0 | 0 | 0.10 | 0 | 0 | 0 | 0 |
| Black-faced Monarch | 0 | 0 | 0 | 0 | 0 | 0 | 0.10 |
| Bower's Shrike-thrush | 0.10 | 0 | 0 | 0 | 0 | 0.10 | 0.10 |
| Bridled Honeyeater | 0 | 0.20 | 0 | 0 | 0 | 0 | 0 |
| Brown Gerygone | 3.60 | 1.60 | 0 | 2.40 | 5.20 | 2.00 | 2.40 |
| Brown Pigeon | 0.10 | 0 | 0.10 | 0 | 0 | 0 | 0.30 |
| Brush Turkey | 0.10 | 0.10 | 0.10 | 0 | 0 | 0 | 0 |
| Cicadabird | 0 | 0 | 0 | 0 | 0 | 0 | 0.50 |
| Crimson Rosella | 0.10 | 0 | 0 | 0 | 0 | 0 | 0 |
| Eastern Spinebill | 0.40 | 0.10 | 0 | 0 | 0 | 0 | 0.10 |
| Eastern Whipbird | 0.55 | 0 | 0.05 | 0.20 | 0.10 | 0 | 0.15 |
| Emerald Dove | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fairy Geryogne | 0 | 0.70 | 0 | 0.90 | 0 | 1.50 | 0.90 |
| Figbird | 0 | 0.70 | 3.30 | 0.10 | 0 | 0 | 0 |
| Golden Whistler | 0.40 | 0.90 | 0.50 | 0.50 | 0.10 | 0.50 | 0.50 |
| Grey Fantail | 0.30 | 0.60 | 0.30 | 0.60 | 0.40 | 0.30 | 0.10 |
| Grey Whistler | 0 | 0 | 0.10 | 0 | 0 | 0 | 0 |
| Grey-headed Robin | 0.65 | 0 | 0 | 0 | 0 | 0 | 0 |
| Helmeted Friarbird | 0 | 0.10 | 0.10 | 0 | 0 | 0 | 0 |
| King Parrot | 0.10 | 1.30 | 2.00 | 0 | 0.10 | 0 | 0 |
| Large-billedScrubwren | 3.20 | 1.10 | 0 | 1.60 | 1.80 | 0.80 | 0 |
| Laughing Kookaburra | 0 | 0 | 0 | 0.30 | 0 | 0 | 0 |
| Lewin's Honeyeater | 1.00 | 1.40 | 1.10 | 1.80 | 1.10 | 0.80 | 1.00 |
| Little Bronze Cuckoo | 0 | 0 | 0 | 0 | 0 | 0.10 | 0 |
| Little Cuckoo-shrike | 0.10 | 0.40 | 0.20 | 0.10 | 0.10 | 0 | 0 |
| Little Shrike-thrush | 0.50 | 0.10 | 0.10 | 0.30 | 0.20 | 0.50 | 0.10 |
| Macleay's Honeyeater | 0.10 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mistletoebird | 0.20 | 0.10 | 0.10 | 0 | 0.30 | 0.30 | 0.40 |
| Orange-footed Scrubfowl | 0 | 0 | 0 | 0 | 0 | 0.10 | 0.30 |
| Pacific Baza | 0 | 0 | 0 | 0 | 0 | 0 | 0.10 |
| Pale-yellow Robin | 0.45 | 0.15 | 0 | 0.35 | 0.10 | 0.05 | 0.30 |
| Pied Currawong | 0 | 0.30 | 0.10 | 0 | 0 | 0 | 0 |
| Pied Monarch | 0.20 | 0 | 0.10 | 0 | 0 | 0 | 0 |
| Rainbow Bee-eater | 0 | 0 | 0 | 0 | 0 | 0 | 0.20 |
| Red-browed Finch | 0 | 0 | 0 | 0 | 0 | 0.40 | 0.20 |
| Rufous Fantail | 0.20 | 0.20 | 0.10 | 0.20 | 0.10 | 0.20 | 0 |
| Scarlet Honeyeater | 0 | 0 | 0 | 0 | 0 | 0 | 0.20 |
| Shining Bronze Cuckoo | 0 | 0 | 0 | 0 | 0 | 0 | 0.10 |
| Silvereye | 0.50 | 0.10 | 0.40 | 1.00 | 0.40 | 2.60 | 1.50 |
| Spectacled Monarch | 0.10 | 0 | 0 | 0.10 | 0.10 | 0.20 | 0.30 |
| Spotted Catbird | 0.30 | 0 | 0 | 0.30 | 0 | 0 | 0.05 |
| Sulphur-crested Cockatoo | 0.30 | 0.10 | 0.30 | 0 | 0 | 0 | 0 |

| Species | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 | Site 7 |
|---|---|---|---|---|---|---|---|
| Superb Fruit Dove | 0 | 0 | 0 | 0 | 0 | 0 | 0.10 |
| Toothbilled Bowerbird | 0.10 | 0 | 0 | 0 | 0 | 0 | 0 |
| Varied Triller | 0 | 0.20 | 0.10 | 0 | 0 | 0.10 | 0 |
| Victoria's Riflebird | 0 | 0 | 0 | 0 | 0.05 | 0 | 0 |
| White-browed Scrubwren | 0 | 0 | 0 | 0.10 | 0 | 0 | 0.10 |
| White-eared Monarch | 0.10 | 0 | 0 | 0 | 0 | 0 | 0 |
| White-throated Gerygone | 0 | 0 | 0.20 | 0 | 0 | 0 | 0 |
| White-throated Treecreeper | 0.50 | 0 | 0.20 | 0.30 | 0.10 | 0 | 0 |
| Yellow-belled Sunbird | 0 | 0 | 0.10 | 0 | 0 | 0 | 0 |
| Yellow-breasted Boatbill | 0.30 | 0.10 | 0 | 0.20 | 0 | 0 | 0.10 |
| Yellow-eyed Cuckoo-shrike | 0.10 | 0 | 0 | 0 | 0 | 0 | 0.20 |
| Yellow-throated Scrubwren | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 |