PERSPECTIVES IN
Biodiversity
VOLUME 4 / ISSUE 1 / 2026

Published ahead of issue
Received: 25 April 2025
Accepted: 1 April 2025
Published: October 2026

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https://doi.org/10.55457/pibdiv.004108

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This publication may be cited as:
Klein, R. R., Owen, J., Coyle, H. (2026). Birds of Mataia, Kaipara, Aotearoa / New Zealand: A comparative study of avian diversity in pine and mixed indigenous forest. *Perspectives in Biodiversity,* 4(1): 97–111.

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ISSN 3021–114X

Birds of Mataia, Kaipara, Aotearoa / New Zealand: A comparative study of avian diversity in pine and mixed indigenous forest

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Senior Editor: Marleen Baling
Article type: Research paper

Abstract

The anthropogenic conversion of indigenous forests into monoculture pine plantations may significantly affect biodiversity. In this study, we compared bird diversity in pine (*Pinus radiata*) plantation forest with a range of different forested vegetation associations at Mataia, near Glorit, Kaipara, Aotearoa / New Zealand. This study compares avian diversity between the pine plantation and the indigenous forest located in the Mataia conservation area near Glorit. Using five-minute point-count surveys, bird species were recorded across both sites, and their abundance and diversity were analysed. The results show that while both environments host 20 bird species, the indigenous forest supported a higher overall bird abundance (235 individuals) than the pine plantation (179 individuals). The indigenous forest was also noted to support more indigenous avian species that were absent in the pine plantation, such as kererū (*Hemiphaga novaeseelandiae*). The pine plantation hosted a higher number of exotic species, likely due to the invasive and adaptable nature of these birds. The study suggests that, although the biodiversity and structure of indigenous Aotearoa forests are not replicated in pine plantations, these plantations still provide an important habitat for various avifauna species.

Keywords

Bird survey, Mataia, Aoterarоa / New Zealand, indigenous species, pine plantation, avian habitat

Introduction

The alteration of natural environments, mainly through anthropogenic land-use changes, is among the primary drivers of shifts in biodiversity composition worldwide (Barlow et al. 2016; Brockerhoff et al. 2008; Kok et al. 2018; Uribe et al. 2021). The leading cause of these changes is deforestation caused by agricultural expansion and urbanisation (Barlow et al. 2016). These alterations to natural environments disrupt ecological processes and reduce the number of suitable habitats for many indigenous faunas (Carlson 1986; Clout & Gaze 1984). This disruption and habitat loss often leads to shifts in community structure and declines in population numbers of indigenous avian species (Zurita et al. 2006).

Forestry practices can have a profound impact on indigenous landscapes, altering the habitats of local avifauna (Barlow et al. 2016). For forestry purposes, natural forests are removed, or previously cleared land is replaced with monoculture plantations of exotic tree species (Zurita 2006). In Aotearoa / New Zealand (hereafter, Aotearoa), these plantations usually consist of a monoculture of radiata pine (*Pinus radiata* D. Don) (O'Brien et al. 2007). Aotearoa has 10.1 million ha of forest, covering 38% of the land (MPI 2022). However, 2.1 million ha of that land is plantation forest and is responsible for a third of the world's supply of pine (McArthur et al. 2019; MPI 2022). Many argue that forestry does not have the same environmental impacts on ecosystem services as other agricultural practices may (Brown et al. 2018; Hocking 2021; Lawler et al. 2014; Xiao et al. 2024); however, there are critical differences between monoculture plantations and indigenous Aotearoa forests that may make pine plantations a potentially challenging environment for Aotearoa fauna. The key differences between pine plantations and Aotearoa's indigenous forests are vegetation composition and ecological functions (Brockerhoff et al. 2008; Zurita et al. 2006). Plantation forests are managed for commercial timber production and are not intended to mimic the complexity of natural ecosystems (O'Brien et al. 2007). Instead, the vegetation composition of pine plantations is sparse (Colihueque et al. 2023). The trees are grown in a relatively uniform pattern, forming a canopy, but have little undergrowth, leading to fewer habitats for fauna to occupy (Figure 1) (Colihueque et al. 2023; Zurita et al. 2006). In contrast, Aotearoa's indigenous forests are complex ecosystems that support a high diversity of flora and fauna, including many endemic species (Allen et al. 2013). Most of Aotearoa's indigenous forest habitats are composed of five tiers (Figure 2) (MPI 2022). This diversity of vegetation types within these indigenous habitats provides a range of ecological niches for various faunal species (Brockerhoff et al. 2008). Aotearoa's indigenous avifaunal species, in particular, have evolved in these biodiverse environments and are thought to require them for survival (East & Williams 1984; Innes et al. 2022).

The lack of structure and complexity in pine plantations in comparison to indigenous forests can affect avifaunal communities (Zurita et al. 2006). Birds rely on their habitat to provide them with resources required for survival, such as food and shelter (Chettri et al. 2005). They have also been noted to be particularly



Figure 1. Schematic of pine plantation vegetation structure. Biodiversity and vegetation complexity are lacking within pine plantations.

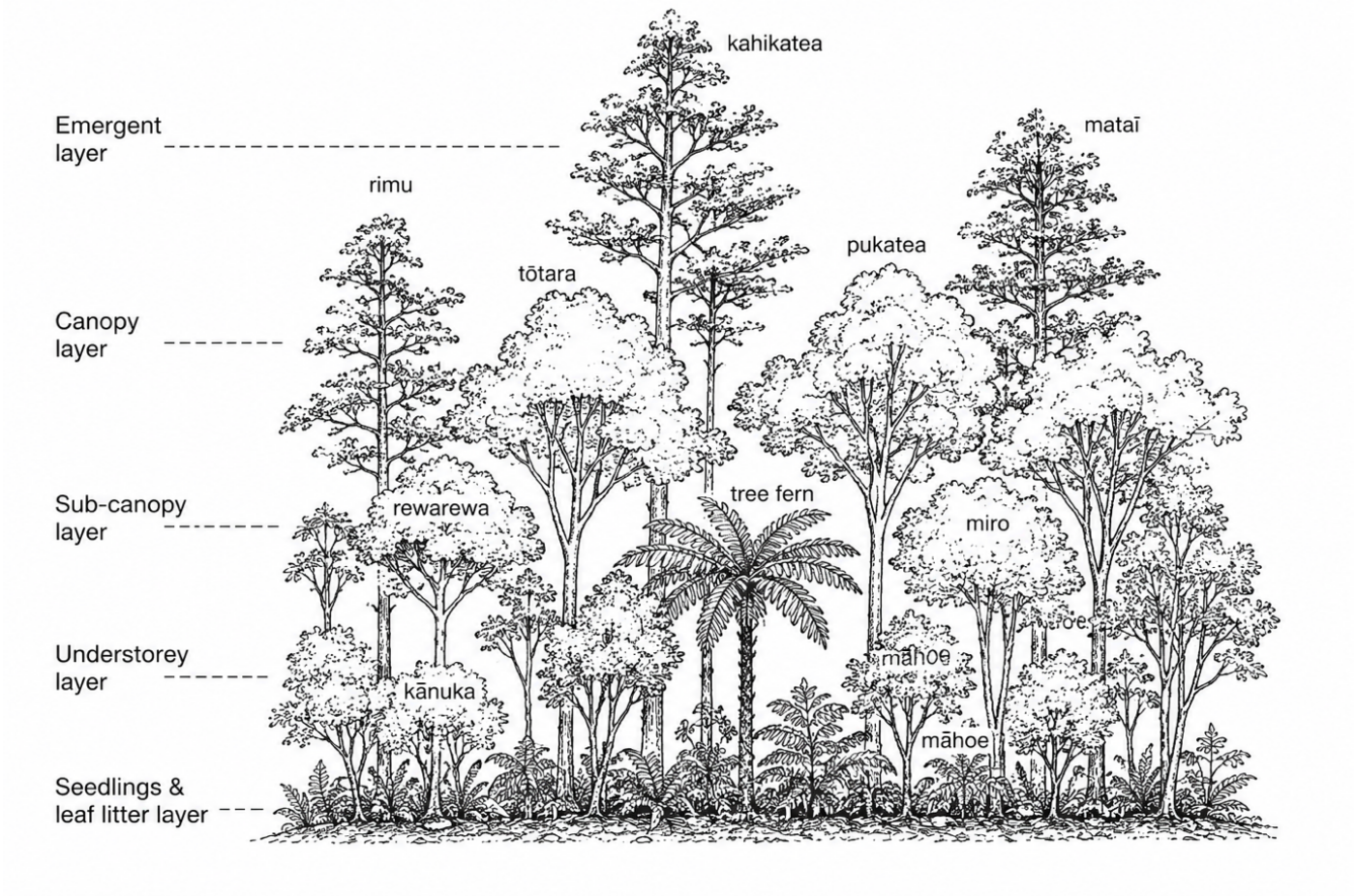


Figure 2. Schematic of indigenous northern Aotearoa lowland forest structure. Aotearoa forests usually consist of five layers: the forest floor, an understorey of shrubs and small plants, a sub-storey of taller ferns and trees, a canopy of trees and, finally, the emergent layer of tall trees.

sensitive to changes within their habitat, such as the loss of associated biodiversity and forest structure. However, while it is understood that indigenous forests provide better habitats for many bird species, pine plantations, though relatively simple in composition and structure, may also provide sufficient resources for the survival of some bird species (Brockerhoff et al. 2008). Knowledge of how indigenous Aotearoa birds use pine plantations is relatively understudied (Seaton et al. 2010; Zurita et al. 2006); therefore, understanding the diversity of avian species across these two environments and how they inhabit them will aid in determining which birds may better adapt to monoculture environments (Chettri et al. 2005).

This study compares avian diversity and abundance within pine plantations with that of associated mixed indigenous forested vegetation. By surveying these forest associations, this study aims to provide insights into diversity differences and how land-use changes can affect bird populations and their relative abundance. Furthermore, it will provide a deeper understanding of whether the avifauna observed show discernible preferences for plantation or indigenous forests.

Method

Study area

The Mataia Queen Elizabeth II Covenant (hereafter, Mataia) is located near Glorit in the Kaipara District, north of Tāmaki Makaurau / Auckland (-36.491303°S 174.425940°E). It is a 1300-hectare farming site, purchased by the Gardner family in 1870, with a historical homestead, now used for accommodation, constructed in 1891 (Thornton 2017). Since 2017, 900 ha of the 1300-ha property have been actively operated as a pastoral ovine and bovine meat farm (Thornton 2017). The remaining 400 ha comprise a combination of manawa / mangrove (*Avicennia marina* subsp.

australasica (Walp.) J.Everett) shrubland, saltmarsh wetland, reverting gum land, kānuka (*Kunzea robusta* de Lange & Toelken) forest, mixed coastal broadleaf, podocarp forest and patches of kauri (*Agathis australis* (D.Don) Lindl.) forest.

These indigenous vegetation associations are collectively part of a long-term restoration project that commenced in 2005 (Fraser et al. 2023). Accordingly, Mataia has a strict pest- and predator-eradication programme to protect indigenous biodiversity, and further restoration of farm areas has also begun, with around 7500 indigenous trees being planted each year (Mataia Homestead 2024). In addition, the farm contains pockets of a radiata pine (*Pinus radiata* D.Don) plantation, grown as a separate source of income for the landowners, with the most extensive planting located northeast of the indigenous reserve (Fraser et al. 2023). As several of these pine plantations are located adjacent to protected and/or restored indigenous forested areas, Mataia was considered an appropriate site for our study. The study's designated survey sites comprised 19 ha of indigenous forest and 15.3 ha of pine plantation. These forested areas were separated by 100 m of pasture at their closest point.

Survey method

To determine the difference in avian species diversity, five-minute point counts were conducted at random co-ordinates (Tables 1 and 2) within each site (Figures 3 and 4). Forty were completed in the pine forest and 40 were completed in the indigenous forest, over two days. It was decided for the first day of surveying that 20 five-minute point counts would be completed in the pine plantation in the morning, and 20 five-minute point counts would be completed in the indigenous forest in the afternoon. On the second day, the survey timings swapped, with the first 20 five-minute point counts conducted in the morning in the indigenous forest and the following 20 counts in the afternoon in the pine plantation. This method was designed to limit variation

Table 1. GPS co-ordinates of pine plantation five-minute point count recording locations at Mataia.

PP01	-36.48844, 174.42868	**PP21**	-36.48857, 174.42875
PP02	-36.48862, 174.42925	**PP22**	-36.48838, 174.42924
PP03	-36.48819, 174.42964	**PP23**	-36.48872, 174.42957
PP04	-36.48829, 174.4305	**PP24**	-36.48778, 174.43036
PP05	-36.48784, 174.43101	**PP25**	-36.48809, 174.43147
PP06	-36.48715, 174.43065	**PP26**	-36.48793, 174.43228
PP07	-36.48747, 174.43145	**PP27**	-36.48775, 174.43184
PP08	-36.4873, 174.43193	**PP28**	-36.48731, 174.43101
PP09	-36.48732, 174.43315	**PP29**	-36.48689, 174.43165
PP10	-36.48618, 174.43204	**PP30**	-36.48739, 174.43231
PP11	-36.48619, 174.43348	**PP31**	-36.48694, 174.43312
PP12	-36.48585, 174.43302	**PP32**	-36.48681, 174.4327
PP13	-36.48682, 174.43408	**PP33**	-36.48631, 174.43282
PP14	-36.48582, 174.4344	**PP34**	-36.48574, 174.43255
PP15	-36.48553, 174.43396	**PP35**	-36.48512, 174.43286
PP16	-36.48523, 174.4347	**PP36**	-36.48529, 174.43422
PP17	-36.48558, 174.43548	**PP37**	-36.4857, 174.43476
PP18	-36.48495, 174.43606	**PP38**	-36.48529, 174.43523
PP19	-36.48465, 174.43429	**PP39**	-36.48531, 174.43622
PP20	-36.48518, 174.43348	**PP40**	-36.48468, 174.43575

Table 2. GPS co-ordinates of native forest five-minute point count recording locations at Mataia.

NZ01	-36.49062, 174.42436	**NZ21**	-36.49071, 174.4248
NZ02	-36.49042, 174.42532	**NZ22**	-36.49086, 174.42528
NZ03	-36.49046, 174.42627	**NZ23**	-36.49066, 174.42585
NZ04	-36.49099, 174.42603	**NZ24**	-36.49082, 174.42638
NZ05	-36.49077, 174.42746	**NZ25**	-36.49068, 174.42701
NZ06	-36.49005, 174.42763	**NZ26**	-36.49026, 174.42723
NZ07	-36.4897, 174.42867	**NZ27**	-36.48999, 174.42825
NZ08	-36.49035, 174.42921	**NZ28**	-36.49069, 174.42813
NZ09	-36.49055, 174.42861	**NZ29**	-36.49093, 174.4286
NZ10	-36.49171, 174.42907	**NZ30**	-36.49141, 174.42875
NZ11	-36.49175, 174.42841	**NZ31**	-36.49229, 174.42814
NZ12	-36.49143, 174.42818	**NZ32**	-36.49215, 174.42764
NZ13	-36.49151, 174.42758	**NZ33**	-36.49163, 174.42727
NZ14	-36.49185, 174.42716	**NZ34**	-36.49127, 174.42659
NZ15	-36.49239, 174.42774	**NZ35**	-36.49158, 174.42557
NZ16	-36.49216, 174.42653	**NZ36**	-36.49224, 174.42532
NZ17	-36.49176, 174.42615	**NZ37**	-36.49253, 174.42617
NZ18	-36.49256, 174.42565	**NZ38**	-36.49299, 174.42466
NZ19	-36.49183, 174.42497	**NZ39**	-36.49243, 174.42401
NZ20	-36.49196, 174.42416	**NZ40**	-36.49132, 174.42385



Figure 3. Aotearoa indigenous forest co-ordinates for five-minute point counts at Mataia. Different colours denote the two sets of 20 five-minute point counts. Each set of counts was recorded over two consecutive days (20 on each day). Scale bar: 600 m.



Figure 4. Pine plantation co-ordinates for five-minute point counts at Mataia. Different colours denote the two sets of 20 five-minute point counts. Each set of counts was recorded over two consecutive days (20 on each day). Scale bar: 200 m.

in bird activity levels across times of the day. Because birds are often most active at dawn and before dusk, this method captured a broader, more even range of bird activity across both sites.

Recording method

Birds were recorded at each point count within a 20-metre radius using anecdotal sightings by visual and auditory means over five minutes. Merlin Bird ID by the Cornell Lab (https://merlin.allaboutbirds.org) was used to further and formally identify birds. This mobile-phone application listens to birdsong via its microphone and displays real-time suggestions for the bird species singing in the vicinity of the recorder. Ebird (https://ebird.org/home) was also used as a checklist for species seen or heard at each survey site. This application documents bird data, including distribution, abundance and trends, to help correctly identify species within a location. The Aotearoa bird pack was downloaded and loaded onto both apps ahead of time.

Birds that were heard or seen were counted in the following way: one person recorded data, one listened for bird calls and the other made visual identifications at each five-minute sampling. After each sampling had ceased, the recorded data was collated and checked to ensure the same bird was not counted more than once. If a bird was seen in an area in which we had previously heard its call, it was counted as one observation. All three authors were involved in taking photos as evidence of observed species.

Data analysis

After completing the survey, all results were transferred to a Microsoft Excel spreadsheet. The number of each bird species was entered against the co-ordinate of each count. Two tables were formed: one comprised the numbers of birds from the pine plantation counts, and the other the indigenous forest counts. Species richness was used as a measure for avian diversity to represent the total numbers of different species detected within the different sites.

Results

In the overall study area, 24 bird species were recorded (Table 3). Observed species richness was equal between habitats, with 20 species recorded in both

Table 3. List of bird species located over both sites surveyed in Mataia.

Scientific name	Common name	Maori Name
Acridotheres tristis (Linnaeus, 1766)	common myna	maina
Alauda arvensis Linnaeus, 1758	Eurasian skylark	kairaka
Carduelis carduelis britannicus (Hartert, 1903)	European goldfinch	kōurarini
Chloris chloris (Linnaeus, 1758)	European greenfinch	–
Chrysococcyx lucidus (Gmelin, 1788)	shining cuckoo	pīpīwharauroa
Circus approximans Peale, 1848	swamp harrier	kāhu
Egretta novaehollandiae novaehollandiae (Latham, 1790)	white-faced heron	matuku moana
Fringilla coelebs gengleri Kleinschmidt, 1909	common chaffinch	pahirini
Gerygone igata (Quoy & Gaimard, 1830)	grey warbler	riroriro
Gymnorhina tibicen tyrannica Schodde & Mason, 1999	Australian magpie	makipai
Hemiphaga novaeseelandiae (Gmelin, 1789)	New Zealand pigeon	kererū
Hirundo neoxena neoxena Gould, 1842	welcome swallow	warou
Ninox novaeseelandiae novaeseelandiae (Gmelin, 1788)	morepork	ruru
Passer domesticus domesticus (Linnaeus, 1758)	house sparrow	tiu
Phasianus colchicus Linnaeus, 1758	common pheasant	–
Platycercus eximius eximius (Shaw, 1792)	eastern rosella	kākā uhi whero
Prosthemadera novaeseelandiae novaeseelandiae (Gmelin, 1788)	tūī	tūī

Prunella modularis (Linnaeus, 1758)	dunnock	–
Rhipidura fuliginosa placabilis Bangs, 1921	fantail	pīwakawaka
Streptopelia chinensis tigrina (Temminck, 1810)	spotted dove	–
Tadorna variegata (Gmelin, 1789)	paradise shelduck	pūtangitangi
Todiramphus sanctus vagans (Lesson, 1828)	sacred kingfisher	kōtare
Turdus merula merula Linnaeus, 1758	Eurasian blackbird	manu pango
Turdus philomelos clarkei Hartert, 1909	song thrush	manu-kai-hua-rākau
Zosterops lateralis lateralis (Latham, 1802)	silvereye	tauhou

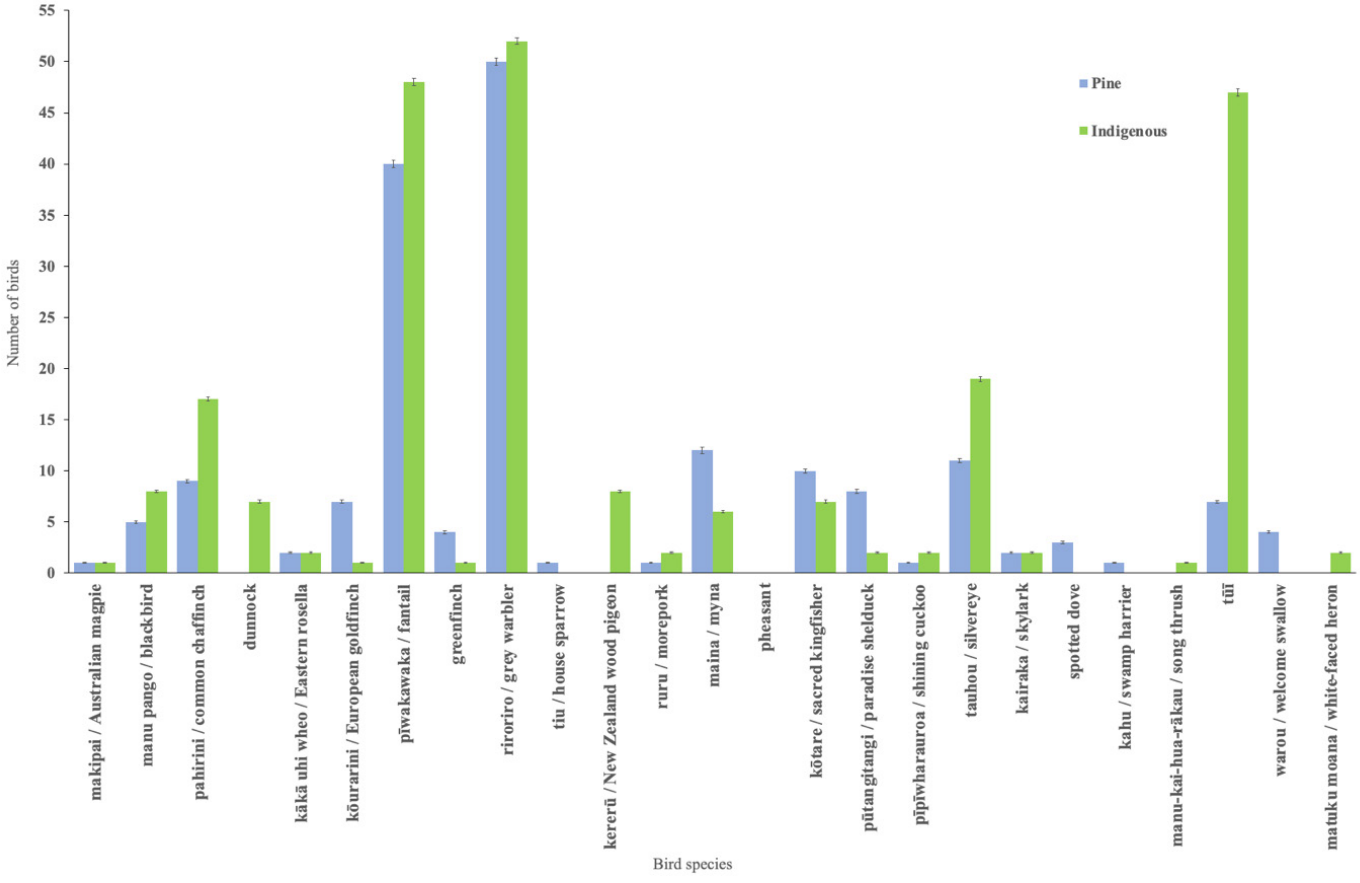


Figure 5. Comparison between both survey sites at Mataia for the total count of each bird species. *Phasianus colchicus* (common pheasant) was heard in the pine plantation area; however, they were deemed outside the 20-metre radius of point counts. Therefore, the data was removed. The error bars show the variability in the data.

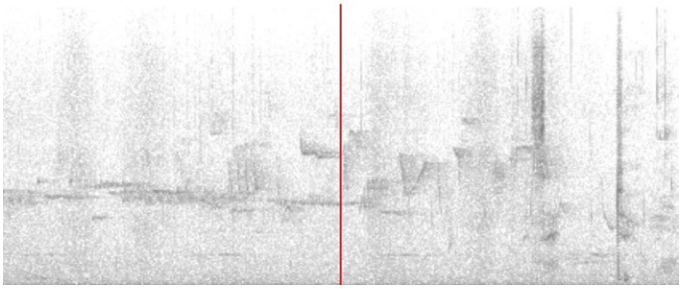


Figure 6. Spectrogram of a dunnock (*Prunella modularis*) (recorded using Merlin Bird ID at -36.49042, 174.42532).

the pine plantation and the indigenous forest. A total of 179 individual bird observations was recorded in the pine plantation, compared with 235 in the indigenous forest. Shannon diversity was slightly higher in the pine plantation (*H'* = 2.33) than in the indigenous forest (*H'* = 2.24) (Figure 5).

Riroriro (*Gerygone igata* (Quoy & Gaimard, 1830)) and pīwakawaka (*Rhipidura fuliginosa* (Sparrman, 1787)) were the most frequently recorded species in both habitats. Riroriro counts were similar in the pine plantation and the indigenous forest, with 50 and 52 observations respectively. Pīwakawaka counts were also broadly similar, with 40 observations in the pine plantation and 48 in the indigenous forest.

Tūī (*Prosthemadera novaeseelandiae* (Gmelin, 1788)) were recorded substantially more frequently in the indigenous forest, with 47 observations, compared with seven in the pine plantation.

Species recorded exclusively in the indigenous forest were dunnock (*Prunella modularis* (Linnaeus, 1758)) (Figure 6), song thrush (*Turdus philomelos clarkei* Hartert, 1909) (Figure 7), kererū (*Hemiphaga novaeseelandiae* (Gmelin, 1789)) (Figure 8) and white-faced heron (*Egretta novaehollandiae novaehollandiae* (Latham, 1790)).

House sparrow (*Passer domesticus domesticus* (Linnaeus, 1758)), spotted dove (*Streptopelia chinensis tigrina* (Temminck, 1810)) (Figure 9), kāhu (*Circus approximans* Peale, 1848) and warou (*Hirundo neoxena neoxena* Gould, 1842) were observed exclusively in the pine plantation.

While the common chaffinch (*Fringilla coelebs gengleri* Kleinschmidt, 1909) was counted at both sites, it was more commonly counted in the indigenous bush (Figure 5). This was similar to the results for the Eurasian blackbird (*Turdus merula merula* Linnaeus, 1758) (Figure 10).

The common myna (*Acridotheres tristis* (Linnaeus, 1766)), European goldfinch (*Carduelis carduelis britannicus* (Hartert, 1903)) (Figure 11) and greenfinch (*Chloris chloris* (Linnaeus, 1758)) were most common in the pine plantation (Figure 5).

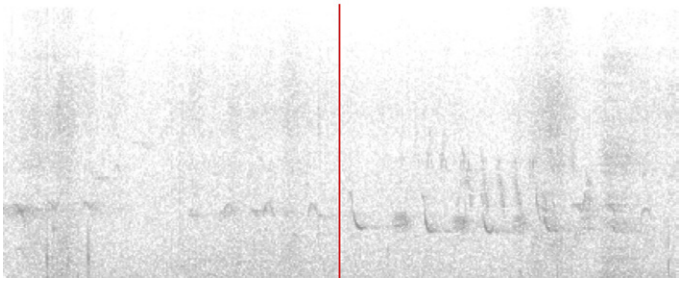


Figure 7. Spectrogram of a song thrush (*Turdus philomelos clarkei*) (recorded using Merlin Bird ID at -36.49062, 174.42436).



Figure 8. Kererū (*Hemiphaga novaeseelandiae*) seen in the Mataia indigenous forest survey at -36.49229, 174.42814.

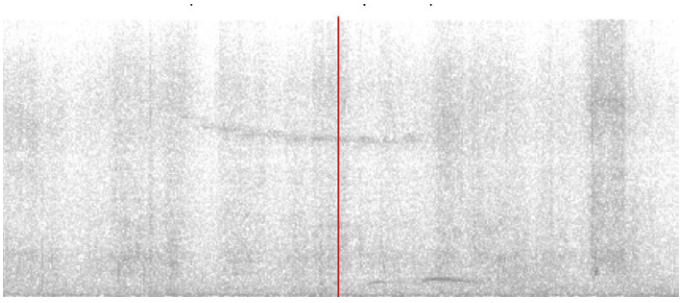


Figure 9. Spectrogram of the vocalisation of spotted dove (*Streptopelia chinensis tigrina*) (recorded using Merlin Bird ID at -36.48523, 174.4347).

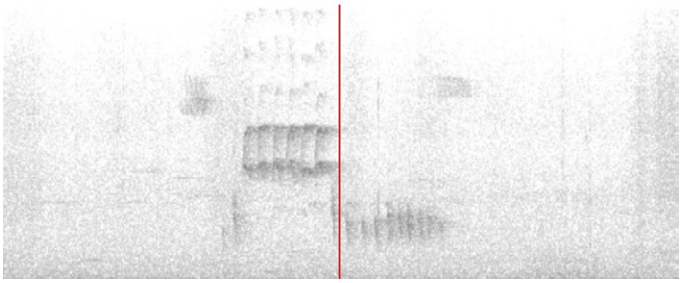


Figure 10. Spectrogram of the vocalisation of Eurasian blackbird (*Turdus merula merula*) (recorded using Merlin Bird ID at -36.49151, 174.42758).

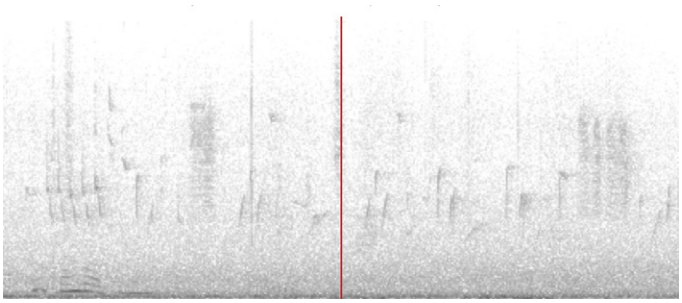


Figure 11. Spectrogram of the vocalisation of European goldfinch (*Carduelis carduelis britannicus*) (recorded using Merlin Bird ID at -36.49176, 174.42615).

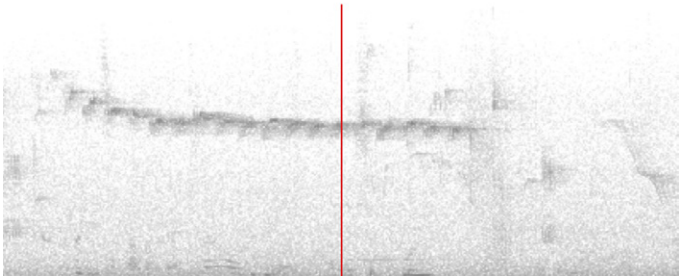


Figure 12. Spectrogram of the vocalisation of pīwakawaka (*Rhipidura fuliginosa placabilis*), heard in pine plantation (recorded using Merlin Bird ID at -36.49185, 174.42716).

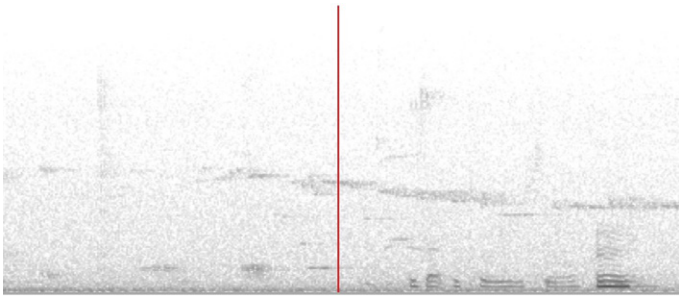


Figure 13. Spectrogram of the vocalisation of riroriro (*Gerygone igata*) overlaying a tūī (*Prosthemadera novaeseelandiae novaeseelandiae*), as heard in the Mataia pine plantation (recorded using Merlin Bird ID at -36.48775, 174.43184).

Discussion

The ecological and biodiversity differences between pine plantations and indigenous forests are well documented (Chettri et al. 2005; Estades & Temple 1999); however, this report provides insights into the differences between a close-proximity pine plantation and mixed indigenous forest in a similar landscape environment. The results of this survey suggest that, while indigenous forests still provide a more complex habitat for indigenous avifauna, plantations are not inhospitable to them, as noted by Brockerhoff et al. (2008).

Avifaunal abundance and diversity

Many indigenous avifauna in Aotearoa are specialist niche taxa that have evolved to suit very particular environments. In contrast, many exotic species are considerably more adaptable to the environments now available in the much-modified landscape of Aotearoa (Bicudo et al. 2010). This study has shown that the vegetative complexity of the indigenous forest associations at Mataia supports a wide range of avifauna, both indigenous and exotic. Although both pine plantation and indigenous forested site supported the same number of species (20), the indigenous forest site had 31.28% more birds (235 individuals) than the pine plantation (179 individuals).

The larger number of birds at the indigenous forest site could be attributed to habitat resource availability (Innes et al. 2022). Past research has emphasised the importance of complex, multi-layered habitats for avifauna. One example of a species that depends on intricate habitats is tūī, which requires a diverse range of nectar-producing plants and is considered a bioindicator across various environments (Chettri et al. 2005; Kelly et al. 2010; Mariyappan et al. 2023). The results of the present study align with these findings, as indicated by the higher number of tūī counted in the indigenous forest than in the pine plantation. Furthermore, this study suggests that other species, such as the kererū, depend on the intricate ecosystems indigenous forests possess, aligning with existing research making this claim, such as Clout and Gaze (1984).

Species in pine plantations

In general, pine habitats are not suited to a wide diversity of bird species, because vegetation is simple, resulting in limited resources (Seaton et al. 2010). For example,

the European greenfinch is a granivore (Glück 1986) and is often associated with pine plantations because it particularly likes the seeds of *Pinus radiata* (Angus 2013). In contrast, a kererū would struggle to find sufficient fruit to feed on due to the lack of fruit trees in the same habitat (Clout & Gaze 1984).

As a result of specific food preferences, the pine plantation was noted to have a higher proportion of exotic avifaunal species. Exotic species counted there included the common myna, European goldfinch and house sparrow. These birds are likely more adaptable to monoculture forests, as they have evolved to thrive in various habitats and can exploit the limited resources available in pine plantations (Seaton et al. 2010; Vergara & Simonetti 2004).

The greater number of exotic avian species observed during this study suggests that pine plantations may also serve as refuges for both generalist and invasive species (Uribe et al. 2021). It may also reflect the impact of predator-control operations on the nearby indigenous vegetation, as well as their general control on the farm itself, reducing the predator population in the pine plantations.

Additionally, within the plantation, several pine plots were observed to be of different ages. The avian species counts were higher in plots with more established trees This may be because older trees harbour more resources and offer additional habitat opportunities. The understorey in established pine plots is often denser, further complicating the monoculture environment (Dagan & Izhaki 2019; Peterson & Hayman 2018), which may contribute to the presence of indigenous avifauna observed in the pine plantation.

Both pīwakawaka and riroriro were noted to be in relatively high numbers throughout the pine plantation (Figures 12 and 13). Because both species are insectivores, it was assumed that this would be their primary food source there (Anderson 2013; Powlesland 2013); however, pine plantations do not offer the same insect diversity as indigenous forests (Ratsirarson et al. 2002), so the survey results could be seen to suggest that these species may be more adaptable to foraging within monoculture environments.

Furthermore, tūī were also noted in the pine plantation (Figure 5), although it is possible that some birds were not resident, rather using the pine plantation as a forest corridor between indigenous forested areas (Seaton et al. 2010). This consideration aligns with previous studies that have found indigenous forests near forestry blocks can increase the number of indigenous birds within pine plantations (Brockerhoff et al. 2008; Innes et al. 2023; Lindenmayer et al. 2002). Nevertheless, the findings of this study suggest that while pine plantations would not supersede indigenous forests as biodiverse habitats, they have ecological value and are important habitats for indigenous birdlife.

Further observations

The survey observations included signs of kiwi. In 2013 kiwi-nui (*Apteryx mantelli* Bartlett, 1852) were reintroduced into the indigenous bush in Mataia (Mataia Homestead 2024). Through the indigenous bush, on damp ground, we saw numerous kiwi-nui beak holes and occasional feathers (Figure 14), and, notably, beak holes were also present throughout the pine plantation. It would be interesting to conduct night surveys in the future to understand how kiwi-nui utilise the environment at Mataia and how often they travel to the pine plantation to forage. Furthermore, it would be beneficial to determine whether pine plantations can provide suitable habitats for kiwi-nui (Pawson et al. 2010). If so, further research would be required to determine how to protect the species during logging in pine plantations (Lindenmayer & Hobbs 2004).

Another interesting note was that the Merlin Bird ID application picked up korimako (*Anthornis melanura melanura* (Sparrman, 1786)) song and identified the species as present in the area during a count (Figure 15). This was recorded at a single location within the Mataia indigenous forest. Korimako have not been seen in the area since the 1860s, making their presence in the Mataia region doubtful (P. J. de Lange, pers. comm., 21 September 2024). However, the birds making these calls, identified by Merlin Bird ID as korimako, were not observed visually.

It was decided that an early-morning trip on departure day was required to confirm which bird species was making the call. Upon arriving at the co-ordinates where the korimako song was identified, it was noted that several pairs of tūī were present who were confirmed to be responsible for the korimako-like song, completed without any 'coughs' or 'wheezes' typically heard in tūī communication. Given the mimicking nature of tūī, which often learn their song from sounds in their environment, we are curious where these individuals may have heard korimako song (Hill et al. 2017). Future studies could focus on understanding this observed phenomenon or identifying any flaw in the Merlin Bird ID application's ability to deal with mimicking birdsong.



Figure 14. Signs of kiwi-nui (*Apteryx australis*) presence at Mataia. **A.** Feather lying on moss (*Dicranoloma* sp.) in forest. **B.** Probe hole in forest soil. Both feather and probe hole were seen at -36.49199, 174.42321.

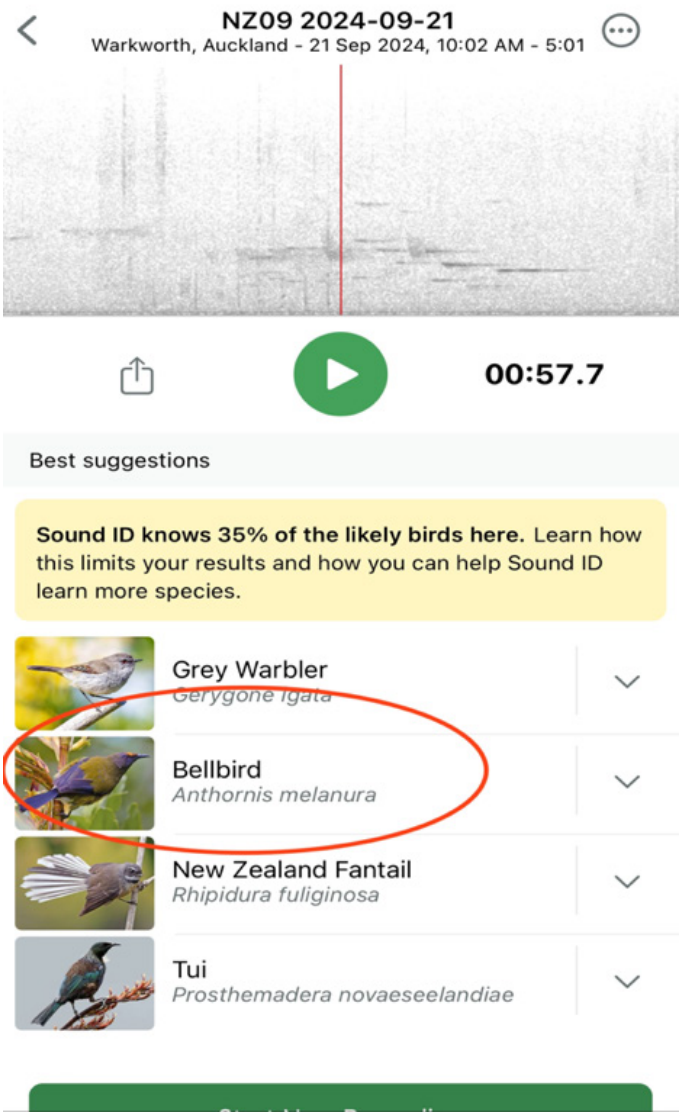


Figure 15. Showing the Merlin Bird ID algorithm that was tricked into mistaking tūī calls for korimako (*Anthornis melanura melanura*). These calls were recorded at -36.48689, 174.43165 and -36.48694, 174.43312.

Conclusion

Aotearoa's indigenous forests are irreplaceable habitats for native avifauna because they provide a structurally complex, varied environment. While pine plantations are less diverse, they can still provide a workable habitat for some bird species, particularly those with adaptable natures. The results of this study emphasise the importance of understanding the ecological value of both forest types, and underline the limitations of pine plantations in supporting the needs of speciality feeders such as kererū and tūī.

In addition, exotic species comprised the greater proportion of detections in the pine plantation, suggesting that these monoculture habitats may provide a suitable habitat for some invasive and generalist species. However, the lower abundance of indigenous birds recorded in the pine plantation indicates that it did not support indigenous avifauna to the same extent as the indigenous forest. Pine plantations may therefore facilitate the persistence of some exotic bird species while providing more limited habitat value for indigenous species. Further research is needed to understand how the indigenous avifauna of Aotearoa use pine plantations and whether management strategies could enhance the value of these environments for particular species.

Acknowledgements

Thanks to Jenny and Shane for granting us access to their Mataia property so we could complete the survey. Thank you to Professor Peter de Lange of Unitec for organising the field trip, trusting us to complete our survey independently, and providing entertaining memories and laughs throughout the trip. Further thanks are extended to Unitec lecturers Marleen Baling and Wesley Webb for their valuable input on observations made during the survey.

Data Accessibility Statement

No additional database.

Author Contributions

Rachel R. Klein: Conceptualisation (equal); data curation (equal); validation (lead); visualisation (equal); writing – original draft (lead); writing – review and editing (lead).
Jemma Owen: Conceptualisation (equal); data curation (equal); visualisation (equal); writing – review and editing.
Hannah Coyle: Conceptualisation (equal); data curation (equal); visualisation (equal); writing – review and editing.

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