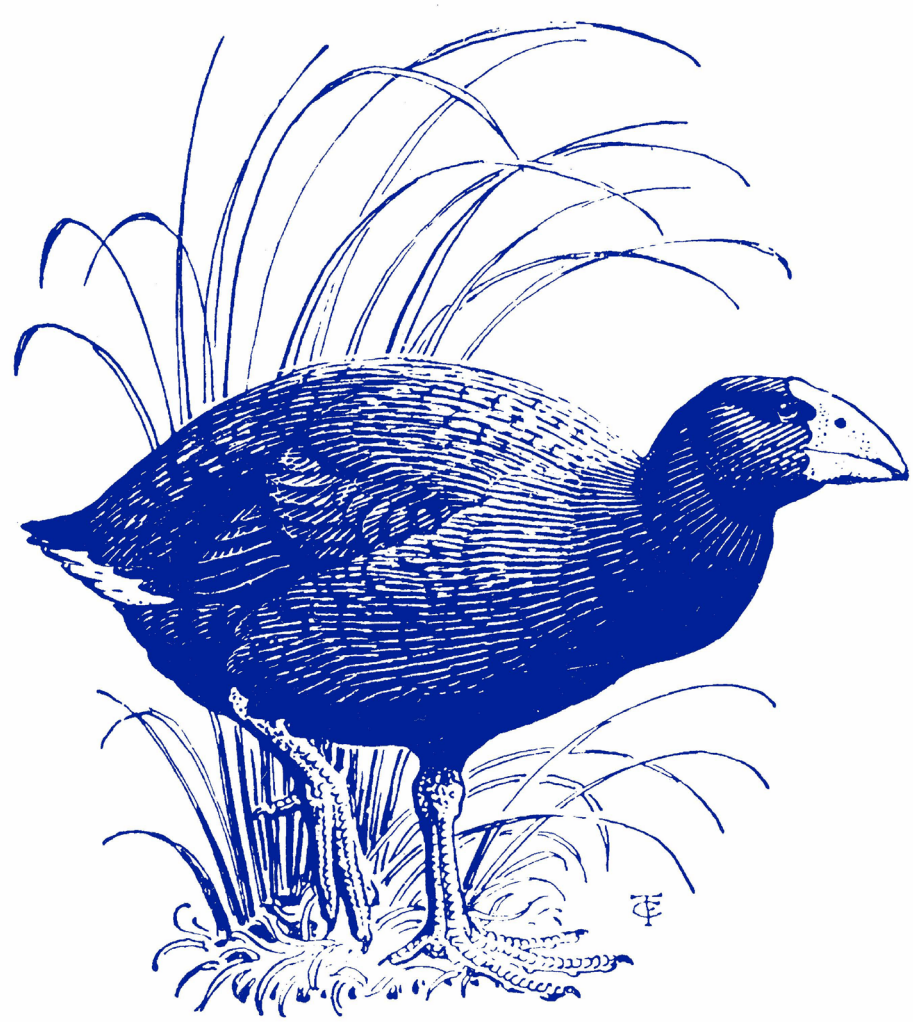
NOTORNIS

Ornithology of the Southern Pacific



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The mysterious Miss Rebecca Stone and her collection of birds from Hokianga, 1842: a window into early ornithology in Aotearoa New Zealand

ROSS GALBREATH*
Onewhero, RD2 Tuakau 2697, New Zealand, ORCID 0000-0001-7160-1178

HEIN VAN GROUW
Bird Group, Department of Life Sciences, Natural History Museum, Tring, Herts. HP23 6AP, UK,
ORCID 0000-0002-3600-4279

ALAN J.D. TENNYSON
Museum of New Zealand Te Papa Tongarewa, PO Box 467, Wellington 6140, New Zealand, ORCID 0000-0001-6374-6924

Abstract: A collection of 16 birds from Hokianga, including the type specimens of banded rail *Hypotaenidia philippensis assimilis* and black petrel *Procellaria parkinsoni*, is recorded as presented to the British Museum in 1842 by a mysterious "Miss Rebecca Stone." She is identified as Rebecca Stones of London, who presented birds brought from Hokianga by her brother William Stones. A further search for the collector in Hokianga, based on the evidence of the specimens and how they were obtained, prepared and documented, points to the Wesleyan missionary William White, and also reveals much about the practices of ornithology of the time. It also reveals that Hokianga Māori, notably Mohi Tāwhai of Waimā, played a significant role in obtaining and naming birds for the collection. The type localities for New Zealand banded rail, black petrel, and *Botaurus melanotus* are restricted to Hokianga, Northland.

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Keywords: Rebecca Stones, William White, Mohi Tāwhai, George Robert Gray, preparation of museum specimens, Māori involvement in collecting birds

INTRODUCTION

Rebecca Stone is an enigmatic figure, and a rare female contributor, in the early ornithology of Aotearoa New Zealand. The 16 birds from Hokianga, Northland, that she presented to the British Museum in 1842 represented the first significant collection of New Zealand birds seen in Europe since those from the great British and French exploring expeditions, and added five species to the list of New Zealand birds (Watola 2008). Who was Rebecca Stone, and how did she obtain those birds? In setting out to answer these questions we looked closely at the collection of birds that she presented: how they were obtained, prepared as specimens, and conveyed to the British Museum. These investigations helped to identify Rebecca Stone and how she obtained the birds, while also providing insights into the practice of ornithology in that pivotal period between the European exploration and colonisation of New Zealand.

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*Correspondence: *onewhero@ps.gen.nz*

ANALYSIS AND RESULTS

Rebecca Stone: the published record

We begin with the published accounts of Rebecca Stone and her collection of birds. When she presented them to the British Museum they were hailed as the first New Zealand birds it had received apart from a single kiwi (*Apteryx* sp.) gifted by the Earl of Derby (J.E. Gray 1843). A contemporary observer immediately ranked her alongside Banks, Forster, Dumont d'Urville, and Gould among those

who had elucidated the natural history of New Zealand, with the comment that "the study of natural history is one of the pursuits which does great credit to the female sex. In common with botany, it should be followed by those who have leisure at the antipodes" (E. Wakefield 1844). Since then, Rebecca Stone's contribution has been acknowledged in catalogues of birds in the British Museum (G.R. Gray 1844a, 1844b, 1859; British Museum 1874–1898; Warren 1966), in early species lists of New Zealand birds (G.R. Gray 1843, 1862), and in later accounts of their discovery and naming (Buller 1872-73, 1887-88; Cheeseman 1882; Oliver 1930, 1955; Fleming 1982; Andrews 1986; Medway 1990; Watola 2008).

For all that, however, next to nothing is known about her. The few details that have been published seem contradictory: she has been located both in New Zealand as "an early resident collector" (Gordon 1938) and in London as "Miss R. Stone of the Excise Office" (Warren 1966). Even her name is uncertain: J.E. Gray (1843) and most subsequent authors referred to her as "Miss Rebecca Stone"; however, Godman (1908) and Oliver (1955) referred to her as "Miss Rachel Stone." Fleming (1982) also used the latter name, describing her as "a pioneer of her sex among ornithologists, about whom we would like to know more than we do." Watola (2008) repeated Fleming's comment, while referring to her as "the mysterious Miss Rebecca Stone".

The collection presented by Rebecca Stone

Who was Rebecca Stone, and what were the birds that she presented to the British Museum? We began by examining the original record of that presentation in the register of zoological accessions at the British Museum, which is now held by its natural history successor, the Natural History Museum. The zoological accessions register for 1841–44, now in the museum archives under *DF ZOO/218/1/3*, records, under date "42 / 5.17" (i.e. 17 May 1842), the accession of 16 birds "Presented by Miss Rebecca Stone Excise office Cath. Dock". The entry appears to be in the hand of George R. Gray, the museum assistant responsible for the ornithological collection. He evidently identified and named the birds at accession (there is no sign of later additions or alterations to the names), beginning with the more readily identifiable birds – the first ten in the list are mainly identified to species, with the last six identified to genus only. There are notes with each bird, evidently provided by the collector, giving its locality (all are listed as from "River Hokianga New Zealand"), its Māori name, and its eye colour. Table 1 gives a transcription

Table 1. Transcription of the entries and associated notes in the British Museum zoological accessions register for the 16 birds presented by Rebecca Stones, registered on 17 May 1842. Current names are added in square brackets.

1. Apteryx australis male	River Hokianga New Zealand		black eye green pupil 5 lb
2. " " female	" "	"Kiwi"	
[= North Island brown kiwi, *Apteryx mantelli*]			
3. Falco brunnea	" "	"Kaiaia or Kauaua"	eye dark brown. blk pupil
4. " "	" "	"	"
[= New Zealand falcon, *Falco novaeseelandiae*]			
5. Athene	" "	Koukou	yellow rim, brown eyes
6. "	" "	"	"
[= Ruru, *Ninox novaeseelandiae novaeseelandiae*]			
7. Callaeas cinerea	" "	Kokako	Black eye
[= North Island kokako, *Callaeas wilsoni*]			
8. Prosthemadera novæzealandia	" "	Tui	Black eye green pupil
9. " "	" "	"	"
[= Tūī, *Prosthemadera novaeseelandiae novaeseelandiae*]			
10. Ptilotis cinctus female	" "	Kotihe	Green eye black pupil
[= Hihi, *Notiomystis cincta*]			
11. Eudynamys	"	Kohepuroa bird of passage	Green eye black pupil
[= Long-tailed cuckoo, *Eudynamys taitensis*]			
12. Platycercus	"	Powaitere	" "
[= Yellow-crowned parakeet, *Cyanoramphus auriceps*]			
13. Charadrius	"	Tuturiwhatu	
[= Pacific Golden plover, *Pluvialis fulva*]			
14. Rallus	"	Katatai	yellow eye green rim
[= Banded rail, *Gallirallus philippensis assimilis*]			
15. Botaurus	"	Matuku	Black pupil yellow rim
[= Australasian bittern *Botaurus poiciloptilus*]			
16. Puffinus	"	Taiko	Dark dun eye, black pupil
[= Black petrel, *Procellaria parkinsoni*]			

of the entries and associated notes in the accession register, with the current identification of each bird provided in brackets. The list numbers, prefixed by the date (in numerical year.month.day format) constitute the Museum's register numbers for the birds: 1842.5.17.1 to 1842.5.17.16.

Fourteen of the 16 birds are still held by the Natural History Museum (no. 1, the male North Island brown kiwi (*Apteryx mantelli*), was exchanged in 1950, and no. 11, the long-tailed cuckoo (*Eudynamis taitensis*), is now missing). There are some notable specimens in the remaining collection:

No. 7, entered in the accession register as "*Calleas cinerea*" is the first recorded museum specimen of North Island kokako (*Calleas wilsoni*). George Gray evidently set out to describe it as a new species (see his entry "Callaeas wilsoni, G.R. Gr. MSS" in G.R. Gray 1862); however, the name *C. wilsoni* was published first by Bonaparte (1850).

No. 10, entered in the accession register as "*Ptilotis cinctus* female", is the first museum specimen of a female hihi, now *Notiomystis cincta* (Fig. 1a). Up to this time the only specimens that had reached Europe had been of the more colourful male, and the descriptions and illustrations of the species (as *Meliphaga cincta* by du Bus de Gisignies 1839, and a few months later as *Ptilotis auritus* by Lafresnaye 1839) were based entirely on the male bird's striking black, white and yellow plumage. How George Gray identified the olive-brown bird in Rebecca Stone's collection as the same species will be discussed further below. In his register entry he listed it as a female, but later described it as a juvenile (G.R. Gray 1845). The sexual dimorphism of *Notiomystis cincta* was not clearly described until Buller (1872-73) and subsequently this specimen became listed again as an adult female (Gadow 1884).

This specimen is also significant as a relatively well-dated and located early record of the species. Hihi were probably already declining in 1840 and disappeared from the north of the North Island by 1870 and entirely by 1885, apart from a relict population on Hauturu/Little Barrier Island (Buller 1887-88; Angehr 1984). Only perhaps 30 specimens of mainland hihi have been preserved and few of these have any definite location (Angehr 1984; Salvador *et al.* 2019). The present specimen from "River Hokianga" collected before 1842, and another in the Muséum national d'Histoire naturelle in Paris collected during the visit of the *Venus* to the Bay of Islands in 1838 (www.gbif.org/occurrence/1042802909, viewed 27 Jan 2025), confirm (against the doubts of Scofield & Stephenson 2013) the historic presence of hihi in Northland.

Figure 1. Some of the birds from Hokianga presented by Rebecca Stones in 1842, now in The Natural History Museum, Tring, UK. The scale mark with each = 10 cm. Photographs: Jonathan Jackson, © Trustees of the Natural History Museum, London.

a. Female hihi, *Notiomystis cincta* (register no. NHMUK 1842.5.17.10).

b. Pacific golden plover, *Pluvialis fulva* (register no. NHMUK 1842.5.17.13) The first New Zealand record of this species.

c. Black petrel, *Procellaria parkinsoni* (register no. NHMUK 1842.5.17.16) The first record and holotype of this species.

No. 13, entered in the accession register under the generic name "*Charadrius*," represents the first documented New Zealand record of Pacific golden plover (*Pluvialis fulva*) (Fig. 1b). This species was evidently an uncommon visitor in the mid-nineteenth century: apart from a specimen in the first Auckland museum in 1855 (Hutton & Buller 1874) there were no further records of Pacific golden plover in New Zealand until the 1880s (Cheeseman (1882). The nomenclatural history of this species is complex. George Gray initially listed this specimen as *Charadrius xanthocheilus* (see G.R. Gray 1843), but following the thinking of the times it was subsequently listed as *C. virginicus* by him (G.R. Gray 1844b), as *C. fulvus* by Buller (1872-73), and as *C. dominicus* by Sharpe (1896). The species is now classified as *Pluvialis fulva* (see Connors 1983).

This species was evidently known to Māori, also under various names. Yate (1835) recorded the name "takahikahi" with a description that fits this species. The name "tuturiwhatu" as given for Rebecca Stone's specimen was also recorded (spelled as "tuturiwatu") for this species by Taylor (1848). However, both these names, takahikahi and tuturiwhatu, are more commonly used for dotterels, particularly New Zealand dotterel, *Anarhynchus obscurus* (see Williams 1971). Pacific golden plover is now more commonly known in New Zealand under another Māori name, kuriri (Miskelly 2022) – borrowing the name used across the South Pacific for the wandering tattler *Tringa incana* (see Emory 1947).

The last three specimens on the list were each named by George Gray as new species:

No. 14, entered in the accession register under the generic name "*Rallus*", with the Māori name "Katatai", is the first museum specimen of banded rail (*Hypotaenidia philippensis*) from New Zealand. G.R. Gray (1843) named it as a new species, *Rallus assimilis.* It is now regarded as the New Zealand subspecies, *Hypotaenidia philippensis assimilis.*

Under his description of *Rallus assimilis* George Gray added notes on its Māori names, beginning with one recorded by Dieffenbach: "Konini of the natives of Cook's Strait" (G.R. Gray 1843). He later misconstrued that note to suggest "Cook's Straits, N.Z." was where the species was recorded from (G.R. Gray 1862). Understandably, this has been taken as the locality of Rebecca Stone's holotype specimen (Warren 1966; Watola 2008), but there is no reason to doubt the locality as originally recorded in the accession register: "River Hokianga". Accordingly, the type locality of the species should be "Hokianga", rather than "Cook's Strait" or "New Zealand" (Checklist Committee 2022).

No. 15, entered in the accession register under the generic name "*Botaurus*", is the first museum specimen of Australasian bittern (*Botaurus poiciloptilus*) from New Zealand. George Gray described it as a new species, *Botaurus melanotus*, and noted that the species was also found in Australia (G.R. Gray 1843). However, he overlooked the name that had already been given to the species there by Wagler (1827). George Gray was normally a careful worker; the reason for his uncharacteristic error here will emerge in our discussion below. Again, the type locality of George Gray's *B. melanotus* should be "Hokianga", rather than "New Zealand" (Checklist Committee 2022).

No. 16, entered in the accession register under the generic name "*Puffinus*," is the first museum specimen of black petrel or tāiko (*Procellaria parkinsoni*) (Fig. 1c). George Gray initially identified it as a white-chinned petrel, *P. aequinoctialis* (see G.R. Gray 1844b: 160); however, 20 years later he described it as a new species, *Procellaria parkinsoni* G.R. Gray, 1862. There is no indication that he had any further specimens by then, and so Rebecca Stone's specimen is the holotype of the species. The type locality of this species can also be refined from "New Zealand" (G.R. Gray 1862; Checklist Committee 2022) to "Hokianga".

We will discuss George Gray's identification of these birds in more detail below. However, first we turn our attention to Rebecca Stone, who presented them to the British Museum.

Identifying Rebecca Stone

We began with the entry in the accession register: "Presented by Miss Rebecca Stone Excise office Cath. Dock". The address "Cath. Dock" evidently refers to St Katharine Docks, on the north bank of the Thames, just below the Tower of London. Searches of the 1841 British census and other records of the time found no Rebecca Stone in that vicinity. However, searches of Excise officers of the period, as listed in *The British Imperial Calendar* (Anon. 1838a and earlier editions), showed a Joseph Stones, a "doorkeeper" in the Excise Office in London. Joseph Stones' will (held in the British National Archives under PROB 11/1894/208) confirms that up to his death in February 1838 he was in the Excise office, living at "Hartshorn Wharf in the parish of St Katharine by the Tower" and that he had a daughter named Rebecca. Perhaps the "Rebecca Stone" in the accession register referred to this Rebecca Stones?

This is supported by further information from shipping records. Here it is relevant that Joseph Stones' will referred also to a son, William Stones. Searches of shipping records found no indication of Rebecca Stones ever travelling to New Zealand, but revealed that her brother William did. In 1838, when he was just 18, he evidently spent some of his inheritance from his father's estate on a passage to New Zealand. William Stones is listed as a cabin passenger on the barque *James*, sailing from Gravesend, London, on 20 Dec 1838, to Hobart, Tasmania, and on to Hokianga, New Zealand (Anon. 1839a)

The arrival of the *James* at Hokianga on 18 Mar 1839 and William Stones' activities there over the next 2 years are recorded mainly in the journals of the Wesleyan missionaries (see the journals of James Buller, John H. Bumby, John Hobbs, Mary Anna Smales, and William Woon, all in the Alexander Turnbull Library, Wellington). William Stones spent time with them but mainly with the timber trader Francis White and his family. He acted as witness for several of White's land purchases (Turton 1882) and assisted his trading operations by sailing with shiploads of kauri (*Agathis australis*) timber to oversee their sale in Sydney or Hobart. After the second such assignment, William Stones sailed on back to London. He departed from Hokianga on 31 Jul 1841, again on the *James* (Anon. 1841a), and after seeing to the final auction of its cargo of timber in Hobart in November (Anon. 1841b), he evidently took another ship back to London. Passenger lists outward from Australia are less well documented than lists inward and we could not find any record of his onward passage from Hobart. However, William Stones was certainly back in London by 27 Sep 1842, when he signed as a witness at his sister Rebecca's marriage to Walter Blanford Waterlow (see the entry in the register of marriages, parish of St George's in the East, Tower Hamlets, available on Ancestry.com). He had arrived probably months earlier, most likely by the *Hebe,* which sailed from Hobart on 19 Dec 1841 and arrived at Gravesend, London on 11 May 1842 (Anon. 1841c; Anon. 1842). William Stones evidently carried the collection of bird-skins from Hokianga to London; they were then delivered to the British Museum and entered in its zoology accession register on 17 May as "presented by Miss Rebecca Stone".

A further line of evidence confirms our identification of "Miss Rebecca Stone" as Rebecca Stones. Some years after William Stones returned to London he wrote a book, *My first voyage; a book for youth* (Stones 1858a), which describes a voyage to Australia and New Zealand. It has been taken as an imaginary voyage (Hocken 1909; Bagnall 1980); however, comparing the incidents of *My first voyage* with those of William Stones' travels to Australia and New

Zealand makes it clear that the book largely relates real events, though with disguised names for the ships and the European people involved. However, real names are used for the Māori people that William Stones encountered. One of these is "Tawhai," who can be identified as Mohi (Moses) Tāwhai, rangatira (chief) of Te Māhurehure hapū of Waimā in Hokianga (Lash & Davidson 2017). One passage in *My first voyage* concerning Tāwhai is particularly relevant:

> "Being desirous of obtaining specimens of those remarkable birds, the Kiwis (Apteryx Australis), inhabiting the mountains at the source of the Waima, we arranged with Tawhai for the purchase of the pair, male and female, which are now in the British Museum" (Stones 1858a: 186).

Checks confirm that the only pair of North Island brown kiwi held by the British Museum at that time are those recorded as "presented by Miss Rebecca Stone" (G.R. Gray 1844b). We conclude that the collection of birds, including the kiwi, were brought from Hokianga to London by William Stones and then presented to the Museum by his sister, Rebecca Stones. Her name was slightly misspelled in the accession register.

To give some further identifying details: Rebecca Stones was born in 1822, married Walter Blanford Waterlow in 1842, and died in 1869. William Stones was born in 1820, married Walter Waterlow's elder sister Mary Valentina Waterlow in 1848, and died in 1866. After returning from New Zealand William Stones kept in contact with friends there and continued to write on "New Zealand (the land of promise)" (Stones 1858b); however, we could find no indication that either he or Rebecca ever had any other dealings with museums or museum specimens or took any interest in natural history.

Tracing the Hokianga collector

Rebecca "Stone", as she has been referred to, has generally been credited as having "obtained" (Watola 2008) or "collected" (Oliver 1930, 1955; Warren 1966; Medway 1990) the birds that she presented to the British Museum (hereafter "the Stones collection"). However, it is clear that she could not have been the collector in the sense of the person who obtained (shot, trapped or perhaps purchased) the birds in the field. And although William Stones evidently conveyed the birds from Hokianga to London, it is doubtful whether he can be credited as having collected them either. By his own account he was involved in purchasing the pair of kiwi, but it seems unlikely that he had the skills or the experience to obtain the other birds in the collection or to prepare them as museum specimens. Given that he was in New Zealand in total for little more than a year and was unfamiliar with any of the local birds, it is unlikely that he could have made such a select collection as this, bypassing the common and conspicuous birds and concentrating on those that were not often seen, being either cryptic (banded rail, bittern, black petrel), occasional (Pacific golden plover), or less conspicuous (the female rather than male hihi) – all birds that no previous European collector in New Zealand had managed to obtain. William Stones, if he was involved at all, was probably assisting someone with more experience and skill in obtaining and preparing bird specimens.

In the following discussion we refer to this person as the "collector", but must note the problems with this term. It is ambiguous, referring either to the person who obtains the bird in the field (a "field collector"), or the person who assembles a collection of bird specimens (a "cabinet collector") (Lucas & Lucas 2014). And the account of William Stones and his companions obtaining kiwi specimens by purchasing them from Tāwhai raises the issue of whether the Māori hunter who initially captured the birds as traditional game should be credited as the (field) collector, or the European who purchased them as specimens. There is a long history of ignoring the role of indigenous helpers and hunters in supplying specimens to European "collectors". As Lucas & Lucas (2014) comment, "we see no good reason for refusing to designate ... the anonymous hunters as collectors, but in much literature the hunters would be ignored. Yet they were clearly a vital part of the supply chain of specimens". In the following discussion we will attempt to include and acknowledge all the different parties in the supply chain which brought the birds from the wild in Hokianga to the British Museum in London; however, for simplicity we will continue to use the term "collector" for the compiler of the collection of birds, who obtained them somehow, had them prepared and preserved as specimens, and consigned the collection to the museum.

The following investigation into who this Hokianga collector might have been strays rather far from Rebecca and William Stones, but in the process does reveal much about the practice of ornithology in New Zealand and specifically in Hokianga in 1835–41, at a time of social and ecological change as New Zealand became a British colony.

We took two approaches to the search:

Known collectors in Hokianga

We first checked the known collectors of birds in northern New Zealand at the time. The naturalists of the four exploring expeditions (American, British, and two French) that visited New Zealand in 1838–41 all collected birds in the Bay of Islands; however, they did not venture further to Hokianga (Andrews 1986). Ernst Dieffenbach, the naturalist employed by the New Zealand Company, collected widely in New Zealand at this time and did pass through Hokianga, in early February 1841 (Dieffenbach 1843). However, he was not in Hokianga long enough to have made the collection of birds there and, even if he did, there is no indication that he was acquainted with William Stones to have him convey them to London. Dieffenbach is most unlikely to have been our collector.

Then there are the lesser-known collectors. Searches of journals and correspondence of early visitors and settlers in Hokianga, and also records of New Zealand bird specimens received in Britain in the 1830s and 40s, identified five visitors or settlers who are recorded as collecting or presenting birds from Hokianga at that time. All five primarily collected kiwi. Although it may not be directly relevant to our search, this does call for some explanation.

The quest for kiwi is a well-known chapter in the history of ornithology in New Zealand. The kiwi had puzzled European naturalists ever since they first learned of it when a skin reached London in 1813. That specimen was later acquired by Lord Derby, the president of the Zoological Society of London, and in 1833 he exhibited it at a meeting of the society for the reading of a paper by William Yarrell confirming, against doubts expressed by some Continental naturalists, that it was a real bird, and summarising the little that was known about it (Yarrell 1833a). Yarrell concluded with an appeal to Britons abroad in New Zealand: "it is hoped that some of our enterprising countrymen in that quarter may, ere long, succeed in acquiring additional specimens and additional knowledge, as regards both the habits and the structure of this curious race" (Yarrell 1833b). And indeed enterprising countrymen in New Zealand heard the call and made special efforts to obtain kiwi specimens and send them to Yarrell or to Derby.

This story has been told many times (Rothschild 1899; Andrews 1986, 1990) – but what has gone unremarked is just how many of the kiwi specimens sent back to Britain in this period came from Hokianga. Of the eight skins and preserved kiwi examined by Richard Owen in 1838 for his classic paper on its external and internal anatomy (Owen

1840), we can determine from his notes and other records that at least six came from Hokianga, sent by four different collectors. One further collector of kiwi from a few years later can also be identified. Here we summarise the available information on these five collectors of kiwi from Hokianga, both as possible candidates in our search for the collector of the birds of the Stones collection, but also as illustrating the role of the colonial collector in general at that time, and some of the ways the relationship operated between the leading men of science in London who wanted specimens of new and interesting birds, and the collectors out in the farthest reaches of the known world who supplied them.

1. William White was a Wesleyan missionary and then timber trader in Hokianga from 1830 to about 1845 (Clover 2018). In that time he twice returned to England; on the second visit he is recorded as bringing specimens of kiwi and tūī (*Prosthemadera novaeseelandiae*) which were "presented, through the kindness of the Rev. Mr White, by the New Zealand Association, to the Zoological Society, in October 1837" (E.G. Wakefield 1837: 332 fn, 335). Apart from that brief note, White appears to have received no thanks or acknowledgement for gifting the specimens. When they reached the Zoological Society the pair of kiwi in particular were admired as "very perfect skins" (Anon. 1838b) and were immediately borrowed by John and Elizabeth Gould to draw the well-known illustration of kiwi in their *Birds of Australia and the adjacent islands* (Gould 1838). Sixty-five years later the kiwi from White were still given special mention in the Zoological Society's history (Scherren 1905). But each time they were credited as "presented by the New Zealand Association" without any mention of White.

2. Thomas McDonnell, a timber trader in Hokianga for many years from 1831, was a more mercenary character (Lee 1997). During one of his visits back to Britain, McDonnell was asked by the Earl of Derby if he could send him birds from New Zealand. Derby especially wanted kiwi – live kiwi – for his private menagerie at his Knowsley estate near Liverpool. To make clear what he wanted, Derby gave McDonnell a picture – evidently the illustration of kiwi from Yarrell's paper. McDonnell didn't know the bird at all; indeed on returning to Hokianga in 1835 he told Derby that "none of the Europeans here, about eighty, have ever seen the species before". But "I have shewn the drawing of your bird the Kévé to several of the Native Chiefs who immediately recognized it". McDonnell managed to persuade them to provide him with a pair of kiwi, for a price ("I had some trouble but a present had its effect"), and promised to send the birds to Derby alive (McDonnell 1835).

McDonnell took the opportunity to gain a favour from Derby in return. Even before the kiwi arrived, Derby, rather unwisely, was persuaded to use his influence at the Colonial Office to have McDonnell appointed as "Additional British Resident in New Zealand" (see Spring-Rice 1834; McDonnell 1836). It did not work out well. McDonnell gained the status he craved but in practice was always at odds with the main British Resident in New Zealand, James Busby, and was soon forced to resign the position. And Derby did not get his promised kiwi. It seems they died on the voyage. McDonnell tried again: in 1837 he sent Derby a shipment of skins of kiwi and other birds, and a whole "pickled" kiwi – and again promised to send live kiwi (McDonnell 1837). The skins and pickled kiwi arrived safely (Derby passed the latter to the Zoological Society for Owen to examine – see Anon. 1838c) but nothing more. Derby never saw a live kiwi – it was not until after his death in 1851 that, with better care than McDonnell managed, one reached London to become the main attraction at the Zoological Society's gardens, the "Zoo" (Mitchell 1852).

3. Less is known about the "Dr Logan, R.N." who was acknowledged by Owen (1840) as the donor of a partial preserved kiwi received in 1838. From shipping records we identify him as Dr Francis Logan, a Scottish naval surgeon, who sailed to Sydney in 1837 as surgeon superintendent on a convict ship and then on his return voyage spent several months in Hokianga when his ship called there to take on a cargo of timber (see records of Dr Logan and the *John Barry* in Anon. 1837a, 1837b, 1838d). It appears that while in Hokianga, Logan obtained and preserved what Owen (1840) described as "the abdominal viscera, with the bones and tendons of the feet of a female Apteryx" – or in other words the discarded offal from a kiwi that had just been skinned and gutted. It is not clear how Logan had got the message that even such scraps of kiwi were wanted, but they fortuitously provided Owen with the only anatomical material he had at that time of the organs of a female kiwi, and he duly acknowledged Logan who had so "liberally presented" them to him (Owen 1840).

4. Allan Cunningham, a well-known botanical collector, spent 5 months in New Zealand in 1838 and left with a collection of plants and "also a specimen of that rarest of all the birds of New Zealand, the Kiwi (*Apteryx australis*), which I shall forward home to Mr Yarrell, for the Zoological Society" (Cunningham 1838a). He sent both the skin and the preserved body of the kiwi, noting that it had been obtained by Māori "on the Hokianga river" (Cunningham 1839).

Cunningham was duly acknowledged by the Zoological Society for the kiwi specimens, and his enclosed "Rough notes ... on the habits of the Apteryx Australis" were read at a meeting of the Society and printed in its *Proceedings* (Cunningham 1839). And although Owen had completed his paper and it was already with the printer, he did manage to have a late footnote added to it drawing one final conclusion about kiwi morphology from Cunningham's preserved kiwi, and acknowledging him for it (Owen 1840: 297). Cunningham thus had the thanks of the leading men of science, but in the gentlemanly correspondence with the Zoological Society he did not mention how much the kiwi had cost him. As he privately told a friend he had had to pay his Māori supplier £1/8/- (equivalent to about $NZ450 today) for it (Cunningham 1838b).

5. Another Hokianga collector a few years later was not responding directly to the appeal from the Zoological Society. Richard Day, an Irish doctor, briefly visited Hokianga in 1838-39 (Anon. 1838e, 1839b) and later settled there as tutor to the mission children (Clover 2018). In 1846 he sent a kiwi specimen from Hokianga to the Cuvierian Society in his home town, Cork (Anon. 1846).

Might any of these collectors of kiwi have also collected the birds presented to the British Museum by Rebecca Stones? That collector must have been in Hokianga long enough to have obtained all the birds in that collection, and to become acquainted with William Stones during his time in New Zealand in 1839–41 to entrust him with conveying the collection to London. On this basis Cunningham and Logan can be immediately ruled out: they each had left Hokianga well before William Stones arrived. McDonnell was not in Hokianga when William Stones was there: McDonnell had left in 1838 (Anon. 1838e) before William Stones arrived and did not return until just after he left in July 1841 (see records of McDonnell on *Sir James Falstaff* and William Stones on *James* in Anon. 1841a, 1841d). Richard Day can also be ruled out: he had been in Hokianga for a few months when William Stones arrived on 18 March 1839, but he left with the *Coromandel* only 7 days later (Anon. 1839c) and did not return to Hokianga until after William

Stones had left in July 1841. William White, however, after returning on the *Coromandel* in December 1838, was based in Hokianga during the time William Stones was there, although he did much travelling beyond the district (Gittos 1982). In fact, William Stones spent much of his time there living with White's brother and close neighbour Francis White. Thus, of the five known collectors of kiwi in Hokianga only William White could also have been the collector of the Stones collection.

Evidence from the bird specimens and how they were obtained, prepared, documented and despatched

In deciding whether William White, or some other collector active in Hokianga at this time might have been the collector of the Stones collection, we considered what further evidence about the collector could be drawn from the birds themselves and the notes about them in the Museum accession register. This examination also reveals much about the practices of ornithology of the time. The following discussion is organised around the processes involved in collecting a bird specimen: obtaining the bird in the field, skinning and preserving it, recording field notes on its locality and other details, and packing and consigning it.

1. Obtaining the bird. Some of the birds in the collection would have only been obtained with the assistance and assent of local Māori. Clearly this was the case with kiwi. As the accounts of the early collectors of kiwi indicate, "without the aid of the New Zealander [i.e. Māori] it cannot be obtained" (Cunningham 1839). From the number of kiwi that were collected in Hokianga it appears that Māori there – perhaps Mohi Tāwhai and his Te Māhurehure hapū – were more amenable than those elsewhere to providing kiwi to favoured pākehā (European) friends. However, as Tāwhai told the group William Stones came with when they asked for kiwi, the birds were highly valued and were not to be taken without consent, or without payment:

> "Being noble birds, the price demanded was one English sovereign in gold for each specimen, as chief's royalty, and remuneration of one dollar for the man ordered to catch them... [Tāwhai] intimated that the price would henceforth be higher, he having tapued the Kiwis in that range of mountains ... so that no one in future would dare to kill a Kiwi without his authority" (Stones 1858a: 186).

One gold sovereign plus one dollar was much the same price as the £1/8/- paid by Allan Cunningham for his kiwi in Hokianga in 1838. Perhaps Tāwhai supplied that one as well, and had a standard price for them. But he did not provide kiwi to any pākehā who asked for one. Ernst Dieffenbach, for instance, was unable to obtain kiwi anywhere, even in Hokianga, despite offering "a liberal reward to any native who would bring me one". He blamed this on "the indolence of the natives" (Dieffenbach 1843: 230); however, it was more likely that they could not be induced to transgress tapu for him without their rangatira's assent. William Stones, or someone in his group, must have had a better understanding and a closer relationship with local Māori, and Tāwhai in particular, to be provided with kiwi.

Black petrel or tāiko was another bird that would probably have been supplied by Māori. The species was unknown to European visitors or settlers of the time. For instance, Richard Taylor, missionary at Waimate North from 1839–43, recorded the name "taiko" for "a sea bird" but thought it was synonymous with "takupu" – the Australasian gannet (*Morus serrator*) (see Taylor 1848). However, tāiko were well-known to Māori. Its nesting colonies had traditionally been a valued food resource and the rights to them were jealously guarded. In Hokianga an incident from several generations earlier was still recalled when a trespasser had taken birds from the nest burrows on Panguru mountain in defiance of Ngāti Manawa's protective prohibition or rāhui over it; he was pursued and killed for that transgression (Tate 1986: 7). If, as appears likely, the tāiko in the collection was obtained from local Māori, our collector must again have had a close relationship with them for this to be allowed.

In Hokianga, Kiwi were hunted by Māori at night (Cunningham 1839), and tāiko were taken from their nest burrows; however, the other birds in the collection would probably have been obtained by shooting. This would have required skill with a "fowling piece," as it was called at the time – a muzzle-loading gun designed for game-shooting. The European settlers and missionaries were accustomed to shooting birds, particularly New Zealand pigeon (*Hemiphaga novaeseelandiae*), as food. The missionary William White had not been in New Zealand very long when he bragged to a friend that "I begin to feel my ability in shooting ... I went out on Friday to shoot pigeons – shot ten and two ducks, which will supply us with fresh meat for three or four days" (White 1823). Māori had also become adept with the fowling piece. "They are excellent marksmen," a visitor to the Bay of Islands noted in 1833; "The natives shoot hundreds [of pigeon] with small pebbles which are used as a substitute for shot" (Hodgskin 1841: 13, 28). It is certainly possible that other birds in the collection, especially those that were uncommon or unusual at that time, may also have been obtained by Māori and offered to the European collector as someone known to be interested in such things – much as happened with the young Walter Buller, growing up on the Wesleyan mission station in Kaipara in the 1850s (Buller 1871).

2. Preparing the bird as a museum specimen. After the bird was obtained, whether by a Māori hunter or directly by the European collector, it had to be prepared as a museum specimen. This was not necessarily done by the collector, but if it was a different person they must have been someone closely associated, as it had to be done soon after the bird was killed.

Preparing a bird as a museum specimen required a particular procedure that would not have been known to Māori, or to many of the European settlers and missionaries. At this time museum specimens were expected to be stuffed and mounted for display: European museums, including the British Museum, still followed the old tradition of putting on display as many as possible of their specimens, especially the rarer ones (Sharpe 1887). The procedure for preparing a bird as a museum specimen was thus intended to make it ready for stuffing and mounting, and was set out in popular manuals of taxidermy of the time, written "for the use of travellers, conservators of museums and private collectors" (Brown 1833; see also Anon. 1820 and Swainson 1822).

The first step was to carefully skin the bird, keeping the feathers clean and undamaged while removing the body, leaving the disembodied skin with its head and beak, legs, wings, and tail all intact and attached. There was a specific procedure for achieving this, set out in the taxidermy manuals. An important part of the procedure was the removal of any residual soft tissue from the skin and remaining bones. If this cleaning was not done carefully, the specimen would soon decompose, as shown by the first kiwi received by the Zoological Society after William Yarrell's appeal in 1833. Given the great interest in kiwi, William Yate of Waimate had sent the skin "as it is", explaining that "One of my [Māori] boys took off the skin" but before long "the legs rotted off" (Yate 1834).

Then there was a further step to try to ensure the preservation of the specimen. Even with careful skinning and cleaning, bird skins or stuffed birds were very vulnerable to insect attack. Up to the 1820s the curators of the natural history collections at the British Museum had held regular bonfires of bird specimens that had become too moth-eaten or disintegrated to leave on display (Stearn 1981). However, a new preservative preparation developed in France promised to overcome this problem. From 1820 the British taxidermy manuals included the use of the French "arsenical soap," and gave recipes for making it (Anon. 1820; Swainson 1822). In 1825 another equally toxic preservative, "corrosive sublimate" (mercury dichloride) was promoted by the eccentric traveller and taxidermist Charles Waterton (Waterton 1825), and this also became widely used. The most popular taxidermy manual of the time (Brown 1833, reprinted at least 30 times to 1899) gave recipes and instructions for using either or both arsenical soap and corrosive sublimate. The use of these preservatives became standard practice for collectors and museums in Britain and beyond (Rookmaaker *et al*. 2006). Even in Hokianga: in 1835 Thomas McDonnell assured Lord Derby that the bird-skins he was sending from there had been "preserved with arsenical soap" (McDonnell 1835).

Examination of the birds of the Stones collection still held in the Natural History Museum confirms that the skins had been expertly prepared, and well preserved. They remain in good condition (Fig. 1). Whoever prepared them clearly had some skill and experience in the procedure of preparing and preserving bird-skins.

3. Documenting the specimen. The mode of documenting museum specimens was also set out in the taxidermy manuals of the time: "A journal ought to be kept detailing all ... the places in which they were killed, and the colour of their eyes, together with any information that can be procured of their habits from the natives" (Brown 1833). Then, to link these notes with the particular specimen they referred to, the notes for each bird were to be numbered, and a tag with the same number indelibly inscribed on it attached to the corresponding specimen (Anon. 1820; Brown 1833). This procedure appears to have been followed with the Stones collection: although no separate journal of notes or numbered tags or other labels have been preserved, the notes recorded in the museum accession register do appear to have been transcribed from such a journal. In our search for the collector of the birds these notes have proven to be particularly informative.

As recommended by the taxidermy manuals, the notes give eye colour for most of the birds. This was wanted for the purposes of taxidermy: so that the bird-skins could be given artificial eyes of the right colour when they were set up and mounted for display. For our purposes, the notes on eye colour are significant because they were necessarily recorded when the bird was fresh or being skinned, which gives some confidence that the notes were indeed made by the collector or preparator rather than added later.

The notes record that all the birds were from "River Hokianga", which, in the terminology of the time, referred to the wider Hokianga area. The restriction to that area suggests the collector and preparator were probably resident there.

The notes also identify each of the birds by its Māori name. No English names are given. In this regard the notes to the Stones collection may be compared with the list of the birds sent by McDonnell to Derby in 1837, which has a mix of Maori and English names: "Ká Ká, Duck, Pigeon, 2 Birds of Passage ... Owl, Tui, ... Peewáká wáká, New Zealand Paroquet" (McDonnell 1837). By contrast, the names in the notes to the Stones collection are all Māori names, indeed standard Māori names for the birds, as still used today. Some of the birds were then unknown to European science; however, they were all known and named by Māori. The black petrel for one could only have been identified by name, tāiko, by Māori. The recorder of these notes clearly had some proficiency in the Māori language and a close relationship with local Māori to be given the names of the birds.

Furthermore, again by contrast with McDonnell's list, the Māori names in the notes to the Stones collection are written in the standard spelling as used today. The recorder of these notes was familiar with the latest orthography of Māori – the way the language was put into written form and spelled using the English alphabet. The orthography of written Māori had been developed by the missionaries in New Zealand, with the help of the Cambridge linguist Samuel Lee (Kendall & Lee 1820), and by the 1830s the orthography they used in their publications was much as it is today, apart from one change pioneered by the Wesleyan missionaries in Hokianga – the use of the letter combination or digraph "wh" to distinguish and represent a distinct sound or phoneme in spoken Māori. The "wh" first appeared in material printed by the Wesleyan mission press in 1841 and did not become more widely used until several years later (Williams 1924; Parkinson & Griffith 2004). It is significant therefore that one of the names of the birds as recorded in the accession register in 1842 is written as "tuturiwhatu" rather than "tuturiwatu" as it was usually written at that time, for instance by the Church Missionary Society (Anglican) missionaries Yate (1835) and Taylor (1848). The names of the birds may well have been provided by Māori but they were probably written down by someone associated with the Wesleyan mission in Hokianga.

Finally, to complete this survey of the process of making museum specimens:

4. Packing and despatching the collection. As the taxidermy manuals put it: "We must now speak of the method of packing zoological objects, so that they may arrive in Europe in a good state of preservation" (Anon. 1820):

> "...attention is required to see that [the skins] are well preserved from the attacks of insects... They are then slightly packed with cotton, but just sufficient to prevent the inside of the skins from pressing on each other. ... they should be each wrapped in paper, and closely packed in a box; and camphor, preserving powder, and strong aromatics, strewed amongst them, to prevent them being attacked by insects ... The box in which they are packed must be pitched all over to prevent damp and air from reaching the inside"
>
> "... when the cases are filled, closed and covered with pitch, they should be enveloped in an oiled canvas, and placed in a part of the vessel ... sheltered as much as possible from excess heat, and out of reach of rats" (Brown 1833; Anon. 1820).

The present good condition of the birds of the Stones collection held in the Natural History Museum confirms not only that they had been well prepared and preserved but also that they were well protected from insect and rodent attack and all the other perils of a long sea voyage. Someone in Hokianga knew not only how to prepare and preserve them, but also how to pack them well, before William Stones stowed them on the *James* as far as Hobart, and then on another ship to carry them safely to London.

When the collection was received at the British Museum most of the birds would have been mounted and put on display, as was the normal practice at that time. Examination of the birds confirms that although all are now skins, at least six of the 14 now remaining had originally been mounted for display (many have holes in the feet from the wires used in mounting). However, years

later museum practice changed toward more naturalistic displays, with smaller groups of birds set in dioramas representing their appropriate natural habitats. The British Museum progressively dismantled its old display cabinets and took down most of the mounted birds and converted them back to skins, which have since then been stored out of the light to preserve them for scientific study (Sharpe 1906; Stearn 1981). An indication of when this was done can be gained from the *Catalogue of the birds in the British Museum* (British Museum 1874–1898) which recorded the entire museum bird collection during this period with an indication whether each specimen was then "standing" (i.e. mounted) or a skin; the entries for the birds of the Stones collection show that the process of converting them from mounts back to skins was under way by 1884 but was still not completed in 1895. Most of them had thus been on display for 40–50 years before they were taken down and stored in more favourable conditions. However, the bird-skins have lasted surprisingly well. After being prepared in Hokianga some time before 1842, they survived the sea voyage to London and then years on display exposed to the light, but now, after more than 180 years, they are still in good condition.

The probable collector

From all the evidence from the bird specimens and the notes about them we can draw some inferences about who obtained, prepared and documented them. At least some of the birds were obtained by Māori in Hokianga, but all were prepared and preserved as museum specimens by someone with some skill and experience in European taxidermy procedures. And they were documented with details of their location, eye colour, and Māori name by someone who had close relations with local Māori and proficiency in oral and written Māori language – probably someone associated with the Wesleyan mission in Hokianga.

This description points again to William White, perhaps in association with others of his extended family living in Hokianga: his self-effacing and capable wife Eliza, and his brother Francis White living close nearby with his wife Jane, their sons William jnr, 20, and Titus, 19, and six younger children. And William Stones, who lived for much of his time in Hokianga with Francis White's family, evidently also played a part in making the collection.

William White had been a Wesleyan missionary in New Zealand since 1823 and leader of the Hokianga mission from 1830. He was a hot-tempered man who fell out with his own mission colleagues, but developed close relations with local Māori and made himself very unpopular with the more mercenary of the local settlers (especially McDonnell), by taking the side of Māori against them (Gittos 1982). White was proficient in the Māori language both as an orator and in writing, and had been one of the first to use the "wh" digraph in written Māori (see his contribution on Māori language in E.G. Wakefield 1837: 299–301). And, as shown above, he had previously presented bird skins in London, skins that were judged "very perfect". He, or someone close to him, was skilled in preparing bird skins. Even the absence of any indication naming the collector of the birds presented to the British Museum in 1842 is consistent with White, who as noted above had presented those bird skins in London in 1837 without seeking any acknowledgement and had allowed others to take the credit for them.

William White had returned to Britain in 1837 primarily to face charges concerning his conduct in Hokianga, which resulted in him being dismissed from the Wesleyan mission (Gittos 1982). He then sailed back to Hokianga in 1838, just ahead of William Stones. In fact, White's declared plan to join in the lucrative trade in kauri timber from Hokianga and Kaipara may have been what inspired young Stones with the idea of going there in the hope of making his fortune too. However, William White's enterprise did not prosper – he lost a whole shipload of kauri timber, and almost his life, when the ship he had chartered to carry his cargo to Britain was wrecked on the Kaipara bar in April 1840 (Gittos 1982).

William Stones did not make his fortune in New Zealand either. He took a small role in Francis White's timber business; however, by April 1841 he was reduced to appealing to the new Governor of New Zealand for a paid position: "More than two years have elapsed since my arrival in this Country, but not finding my situation answer my expectations, I am induced to apply to your Excellency for an appointment to some vacant Clerkship in the Government service" (Stones 1841). He was offered a position as "extra clerk at five shillings a day" (which puts into context the price Tāwhai demanded for kiwi – nearly a week's work for each one). However, William Stones decided to return home to London instead. He left in August 1841, evidently carrying the collection of bird-skins to present to the British Museum.

DISCUSSION

Why was the collection presented to the British Museum?

If it was William White who assembled the collection, why was it presented to the British Museum rather than the Zoological Society where his kiwi had gone earlier? This was in fact a time of contrasting fortunes for these two institutions. The Zoological Society had received so many donations of zoological specimens that its museum collection was growing beyond the Society's capacity to display and care for it. In 1841 the museum collection was put into storage while the Society's Council considered how to proceed (Scherren 1905). The British Museum on the other hand, after years of somnolence and decay (especially of the bird collections), was beginning a period of rapid growth and development. A searching parliamentary inquiry in 1835-36 into the museum's "condition, management and affairs" had forced its governing Trustees to make some changes, particularly in its natural history department (Gunther 1980). In 1837 that department was divided into separate mineralogy, botany, and zoology branches, each with increased funding. Registers of Accessions were initiated to document and keep track of all specimens received. And J.E. Gray, a junior wage-worker in the museum who had proven himself to be the most knowledgeable and insightful of all the witnesses questioned by the parliamentary inquiry, was finally given an official appointment as an Assistant in the zoology branch. Even before he became the Keeper (head curator) of the zoological branch after the retirement of the incumbent in 1839, Gray set out to improve and enlarge its collections of mammals, birds, and other animals to make them greater than any in Europe, even if he sometimes had to spend some of his own (or his wife's) money when the government funding was insufficient (Gunther 1980). He purchased many specimens and collections for the museum, and he found donors who gave many more. It was probably at his recommendation that in December 1837 the Museum Trustees made a general appeal for more natural history specimens for the museum. This appeal was communicated through the governors of all British colonies, Royal Navy captains, and others, along with instructions for potential collectors on "the selection and preservation of mineralogical, zoological and botanical specimens," including the making and use of arsenical soap. The appeal for specimens and the instructions for collectors were duly printed in newspapers in colonies as far as Australia (Anon. 1838f).

Whether that appeal reached Hokianga just as the earlier appeal for kiwi specimens for the Zoological Society had done is not clear. But there must have been some communication regarding specimens for the British

Museum. William White and his family, or whoever the collector in Hokianga was, would hardly have spent so much time and money obtaining and preparing the birds and conveying them half way round the world unless they knew the museum wanted them.

Adding to the first list of the birds of New Zealand

What was the significance of the Stones collection presented to the British Museum in 1842? From the British perspective, it was just one among many sent back from the colonies – part of the great imperial scientific enterprise in which British travellers, naval officers, colonial administrators and colonists around the world collected specimens of plants and animals and sent them back home for study and display. Specimens flowed to the Zoological Society, to the Royal Navy's Haslar Hospital Museum, but especially, once it began its reorganisation, to the British Museum, which, as J.E. Gray (1843) described it, was "the National Collection of the mother country, which should be the richest in the natural curiosities of its different colonies."

Among this great influx of specimens from around the world, the arrival of the birds from Hokianga in May 1842 was particularly timely. New Zealand plants and animals were of special interest to British naturalists at that time, not only because they were new and unusual but also because they were expected to soon disappear. Just as had been seen in other isolated island territories such as Mauritius or Saint Helena, it was expected that European colonisation of New Zealand would bring displacement and extinction of the native plants and animals (Hooker 1844), and especially the peculiar flightless birds – that the kiwi would disappear like the dodo (Strickland 1844.) With this in mind, the British Association for the Advancement of Science (BAAS) had commissioned two experts to survey "the present state of our knowledge of the Zoology of New Zealand" (British Association for the Advancement of Science 1842: xx). Dr J. Richardson of the Haslar Hospital Museum was to survey the fishes, and J.E. Gray of the British Museum the mammals, birds, reptiles and invertebrates. As Richardson (1843) explained, "It is of importance to zoology that the number, range and habits of the animals should be ascertained and recorded before the din and bustle of civilisation scare them from their native haunts".

The bird section of the survey was compiled by the British Museum assistant in charge of the bird collection, J.E. Gray's younger brother George Gray. Initially it was entirely a book exercise, as the British Museum then had no New Zealand birds apart from the kiwi presented by Lord Derby in 1838. George Gray scanned the literature describing species of birds from New Zealand, and also two recent books about the country by a missionary (Yate 1835) and a settler (Polack 1838), which gave accounts of the birds. George Gray was a very conscientious worker and expected to have his section of the survey ready for his brother to present at the BAAS meeting in June 1842.

However, in May, only a few weeks before the BAAS meeting, Rebecca Stones arrived at the Museum with the collection of birds from Hokianga. George Gray hurriedly examined them to find whether there were any more species to add to his list of New Zealand birds. Most of the birds in the collection could be readily identified as known species, although three of these had not been recorded from New Zealand before: long-tailed cuckoo, Pacific golden plover and black petrel (initially identified as a white-chinned petrel *Procellaria aequinoctialis*, not previously recorded from New Zealand). Other birds in the collection were more difficult to identify. The Māori names they came with were helpful here, as they enabled George Gray to match the birds with the accounts by Yate (1835) and Polack (1838), who used the Māori names. This appears to have helped him identify the hihi in particular. As noted above, only the striking black, white and yellow male hihi had been seen in Europe up to this time and the description of the species (as *Meliphaga cincta* by du Bus de Gisignies 1839) was thus based on the male. The bird in the Hokianga collection looked like a *Meliphaga* (a honeyeater), and it had the prominent rictal bristles like whiskers around its beak as described for *Meliphaga cincta*. However, its olive-brown plumage was quite different from the description of that species. It appears that the Māori name the Hokianga bird came with, "Kotihe", led George Gray to the account by Yate (1835) of a bird under this name, which noted that "The male is considerably larger than the female; and has a much more beautiful plumage" and then gave a description of the male which matched du Bus' description of *M. cincta*. George Gray thus identified the Hokianga bird as a female of this species.

Then there were two birds which appeared to be entirely new species, or at least birds which were "undescribed": not having been given scientific names. George Gray quickly named the banded rail as *Rallus assimilis* and the bittern as *Botaurus melanotus* and added them to the list of New Zealand birds as well. Another bittern specimen had just arrived at the museum in a collection from Adelaide, South Australia (specimen NHMUK 1842.6.29.45) which was clearly the same species as the Hokianga, New Zealand specimen, and so he added a note that his *B. melanotus* was "Also found on the Murray, South Australia" (G.R. Gray 1843). In the rush to name these species and complete the list he had neglected his usual checks and overlooked the fact that in Australia the bittern had already been named, as *Ardea poiciloptila* by Wagler (1827), which had precedence over his name. However, under either name it was still new to the New Zealand list. It made five species from the Stones collection added to the list of New Zealand birds.

Shortly after the Stones collection, even more New Zealand birds arrived: 38 specimens collected by Dr Ernst Dieffenbach and presented to the British Museum by his employer, the New Zealand Company (J.E. Gray 1843). By the time George Gray had added the new species from this collection as well, his list of the birds of New Zealand had reached 84 species. It was too late for the BAAS meeting (and new material had also delayed other sections of the survey) and so J.E. Gray arranged to have the whole survey published instead as an appendix to Dieffenbach's forthcoming book on New Zealand, which came out in January 1843 (Dieffenbach 1843). The birds from the Stones collection were thus incorporated in this first published list of the birds and other animals of New Zealand – a baseline list of the known fauna before the full impact of European colonisation.

The Māori contribution

The Stones collection differs from other collections from New Zealand at that time not only by being assembled by a resident European settler rather than a visiting explorer or commercial collector, but also for the significant assistance from Māori in obtaining the birds. With Māori assistance the settler collector was able to obtain more of the occasional, inconspicuous and cryptic birds that passing explorers and visitors had missed, and to record them all by their Māori names. The record of Māori involvement is of particular interest in that, most unusually in the records of early ornithology in New Zealand, one of those Māori is known by name. Mohi Tāwhai arranged the capture of the kiwi and perhaps other birds for the collection, and charged a fair price for them. He may have also been the source of kiwi obtained earlier by other collectors in Hokianga, for the same price.

Tāwhai was a significant figure in Hokianga as rangatira of his Mahurehure people, respected as a peacemaker in

wider disputes among iwi, while meeting the challenges of the new Pākehā world as well. He was among the rangatira who signed He Whakaputanga (the Declaration of Independence of the United Tribes of New Zealand) in 1836 and Te Tiriti (the Treaty of Waitangi) in 1840 (Lash & Davidson 2017). He maintained notably friendly relations with the missionaries and settlers and their children in Hokianga. Hannah, Francis White's young daughter, always remembered how as her father was leaving to sail back to Britain in 1840 he turned to Tāwhai and said "Now, Moses, you take care of my wife and children while I am away." And he did (Martin 1991).

Tāwhai's role in making the Stones collection of birds was recorded only in William Stones' fictionalised account of his time in New Zealand (Stones 1858a). When the collection was received by the British Museum no record was kept or acknowledgement made of any of those, Māori or European, who had been involved in obtaining and preparing the birds. The museum customarily recorded the person or organisation who presented specimens – often it would be an aristocratic donor who would expect due acknowledgement and to see their gift on display – but the lower classes whose efforts had provided and prepared the specimens generally went unnoticed. If there were any labels or other documentation with the Stones collection they were not retained, apart from the notes of eye colour and Maori names, and those were ignored when George Gray gave scientific names to the new species. That process and the place of indigenous names in zoological nomenclature will be the subject of another paper.

CONCLUSION

In summary then, the "mysterious Miss Rebecca Stone" who presented the collection of birds from Hokianga to the British Museum in 1842 is identified as Rebecca Stones, later Waterlow, of Hartshorn Wharf, St Katharine by the Tower of London. And it was not her, but her brother William Stones, who visited Hokianga and returned with the collection of birds.

From the brief account in William Stones' lightly fictionalised account of his time in Hokianga, taken together with all the circumstantial evidence from the bird specimens and the notes on them as recorded in the museum accession register, we can reconstruct much about the processes and the people involved in obtaining, preparing, documenting and delivering the birds to the British Museum. For the pair of kiwi and probably others, it began with the Māori hunters who were sent by their rangatira, Mohi Tāwhai of Waimā, to obtain the birds to provide (for a price) to the pākehā collector. We suggest that this was most likely to have been the former Wesleyan missionary in Hokianga, William White. We suggest that he, or someone close to him, skinned, cleaned and preserved the birds as museum specimens, and made notes on them, identifying them by their Māori names as provided by Tāwhai or some other Māori informant. They were then carefully packed away to be conveyed to London. This role fell to the visitor, William Stones, who had spent much time with the White family. When he decided to return home, he evidently took the package of birds as he sailed from Hokianga to Sydney and Hobart and on to London. There it was his younger sister Rebecca Stones who took the birds across the city to the British Museum in Bloomsbury, where on 17 May 1842 they were entered into the accession register as presented by her.

Altogether, the Stones collection epitomises the mode of ornithology of that time, centred in Europe: a collector in the colonies or further afield obtaining birds (usually by shooting them) and preparing them as specimens to provide to naturalists back in one of the metropolitan centres of Europe, in this case London, where they would be classified and named according to the conventions of Linnaean zoological nomenclature. The collection of birds from Hokianga was one small part of the European scientific enterprise to collect, classify and name plants and animals from all around the world.

The Stones collection also provides a valuable record and reminder of some of the birds that were present in Hokianga in 1841. At the time, the collection provided records for the first list of the New Zealand avifauna compiled by George Gray in 1843, which was intended as a baseline list of the birds of New Zealand before the rising tide of European colonisation swept them away. However, the process of displacement and extinction of native species has not been quite as rapid nor as complete as the naturalists in Britain then expected. Not one of the birds of the Stones collection is yet extinct, although New Zealand falcon (*Falco novaeseelandiae*), hihi, yellow-crowned parakeet (*Cyanoramphus auriceps*), long-tailed cuckoo and tāiko are no longer found in the Hokianga region (Robertson *et al.* 2007). In fact, with the assistance of growing conservation efforts, half of the birds found in 1841 are either still common there (tūī, ruru, banded rail), or declining but still present (bittern, North Island kokako, and even kiwi). Despite all the early predictions of their imminent demise, kiwi still survive in the hills overlooking Waimā, where 180 years ago Tāwhai's hunter found the pair that Rebecca Stones presented to the British Museum.

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Changes in the bird community of Auckland Domain's urban forest between 1987 and 2020

MATT J. RAYNER*
Auckland Museum, Private Bag 92018, Auckland, 1141, New Zealand.
School of Biological Sciences, University of Auckland, 3A Symonds Street, Auckland, PB 92019, New Zealand,
ORCID 0000-0002-1168-6699

JOSIE A. GALBRAITH
Auckland Museum, Private Bag 92018, Auckland, 1141, New Zealand, ORCID 0000-0003-3869-7977

Abstract: The Auckland Domain is the city's oldest park and contains over 70 ha of contiguous, mature urban forest. Five-minute bird counts were made across one year within the domain forest in 2019 and 2020 and compared with counts conducted in 1987 and 1988, using the same methods and at the same survey sites, to investigate changes in the structure of the urban bird community. The abundance and species richness of native and introduced birds increased between the count years and there was structural change within the community driven by increases in the abundance of forest-adapted endemic species, tūī *Prosthemadera novaeseelandiae*, grey warbler *Gerygone igata*, and kererū *Hemiphaga novaeseelandiae*, and declines in generalist native species, silvereye *Zosterops lateralis* and fantail *Rhipidura fuliginosa*. Tūī showed the most profound increase in abundance between count years, reflecting regional conservation management of mainland and island forest habitats that benefit this highly mobile species. Increased abundance of eastern rosella *Platycercus eximius* and common myna *Acridotheres tristis* also altered community structure between count years, indicative of ongoing colonisation by these exotic species in the Auckland region since their introduction to the North Island. The fact that both these species compete with native taxa for nest cavities within forests is of concern. Our results reinforce the need to manage and protect maturing urban forests to enhance native bird populations. Such actions will also support the recovery of native bird populations at a landscape scale.

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Key words: Five-minute bird count, species abundance and diversity, pest control, forest succession

INTRODUCTION

New Zealand's native forest bird populations have been significantly impacted by human settlement through loss of habitat, increased competition with introduced birds, and the catastrophic impact of introduced mammalian predators and herbivores (Krull *et al.* 2015). These impacts have seen the extinction of some species and the retreat of others to remote forest habitats in protected mainland and offshore islands (Diamond 1984; Tennyson & Martinson 2007), though a suite of more adaptable species have maintained populations in human modified forested landscapes (Miskelly 2018; Fitzgerald *et al.* 2019). One of the more challenging and interesting of these habitats are highly modified urban 'forests' constituting either a matrix of backyard emergent vegetation or remnant isolated pockets of mixed native and exotic vegetation within the urban landscape. How forest bird communities respond to the increasing impacts of urbanisation is of interest in the field of urban ecology (Galbraith *et al.* 2015).

Auckland, with over 1.6 million people, is New Zealand's largest urban centre, and is experiencing rapid urban population growth. For example, between 1980s and today the city's central business district (CBD) increased from approximately 2000 residents to over 50,000 and housing intensification and relaxed tree protection laws have seen the removal of much urban forest habitat (Wyse *et al.* 2015). On the edge of Auckland's CBD, the Auckland Domain (275 ha) is the city's oldest park,

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*Correspondence: *mrayner@aucklandmuseum.com*

Table 1. Species recorded during 5-minute point counts conducted within urban forest patches in 1987–1988 and repeated in 2019–2020, in Auckland Domain, Auckland, New Zealand. Species are listed in order of mean abundance across all counts (N = 379). An indication of which species have been included for each analysis is also given. Species shaded in grey showed significant differences in abundance between survey years in GLMM models.

	Species	Scientific name	Primary diet†	Occupancy (%)			Mean abundance			Overall richness measures	Community analysis	Species response GLMMs
				1987/88	2019/20	Overall	1987/88	2019/20	Overall			
1	Silvereye	*Zosterops lateralis*	I, F	91.80	71.74	82.06	3.19	2.364	2.789	X	X	X
2	Eurasian blackbird*	*Turdus merula*	G	78.46	88.04	83.11	1.559	2.179	1.86	X	X	X
3	Tūī	*Prosthemadera novaeseelandiae*	O	21.54	90.22	54.88	0.236	2.663	1.414	X	X	X
4	New Zealand fantail	*Rhipidura fuliginosa*	I, F, N	83.08	67.94	75.73	1.415	1.299	1.359	X	X	X
5	Grey warbler	*Gerygone igata*	N	43.59	64.13	53.56	0.518	1.038	0.77	X	X	X
6	Eastern rosella*	*Platycercus eximius*	I, F	1.03	54.89	27.18	0.01	1.109	0.544	X	X	X
7	Chaffinch*	*Fringilla coelebs*	G	32.82	33.70	33.25	0.497	0.511	0.504	X	X	X
8	Song thrush*	*Turdus philomelos*	I, F	22.05	23.91	22.96	0.282	0.326	0.303	X	X	X
9	House sparrow*	*Passer domesticus*	I	3.59	23.91	13.46	0.056	0.424	0.235	X	X	X
10	Goldfinch*	*Carduelis carduelis*	G, F, H	7.18	22.28	14.51	0.092	0.359	0.222	X	X	X
11	Greenfinch*	*Chloris chloris*	G, I, F	15.39	7.61	11.61	0.272	0.087	0.182	X	X	X
12	New Zealand kingfisher	*Todiramphus sancta*	I	16.41	12.50	14.51	0.185	0.174	0.179	X	X	X
13	Common myna*	*Acridotheres tristis*	I	2.05	13.59	7.65	0.021	0.217	0.116	X	X	X
14	Common starling*	*Sturnus vulgaris*	G	6.67	4.35	5.54	0.087	0.054	0.071	X	X	X
15	New Zealand pigeon	*Hemiphaga novaeseelandiae*	I, C	0.51	3.80	2.11	0.01	0.043	0.026	X	X	X
16	Rock pigeon*	*Columba livia*	C, O	1.03	2.17	1.58	0.01	0.027	0.018	X		
17	Welcome swallow	*Hirundo neoxena*	G	0.00	2.72	1.32	0	0.027	0.013	X		
18	Spotted dove*	*Streptopelia chinensis*	I, C	0.00	1.63	0.79	0	0.016	0.008	X		
19	Australian magpie*	*Gymnorhina tibicen*	I	0.00	1.09	0.53	0	0.011	0.005	X		
20	Shining cuckoo	*Chrysococcyx lucidus*	I, O	0.51	0.54	0.53	0.005	0.005	0.005	X		

* Introduced species. † Primary dietary component/s (derived from Heather & Robertson 1996): C = carnivore (vertebrate prey), F = frugivore, G = granivore, H = herbivore, I = insectivore (insect and invertebrate prey), M = molluscivore, N = nectarivore, O = omnivore (broad diet which may include invertebrates, lizards, chicks, eggs, carrion, fruit, seeds, refuse or waste). NB: main dietary component listed first where two or more components given.

set aside for the people of Auckland in 1845, with planting commencing in 1850 (Gill 1989; Wilcox *et al.* 2004). The park supports the largest contiguous patch of forest habitat within the city's centre with over 70 ha of exotic and native forest, much planted in the mid to late 1800s, but with some remnant examples of native canopy species in the gullies. Examples of exotic canopy trees include oak (*Quercus robur*), cottonwood (*Populus deltoides*), and large araucaria trees including Norfolk Island pine (*Araucaria heterophylla*), Cook pine (*A. columnaris*), and bunya (*A. bidwillii*). Native canopy species includes karaka (*Corynocarpus laevigatus*), pūriri (*Vitex lucens*), kauri (*Agathis australis*), rimu (*Dacrydium cupressinum*), tōtara (*Podocarpus totara*), and tanekaha (*Phyllocladus trichomanoides*). Canopy heights within this forested area can reach to >20 m, with a regenerated understory of predominantly native species. This large mixed forest provides an opportunity to study the structure of an urban bird community.

Five-minute bird counts (hereafter 5MBC) are a technique widely used in New Zealand to describe composition and change in forest bird populations (Dawson & Bull 1975; Hartley 2012). In 1987 and 1988 Gill (1989) used the 5MBC technique to report on the structure of the bird community within the domain's forest habitat. Here, we report the results of a similar survey conducted 30 years later to explore potential changes in the structure of this community in the heart of New Zealand's largest city.

METHODS

We conducted 5MBCs at two sites established by Gill (1989) being 600 m apart and surrounded by forest for 100 m in all directions. At these sites we made c. 15 counts per month, typically across four to six count days, from April 2019 to April 2020 (total counts 1987–88 = 195; 2019–20 = 184). Count days were typically spaced across a month as

best as possible allowing for suitable weather conditions. 5MBC methodology followed Dawson & Bull (1975), with observers recording all birds seen and or heard whilst stationary at each count site. On a given count day three to four counts were made by experienced observers between the two counting sites, with either a single observer doubling back and forth between sites or two observers swapping between sites. Repeat counts at the same site on a day were made at least 25 min apart. Counts were made between the hours of 0900 and 1500, and only conducted in fine to reasonable weather, lacking rain or strong winds. In total five experienced observers conducted the counting work.

We utilised both multivariate parametric and nonparametric methods to assess changes in the avifauna assemblage between survey years. We used a Generalised Linear Mixed Model (GLMM) approach (Bolker *et al.* 2009) to investigate the differences in species richness (overall, native, and introduced), overall abundance, and the abundance of individual species between survey years. Models were fitted in R 4.2.3 (R Core Team 2023) using the glmmTMB function in the *glmmTMB* package. For all models survey year (1987–1988 or 2019–2020) was included as a fixed effect, along with season (spring, summer, autumn, winter) and time of day (minutes after sunrise) to account for expected seasonal and diurnal variation in counts. Site ID was included as a random effect, to account

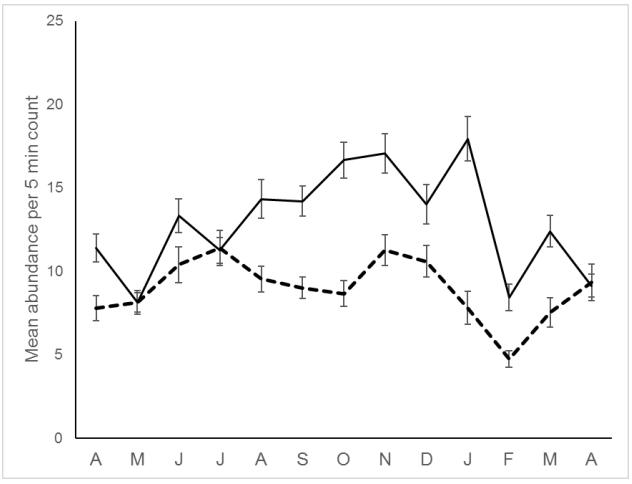

Figure 1. Monthly mean total abundance from 5-min bird counts at two sites in the Auckland Domain forest in 1987–88 (hashed line) and 2019–20 (solid line). Error bars represent ± 1 standard deviation.

Table 2. Summary of generalised linear mixed model (GLMM) results testing for an effect of survey year on community structure measures and individual species abundances in the Auckland Domain Forest, Auckland, New Zealand. Lines shaded grey indicate models where survey year had a significant effect on the response variable.

		Survey year (Reference level: 1987/88)	Season‡ (Reference level: Winter)				Time of day (min after sunrise)‡	Max. daily temp (°C)‡#	Min. daily temp (°C)‡#	Mean daily wind speed (km h^{-1})‡#	Daily rainfall (mm)‡#
	Distribution†	2019/20	Spring	Summer	Autumn	LRT					
Overall community structure responses											
Overall species richness	N	1.788***	1.308	0.726	-0.249	***	-0.002***	-0.094*	-0.020	-0.033***	0.011
Native species richness	N	0.650***	0.675	0.396	0.056	***	-0.001	-0.056*	0.003	-0.018**	-0.007
Introduced species richness	N	1.139***	0.635	0.332	-0.304	***	-0.001**	-0.038	-0.024	-0.015*	0.018
Overall abundance	NB2 (25.5)	0.457***	0.227	0.125	-0.107	***	-0.001**	-0.015	-0.009	-0.004	-0.003
Individual responses: Native species											
Silvereye	NB1 (1.05)	-0.329***	-0.286	0.056	-0.034		-0.0004	-0.016	-0.017	0.002	-0.017
Tūī	P	2.413***	0.235	0.190	-0.450	***	0.0001	-0.009	0.041	-0.006	-0.016
New Zealand fantail	P	-0.057	0.126	-0.208	0.174	*	-0.0002	-0.001	-0.005	-0.006	0.001
Grey warbler	P	0.770***	0.620	0.101	-0.148	***	-0.001	-0.049	-0.013	-0.009	-0.006
Sacred kingfisher	NB1 (0.16)	-0.103	2.187	1.084	-0.361	***	-0.002	0.053	-0.013	-0.018	-0.006
Kererū	NB1 (0.44)	2.016*	-18.77	1.167	0.745		-0.001	-0.080	0.133	-0.104	-0.032
Individual responses: Introduced species											
Eurasian blackbird	P	0.318***	0.441	0.054	-0.078	***	-0.0002	0.026	-0.040*	0.003	0.001
Eastern rosella	ZIP	4.727***	0.460	-0.267	0.144		-0.001	-0.030	-0.017	-0.0003	-0.002
Chaffinch	NB2 (1.67)	0.074	1.132	1.605	0.465	***	-0.003**	0.009	-0.093*	0.008	0.006
Song thrush	ZIP	0.175	0.308	0.170	-1.740	***	-0.0000	-0.034	0.020	-0.029*	0.024
House sparrow	NB1 (0.82)	2.284***	-0.089	0.705	-0.954	**	-0.001	-0.127	0.031	-0.026	-0.014
European goldfinch	ZIP	1.434***	1.586	0.821	0.445	***	0.002	-0.120	-0.048	-0.015	0.031
European greenfinch	NB2 (0.78)	-0.716*	-0.459	-0.820	-1.273		-0.003*	0.009	-0.056	-0.009	-0.114*
Common myna	NB2 (0.57)	2.357***	-2.166	-0.176	0.522	*	-0.002	0.123	-0.068	0.002	0.006
European starling	NB2 (0.44)	0.013	0.851	1.212	0.860		-0.001	-0.623***	0.200	-0.033	0.040

Parameter estimates are presented for each model term at the reference levels stated. Whole effects were tested with likelihood ratio tests (LRTs); significant chi-square test statistics from LRTs are indicated with: *, p <0.05; **, p <0.01; and ***, p <0.001. Species are listed by mean abundance across all counts (highest first). † Error distribution used for model: N = normal, NB = negative binomial (dispersion parameter estimate given in parentheses), P = Poisson, ZIP = zero-inflated Poisson. ‡ Included in the models as control variables. #Data from NIWA National Climate Database.

for correlation of repeated measures at the same sites. In addition, four meteorological variables were also included in the models as controls for changing climate over the timeframe: maximum daily temperature (°C), minimum daily temperature (°C), mean daily wind speed (km h^{-1}), and daily rainfall (mm). These metadata were sourced from NIWA National Climate Database (Auckland Aero weather station; https://cliflo.niwa.co.nz/, accessed 29 Jul 2020). Each count response variable was modelled using the best-fitting distribution as determined with the *fitdistrplus* package (Delignette-Muller & Dutang 2015) in R (Table 1).

To analyse changes in composition of the avian community between survey years, we used non-metric multidimensional scaling (NMDS; Kruskal 1964), permutational multivariate analysis of variance (PERMANOVA; Anderson 2001), and permutational analysis of multivariate dispersions (PERMDISP; Anderson 2006). Rare species (those present in <2% of counts; Table S1) were removed for all analyses (McCune & Grace 2002). As we were interested in changes involving dominant species within bird communities, no transformation was applied to the data before construction of the distance-matrix. NMDS ordinations were performed to visualise differences in bird assemblages, using the metaMDS function of the *vegan* package (Oksanen *et al.* 2013) in R 4.2.3. Species centroids were plotted separately to aid interpretation of observed differences in community structure. PERMANOVA was used to test whether community composition varied between survey years (Anderson & Walsh 2013), performed using the adonis2 function of *vegan* (999 permutations). A PERMDISP analysis was used to test for a difference in the variability of bird assemblages between survey years (Anderson & Walsh 2013), using the betadisper and permutest functions of *vegan* (constraining permutations within sites; based on 999 permutations).

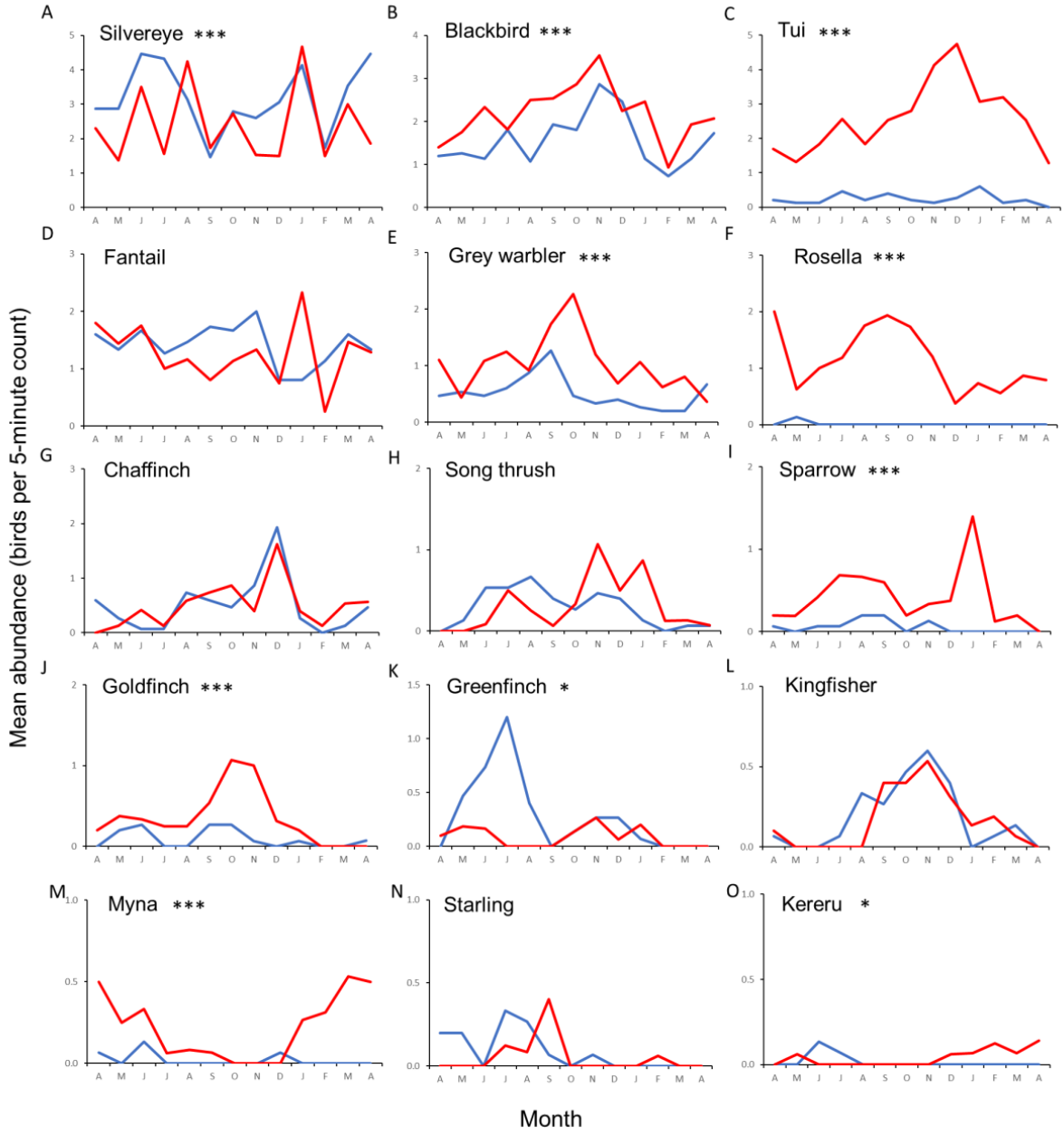

Figure 2. Mean abundance of the 15 most commonly occurring bird species present in Auckland Domain forest during year-long 5-min bird count surveys in 1987–88 (blue line) and 2019–20 (red line). Species are listed in order of mean abundance across all counts (N = 379). Note: y-axis scale varies with species. Asterisks represents statistical significance based on results of GLMM testing (see Table 2).

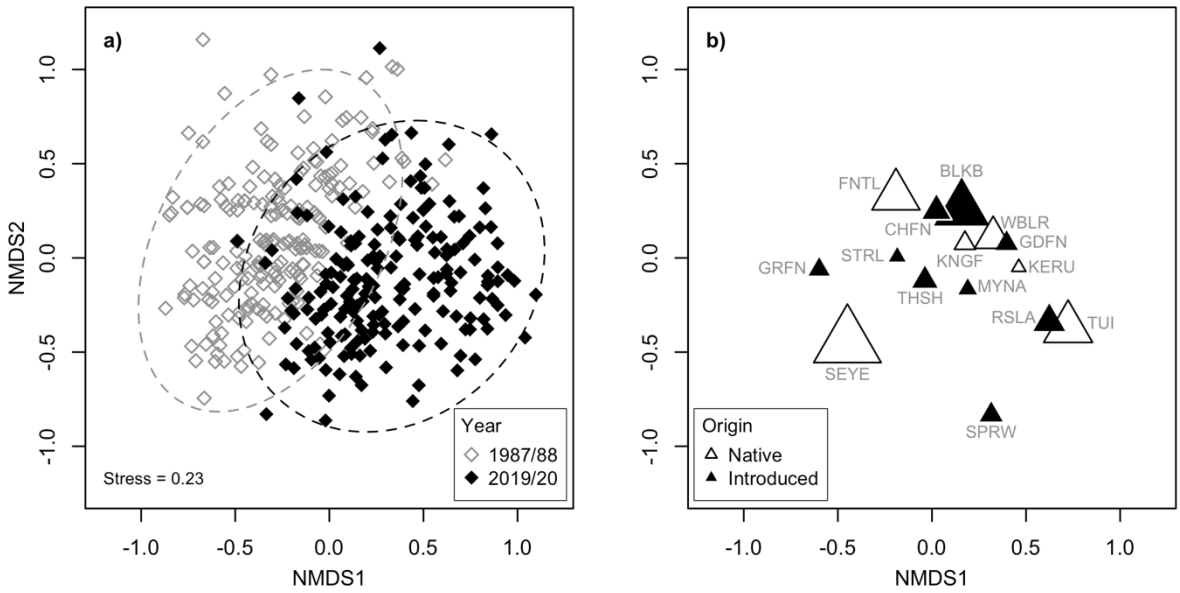

Figure 3. (a) NMDS ordination of avian community composition in 1987–88 vs. 2019–20 with hashed ellipses outlining the 95% confidence intervals for each survey year. (b) Species centroids show the relationships among species as defined by their relative abundance during both survey periods (points scaled by proportion of total abundance). The stress value (0.23) indicates the degree of distortion between the multidimensional data and its two-dimensional representation, with values below 0.2 considered good and values between 0.2 and 0.3 providing an acceptable but moderate fit. Species abbreviations: BLKB, Eurasian blackbird; CHFN, chaffinch; FNTL, fantail; GDFN, goldfinch; KERU, kererū; KNGF, sacred kingfisher; MYNA, common myna; RSLA, eastern rosella; SEYE, silvereye; SPRW, house sparrow; THSH, song thrush; TUI, tūī; WBLR, grey warbler.

Table 3. Summary of PERMANOVA results for the effect of survey year (1987–88 vs. 2019–20) on avian community structure in the Auckland Domain forest. *F*-values (pseudo-*F*) are derived from 999 permutations.

Factor	d.f.	F	R^2	P
Survey year	1	85.0	0.172	0.001***
Season	3	8.94	0.054	0.001***
Site ID	1	8.17	0.017	0.001***
Residuals	373		0.757	
Total	378			

RESULTS

A total of 20 bird species was recorded in the domain forest over both 1987–88 and 2019–20 survey periods, eight of which were native species and 12 introduced (Table 1). Seventeen species were recorded in 1987–88, increasing to 20 in 2019–20. Three additional species (not included in analyses) were recorded flying over during 2019–20 counts: red-billed gull|tarāpunga *Chroicocephalus novaehollandiae*, southern black-backed gull|karoro *Larus dominicanus*, and paradise shelduck|pūtangitangi *Tadorna variegata*. Tūī *Prosthemadera novaeseelandiae*, Eurasian blackbird *Turdus merula*, and silvereye|tauhou *Zosterops lateralis* were the three most frequently encountered bird species in 2019–20 surveys, present in 90.2%, 88.0% and 71.7% of surveys, respectively (Table S1). In comparison, the three most observed species in 1987–88 were silvereye (91.8% of surveys), New Zealand fantail|pīwakawaka *Rhipidura fuliginosa*, 83.1%), and blackbird (78.5%). Similarly, the most abundant species in 2019–20 counts was tūī (mean ± SE = 2.7 ± 0.12 birds/5-min count), whereas in 1987–88 counts it was silvereye (3.2 ± 0.18 birds/5-min count; Table 1).

Survey year had a significant effect on overall community structure measures, even after accounting for season, time of day, temperature, wind, and rain (GLMMs, Table 1), with overall species richness, native species richness, introduced species richness and overall abundance all higher in 2019–20 compared to 1987–88 (Fig. 1). Three native species (tūī, grey warbler|rirororiro *Gerygone igata*, and kererū|New Zealand pigeon *Hemiphaga novaeseelandiae*) showed an increase in abundance in 2019–20, while one native species decreased (silvereye; Table 1, Fig. 2). The abundance of five introduced bird species also showed a significant increase in 2019–20 (blackbird, eastern rosella *Platycercus eximius*, house sparrow *Passer domesticus*, goldfinch *Carduelis carduelis*, and common myna *Acridotheres tristis*). European greenfinch *Chloris chloris* declined in abundance between survey years (Table 1, Fig. 2).

The NMDS ordination plot provided further evidence of a divergence in avian communities between 1987–88 and 2019–20 survey periods, supported by PERMANOVA analyses (Table 2), with the group centroid of 2019–20 counts shifting significantly to the right (Fig. 3). Survey year explained a greater amount of variation in community composition (R^2 = 0.17) in comparison to season or site variation (R^2 = 0.05 and 0.01, respectively; Table 3). However, PERMDISP analyses indicated that variability in community composition was not significantly different between years (PERMDISP; F = 2.02, df = 1, P = 0.16).

DISCUSSION

Increases in overall abundance and species richness of native and introduced birds in the domain forest is encouraging and shows the importance of mature urban forest habitats for supporting healthy urban avian communities. Though species specific detection probabilities have not been accounted for in our analysis, changes between counts of Gill (1989) and our current survey are most likely driven by a combination of forest habitat succession and increasing levels of pest control. In the three decades since previous counts, forest growth as well as pest plant control by Auckland Council of species such as tree privet (*Ligustrum lucidum*) has resulted in a reduction of competition for native shrubs and ground cover plant species, and healthy succession of diverse canopy, subcanopy and understory habitats providing food supply and nesting habitats for a

range of native and introduced birds (Boffa Miskell 1993; Wilcox *et al.* 2004). In addition, in 1980s there was no pest control within the domain (B.J. Gill *pers. comm.*) in contrast to the sporadic trapping and poisoning of rodents and possums by contractors and local conservation volunteers at present under the Auckland Council Regional Pest Management Strategy (Auckland Council 2020). Control of pests in urban forests can benefit the bird community by either release of direct predation or reduction food competition from forest browsers such as possums. For example, in Wellington populations of native and introduced birds increased in the 1990s following regional pest control which also resulted in rarer endemics such as bellbird|korimako *Anthornis melanura*, kākāriki|red-crowned parakeet *Cyanoramphus novaezelandiae* and kākā *Nestor meridionalis* recolonising the city several years before they were translocated to the region following the creation of the pest-free Karori Wildlife Sanctuary (Miskelly *et al.* 2005; Brockie & Duncan 2012; Miskelly 2018).

The changing climate over recent decades could also have a contributory role in the observed bird assemblage differences between survey years. The effect of climate change on the domain bird assemblage cannot be fully understood here, without a multi-year dataset to disentangle long term trends from short term seasonal and natural interannual variation. However, by including daily weather variables in the models as a proxy, we can, at a minimum, discern which species counts are significantly affected by these, and control for gross differences in temperature, wind, and rainfall between survey years. Furthermore, the effect size of the weather variables on count numbers was, for most species, observed to be much smaller than the effect size for survey year, supporting the argument that factors other than weather were the major driver of observed community change.

The restoration of forest habitats can have complex and species-specific effects of forest avifauna composition (Fea *et al*. 2020; Binny *et al*. 2020). The approximately 30 years between year-long counts in the domain's forest saw an increase in abundance of forest-adapted endemic species including tūī, kererū, and grey warbler, and a decline in generalist natives silvereye and fantail. The NMDS structure analysis demonstrates the difference between these communities, which were structured around a dominance of silvereye and fantail in the 1980s and tūī in the 2020s (Fig. 2). These data are consistent with other studies of mainland forest avifaunas that have received conservation management. For example, Miskelly (2018) showed that where habitats are restored through invasive mammal removal and numbers of endemic forest taxa increased through targeted translocations, forest adapted endemic species can outcompete more common and widespread taxa that tend to be habitat generalists. However, these community changes appear to be context-specific, with Spurr & Anderson (2004) reporting an increase in both forest-adapted tūī and generalist grey-warbler following the eradication of possums from Rangitoto Island. Interestingly, our data also indicate an increase in a number of introduced bird species between our count years in the Auckland Domain; it may be that in urban forests, with more limited number of endemic species and a lack of complete pest removal, that the suppressing effects of endemic habitat dominance is reduced.

The large increase of tūī in the domain forest between counts in 1987–88 and 2019–20 is noteworthy. This result is consistent with other studies showing increases in this iconic endemic bird across the Auckland isthmus over the past 30 years (Spurr & Anderson 2004; Lovegrove & Parker 2023). Tūī are mobile and move seasonally between islands in the Hauraki Gulf, larger rural forests on the city's periphery and Auckland urban forests (Stewart & Craig 1985). Recent research has established that pest mammal control or eradication can lead to landscape scale spillover over of tūī into surrounding habitats (Fitzgerald *et al.* 2019). It is likely that pest eradication and/or revegetation projects on Hauraki Gulf islands near to Auckland (e.g., Rangitoto, Motutapu, Tiritiri Matangi, The Noises, and Rotoroa Island), and landscape-scale pest control programs in the large, forested parks such as the Hunua and Waitakere Ranges on the city's fringe is significantly benefitting tūī numbers across the region, including in urban forests (Lovegrove & Parker 2023).

Introduced bird species, including Eurasian blackbird, eastern rosella, house sparrow, European goldfinch, and common myna, also increased in abundance in the domain forest between 1987–88 and 2019–20. As with native taxa, these species have likely benefitted from habitat maturation and control of mammalian predators and browsers. However, for two of these species, regional colonisation histories and cavity-nesting behaviour may play role in explaining increases. Eastern rosella were established by introductions in Auckland prior to 1920, and by 1960 had moved into Northland with a slower progression into the Waikato (Fleming 1944; Wright & Clout 2001). Rosellas had an incomplete distribution across Auckland between 1969 and 1979 (Bull *et. al.* 1985); however, they were present in all areas of the region in 1999–2004 and had expanded southwards into the central North Island (Robertson *et. al.* 2007). The single occurrence of this species in counts by Gill (1989) is consistent with these observations, suggesting that by the 1980s the species was near to occupying the entire region albeit at lower abundance (Wright & Clout 2001). Rosellas had increased significantly within Auckland by 2020, being the fifth most common species in counts in the domain forest. Common myna were introduced to the South Island and the west and east coasts of the central and southern North Island between 1869 and 1883 (Beesley *et al.* 2023). In the North Island the species reached Auckland in the late 1940s and early 1950s (Cunningham 1948, 1951 & 1954; Beesley *et al.* 2023). Our data suggest increasing numbers of birds between 1987–88 and 2019–20, particularly during the summer breeding season, which is also consistent with observed increases of the species in six Northland forests across a similar time period (Pierce *et al.* 1993). Additionally, as a cavity-nesting species, the maturation of forest is likely to have a positive effect on eastern rosella and common myna numbers by increasing availability of nest sites as natural cavities form over time in older trees (Galbraith *et al.* 2014). This is concerning, as both species directly compete with native bird species for nest-cavity resources, which are already typically limited in young forest particularly in systems where cavity-excavating species (e.g., woodpeckers, Picidae) are absent (Galbraith *et al.* 2014; Krull *et al.* 2015).

In conclusion, comparison of birds counts within Auckland Domain between 1987–88 and 2019–20 show an increase in the overall abundance and species richness of native and introduced birds. Of note was the increase in forest-adapted endemic species and a decline in generalist natives, which has also been observed in other studies where forest succession is aided by management actions such native replanting and pest plant and mammal control at a local scale. However, external factors can also drive changes in urban avian communities. The large increase in numbers of highly mobile tūī visiting the domain forest has likely been driven by conservation management actions at a regional level, whereas changes in abundance of introduced eastern rosella and common myna reflect the timeline of their respective invasion histories. Overall, our results reinforce the need to protect maturing urban forest habitats, supporting the native forest recovery within these forest matrices, particularly to enhance native bird

populations, whilst thinking about recovery of urban bird populations at a landscape scale.

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Records of petrels (families Oceanitidae and Procellariidae) in the Cook Islands, 1970 to present

ALANNA M. SMITH*
Te Ipukarea Society, PO Box 649, Rarotonga, Cook Islands

GERALD McCORMACK
Cook Islands Natural Heritage Trust, PO Box 781, Rarotonga, Cook Islands, ORCID 0009-0000-8683-6906

CHRIS P. GASKIN
Northern New Zealand Seabirds Trust, 174 Ti Point Road, RD5, Warkworth 0985, New Zealand,
ORCID 0000-0002-9343-0303

Abstract: The Cook Islands are a scattered group of mainly inhabited tropical islands in the South Pacific Ocean. We provide a comprehensive review of petrel and shearwater (Oceanitidae and Procellariidae) records for the Cook Islands. Records include new fossil and subfossil records; however, the focus is on specimen records and observations made on land since 1970. Records and observations comprise details of 13 species of seabirds within the order Procellariiformes, from the Northern and Southern Groups, Cook Islands. This paper includes extensions to the breeding ranges of some Procellariiformes within the South Pacific Ocean. Significant new records include confirmation of Herald petrel (*Pterodroma heraldica*) breeding on Rarotonga, and the suspected breeding of black-winged petrel (*P. nigripennis*) on Ātiu, wedge-tailed shearwater (*Ardenna pacifica*) on Aitutaki, and tropical shearwater (*Puffinus dichrous*) on Mangaia. A thorough field survey across all islands needs to be conducted to determine more completely the breeding status and distribution of these species, and to potentially locate other species. We recommend surveys using a range of methods to determine the breeding status of species in the Cook Islands and, importantly, developing local capacity towards improving conservation efforts to protect Procellariiformes, including urgent predator control at some locations on Rarotonga.

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Keywords: Procellariiformes, petrels, shearwaters, conservation, seabirds, Cook Islands, South Pacific

INTRODUCTION

Seabirds are among the most threatened birds globally (Croxall *et al*. 2012; Dias *et al*. 2019). Across the Pacific, storm-petrels, petrels, and shearwaters (families Oceanitidae and Procellariidae; here collectively referred to as petrels) are among the seabird species that have experienced large population declines and local extinctions (Steadman 2006). The loss of Oceania's seabirds also represents a loss of cultural values for Oceanic people. There are eight petrel species in the Cook Islands classified as threatened, including several seen at sea (Table 1) (IUCN Red List of Threatened Species, viewed July 2024). Additionally, many more species have become locally extinct due to human activity, both in recent and prehistoric times (Steadman 1991, 1995 & 1997). The Mangaia fossil record details human occupation overlapping with the extirpation of numerous bird species, drawing the conclusion that the arrival of early Polynesian settlers, and the dogs (*Canis familiaris*) and Pacific rat (*Rattus exulans*) that accompanied them, had a major effect on island biodiversity (Steadman & Kirch 1990).

Geography of the Cook Islands

The Cook Islands is made up of 15 separate islands spread over an Exclusive Economic Zone (EEZ) of around 2 million km^2 (Petterson & Tawake 2019). The total land area is 237 km^2, and the islands are divided geographically into two

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*Correspondence: *a.smith@tiscookislands.org*

Table 1. Threatened petrels (families Oceanitidae and Procellariidae) recorded in the Cook Islands EEZ (IUCN Red List of Threatened Species, viewed July 2024).

Scientific name	Common name	Threatened Status
Nesofregetta fuliginosa	Polynesian storm petrel	Endangered
Pterodroma cervicalis	White-naped petrel	Vulnerable
Pterodroma cookii	Cook's petrel	Vulnerable
Pterodroma brevipes	Collared petrel	Vulnerable
Ardenna bulleri	Buller's shearwater	Vulnerable

distinct groups, a Northern and a Southern Group (Fig. 1). The Northern Group consists of five atolls (Suwarrow, Manihiki, Penrhyn, Pukapuka, and Rakahanga) and one sand cay (Nassau). The Southern Group has one high volcanic island (Rarotonga) (Fig. 2), four uplifted volcanic/limestone islands known as *makatea* (Ātiu, Mitiʻāro , Mangaia, and Maʻuke), one near-atoll (Aitutaki), two atolls (Manuae and Palmerston) and one sand cay (Takūtea). The islands where petrels have been recorded breeding or seen flying over are Rarotonga, Mangaia, Ātiu, Aitutaki, and Takūtea.

Trans-equatorial migrations

Many petrels are pelagic, renowned for covering large distances across the open ocean with minimal effort.

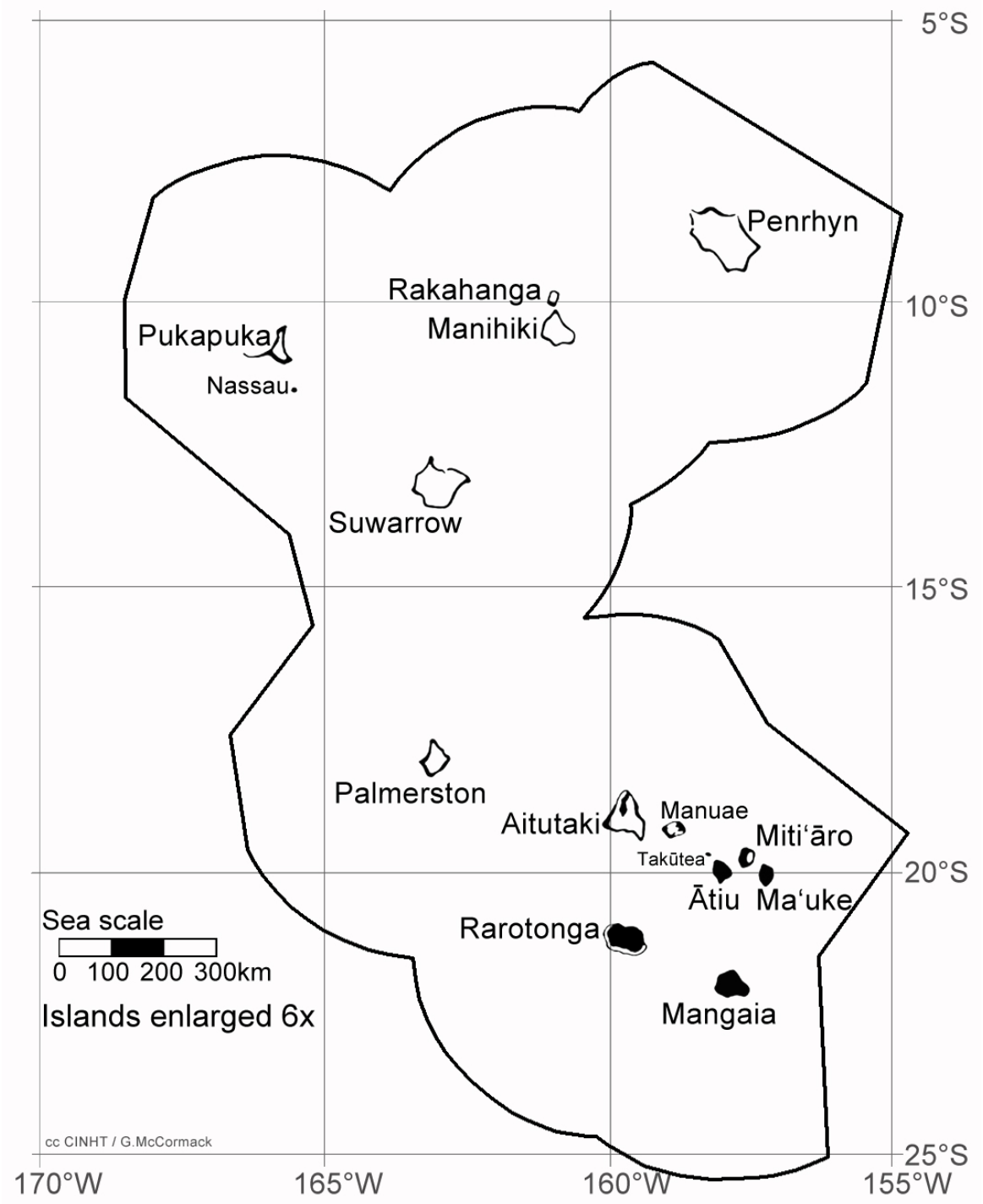

Figure 1. Exclusive Economic Zone of the Cook Islands showing the position of all 15 islands that make up the Cook Islands.

Many species make trans-equatorial migrations, for example, the annual migration of sooty shearwaters (*Ardenna grisea*) follows a broadly figure-eight pattern across the Pacific Ocean, with latitude coverage ranging from Antarctic waters to the Bering Sea and longitude ranging from Japan to Chile (Shaffer *et al*. 2006).

In tropical marine environments, food resources have less seasonal variation than in temperate and polar regions (Ashmole 1971; Weimerskirch 2007), which partly explains why most tropical seabirds, except for populations breeding at the edge of tropical zones, do not perform migrations to the same extent as their temperate or polar counterparts (Catry *et al*. 2009). There is a pressing need to increase understanding of how seabirds find food in trophically unpredictable tropical ocean ecosystems at a time when the world's marine ecosystems are undergoing unprecedented change (Dunn *et al*. 2024).

Invasive predators

There are many threats to seabirds globally, with one of the worst being invasive predators. Invasive predators in the Cooks Islands include dog, Pacific rat, ship rat (*Rattus rattus*), Norway rat (*R. norvegicus*), feral cat (*Felis catus*), and pig (*Sus scrofa*) (Towns *et al.* 2011). Breeding seabirds are at particular risk from predatory mammals when ashore due to their limited mobility on land and predictable occurrence once nesting. Petrels are often social or colonial breeders, nesting on the surface or in burrows (Warham 1990). Of these introduced predators, the ship rat is considered to have the greatest impact on tree-nesting birds (Robertson & Saul 2007). Norway rats have more limited distribution compared with other rats; however, they have greater impact on seabirds (Moors *et al*. 1992). The Pacific rat has less impact on birds compared to the ship or Norway rats; however, Pacific rats can still have a significant impact on procellariiform species (Pierce 1998a & b; Rayner *et al*. 2007). Dogs, cats, and pigs can also have a devastating impact of ground nesting seabirds, taking breeding adults as well as chicks, with pigs also digging out burrows.

Conservation history

Apart from ongoing rat poisoning to protect the highly threatened Rarotonga monarch (*kākerōri*, *Pomarea dimidiata*) over 150 ha within the Takitumu Conservation Area on Rarotonga since 1989 (Saul *et al*. 1998; Robertson & Saul 2007; H. Robertson, *pers. comm*.), there is no regular predator control done on any of the four islands that are or have been inhabited by breeding petrels and shearwaters in the Cook Islands. Whilst the conservation area was established for threatened land birds, the very steep, high peaks covered with thick, evergreen bush within the conservation area provide suitable habitats for petrels to nest and breed. However, cats, rats and dogs continue to pose threats to the distribution and abundance of seabirds, requiring an urgent extension in conservation efforts.

There have been three rat eradication projects undertaken in the Cook Islands: Suwarrow Atoll (Cook Islands' only national park) in the early 2000s, Palmerston Island, completed in September 2023, and Takūtea Island, a Wildlife Sanctuary that is home to the largest and most important seabird colony in the Southern Cook Islands, completed in 2024. Although no Procellariiformes were recorded breeding at the time of eradication, these projects provided predator-free habitat suitable for colonisation by petrels.

The following documentation of observations made within the Cook Islands is intended to provide background material for future surveys and conservation effort at the terrestrial breeding grounds, which is pivotal to species recovery efforts across the Cook Islands.

MATERIALS AND METHODS

This paper presents records of field observations of petrels observed within the Cook Islands EEZ since 1970, plus an overlooked record from 1904 that we have included because of its importance. Field observations were conducted by local Cook Islanders who were either fisherman or terrestrial game hunters, as well as ecologists who have had a long association with Cook Islands birds. Additional records include from museum collections, acoustic recordings, online global database records (notably eBird), and literature reviews. At-sea and offshore observations have also been made by birders including D. Holyoak, R. White, and various contributors to eBird. We have taken these records at face value.

Nomenclature and presentation order follows the *Checklist of the birds of New Zealand* (https://www.birdsnz.org.nz/society-publications/checklist/)(viewed July 2024) where possible. For species not in the New Zealand checklist, we list them in the sequence shown in Birds of the World Online (https://birdsoftheworld.org/bow/home) (viewed July 2024). Local names (if known) are included following common and scientific names at the start of each entry. Cook Islands Māori names, are based on https://naturalheritage.gov.ck, the national biodiversity database of the Cook Islands.

RESULTS

An annotated checklist of petrels found within the Cook Islands is presented here and summarised in Table 2.

Confirmed or suspected breeding species

Kermadec petrel (*Pterodroma neglecta*)

Kermadec petrels breed in several island groups across the subtropical South Pacific, from Lord Howe Island to the Juan Fernandez Islands, with the largest population at Pitcairn Islands (Harrison *et al.* 2021). Imber (2004) believed the species was breeding on Rarotonga after hearing vocalisations of these petrels in 1986, and further calls were heard within the Takitumu Conservation Area between 1990 and 1993 (E. Saul, *pers. comm*.). Identifications of the petrels were made by the white shafts of the primaries and their distinct call which sounds like a 'howling primate'. The petrels were seen flying and on the ground in tangle fern (*Dicranopteris linearis*) areas on high ridges overlooking the coast (E. Saul, *pers. comm*.); however, no birds were found nesting. It is likely that ongoing predation pressure prevents Kermadec petrels from breeding on Rarotonga, although intensive survey effort may reveal them to breed, especially as Herald petrels, another surface-nesting procellariform, continue to do so.

Herald petrel (*Pterodroma heraldica*) Kōputu

Herald petrels breed in the Pitcairn Group, Rapanui/Easter Island, Southern Tuamotu, Marquesas, Tonga, Chesterfield Reef (New Caledonia), and Raine Island (Australia) (Harrison *et al.* 2021). The species has an extended breeding season and visits nesting areas throughout the year. Gill (1885) reported that a bird known as the Kōputu, which nested on the high cliffs of Rarotonga, was a source of food and sport. McCormack (1989) concluded that Gill's description was an excellent fit for Herald petrel.

Early records of the Herald petrel in Rarotonga include five seen flying over high ridges 23 Jul 1973 (Holyoak 1980), one over the ridge between Ikurangi and Te Manga and several flying inland over Muri in July & August 1976 (Turbott 1977), and several around the Te Manga-Te Atukura divide in August-September 1981 (McCormack 2007). A nestling was found in a nest on a ridge 480 m just east of Te Atukura in September 1981 (Tim Lovegrove, *pers.*

Table 2. Summary of records of petrels (families Oceanitidae and Procellariidae) in the Cook Islands. Breeding*= assumed to have bred formerly; island names separated by '/' indicates sightings on voyages between islands.

Common and scientific names	Islands	Observations
White-faced storm petrel *Pelagodroma marina*	Palmerston/Rarotonga	At sea
Polynesian storm petrel *Nesofregetta fuliginosa*	Mangaia Suwarrow	Breeding* At sea
White-bellied storm petrel *Fregetta grallaria*	Rarotonga/Ma'uke	At sea
Southern giant petrel *Macronectes giganteus*	Rarotonga	On land
Northern giant petrel *M. halli*	Rarotonga Ma'uke Aitutaki	On land At sea At sea
Cape petrel *Daption capense*	Rarotonga Aitutaki/Rarotonga	At sea At sea
White-headed petrel *Pterodroma lessonii*	Rarotonga Nassau	On land and at sea At sea
	Ātiu	At sea
	Palmerston	At sea
Kermadec petrel *Pt. neglecta*	Rarotonga Palmerston	Breeding* and at sea At sea
Murphy's petrel *Pt. ultima*	Rarotonga Takutea	On land On land
Mottled petrel *Pt. inexpectata*	Rarotonga Miti'āro	At sea At sea
White-naped petrel *Pt. cervicalis* or Juan Fernandez petrel *Pt. externa*	Palmerston Ātiu/ Palmerston Rarotonga/ Palmerston Nassau	At sea At sea At sea At sea
Black-winged petrel *Pt. nigripennis*	Rarotonga Mangaia Ātiu	Breeding* Breeding Breeding
Collared petrel *Pt. brevipes*	Palmerston/Rarotonga Aitutaki Palmerston	On land At sea At sea
Herald petrel *Pt. heraldica*	Rarotonga Aitutaki	Breeding and at sea On land
Phoenix petrel *Pt. alba*	Rarotonga	At sea
Cook's petrel *Pt. cookii*	Palmerston/Rarotonga	At sea
Bulwer's petrel *Bulweria bulwerii*	Nassau	At sea
Tahiti petrel *Pseudobulweria rostrata*	Rarotonga Palmerston/Rarotonga Mangaia	At sea Breeding* At sea
Buller's shearwater *Ardenna bulleri*	Rarotonga Mangaia	At sea At sea
Wedge-tailed shearwater *A. pacifica*	Rarotonga Mangaia Aitutaki	On land and at sea Breeding and at sea At sea
Sooty shearwater *A. grisea*	Rarotonga Aitutaki	On land and at sea At sea
	Ātiu	At sea
	Palmerston	At sea
Short-tailed shearwater *A. tenuirostris*	Rarotonga	At sea
Christmas Island shearwater *Puffinus nativitatis*	Aitutaki	At sea
Tropical shearwater *P. dichrous polynesiae*	Rarotonga Mangaia	On land and at sea Breeding

comm). Several birds were seen circling along the eastern and northern side of Maungatea in July-August 1983 (M. Merlin, *pers. comm*). From early 1984 to late 1986, GM made several trips to Maungatea and Te Manga, including three overnight trips, to observe Herald petrels (McCormack 2007). In 1984, *c*.10 birds were seen in aerial displays on the western side of the Te Manga-Te Atukura divide, with infrequent flights to the eastern side of the divide (McCormack 2007). Most of the aerial activity occurred between about 300 m and 700 m asl., with the birds making close approaches to the bush-covered cliffs at 450–550 m asl. In 1986 GM saw more than 20 birds in the air along the divide and 10 more on the eastern side of Maungatea (McCormack 2007). Past sightings of Herald petrels circling the peaks of Te Atukura were also confirmed by Hugh Robertson (*pers. comm.*); however, he noted that numbers have dwindled over the last 35 years, and since 2015 the species has been rarely seen. Also recorded by Ray Pierce (*pers. comm.*) in late 1989.

McCormack (1989) noted that smaller Herald petrel colonies could also be found on Maungatea and possibly even on Maungaroa. These numbers have dwindled

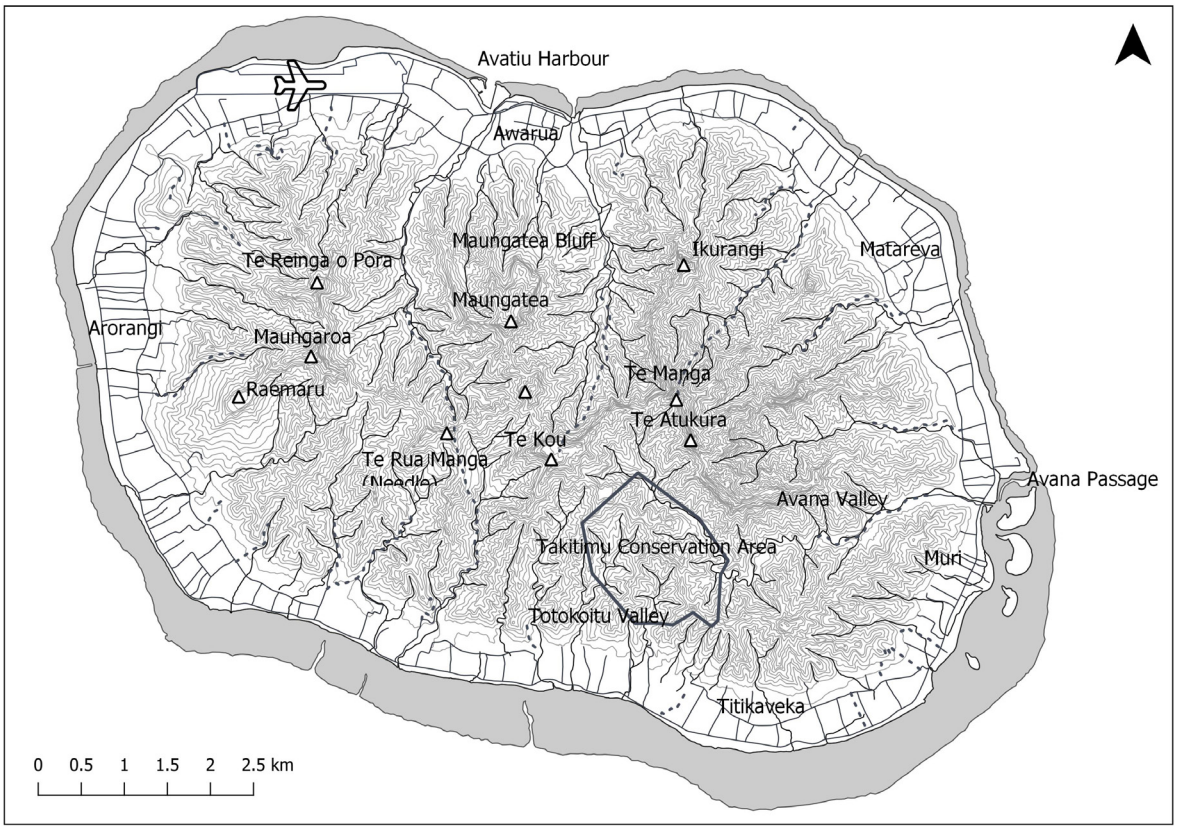

Figure 2. Rarotonga showing locations mentioned in text. Herald petrel breeding sites are shown as Δ.

over the years; however, birds can still be seen in the late afternoons (E. Saul, *pers. comm.*). More recent records of Herald petrels include birds seen and photographed flying above Maungatea Bluff by Alan Tennyson and Ed Saul briefly around 1730 hrs on 10 Aug 2010 (Ed Saul, *pers. comm*). Tennyson noted the birds "circling around and hovering on the Maungatea Bluff, with at least 10 that called frequently 'he he he he he …' c. 10/second for c. 2 seconds – a staccato, continuous, lower pitched call than other *Pterodroma* species such as black-winged petrels". Herald petrel calls were confirmed on 3 Nov 2016 from an acoustic recorder placed at the base of the Maungatea Bluff on Rarotonga by CG. AS and GM visited the top of the Maungatea Bluff on 28 Mar 2017 to confirm CG's 2016 record, and observed four Herald petrels flying above and around the cliff between 1500 and 1600 hrs. During that hour, display chases between two Herald petrels were observed, with one bird calling to the other with its chattering 'staccato' call.

Recent inland observations suggest Herald petrels are likely to be breeding in areas of intact montane rain and cloud forests in the upland forest of Rarotonga, which has relatively few invasive plants (GM). On 27 Jul 2024, André Raine and B. Panzarella found three dead Herald petrels up Te Ko'u, all likely killed by a cat or dog(s). On their way down from Te Ko'u, they saw 10+ petrels display flying and calling (A. Raine *pers. comm.*).

In addition to Herald petrels displaying and calling over the high peaks of Rarotonga, M. Feuersenger recorded them flying over a coconut grove on the slopes of Maungapu, at 123 m asl on Aitutaki 25 Jul 2012 (Feuersenger, M. 2012, recording accessible at https://www.xeno-anto.org/contributor/HBPYQXTJEV?query=herald+petrel).

In June 2024, there was an extraordinary record of a Herald petrel attacking or approaching a drone that was flown to film a sunset at Te Rua Mangā or Needle, one of Rarotonga's impressive high peaks. The image was posted on Facebook by M. Tuari'i (5 Jun 2024).

On 26 Aug 2024, a young petrel was found at the top of the Maungatea Bluff on the western side grounded amongst the ferns. AS, B. Panzarella and K. Silk found the bird whilst they were deploying an acoustic recorder to monitor potential petrels in the area. Photos of the petrel was shared with André Raine who confirmed it as a Herald petrel.

Nearshore observations comprise one seen from Rarotonga on 16 Jan 2020 (L. Ballard, eBird, viewed January 2022). At-sea records comprise four pale morph birds in August 1973 in the Northern Cooks; three pale morph birds and one dark morph bird in August and September 1973 in the Southern Group (Holyoak & Thibault 1984); one off Avatiu Harbour on the 3 April, three off Avatiu Harbour 4 April and six off Avatiu Harbour 6 Apr 1999 (Jowett 2000). An additional nearshore sighting about 400 m from the Avatiu Harbour at 14.45 hours was made in October 2020 (AS). The petrel had a white under belly and was possibly feeding at the time of observation.

Murphy's petrel (*Pterodroma ultima*)

Murphy's petrels breed east of the Cook Islands in the Austral, Gambier, Tuamotu, and Pitcairn archipelagos, as well as Easter Island and the Juan Fernandez Islands, off the coast of Chile (Harrison *et al*. 2021). In the Cook Islands, a specimen was collected in the Southern Group, most likely from Rarotonga, sometime between *c*.1899 and 1904 (Gill 1996). The specimen (AIM, LB6902) was presented to Auckland Museum by R.W. Gosset of Sydney, Australia in 1927, along with a collection of skins and eggs (Anon. 1940; Gill 1996). Although the date, provenance and breeding status of the petrel is unclear, this is the earliest record of any identified petrel documented for the Cook Islands. The specimen was first catalogued as a Kermadec petrel, but was identified by Robert Falla, and more recently by Mike Imber, as *Pterodroma ultima* (see Gill 1996).

A possible sighting of a Murphy's petrel was made by AS and K. Floyd on Takutea, during the 2024 rat eradication

project, during 2–8 Sep 2024. The petrel was seen flying to and from the centre of the island in the late evenings and early mornings. It had distinctive white markings on the underside of its primaries; however, confusion with either dark-morph Herald or Kermadec petrels is possible, both species recorded for the Cook Islands.

Black-winged petrel (*Pterodroma nigripennis*) Tītī
Black-winged petrels breed on islands of the southwest and central South Pacific Ocean, including Lord Howe (Australia), Phillip Island (Norfolk Island), New Caledonia, Kermadecs (the largest population), northern North Island offshore islands, and Chatham Islands (New Zealand), the Austral Islands (French Polynesia), and more recently, Motu Nui, Easter Island (Chile), and on islands in the Indian Ocean (Harrison *et al* 2021). The black-winged petrel was extirpated on Mangaia following the arrival of humans and their attendant predators (Steadman & Kirch 1990; Medway 2001). A total of 37 faunal remains of this petrel were found across all trenches dug at the Tangatatau Rock Shelter (MAN – 44) site (Steadman & Kirch 1990). The relatively high density of remains strongly suggests breeding prior to the arrival of humans.

Gill (1880, p.8) provided oral history of a former hunting practice by Mangaian locals on the petrel:

"*The hunter has only to call at the entrance of the dark cave, in a plaintive tone, E titi e, when the foolish bird, imagining it to be the voice of its mate comes out of its secure hiding place, and dazzled by the unwelcome light, allows itself to be caught by hand*".

Moreover, Clerk (1981) stated that this species served as a common food source and was harvested regularly from inland burrows. GM concluded that the petrel species mentioned by Gill was the black-winged petrel based on the call and habit of nesting in burrows in the volcanic soils (McCormack 2007).

Records of the black-winged petrel in Rarotonga include one found injured by a dog in February 1986 (McCormack 2007). The petrel died and was donated to National Museum of New Zealand Te Papa Tongarewa (Te Papa; registration no. OR.023679). The bird had been in a horizontal burrow among the roots of a small ironwood tree on a hillside in Muri. A damaged egg, which contained a fully developed embryo, was also found alongside the injured petrel. No other nests were found within the vicinity (GM). The other Rarotongan record was of a bird seen(?) in the Takitumu Conservation Area on the 17 Mar 2000 by Algirdas Knystautas (*pers. comm.*).

In March 1985, three boys found a black-winged petrel in a burrow on Ātiu and gave it to the priest of the St Anthony's Catholic Church. GM notes that one of the boys who found this bird knew the location of three more burrows and in the previous year, reportedly found a similar bird with a chick during April to August. The identification of the petrel found in 1985 was confirmed by Mike Imber from photographs.

There have been other possible black-winged petrel sightings on Ātiu, with a bird in a burrow under a coconut tree at Te Tiare swamp, about 50–80 m asl in October 2015. Described as small, about the size of two myna birds (*Acridotheres tristis*), its colour was a shade of dark grey with blue and black on its back and head. It had a black bill with a light grey white on its belly and black webbed feet (J. Tuara, *pers. comm.*). Tuara could not confirm whether the bird was on an egg as he could not see into the nest chamber. When presented with an image of a black-winged petrel that was spotted on Rarotonga, Tuara recognised it as like the bird on Ātiu. A nearshore sighting on Rarotonga was of a bird flying over the lagoon at Bella Beach on the south coast 6 Jul 2019 (R. Cannings, eBird, viewed January 2022). The evidence supports the likelihood of breeding on Ātiu, and potentially on Rarotonga.

Collared petrel (*Pterodroma brevipes*)
The collared petrel's breeding range is uncertain, but it has been confirmed for Vanuatu and Fiji (Gau and Kadavu) (Harrison *et al.* 2021). It nests in burrows in forest, scrub, or among tree roots (del Hoyo *et al*. 2020).

Records in Rarotonga include an injured collared petrel fledgling found by GM on a ridge (150 m a.s.l.) on the western side of the Avanā Valley on 26 Jul 1984. This is the easternmost record of this species (McCormack 2007). The specimen was later donated to Te Papa (OR.023110) (Tennyson *et al*. 2012). In the late 1980s and early 1990s, cat-killed birds were found along the ridge tops at the head of the Totokoitu Valley and on the spur running northeast from the head of the Totokoitu near the outer rim of poison baiting in those days (Hugh Robertson & Ed Saul *pers. comm.*) No remains have been found since about 1997, with extirpation of the colony likely (Hugh Robertson & Ed Saul *pers. comm.*). These records suggest that this species was breeding in the Takitumu Conservation Area from 1984 to 1997. Discovery of any active burrows on Rarotonga should be monitored for the possible presence of this species. At-sea sightings of collared petrels include one near Aitutaki in April 1999 and another between Palmerston and Rarotonga in July 2006 (Jowett 2000; White 2006).

Wedge-tailed shearwater (*Ardenna pacifica*) Ūpoa, 'E'engu/'E'emu (Aitutaki)
The wedge-tailed shearwater is relatively widespread in the tropical and subtropical Indian and Pacific Oceans (Harrison *et al.* 2021). On land and at night it is known for its distinctive call, described as 'an uncanny imitation of a crying baby' (GM). An all dark grey-brown bird was found on Mangaia, collected, and later identified from photographs (D. Holyoak *in* Clerk 1981). Historically, it appears that wedge-tailed shearwaters were likely breeding on Mangaia, as locals knew it as ūpoa and could identify it by its call.

On Aitutaki, G. Hancock, reported frequently hearing birds calling inland of the Rapae Motel (now Pacific Resort) from after dark until about 3 am from November to March, 1983-84. The call of birds flying near the colony sounded like a foghorn alternating with a baby's cry, which led GM to the identify the birds as wedge-tailed shearwater. Residents also reported that the 'E'engu/'E'emu was frequently heard west of Mā'ina-'atupuka near the Rapae Motel. Searches by R. Hay and GM failed to find evidence of nesting in the mid-1980s.

More recently at Aitutaki, Russell *et al.* (2025) in October 2014 found ten burrows on the eastern ridgeline of Rapota and about 50 on the south-western dune faces of Maina. Some of the medium-sized burrows found had recently been excavated on each island indicating the commencing of prospecting and start of the breeding season. Adult feathers collected around burrows on Rapota appeared to be wedge-tailed shearwater, and a wedge-tailed shearwater was observed east of Aitutaki on passage to Manuae atoll (Russell *et al.* 2025).

A dark morph wedge-tailed shearwater was found during a stormy evening on Rarotonga's main road in Arorangi in December 1984 (McCormack 2007). It was released after photographs and notes were taken. Its identity was later confirmed by Mike Imber (McCormack 2007).

Further records of this species in the Cook Islands include three dark-morph birds seen at sea in between Nassau and Suwarrow on 7 Aug 1973, and two in the Southern Group in September 1973 (Holyoak 1980). Sightings at sea for the Cook Islands include 16 near Aitutaki in April 1999 and another near Rarotonga in September 2000 (Jowett 2000), one north east of Mangaia on 19 May 2019 (M. Rigney, eBird, viewed 2022), and two between Palmerston

and Rarotonga 23 Jan 2025 (P. Chaon, eBird, viewed February 2025).

Tropical shearwater (*Puffinus dichrous polynesiae*) Rākoa
The tropical shearwater was formerly considered part of the Audubon shearwater *(P. lherminieri*) complex. It breeds in the Marianas Islands, Palau, Solomon Islands, Vanuatu, Kiribati (Phoenix and Line Islands), Fiji, Tonga, Samoa, American Samoa, and French Polynesia (Harrison *et al.* 2021). The earliest record in the Cook Islands is from Mangaia at the Tangatatau Rock Shelter, where a total of three faunal remains were identified (Steadman & Kirch 1990). Unlike the black-winged petrel or the Polynesian storm petrel, which the authors suggest were extirpated on Mangaia, Steadman & Kirch (1990) clearly stated that these small shearwaters were still breeding there. Steadman (1997) stated that numbers had declined to less than 100 birds, although archaeological and ethnographic evidence suggests it was once a common and widespread species on Mangaia.

With tropical shearwaters formerly known as Audubon's shearwaters, and confusion with little shearwaters *P. assimilis*, a fledgling found on Mangaia in April 1984 was described by Steadman & Olson (1985) as *P. lherminieri/ assimilis*. He also obtained the local name rākoa for the species (GM). Little shearwaters are winter breeders, as are Rapa shearwaters (*P. myrtae*) in the Gambier Islands and Rapa (French Polynesia) and their chicks fledge between September and November (Harrison *et al.* 2021). This suggests that the fledgling seen on Mangaia was possibly a tropical shearwater rather than a little shearwater.

A dead tropical shearwater was found on a northern coastal road in Rarotonga in July 2003, possibly attracted to the bright lights of the all-night fuel station. The specimen was collected and donated to Te Papa (OR.027467; McCormack 2007).

A nearshore sighting off Rarotonga was recorded on the 16 Jan 2020 (L. Ballard eBird, viewed January 2022). Other records of this species in the Cook Islands are 10 birds seen at sea in the Southern Group in July and August 1973 (Holyoak 1980).

Unidentified procellariid
During a biodiversity survey on Manuae atoll in October 2024, petrel or shearwater feathers were found in burrows in a section of eroded beach (J. Russell *pers comm.* to CPG).

Migrant or vagrant species
White-faced storm petrel (*Pelagodroma marina*)
The white-faced storm petrel breeds in eastern Australia and New Zealand and has a range as far as the northern Indian Ocean and the north-west coast of South America (Southey 2013). The only record from the Cook Islands is one seen at sea between Palmerston and Rarotonga 21 Sep 2006 (White 2006).

White-bellied storm petrel *(Fregetta grallaria)*
The white-bellied storm petrel breeds across the South Pacific, South Atlantic, and South Indian Oceans, and migrates north towards the tropics after breeding (Tennyson 2013). A single bird was seen at sea on 26 Aug 1973 during a cruise between Rarotonga and Ma'uke (D. Holyoak, eBird viewed January 2022).

Polynesian (white-throated) storm petrel
(*Nesofregetta fuliginosa*)
The Polynesian storm petrel breeds in New Caledonia, Phoenix, Kiritimati (Line Islands), and French Polynesia (Harrison *et al.* 2021); Pierce 2012; Pierce *et al*. 2020). Bones of two Polynesian storm petrels were found at the Tangatatau Rock Shelter on Mangaia (Steadman & Olson 1985; Steadman & Kirch 1990). They suggested that extirpation of this species coincided with early human arrival.

Later records in the Cook Islands are of six light morph and one dark morph bird seen at sea in the Northern Group on 6 Aug 1973 (Holyoak 1980). A much later nearshore sighting from Suwarrow was recorded on 10 Aug 2011 (H. Krajewsky, eBird viewed January 2022).

Southern giant petrel (*Macronectes giganteus*)
In June 2015, a live juvenile found in a swimming pool at Crown Beach Resort, Rarotonga, was identified from photographs taken by GM that showed an ivory bill-tip.

Northern giant petrel (*Macronectes halli*)
Northern giant petrels breed on islands in the subantarctic region (Harrison *et al*. 2021). Records in the Cook Islands include live juveniles found at Ma'uke in 1970 and Aitutaki in 1985 (McCormack 2007), and a dead juvenile found in Titikaveka (Rarotonga) in 1998 (J. Bosanquet, *pers. comm.*). In 1997 another juvenile was rehabilitated on Rarotonga by a local fisherman (McCormack 2005; J. Papa, *pers. comm*), and others were rehabilitated in Rarotonga in 2009 and in June 2012 (Smylie 2012). Identifications (other than for the Ma'uke specimen in 1970) were made by M. Imber and/ or GM.

Cape petrel (*Daption capense*)
Cook Islands sightings include five seen at sea from Aitutaki to Rarotonga on 19 Aug 1973 and one at sea 10 miles ENE off Ātiu 16 Sep 1973 (Holyoak 1980). In 2001, there is an inshore record from Rarotonga in August 2001 (C. Boyle *pers. comm.*; McCormack 2007) comprising 8 individuals seen flying around a dive boat for roughly one hour. Another reported inshore sighting was at Avarua in July 2009, where a Cape petrel joined a local outrigger canoe training session and followed them back to the Avarua Harbour (GM).

White-headed petrel (*Pterodroma lessonii*)
White-headed petrels have a circumpolar range and are found throughout the Southern Ocean (Harrison *et al*. 2021). They breed on Macquarie (Australia), Auckland and Antipodes (New Zealand), Crozet and Kerguelen Islands (French Southern Territories) and possibly on the Prince Edward (South Africa) islands (Harrison *et al* 2021). The only record of this species from the Cook Islands was one found in Matavera, Rarotonga in July 2016 by the Esther Honey Foundation. The bird was found the morning after a storm and was rehabilitated and set free 2 weeks later (S. John, *pers. comm*.). Russell *et al*. (2015) suggested white-headed petrels may be regular in Eastern Polynesian waters during the mid-year non-breeding season.

At-sea records for the Cook Islands include one in the Northern Group and the other in the Southern Group in August 1973 (Holyoak 1980), and one at Palmerston Atoll on 2 Aug 2006 (M. Greenfelder, eBird viewed January 2022).

Phoenix petrel (*Pt. alba*)
The Phoenix petrel breeds abundantly on Kiritimati (Line Islands, Gallagher 1960; Schreiber & Ashmole 1970, Pierce *et al.* unpublished), Phoenix Islands (Kiribati, Pierce 2012), Marquesas Islands (French Polynesia) (Gangloff *et al*. 2009) and the Pitcairn Islands (Brooke 1995). Additionally, Russell *et al.* (2015) discovered a beach-wrecked petrel in the Society Islands (French Polynesia), that was later identified by Te Papa staff as *Pterodroma alba*. Colonies tend

to occupy islets in lagoons of coral atolls or volcanic islands (Holyoak & Thibault 1984). The one confirmed sighting of Phoenix petrel off Rarotonga was by J. McCormack August 2021 with photographs (https://naturalheritage.gov.ck/cibed/dbs/species.html?pval=8723, viewed 12 March 2025). Two possible offshore sightings for the Phoenix petrel have been recorded from Rarotonga: one flying offshore from the Edgewater Resort 6 May 1994 (A. Starrett, eBird, viewed January 2022), and one off Avatiu Harbour in April 1999 (Jowett 2000). However, confusion with intermediate morphs of either Herald or Kermadec petrels is possible.

Mottled petrel (*Pterodroma inexpectata*)
Mottled petrel is endemic to New Zealand, breeding in Fiordland, on islands around Rakiura Stewart Island (including Whenua Hou and Big South Cape Island), and the Snares Islands. At-sea records for the Cook Islands (all supported by photographs) are one off Rarotonga on 31 Mar 2023, and two on 2 Apr 2023 (one off Rarotonga and another east of Miti'āro; M. Greenfelder, eBird viewed 10 Feb 2025)

White-naped petrel (*Pterodroma cervicalis*) **or Juan Fernandez petrel** (*Pt. externa*)
White-naped petrels breed almost entirely on Macauley Island, Kermadec group, apart from a few pairs nesting on Phillip Island, Norfolk group (Tennyson 2013). The White-naped petrel is similar to the Juan Fernandez petrel, but the black cap is split from the grey back by a white collar. At-sea records for the Cook Islands, which could be for either of these species, are a single bird seen halfway between Ātiu and Rarotonga on 30 Aug 1973 (Holyoak 1980), one between Palmerston and Rarotonga, on 24 Sep 2006 (White 2006), and one off Nassau on 26 Nov 2014 (M. Greenfelder eBird, viewed January 2022).

***Cookilaria* species** (*Pt. cookii/pycrofti*)
Cook's petrel is endemic to New Zealand, where it breeds on Little Barrier, Great Barrier and Whenua Hou (Harrison *et al.* 2021). Pycroft's petrel is also endemic to New Zaland, breeding principally on the Mercury, Poor Knights, Taranga and Marotere Islands. The two species are extremely difficult to separate at sea and consequently are lumped here. Records from the Cook Islands are one individual near Aitutaki in July 2006, another at sea between Palmerston and Rarotonga in September the same year (White 2006), and one between Ātiu and Bora Bora on 28 Oct 2015 (D. Pairo, eBird, viewed January 2022).

Bulwer's petrel (*Bulweria bulwerii*)
In the central Pacific Ocean, Bulwer's petrel breeds in the Phoenix and Marquesas Islands (Harrison *et al*. 2021). There is one record for the Cook Islands, near Nassau on 26 Nov 2014 (M. Greenfelder, eBird, viewed 2022). The observation was of 'a small dark petrel with a distinctive flight pattern to that of a Bulwer's Petrel'. Bulwer's petrel typically flies with rapid wing beats to short twisting glides, rarely >2m above surface (Harrison *et al*. 2021).

Tahiti petrel (*Pseudobulweria rostrata*)
Tahiti petrels breed in New Caledonia, Fiji, American Samoa, and French Polynesia, and are commonly seen at sea in the tropical and subtropical South Pacific Ocean (Harrison *et al.* 2021). Excavations conducted in Aiutaki at the Moturakau Rock Shelter revealed Tahiti petrel remains (Steadman 1991). Steadman (1991) postulated that the Tahiti petrel remains from the Moturakau Rock Shelter site on Aitutaki were another example of a seabird species being extirpated in the Cook Islands due to early harvesting and/or predation by introduced mammals.

Recent records of the Tahiti petrel from the Cook Islands were all at sea: three individuals seen out at sea near Rarotonga between 23 July and August 1973 (Holyoak 1980), one between Palmerston and Rarotonga in July 2006, near Ātiu in September 2006 (White 2006), one north east of Mangaia on 19 May 2019 (M. Rigney, eBird viewed January 2022), and one east of Miti'āro on 2 Apr 2023 (M. Greenfelder, eBird viewed 10 Feb 2025).

Buller's shearwater (*Ardenna bulleri*)
Buller's shearwaters breed only at the Poor Knights Islands, New Zealand. After breeding, they migrate to the North Pacific Ocean passing through equatorial Pacific in May heading north and September/October on their return (Harrison *et al.* 2021). At-sea sightings are one seen near Rarotonga in September 2000 (Jowett 2000), and a second near Mangaia on 19 May 2019 (M. Rigney, eBird viewed 2022).

Short-tailed shearwater (*Ardenna tenuirostris*)
Short-tailed shearwaters breed around Tasmania and on islands off the coast of South Australia. Like the sooty shearwater, it undertakes trans-equatorial migration, wintering in the North Pacific Ocean, with some moving north through the Bering Strait (Harrison *et al.* 2021). The return migration route for most birds is through the central Pacific. The only records from the Cook Islands are of two seen at sea, both near Rarotonga, in April 1999 (Jowett 2000).

Sooty shearwater (*Ardenna grisea*)
Sooty shearwaters breed on islands around New Zealand and southern South America during the Austral summer (Harrison *et al.* 2021). Post-breeding, they migrate to the North Pacific Ocean, passing through the tropics mainly in May and June when northbound, and September and October southbound (Shaffer *et al*. 2006).

The only land record for this species was one on Rarotonga on 9 Dec 2021. The bird was found at the Punanga Nui Market, Avarua by S. George, possibly attracted by the harbour and town lights. Identification of the bird was confirmed by CG from photographs and measurements.

Records of sooty shearwaters seen at sea in the Cook Islands are of 18 individuals flying south 12 miles ENE of Ātiu in the Southern Cook Islands in September 1973 (Holyoak 1980), one near Rarotonga in April 1999, another near Aitutaki in April, three near Rarotonga in September 2000 (Jowett 2000), and near Palmerston in September 2006 (White 2006).One was found aboard a ship on 12 Dec 2023 (A. Williams, eBird, viewed February 2025), and another on 2 Apr 2023 (precise locations not given, but within Cook Islands EEZ) (M. Greenfelder, eBird, viewed February 2025). On Rarotonga, a bird was seen off Turoa Beach on 15 Apr 2019 (C. Stapelmann, eBird, viewed January 2022).

Christmas Island shearwater (*Puffinus nativitatis*)
The Christmas Island shearwater breeds on remote islands in the central Pacific Ocean, from the Hawaiian Islands (USA) in the north south to Phoenix Islands (Kiribati), and east to French Polynesia and Easter Island (Chile) (Harrison *et al*. 2021). Outside the breeding season it ranges off the coasts of Mexico and northern Chile in the east, to the Bonin Islands (Japan) in the west. At sea sightings include one seen near Aitutaki in April 1999 (Jowett 2000), and another from a yacht between Fiji and Rarotonga on 11 Jul 1990 (P. Rosen, eBird, viewed January 2022).

DISCUSSION

Archaeological surveys revealed that during the pre-human era, before 900AD, at least four species of Procellariiformes were breeding in the Southern Group, Cook Islands: black-winged petrel, Tahiti petrel, tropical shearwater, and Polynesian storm petrel (Steadman 1991, 1997, Steadman & Olson 1985). Species that may currently be breeding in the Cook Islands include the Herald petrel on Rarotonga, black-winged petrel on Ātiu, wedge-tailed shearwater on Aitutaki, and tropical shearwater on Mangaia. It is possible these species breed, or attempt to breed, elsewhere in the Cook Islands archipelago. Further surveys and observations need to be carried out urgently to determine the breeding status and distribution of all petrel species in the Cook Islands.

With so little known about procellariiform populations in the Cook Islands, the lack of knowledge about their ecology, breeding biology, breeding success and threats is a major obstacle to developing conservation plans. The highest priorities are:

1. Confirm whether certain species are still breeding in known areas, i.e., find nesting sites for Herald petrels on Rarotonga (Fig. 2); work with the Mangaian community to confirm whether small shearwaters are still breeding on Mangaia, and confirm what species they are; with the Aitutaki community to confirm that wedge-tailed shearwaters are breeding on islands within the atoll, with the community on Ātiu to confirm if black-winged petrels are still breeding there 40 years after the initial records; and follow up on sightings of Herald petrels at Aitutaki, and possible Murphy's petrel on Takutea.
2. Extend surveys and outreach to communities in other places and islands in the Cook Islands group.
3. If birds are found breeding in any of these places, seek support for implementation of predator control (i.e., exclude pigs and dogs, and control rats and feral cats) around the remaining nests.
4. Of less immediate concern is the lack of knowledge about diet and foraging, during breeding and movements after breeding. However, if breeding populations can be found, and prove to be reasonably accessible, then diet and tracking studies could be initiated to help broaden our understanding of the ecology of tropical Procellariiformes and their use of the Cook Islands EEZ.

Our recommendation is that a staged survey approach be adopted for the Cook Islands, as follows:

1. There is a wealth of knowledge about seabirds to be found at the grassroots level within the communities of the Pacific, especially among people who are living near where birds could be breeding. Therefore, community surveys can be a good approach to gather more records, either through in-person meetings, or the use of social media and printed posters.
2. Acoustic surveys using automated recorders at all reported and likely breeding localities on Rarotonga, Ātiu, and Mangaia, to identify or rule out sites.
3. Follow-up searches at areas where seabirds were detected during acoustic surveys. This could involve ground searches, use of playback of calls, spotlighting, or the use of a specially trained petrel detection dog.
4. Radio transmitters could be deployed on birds captured during spotlighting/playback surveys and then tracked to their nests. (Rayner *et al*. 2015).
5. Threat assessments need to be made at each stage, and if breeding birds, active nests and burrows are found, then immediate predator control needs to be implemented.
6. There is the potential to recover petrel populations via sustained predator management or eradication of pests from islands, combined with species attraction by broadcasting recorded calls, and/or through translocations to speed up (re)colonisation.
7. Robertson *et al*. (2020) recommended establishing playback stations and artificial burrows in the Takitumu Conservation Area to try to encourage Herald petrels and collared petrels to establish a colony within the 150 ha that is currently being managed. This would require the addition of intensive cat control and a longer period each year of sustained rat control, and/or the construction of a predator-proof fence around any new colony to protect birds on the ground.

Once breeding sites have been located and protection measures implemented, then conservation management plans can be prepared and implemented for each of the islands, through collaboration between Cook Islands environmental groups, government agencies, and (most importantly) local communities, supported by expertise from other countries. Capacity building can also be achieved by strengthening community and institutional capacities, developing appropriate field skills and survey and monitoring techniques, and training on biodiversity, threat assessment and on-going pest management. While the way ahead is extremely challenging for the Cook Islands to recover its petrel populations, it is possible through eradication programmes and sustained predator management, and possibly by translocations of chicks as undertaken successfully elsewhere in the Pacific and the world (Miskelly *et al.* 2009; Gummer *et al.* 2014; Young *et al.* 2023).

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Dispersal of invasive *Berberis glaucocarpa* in secondary forest occurs mainly by exotic frugivores

ARCHIE E.T. MACFARLANE*
School of Biological Sciences, University of Canterbury, Christchurch, New Zealand

Current address: Department of Conservation, 32 River Road, Rangiora, 7400, New Zealand,
ORCID 0000-0002-8725-469X

JAMES V. BRISKIE (ORCID 0000-0001-5813-4392)
DAVE KELLY (ORCID 0000-0002-9469-2161)
School of Biological Sciences, University of Canterbury, Christchurch, New Zealand

Abstract: Understanding plant invasions is important in conservation ecology and land management, as invasive plant species worldwide have caused irreparable damage and often incur substantial control costs. To record the dispersal vectors for the invasive barberry (*Berberis glaucocarpa*) in a New Zealand regenerating forest, video cameras were used to film 24 barberry plants in fruit in Kowhai Bush, Kaikoura. During 242 hours of video, a total of 101 foraging events were recorded by four bird species: silvereye (*Zosterops lateralis*), blackbird (*Turdus merula*), song thrush (*T. philomelos*), and starling (*Sturnus vulgaris*). The four bird species varied in visitation frequency, time spent on plants, and fruit removal rates. The estimated daily contribution to recorded barberry fruit removal was 42.8% by song thrush, 32.6% by silvereye, 24.3% by blackbird, and 0.2% by starling. No endemic bird species were observed feeding on barberry, despite bellbirds (*Anthornis melanura*) being common in Kowhai Bush. Removal rates for ripe barberry fruit were relatively modest (1.14% per day), but given the ~3 month fruiting season, represented a sizable seed rain in the surrounding forest. Although barberry is now sympatric with several introduced frugivores in New Zealand, none of its dispersers from its native range in Nepal and northern India are present. Instead, dispersal in New Zealand is facilitated primarily by introduced European bird species and native silvereyes.

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Keywords: frugivores, seed dispersal, fleshy-fruited invasive plant, introduced frugivores.

INTRODUCTION

The presence of an efficient seed disperser is a key predictor for the potential spread of a fleshy-fruited invasive plant species (Rejmánek & Richardson 1996). For many invasive fleshy-fruited plant species, birds are the main dispersal agents (Gosper *et al*. 2005). In New Zealand many endemic and native frugivorous bird species display generalist foraging strategies and disperse a wide array of native fleshy-fruited plant species (Thorsen *et al*. 2011). However, in the last 200 years, several additional frugivorous bird species have become naturalised and are now widespread (Heather & Robertson 2000). For example, Eurasian blackbirds (*Turdus merula*) are key dispersers of weeds (Williams 2006), and facilitated the spread of the invasive hawthorn (*Crataegus monogyna*) in Porters Pass, New Zealand (Williams *et al.* 2010).

The combination of generalist foraging strategies in native and endemic frugivores, and the introduction of additional avian dispersal vectors, could promote the spread of invasive fleshy-fruited plants in New Zealand. As an increasing number of plants naturalise within native forests, understanding bird-mediated seed dispersal is important for both modelling and managing weed invasions (Overton *et al*. 2003). Despite this, only a few of

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*Correspondence: *archmac99@googlemail.com*

the introduced fleshy-fruited plant species have had their dispersal vectors identified (Vitousek *et al*. 1996; Callaway & Aschehoug 2000; Mack *et al*. 2000; Wotton & McAlpine 2015).

Barberry (*Berberis glaucocarpa*) is a common invasive weed species found throughout much of New Zealand (Popay *et al*. 2010). Its primary dispersal vectors are frugivorous birds; however, the relative importance of native versus introduced birds in dispersal has not been well studied (Timmins & Williams 1987; Bakker *et al*. 1996). The objectives for this study were: (1) to determine the bird species feeding on barberry fruit in a regenerating native forest, (2) to measure fruit removal rates from fruiting plants and, (3) to quantify which disperser(s) removed the most fruit and subsequently were most likely to disperse barberry seeds.

To address these objectives, we used video cameras to document bird interactions with barberry. Video monitoring has been widely used in ecological research to record frugivore activity and fruit removal rates (Drummond 2005; Dumont 1999; Jayasekara *et al*. 2007; Kitamura *et al*. 2004; Levey *et al*. 2006; Tewksbury *et al*. 1999), making it a suitable method for this study.

METHODS

Study site and species

All observations were carried out at Kowhai Bush (173° 37′ E, 42° 23′ S), a 240 ha regenerating native forest near Kaikoura that is managed by Environment Canterbury. The areas to the north and east of Kowhai Bush are agricultural pastures while to the south and south-west are river shingle plains. Kowhai Bush is connected to lowland podocarp–hardwood forests in the foothills of the Kaikoura Range by a narrow strip of vegetation running along its north-western edge. This has created a corridor between the regenerating and older forests.

The forest interior of Kowhai Bush is a flood-induced successional patchwork of differing age, structure and species composition (Hunt & Gill 1979). The forest canopy ranges from 5-12 m high and is dominated by kanuka (*Kunzea ericoides*) and manuka (*Leptospermum scoparium*), with occurrences of *Melicytus ramiflorus* and *Pseudopanax arboreus* on the north-eastern side. Along the eastern margins, areas have an understory of barberry and hawthorn. Barberry is native to Nepal and northern India and was introduced into New Zealand in 1916 as a hedgerow species (Roy *et al*. 2004; Lakhey *et al*. 2024). It soon become naturalised and is now classified as a noxious weed species (Owen 1997; Froude 2002; Rahman *et al*. 2003; McAlpine & Howell 2024). If left unchecked in open or regenerating habitats, it can replace other shrubland species (Sullivan *et al*. 2007). Flowering of barberry in Kowhai Bush occurred from the start of October until end of November 2010. Flowers were small, yellow and occured in clusters of 4–12 (MacFarlane 2012). Fruits are small and fleshy, ~8 mm in diameter, round, black or purplish, with a white surface bloom, typically containing two seeds (Webb *et al*. 1988). Fruit was ripe in Kowhai Bush from late February until late May in 2011 (MacFarlane 2012).

Video observations

To identify the bird species feeding on barberry fruit, video cameras were used to capture foraging events on 24 randomly selected barberry plants. Filming was carried out 24 Feb–20 May 2011, using two Sony DCR-SR68 video cameras. Video cameras were set up 5–7 m from plants so that the entire plant was visible plus a minimum margin of >1 m surrounding the plant. This increased the observer's ability to identify visiting birds. Although it was sometimes difficult to identify some birds while feeding, all could be identified from their flight patterns as they entered and left the area. Filming was divided into morning and afternoon sessions to account for time-of-day effects. Morning sessions ran from dawn (6:30–7:30 h) to approximately 13:00 h, while afternoon sessions began the following day at the same time the previous morning session had ended and continued until dusk (17:30–19:00 h). This schedule was necessary due to the camera battery life, which was limited to eight hours, and the time required for recharging batteries. Together, these sessions spanned the period from sunrise to sunset, with each plant filmed for both a morning and afternoon session. A total of 242 hours of recordings were collected, with an average of 610 ± 30 minutes (mean ± 95% CI) per plant.

The day after the afternoon filming, we estimated the total number of ripe, unripe and damaged fruit available on that plant. Due to the size and position of many of the plants it was not possible to count all fruit, and so 25 clusters of fruit were selected at random on each plant. From each cluster the total ripe and damaged fruit was recorded, and the average number of fruit per cluster calculated. The total numbers of clusters per plant was then counted, and total fruit per plant calculated by multiplying fruit per cluster times clusters per plant.

Video recordings were watched later, and for each bird landing on a plant we recorded: (1) bird arrival and departure times, to calculate total seconds spent on the plant, (2) species of bird, (3) whether a foraging event occurred, defined as fruit seen to be eaten or birds displaying feeding behaviours like pecking or swallowing motions, and (4) if possible, the total number of fruit eaten.

Analysis

The software package R version 2.13.2 2 was used for all statistical analyses. All selected models were checked for goodness of fit (Agresti & Kateri 2011), with the gof function, R package aods3 v0.4-1.1. Morning and afternoon filming sessions were combined to form one period. For all foraging events, the observer was able to record how long each individual bird remained feeding (seconds) on the plant.

While the number of fruits eaten could not be determined for every foraging event, time spent feeding was significantly correlated with fruit removal (see Results). Given this relationship, total feeding time was used as a proxy to estimate each bird species' relative contribution to fruit removal. A GLM with a Poisson distribution was used to estimate differences in fruit removal rates among the four bird species. Lastly, to estimate each bird species' overall contribution to barberry fruit removal, we first calculated feeding intensity for each monitored plant using the formula:

$$\text{Feeding Intensity} = \left(\frac{\sum \left(\frac{T}{H} \right)}{\sum F} \right) \times 1000 \times P$$

Where T is the total time a bird spent feeding on a plant (seconds), H is the total duration of video recording for that plant (hours), F is the total number of available fruits on the plant, and P is the proportion of plants visited by the species. Since this calculation applies to individual bird visits, we then averaged feeding intensity across all monitored plants (N) to obtain a final estimate for each species:

$$\text{Overall feeding intensity} = \frac{1}{N} \sum_{i=1}^{N} \text{Feeding intensity}_i$$

This final metric provides a standardised estimate of each species' feeding effort per 1000 available fruits per hour across all sampled plants, accounting for both visitation frequency and time spent feeding.

RESULTS

In total, 101 foraging visits to barberry plants were recorded. It was possible to identify all bird species and to measure their duration of feeding on barberry fruit for all visits. However, it was only possible to record how many fruits was eaten per visit for 35 birds. Four bird species were observed feeding on barberry fruit: the native silvereye (*Zosterops lateralis*), and introduced Eurasian blackbird, song thrush (*Turdus philomelos*) and common starling (*Sturnus vulgaris*) (Table 1). Endemic frugivorous birds (of which the most locally common was the bellbird, *Anthornis melanura*) were not observed feeding on barberry plants. Each plant was visited by 4.2 ± 1.7 (mean ± SE) birds during an individual filming period (morning and afternoon sessions combined), and each bird remained feeding for 47 ± 12.7 seconds per visit. Filmed barberry plants carried a mean of 1,324 ± 463 ripe fruits. For all bird species combined, a mean of 3.6 ± 1.1 fruits was removed per individual visit. This equates to 15.1 ± 4.6 fruits removed from each plant per day. For a filmed plant this would mean 1.14% of its fruit was removed daily. The fruiting season in 2011 lasted from late February until late May, a period long enough for most fruits to be removed.

Significant differences in fruit removal rates were detected among the four bird species (χ^2 = 34.92, DF = 3, P <0.001). This difference was driven by silvereyes, which made the most visits but removed fewer fruits per visit, compared to starlings which had the highest fruit removal rate per visit despite very few visits (Table 1). Blackbirds and song thrushes had intermediate values for both the number of visits and fruits removed per visit.

There was a significant relationship between the duration that birds remained on the plants and the total number of fruits they removed (χ^2 = 42.44, DF = 1, P <0.001, Figure 1). The longer a bird remained on the plant the more fruits it removed. For this reason, using total time of visits per 1000 fruit is a reasonable estimate of each bird species' contribution to fruit removal. Overall, the daily contribution to recorded barberry fruit removal was 42.8% for song thrushes, 32.6% for silvereyes, 24.3% blackbirds, and 0.2% for starlings. These estimates suggest that song thrushes were the most important dispersal vector.

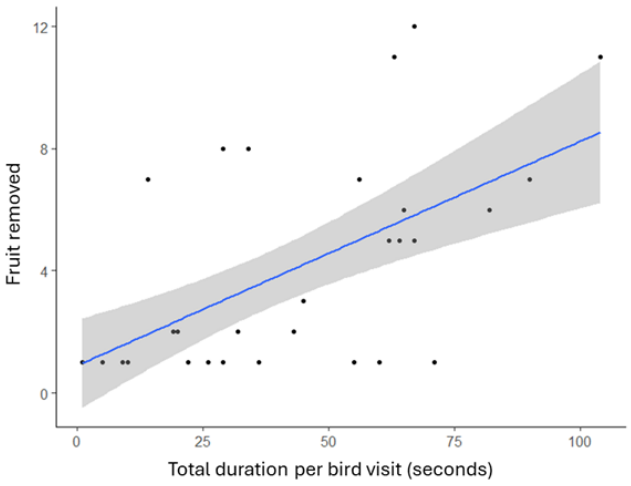

Figure 1. The relationship between mean duration of bird visits (seconds; model mean is indicated by the blue line) and the mean number of fruits removed per visit, with 95% CI.

DISCUSSION

Consumption of barberry was restricted to one native and three introduced frugivorous bird species. Although silvereyes are native, they colonised New Zealand relatively recently, in the 1850s (Heather & Robertson 2000). The other three species were introduced to New Zealand from Europe between 1862 and 1883 (Heather & Robertson 2000). Of the four species recorded feeding on barberry, all except one (starling) were observed frequently enough to be considered a major dispersal vector of barberry in Kowhai Bush. Differences in feeding behaviours among silvereyes, blackbirds, song thrushes, and starlings contributed to the differences in seed dispersal dynamics. Blackbirds and song thrushes showed moderate visitation frequencies and fruit removal efficiencies and accounted for most seed dispersal. Silvereyes, despite spending shorter periods per visit and consuming fewer fruits on average, compensated with frequent visits. This pattern resulted in a substantial but still comparatively lower overall contribution to fruit removal. In contrast, starlings had high fruit consumption rates per visit but made few visits, suggesting they played a lesser role in dispersing barberry seeds.

Frugivore body size plays a key role in determining fruit consumption rates, as larger-bodied birds tend to consume greater quantities of fruit per feeding event due to their higher energy demands and they can consume larger fruits due to larger gape widths (Case & Tarwater 2020). In the Hawaiian Islands, the loss of large native frugivores and the introduction of smaller-bodied species reduced the dispersal of larger-seeded plants, altering plant-frugivore interactions (Case & Tarwater 2020). A similar pattern may explain the differences in fruit removal rates observed in this study. Blackbirds and song thrushes, both mid-sized frugivores, accounted for most barberry seed dispersal, while silvereyes, with their smaller size and gape, removed fewer fruits per visit. These results align with broader patterns in seed dispersal research, where frugivore body size influences both the quantity of fruit consumed and the effectiveness of seed dispersal (Howe & Smallwood 1982; Schupp 1993).

Our observations suggest that barberry does not appear to be dispersal-limited in New Zealand, despite being introduced and no longer sympatric with its native dispersers in Nepal and northern India. This pattern is consistent with broader trends, as ~32.9% of New Zealand's 295 environmental weed species produce fleshy fruits adapted for animal-mediated dispersal (Wotton & McAlpine 2015). Among these, blackbirds, silvereyes, song

Table 1. Visitation and fruit removal rates to barberry *Berberis glaucocarpa* at Kowhai Bush by four bird species (means ± 95% CIs from 242 hours of videos on 24 plants).

Bird species	Silvereye	Blackbird	Song thrush	Starling
Total number of visits	42	27	29	3
N fruit removed per visit	1.4 ± 0.47	3.5 ± 1.8	3.6 ± 1.8	9.3 ± 2.6
Proportion of plants visited by each bird species	0.46	0.37	0.42	0.08
Duration per visit (seconds)	31.5 ± 5.1	81.2 ± 47.9	42.4 ± 12.2	44.3 ± 22.6
Overall feeding intensity (seconds of feeding per 1000 fruits per hour)	3.96	2.95	5.20	0.02

thrush, and starlings have been identified as key dispersers, playing a significant role in accelerating plant invasions. Similarly, Williams & Karl (1996) found that introduced birds, such as blackbirds and song thrushes, consumed fruits from both native and exotic plants, whereas endemic species showed a stronger preference for native fruits. This pattern is also evident in Kowhai Bush, where barberry was largely ignored by endemic seed dispersers despite the presence of several frugivorous native birds, including bellbirds, South Island robins (*Petroica australis*), and the occasional visiting tūī (*Prosthemadera novaeseelandiae*) and kererū (*Hemiphaga novaeseelandiae*). The adaptability of introduced birds, along with their ability to thrive in human-modified landscapes, likely enhances their effectiveness as vectors of weed proliferation, often outcompeting or replacing native dispersers in disturbed ecosystems (Kelly *et al*. 2010).

An estimated 1.14% of barberry fruit per plant was consumed daily by birds. This dispersal estimate is likely higher, as possums (*Trichosurus vulpecula*) were also recorded dispersing barberry seeds at Kowhai Bush (Wyman & Kelly 2017). However, as the barberry fruiting season in 2011 at Kowhai Bush lasted from late February until late May, even rates of 1.14% of fruit eaten per day would have been sufficient for nearly all fruits to be removed. Indeed, by the end of May, few fruits remained on the barberry plants in Kowhai Bush, suggesting most had been eaten (AETM *pers. obs.*). This indicates that many plants likely were receiving adequate fruit removal services.

Apart from rates of fruit removal, the quality of seed dispersal depends on the treatment given to a seed in the mouth and gut, as well as the quality of seed deposition site (Schupp 1993). None of the four bird species that we observed eating barberry fruits are considered seed predators, and all barberry seeds collected from blackbird, silvereye, and song thrush faecal samples were intact (MacFarlane *et al*. 2016). Movement of seeds by dispersers away from parent plants is usually advantageous, as seedlings that germinate under parent plants can have higher predation rates and additionally will have to compete with both the parental plants and siblings as they grow (Schupp *et al*. 2010). The longer that a frugivore remains on the parent plant the more likely it is to deposit the seeds under this plant (Pratt & Stiles 1983). Birds that visited barberry plants remained feeding for 47 seconds on average and the maximum time was 493 seconds. Gut passage time normally averages *c*. 30 minutes for blackbirds (Sorensen 1981; Barnea *et al*. 1991), 20 minutes for silvereyes (Stanley & Lill 2002), 43 minutes for song thrushes (Herrera 1984) and 38 minutes for starlings (Karasov & Levey 1990; LaFleur *et al*. 2009). Therefore, it is likely that most barberry seeds were defecated away from the parental plants by all the foraging bird species.

Successful dispersal away from the parent plant, and germination of dispersed seed, means there is likely to be continued expansion of barberry into Kowhai Bush in the future. Barberry has only recently become established in Kowhai Bush, and its stands are still relatively small and young. It could be assumed that as stands increase in density there will be increased fruit availability and, subsequent increased visitation from frugivores and dispersal of seeds. Similar trends have been observed with hawthorn dispersed by blackbirds at Porters Pass, New Zealand (Williams *et al*. 2010). Barberry has the potential to negatively affect native biota by successionally replacing native seral species (Sullivan *et al*. 2007) and may compete with other native fruiting shrubs such as *Coprosma* species for resources. This could reduce habitat quality and eventually food availability for endemic frugivorous bird species, which do not appear to feed on barberry.

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GPS tracker trial on kea (*Nestor notabilis*) at Aoraki/Mount Cook National Park

TERRY C. GREENE* (ORCID 0000-0002-4183-0719)
SAM KROUSE (ORCID 0009-0006-7234-3477)
Department of Conservation, Private Bag 4715, Christchurch, New Zealand 8140

TOM GOODMAN
Department of Conservation, PO Box 5, Aoraki/Mt Cook, New Zealand 7999

EMMA M. WILLIAMS
Department of Conservation, Private Bag 4715, Christchurch, New Zealand 8140, ORCID 0000-0002-6993-7577

Abstract: Understanding the drivers for the seasonal movements of kea at landscape scales is critical to their conservation. Recent developments and increasing use of Global Positioning System (GPS) trackers prompted a small-scale trial on kea (*Nestor notabilis*) in Aoraki/Mount Cook National Park during October 2021 to February 2022. We attached a solar charged Druid Debut Lego™ tracker to four birds: two nesting females, a juvenile male and a recently fledged male. One tracker, with a raised solar panel, transmitted data by 3G cell phone network and the others sent data by 2G GSM cell phone network. The two trackers with raised solar panels collected and transmitted substantially more data than the flush-mounted solar panels. Location data was mapped, and elevation, distances travelled, 24-hour movement patterns and activity behaviour were analysed. The limitations of these GPS trackers are discussed, and recommendations are made for future use of GPS trackers on kea where topographic shading, power consumption, satellite reception, and data transmission are likely to remain significant challenges.

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Keywords: telemetry, cell networks, solar charging, mobility, home-range, behaviour

INTRODUCTION

The conservation of mobile species, such as kea (*Nestor notabilis*) requires an understanding of their distribution and movement patterns throughout the year (Williams 2021). Their often remote, rugged and inaccessible location, coupled with large home range, low density and cryptic nature, makes estimating their population size difficult. Consequently, kea studies have tended to focus on short term behaviour and local movement patterns (Weston *et al*. 2023).

Local kea movement has been studied via VHF (very high frequency) radio telemetry (Kemp *et al*. 2022; van Klink & Crowell 2015), mark-resight of colour banded birds (Bond & Diamond 1992; Diamond & Bond 1999; Jarett & Wilson 1999) and Global Positioning System (GPS) trackers (Kennedy *et al*. 2015; Latham *et al*. 2015). Limitations of these methods include irregular and infrequent collection of location data (radio telemetry), dependence on often chance encounters (mark-resight), or requirement to recapture birds (GPS data loggers). All methods are constrained by data collection and transmission as determined by battery life. This is particularly problematic for kea that habitually frequent remote back-country areas, where observations of individuals and recaptures are difficult.

Recent developments of GPS trackers for wildlife have provided researchers with an opportunity to collect finer-scale data on bird movements over longer periods

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*Correspondence: *tgreene@doc.govt.nz*

of time (López-López 2016; Van Der Kolk *et al*. 2022; Iverson *et al*. 2023). GPS trackers can collect environmental, accelerometer, altitudinal, and location data and can be deployed with smaller batteries supported by solar panels. The type of data and frequency with which it is collected can be programmed by users before tag deployment and, if necessary, altered following deployment using appropriate data transmission networks. There are four main methods of GPS data transmission: 1) physical retrieval and download of archival tags (Kennedy *et al*. 2015); 2) remotely via proprietary receiver (often referred to as 'gateways', 'nodes' or 'hubs') (Mainwaring *et al*. 2002); 3) automated download via satellite (e.g. ARGOS, Iridium) (Yeap 2022); and 4) automated download via cell phone networks (Yeap 2022).

Determinants for the successful deployment of GPS trackers include topography, remoteness, climate, bird movement patterns and habitat use, bird behaviour, vegetation density, canopy cover, and the flexibility of the chosen method for data download. Kea pose a particular challenge as they frequently inhabit some of the most inhospitable terrain in New Zealand from which to collect movement data.

To test GPS tracker performance for kea, we carried

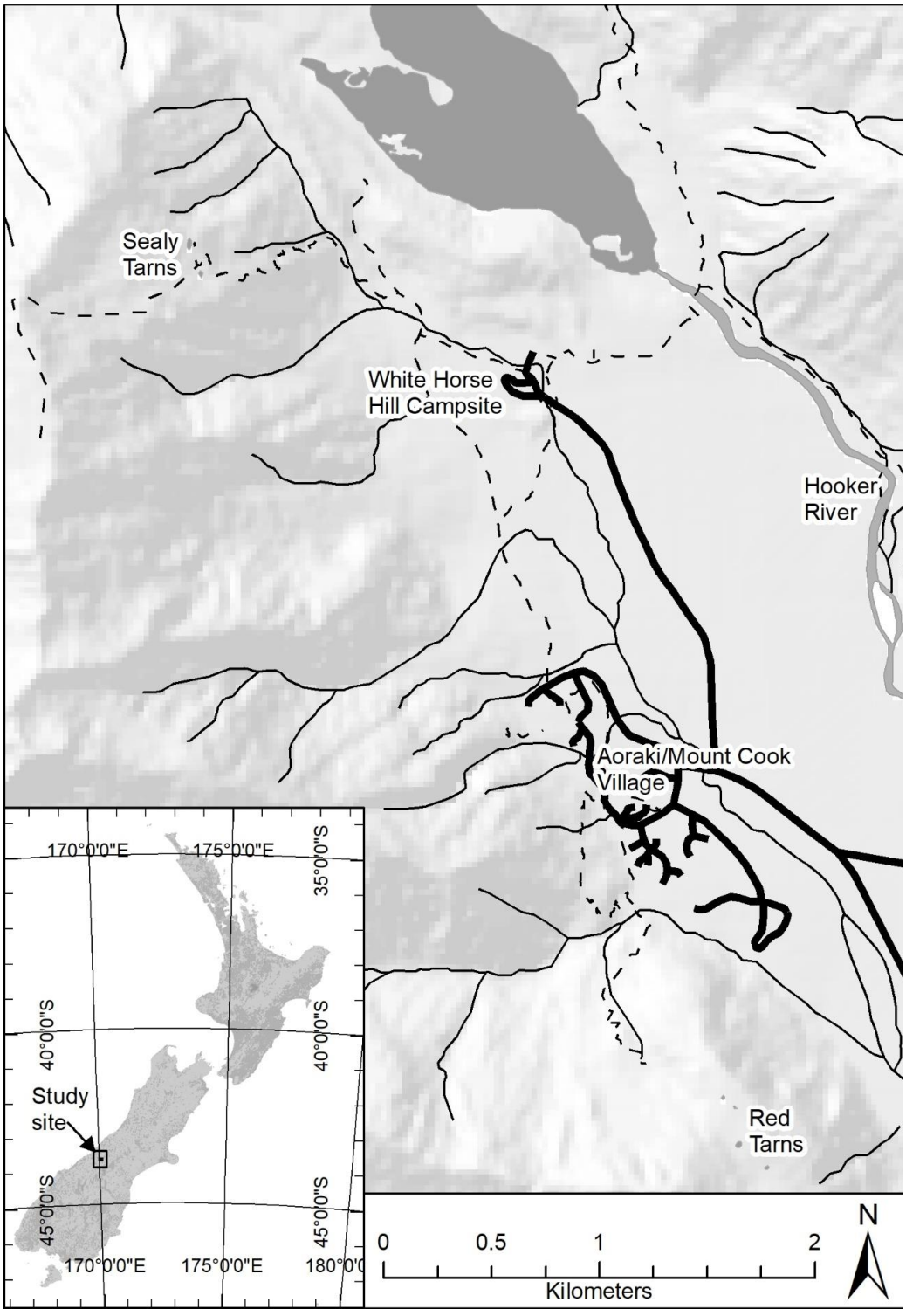

Figure 1. Location of study area and kea capture sites at Aoraki Mt Cook National Park

out a small-scale trial of Druid Debut Lego™ GPS trackers on four kea at Aoraki/Mount Cook National Park, in the Southern Alps of the South Island. As cell phone network coverage was greater to the east than to the west of the Southern Alps and kea were more readily accessible, we based our study within <5 km of Aoraki Mount Cook village. We assessed the performance of the GPS trackers on kea by examining the physical robustness of tags and comparing data collection and transmission of two solar panel configurations: one that sits flush and one that is elevated above the body of the device. Raising the panel was expected to increase tag performance by increasing the energy gain/power levels of the device. Results from this study will be used to inform future use of GPS trackers on kea (and other species of similar size) so that the accurate assessment of population trends, impact of management actions, and kea mobility can be better explored.

Figure 2. Images of Druid Debut Lego™ GPS trackers with a flush (left) and raised (right) solar panels on kea.

METHODS

Study site

Aoraki/Mount Cook National Park (42.93°S, 171.56°E) is in the Southern Alps, New Zealand (Fig. 1). The landscape is characterised by deeply incised glacial valleys, high alpine peaks, and steep scree slopes, ranging from 300 m to 1,720 m above sea level. The study area has a mean annual rainfall of >4 m and mean monthly air temperatures range from a low of −2°C in July to a high of 18°C in February (CliFlo 2022).

Kea

Kea (*Nestor notabilis)* are large, olive-green parrots, with scarlet underwings (males 900-1100 g and females 700-900 g); they are endemic to New Zealand with a conservation status of Nationally Endangered (Robertson *et al.* 2021). Found throughout much of the South Island, kea are most common within montane forests, adjacent alpine zones, and the lowland forests of South Westland.

Four kea: two nesting females, a juvenile male, and a fledgling male were caught and fitted with Druid Debut Lego™ GPS trackers during October 2021 to February 2022 at Aoraki/Mount Cook National Park (Fig. 1). Work was undertaken as part of routine nest monitoring checks by the Department of Conservation. Birds were only handled by highly capable operators with extensive previous kea handling experience. All birds were captured, weighed, measured (bill length, tarsus, wing chord), banded, and tagged with GPS trackers immediately following capture. Birds were then given a quick health check before being released as quickly as possible.

GPS tracker units

The Druid Debut Lego™ GPS trackers are lightweight (18.7 g, which is ~2% of kea bodyweight), have a working temperature range of between -20°C and ~60°C, a solar panel for maintaining charge, and are capable of storing 380,000 data records (460 days of regular use). The internal batteries have high capacity for their size (210 mAh) and are capable of recording 700 or more GPS fixes without any solar charge.

GPS trackers were attached using a standard 'backpack' type harness with an integrated linen weak link (Karl & Clout 1987). Trackers #5037 and #4944 had solar panels flush with the top of the main unit. Trackers #4789 and #5208 had solar panels elevated above the main body of the device (Fig. 2). These elevated units also had 6 solar cells compared to the 4 cells found on the flush mounted units and as such had a 50% increase in available solar charging area. Tracker #5208 was programmed to transmit and collect data using the 3G cellular network. The other three trackers (#4789, #4944, #5037) were programmed to use the 2G GSM cellular network, which had greater coverage (https://one.nz/network/coverage/) but lower data transmission rates (Table 1). Two of the trackers (#4789 and #5037) were deployed in late October 2021 on nesting adult female kea at Sealy Tarns and near White Horse Hill Campground. The other two trackers (#4944 and #5208) were deployed on a juvenile and a fledgling male at Red Tarns in February 2022.

All trackers were programmed to collect GPS locations at one-hour intervals. Trackers also had 'Inflight boost' mode enabled so that sampling increased to one fix per 20 seconds provided the bird was moving at a speed ≥5 m/s, and the tag's battery threshold was ≥3.92 V (Druid default settings). The tracker then returns to its normal sampling rate (of once per hour) if the voltage fell below 3.92 V or the speed became lower than 2 m/s. Three other default dynamic boost modes were also enabled which essentially increased data collection and transmission intervals as voltage dropped (steps at 4.1 V, 4.02 V, and 3.97 V). Trackers recorded Overall Dynamic Body Acceleration (ODBA), which is a measure of activity derived from triaxial accelerometers (Wilson *et al*. 2006). This information can be used to interpret activity levels and speed. Trackers were also programmed to search for the 2G and 3G GSM networks every 12 hours. If the trackers were successful (i.e. within range of the local network), any movement and tracker diagnostic data on the tracker were automatically uploaded to the Druid data servers and accessible to us via their website or mobile phone app. All environmental and

Table 1.

Kea	Tracker ID	Date attached	Last record	Days operative	Number of fixes	Network	Solar panel
Nesting female	#4789	21 Oct 2021	19 Aug 2022	303	1731	2G	Raised
Nesting female	#5037	20 Oct 2021	24 Sep 2021	4	76	2G	Flush
Juvenile male	#4944	23 Feb 2022	02 Mar 2022	7	149	2G	Flush
Fledgling male	#5208	23 Feb 2022	23 Jun 2022	120	693	3G	Raised

tag sensors embedded within the trackers were enabled (e.g. temperature, light, acceleration) and were a customisation of default Druid settings (i.e. ODBA collection rate was increased and data transmission interval decreased). Transmission of data stopped when battery voltage fell below 3.72 V, and collection of GPS and environmental/OBDA data ceased when battery voltage reached 3.67 V and 3.65 V respectively.

RESULTS

Collection and transmission of data from kea

All trackers collected and transmitted GPS location data; however, performance was erratic (Table 1). The total number of satellite fixes logged for each individual ranged from 76 to 1731. The flush-mounted solar panel trackers (#4944, #5037) only operated for 4 and 7 days, while the elevated solar panel trackers operated for 120 days (#5208) and 303 days (#4789) respectively.

There were insufficient data from the fledgling male kea (#5208) to determine any movement patterns. The low number of fixes for the juvenile male kea (#4944) only recorded short-term movement. The raised solar panel tracker #4789 on the 2G network collected and transmitted more than twice the number of locations than raised solar panel tracker #5208 on the 3G network over the same number of days. Tracker #4789 also reawakened itself to transmit data some 6 months after it was assumed to have failed on 17 Feb 2022. It continued to record for at least a further 2-3 months.

Outliers were only occasionally recorded. For example, although the kea carrying tag #5037 recorded a single location almost 9 km from its usual range within a 2-hour period, there was no evidence from the GPS data that this was an inaccurate result.

#4789 Nesting adult female

This nesting female was caught on 21 Oct 2021 near White Horse Hill Campground (Fig. 3A). The raised solar panel recorded and transmitted data over the 2G network for 303 days. Most movements were concentrated within a relatively small area around her capture site at her nest on White Horse Hill and the track leading to Sealy Tarns (Fig. 3A). Her movements were bounded by the northern end of the Sealy Range south to Black Birch Stream, with a secondary area of activity on the slopes immediately east of the southern end of Mueller Lake. Her longest flights were 8 km south into the head of the Dobson River and a 5 km north-east to the west facing slopes above Hooker Lake. She also made visits to the White Horse Hill Campground and the back door of The Hermitage.

#5037 Nesting adult female

This nesting female was caught on 20 Oct 2021 on the slopes below Sealy Tarns (Fig. 3B). The flush solar panel tracker #5037 only collected and transmitted data over the 2G network for 4 days. Most movements were near her nest site. Her movements were bounded by the very northern end of the Sealy Range. Her longest flight was 8.9 km north-west across the Southern Alps to the Sierra Range/Lucy Walker Pass region.

#4944 Juvenile male

A juvenile male was caught on 23 Feb 2022 at Red Tarns (Fig. 3C). The flush mounted solar panel tracker connected to the 2G network but only operated for 7 days. Most of this bird's movements were to the north-facing slopes adjacent to the Red Tarns below Mount Sebastopol and near the head of Birch Hill Stream below Mt. Cran. Its longest flights were 5 km north to the end of the Sealy Range and 10 km south

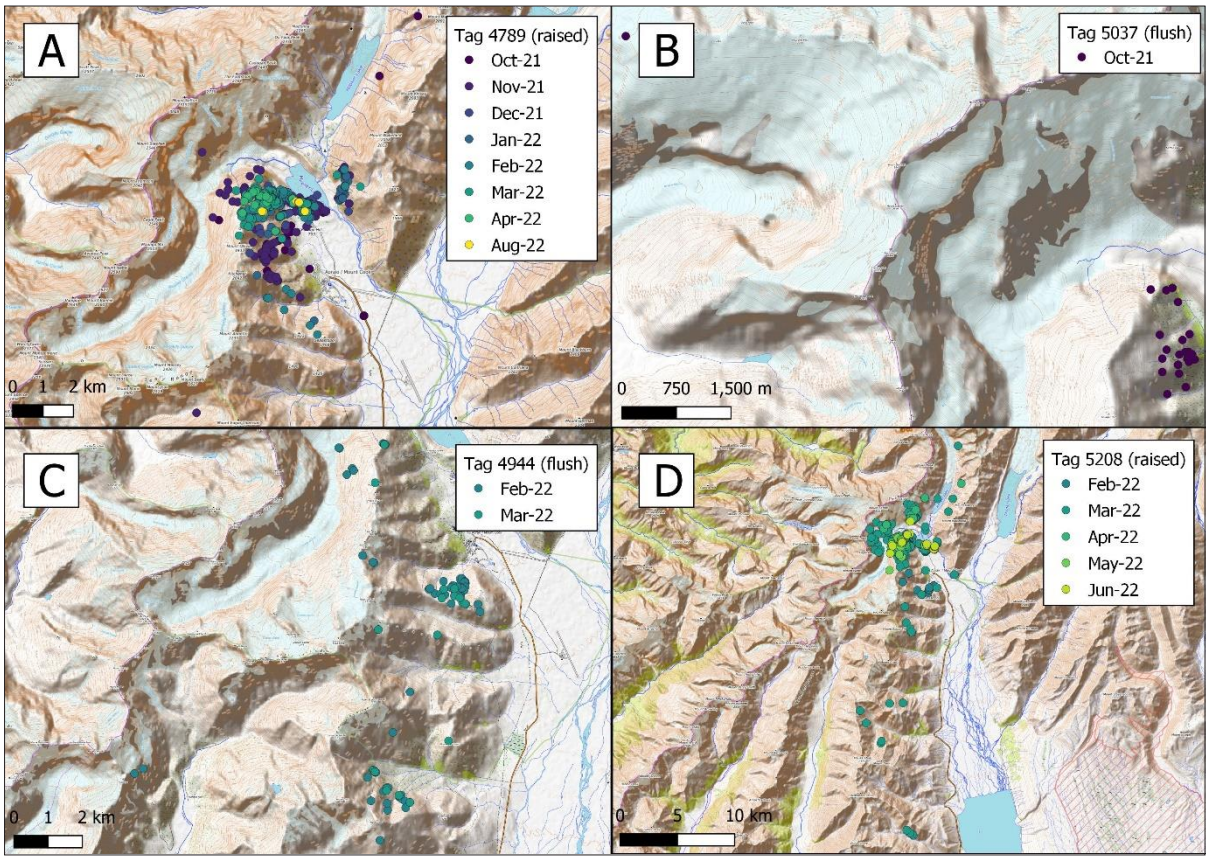

Figure 3. Location data for four kea tagged with GPS trackers (two with trackers that had raised solar panels and two with trackers that had flush solar panels). Kea were caught and tagged in Aoraki/Mount Cook National Park, Aotearoa/New Zealand, between October 2021 and February 2022.

Table 2.

Kea	Tracker ID	Period	Min distance (m)*	Mean distance (m)	Max distance (m)
Nesting female	#4789	Day	53.25	5708.21	18236.4
	#4789	Night	2.2	911.38	7455.76
Nesting female	#5037	Day	158	5866.21	11767.04
	#5037	Night	11.14	46.22	129.61
Juvenile male	#4944	Day	2557.21	10121.41	16799.99
	#4944	Night	77.74	2943.02	11399.52
Fledgling male	#5208	Day	16.64	4729.68	28567.36
	#5208	Night	0	1728.52	14414.58

*Tests by Druid suggest that >85% of GPS fixes obtained by their tags have a horizontal error within 5 m from the centre position indicated.

Table 3.

Kea	Tracker ID	No. of fixes	Mean elevation above ground (m)	Max elevation above ground (m)	100% MCP (km^2)
Nesting female	#4789	1415	6.7	1974.6	54.4
Nesting female	#5037	76	0.6	41.2	5.9
Juvenile male	#4944	149	6.6	199.3	67.0
Fledgling male	#5208	693	4.6	680.7	179.4

to the Faith Col/Hourglass Glacier area in the Naumann Range, west of the Dobson River.

#5208 Fledgling male
A fledgling male from a nest in the vicinity of the Sealy Tarns was caught on 23 Feb 2022 at Red Tarns (Fig. 3D). The raised solar panel tracker transmitted data over the 3G cellular network for 3–4 months. Most of this bird's movements were near the Sefton Bivvy and above the Frind and Mueller Glaciers. His longest flights were 9 km north up the Hooker Glacier, and ~26 km south along the Sealy Range, as far as the south-facing slopes above Whale Stream.

Movement patterns and nest activity
All four kea frequently moved several kilometres and occasionally moved longer distances. The shortest mean distance travelled was 46 m at night (nesting female #5037) and the largest was 10 km during the day (juvenile male #4944) (Table 2). During a 24-hour period, ODBA measurements suggested that nesting female #4284 and fledgling male #5208 were active between 05:00 and 21:00 hrs. There were two periods of activity before and after a rest during the middle of the day. The nesting adult female was more active during the warmer month of February (06:00–21:00 hrs) compared to the cooler month of June (06:00–18:00 hrs). Between 21 and 24 Oct 2021, the nesting female #5037 seldom moved more than 1 km from her nest, apart from a short 7–8 km flight. Between 1 Nov 2021 and 7 Aug 2022, the second nesting female #4789 frequently moved about 2 km from her nest site, with occasional movements of 4–7.5 km. There were at least 6 distinct breaks in her data stream, perhaps when she spent a long time inactive in her nest. Between the end of November 2021 and the beginning of December 2021 she no longer returned to her nest site but remained within about 2 km of its location.

All kea tended to remain relatively close to the ground (Table 3). The maximum elevation reached by the adult female #4289 and fledgling male #5208 was 1,974 m and 680 m, respectively.

Home range
Naïve estimates of home range using 100% minimum convex polygons (MCP) suggest that range sizes are highly variable between individual birds and seemed somewhat independent of the number of locations recorded (Table 3). The nesting female #4789 had a home range of 5,440 ha, while the fledgling male #5208 had a home range about three times larger (17,940 ha), despite having fewer than half the number of fixes. The juvenile male #4944 had a home range of 6,700 ha. The nesting female #5037 had a very small home range, which was a function of the lack of data.

Operational parameters of GPS trackers
All kea trackers rapidly lost voltage (Fig. 4A) within the first fortnight. Adequate operational voltage levels were never reached by the flush mounted solar trackers, or were unable to be sustained at the 'boost' level (3.92 V) for raised solar panel trackers. Voltage gain and loss as well as transmitter failure was directly correlated with the low light intensities (Fig. 4B) recorded by the trackers.

A minimum of four satellites are needed to record an accurate spatial location, and the median number of satellites detected by the kea trackers was low (4–5), with the mean time required to fix a location being 62 seconds (Fig. 5A; 4). The average GPS time consumption (or 'search time') for failed tracker fixes for kea was 131 seconds and all kea trackers had a high number of fix failures (total across all four birds = 544; Fig. 5B). For the fixes that failed (i.e. their lat/long was 200), satellite search time was high, i.e. 84 took approximately 20 seconds before giving up, while the remaining 151 took approximately 151 seconds (Fig. 6).

DISCUSSION

GPS tags present significant opportunities for improving both the frequency and spatial accuracy of location data for mobile species at considerably greater resolution than more traditional technologies. Despite the small sample in this pilot study, much useful data were collected, particularly concerning the operational limitations of the tags deployed

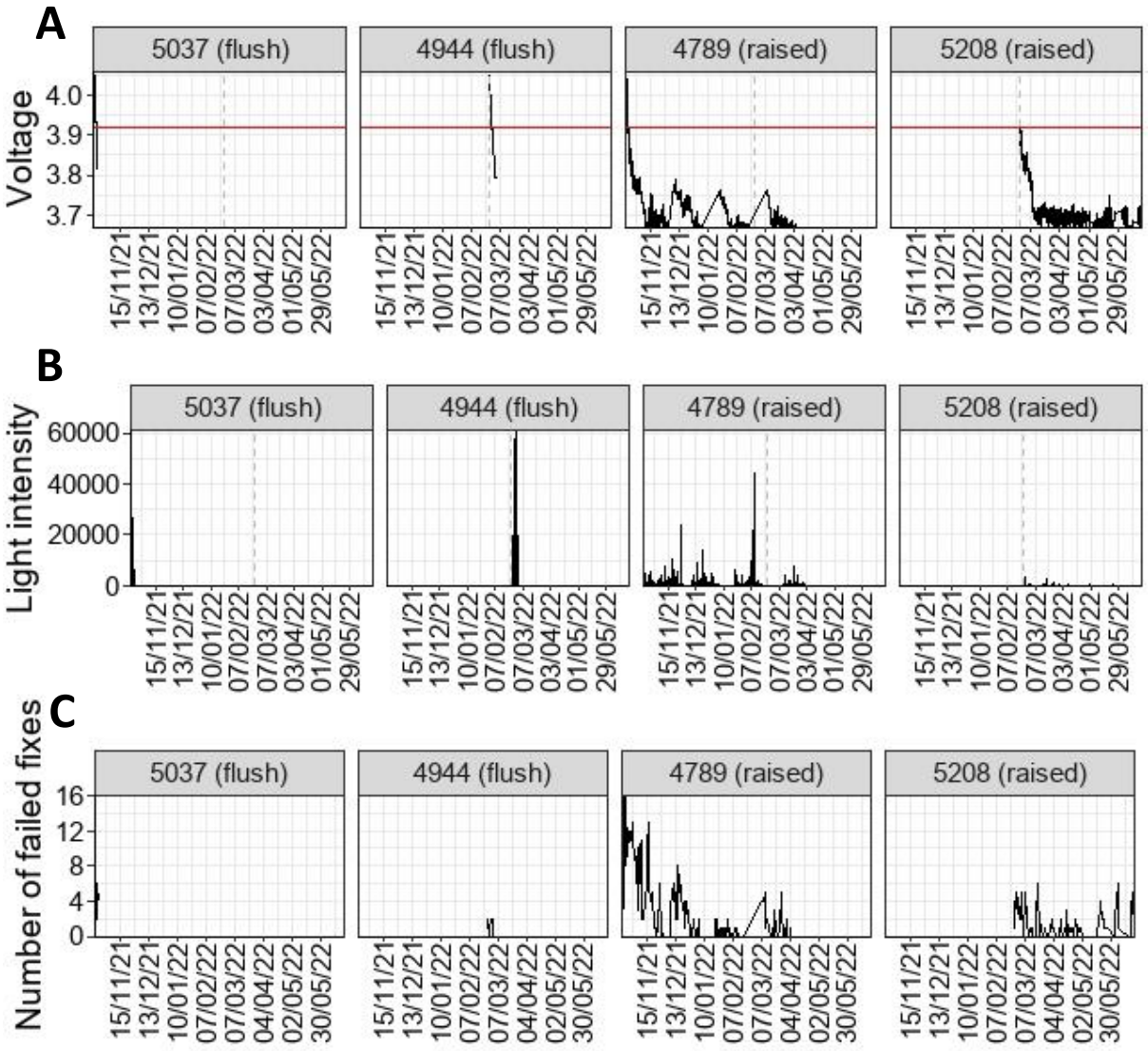

Figure 4. Performance of four Lego tags (two with raised solar panels and two with flush solar panels) deployed on four kea in Aoraki/Mount Cook National Park, Aotearoa/New Zealand, between October 2021 and February 2022. Graphs show: A) rapid declines in voltage (V) over time (s), with the red line showing the threshold the tags would need to exceed to trigger 'inflight boost' mode; B) rapid declines in light intensity (Lx) over time (s); and C) change in number of failed fixes over time (s).

in this mountainous environment and the rapid long-distance movements displayed by kea, which would be difficult to capture using other technologies.

All trackers collected and transmitted GPS location data. However, performance was impacted by low light intensity and difficulties receiving sufficient GPS signals when tall mountains were present, which frequently shaded the solar panels and blocked obtaining satellite fixes. This led to increased connection attempts, which in turn, resulted in battery voltages being run down prematurely.

The two trackers with raised (and larger) solar panels collected and transmitted substantially more data compared to the two trackers with flush-mounted solar panels, likely because the solar panels were covered less frequently by the surrounding feathers. Of the raised solar panel trackers, the one connected to the 2G GSM cellular network (#4789) transmitted substantially more data than the one connected to the 3G network (#5208). This may be because the coverage extended by a 2G tower is further (up to 10 km), compared with a 3G tower (that can only extend up to 3 km). The length of time (over 9 months) this tracker operated suggests that the tracker units themselves are robust to both kea interference and environmental extremes. In comparison, the two flush mounted solar panel trackers (#5037 and #4944) operated for less than a week. As tracker voltage levels declined rapidly immediately after they were deployed, we consider it likely that direct shading of the solar panels, either by preened feathers or time spent in deep shade (e.g. nests, topographic shading, or extended overcast skies) caused tracker failure; however, as we did not resight birds, this could not be confirmed. It is also likely that power failure was exacerbated by inadequate cell phone and GPS signal reception resulting in an increased duration of attempts to communicate with cellular networks or GPS satellites. There is also the possibility that both birds simply removed the trackers or that the embedded software or hardware failed.

GPS trackers can re-establish communication after considerable periods in low power hibernation, if their batteries recharge sufficiently, and they can provide some data from periods they were 'offline' (What are the working voltage thresholds for DEBUT devices? | Help Center; viewed 26 Feb 2025). For example, although fixes from

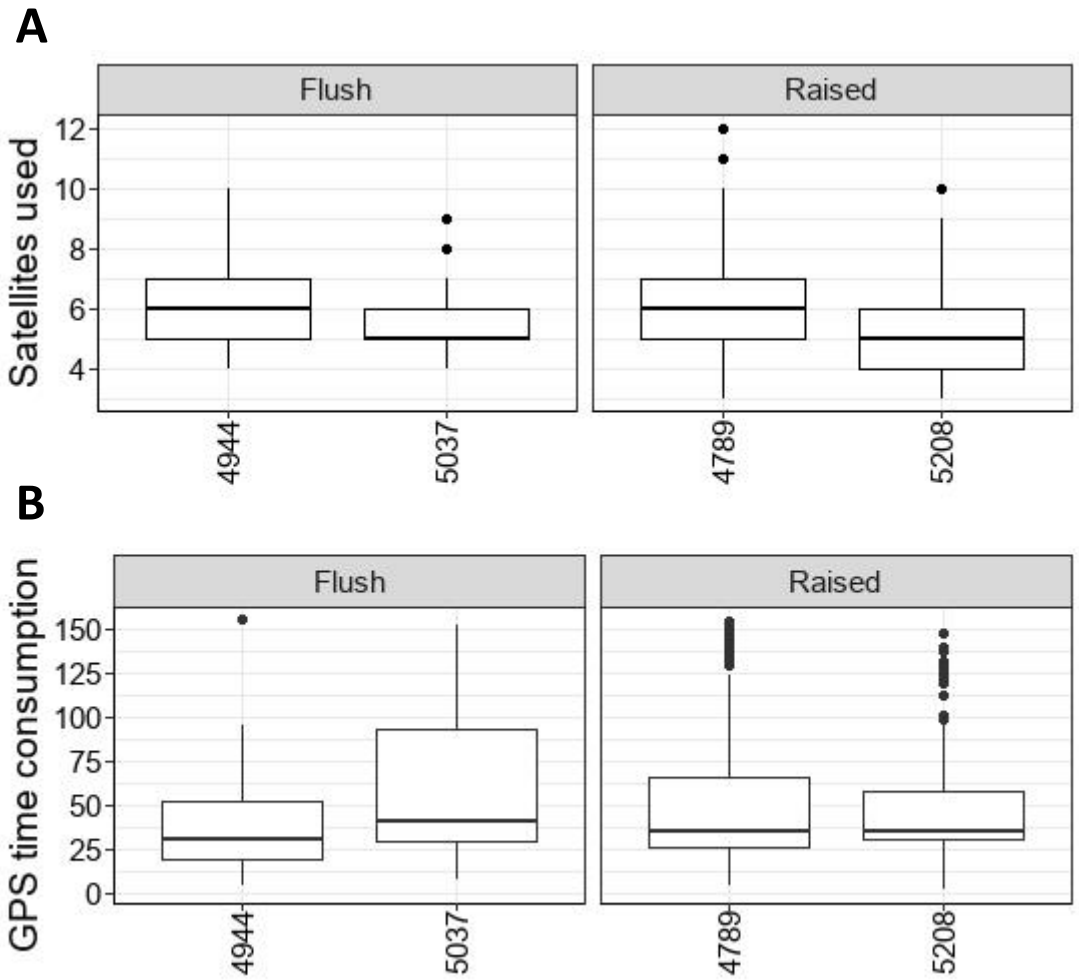

Figure 5. Box plots showing: A) the number of satellites used to achieve resultant fixes; and B) amount of time (s) it took to achieve the resultant fix. Data are from four Lego tags (two with flush solar panels and two with raised solar panels) deployed on four kea in Aoraki/Mount Cook National Park, Aotearoa/New Zealand, between October 2021 and February 2022.

GPS trackers on the Eurasian oystercatcher (*Haematopus ostralegus)* in the Netherlands revealed frequent large gaps in data during winter months, data were able to be recovered when tagged birds were located for 'manual' download or when trackers were retrieved from dead birds (Van Der Kolk *et al.* 2022). The kea wearing tracker #4789 did not transmit data for about 6 months, but once light intensity and voltage subsequently increased, it resumed operation for at least another 3 months. We therefore recommend that any attempt to recapture and remove trackers from live birds (e.g. for birds #4789 and #5208) be carried out at least a year after their last communication. Attempts should, however, be regularly made (monthly) to observe all tagged birds to confirm the tracker status (presence/absence) and/or condition of the trackers, as well as the bird's welfare.

The amount of power needed to achieve a GPS fix was significantly higher for kea than that for other species fitted with similar trackers being tracked by the authors (i.e. Australasian bittern *Botaurus poiciloptilus* and South Island pied oystercatcher *Haematopus finschi*; authors' unpubl. data). This is despite us using the same tracker type and settings on both kea and bittern. Fix failure rates (544 failed fixes) were high in our kea study, as was the GPS consumption time (i.e. 84.6% of failed fixes took the maximum amount of time to try to find a fix). Yet for the South Island pied oystercatcher data, where tag performance appeared to be better, only 11.2% of failed fixes took the maximum amount of time to try to find a fix (14 tags; 905 failed fixes, where 804 took approximately 20 seconds and 101 took approximately 151 seconds). For our bittern data, 100% of failed fixes took the maximum amount of time to try to find a fix (2 tags; 14 failed fixes, all 14 took approximately 154 seconds), but total fix failure rates were low (only 14 failed fixes in total), which was why tag batteries seemed better able to recover. This suggests that for kea it is the two factors (GPS consumption time and fix failure rate) that caused the higher power usage observed. The steep terrain inhabited by kea in the Southern Alps, likely exacerbated these factors by blocking a higher proportion of available satellite signals, compared to the open habitats where Australasian bittern and South Island pied oystercatchers were being tracked.

Other factors may have also contributed. Bittern trackers had a longer battery life but had an identical search time to kea trackers. Differences in tag performance may have been attributable to the markedly different environments they inhabit, as well as improved cell phone coverage and reception in Australasian bittern habitats, and differences in species' behaviour. In general, bitterns inhabit dense vegetation but are known to walk along reed bed edges as they forage for prey in the water. During these occasions, bitterns may prefer to forage with the sun on their backs as this casts a shadow across their line of sight, making it easier to see and catch their prey. Direct sun on the tracker would greatly extend the operational life of solar powered GPS trackers.

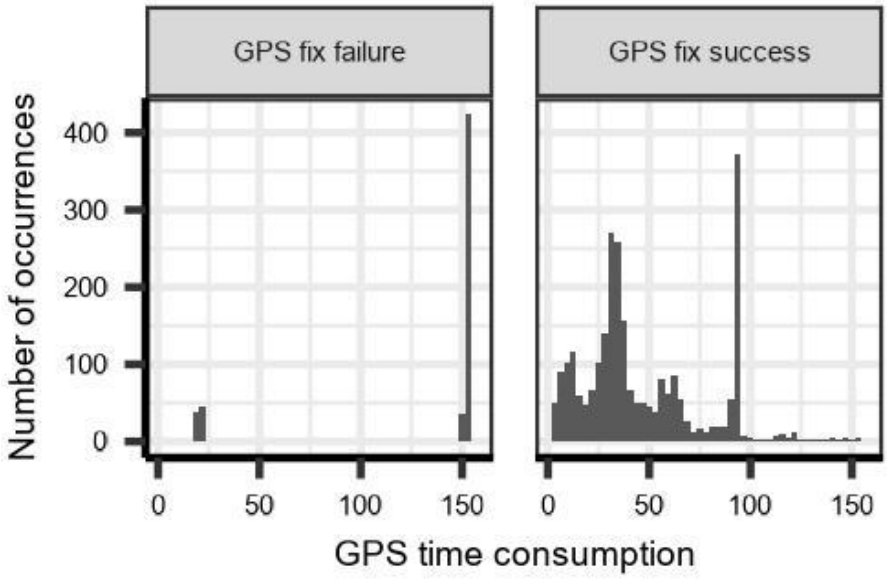

Figure 6. Graph showing the number of seconds a tracker took to look for a satellite in an attempt to gain a fix. Data are from four Lego tags (two with flush solar panels and two with raised solar panels) deployed on four kea in Aoraki/Mount Cook National Park, Aotearoa/New Zealand, between October 2021 to February 2022.

The power requirements and expense of GPS trackers are generally greater than that for VHF tags. This makes it essential that objectives for GPS tracker studies are well defined, that there is a clear understanding of the advantages and disadvantages of the technology, and rational expectations of the scale of likely data collection prior to deployment. Elevation of solar panels above the tag enclosure (within reason) to avoid obstruction by feathers seems to be a key requirement for deployment on kea. Although the use of solar panels to supplement power supply and therefore significantly extend tag life is seductive, in some cases it might be more useful to consider either, a) increasing the number of solar cells used on the panel (to increase solar charging capacity), or b) using a larger battery without solar panels to provide a more stable and continuous data collection and transmission platform (albeit over shorter time frames).

Deployment of GPS trackers (with or without solar panels) on wildlife in less-than-optimal environments is likely to remain problematic. Limited opportunities for solar charging such as changes in behaviour (e.g. females nesting in dark cavities for prolonged periods), environmental limitations (e.g. topographic shading and poor weather), difficulties receiving sufficient GPS satellite signals in all locations, and the subsequent transmission of data all need to be considered, especially if the rate of failures is likely to be high.

Selection of GPS tracker model and the choice of available settings before and during deployment also need to be carefully considered. The greater the frequency data are collected and transmitted, the greater the drain on the battery. If the number of satellite fixes are likely to be low and search time high, there will be a trade-off between the time taken to secure a fix, the frequency of fixes and the probable success of subsequent attempts. With hindsight, reducing the GPS and OBDA data collection rates (to 12 hours and 30 min respectively), neutralising the default dynamic boost modes (especially modes 2 and 3), and increasing the voltage threshold for dynamic boost mode 1 to >4.1 V would significantly increase both the data collection and transmission intervals and reduce power demands.

Less predictable is the power required to send data through cell phone networks, particularly when the networks are sparse, as many attempts may fail to connect. The facility to control 'connection' time and the use of alternative data transmission networks (e.g. Ultra High Frequency (UHF), Bluetooth, LoRA) should be investigated. Additionally, the use of the 'Boost' function that automatically increases data collection and transmission (depending on battery condition and movement state, i.e. 'dynamic sampling') to set the rate of fix collection may also contribute to slower battery recovery rates. As such, it is important to carefully consider the voltage thresholds for turning on settings that result in extra sampling, like the Boost feature.

Erratic data collection and transmission often makes describing and measuring a species' behaviours problematic. If behavioural (e.g., accelerometer) data is considered a sufficiently important objective in addition to the core work of logging location data, the algorithms that are available to carry out on-board tracker processing of trained behaviour classes should be enabled (i.e. Yu *et al*. 2022). Onboard algorithm use will significantly reduce the data transmission load and battery drain, thereby extending battery life. However, only certain tag types have such a capacity, and training the algorithms to recognise an individual's behaviours accurately requires considerable observational data, which can be problematic or impossible to obtain, particularly for cryptic, secretive, or remotely located species.

Further efforts to improve battery life and tracker capability may be a relatively simple matter of discarding solar recharging in favour of installing a larger battery. Optimal data download mechanisms other than cell phone networks such as 'local' UHF nodes/hubs and/or ARGOS enabled trackers, along with optimised software settings, would also reduce power demands. Depending on the location at which trackers are to be deployed, such changes are likely to markedly prolong the operational life of the GPS trackers and should be explored.

To date, most GPS tracker studies of small birds (<500 g) have been undertaken on shorebirds, songbirds, and raptors (e.g. Iverson *et al*. 2023), that typically occupy open habitats with little shade. Species that spend considerable time beneath vegetation canopies, particularly where there are significant topographic and technological barriers to signal propagation, will continue to be challenging. However, continued advances in GPS tracker technology data transmission such as LoRA and 'direct-to-cell' (DTC)

cellular networks are likely to provide further opportunities for development and improvement.

With increased sample sizes and using trackers that are better optimised for power, GPS, and data transmission, significant further data capture and analysis could be undertaken, particularly in relation to home-range and network analysis for individuals and groups of kea. The combination of GPS and accelerometer, for example, provides the means to calculate and merge information on time budgets, foraging strategies and efficiency, resource use, and energy expenditure (Shamoun-Baranes *et al*. 2012).

Notwithstanding the issues raised above, despite the small number of kea tracked in this study, and the high cost of GPS trackers, valuable data were captured, particularly in relation to accurate 3D positioning and long-distance movements, which would be difficult to collect using other technologies.

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Birds observed and collected by the Austrian Novara Expedition when in New Zealand, 1858–1859

JAMES BRAUND*
School of Cultures, Languages and Linguistics, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand, ORCID 0000-0001-8042-1566

COLIN M. MISKELLY
Museum of New Zealand Te Papa Tongarewa, PO Box 467, Wellington 6140, New Zealand, ORCID 0000-0001-8789-3208

Abstract: Birds collected and reported by the Austrian Novara Expedition while in northern New Zealand in December 1858 and January 1859 are described. These included birds collected at sea east of Northland and Auckland, and birds seen and collected between the Auckland isthmus and Waikato River during 18 days that SMS *Novara* was at Auckland. Notable records include the earliest known specimen of Pycroft's petrel (*Pterodroma pycrofti*), and the earliest record of Kermadec petrel (*Pt. neglecta*) from near the New Zealand mainland. Scientists from the *Novara* encountered many species that are now rare or absent near Auckland city and northern Waikato, including brown teal (*Anas chlorotis*), long-tailed cuckoo (*Eudynamys taitensis*), New Zealand falcon (*Falco novaeseelandiae*), kākā (*Nestor meridionalis*), red-crowned parakeet (*Cyanoramphus novaezelandiae*), yellow-crowned parakeet (*C. auriceps*), bellbird (*Anthornis melanura*), whitehead (*Mohoua albicilla*), and North Island robin (*Petroica longipes*), and possibly also North Island saddleback (*Philesturnus rufusater*) and the extinct North Island piopio (*Turnagra tanagra*). Other specimens obtained in Auckland (of uncertain provenance) included North Island kokako (*Callaeas wilsoni*) and hihi (*Notiomystis cincta*). All these species became much scarcer or extinct following the introduction of ship rats (*Rattus rattus*) and stoats (*Mustela ermina*) and other mammalian predators to New Zealand after 1859.

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Keywords: Austria, bird specimens, Novara Expedition, museum collection, New Zealand

INTRODUCTION

On 30 Apr 1857, SMS *Novara*, a 2030-ton wooden sail frigate, departed from Trieste on what would become a 28-month voyage round the world and the first circumnavigation of the globe to be completed by an Austrian naval vessel (Scherzer 1861a & b, 1862; Basch-Ritter 2008). Intended as a flag-waving exercise for the Austrian empire, and with the proposed construction of the Suez Canal very much in mind, the Novara Expedition had the investigation of trade opportunities in the Far East as one of its primary objectives, while the acquisition of overseas territories in the region was an ulterior consideration as well (Weiss & Schilddorfer 2010). Scientific exploration was a further major objective of the Novara Expedition, and to expedite this, a small but capable scientific team of seven men (referred to officially as a 'commission') was assembled to accompany the mission. It comprised Karl Scherzer (geographer and ethnographer), Ferdinand Hochstetter (geologist), Georg Frauenfeld (zoologist), Johann Zelebor (zoological collector and taxidermist), Eduard Schwarz (botanist), Anton Jelinek (plant collector), and Joseph Selleny (artist). Frauenfeld and Hochstetter had been selected by Austria's Kaiserliche Akademie der Wissenschaften (Imperial Academy of Sciences) as the expedition's principal naturalists, with Zelebor and Jelinek as their assistants (Anon. 1857: iv). Besides their primary

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*Correspondence: *j.braund@auckland.ac.nz*

responsibilities for zoology and geology respectively, Frauenfeld and Hochstetter had initially been entrusted with the mission's botany as well. However, this task was subsequently delegated to Schwarz, who was one of the *Novara*'s surgeons (Riedl-Dorn 2012a). Before departure, the naturalists were given, each according to their individual duties, a list of instructions relating to the collection and preservation of specimens, as well as a wish-list of items to be obtained at various stations of the voyage. As far as New Zealand avifauna was concerned, the naturalists were given specific directions to try to obtain specimens of kiwi (*Apteryx* spp.) and kākāpō (*Strigops habroptilus*) (Anon. 1857: 58–59).

The *Novara* arrived in Auckland late in the afternoon of 22 Dec 1858, and departed in the morning of 8 Jan 1859 after 16 days of hectic scientific and ethnographic activity in and around the young colonial capital. A particular highlight of the visit was an excursion undertaken by several members of the expedition along with a few interested settlers to the south Auckland and northern Waikato area over the period from 28 Dec 1858 to 2 Jan 1859 (Anon. 1859a & b). The primary purpose of this fieldtrip was for Hochstetter to survey a recently discovered coalfield in the Drury and Hunua districts. However, the excursion also provided encounters with New Zealand birds in virgin forest south of Drury and during a canoe ride down the Mangatāwhiri and Waikato Rivers as far as Tuakau. Brief though the *Novara's* visit was, it resulted in the collection of a considerable body of material across a variety of disciplines, and has led to the expedition being described as the only visiting scientific expedition to have left a substantial local impact in New Zealand in the 50 years between the surveys of HMS *Acheron* (1848–51) and the end of the nineteenth century (Andrews 1986: 158). General awareness of the *Novara*'s visit has been largely dominated within New Zealand by the achievements of Hochstetter, who stayed behind at the request of the colonial government for nine months after the frigate's departure, to conduct pioneering geological surveys of Auckland and Nelson Provinces (Hochstetter 1959; Johnston & Nolden 2011). However, our research indicates that members of the Novara Expedition, assisted by local residents, also made an important but otherwise little-known contribution to mid-nineteenth-century New Zealand ornithology.

Published sources

The ornithological results of the Novara Expedition's visit to New Zealand over the summer of 1858–59 are scattered across a variety of published sources, the most important of which are listed here.

The most immediate source, at least in a chronological sense, for parts of the ornithological fieldwork conducted by expedition members while in New Zealand is a manuscript diary kept by the zoologist Georg Frauenfeld. The New Zealand section of this was not published until comparatively recently (Riedl-Dorn 2012b), though it clearly formed the basis for part of a much earlier paper reporting on the *Novara*'s visit to Australia, New Zealand and Tahiti that was read to a session of the Austrian Imperial Academy of Sciences on 13 Oct 1859 and published the following year (Frauenfeld 1860). Taken together, the diary and paper provide a substantive record of the many New Zealand birds that Frauenfeld and his companions observed while in New Zealand.

A further first-hand account of the expedition members' excursion to south Auckland and northern Waikato can be found in a series of newspaper articles relating the *Novara*'s visit to New Zealand which were written by Julius Haast under the pseudonym of Julius Hanf, and which appeared in the *Wiener Zeitung*, the leading Viennese daily and official Austrian government newspaper of the time (Hanf 1859a–h). Clearly intended for a popular audience, these articles are more descriptive and livelier in tone than the account that emerges from Frauenfeld's diary and Academy paper, and they occasionally provide more ornithological detail. A highly abridged version of Haast's account can be found in the New Zealand section of the official narrative of the *Novara*'s voyage (Scherzer 1862: 143–156; English version: Scherzer 1863: 155–169).

Ferdinand Hochstetter's monograph on New Zealand, which appeared first in German in 1863 and then in an English version in 1867, contains further notes on New Zealand birds met with by members of the Novara Expedition, most of which can be found in the chapter devoted to the country's fauna (Hochstetter 1863: 431–433; Hochstetter 1867: 165–168). The fauna chapter was written by Frauenfeld with a few footnotes being added later by Hochstetter, though the initial footnote stating the precise authorship was left out of the English version of the monograph (compare Hochstetter 1863: 426, with Hochstetter 1867: 160). The relevant section of the chapter contains references to several birds which Frauenfeld did not see while in New Zealand (e.g. kākāpō), based on information that he drew from other sources. However, in places it expands somewhat on his observations of New Zealand birds that he mentions in both his diary and his address to the Imperial Academy of Sciences.

By far the most important published source for the ornithological fieldwork of the Novara Expedition is the overview of the mission's ornithology written by the Austrian ornithologist August von Pelzeln. This was presented in the first of the eight zoological volumes of the 21-volume official publication series arising from the frigate's voyage (von Pelzeln 1865). Drawing heavily on manuscript notes supplied by the expedition's assistant zoologist Johann Zelebor, von Pelzeln provided notes on individual specimens collected over the course of the voyage, including 29 New Zealand species. In the account, von Pelzeln lists more bird species than the above sources combined, and in doing so casts a great deal of light not only on what was collected, but also on who contributed the specimen in question and whether it was obtained by shooting, donation, or, in one case, purchase.

Key locations

Members of the Novara Expedition observed and collected birds at four principal locations during their visit to New Zealand.

The first of these was an area off the eastern Northland coast traversed during the frigate's approach to Auckland. A boat was lowered on 19 Dec 1858 at a point recorded as 35° S, 175° 5′ E (about 110 km north-east of the Poor Knights Islands), allowing Frauenfeld and the expedition's commander, Commodore Bernhard von Wüllerstorf-Urbair, to shoot seabirds; specimens of at least three petrel species and an albatross were obtained on this occasion (Riedl-Dorn 2012b: 171; von Pelzen 1865: 144, 146, 148). A boat was lowered again the following day near Great Barrier Island, to allow Frauenfeld and the *Novara's* captain, Friedrich von Pöck, to shoot more seabirds, though this time without the same success as the previous day (Riedl-Dorn 2012b: 172).

A second and more general area of ornithological activity was the Auckland isthmus in the vicinity of Auckland township (i.e. the area corresponding roughly to the present-day central business district of Auckland), around which individual naturalists and other members of the expedition ranged during the *Novara's* visit. Examples of land birds observed or taken in or near Auckland township, for which a relatively precise location is given, include a New Zealand falcon (*Falco novaeseelandiae*) and New Zealand pipits (*Anthus novaeseelandiae*) observed by Frauenfeld as he

moved over the then fern-clad terrain between Mt Eden and Onehunga on 24 Dec 1858 (Frauenfeld 1860: 734), as well as a red-crowned parakeet (*Cyanoramphus novaezelandiae*) and a yellow-crowned parakeet (*C. auriceps*) collected by Frauenfeld and Zelebor respectively at a location given on the collection labels as 'Auckland Council' – likely referring to the former Auckland Provincial Council assembly building then located near the southern end of present-day Anzac Avenue in central Auckland. Mention of several sea and shore birds by von Pelzeln (1865) – a red-billed gull (*Chroicocephalus novaehollandiae*), a pied shag (*Phalacrocorax varius*), and a little shag (*Microcarbo melanoleucos*) – suggests that some of the specimens collected by (or possibly for) members of the Novara Expedition were found on the adjoining shorelines of the Waitematā Harbour. It is worth adding here that Australasian gannets (*Morus serrator*) and flocks of a small petrel had been seen on the harbour on 22 Dec 1858 as the *Novara* arrived in Auckland (Frauenfeld 1860: 733), and that gannets were sighted on those waters again as the frigate departed on 8 Jan 1859 (Riedl-Dorn 2012b: 175).

The third main area of collection and observational activity was in south Auckland and northern Waikato during the excursion to Drury mentioned above. Frauenfeld's diary mentions falcons (between Papakura and Drury, 28 Dec 1858), ducks and shags (unnamed cove on the southeast Manukau Harbour west of Drury, 29 Dec 1858), and tūī (*Prosthemadera novaeseelandiae*) and fantails (*Rhipidura fuliginosa*) in forest south of Drury on 30 Dec 1858 (Riedl-Dorn 2012b: 173-174), while his address to the Imperial Academy of Sciences also mentions pūkeko (*Porphyrio melanotus*), bitterns (*Botaurus poiciloptilus*), ducks, a shoveler (*Spatula rhynchotis*), and shags along the Mangatāwhiri and Waikato Rivers on 31 Dec 1858 (Frauenfeld 1860: 736). Haast supplied further details in his newspaper piece describing the visit to the forest on 30 Dec 1858, in which he mentions the shooting by excursion members of tūī, red-crowned parakeets, and a long-tailed cuckoo (*Eudynamys taitensis*) (see Hanf 1859e). Frauenfeld, in both his paper read to the Academy of Sciences and in his chapter in Hochstetter's monograph, provides further generic descriptions of forest birdlife which are clearly based on first-hand observation and which, while giving neither a precise date nor a location, can only refer to forest south of Drury (Frauenfeld 1860: 739-740; Hochstetter 1863: 431-432). Frauenfeld's recollections of forest birdlife in his chapter in Hochstetter's monograph are especially intriguing. The English version of his chapter contains a passage which reads as follows: 'Of the *Certhiparus* species among the real warblers [i.e. 'Sänger', or 'songbirds', in the earlier German version], likewise of the New Zealand thrush (*Turnagra crassirostris*), and the starlings *Aplonis* and *Creadion*, I am not able to say, whether and how they sing' (Hochstetter 1867: 166). At the corresponding point in the German original, however, the sentence had continued with a remark that can be translated as: 'as I did observe and shoot them several times, but never heard them sing' (Hochstetter 1863: 432). Species referred to here were most likely whitehead (*Mohoua albicilla*) = '*Certhiparus*', North Island piopio (*Turnagra tanagra*) and North Island saddleback (*Philesturnus rufusater*) = '*Creadion*', with *Aplonis* included in Frauenfeld's New Zealand list erroneously following Quoy & Gaimard (1832: 190). The fate of the piopio and saddleback specimens that Frauenfeld alludes to here is unknown.

The fourth and final area of collecting activity was in west Auckland. The same day that Hochstetter and his companions returned to Auckland from their excursion to Drury (2 Jan 1859), a smaller party consisting largely of *Novara* crew members went on a day trip to view kauri forests in north Titirangi, where they visited the farm of local timber-miller Captain Hibernicus (or Hibernia) Smyth (referred to as 'Smith' in the official narrative of the voyage – Scherzer 1862b: 138; cf. Bonny *et al*. 2011). Wüllerstorf-Urbair and Zelebor shot a tūī and a North Island robin (*Petroica longipes*) respectively at a location we interpret as corresponding to present-day Glendale Road, Glen Eden (von Pelzeln 1865), while Wüllerstorf-Urbair may also have shot kererū (*Hemiphaga novaeseelandiae*) there (unpublished manuscript diary of Karl Scherzer, State Library of New South Wales).

Key personnel

New Zealand bird specimens in the Novara Expedition's ornithological collection were largely obtained by several key figures.

Georg Frauenfeld (1807–1873; from 1860: von Frauenfeld) was the expedition's lead zoologist (Stolz-Fechner 1994). He was a highly competent scientific autodidact who, despite lacking a university education, had risen from humble career beginnings as a postal worker to become one of Vienna's leading zoologists. A co-founder (in 1851) and long-term secretary of the Zoologisch-Botanische Gesellschaft (Zoological-Botanical Society) in Vienna, Frauenfeld found employment in the K. K. Zoologisches Hof-Cabinet (Imperial-Royal Zoological Court Cabinet, i.e. one of the three official natural history museums that existed in the Austrian capital from the early 1850s to the mid-1880s) in 1852. At the time the *Novara* began its circumnavigation of the globe in late April 1857, he held the position of 3rd Assistant Curator. Frauenfeld's movements around Auckland and its environs in late December 1858 and early January 1859 are based on his diary (Riedl-Dorn 2012b). While he is known to have shot several birds during his visit to New Zealand, his primary scientific interests lay in invertebrates and, as he had done throughout the voyage, he left the collection of bird specimens largely to his assistant Zelebor (von Pelzeln 1865: i). After the *Novara*'s return to Europe, Frauenfeld, became 1st Assistant Curator of the Zoological Court Cabinet in 1861. Following a restructuring in 1867, he assumed the title of Curator, a rank he held until his death 6 years later.

Johann Zelebor (1815–1869) came, like Frauenfeld, from a humble background (von Pelzeln 1889: 604–605; Dafert 2021). Beginning his working life as a carpenter, Zelebor was an enthusiastic self-taught collector of natural history specimens who had found employment, initially as a servant and then as a taxidermist, in the Imperial-Royal Zoological Court Cabinet some years before Frauenfeld. At the time of his appointment to the Novara Expedition, he held the position of Assistant. Although troubled by poor health in the weeks before the *Novara*'s arrival in Auckland, Zelebor was an active collector during the frigate's visit and ultimately contributed more bird specimens to the expedition's collection during this period than anyone else. As was the case with the other naturalists of the *Novara*, most of his collecting seems to have been done on short trips in the immediate vicinity of Auckland township (Hanf 1859a: 338). He did not participate in the excursion to Drury due to illness (Hanf 1859b: 343), and the only extended trip he made into the field that is documented was the excursion to north Titirangi on 2 Jan 1859 (unpublished manuscript diary of Karl Scherzer, State Library of New South Wales). After his return to Austria, Zelebor was appointed 4th Assistant Curator in the Zoological Court Cabinet in 1860, and advanced to 3rd Assistant Curator the following year. In 1867, like Frauenfeld, he assumed the title and rank of Curator (Stolz-Fechner 1994: 276, 283, 338). Zelebor was given responsibility for the Cabinet's mammal collection in 1861 and in this capacity wrote up the mammalogical results of the Novara Expedition for the voyage's official

publication series (Zelebor 1868). He held this position until his death in 1869.

A small but significant number of New Zealand birds were shot by Bernhard von Wüllerstorf-Urbair (1816–1883), the commander of the Novara Expedition (Wurzbach 1889; Regele 2004). Wüllerstorf-Urbair had been a serving naval officer since 1836 and later served a term as Austria's Minister of Trade (1865–67). He had a strong scientific background and outlook, and can be credited with persuading Archduke Ferdinand Maximilian, the commander-in-chief of the Austrian navy, to entrust the Novara Expedition with a scientific dimension from the outset. Wüllerstorf-Urbair was himself responsible for the expedition's astronomy, meteorology and hydrography, and in discharging these duties during the voyage he was assisted by various ensigns and cadets (Basch-Ritter 2008: 47). He was also an enthusiastic hunter, and contributed examples of some 40 different bird species to the voyage's collection (von Pelzeln 1865). The practice of naval officers providing their naturalists with bird specimens, often in the course of what might be described as gentlemanly sport, is an old one, and in a New Zealand context calls to mind the example seen in the visit of HMS *Resolution* to Dusky Sound in 1773 (Hoare 1982: 243–267).

A less expected contributor to the Novara Expedition's collection of New Zealand birds was the mission's geologist, Ferdinand Hochstetter (1829–1884; from 1860: von Hochstetter), who stayed behind in New Zealand after the frigate left Auckland in January 1859, while remaining an official member of the expedition. Born in the southwestern German town of Esslingen, Hochstetter had studied theology and natural history in nearby Tübingen before being recruited by Austria's K. K. Geologische Reichsantalt (Imperial-Royal Geological Survey) to undertake fieldwork in western Bohemia in the early 1850s. After returning to Europe from New Zealand in early 1860, he would eventually rise through Austrian scientific circles to be appointed, in 1876, the first director of what is now the Naturhistorisches Museum in Vienna. The most widely known instance of Hochstetter obtaining a specimen of an extant New Zealand bird is his receipt while in Nelson of two live kiwi (*Apteryx* sp.), one of which escaped and the other of which he kept in his hotel room before having it preserved in spirits (Hochstetter 1863: 444, 445; see also Hochstetter 1959: 267). Hochstetter went on to provide some notable early scientific intelligence on this iconic bird for both German- and English-speaking readerships, often in conjunction with moa (Dinornithiformes), which he considered to be related to kiwi (Hochstetter 1860–61, 1863, 1867; Sclater & Hochstetter 1861). Von Pelzeln's report of birds collected by the Novara Expedition credited Hochstetter with contributing specimens of four New Zealand birds to the mission's collection: a red-crowned parakeet, a weka (*Gallirallus australis*), a red-billed gull, and a little shag (von Pelzeln 1865). We do not include reference to birds that Hochstetter encountered after the departure of the *Novara* from Auckland.

Von Pelzeln (1865) also acknowledged Auckland resident Dr Fischer as having provided the Novara Expedition with bird specimens. Dr Carl Frank Fischer was a high-profile German-born homeopathic doctor, who lived in Auckland from 1853 or 1854 to 1869 and who hosted receptions for members of the frigate's crew during its visit (von Pelzen 1865: ii; Belgrave 1990; Riedl-Dorn 2012b: 173, 175). Fischer was a keen amateur naturalist, and Haast wrote that his thorough knowledge of natural science made the task of collecting much easier for the *Novara's* scientists, in that he not only acquainted them with the best places to find things, but also made his own collections available to them with the greatest readiness (Hanf 1859a: 338). Von Pelzen (1865) credited Fischer with providing specimens of a North Island kiwi (*Apteryx mantelli*), a pūkeko, and a little penguin (*Eudyptula minor*). Hochstetter, in a footnote in his monograph, suggests that Fischer provided Frauenfeld and Zelebor with kiwi skins during the *Novara*'s visit to Auckland, as well as sending a further set of kiwi specimens to Vienna on a subsequent occasion. One of the latter was given live to the ship's captain, but died during the voyage (Hochstetter 1863: 443, n. 1).

Julius Haast (1822–1887; from 1875: von Haast) arrived in Auckland as an immigration agent the day before the *Novara*, and went on to achieve fame as a provincial surveyor and museum director (von Haast 1948). Haast was both a participant in and chronicler of the excursion to South Auckland. While he is not known to have personally collected any specimens for the *Novara*'s naturalists while they were in Auckland, he nevertheless provides an important ornithological footnote to the expedition. Haast corresponded intermittently with Frauenfeld for several years after the frigate's return to Austria (Stolz-Fechner 1994: 221), and he also despatched two large consignments of New Zealand bird specimens to Vienna. The first was 39 skins, in 1866 (von Pelzeln 1867), followed by 60 mounted birds of 35 species plus three moa skeletons that were exhibited in the New Zealand court of the Vienna International Exhibition of 1873 (AJHR 1873: Appendix p. 9–10). Haast was knighted in 1886.

August von Pelzeln (full surname: Pelzel von Pelzeln; 1825–1891) was the Austrian ornithologist who wrote up and published the ornithological results of the *Novara*'s voyage round the world (Kohl 1891; Bauer 1978). Born into a noble family and possessed of a deep interest in natural history from his earliest years, von Pelzen had initially studied law before gaining a position as an intern in Vienna's Imperial-Royal Zoological Court Cabinet in 1851 and becoming an assistant there the following year (Stolz-Fechner 1994: 55, 63). Appointed 4th Assistant Curator in 1857, he was given responsibility for the Cabinet's bird collection at the same time and, after rising through the ranks to the position of Curator (Stolz-Fechner 1994: 159, 275, 283, 338), was also given responsibility for the Cabinet's mammal collection on the death of Zelebor in 1869. He retained those responsibilities until ill-health forced his retirement in 1888. Aside from his work on the birds collected by the Novara Expedition, von Pelzeln holds a notable place in nineteenth-century New Zealand ornithology by being first to describe the New Zealand rock wren (*Xenicus gilviventris*) (see Verry *et al.* 2019; cf. von Pelzeln 1867: 316). He was also the author of an early study of the birds of Norfolk Island, some of which he suggested were related to New Zealand species (von Pelzeln 1860).

The *Novara's* bird specimens after the voyage

The *Novara* returned to Trieste on 26 Aug 1859. Over the course of the expedition's voyage round the world, its scientific team collected over 26,000 zoological specimens in addition to several thousand geological and ethnographic items (Scherzer 1862: 410) – and this raised immediate questions about where to store and exhibit such a large body of material. A temporary solution was found in the establishment of the so-called Novara Museum, which was directed by Frauenfeld and occupied two buildings in the Augarten public park in Vienna (Anon. 1860a–c; Stolz-Fechner 1994: 240–251). The museum opened to the public on 1 May 1860. A catalogue of its exhibits produced by Frauenfeld reported that 30 mounted New Zealand bird specimens were among the thousands of natural history items on display, including a tūī, a kererū, a pūkeko, and 'some parrots' (Frauenfeld 1863). The Novara Museum remained open to members of the Viennese public until it was closed in early 1865, whereupon its zoological items (including the New Zealand birds from the Novara Expedition) went to the Zoological Court Cabinet, while

Figure 1. Pycroft's petrel (NHMW 48835, above) and Cook's petrel (NHMW 48837) collected by the Novara Expedition shortly before arriving in Auckland in December 1858. Image courtesy of Naturhistorisches Museum, Vienna, prepared for publication by Jean-Claude Stahl (Te Papa).

everything else was placed in storage. The Zoological Court Cabinet closed in 1885 along with the other two Court Cabinets (Botanical and Mineralogical) so that their respective collections could be transferred to the recently completed K. K. Naturhistorisches Hofmuseum (Imperial-Royal Natural History Court Museum, now the Naturhistorisches Museum in Vienna), and at that point all the *Novara* material ceased to be accessible to the general public (Fischer *et al*. 1976: 11; Riedl-Dorn 2004: 318). Many Novara Expedition specimens remain in the Naturhistorisches Museum Wien (NHMW), as listed below (courtesy of Hans-Martin Berg, NHMW, *pers. comm*. to CMM). Some of the specimens retain their original collection labels (see Miskelly & Braund 2025, Figs 1 & 2).

SYSTEMATIC ACCOUNT

Pelagic seabirds

Antipodean albatross *Diomedea antipodensis*
Two specimens shot by Wüllerstorf-Urbair and Frauenfeld north-east of the Poor Knights Islands on 19 Dec 1858 (NHMW 13647 & 13668) were referred to *D. exulans* by von Pelzeln (1865), and are now identified from photographs as *D. antipodensis* (CMM, *pers. obs*). An additional skeleton of '*D. exulans*' from New Zealand, attributed to Zelebor, (NHMW 1487) was not mentioned by von Pelzeln (1865).

Kermadec petrel *Pterodroma neglecta*
Four specimens shot north-east of the Poor Knights Islands on 19 Dec 1858 (NHMW 48830, 48832, 48833 & 48834) are the earliest known record of this species from near the New Zealand mainland (Miskelly & Braund 2025). The specimens were misidentified as *Procellaria mollis* (now *Pterodroma mollis* = soft-plumaged petrel) by von Pelzeln (1865), and the error was promulgated by Finsch (1875) and Buller (1905).

Cook's petrel *Pt. cookii*
Von Pelzeln (1865) referred to two specimens of *Procellaria velox* (= *Pterodroma cookii*) shot by Wüllerstorf-Urbair and Frauenfeld north-east of the Poor Knights Islands on 19 Dec 1858, with field tag numbers 783 & 786. The field tags for these birds were subsequently attached to two sooty shearwater (*Ardenna grisea*) specimens of uncertain provenance (Hans-Martin Berg, *pers. comm*. to CMM, and see sooty shearwater text below). Both Cook's petrels were described in detail by von Pelzeln; however, they are no longer held by NHMW or their data have been lost. One of the Cook's petrel specimens is likely to be NHMW 48837, a specimen with no collection data that was prepared in the same way as Pycroft's petrel NHMW 48835 (Hans-Martin Berg, *pers. comm*. to CMM, and see Fig. 1 and next entry).

Pycroft's petrel *Pt. pycrofti*
The Novara Expedition likely collected three specimens of small gadfly petrels (Cook's petrel and Pycroft's petrel) before arriving in Auckland, although the fate of at least one of the Cook's petrel specimens is unknown. In addition to the two specimens collected on 19 December, the frigate's captain, Friedrich von Pöck shot another "*Procellaria*" (not mentioned by von Pelzeln 1865) near Great Barrier Island the following evening (Riedl-Dorn 2012b). Riedl-Dorn's translation referred to Frauenfeld collecting a tick from "one of the *Procellaria* (the white-bellied ones)" earlier on 20 December, implying that at least two specimens then referred to Cook's petrel were collected on 19 December (i.e. matching von Pelzeln's account above). This provides supporting evidence for three specimens being involved.

NHMW 48835 is a Pycroft's petrel collected by von Pöck in the Pacific Ocean on "29 Dec 1858" (Hans-Martin Berg, *pers. comm*. to CMM; Fig. 1). The specimen was registered as a Cook's petrel until it was re-identified by Te Papa bird curator Sandy Bartle during a visit to NHMW in 1997. The collection date is in error (as SMS *Novara* was

at anchor at Auckland on 29 December) and likely should be 20 Dec 1858. It is possible that this specimen was one of the two "*Procellaria velox*" shot north-east of the Poor Knights Islands on 19 Dec 1858; however, von Pöck was not a member of the two-person shooting party on that day (Riedl-Dorn 2012b). We consider that the Pycroft's petrel specimen was most likely collected near Great Barrier Island on 20 Dec 1858.

Black petrel *Procellaria parkinsoni*
Two males shot by Wüllerstorf-Urbair north-east of the Poor Knights Islands on 19 Dec 1858 (NHMW 13623 & 48809) were referred to '*Puffinus parkinsoni*' by von Pelzeln (1865).

Sooty shearwater *Ardenna grisea*
Two specimens currently registered in the NHMW database as part of the Novara collection (NHMW 48800 & 53340) were not mentioned by von Pelzeln (1865). They both have field tags that were originally applied to "*Procellaria velox*" specimens (see under Cook's petrel above), and are best considered as being of uncertain provenance (Hans-Martin Berg, *pers. comm*. to CMM).

Coastal birds and land birds

North Island kiwi *Apteryx mantelli*
Von Pelzeln (1865) referred a specimen gifted by Dr Fischer and an egg gifted by a Mr Graham [likely the leading Auckland citizen Robert Graham] to *A. australis*. Their collection localities are unknown, but are likely to be from the North Island (i.e. *A. mantelli*). The fate of the skin or mount is unknown. The egg is registered as NHMW 34.

Brown teal *Anas chlorotis*
A study skin collected in "Auckland" by Frauenfeld in December 1858 (NHMW 49433; von Pelzeln 1865) may have been collected along the Mangatāwhiri River or Waikato River on 31 Dec 1858 (Frauenfeld 1860; Riedl-Dorn 2012b).

Australasian shoveler *Spatula rhynchotis*
Frauenfeld (1860) reported a shoveler along the Mangatāwhiri or Waikato Rivers on 31 Dec 1858. Not mentioned by von Pelzeln (1865). No specimen collected.

Kererū *Hemiphaga novaeseelandiae*
A specimen collected in December 1858 by Frauenfeld (von Pelzeln 1865; NHMW 48436).

Shining cuckoo *Chrysococcyx lucidus*
A juvenile collected in December 1858 by Zelebor (von Pelzeln 1865; NHMW 50908).

Long-tailed cuckoo *Eudynamys taitensis*
NHMW 50926 collected in December 1858 by Frauenfeld is likely the bird shot in forest near Drury on 30 Dec 1858 (Hanf 1859e).

Pūkeko *Porphyrio melanotus*
Although Frauenfeld (1860) mentioned seeing pūkeko along the Mangatāwhiri or Waikato Rivers on 31 Dec 1858, the specimen retained (NHMW 13696) was attributed to Dr Fischer (von Pelzeln 1865).

Weka *Gallirallus australis*
A juvenile weka was collected by Hochstetter in 'Neu-Seeland' (precise location and date unknown; von Pelzeln 1865). The current location of this specimen (which was later identified as a North Island weka *G. a. greyi*) is unknown (Hans-Martin Berg, *pers. comm*. to CMM).

Red-billed gull *Chroicocephalus novaehollandiae*
Von Pelzeln (1865) referred a specimen collected by Hochstetter in Auckland to *Larus jamesoni*. The current location of this specimen is unknown (Hans-Martin Berg, *pers. comm*. to CMM).

Little penguin *Eudyptula minor*
Von Pelzeln (1865) referred a specimen received from Dr Fischer in Auckland to *Spheniscus minor*. The current location of this specimen is unknown (Hans-Martin Berg, *pers. comm*. to CMM).

Australasian gannet *Morus serrator*
Frauenfeld noted gannets in the Hauraki Gulf on 22 Dec 1858 and 8 Jan 1859 (Frauenfeld 1860; Riedl-Dorn 2012b). No specimen collected.

Little shag *Microcarbo melanoleucos*
Von Pelzeln (1865) referred a specimen collected by Hochstetter in New Zealand to *Graculus melanoleucos*. The current location of this specimen is unknown (Hans-Martin Berg, *pers. comm*. to CMM).

Pied shag *Phalacrocorax varius*
A specimen collected in January [1859] by Wüllerstorf-Urbair in a bay near Auckland (von Pelzeln 1865; NHMW 13587).

Australasian bittern *Botaurus poiciloptilus*
Frauenfeld (1860) reported bitterns along the Mangatāwhiri or Waikato Rivers on 31 Dec 1858. Not mentioned by von Pelzeln (1865). No specimen collected.

Ruru *Ninox novaeseelandiae*
Von Pelzeln (1865) listed '*Athene novae zelandiae*' from Auckland, without referring to specimens. Three Novara Expedition specimens are known (NHMW 44033, 49741 & 49742).

New Zealand falcon *Falco novaeseelandiae*
Frauenfeld observed a falcon between Mt Eden and Onehunga on 24 Dec 1858, and several between Papakura and Drury on 28 Dec 1858 (Frauenfeld 1860; Riedl-Dorn 2012b). Not mentioned by von Pelzeln (1865). No specimen collected.

Kākā *Nestor meridionalis*
A specimen collected in December 1858 in Auckland by Zelebor (NHMW 68241). Listed as *Nestor australis* by von Pelzeln (1865).

Red-crowned parakeet *Cyanoramphus novaezelandiae*
Expedition members encountered red-crowned parakeets near Drury on 30 Dec 1858 (Hanf 1859e) as well as central Auckland. Von Pelzeln (1865) reported two specimens (as

Figure 2. Male hihi (NHMW 50792) obtained by the Novara Expedition in Auckland in December 1858. Image courtesy of Naturhistorisches Museum, Vienna.

Platycercus novae zelandiae) collected by Frauenfeld and Hochstetter, with one of these (NHMW 50370) known to survive.

Yellow-crowned parakeet *C. auriceps*
A specimen collected in December 1858 in Auckland by Zelebor (NHMW 50410). Listed as *Platycercus auriceps* by von Pelzeln (1865).

Bellbird *Anthornis melanura*
Listed by von Pelzeln (1865) without referring to the number of specimens. Three Novara Expedition specimens are known (NHMW 43830, 52247 & 52269), including two collected by Zelebor. Von Pelzeln (1867) subsequently described *Anthornis ruficeps* (a synonym of *A. melanura*) based on a pollen-stained specimen provided by Haast (Finsch *in* Buller 1871).

Tūī *Prosthemadera novaeseelandiae*
Von Pelzeln (1865) provided details of a tūī specimen (NHMW 52260) collected by Wüllerstorf-Urbair on 2 Jan [1859] at Manukau Forest near Whau Road, 13 miles west of Auckland, (we interpret this as Glen Eden). Three additional Novara Expedition specimens (NHMW 35348, 52258 & 52259) were collected at Auckland by Zelebor in December 1858. Frauenfeld, Hochstetter, and Haast also encountered tūī near Drury on 30 Dec 1858 (Hanf 1859e; Riedl-Dorn 2012b)

Grey warbler *Gerygone igata*
Von Pelzeln (1865) listed *Gerygone igata* from Auckland, and also proposed a new species (*G. aucklandica*) based on NHMW 51161 obtained by Zelebor 'in a bush near Auckland' on 5 Jan [1859]. Finsch (1875) considered the holotype of *G. aucklandica* to be a juvenile *G. flaviventris* (the name then in use for grey warbler), and subsequently confirmed that *G. flaviventris* and *G. igata* were the same species (Finsch *in* Buller 1876). Both *G. aucklandica* and *G. flaviventris* are now treated as synonyms of *G. igata* (Checklist Committee 2022).

North Island kokako *Callaeas wilsoni*
One specimen (NHMW 87862) obtained by Zelebor in Auckland in December 1858. Von Pelzeln (1865) referred to the specimen as 'erhalten' (received), indicating that the specimen was collected by a person unknown. Von Pelzeln (1867) subsequently named *Callaeas olivascens* based on this specimen; however, Buller (1871) considered the differences from '*C. cinerea*' to be inconsequential. *C. olivascens* is now treated as a synonym of *C. wilsoni* (Checklist Committee 2022). This species was not otherwise recorded by the *Novara* scientists.

North Island saddleback *Philesturnus rufusater*
Frauenfeld (*in* Hochstetter 1863: 432) implied that he had seen and shot saddlebacks (as *Creadion*). Not mentioned by von Pelzeln (1865), and no specimens exist.

Hihi *Notiomystis cincta*
A male (NHMW 50792) obtained by Zelebor in Auckland in December 1858 (Fig. 2). Von Pelzeln (1865) referred to the specimen as 'gekauft' (bought), indicating that the specimen was collected by a person unknown. This species was not otherwise recorded by the *Novara* scientists.

Whitehead *Mohoua albicilla*
Von Pelzeln (1865) listed '*Certhiparus albicillus*' from New Zealand, and Frauenfeld (*in* Hochstetter 1863: 432) implied that he had seen and shot '*Certhiparus*', presumably in forest south of Drury. No specimens are known to exist.

North Island piopio *Turnagra tanagra*
Frauenfeld (*in* Hochstetter 1863: 432) implied that he had seen and shot piopio (as *Turnagra crassirostris*). Not mentioned by von Pelzeln (1865), and no specimens exist.

New Zealand fantail *Rhipidura fuliginosa*
Listed as *Rhipidura flabellifera* by von Pelzeln (1865). Zelebor provided detail of his observations of fantails, quoted by von Pelzeln (1865), and which we translate as: 'The liveliest bird I have ever observed. With delicate movements that are peculiar to the flycatchers it moves fast even through dense bush, in the manner of the Eurasian wren, and often utters a quiet *tscherr-tscherr* in the process. Like the Eurasian nuthatch it sometimes runs around a trunk or branch while constantly moving its fan-like tail over the back towards its head, more as it seemed to me for amusement than to look for food. I watched this bird for hours with true pleasure and it would perhaps take an equal amount of time to describe the way of life of this happy little animal.'

A study skin (NHMW 51184) and a skeleton (NHMW 1163) remain in the NHMW collection.

Tomtit *Petroica macrocephala*
Listed as *Petroica toitoi* by von Pelzeln (1865), based on a specimen collected by Zelebor (NHMW 43440).

North Island robin *P. longipes*
Listed as *Petroica australis* by von Pelzeln (1865), based on a specimen collected by Zelebor at 'Manukau forest on Mr Smith's farm near Whau Road west of Auckland' [Glen

Eden] on 2 Jan 1859 (NHMW 51176). NHMW holds a second specimen (NHMW 51177) also collected by Zelebor.

New Zealand pipit *Anthus novaeseelandiae*
A single specimen (NHMW 52378) collected by Wüllerstorf-Urbair at Auckland in December 1858 (von Pelzeln 1865). Frauenfeld also observed pipits, among fern between Mt Eden and Onehunga on 24 Dec 1858 (Frauenfeld 1860).

DISCUSSION

The Novara Expedition visited New Zealand early in the nation's colonial period, during the brief interval (1841–1865) that Auckland was the capital. It was one of the last international scientific expeditions to visit New Zealand before collection of native bird specimens began to be regulated by legislation (Miskelly 2014). Although Auckland Museum was founded in 1852 (Gill 2000), there is no record of *Novara* scientists interacting with honorary curator John Smith, or exchanging bird specimens with the museum before the *Novara* departed (Mason 1996; Park 1999). All these factors contributed to the bird specimens that were collected by the expedition being taken back to Austria (von Pelzeln 1865), where many are still held by the Naturhistorisches Museum in Vienna.

The birds seen and collected in and near Auckland by the Novara Expedition in 1858–59 are a reminder of the diversity of mainland bird communities before the most harmful introduced mammalian predators became widespread (Thomson 1922; King 1984, 2020; Atkinson 1985, 1996) and before introduced bird species became established (Thomson 1922). Species encountered by the expedition that are now rare or absent near Auckland included brown teal, long-tailed cuckoo, New Zealand falcon, kākā, red-crowned parakeet, yellow-crowned parakeet, bellbird, North Island kokako, hihi, whitehead, and North Island robin, and possibly also North Island saddleback and the extinct North Island piopio. All these species became rare or extinct in the northern North Island following the establishment and spread of ship rats (*Rattus rattus*) and stoats (*Mustela erminea*) in the late nineteenth century (Atkinson 1985; Lee 2005; Innes *et al*. 2010; King *et al.* 2021; Wilmshurst *et al*. 2021). Although expedition members encountered most of these species personally, acquisition of some specimens (notably hihi and North Island kokako) from other parties means there is uncertainty over where these specimens were collected before they were purchased by or gifted to the Novara Expedition.

The most notable ornithological findings of the Novara Expedition while in New Zealand were among the pelagic seabirds collected during their approach to Auckland. These included the first record of Kermadec petrels from near New Zealand, 74 years before the next specimen washed up on Muriwai Beach west of Auckland (Falla 1933; Miskelly & Braund 2025). The expedition also collected the earliest known specimen of Pycroft's petrel, 22 years before their countryman Andreas Reischek encountered the species on the Chicken (Marotiri) Islands (Reischek 1886; Oliver 1955), and 75 years before the species was recognised as distinct from Cook's petrel (Falla 1933).

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SHORT NOTE

First record of Kermadec petrel (*Pterodroma neglecta*) near the New Zealand mainland

COLIN M. MISKELLY*
Museum of New Zealand Te Papa Tongarewa, PO Box 467, Wellington 6140, New Zealand, ORCID 0000-0001-8789-3208

JAMES BRAUND
School of Cultures, Languages and Linguistics, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand, ORCID 0000-0001-8042-1566

The Novara Expedition (1857–1859) was the first expedition of the Austrian Navy to circumnavigate the world, and visited New Zealand during late December 1858 to early January 1859 (Braund & Miskelly 2025). Before arriving in Auckland from Sydney, Australia, members of the SMS *Novara* crew and scientific team collected seabirds at 35° 0' S, 175° 5' E on 19 Dec 1858 (Scherzer 1863, p.91; von Pelzeln 1865; Braund & Miskelly 2025); this location is about 110 km north-east of the Poor Knights Islands.

Four of the seabirds collected on 19 Dec 1858 were described by von Pelzeln (1865) as "*Procellaria mollis* Gould", which is a synonym of *Pterodroma mollis* (soft-plumaged petrel). The soft-plumaged petrel was added to the New Zealand list in February–March 1969, when eight birds were captured on Antipodes Island (Warham & Bell 1979). However, a hybrid between *Pt. mollis* and *Pt. lessoni* collected offshore from Antipodes Island in February 1926 (Bourne 1995; Tennyson *et al*. 2013) indicates that soft-plumaged petrels started to colonise Antipodes Island more than 40 years before they were found ashore there.

We suspected that the four "*Procellaria mollis*" specimens collected off the Northland coast in 1858 were misidentified, and that they were more likely to be Kermadec petrels (*Pt. neglecta*). Kermadec petrel is a polymorphic species that has in the past been confused with *Pt. mollis* (Finsch 1875; Cheeseman 1891; Hutton 1893; Buller 1905). Finsch (1875) and Buller (1905, p. 113) referred to the Novara Expedition specimens as part of their justification for including *Pt. mollis* in the New Zealand bird list.

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*Correspondence: *colin.miskelly@tepapa.govt.nz*

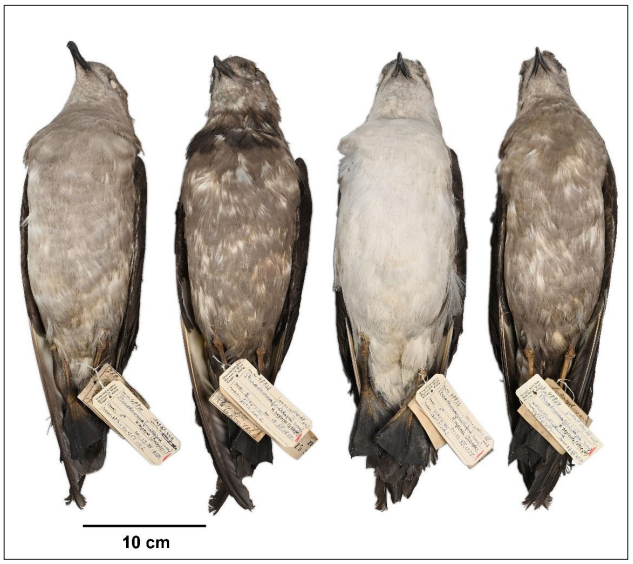

Figure 1. The four Kermadec petrel (*Pterodroma neglecta*) specimens collected by the Novara Expedition about 110 km north-east of the Poor Knights Islands on 19 Dec 1858. Naturhistorisches Museum Wien specimens NHMW 48830, 48832, 48833 & 48834. Image courtesy of Chloe Potter and Hans-Martin Berg (NHMW), prepared for publication by Jean-Claude Stahl (Te Papa).

Figure 2. Original label attached to Kermadec petrel (*Pterodroma neglecta*) specimen NHMW 48834, showing the field number (782), collection location and date. Image courtesy of Chloe Potter and Hans-Martin Berg (Naturhistorisches Museum Wien), prepared for publication by Jean-Claude Stahl (Te Papa).

An enquiry to the Naturhistorisches Museum Wien (NHMW, Vienna) revealed that the *Novara* '*Procellaria mollis*' specimens are held there, along with other Novara Expedition bird specimens (Hans-Martin Berg, *pers. comm.* to CMM, 28 Jun 2024; Braund & Miskelly 2025).

Von Pelzeln (1865) referred to five specimens of '*Procellaria mollis*' collected by the Novara Expedition, with the fifth specimen (field no. 145) collected at 40° 44' S, 60° 9' E "Indischer Ocean, gegen St. Paul zu" [Indian Ocean, towards Saint Paul Island]. This specimen is correctly identified as a soft-plumaged petrel; it was prepared as a mount (with field collection number and collection details attached) and remains in the NHMW collection (images supplied by Hans-Martin Berg). The four other specimens are study skins (relaxed mounts) of Kermadec petrels (Fig. 1), identifiable by their larger size (cf. *Pt. mollis*), pale primary shafts, and variable ventral plumage.

All four Novara Expedition Kermadec petrel specimens still have their original labels with field numbers (779–782), date and location as documented by von Pelzeln (1865) under his account for '*Procellaria mollis*' (e.g. Fig. 2). Note that von Pelzeln erred in referring to one of the specimens as no. 783, which was a Cook's petrel (*Pterodroma cookii*) or possibly a Pycroft's petrel (*Pt. pycrofti*) with the same collection details, which he listed as "*Procellaria velox*" (von Pelzeln 1865; Braund & Miskelly 2025). Three of the Kermadec petrel specimens were shot by the expedition's commander, Baron Bernhard von Wüllerstorf-Urbair, and the fourth (now NHMW 48834) was shot by zoologist Georg Frauenfeld. Field notes for the bird specimens were prepared by the expedition's assistant zoologist Johann Zelebor (von Pelzeln 1865).

Subsequent labels attached to the Kermadec petrel specimens show that their identification was corrected to *Aestrelata neglecta* and then *Oestrelata neglecta* in "Pelzeln's time" (Hans-Martin Berg, *pers. comm.* to CMM, 3 Jul 2024), and they are currently labelled and registered as *Pterodroma n. neglecta*. The four specimens were accepted by the Birds New Zealand Records Appraisal Committee as the earliest record of Kermadec petrel from near the New Zealand mainland (Unusual Bird Report 2024/050).

The Novara Expedition Kermadec petrel specimens were collected 74 years before the first accepted record of Kermadec petrel from the New Zealand mainland – a bird found dead on Muriwai Beach, west Auckland, in November 1932 (Falla 1933; Checklist Committee 1953). All ten subsequent accepted records from the mainland or coastal waters, plus one at Cuvier Island, have been of single birds (Reed 1976; Checklist Committee 2022; Miskelly *et al.* 2023). The *Novara* specimens were collected 5 years before *Procellaria neglecta* (with a type locality of Sunday Island = Raoul Island) was named by Schlegel (1863). However, Schlegel's description was available before von Pelzeln (1865) listed the birds collected during the Novara Expedition as *Procellaria mollis*.

While seeing (or collecting) four Kermadec petrels at one time near the New Zealand mainland seems exceptional, the species was vastly more abundant in the 1850s compared to its status over recent decades (Veitch *et al.* 2004). The breeding population on Raoul Island (860 km north-east of where the Novara Expedition specimens were collected) likely exceeded a million pairs before it was reduced and eventually extirpated by cats (*Felis catus*) and Norway rats (*Rattus norvegicus*). The Raoul Island population was estimated at "about half a million individuals" in 1908 (Iredale 1914), which was 72 years after cats were reported to be established on the island (Straubel 1954) and 13 years before Norway rats likely established following the wreck of the schooner *Columbia River* (Ingram 1972; Merton 1968). The remnant population breeding on small islands in the Kermadec group is estimated at about 6,000 pairs (Veitch *et al.* 2004).

The collection of four Kermadec petrels north-east of the Poor Knights Islands by the Novara Expedition in 1858 provides an insight into the extent to which predatory mammals introduced to remote islands can impact the ecology of vast areas of the surrounding ocean (Ashmole 1963; Gaston *et al.* 2007; Oppel *et al.* 2015; Weber *et al.* 2021).

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SHORT NOTE

New Zealand pipit (pīhoihoi, *Anthus novaeseelandiae*) preying on a gecko

DALLAS M. BISHOP*
GEOFFREY W. DE LISLE
244 Blue Mountains Road, RD 1, Upper Hutt 5371

On 16 Apr 2024, we departed Te Pākeka / Maud Island, Pelorus Sound (41.025 S 173.890 E) at about 0900 hours on the Department of Conservation (DOC) boat, with the ranger and family, and motored out along the northern coastline of the peninsula that extends to Harter Point. As we idled close to a spotted shag (kawau tikitiki, *Phalacrocorax punctatus*) nesting colony midway along the northern face, we observed a single New Zealand pipit (pīhoihoi, *Anthus novaeseelandiae*) with a gecko in its beak on the coastal rocks below the colony (Fig. 1). The pipit was bashing the gecko against the rocks, suggesting that the lizard was caught alive. The bird walked over the rocks, carrying the gecko, before disappearing from sight. A series of four photos were taken (G. de Lisle & D. Bishop, http://ebird.org/atlasnz/checklist/S168992350).

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*Correspondence: *miromiro@xtra.co.nz*

This was only the second pipit observed during our stay on the island (21 Mar–16 Apr 2024). Bird counts recording 34 species had been carried out over a wide area of the island. The only other pipit recorded was at the historic gun emplacement at the northern tip of the island on 28 Mar 2024 (G. de Lisle & D. Bishop, http://ebird.org/atlasnz/checklist/S166210309).

The New Zealand pipit's diet consists of a wide variety of invertebrates and seeds; however, there are previous accounts of lizards in the diet. Higgins *et al*. (2006) reported a food item identified as 'lizard', based on a February 1998 record from Mt Cargill (Otago) by Audrey Eagle (O'Donnell 2001). An earlier observation of 'lizards' being eaten by pipits was made on Kapiti Island (Wilkinson & Wilkinson 1952: 109). In April 2009 on Takapourewa / Stephens Island, a pipit was observed bashing a dead tail-less Raukawa gecko (*Woodworthia maculata*, formerly *Hoplodactylus maculatus*) on the ground (Powlesland & Moran 2010).

Fig 1. New Zealand pipit with a Raukawa gecko in its beak, Home Bay, Te Pākeka, 16 Apr 2024.

There are three gecko species recorded for Te Pākeka: Raukawa gecko, forest gecko (*Mokopirirakau granulatus*), and southern striped gecko (*Toropuku stephensi*). The uniform brown ventral surface of the gecko (Fig. 1) identifies it as a Raukawa gecko (N. Fisentzidis *pers. comm*.). Further support for this identification is provided by the short toes, general build, and relative tail length. The other two species have longer toes, a more elongated build, and a relatively longer tail (R. Hitchmough *pers. comm*.). The distribution of this gecko includes the northern South Island and many offshore islands (van Winkel *et al*. 2018). Although nocturnal, they are described as "cryptic sun-baskers" that stay close to vegetation for cover (van Winkel *et al*. 2018). The Raukawa gecko was the most common gecko encountered on Te Pākeka while checking artificial covers for speckled skinks (*Oligosoma infrapunctatum*) (22 & 23 Mar 2024) and checking and re-baiting biosecurity traps (09–14 Apr 2024).

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SHORT NOTE

First record of Horsfield's bronze-cuckoo (*Chrysococcyx basalis*) in New Zealand

J.A. GALBRAITH
Auckland War Memorial Museum, Auckland, New Zealand, ORCID 0000-0003-3869-7977

B.J. GILL*
Auckland War Memorial Museum[#], Auckland, New Zealand, ORCID 0000-0003-4026-2905

On 16 March 2024 an unusual small bird was found dead on Muriwai Beach, on the west coast near Auckland, by Ariel Wijaya and Miguel Mejías during the monthly Birds New Zealand (Auckland Branch) beach patrol organised by Ian McLean. It was Freshness Category B ("Decaying"; Powlesland & Imber 1988). Because the bird had rufous plumage, Ian initially thought it was a rufous fantail (*Rhipidura rufifrons*) but later realised it was a bronze-cuckoo (*Chrysococcyx* sp.). He took the bird to Auckland Museum for identification and preservation (freezer number Tax. 24-032). The specimen has been processed (registration number LB16349) into a spread wing and tail, feather and tissue samples, and set of bones.

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*Correspondence: *adiantum@outlook.co.nz*
[#]retired

We examined and measured the defrosted bird at Auckland Museum, confirming it was a bronze-cuckoo. With substantial rufous colouring on the under-tail it was clearly not a shining cuckoo *Ch. lucidus*, the only member of the genus normally present in New Zealand (as a summer migrant). The most likely candidate species were little bronze-cuckoo *Ch. minutillus*, Gould's bronze-cuckoo *Ch. russatus* (regarded as a subspecies of *Ch. minutillus* in some texts), or Horsfield's bronze-cuckoo *Ch. basalis* – all species found in northern and eastern Australia.

We compared measurements of the unknown specimen with those given by Higgins (1999) for various Australian bronze-cuckoo populations. Table 1 shows full ranges of measurements for Australian populations with sexes and ages combined. Measurements of the mystery bird are given in the table's first data column, taken in the same way as for the measurements tabulated in Higgins (1999).

Table 1. Measurements (mm) of the beach-wrecked bronze-cuckoo found at Muriwai Beach, and of various populations of Australian bronze-cuckoos (*Chrysococcyx* spp.; ranges of adults and juveniles combined from Higgins 1999). An asterisk indicates that the measurement for the mystery bird lies within the given range.

	Muriwai specimen	*Ch. basalis*	*Ch. m. minutillus*	*Ch. m. barnardi*	*Ch. russatus*
Wing	94.5	93–108*	88–99*	98–107	89–102*
Tail	69	62–76*	56–66	58–69*	56–72*
Tarsus	19.8	14.9–19.8*	13.1–17.5	14.6–16.6	14.3–16.9
Bill S	14.3	13.9–18.7*	15.6–19.5	16.2–19.3	15.0–20.3
Bill N	9.4	8.0–11.8*	9.9–11.5	10.6–11.9	10.7–13.0

Wing was the flattened and straightened chord (*Wmax* of Eck *et al*. 2011). *Tail* was taken ventrally from base to tip of the folded tail (*T1* of Eck *et al*. 2011). *Tarsus* was taken from the posterior notch of the ankle joint to the edge of the bent-over foot (*Tar1* of Eck *et al*. 2011). *Bill S* was taken from the junction of bill and skull to tip (*BSk* of Eck *et al*. 2011). *Bill N* was taken from the distal corner of the nostril to tip (*BNdist* of Eck *et al*. 2011).

For plumage characteristics, we compared the unknown specimen with the illustrations and descriptions in Higgins (1999), and with images of representative study-skins of Australian bronze-cuckoos from the Australian Museum collection (e.g., those shown in Fig. 1) provided by Mark Eldridge and Emily Cave.

Table 1 shows that the measurements of the Muriwai cuckoo are a closest match to those of *Ch. basalis*, falling within the ranges of that species for all five selected characters. For the other populations the unknown bird matches on only one or two ranges. Despite the poor condition of the feathering, two key plumage features are evident that support an identification of *Ch. basalis*. First, the black and white patterning on the ventral side of the outermost retrices more closely resembles that for *Ch. basalis* (Fig. 1B, 1C) than for the other species – specifically there are numerous white spots that are rounded rather than squarish (as in *Ch. minutillus*, Fig. 1D). Second, the dorsal wing coverts of *Ch. basalis* have prominent pale edges, and this is evident also in the unknown specimen (Fig. 2A).

Within the *Ch. basalis* size-ranges, the wing and bill measurements of the unknown bird are relatively short, contrasting with the tarsal measurement being at the upper end of the range. This suggests that the mystery bird is a juvenile. Higgins (1999) states that juvenile Horsfield's bronze-cuckoos "are significantly smaller than adults for all measurements except the tarsus of males and toe of both sexes". Plumage characters confirm that the specimen is a juvenile. It lacks the barring on the chest, belly and flanks that characterises adults in the candidate species; the drab upperparts with quite weak green iridescence are also typical of juvenile Horsfield's bronze-cuckoo. The rictal flanges of the gape are pale and fleshy in the Muriwai bird (Fig. 2B), also suggesting a young bird.

The beach-wrecked bird weighed about 17 g, but that is merely indicative as the bird was partly decayed, possibly emaciated, damp when weighed and the plumage infiltrated by sand. The head–bill length (*HL* of Eck *et al*. 2011) was 32.3 mm and the exposed culmen (*BF* of Eck *et al*. 2011) 11.1 mm. The bill was black, slightly paler at the base of the lower mandible. The feet and soles were dark grey.

Among the cuckoos, New Zealand has two breeding species and four other species recorded as stragglers (Miskelly *et al*. 2022). The discovery of a Horsfield's bronze-cuckoo at Muriwai Beach brings New Zealand's number of cuckoo straggler species to five. There is a long history of birds from south-east Australia turning up in New Zealand aided by the predominantly westerly winds.

Horsfield's bronze-cuckoo is common throughout Australia, where it is a summer migrant in the south and an all-year resident in the north (Menkhorst *et al*. 2019). It is unsurprising that this species should reach

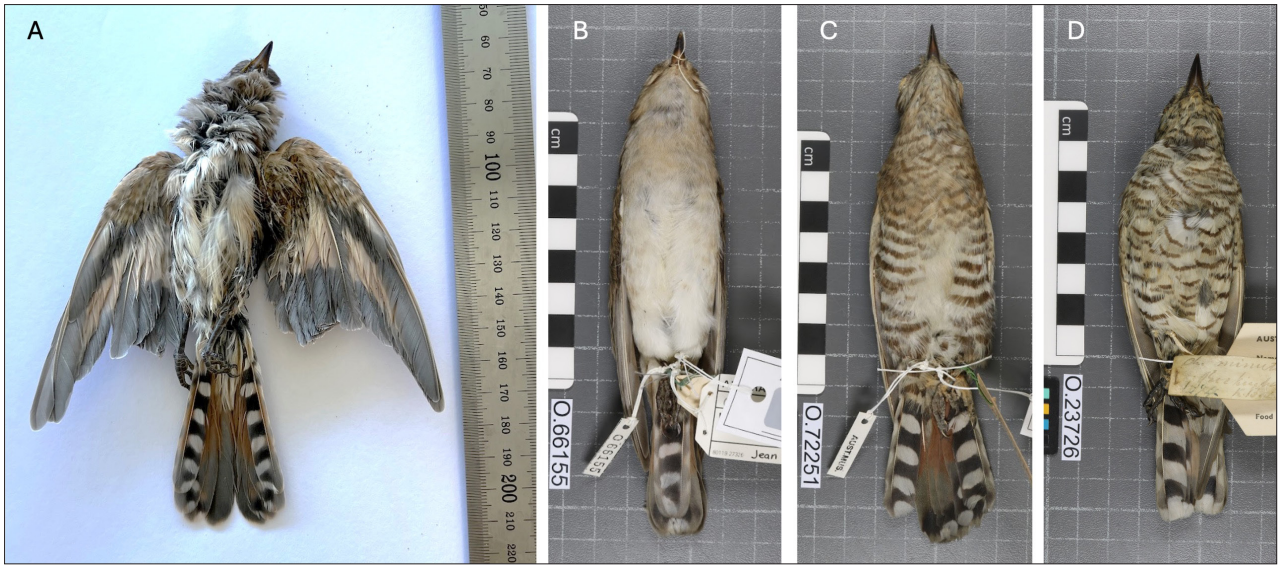

Figure 1. Ventral comparison of Muriwai beach-wrecked cuckoo with study-skins from the Australian Museum. (A) Muriwai cuckoo. (B) Juvenile male Horsfield's bronze-cuckoo (*Ch. basalis*). (C) Adult male Horsfield's bronze-cuckoo. (D) Adult male little bronze-cuckoo (*Ch. minutillus*). Photos: (A) J.A. Galbraith, (B–D) E. Cave.

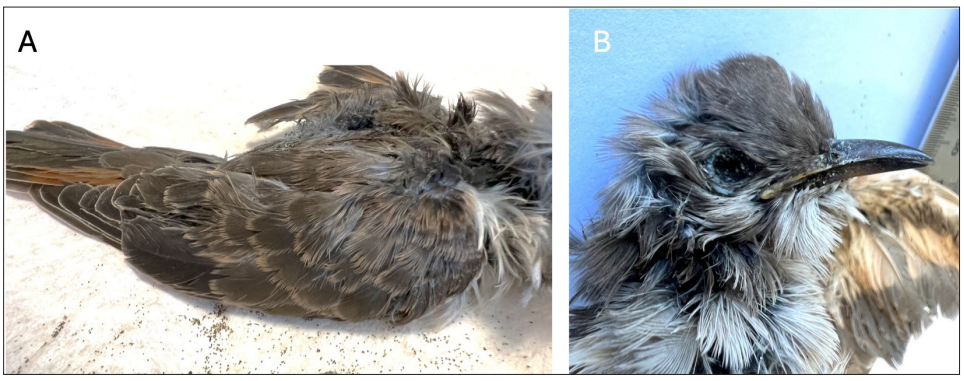

Figure 2. Features of the Muriwai beach-wrecked cuckoo used in identifying and aging the bird. (A) Prominent pale edges of the dorsal wing coverts (R wing) support the identification as Horsfield's bronze-cuckoo (*Ch. basalis*). (B) Pale and fleshy rictal flanges of the gape (R view of head) suggest the bird is a juvenile. Photos: J.A. Galbraith.

New Zealand, given that it is widespread in south-east Australia. However, the timing is odd. You might expect a cuckoo to reach New Zealand in Spring by overshooting on the southwards migration. Such a bird would be adult. Instead, the Muriwai bird arrived in Autumn. It was a juvenile, probably raised in the 2023–2024 breeding season and due to head north on its first migration. Instead it travelled south-east.

The cuckoo may not have quite reached the New Zealand mainland, and it is likely to have died at sea and been carried to Muriwai Beach by ocean currents. However, it cannot have been at sea for long because it was still intact (head, wings, legs and tail still attached to body) and fairly well preserved (much of the plumage still attached to skin).

ACKNOWLEDGEMENTS

We thank Ariel Wijaya, Miguel Mejías and Ian McLean for recognising that the dead bird was significant and presenting the specimen to the Auckland Museum collection. We thank the following specialists for helpful advice or assistance when the mystery bird was first found: Julia Allwood, Emily Cave, Mark Eldridge, Natalie Forsdick, and Richard Noske.

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SHORT NOTE

Breeding success of northern New Zealand dotterel (tūturiwhatu, *Anarhynchus obscurus aquilonius)* and variable oystercatcher (tōrea pango, *Haematopus unicolor)* at an Auckland coastal site 2018–2025

BERNARD MICHAUX
PO Box 191, Kaukapakapa 0843, New Zealand, ORCID 0000-0002-9592-9351

The northern New Zealand dotterel (tūturiwhatu, *Anarhynchus obscurus aquilonius*) and variable oystercatcher (tōrea pango, *Haematopus unicolor*) are two endemic shorebirds that are classified as Threatened (Nationally Increasing) and At Risk (Recovering) respectively (Robertson *et al.* 2021). The population estimate for tōrea pango is 6000–7000 individuals (Dowding & Chamberlin 2025) and for tūturiwhatu was *c.* 2700 in 2023 (Dowding *et al*. 2024). Tūturiwhatu numbers have increased in recent decades in large part due to the efforts of volunteers who manage coastal breeding sites by undertaking pest control, protecting breeding sites, and educating the public about the threats that some human activities pose to ground-nesting birds (Dowding 2020).

Shorebird nest monitoring was part of a long-term study of a local avifauna at a coastal site on Auckland's North Shore undertaken to describe, protect, and promote the value of the area's avifauna to decision makers and the general public. For example, detailed distributional and abundance data for a wide range of species were used in a successful appeal against a proposed housing development and, more recently, to persuade Auckland Council to employ contractors to live-trap cats. Regular updates about when birds are breeding, number of chicks hatched, and how many fledge are provided to the public through the Friends of Okura Bush website (https://okurabush.org.nz/).

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*Correspondence: *bjmichaux@gmail.com*

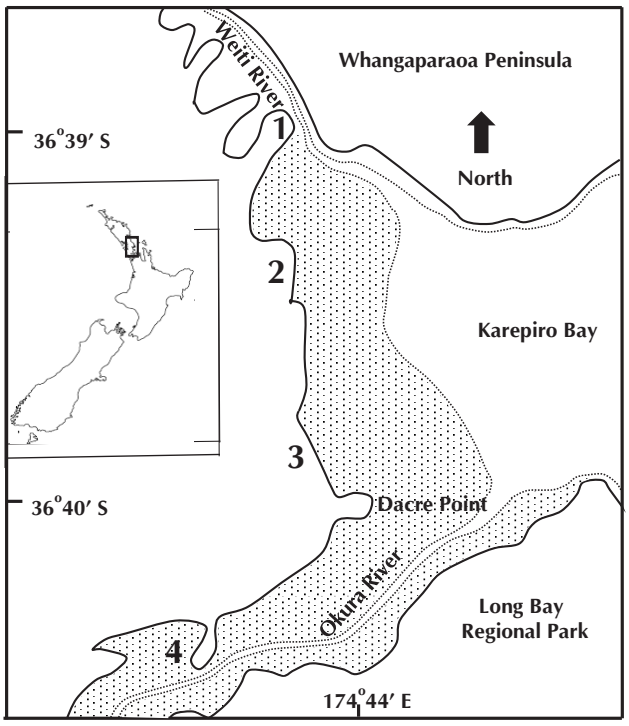

Figure 1. Locality map of the study area. 1 = Weiti chénier, 2 = coast between Weiti and Karepiro, 3 = Karepiro Beach, 4 = Okura chénier. Stippled area represents the approximate extent of tidal mudflats.

Tūturiwhatu and tōrea pango nest monitoring was carried out between 2018 and 2025 along a 4 km stretch of coastline on Auckland's east coast between the urban centres of Long Bay and the Whangaparaoa Peninsula (Fig. 1). This locality is an important part of Auckland's green infrastructure and provides habitat for a range of endemic and native birds. Habitat diversity is high and includes chéniers, a brackish lagoon, saltmarsh and wetlands, cliffs and rock platforms, sandy beaches and dunes, small creeks, and extensive mudflats found between the confluence of the Weiti and Okura rivers. Most of this coastline is under the stewardship of Auckland Council, which recognised its biodiversity value by designating it as a Significant Ecological Area in its 2016 Unitary Plan, banning dogs at all times and, since February 2023, live-trapping cats on the Weiti chénier (Fig. 1: site 1) and Karepiro Beach (Fig. 1: site 3). Volunteer trappers have carried out pest and weed control throughout the area since 2014.

As winter flocks of tuturiwhatu and tōrea pango disperse at the end of winter and the beginning of spring, several pairs take up breeding territories within the study area, where their breeding success was monitored between 2018 and 2025 (Table 1). Tūturiwhatu bred at sites 1, 3, and 4 while tōrea pango also bred along the rocky shore at site 2 (Fig. 1). Three of the tūturiwhatu were identifiable by either a unique colour band combination or 3-letter flags, allowing determination of breeding site fidelity. YR-OM is a captive-reared female who is a now 27 years old and has bred at site 1 for at least 10 years and probably all her life, only being recorded away from this site once (John Dowding, *pers. comm*.). The sites were visited a total of 133 times during the study period, generally monthly outside the breeding season (March–August) and fortnightly during the breeding season. First clutches were usually laid between the end of October and early December, although in 2023 a pair laid in mid-September. Nests were monitored and the number of chicks present recorded each visit. Chicks were categorised as fledged when they could fly.

Breeding success for both species varied from year to year, especially for tūturiwhatu (Table 1) which had consistently larger 95% confidence intervals around the number of chicks fledged, number of pairs breeding, and productivity. Overall, the average productivity for tōrea pango (0.87, range 0–2) was similar to that reported by Michaux (2013) and Dowding & Chamberlin (2025). Average tūturiwhatu productivity (0.60, range 0–1.4) lies within the range reported for Coromandel (Dowding 2006; Ogden & Dowding 2013) and Bay of Plenty (Wills *et al*. 2003) populations, but lower than that reported by Neate *et al*. (2011) for mammalian predator-free Motuihe Island in the Hauraki Gulf.

Unsurprisingly, the number of tūturiwhatu chicks fledged was in part a function of the number of breeding pairs. For the four years when nesting was not affected by northeasterly storms, there is a strong positive correlation between the number of nesting pairs and number of chicks fledged ($R^2 = 0.995$). All other things being equal, the more breeding pairs there are the greater the potential to produce chicks. The availability of suitable nesting sites can limit the number of breeding pairs. For example, tidal scouring of the Okura chénier (site 4) over the 2024 winter resulted in erosion and the loss of this site as suitable breeding habitat. The dynamic nature of the coast here is such that potential breeding sites will vary with time. However, the major factors influencing productivity were storm surges that washed out nests, and predation of young or adults. All three tūturiwhatu breeding sites were susceptible to inundation during king tides or when northeasterly storms coincided with nesting; these were major causes of nest loss. For instance, in the last breeding season (2024-25) all five nesting attempts by the two pairs of tūturiwhatu on Karepiro Beach were washed out. Predation was a factor in the loss of two nests with a swamp harrier (kāhu, *Circus*

Table 1. Results of variable oystercatcher/tōrea pango and northern New Zealand dotterel/tūturiwhatu breeding over a 7 year period. Averages with 95% confidence intervals.

	Variable oystercatcher/tōrea pango			NZ dotterel/tūturiwhatu			
Season	Fledged	Pairs	Productivity	Fledged	Pairs	Productivity	Comments
2018/19	0	3	0.00	1	6	0.16	NE storms during breeding season
2019/20	4	5	0.80	1	5	0.20	NE storms during breeding season
2020/21	2	4	0.50	1	2	0.50	Covid restrictions limited number of visits
2021/22	4	4	1.00	2	3	0.67	Covid restrictions limited number of visits
2022/23	6	3	2.00	6	5	1.20	
2023/24	3	4	0.75	11	8	1.40	
2024/25	4	4	1.00	0	5	0.00	NE storms during breeding season Probable cat predation, kahu predation
Average	3.3	3.9	0.87	3.1	4.9	0.60	

approximans) recorded on a trail camera at one nest and the body of an adult (probably killed by a cat) found at another nest. This latter example was within a recently planted native area in the Weiti housing development. It is becoming increasinglly common for tūturiwhatu to nest at inland sites in the Auckland region (Dowding 2020). Given the susceptibility of Karepiro Beach nest sites to inundation, use of inland breeding sites may be beneficial for the local population.

The breeding population of tōrea pango was relatively stable and their average productivity was less variable. The data presented by Dowding & Chamberlin (2025) included details of breeding on the Weiti chénier (site 1) during the 1994-95 to 1998-99 seasons. Three pairs used this site during their study period. Only a single pair now regularly nests there; however, two other pais have taken up territories along the coast immediately south of the chénier. Dowding & Chamberlin (2025) reported an average productivity of 0.83 for these three pairs, which was the same as the average productivity recorded in this study. Dowding & Chamberlin's (2025) average productivity across all sites was 0.42 compared to 0.87 in this study, perhaps an indication of the effectiveness of local management efforts.

While the failure of the tūturiwhatu pairs to produce any fledglings in the 2024-25 season was particularly disappointing, it should be viewed in context. Tūturiwhatu typically nest just above the mean high tide mark, where nests are vulnerable to inundation (a factor in three of the seven seasons), and they and their eggs and young have many native and introduced predators. Their breeding strategy and long-term survival is based on the longevity of individual birds and the ability of females to lay multiple clutches each season. At this site the maximum number of clutches recorded was three with a maximum of three eggs per clutch. When conditions are suitable, tūturiwhatu are capable of a rapid increase in numbers, which offsets poor breeding years. According to Dowding & Davis (2007) the threshold for successful management of this species is an average productivity of 0.50, which was exceeded by the annual average in this study (0.60). Continued management of mammalian predators and minimisation of human disturbance are important factors in maintaining this success. However, the expected negative effects of climate change on both sea-level rise and the frequency and severity of storms during the breeding season will be harder to mitigate, and may degrade these sites as breeding habitat.

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SHORT NOTE

Monitoring endemic forest birds on Atuanui/Mount Auckland between and within years

BERNARD MICHAUX
PO Box 191, Kaukapakapa, 0843, New Zealand, ORCID 0000-0002-9592-9351

HEMI TAPARAU
Nga Maunga Whakahii o Kaipara Development Trust, PO Box 41, Te Awaroa, Helensville 0840, New Zealand

Atuanui maunga is a 615 ha native forest remnant bordering the eastern shore of the southern Kaipara Harbour. It is a remnant of Northland's once widespread coastal kauri – podocarp – broad leaf forest, with mature and regenerating kauri (*Agathis australis*), rimu (*Dacrydium cupressinum*), kahikatea (*Podocarpus dacrydioides*), tōtara (*P. totara*), taraire (*Beilschmiedia tarairi*), karaka (*Corynocarpus laevigatus*), pūriri (*Vitex lucens*), kohekohe (*Didymocheton spectabile*), kōwhai (*Sophora tetraptera*) and rewarewa (*Knightia excelsa*). When Atuanui maunga was returned to Ngāti Whātua o Kaipara in 2013 as part of their Treaty of Waitangi Settlement Claim, a systematic pest control programme was initiated to return the maunga to health and provide suitable habitat for any kiwi-nui (*Apteryx mantelli*) that might disperse from a translocated population at the nearby Mataia Restoration Project.

Monitoring of birds on Atuanui has been undertaken for 20 years, with results previously reported by Michaux (2009) and Michaux & Taparau (2019). This note updates the data reported in Michaux & Taparau (2019) for territorial male miromiro (*Petroica macrocephala toitoi*) counts along a 3.5 km ridgeline transect, and includes encounter rates of other common forest endemics along the same transect. Encounter rate data were derived by recording all birds seen or heard whilst walking the transect (Michaux 2009; raw data are available from eBird https://ebird.org). The results of a year-long monthly 5-minute bird count (5MBC) (Dawson & Bull 1975) study carried out in 2023 are also reported on.

There has been an intensification of pest control at Atuanui during the years covered by this report, as the programme run by the kaitiaki employed by Nga Maunga Whakahii o Kaipara Development Trust (NMWK) has been augmented by trapping carried out by the Forest Bridge Trust (FBT) (https://www.theforestbridgetrust.org.nz/). The FBT carry out pest control on a landscape scale with the aim of connecting kiwi-nui populations at Mataia, Mount Tamahunga (Warkworth) and Tāwharenui by transforming 54,000 hectares of North Auckland into kiwi-safe habitat. Because of the importance of Atuanui as potential kiwi-nui habitat and its proximity to Mataia (1.3 km at the closest point), the FBT installed four circuits of DOC 200s (80 traps), DOC 250s (53 traps), AT220s (28 traps), and 12 SA cat traps. In addition the FBT employ a kaitiaki for 2 days a week to maintain the trap circuits. The kaitiaki of NMWK have also installed 60 AT220s - multi-species, automated traps that increase the efficiency of pest

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*Correspondence: *bjmichaux@gmail.com*

control by decreasing the effort per kill. In 2023, 30 of these traps were set along the reserve's northern boundary (in a transect parallel to the Hoteo River) and a further ten along the Mangatū Stream, which flows into the Hoteo River. Five additional traps were integrated along each of the FBT circuits in 2024. Fallow deer (*Dama dama*) and pigs (*Sus scrofa*) periodically invade the reserve and are hunted as soon as their presence is detected.

The number of territorial miromiro counted each year between 2005/06 and 2024/25 is shown in Fig. 1, with the trend line indicating a significant growth rate of 0.25 territories/year (t = 2.86, P = 0.01). However, only 31% of the variance in territory numbers can be explained by year. While we have used a linear model to analyse the change in miromiro encounter rates, the graph may indicate a stepwise response, with the population oscillating around a higher equilibrium after pest control effort was increased in 2018.

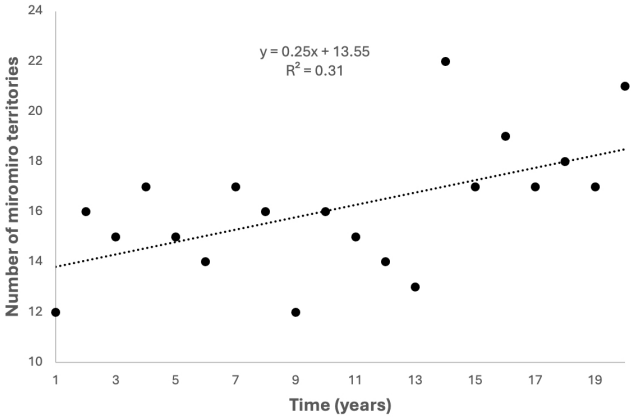

Figure 1: Estimated number of miromiro territories 2005/06 – 2024/25. Dotted line = best fit trend line, R^2 = coefficient of determination, which measures the proportion of variation in the y-values explained by the x-values. Year 1 = 2005/06 breeding season.

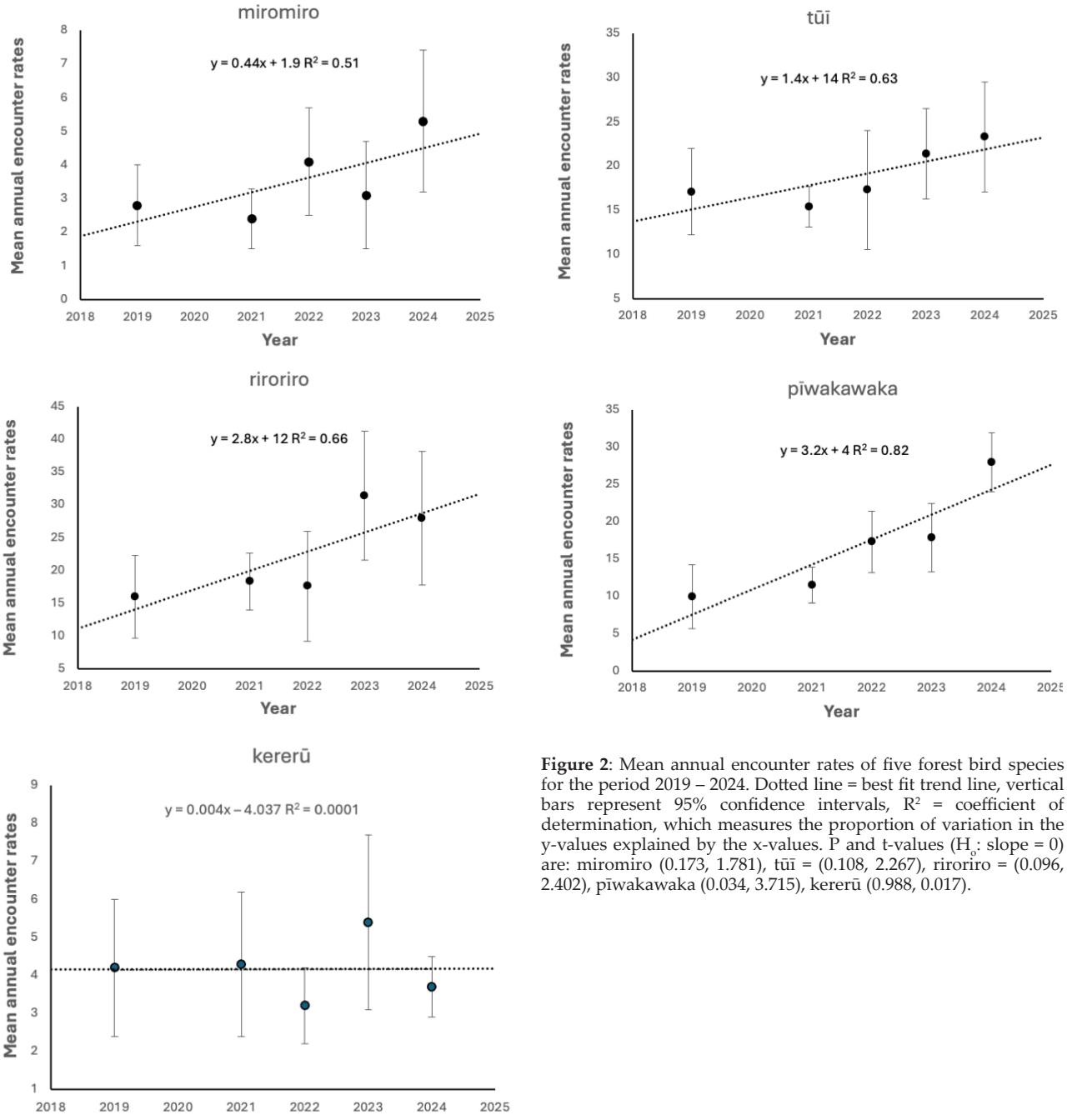

Figure 2: Mean annual encounter rates of five forest bird species for the period 2019 – 2024. Dotted line = best fit trend line, vertical bars represent 95% confidence intervals, R^2 = coefficient of determination, which measures the proportion of variation in the y-values explained by the x-values. P and t-values (H_o: slope = 0) are: miromiro (0.173, 1.781), tūī = (0.108, 2.267), riroriro = (0.096, 2.402), pīwakawaka (0.034, 3.715), kererū (0.988, 0.017).

Mean encounter rates (± 95% CI) of five endemic species for 2019–24 are presented in Fig. 2. Data for 2020 have been omitted due to covid lockdowns that limited counts to spring months, leading to biased results because of seasonal changes in encounter rates described below. Kererū (*Hemiphaga novaeseelandiae*) remained stable over the 6 years, contrasting with the previous 7 years when the population growth rate was estimated at +0.2 birds/year (Michaux & Taparau 2019). Kererū are highly mobile and able to travel long distances to access seasonal food resources (Innes *et al*. 2022), and so local encounter rates may be influenced by landscape-scale food availability. Miromiro, rironiro (*Gerygone igata*), and pīwakawaka (*Rhipidura fuliginosa*) all had growth rates approximately double that recorded by Michaux & Tapurau (2019), while tūī (*Prosthemadera novaeseelandiae*) had growth rates that were similar to those reported over the previous 7 years.

Variable population responses by New Zealand forest species to mammalian pest control have been reported in other studies (Innes *et al*. 2004; O'Donnell & Hoare 2012; Binny *et al*. 2021; Lovegrove & Parker 2023). Binny *et al*. (2021) concluded that 'deep endemics' such as tīeke (*Philesturnus rufusater*) and hihi (*Notiomystis cincta*), which belong to endemic families, had the highest response rates after pest control, followed by endemic genera, and then endemic species. Non-endemic species (including introduced species) tended to decline over time as deep endemic species increased. Fea *et al*.'s (2021) meta-analysis reported that large-bodied endemics such as kākā (*Nestor meridionalis*) and kererū responded most strongly to pest control, with rironiro, pīwakawaka and tauhou responses either neutral or declining. The decline in these three small insectivores following pest eradication in Zealandia (Karori Wildlife Sanctuary) was also reported by Miskelly (2018), who concluded that rironiro, pīwakawaka, and tauhou were outcompeted when a full suite of endemic insectivores was present.

Fea *et al*.'s (2021) results indicate that predation by the common brushtail possum (*Trichosurus vulpecula*) may impact the abundance of indigenous species, because low-intensity pest control (which is effective against possums but not ship rats *Rattus rattus*) produced low but still positive responses for several endemic species. This may explain the persistence of Atuanui's miromiro population prior to 2013, when DOC managed the forest by using ground-based cyanide poisoning targeting possums on a 5-year cycle (although there may have been secondary kills of other pests). Confirmation that targeted possum control can result in an increase in abundance of indigenous birds comes from a 22-year-long study in the Waitakere Ranges, Auckland, which revealed an overall increase in bird numbers and in the proportion of endemic bird species (Lovegrove & Parker 2023). Tūī and rironiro increased significantly, while kererū and pīwakawaka remained stable. The response of miromiro was more complex, with an initial increase followed by a levelling off and then a decline. Introduced species either had a neutral response or declined (Lovegrove & Parker 2023).

In 2023, BM conducted a year-long study at Atuanui using 5MBC to track changes in bird conspicuousness throughout the year, to inform the best time of year to undertake monitoring. Fourteen listening stations placed 250 m apart along the ridgeline transect were visited monthly. Atuanui has been closed to the public since 2018 to protect kauri from *Phytophthora agathidicida*, a soil-borne fungus that causes kauri dieback disease, and so there

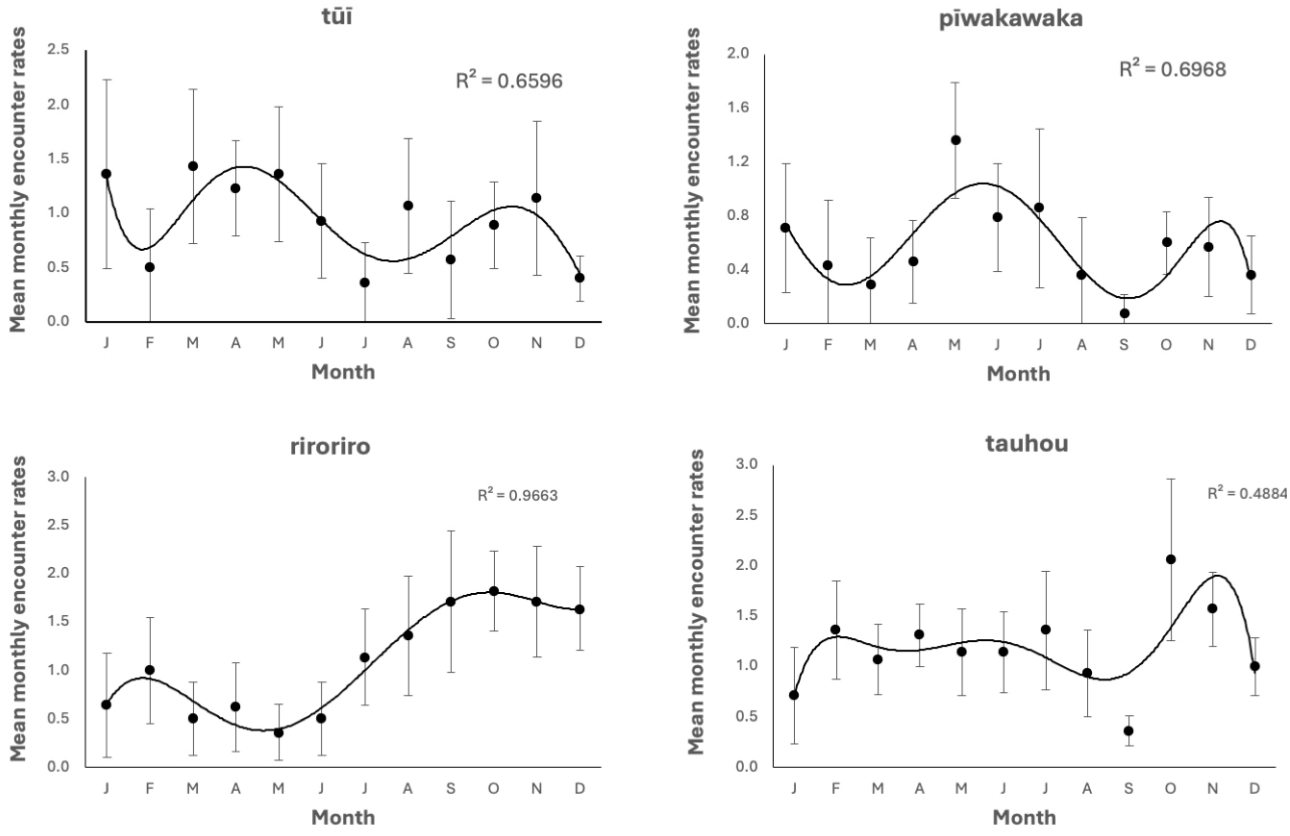

Figure 3: Seasonal variation in mean monthly encounter rates of four forest bird species during 2023 based on 5-minute counts. Curve = best fit polynomial (order 6), vertical bars represent 95% confidence intervals. R^2 = coefficient of determination, which measures the proportion of variation in the y-values explained by the x-values.

was minimal disturbance that may have affected bird behaviour and altered the probability of detection. Every bird heard or seen during 5 minutes was recorded for each station (raw data available on request). The mean monthly encounter rates (average number of individuals encountered per visit, with 95% confidence intervals) was 59.4 ± 7.6, the mean species' richness (average number of species counted per visit with 95% confidence intervals) was 8.0 ± 1.3, and dominance measure (average ratio of indigenous species to total species with 95% confidence intervals) was 0.82 ± 0.06. While some exotics such as chaffinch (*Fringilla coelebs*), blackbird (*Turdus merula*), myna (*Acridotheres tristis*), and eastern rosella (*Platycercus eximius*) were relatively common, Atuanui's avifauna was dominated by a restricted range of indigenous species, as reported for other forested restoration sites (Bell 2015; Miskelly 2018).

Monthly changes in encounter rates of tūī, riroriro, pīwakawaka, and tauhou (*Zosterops lateralis*) are shown in Fig. 3, with best fit curves (polynomial, order 6) shown for each species. Tūī and pīwakawaka exhibited a bimodal pattern, while riroriro and tauhou had a single spring peak, which was the same pattern observed for these four species at Zealandia (Bell 2015). These results indicate that spring is the best time to monitor these endemic bird species, followed by autumn if resources allow.

The pest control programmes run by NMWK and FBT do not specifically target rats, and are primarily designed to control stoats (*Mustela erminea*) and other mustelids. NMWK also target possums and feral cats (*Felis catus*). Our monitoring has revealed that pest control has led to an increase in abundance of resident birds on the maunga. However, unless effective rat control is implemented, it is unlikely that other more vulnerable endemic bird species could re-establish at the site.

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