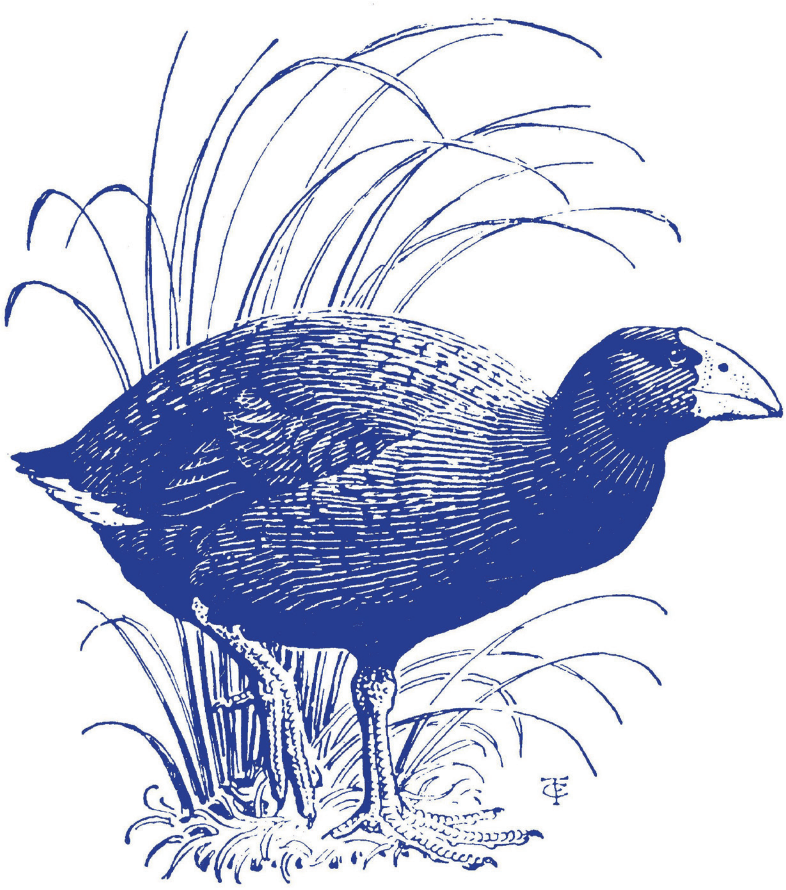
NOTORNIS

Ornithology of the Southern Pacific



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Diet of the Floreana mockingbird (*Mimus trifasciatus*) during the dry season on Champion and Gardner Islets, Galápagos Islands, Ecuador

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Abstract: The Floreana mockingbird (*Mimus trifasciatus*) is one of the most endangered passerines in the world, with a global population of *c.* 400 individuals, restricted to two isolated islets: Champion and Gardner-by-Floreana. Due to its rarity and the inaccessibility to these islets, the biology of the Floreana mockingbird has remained poorly documented. Here we present a study on the diversity of food items consumed by Floreana mockingbirds prior to the rainy season. We recorded 269 foraging bouts, from 148 individuals on three independent sampling events. Floreana mockingbirds exhibited a generalist diet, which included flowers, nectar, stamens, sap, fruits, seeds, and seedlings from 12 plant species; larvae, pupae and adults of at least 10 arthropod orders; and small vertebrate prey, carrion, and egg contents. The diversity of food items between months and islets supports the idea of a generalist diet for the species. Our study provides useful information to identify and monitor the abundance of key resources for the species as part of the restoration of Floreana Island.

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Key words: bird behaviour, conservation, generalist diet, island avifauna, scavenging

INTRODUCTION

Developing management strategies for species of conservation interest requires an understanding of the biology of the target species. For instance, the successful conservation of the kakapo (*Strigops habroptilus*) (a nocturnal flightless parrot from New Zealand) has been fine-tuned since the 1970s as more research on the mating system and dietary requirements of the species is developed (Harper *et al*. 2006). Additionally, an understanding of the food preferences of a species can help managers identify

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suitable areas for reintroduction (Kelle *et al*. 2014). Unfortunately, the biology of many endangered species remains poorly documented. One example is the Floreana mockingbird (*Mimus trifasciatus*), one of four species of mockingbirds endemic to the Galapagos Islands (Arbogast *et al*. 2006).

The mockingbirds (*Mimus* spp.) of the Galapagos Islands played an important role in the development of Darwin's theories about natural selection (Nicholls 2015); however, compared to Darwin's finches (*Geospiza, Camarhynchus, Certhidea*, and *Platyspiza* spp.) they have been the subject of fewer field studies. Four species of mockingbird exist in the Galapagos archipelago, all within the genus *Mimus* (Arbogast *et al*. 2006). Three of these are endemic to a single island, and their near-shore islets, all located in the south-east of the archipelago: the Española mockingbird (*M. macdonaldi*), the Floreana mockingbird (*M. trifasciatus*), and the San Cristobal mockingbird (*Mimus melanotis*). The fourth species, the Galapagos mockingbird (*M. parvulus*) occurs on nine main islands and several islets across the centre, north, and west of the archipelago (Arbogast *et al*. 2006; Hoeck *et al*. 2010a). A subspecies of Galapagos mockingbird (*M. parvulus bauri*) represents a lineage of hybrid ancestry between the San Cristobal mockingbird and Galapagos mockingbird (Nietlisbach *et al*. 2013) indicating temporary co-occurrence of two species on a single island. Lastly, the co-occurrence of two species of mockingbirds on a single island has been reported on Gardner-by-Floreana, where a single San Cristobal mockingbird coexisted in a population of Floreana mockingbirds for at least 10 months (Ortiz-Catedral *et al*. 2021).

The endangered Floreana mockingbird was historically present on the lowlands of Floreana Island, but became extinct on its namesake island due to the effects on introduced species and large-scale habitat modification by early inhabitants on Floreana Island (Curry 1986; Steadman 1986; Grant *et al*. 2000). Two remnant populations, geographically and genetically isolated on the islets of Champion and Gardner-by-Floreana, represent the last strongholds for the species (Hoeck *et al*. 2010b), with an estimated population of 400 individuals on both islets (Ortiz-Catedral 2018). In order to increase the geographic range and population size of the species, a reintroduction plan to the lowlands of Floreana has been developed (Charles Darwin Foundation 2008; Hoeck *et al*. 2010b), and a range of reintroduction scenarios had been analysed taking into account the genetics of the remnant populations (Bozzuto *et al*. 2017). However, to date there is only limited information on the range of food types and species that Floreana mockingbirds consume (Ortiz-Catedral 2014, 2018; Ortiz-Catedral *et al*. 2017). Prior to the reintroduction of the species to the lowlands of Floreana Island, it is imperative to determine whether their preferred prey items occur at potential release locations, and also how these resources increase in abundance as the restoration of Floreana Island progresses. Nevertheless, the diversity of food items that Floreana mockingbirds consume has not been quantified. We conducted a field study on the diversity of foods consumed by Floreana mockingbirds during the dry season, three months prior to the typical breeding season of the species: November, December (2015), and January (2016) (Ortiz-Catedral *et al*. 2017) in order to characterise the range of food species that need to be monitored on Floreana Island to assess whether their abundance can sustain a reintroduced population of Floreana mockingbirds in the near future.

METHODS

Our study was conducted on two islets: Champion (9.4 ha) (90°21′47′′W, 01°13′55′′S) and Gardner-by-Floreana (80 ha) (90°17′44′′W, 01°20′48′′S). Both islets represent land fragments of Floreana Island, which historically had a much larger area than present (Ali & Aitchinson 2014). Access to these islets is highly restricted and the Directorate of the Galapagos National Park have implemented stringent biosecurity measures in place to prevent the accidental introduction of invasive species. Further, both islets harbour remnant populations of vertebrate species now extinct on Floreana Island, including the Floreana mockingbird (Grant *et al*. 2000) and the Western Galapagos racer (*Pseudalsophis biserialis*) (Ortiz-Catedral *et al*. 2019), and are thus considered islets of high conservation value. Therefore, we visited the islets for two to a maximum of two to four days to conduct observations in November and December 2015 and January 2016. All biosecurity protocols were followed as part of this research. We conducted observations from 0600 h to 1800 h with a recess from 1200 h to 1400 h during the hottest period of the day, when mockingbirds are less active (Ortiz-Catedral *pers. obs.*). Individual observers (2–4) covered the study areas on foot: the total accessible land area of Champion, equivalent to 9 ha, and a 12 ha section of Gardner known as "The Plateau". The Plateau has been a study area for the population of Floreana mockingbirds for previous studies (see Ortiz-Catedral 2014; Hoeck *et al*. 2010b), and represents the only part of the islet that can be accessed safely. Whenever a mockingbird was encountered, the location, time, height to nearest 0.5 m, and only the first food item consumed within 30 seconds from sighting were noted to maximise independence of observations. Birds were observed at an approximate distance of 5 to 15 m using 8 x 42 binoculars.

Table 1. Plant and animal species consumed by Floreana mockingbirds on Champion and Gardner-by-Floreana (Gardner) from November 2015 to January 2016. ND indicates not determined.

Order/Family	Common name	Scientific name	Champion	Gardner	Part eaten
Boraginales/Boraginaceae	Muyuyo	*Cordia lutea*	0	1	Fruit
Boraginales/Boraginaceae	Heliotrope	*Heliotropium angiospermum*	0	1	Flower
Caryophyllales/Aizoaceae	Galapagos carpetweed	*Sesuvium edmonstonei*	2	0	Flower
Caryophyllales/Cactaceae	Prickly pear	*Opuntia megasperma*	51	14	Stamens, nectar, sap
Caryophyllales/Nyctaginaceae	Wartclub	*Commicarpus tuberosus*	0	1	Seedling
Caryophyllales/Portulacaceae	Galapagos purslane	*Portulaca howellii*	0	13	Flower
Caryophyllales/Portulacaceae	Common purslane	*Portulaca oleracea*	1	0	Flower
Euphorbiales/Euphorbiaceae	Chala	*Croton scouleri*	1	3	Seed, seedling
Solanales/Convolvulaceae	Lava morning-glory	*Ipomoea habeliana*	5	0	Flower
Solanales/Solanaceae	Galapagos ground cherry	*Physalis galapagoensis*	13	2	Fruit
Solanales/Solanaceae	Galapagos shore petunia	*Exedecomus miersii*	0	4	Fruit, seeds
Lamiales/Verbenaceae	Galapagos lantana	*Lantana peduncularis*	0	1	Flower
Araneae/Araneidae	Garden orb-web spider	*Argiope trifasciata*	2	0	Adult
Araneae/Lycosidae	Wolf spider	*Hogna albemarlensis*	1	1	Adult
Blattodea/Kalotermitidae	Termite	*Incisitermes sp.*	1	2	Larvae
Diptera/Syrphidae	Fly	*Ornidia obesa*	0	3	Adult
Hymenoptera/Vespidae	Yellow paper wasp	*Polistes versicolor*	1	0	Adult
Neuroptera/Myrmeleontidae	Galapagos antlion	*Galapagoleon darwini*	0	1	Adult
Orthoptera/Acrididae	Large panted locust	*Schistocerca melanocera*	12	15	Adult
Scolopendromorpha/Scolopendridae	Galapagos centipede	*Scolopendra galapagoensis*	1	0	Adult
Solifugae/Ammotrechidae	Sun spider	*Neocleobis solitarius*	0	1	Adult
Columbiformes/Columbidae	Galapagos dove	*Zenaida galapagoensis*	0	1	Egg contents
Pinnipedia/Otariidae	Galapagos sealion	*Zalophus wollebaeki*	10	0	Carrion
Squamata/Gekkonidae	Floreana gecko	*Phyllodactylus baurii*	0	1	Adult
Squamata/Tropiduridae	Floreana lava lizard	*Microlophus grayii*	1	1	Adult, carrion
Suliformes/Sulidae	Nazca booby	*Sula granti*	0	4	Egg contents
Araneae	Spider	ND	7	3	Adult
Lepidoptera	Moth, butterfly	ND	0	3	Adult, caterpillar, pupae
Blattodea	Cockroach	ND	1	1	Adult
Excoetidae	Flying fish	ND	0	1	Carrion
Coleoptera	Beetle	ND	1	4	Adult
Diptera	Fly	ND	11	6	Adult
Formicidae	Ant	ND	1	7	Adult
Gryllidae	Cricket	ND	0	7	Adult
ND	Arthopod	ND	17	29	Adult
-	Pebble	-	1	0	Non-dietary

Efforts were made to identify food items to species or at least major taxonomic groups (i.e. family or order for invertebrates). Plant food types were assigned to the following categories: flower bud, stamens, nectar, fruit, seeds, seedling, sap. Animal food types were classified as either invertebrate or vertebrate. Invertebrate food items were assigned to the following categories: larvae, pupae, adult. Vertebrate food items were classified as: carrion, egg contents, adult, or juvenile. Whenever possible we classified the foraging behaviour for each feeding bout according to the proposed terminology by Remsen & Robinson (1990). However, in over 30% of cases we could not clearly classify the type of foraging behaviour. Foraging behaviours are thus presented only for descriptive purposes. We analysed our data, as absolute frequency of occurrence (Wright 2010) per month, between populations, using Fisher's exact test in R (R Core Team 2020). We excluded the ingestion of sap (two observations) and pebbles from statistical analyses due to the low number of observations of these items. We also contrasted foraging heights per islet per sampling period using a two-sample t-test.

RESULTS

We recorded a total of 269 incidental foraging bouts by Floreana mockingbirds during November 2015 to January 2016 on 26 species of plants, invertebrates and vertebrates (Table 1). Floreana mockingbirds ingested invertebrate prey (larvae, pupae, adult insects), flowers (including petals, stamens, nectar, whole flowers), fruits, seeds, and seedlings, and vertebrate matter including carrion, small vertebrate prey, and contents of bird's egg. (Table 1). We also recorded a single instance of a non-dietary item ingestion, small pebbles (Table 1). In general, Floreana mockingbirds fed on similar food types in November and December (Fisher's exact test November $P = 0.06$, $n = 32$; Fisher's exact test December $P = 0.71$, $n = 124$). In January, Floreana mockingbirds on Champion fed predominantly on flowers, while on Gardner-by-Floreana, they consumed primarily invertebrates (Fisher's exact test January $P < 0.001$, $n = 113$) (Fig. 1). Floreana mockingbirds on Champion and Gardner-by-Floreana foraged on resources at the same height in November, but as our sampling progressed, individuals on Champion foraged at significantly higher strata than on Gardner-by-Floreana (Table 2). Floreana mockingbirds captured invertebrate prey using a variety of methods including: glean (flies, ants, spiders), flush pursue (Galapagos painted locust *Schistocerca melanocera*, yellow paper wasp *Polystes versicolor*), flake (termites), leap (Galapagos painted locust), lunge (Galapagos centipede *Scolopendra galapagoensis*, sun spider *Neocleobis solitarius*), and peck (termites). Floreana mockingbirds captured small vertebrates using lunge (Floreana lava lizard *Microlophus grayii*) and flake (Floreana gecko *Phyllodactylus baueri*). Floreana mockingbirds pulled pieces of carrion for ingestion, drank egg contents (Nazca booby *Sula granti*, Fig. 2; Galapagos dove *Zenaida galapagoensis*) and drank sap (prickly pear *Opuntia megasperma*). Fruits, and flowers were foraged by reach (Uvilla *Physalis peruviana*; purslane *Portulaca howellii*) and stamens and nectar by probe (prickly pear). With the exception of the yellow paper wasp, all species registered in our study are native species to the Galapagos Islands.

DISCUSSION

The diversity of food types and species consumed by Floreana mockingbirds during our study indicates that it is a generalist species, like the Galapagos mockingbird (*M. parvulus*) which feeds on a variety of invertebrates (Grant & Grant 1979; Curry 1986), booby (*Sula* spp.) blood (Curry & Anderson 1987), and even introduced mice (*Mus musculus*) (Gotanda *et al*. 2015). Similarly, another island species, the Socorro mockingbird (*Mimoides graysoni*) endemic to Socorro Island, Mexico consumes arthropods and fruits of at least seven plant species (Martínez-Gomez *et al*. 2001). Prior to our study, preliminary information on the breeding season diet of Floreana mockingbirds showed the consumption of nectar, pollen, and invertebrates (Ortiz-Catedral 2014). Our observations thus expand the list of known dietary items for the species. The consumption of carrion from sea lions (*Zalophus wollebaeki*), Floreana lava lizard (*Microlophus grayii*), and flying fish (Excoetidae) are of interest as these have not been documented for the species before. The

Table 2. Monthly changes in foraging height (m) of Floreana mockingbirds on Champion and Gardner Islets. *Significant differences.

Month	n	Champion	Gardner	t value	*P*
November	33	0.10 ± 0.34	0	1.28	0.21
December	125	0.37 ± 0.81	0.11 ± 0.39	2.25	0.03*
January	106	1.06 ± 0.92	0.27 ± 0.56	5.32	<0.001*

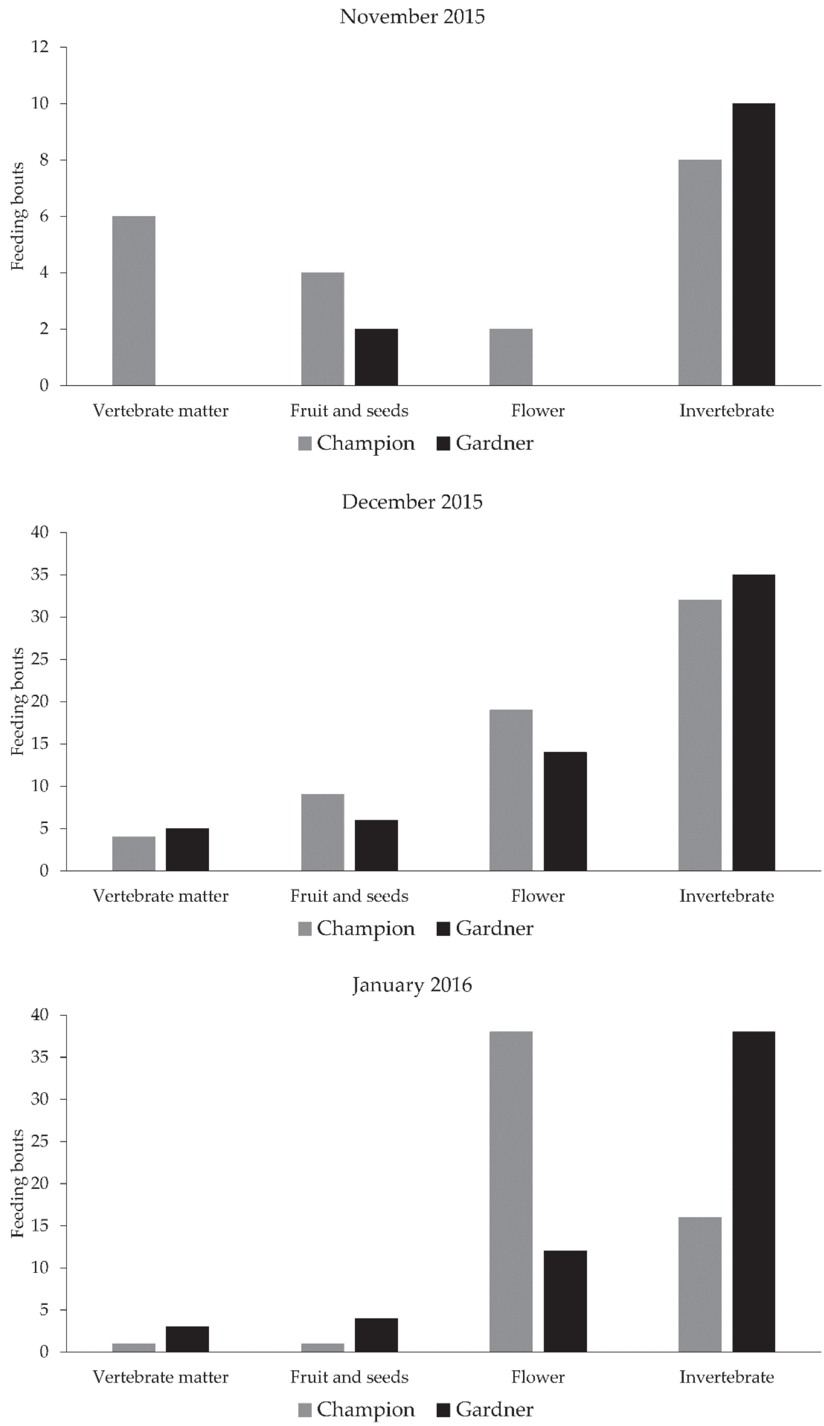

Figure 1. Monthly changes in proportion of food types in Floreana mockingbirds on Champion and Gardner-by-Floreana ("Gardner").

Figure 2. Floreana mockingbird (*Mimus trifasciatus*) drinking the contents of a Nazca booby (*Sula granti*) egg on Gardner-by-Floreana. Photograph: L. Ortiz-Catedral.

drinking of egg contents of Nazca boobies (*Sula granti*) and Galapagos dove (*Zenaida galapagoensis*) also represent new records on the diversity of foods consumed by the species, a trait shared with Española mockingbirds (Hatch 1965; Harris 1968). Harris (1968) suspected Floreana mockingbirds fed on eggs and nestlings of blue-footed boobies (*Sula nebouxii*), based on the disappearance of an egg and hatchling in a single nest on Gardner-by-Floreana, but did not directly observe mockingbirds. In fact, based on the description provided, we suspect that the predation of an egg and hatchling of blue-footed booby described in Harris (1968) more likely represents scavenging by Western Galapagos racers (*Pseudalsophis biserialis*), an endemic terrestrial snake (see Ortiz-Catedral *et al*. 2017; Ortiz-Catedral *et al*. 2019). Similarly, Bowman & Carter (1971) suspected that the ingestion of bird eggs was a trait shared by all mockingbird species in the Galapagos islands. They observed Floreana mockingbirds pecking at blue-footed booby (*Sula nebouxii*) eggs without breaking them, and in controlled experiments they induced starvation on Floreana mockingbirds and offered them broken chicken eggs, which the mockingbirds consumed (Bowman & Carter 1971). Therefore, our observations of consumption of egg contents of Nazca booby (Fig. 2) and Galapagos dove represent the first confirmed record in the wild of ingestion of this resource by Floreana mockingbirds.

The Galapagos Islands have suffered large-scale habitat modification prompted by the settlement of humans on the islands in the last 200 or so years (Watson *et al*. 2009), and the introduction of invasive species (Mauchamp 1997; Wikelski *et al*. 2004; Tye 2006; Wiedenfeld *et al*. 2007). This in turn has been associated with reductions in population size, and local extinction of vertebrate species on human inhabited islands, like Floreana Island (Grant *et al*. 2005; Dvorak *et al*. 2017). Nevertheless, since the late 1960s there have been numerous efforts to control or eradicate introduced species from various islands across the archipelago (Cruz *et al*. 2009; Carrion *et al*. 2011), in an effort to restore populations of endemic species (Donlan *et al*. 2007) and more recently, to holistically restore island ecosystems and species' function via reintroductions of locally extinct taxa, such as the Floreana tortoise (*Chelonoidis nigra*) (Hunter *et al*. 2019). The Floreana mockingbird is one of the bird species identified for reintroduction to the lowlands of Floreana Island in coming years (Charles Darwin Foundation 2008; Hoeck *et al*. 2010b; Bozzuto *et al*. 2017).

At this stage however, there is uncertainty about how long after the eradication of introduced species, the lowlands of Floreana will be suitable for reintroducing Floreana mockingbirds. Examples on other systems show that habitat enhancement, for instance via supplementary feeding and targeted restoration of food resources can assist in the reintroduction of critically endangered species (Maggs *et al*. 2019). Our study provides information on the diversity and temporal changes in diet composition of the remnant populations of this endangered species prior to the wet season, and can therefore be used to identify species to monitor on Floreana Island as groundwork for the eventual reintroduction of this endemic species to its namesake island. Future studies should aim to characterise the diet of the species immediately after the breeding season and explore the relationships between group size and territory quality.

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Vagrant and extra-limital bird records accepted by the Birds New Zealand Records Appraisal Committee 2019–2020

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Abstract: We report Records Appraisal Committee (RAC) decisions regarding Unusual Bird Reports received between 1 January 2019 and 31 December 2020. Among the 149 submissions accepted by the RAC were the first New Zealand records of collared petrel (*Pterodroma brevipes*), South Polar skua (*Catharacta maccormicki*), and rose-crowned fruit dove (*Ptilinopus regina*). We also report the first accepted breeding record for gull-billed tern (*Gelochelidon nilotica*), and the second accepted sightings of Australian white-faced storm petrel (*Pelagodroma marina dulciae*) and buff-breasted sandpiper (*Tryngites subruficollis*). Other notable records included the first records of Atlantic yellow-nosed mollymawk (*Thalassarche chlororhynchos*) from the Snares Islands, nankeen kestrel (*Falco cenchroides*) from Antipodes Island, long-tailed skua (*Stercorarius longicaudus*) from the Chatham Islands, and Arctic tern (*Sterna paradisaea*) from the Bounty Islands.

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INTRODUCTION

Birds New Zealand (Birds NZ) requires sightings of vagrant or extra-limital bird species, or species otherwise considered to be extinct, to be verified by the Records Appraisal Committee (RAC) before the records can be presented as accepted New Zealand records in the periodicals *Notornis* or *New Zealand Birds*, or in books and websites published by Birds NZ.

We here report RAC decisions made on Unusual Bird Reports (UBRs) received between 1 January 2019 and 31 December 2020, following on from the last report of the RAC (Miskelly *et al.* 2019).

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Results of RAC decisions are posted on the Unusual Bird Report website (http://rare.birds.org.nz/) every 2 months. The website provides a means for observers to determine whether a UBR has already been submitted for any vagrant bird seen or reported, and (within 2–4 months) to see the RAC decision on the UBR. This biennial report provides more detail about sightings than what is presented on the website, including providing context for the significance of each sighting.

Each Unusual Bird Report received is given a number whereby the first four digits represent the year the record was received and the last three digits the chronological sequence of receipt within that year. These reference numbers are given for each record below. Nomenclature and taxonomic sequence follow Gill *et al*. (2010), apart from where we follow Heidrech *et al*. (1998) in placing large shearwaters in the genus *Ardenna*. Where images of birds reported here have been published on New Zealand Birds Online (NZBO, www.nzbirdsonline.org.nz, viewed 5 May 2021) this is mentioned in the text.

We discuss the context of each accepted record in relation to the history of each species' occurrence in New Zealand. The RAC convenor maintains a database of verified sightings of vagrant birds in New Zealand. Information from this database is presented below (sourced as "CMM, *unpubl. data*") if it conflicts with or augments information from published sources.

DECISIONS ON SUBMITTED SIGHTINGS

Accepted records of vagrant and rare migrant species to New Zealand

Plumed whistling duck (*Dendrocygna eytoni*)
One at Anderson Park, Taradale, Napier, on 11 Feb 2020 (Jim Cowan; UBR 2020/020) was the last survivor of three that arrived at the park in 2011 (Miskelly *et al.* 2013).

Chestnut-breasted shelduck (*Tadorna tadornoides*)
One to nine birds at Tip Lagoon, Invercargill, between 8 Oct (3 birds) and 28 Nov 2018 (2 birds), with the highest count on 31 Oct (Sean Jacques; UBR 2019/057). Two females at Miranda, Firth of Thames, on 8 Jan 2019 (Lisa Fraser; UBR 2020/109), with one female there on 18 Jan 2019 (Matthias Dehling; UBR 2020/035). A pair at Ringaringa Golf Course, Stewart Island, on 5 Dec 2020 (Matt Jones; UBR 2020/106). Chestnut-breasted shelducks were also recorded at Miranda and Invercargill (but no other sites) during 2017–18 (Miskelly *et al.* 2019). There are about 38 accepted records in New Zealand since 1973 (Heather 1987; CMM, *unpubl. data*).

Chestnut teal (*Anas castanea*)
A male in eclipse plumage at Tip Lagoon, Invercargill, 19–21 Oct 2018 (Sean Jacques; UBR 2019/056) was the 19th accepted New Zealand record, and the 1st since 2010 (Miskelly *et al.* 2011).

Northern shoveler (*Anas clypeata*)
The most frequently reported unusual bird species during 2019–20. All records were of males in full or partial breeding plumage. One at Tip Lagoon, Invercargill 21 Oct to 3 Nov 2018 (Sean Jacques; UBR 2019/058); one at Bromley Oxidation Ponds on 26 Apr 2019 (Adam Colley; UBR 2019/033, image on NZBO); one at Pegasus wetland, North Canterbury, on 4 May 2019 (Bev Alexander; UBR 2019/037), and again 27 May to 28 Aug 2020 (Eleanor Gunby, Richard Scofield, Christian Cosgrove, and Jean Williams; UBRs 2020/069, 2020/108 & 2020/084, image on NZBO). One at Kaitorete Spit, Lake Ellesmere 16 Jun 2019 (Dale McEntee; UBR 2019/049); one at Te Aroha, Waikato, on 19 Aug 2019 (Russell Cannings; UBR 2019/069); one at Otaki sewage pond on 16 & 17 Sep 2019 (Hugh Robertson; UBR 2019/071); one at Lake Elterwater, Marlborough, on 29 Sep 2019 (Paul Gibson; UBR 2019/077, images on NZBO); one at Waituna Lagoon, Southland, on 16 Nov 2019 (Sean Jacques; UBR 2019/091); and one at Lake Rotomahana inlet, Waimangu Valley, Rotorua, on 19 Jul 2020 (Troy Makan; UBR 2020/068).

There had been only nine accepted records of northern shovelers from New Zealand before 2017 (Miskelly *et al*. 2019). Multiple individual birds were sighted from October 2017, with at least five different birds present in June 2018 (Miskelly *et al*. 2019).

Hoary-headed grebe (*Poliocephalus poliocephalus*)
A pair with three fully-grown young at Lake Elterwater, Marlborough, on 13 Jul 2019 (Maria Clement; UBR 2019/062, images on NZBO). One or two pairs bred at this site in 2017-18, following several sightings at Lake Elterwater since 2014 (Miskelly *et al*. 2019).

Western rockhopper penguin (*Eudyptes chrysocome*)
One at Victory Beach, Otago Peninsula, on 9 Feb 2019 (Trudi Webster; UBR 2019/034, Fig. 1 and image on NZBO) was the first mainland record of this species. Western rockhopper penguins breed at the Falkland Islands and southern Chile. Within New Zealand they had previously been recorded solely from the Snares Islands, between 1985 and 2000 (Tennyson & Miskelly 1989; Miskelly *et al*. 2001).

Figure 1. Newly-moulted immature western rockhopper penguin (*Eudyptes chrysocome*), Victory Beach, Otago Peninsula, 9 February 2019. First mainland record (image by Trudi Webster).

Macaroni penguin (*Eudyptes chrysolophus*)
One moulting at Boat Harbour, Snares Islands, on 6 Mar 2019 (Paul Sagar; UBR 2019/026) was the 5th reported from the Snares Islands (Miskelly *et al*. 2001, 2017). The only other New Zealand records are from Campbell Island (Kinsky 1969; Miskelly *et al*. 2013).

Royal penguin (*Eudyptes schlegeli*)
One at Te Whanga Lagoon mouth, Chatham Island, on 14 Feb 2020 (Keri Moir; UBR 2020/033) was the 4th record from the Chatham Islands (Miskelly *et al*. 2006; CMM, *unpubl. data*). One on Whenua Hou/ Codfish Island on 6 Mar 2020 (Sarah Little; UBR 2020/028) was the first record from the Stewart Island region. There have been at least 11 records from the South Island (Miskelly *et al*. 2019), and two from the southern North Island (specimens from Lyall Bay, 10 Jun 1926, and Tora, Wairarapa, 13 Feb 2013, held by Te Papa).

Atlantic yellow-nosed mollymawk (*Thalassarche chlororhynchos*)
One photographed offshore from the Snares Islands on 15 Nov 2019 (John Martin; UBR 2020/011) was the fifth record from New Zealand, and the first away from the Chatham Islands or Kaikoura (Miskelly *et al*. 2017)

Juan Fernandez petrel (*Pterodroma externa*)
One north-west of Mana Island, Cook Strait, on 24 Mar 2019 (Colin Miskelly; UBR 2019/025) was the fourth record away from the Chatham Islands (Miskelly *et al*. 2015).

Collared petrel (*Pterodroma brevipes*)
One near King Bank, north-east of Three Kings Islands, on 4 Mar 2011 (Brent Stephenson; UBR 2019/032, Fig. 2 and images on NZBO). One 150 km north-west of Three Kings Islands, and another 200 km north-west, on 17 Mar 2019 (Ian Saville; UBRs 2019/065 & 2019/066). Collared petrels breed on a few islands in the tropical south-west Pacific, including islands in Vanuatu and Fiji (Tennyson *et al*. 2012; O'Brien *et al*. 2016). The sightings reported here are the first, second, and third records of collared petrel from New Zealand.

Figure 2. Collared petrel (*Pterodroma brevipes*) north-east of Three Kings Islands, 4 March 2011. First New Zealand record (image by Brent Stephenson, Eco-Vista).

Pink-footed shearwater (*Ardenna creatopus*)
One off Kaikoura on 6 Dec 2001 (Alan Tennyson; UBR 2019/048, images on NZBO), and another at Wreck Reef, east coast of Stewart Island, on 23 Nov 2018 (Matt Jones; UBR 2019/003) were the sixth and tenth records from New Zealand (Miskelly *et al*. 2019).

Great shearwater (*Ardenna gravis*)
One east of the Poor Knights Islands on 20 Apr 2011 (Mark Maddock; UBR 2020/053) was the seventh record from New Zealand, and was one of four sightings that month, with the three others all near Foveaux Strait (Miskelly *et al*. 2013).

Figure 3. Australian white-faced storm petrel (*Pelagodroma marina dulciae*) offshore from Kawhia, 2 April 2016. First live New Zealand record (image by Matthias Dehling).

Australian white-faced storm petrel (*Pelagodroma marina dulciae*)
One at sea off Kawhia on 2 Apr 2016 (Matthias Dehling; UBR 2020/036, Fig. 3 and image on NZBO) was the second New Zealand record, and the first record of a live bird of this subspecies (Imber 1984).

Red-footed booby (*Sula sula*)
A white morph bird found dead on Pakatoa Island on 15 May 2017 (Fiona Powell and Matt Rayner; UBR 2020/006) is now a skeleton in Auckland War Memorial Museum (LB15822). White tail feathers indicate that this bird was of the south-west Pacific subspecies *S. s. rubripes* (contra the previous record, which was of the eastern Pacific subspecies *S. s. websteri*; Miskelly *et al.* 2019). One (subspecies unknown) perched on a boat in the North Taranaki Bight on 10 May 2019 (Ian Brown; UBR 2019/036). These are the third and fourth accepted records from New Zealand (Miskelly *et al.* 2017, 2019).

Brown booby (*Sula leucogaster*)
An immature at Muriwai gannet colony, west Auckland, on 3 Aug 2019 (Harry Boorman; UBR 2019/059). Brown boobies probably reach mainland New Zealand every year, with most records from the northern North Island (Gill *et al*. 2010; Miskelly *et al.* 2019).

Frigatebird sp. (*Fregata* sp.)
A frigatebird of uncertain specific identity was seen at Masterton on 9 Aug 1949 (Bob Stidolph via Nikki McArthur; UBR 2020/062).

Little egret (*Egretta garzetta*)
One at Rough Island, Tasman, 15 Jan to 7 May 2003 (UBR 2020/082) and 8 Feb to 5 Jul 2004 (UBR 2020/083; both records by Peter and Charmaine Field), and again on 21 Jun 2020 (Peter Field; UBR 2020/064). One at Okari Estuary, south of Westport, on 6 Oct 2015 (UBR 2020/081) and on 17 Jul 2016 (UBR 2020/080; both records by Peter and Charmaine Field); one at Cobden, Greymouth 22 Jun 2019 (Annette Ching; UBR 2019/055); one at Ashley River mouth, North Canterbury, on 17 Nov 2019 (Bev Alexander; UBR 2020/061); two at Pahurehure Inlet, Manukau Harbour, on 21 May 2020 (Jampa Kalden; UBR 2020/052); one at Manawatu River estuary on 7 Jun 2020 (Alan Tennyson; UBR 2020/059). Up to five little egrets are present in New Zealand most years (Miskelly *et al.* 2019).

Glossy ibis (*Plegadis falcinellus*)
One between Manapouri and Te Anau on 20 Apr 2017 (Robert Leslie; UBR 2020/085) was a rare inland record of this colonising species, which has been breeding in New Zealand since 2015 (Thompson 2015; Anonymous 2016; Miskelly *et al*. 2019).

Black kite (*Milvus migrans*)
One near Patetonga, Hauraki Plains, on 12 Feb 2020 (Russell Cannings; UBR 2020/027) may have been the same bird that was present north of Meremere (about 35 km away) for more than a year from 2016 (Hyde *et al.* 2017).

Nankeen kestrel (*Falco cenchroides*)
Two on Antipodes Island, 2 Feb 2013 (Kath Walker and Graeme Elliott; UBR 2019/043) were the first recorded from the island, and the second record from a New Zealand subantarctic island following one on Campbell Island in 1942 (Miskelly *et al.* 2019). One at Peria, Northland, on 24 May 2019 (Kerrie Edmonds; UBR 2019/045). The nankeen kestrel is an infrequent straggler to mainland New Zealand (Gill *et al*. 2010).

Great knot (*Calidris tenuirostris*)
One at Farewell Spit on 6 Jul 2019 (Steve Wood; UBR 2019/053); one at Karaka shellbanks, Manukau Harbour 23 Jan 2020 (Oscar Thomas; UBR 2020/015). There are about 20 previous accepted records from New Zealand (Miskelly *et al*. 2017).

Sanderling (*Calidris alba*)
One at Awarua Bay, Southland, 17 Nov 2018 & 17 Feb 2019 (UBR 2019/046) and again on 29 Dec 2019 (UBR 2020/009; all records by Sean Jacques). One at Ashley River estuary, North Canterbury, on 10 & 16 Nov 2020 (Christian Cosgrove and Adam Colley; UBR 2020/100). One or two sanderlings reach New Zealand most years (Saunders 2015; Miskelly *et al.* 2019).

Little stint (*Calidris minuta*)
One at Karaka, Manukau Harbour, on 15 Sep 2019 (Tony Habraken and David Lawrie; UBR 2019/070, images on NZBO) was the fourth record from New Zealand, and the first away from Lake Ellesmere, Canterbury (Miskelly *et al.* 2011). Another was seen at Lake Ellesmere from 14 Oct to 25 Nov 2019 (Nick Allen; UBR 2020/079, images on NZBO).

Broad-billed sandpiper (*Limicola falcinellus*)
One at Miranda, Firth of Thames, on 20 Nov 1994 (Nicholas Allen; UBR 2020/038), and another at the same site on 22 Jan 2019 (David Melville; UBR 2019/010). There have been eight accepted records from Miranda, which is about a third of the New Zealand records (CMM, *unpubl. data*).

Buff-breasted sandpiper (*Tryngites subruficollis*)
One at Ashley River estuary, North Canterbury, on 19 Nov 2019 (Kelly and Jamee Johnson; UBR 2019/090, images on NZBO) was likely the same bird that was subsequently found at Kaitorete Spit, Lake Ellesmere, on 22 Dec 2019 (Adam Colley and David Thomas; UBR 2020/026, images on NZBO). There is one previous record from New Zealand (Miskelly *et al.* 2015).

Whimbrel (*Numenius phaeopus*)
One at Hikurangi Channel, Te Whanga Lagoon, Chatham Island, on 24 Oct 2020 (Mike Bell; UBR 2020/104) was the seventh accepted record from the Chatham Islands (Miskelly *et al.* 2006, 2017).

Wandering tattler (*Tringa incana*)
Two at Waitangi West, Chatham Island, on 29 Aug 2018 (Kailash Willis; UBR 2019/042), and one at Cape Pattisson, Chatham Island, on 13 Oct 2020 (Mike Bell; UBR 2020/105). There are seven previous accepted records from the Chatham Islands (Miskelly *et al.* 2006).

Common sandpiper (*Tringa hypoleucos*)
One at Waipu Cove, North Auckland, on 24 Dec 2019 (Ayla Wiles; UBR 2020/014). There are 38 previous accepted records from New Zealand (Miskelly *et al.* 2015).

Common greenshank (*Tringa nebularia*)
One at Okawa Point, Chatham Island, on 30 Oct 2020 (Mike Bell; UBR 2020/103) was the second record from the Chatham Islands (Sibson 1978). One at Kaitorete Spit, Lake Ellesmere, on 29 Nov 2020 (Andrew Crossland; UBR 2020/107). Formerly a regular vagrant to New Zealand, greenshanks have been reported at a rate of less than one per annum since 2000 (Miskelly *et al.* 2015).

Grey phalarope (*Phalaropus fulicaria*)
One in breeding plumage off Kaikoura on 17 July 2019 (Richard Crossley; UBR 2019/054, images on NZBO) was the 12th accepted record from New Zealand (Miskelly *et al.* 2013).

Red-necked phalarope (*Phalaropus lobatus*)
One at Nelson sewage ponds on 16 May 2018 (Matthias Dehling; UBR 2020/034) was the 15th accepted record from New Zealand (Miskelly *et al.* 2011).

Grey plover (*Pluvialis squatarola*)
One at Whanganui River estuary on 22 Oct 2019 (Paul Gibson; UBR 2019/083, images on NZBO). Single grey plovers were reported annually from 2001 to 2005; this is the fourth record since then (Miskelly *et al.* 2019).

Lesser sand plover (*Charadrius mongolus*)
One at Farewell Spit on 23 Feb 2019 (Steve Wood; UBR 2019/023); one at Miranda, Firth of Thames, on 16 Jan 2020 (Oscar Thomas; UBR 2020/016). Previously considered an annual visitor to New Zealand, these are only the second and third records since 2010 (Gill *et al.* 2010; Miskelly *et al.* 2015).

Greater sand plover (*Charadrius leschenaultii*)
One at Ashley River estuary, North Canterbury, on 14 Oct 2019 (Jill Hanna; UBR 2020/001) and again on 19 Sep 2020 (Bev Alexander; UBR 2020/087, images on NZBO). Considered an annual visitor to New Zealand before 2010, these are only the third and fourth records since then (Gill *et al.* 2010; Miskelly *et al.* 2017).

South Polar skua (*Catharacta maccormicki*)
One collected at Laurie Harbour, Auckland Island, on 28 Mar 1904, was the first record of this species from New Zealand, predating the next two records by 36 years (UBR 2019/052; Falla 1940; Miskelly 2020a).

Long-tailed skua (*Stercorarius longicaudus*)
One south of Pyramid Rock, Chatham Islands, on 12 Dec 2009 (Peter Zika; UBR 2020/057) was the first record from the Chatham Islands. Long-tailed skuas are scarce annual migrants to New Zealand (Miskelly *et al.* 2019).

Laughing gull (*Leucophaeus atricilla*)
An adult in breeding plumage at Wairoa River, Wairoa, on 26 Jan 2018 (Graham Fyfe; UBR 2020/067), and at Cape Kidnappers on 18 Oct 2018 (Colin Lindsay; UBR 2020/086). These birds were likely the same individual that was present near Opotiki in December 2017 and also the previous summer (i.e. New Zealand's first laughing gull; Miskelly *et al.* 2017, 2019).

Little tern (*Sternula albifrons*)
One at Motutapu Point, Pitt Island, Chatham Islands, on 3 Nov 2020 (Mike Bell; UBR 2020/102) was the second record from the Chatham Islands (Bell & Bell 2002).

Gull-billed tern (*Gelochelidon nilotica*)
A pair attending a nest with three eggs at Awarua Bay, Southland, on 21 Dec 2019 was the first recorded breeding of this species in New Zealand (Glenda Rees; UBR 2019/094, Fig. 4 and images on NZBO).

A major influx of gull-billed terns began in 2011 (Miskelly *et al.* 2013), and a few birds continue to be reported. Up to five birds were present at Manawatu River mouth on 4 Jul (1), 9 Oct (4) & 29 Dec (5) 2011 (Alan Tennyson; UBR 2020/112), with one bird there on 2 Jun 2020 (Imogen Warren; UBR 2020/055). Two at Lake Ellesmere, Canterbury, on 1 Feb 2019 (Andrew Crossland; UBR 2019/014). One at Bell Island, Waimea Inlet, on 12 Feb 2019 (David Melville; UBR 2019/013) and on 19 Oct 2019 (Don Cooper; UBR 2019/082). One at Lake Wairarapa 20 Feb 2019 (Darren Lees and Diane John; UBR 2019/022). One at Motueka sandspit on 8 Apr 2020 (Steve Wood; UBR 2020/048) and 6 Jun 2020 (Fraser Gurney; UBR 2020/077).

Figure 4. Gull-billed tern (*Gelochelidon nilotica*) nest with 3 eggs, Awarua Bay, 21 December 2019. First New Zealand breeding record (image by Glenda Rees).

White-winged black tern (*Chlidonias leucopterus*)
An adult in breeding plumage northeast of Haast, West Coast, on 9 Jan 1985 (Ray and Deb Wershler; UBR 2019/008). One at Manawatu River estuary on 29 Dec 2012 (Alan Tennyson; UBR 2020/114, images on NZBO), and two at Ahuriri estuary, Napier, on 12 Apr 2019 (Lynne Anderson; UBR 2019/031). White-winged black terns are regularly present and not reportable in the eastern South Island (Miskelly *et al.* 2019).

Whiskered tern (*Chlidonias hybridus*)
One at Balclutha airfield, South Otago, on 31 Jan 2020 (Richard Schofield; UBR 2020/017) was the 12th accepted record from New Zealand (Miskelly *et al.* 2019).

Arctic tern (*Sterna paradisaea*)
One at Aramoana Mole, Otago, on 25 Dec 2014 (Derek Onley; UBR 2019/029). At least two at the Bounty Islands, in late Oct 2019 (Alan Tennyson; UBR 2020/029, image on NZBO) were the first record from this subantarctic island group.

Common tern (*Sterna hirundo*)
One at Waikanae River estuary on 20 Jan 2011 (UBR 2020/116, image on NZBO), with another there on 29 Dec 2015 (UBR 2020/115; both records Alan Tennyson). One at Manawatu River estuary on 29 Dec 2011 (Alan Tennyson; UBR 2020/113), 22 Jan 2019 (Imogen Warren; UBR 2019/006), 3 Jan 2020 (Alan Tennyson; UBR 2020/008, image on NZBO) 22 Mar 2020 (Imogen Warren; UBR 2020/031), and 19 & 22 Dec 2020 (Imogen Warren and Alan Tennyson; UBR 2020/111). One at Lake Ellesmere outlet, Canterbury, on 6 Feb 2019 (Andrew Crossland; UBR 2019/016); one at Ashley River mouth, north Canterbury, on 11 Feb 2020 (Adam Colley; UBR 2020/025). One in breeding plumage at Big Sand Island, Kaipara Harbour, on 6 Jun 2020 (Phil Hammond; UBR 2020/099).

There are about 53 accepted records of common terns from New Zealand, with nearly half of these being from the Manawatu estuary/Foxton Beach or from Waikanae, 49 km to the south (CMM, *unpubl. data*).

Crested tern (*Sterna bergii*)
One at Whanganui River estuary on 22 Oct 2019 (Lynne Douglas and Peter Frost; UBR 2019/084) was the 17th accepted record from New Zealand (Miskelly *et al.* 2017).

Rose-crowned fruit-dove (*Ptilinopus regina*)
One found alive on a vessel moored in South

Taranaki Bight on 23 Aug 2019 (and subsequently killed as a perceived biosecurity risk) was the first record of this species from New Zealand (UBR 2019/095; Miskelly 2020b).

Pallid cuckoo (*Cuculus pallidus*)
A juvenile near Bainham, Golden Bay, on 11 Dec 2019 (Steve Wood; UBR 2020/002, images on NZBO) was the seventh accepted record from New Zealand (Scofield 2008).

Barn owl (*Tyto alba*)
Footage of one at Milson, Palmerston North, on 8 Apr 2020 was captured on a security camera (Trevor Anderson; UBR 2020/041). Despite having an established breeding population in the Far North (Hyde & Matthews 2017), and many sightings being reported elsewhere in the country, this is the first sighting accepted by the RAC since 2008.

White-throated needletail (*Hirundapus caudacutus*)
One south of Punakaiki, West Coast, on 11 Nov 1977 (Derek Onley; UBR 2019/041); one at Tawhiti Rahi, Poor Knights Islands, on 5 Dec 2019 (Edin Whitehead; UBR 2019/092); one at Farewell Spit 14 Dec 2019 (Steve Wood; UBR 2020/003); at least 80 at Upper Moutere during 13-20 Feb 2020 (Steve Wood; UBR 2020/049). White-throated needletails are frequent vagrants to New Zealand (Gill *et al.* 2010). The Upper Moutere sighting was one of the largest flocks reported in New Zealand. McCaskill (1943) reported "hundreds" near Greymouth on 2 Dec 1942, with "60 to 70 birds, or even more" reported by a different observer nearby on 5 Dec 1942. At least 60 were seen at Tautuku, South Otago, in February 1979 (Miller 1980).

Fork-tailed swift (*Apus pacificus*)
One at Halfmoon Bay, Stewart Island, on 5 Dec 2019 (Ian Saville; UBR 2019/093), with three seen at nearby Lee Bay on 25 Dec 2019 (Jack Bushong; UBR 2020/040). One at Orangihina Park, Te Atatu, Auckland, on 21 Mar 2020 (Ian McLean; UBR 2020/050); one at Deep Bay, Arapawa Island, Marlborough Sounds, on 20 Oct 2020 (Peter Reese; UBR 2020/089). There were 16 previous accepted New Zealand records, with the most recent on Antipodes Island in 2002 (Medway 2003; CMM, *unpubl. data*).

Black-faced cuckoo-shrike (*Coracina novaehollandiae*)
One at Waimarama, Waikato, on 8 Jul 2019 (David Walter; UBR 2019/086) was the 22nd accepted record from New Zealand (Miskelly *et al.* 2017).

Masked woodswallow (*Artamus personatus*)
An adult male at Waitawheta, Waihi, on 11 Nov 2019 (David Hartley; UBR 2019/087) was the third accepted record from New Zealand, and the first since 2006 (Te Papa specimen OR.028216 from Otatara, Southland, 16 Oct 2006).

Australian tree martin (*Petrochelidon nigricans*)
One at Punakaiki River estuary, West Coast, on 5 Jun 1977 (Derek Onley; UBR2019/039); one at Farewell Spit on 14 Dec 2019 (Steve Wood; UBR 2020/004); one at Lake Ellesmere, Canterbury, on 17 Feb 2020 (Ian Saville; UBR 2020/023); one at Wainono Lake Road, South Canterbury, on 25 Oct 2020 (Fraser Gurney; UBR 2020/094). There are more than 50 accepted records from New Zealand (Miskelly *et al.* 2019).

Accepted extra-limital records of New Zealand breeding species

Cape Barren goose (*Cereopsis novaehollandiae*)
One at Te Marua Lakes, Upper Hutt, on 24 Oct 2020 (Sue Wild; UBR 2020/090), and one at Waiwhakaiho River mouth, New Plymouth, on 2 Nov 2020 (Jean Caulton; UBR 2020/097). Cape Barren geese are widely held by wildfowl enthusiasts (Frost 2013), and are no longer reportable from the main islands.

Canada goose (*Branta canadensis*)
One at Boat Harbour, Snares Islands, on 14 Jan 2020 (Keith Springer; UBR 2020/010) was the third record from the Snares Islands (Miskelly 2001; CMM, *unpubl. data*).

New Zealand dabchick (*Poliocephalus rufopectus*)
A pair with two large chicks at Lake Killarney, Takaka, on 21 Dec 2018 (Ken George; UBR 2019/002); one at Nelson oxidation ponds 1 on 7 Jun 2019 (Maria Clement; UBR 2019/064), with four there on 30 May 2020 (Peter and Charmaine Field; UBR 2020/054); one at Lake Elterwater, Marlborough, on 13 Jul 2019 (Maria Clement; UBR 2019/063); one (possibly two) at Pegasus Wetlands, North Canterbury, on 6 May 2020 (Bev Alexander; UBR 2020/051); one at Appleby Hills dam, Ridgeview Rd, Tasman, on 12, 14 & 27 Jun 2020 (Peter and Charmaine Field; UBR 2020/065); one at St Annes Lagoon, Cheviot, on 11 Oct 2020 (Nick Allen; UBR 2020/093).

New Zealand dabchicks are widespread in the North Island and have a small recently established population in the Nelson and Marlborough regions (Miskelly *et al.* 2019, and sightings reported above). They are no longer reportable in Marlborough, Nelson, and Golden Bay.

Australasian little grebe (*Tachybaptus novaehollandiae*)
One at Hands Road, Charleston, West Coast, on 20 May 1979 (Derek Onley; UBR 2019/040); one at Lake Mangamahoe, Taranaki, on 31 Dec 2018 (Tony Green; UBR 2019/030) and 22 May 2019 (Simon Nicholas; UBR 2019/038); one at Millwater, Auckland, on 1 Jul 2019 (Patricia Burgess; UBR 2019/051), one at Haldon boat harbour, Lake Benmore, Canterbury, on 29 Sep 2020 (Nick Allen; UBR 2020/091). This rare breeding species is resident in Northland and North Auckland; however, it is rarely reported south of Auckland city (Beauchamp 2019; Miskelly *et al.* 2019).

Fiordland crested penguin (*Eudyptes pachyrhynchus*)
One at Gore Bay, North Canterbury, on 10 Jan 2020 (Anita Spencer; UBR 2020/013).

Erect-crested penguin (*Eudyptes sclateri*)
One on Rangatira Island, Chatham Islands, on 26 Jan 2019 (Bridget Makan; UBR 2019/020). One on Mangere Island, Chatham Islands on 7 & 16 Feb 2019 (Bridget Makan; UBR 2019/021, Hamish Spencer, UBR 2019/019 respectively). One at Timaru port breakwater on 19 Feb 2020 (David Pease; UBR 2020/045). Erect-crested penguins breed on the Bounty and Antipodes Islands, with at least one bird reported moulting on the east coast of the South Island and on the Chatham Islands during January–March most years (Miskelly *et al.* 2019).

Yellow-eyed penguin (*Megadyptes antipodes*)
One at Kaikoura Peninsula 5 Nov 2017 (Nicholas Allen; UBR 2020/037), and again on 19 Feb 2020 (Roger McLean; UBR 2020/024) were north of their usual range (Marchant & Higgins 1990).

Australasian gannet (*Morus serrator*)
One at Flowerpot Bay, Pitt Island, Chatham Islands, 16 Feb 2019 (UBR 2019/017). Possibly the same bird was seen at Waitangi Bay, Chatham Island, on 17 Feb 2019 (UBR 2019/018; both records by Hamish Spencer). There are at least 14 previous records from the Chatham Islands (Miskelly *et al.* 2006).

Stewart Island shag (*Leucocarbo chalconotus*)
Four records from Ashburton River mouth, South Canterbury: 26 Mar 2019 (1 bird; UBR 2019/027), 25 Mar 2020 (1 bird; UBR 2020/072), 21 Jul 2020 (4 birds; UBR 2020/071), and 17 Jun 2020 (1 bird; UBR 2020/073). Two records from Timaru Harbour on 21 Apr 2019 (1 bird; UBR 2020/070) and 8 Aug 2019 (3 birds; UBR 2020/075). One at Damon's Bay, Banks Peninsula, on 29 Oct 2020 (UBR 2020/095). See Crossland (2021) for further detail. Stewart Island shags are no longer reportable south of Banks Peninsula on the South Island.

Banded rail (*Gallirallus philippensis*)
Three at Pauatahanui Wildlife Reserve, Porirua, Wellington, on 7 Jan 2019 (Imogen Warren; UBR 2019/001). There were two records of single birds at this site in 2018 (Miskelly *et al.* 2019).

Marsh crake (*Porzana pusilla*)
One north of Waikato Stream, Te Whanga Lagoon, Chatham Island, on 22 Sep 2019 (Peter de Lange; UBR 2019/073) was the 3rd record from the Chatham Islands (Miskelly *et al.* 2006).

Black-fronted dotterel (*Elseyornis melanops*)
An adult at Horseshoe Beach, Stewart Island, on 14 Oct 2019 (Matt Jones; UBR 2019/080) was the first record from Stewart Island.

Subantarctic skua (*Catharacta antarctica*)
One off Foxton Beach, Manawatu, on 12 Jun 2020 (Imogen Warren; UBR 2020/063). Within the New Zealand region, subantarctic skuas breed on the Chatham Islands and the subantarctic islands, with a few in Fiordland and the Stewart Island region (Higgins & Davies 1996).

Black noddy (*Anous minutus*)
One at Milford Beach, Auckland, on 6 Jan 2020 (Brian Kuan; UBR 2020/012); one at sea, between the Cavalli Islands and Mahinapua, on 12 Jun 2020 (John Rowe; UBR 2020/066). Within the New Zealand region, black noddies breed only on the Kermadec Islands (Veitch *et al*. 2004). There are five previous accepted records from the mainland (CMM, *unpubl. data*).

White tern (*Gygis alba*)
Two found dead on the Otaki coast, Horowhenua, on 11 Jun 2019 (Hugh Robertson; UBR 2019/072); one found dead on the Mangamuka Hut track Kaimai Range, western Bay of Plenty, on 21 May 2020 (John Heaphy; UBR 2020/058). There are about 15 previous New Zealand records away from the Kermadec Islands (Miskelly *et al.* 2017).

Sooty tern (*Onychoprion fuscata*)
One at Rangaunu Harbour, Far North, on 13 Nov 2020 (Phil Hammond; UBR 2020/098). One taken

into care at Onetangi Beach, Waiheke Island, on 26 Nov 2020 (Karen Saunders and Jemma McLean; UBR 2020/101) subsequently died and is now a study skin in Auckland War Memorial Museum (LB15823). Within the New Zealand region, sooty terns breed only on the Kermadec Islands, with at least 12 previous records from elsewhere in the region (Veitch *et al*. 2004; CMM, *unpubl*. *data*).

Fairy tern (*Sternula nereis davisae*)
A colour-banded (1st-year female) at Manawatu River estuary on 19 Dec 2020 (Imogen Warren; UBR 2020/110) was 488 km south of its banding site at Mangawhai, Northland.

Barbary dove (*Streptopelia risoria*)
Three at Bottle Lake Forest, North Canterbury, on 18 Sep 2020 (Christian Cosgrove; UBR 2020/096). Barbary doves are no longer reportable on the North and South Islands.

Red-crowned parakeet (*Cyanoramphus novaezelandiae*)
One at Waiatarua, West Auckland, on 26 May 2020 (Willem van Straten; UBR 2020/056).

Fernbird (*Bowdleria punctata*)
A pair at Lake Wainono, South Canterbury, on 28 Sep 2020 (Nick Allen; UBR 2020/092) was the first record from Canterbury since c.1905 (Holdaway & Worthy 2008).

Records not accepted, or held in suspense
Some of the following records may have been genuine, but were insufficiently documented to be accepted by the Records Appraisal Committee. At least 15 were considered to be misidentifications.

Tasmanian (shy) mollymawk (*Thalassarche cauta cauta*)
Single birds photographed off Kaikoura on 20 Mar 2019 (UBR 2019/028) and west of Codfish Island on 11 Mar 2020 (UBR 2020/030) were probably this subspecies. However, the variation in bill colour of white-capped mollymawks (*T. c. steadi*) reported by Tennyson (2020) at their main breeding colony on Disappointment Island, Auckland Islands, has cast doubt on whether these two subspecies can be reliably distinguished at sea.

Great-winged petrel (*Pterodroma macroptera macroptera*)
Two reported off Otago Peninsula on 29 Jun 2017 (UBR 2020/088).

Chatham Island taiko (*Pterodroma magentae*)
Four reported at sea out from Otago Harbour, on 4 Mar 1997 (UBR 2019/012) were considered more likely to have been distant Hutton's shearwaters (*Puffinus huttoni*).

Fiji petrel (*Pseudobulweria macgillivrayi*)
One reported north of the Three Kings Islands on 17 Mar 2019 (UBR 2019/067).

Pink-footed shearwater (*Ardenna creatopus*)
One reported in Cook Strait on 30 Apr 2019 (UBR 2019/035).

Darter (*Anhinga melanogaster*)
One reported from Mangere, Auckland, on 2 Jan 2019 (UBR 2019/004) was likely to have been a misidentified shag.

Pacific heron (*Ardea pacifica*)
Six reported at Takaka River estuary on 6 Oct 1946 (UBR 2020/047).

Reef heron (*Egretta sacra*)
One reported from Rangatira Island, Chatham Islands, on 16 Feb 2020 (UBR 2020/022) may be a hybrid between a reef heron and a white-faced heron (*E. novaehollandiae*) (see Thomas 2020). This is likely the same individual considered to have been a juvenile white-faced heron by Miskelly *et al*. (2017).

Heron sp.
A 'black heron', photographed distantly at Waimauku, North Auckland, on 31 Aug 2019 (UBR 2019/068), was most likely a black shag (*Phalacrocorax carbo*).

White ibis (*Threskiornis molucca*)
One reported at Lake Elterwater, Marlborough, on 7 Dec 2019 (UBR2020/005), was considered more likely to have been a juvenile royal spoonbill (*Platalea regia*).

Yellow-billed spoonbill (*Platalea flavipes*)
Reports of eight, Opunake, Taranaki, on 20 Nov 2019 (UBR 2019/089), two at Lost Lagoon, Westport, on 22 Apr 2020 (UBR 2020/042), and one at Ashwick Flat, Fairlie, 3 Aug 2020 (UBR 2020/074), are all likely to have been of royal spoonbills.

White-bellied sea eagle (*Haliaeetus leucogaster*)
One reported to have been photographed in flight

near Miranda on 5 Nov 2017 (UBR 2020/044) was identified from the image as a spur-winged plover (*Vanellus miles*).

Black kite (*Milvus migrans*)
One reported near Kaikoura, on 22 Dec 2019 (UBR 2020/007).

Nankeen kestrel (*Falco cenchroides*)
One reported near the Hibiscus Coast Highway, Auckland, in summer 2001 (UBR 2019/047).

Common greenshank (*Tringa nebularia*)
One reported at Yarrs Bay, Lake Ellesmere, Canterbury, on 30 Dec 2019 (UBR 2020/019).

Lesser sand plover (*Charadrius mongolus*)
One reported at Manawatu River estuary on 22 Jan 2019 (UBR2019/007).

Subantarctic skua (*Catharacta antarctica*)
A large skua reported off Kaikoura Peninsula on 26 Sep 2016 (UBR 2019/081) was probably a subantarctic skua.

Fairy tern (*Sternula nereis davisae*)
Three reported from Porirua Harbour, Wellington, on 6 Jan 2019, were identified from a photograph as white-fronted terns (*Sterna striata*) (UBR 2019/015).

Gull-billed tern (*Gelochelidon nilotica*)
One photographed distantly at Harmers Beach, Kaikoura, on 2 Oct 2019 (UBR 2019/079) was likely to have been a Caspian tern (*Hydroprogne caspia*).

White-winged black tern (*Chlidonias leucopterus*)
One reported from Onoke Spit, south Wairarapa, on 6 Feb 2019 (UBR 2019/011) was identified from a photograph as a juvenile black-fronted tern (*C. albostriatus*).

Common tern (*Sterna hirundo*)
One reported at Halfmoon Bay, Stewart Island, 23 Jan 2019 (UBR 2019/024), was probably a 1st-year white-fronted tern (*Sterna striata*). One reported at Ashley River estuary, North Canterbury, on 7 Mar 2020 (UBR 2020/039).

Kakariki (*Cyanoramphus* sp.)
Four reported at Puketi Forest, Northland, on 6 Aug 2020 (UBR 2020/078).

Fan-tailed cuckoo (*Cacomantis flabelliformis*)
One reported at Nikau Valley, Paraparaumu, on 20 Nov 2019 (UBR 2019/088).

Barn owl (*Tyto alba*)
Several reports of possible barn owls were considered to be misidentifications of other species, or contained too little information to allow verification: two at Staveley, Canterbury, on 16 Jan 2019 (UBR 2019/005); one at Lyttelton on 21 Apr 2020 (UBR 2020/043); one at New Lynn, Auckland, on 29 Apr 2020 (UBR 2020/046); one at Pokeno, South Auckland, on 19 Oct 2019 (UBR 2020/060); and one at Charteris Bay, Lyttelton, on 5 Aug 2020 (UBR 2020/076).

South Island kokako (*Callaeas cinerea*)
Single birds reported at Waikawa, Picton, on 23 Jun 1997 (UBR 2019/076), Cable Bay, Nelson 25 Feb 2016 (UBR 2019/075) and Oct 2018 (UBR 2019/074), and Harwoods Hole, Abel Tasman National Park, on 13 Oct 2017 (UBR 2019/078).

South Island saddleback (*Philesturnus carunculatus*)
One reported at Point Elizabeth Walkway, Greymouth, on 18 Jan 2020 (UBR 2020/018), and one reported at Travis Wetland, Christchurch, on 30 Jun 2019 (UBR 2019/050).

Mohua (*Mohoua ochrocephala*)
One reported in open habitat at Diamond Lakes, Wanaka, on 9 Feb 2020 (UBR 2020/021).

White-winged triller (*Lalage tricolor*)
Sound recording from Secretary Island, Fiordland, 15 Mar 2019 (UBR 2019/060; withdrawn).

Masked woodswallow (*Artamus personatus*)
One reported from Waimarama, Waikato, on 8 Jul 2019 (UBR 2019/061) was identified from a photograph as a black-faced cuckoo-shrike (see UBR 2019/086).

Australian tree martin (*Petrochelidon nigricans*)
Six reported at Battle Hill Park, Pauatahanui, Porirua, on 27 Jan 2019 (UBR 2019/009) were considered likely to have been juvenile welcome swallows (*Hirundo neoxena*).

Records of species not requiring RAC verification
Two bobwhite quail (*Colinus virginianus*) at

Kaikoura on 14 May 2019 (UBR 2019/044), and an Australian king parrot (*Alisterus scapularis*) at One Tree Hill/Cornwall Park, Auckland, on 6 Sep 2016 (UBR 2020/032) and 25 Oct 2019 (UBR 2019/085) had probably escaped or been released from captivity.

DISCUSSION

The Records Appraisal Committee received 193 Unusual Bird Reports between January 2019 and December 2020. Excluding two reports of 'non-reportable' species, 149 of 191 submitted UBRs were accepted (78%). This compares with an acceptance rate of 81% for 722 submissions over the previous decade (Miskelly *et al*. 2011, 2013, 2015, 2017, 2019). The number of UBRs received during 2019–20 (8.0 month^{-1}) was the second highest reporting rate in the history of the reporting scheme, but was lower than the record high of 9.2 month^{-1} received during 2017–18 (Miskelly *et al*. 2019).

The most notable records assessed during 2019–20 were the addition of two further taxa to the New Zealand list (collared petrel and rose-crowned fruit-dove), and the first recorded breeding by gull-billed tern. The South Polar skua collected on the Auckland Islands in 1904 becomes the earliest accepted record of a species that has been reported from New Zealand about 20 times since (Miskelly 2020a).

The nearest known breeding colonies of collared petrel to New Zealand are in Fiji (confirmed on Gau Island, and suspected on Kadavu, Moala, Koro, Totoya, and Matuku Islands; O'Brien *et al*. 2016). Birds from these colonies have not been tracked to determine where they forage during the breeding season. They may yet prove to be regularly present in northern New Zealand waters. Rose-crowned fruit-doves occur in rainforests of eastern Australia as far south as northern New South Wales, and are seasonal migrants in the southern part of their range (Higgins & Davies 1996; Menkhorst *et al*. 2017). The bird captured off the Taranaki coast in August 2019 was a recent fledgling that was still growing its main flight feathers. (Miskelly 2020b).

The Australian subspecies of gull-billed tern (*Gelochelidon nilotica macrotarsa*) is the only form of the species recognised from New Zealand (Miskelly *et al*. 2013). It breeds colonially on ephemeral inland lakes and wetlands in Australia (Higgins & Davies 1996; Menkhorst *et al*. 2017). The first New Zealand breeding record reported herein was close to the locality of the first reported sighting of this species in the country 64 years earlier (McKenzie 1955).

The addition of collared petrel and rose-crowned fruit-dove increases the number of bird species recorded naturally from New Zealand since AD 1800 to 355 (Gill *et al*. 2010; Miskelly *et al*. 2019). Of these, 15 are considered extinct. In addition, 36 introduced species are currently considered established in the wild in New Zealand, making the current avifauna 376 species (including 26 migrant species and 141 vagrant species).

Northern shoveler was the most reported species during 2019–20. This followed an exceptional incursion of this species that began in late 2017 (Miskelly *et al*. 2019). Declining reports over time suggest that the birds reported in 2019 (7) and 2020 (2) were survivors from the 2017–18 incursion. Other species reported in exceptional numbers in 2019–20 included two species of swifts. The four reports of fork-tailed swifts from three locations between December 2019 and October 2020 was the highest reporting rate for this species in a 12-month period (they were reported from two locations in 1983; Fennell 1983), and the 80+ white-throated needletails at Upper Moutere in February 2020 was the second largest flock of this species recorded in New Zealand (McCaskill 1943).

Of the 53 vagrant species accepted by the RAC in 2019–20, 21 species (39.6%) were holarctic breeding migrants (12 Eurasian, 2 North American, 7 either), 18 species (34.0%) breed in Australia, 4 species were probably from the tropical Pacific, three species were from the South Atlantic Ocean, and two species (Juan Fernandez petrel and pink-footed shearwater) were from Chile. Single species arrived from Antarctica (South Polar skua), Macquarie Island (royal penguin), south-east Asia (fork-tailed swift), the southern Indian Ocean or South Atlantic (macaroni penguin), and North or Central America (laughing gull). This continues the pattern of Holarctic migratory species, followed by Australian species, being the main sources of vagrant bird records in New Zealand (Miskelly *et al*. 2017).

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Seasonal survey of waterfowl (Anatidae), shags (Phalacrocoracidae) and fernbird (*Bowdleria punctata*) at Te Nohoaka o Tukiauau/Sinclair Wetlands, Otago: July 2015 – July 2018

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Abstract: Birds were surveyed once per season over three years from 2015–2018 at Te Nohoaka o Tukiauau/Sinclair Wetlands, Otago. Eight species of waterfowl were observed, including four native species: New Zealand scaup (*Aythya novaeseelandiae*), Australasian shoveler (*Anas rhynchotis*), paradise shelduck (*Tadorna variegata*), and grey teal (*Anas gracilis*). Native species made up 68% of all waterbirds counted. New Zealand scaup dominated at 53%. The highest total number of birds counted was 1167 in winter 2015, and the lowest was 76 in spring 2016. The counts for some species varied greatly from year to year and each species showed some seasonal variation. It appears that more waterfowl are using the lagoons now than 15 years ago. Shag numbers were never greater than 8 individuals. The estimated density of fernbird (*Bowdleria punctata*) along a 750 m transect varied from 1.0/ha in winter to 2.7/ha in summer. This survey of waterfowl, shags and fernbird provides a reference against which future comparisons investigating long-term trends in bird populations at the Sinclair Wetlands can be made.

Thompson, M.P.; McKinlay, B. 2021. Seasonal survey of waterfowl (Anatidae), shags (Phalacrocoracidae) and fernbird (*Bowdleria punctata*) at Te Nohoaka o Tukiauau/Sinclair Wetlands, Otago: July 2015 – July 2018. *Notornis 68(4)*: 266–273.

Key words: Sinclair Wetlands, seasonal counts, waterfowl, shags, fernbird

INTRODUCTION

Wetlands support a high diversity of birds, fish, invertebrates, algae and plants. They offer refuge to many threatened species and include naturally rare ecosystems. Many of New Zealand's native fauna rely on wetlands during all or part of their life cycle. Nationally, wetlands provide a variety of important ecosystem services including maintaining water quality, mitigation of flood effects and sequestering of carbon (Department of Conservation, 2020a). Threatened species such as the Australasian bittern (*Botaurus poiciloptilus*), brown teal (*Anas chlorotis*), fernbird (*Bowdleria punctata*), crakes (*Porzana* spp.), and white heron (*Ardea modesta*) all rely on the remnant wetlands present in New Zealand for their survival. Equally, wetlands provide habitat for highly mobile waterfowl which use a national network as part of their annual cycle (Sutton *et al.* 2002; Caithness *et al.* 2002).

The Te Nohoaka o Tukiauau/Sinclair Wetlands is part of the nationally important wetland complex of Lake Waihola and Lake Waipori on the Taieri Plain south of Dunedin. This larger complex is considered

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of national importance due to the size of the wetland and the diversity of habitats present (Stephenson *et al.* 1983; Cromarty & Scott 1995). Over 90% of New Zealand's wetlands have been drained or modified by human activities, resulting in a decline in flora and fauna that depend on wetland habitat (Myers *et al*. 2013; Department of Conservation 2020a). The conservation and restoration of what remains is essential to halt, and hopefully reverse, this decline (Department of Conservation 2020b).

Over 50% of the Sinclair Wetlands was originally drained for farming, but farming ceased in the 1960s and the area was re-flooded and regeneration of a matrix of native wetland plants occurred. In 1998 the property was returned to Ngāi Tahu and sustained restoration efforts began. Te Nohoaka o Tukiauau/Sinclair Wetlands Trust is actively overseeing restoration of the wetland, including removal of exotic weed species, re-planting with native vegetation, and mammalian predator control. A draft management plan has as its main objective "to implement a matauranga based mahinga kai focused management", along with monitoring of bird species and numbers. As part of the implementation of this plan, Birds New Zealand (Otago Region) was asked to obtain a current record of birds in the wetlands. The long-term objective is to provide a baseline reference point for future comparisons that can contribute to monitoring restoration and inform decisions about management of the wetlands. This in turn can ensure healthy habitats, ecological diversity, sustainable practices, and promote community engagement in the area.

This survey was the first time that an integrated programme to survey birds seasonally with specific methods for each taxonomic group was completed for this wetland. We used standardised methods to allow comparison of relative abundances within species in subsequent years if surveys were repeated. We chose species that we expected to be present in large numbers and that are amenable to being sampled by direct observation methods.

METHODS

Survey area

The Sinclair Wetlands along with the associated Lakes Waihola and Waipori are distinctive in New Zealand in that they are a fluvial delta of the Waipori and Taieri Rivers. The wetlands are near sea level and consequently have occasional saltwater intrusion. The Sinclair Wetlands comprises 315 hectares situated on the northwest corner of the greater Lakes Waihola and Waipori wetland complex on the Taieri Plain 50 km south of Dunedin (45°59'S, 170°06'E; Fig. 1). The Sinclair Wetlands is now a matrix of natural marshes and pools as well as drainage ditches. The vegetation now includes many native wetland species such as sedges (*Carex* spp.), flaxes (*Phormium tenax*), raupō beds (*Typha orientalis*), and *Coprosma propinqua* shrubs.

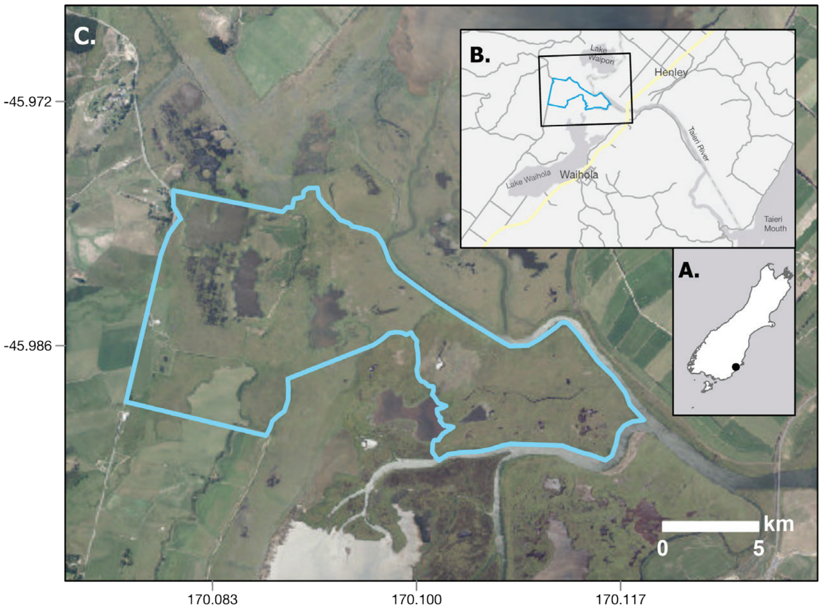

Figure 1. Location of Te Nohoaka o Tukiauau/Sinclair Wetlands. A. South Island of New Zealand; B. Lakes Waihola and Waipori wetland complex; C. Sinclair Wetlands with boundary shown in blue.

Table 1. Dates when seasonal bird surveys were done at the Sinclair Wetlands, 2015 – 2018.

Season	Dates			
Winter	11 July 2015	no survey	15 July 2017	7 July 2018
Spring	4 October 2015	15 October 2016	7 October 2017	-
Summer	30 January 2016	28 January 2017	27 January 2018	-
Autumn	9 April 2016	8 April 2017	7 April 2018	-

All surveys were carried out on calm, fine days between 0900 h and 1200 h to minimise variations of counts due to time or weather conditions. The species-specific surveys were completed by different teams. The counts were carried out on one day in each season for 3 years (Table 1). The autumn counts were completed in April each year well before the opening of the waterfowl hunting season in May. This survey did not set out to survey cryptic species such as Australasian bittern and crakes.

Waterfowl and shags

A point count methodology was used with count stations established on Lonely Island (45°59′07.0″S, 170°05′14.8″E), and at the western point (45°58′45.9″S, 170°05′14.3″E) and east side (45°58′54.2″S, 170°05′24.0″E) of Whakaraupuka/ Ram Island; these stations have an elevation between 20 and 25 m a.s.l. and were chosen to overlook the major open water areas (Fig. 2). This covered nearly 90% of the open water of the ponds. Birds hidden in the reeds could not be counted. Spotting scopes with 20x magnification were used. All individual waterfowl and shags of each species seen from these observation points were counted. The total number counted per survey was used as the index of abundance: double counting was minimised by completing counts as fast as could be achieved and only counting birds when they were at rest and not being disturbed. Seasonal variation in behaviour, such as nesting within reeds, could lead to underestimates of total numbers of birds present and no correction was made for this. We were not able to distinguish between mallard, grey duck, and any hybrids or colour forms that were present in the wetland (Williams 2019) and so all birds that displayed these phenotypes are reported as 'mallard'.

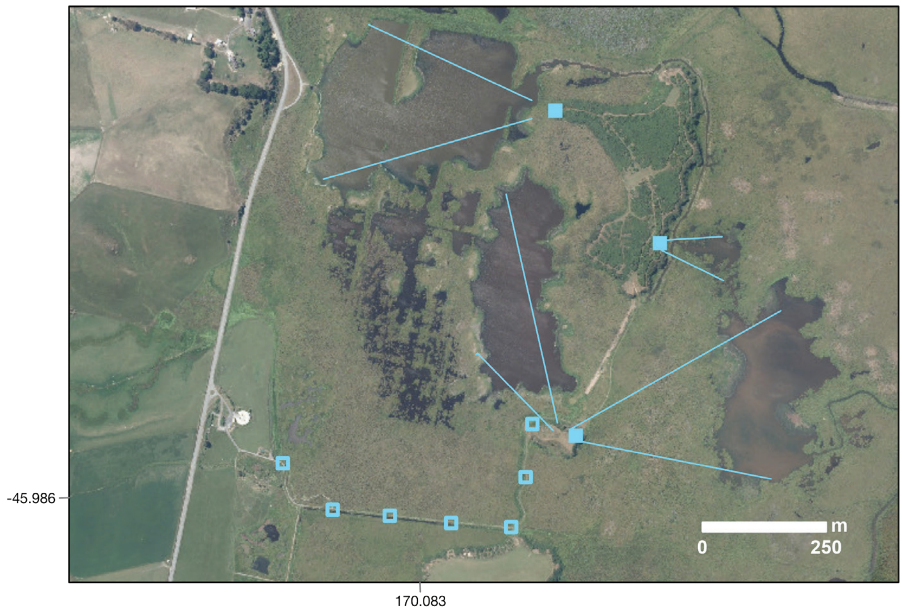

Figure 2. Satellite view of the section of the Sinclair Wetlands where the survey was done. Fernbird count stations are marked with open squares and waterfowl observation points are marked with closed squares.

Table 2. Seasonal counts of waterfowl at Sinclair Wetlands 2015–2018. The three separate seasonal counts and the total number of each species of waterfowl are shown. The mean for the seasonal counts was calculated. Percent abundance was calculated from the total number of each species as a percent of the total number of birds. Native species shown in bold typeface.

Species	Summer			Autumn			Winter			Spring			species total	% of total
	2016	2017	2018	2016	2017	2018	2015	2017	2018	2015	2016	2017		
New Zealand scaup	83	90	269	386	124	340	617	93	305	59	64	75	2,505	53.9
Mallard	35	9	77	43	55	57	299	55	52	3	2	5	692	14.9
Canada goose	25	45	51	83	55	37	31	16	30	10	0	12	395	8.5
Paradise duck	87	0	216	4	0	2	0	0	0	0	0	2	311	6.7
Black swan	27	7	2	38	4	42	97	8	29	29	3	22	308	6.6
Australasian shoveler	2	4	7	157	32	7	12	0	19	7	7	2	256	5.5
Grey teal	0	0	0	8	4	0	72	0	2	5	0	0	91	1.9
Greylag goose	0	4	6	0	3	9	39	3	14	5	0	6	91	1.9
Total number of birds	259	159	628	719	277	494	1,167	175	451	118	76	124	4,649	
Mean			348			372			598			106		

Fernbird

Fernbirds were counted along a 750 m transect along a footpath through the sedgeland with seven count stations positioned every 100 m (Fig. 2). Based on previous studies at the Sinclair Wetlands which mapped fernbird territory as 1.35 ha (Harris 1986) we assessed that a 100 m gap between count stations would reduce the risk of double counting between stations but would ensure sufficient coverage. Observers counted all fernbirds seen or heard during 5 minutes at each station, then played fernbird calls for one minute from a portable speaker (DiVoom iTour-30, 4.8W) on full volume and then counted any other fernbirds that responded. The largest total was recorded for each station and then the counts for all stations were combined to give the total count for the survey. To derive estimates of density we assumed that birds 50 m either side of this transect were included in the count, and thus the total area surveyed was *c.* 7.5 hectares.

RESULTS

Waterfowl

Eight species of waterfowl were seen, which included four native species (Table 2). A total of 4,649 birds were counted. The highest number seen at one count was 1,167 for winter 2015, and the lowest was 76 for spring 2016. There was a high variability for numbers of certain species from year to year within a season; numbers were low in winter of 2017 (total: 175) and very high in winter of 2015 (total: 1,167). All native species combined made up 68% of the waterfowl observed. Overall, New Zealand scaup (*Aythya novaeseelandiae*) dominated the count totals, accounting for 53% of all observed waterfowl, with the next most abundant being the introduced species, mallard (*Anas platyrhynchos* x *supercilliosa*) at 15% followed by Canada goose (*Branta canadensis*) at 8.5%, and black swan (*Cygnus atratus*) at 6.6%. Greylag geese (*Anser anser*) were uncommon in the surveys, making up 1.9% of the total counted, with the highest count in winter 2015.

To compare the pattern of seasonal variation of the six most abundant waterfowl species the mean number for each species for each season across the three years was used (Fig. 3). All species except paradise shelduck (*Tadorna variegata*) and grey teal (*Anas gracilis*) were present all year, but in varying numbers. New Zealand scaup, black swan, and mallard occurred in greatest numbers in winter. Paradise shelduck were present in significant numbers only in summer, although there were none for one summer count; only one or two paradise shelducks were seen on the lagoons in other seasons. The highest number of Australasian shoveler (*Anas rhynchotis*) was in autumn. Grey teal were only seen once in high numbers (72 in 2015) and that was in winter.

Fernbird

The highest count for fernbird was recorded in summer and the lowest in winter (Table 3). The estimated density ranged from 1 bird/ha in winter to 2.7 bird/ha in summer.

Other water birds

Small numbers of black shag (*Phalacrocorax carbo*) and little pied shag (*Phalacrocorax melanoleucos*) were counted (Table 4). The highest number of little pied shag was in autumn. Other birds using the lagoon area, but not surveyed, were pukeko

(*Porphyrio melanotus*), coot (*Fulica altra*; only one seen during the survey), and marsh crake (*Porzana pusilla*) and spotless crake (*Porzana tabuensis*), which were reported occasionally at the wetlands during the survey period.

DISCUSSION

Our survey reinforces the value of Te Nohoaka o Tukiauau/Sinclair Wetlands as part of the larger Lakes Waihola and Waipori wetland complex and its contribution to populations of wetland species

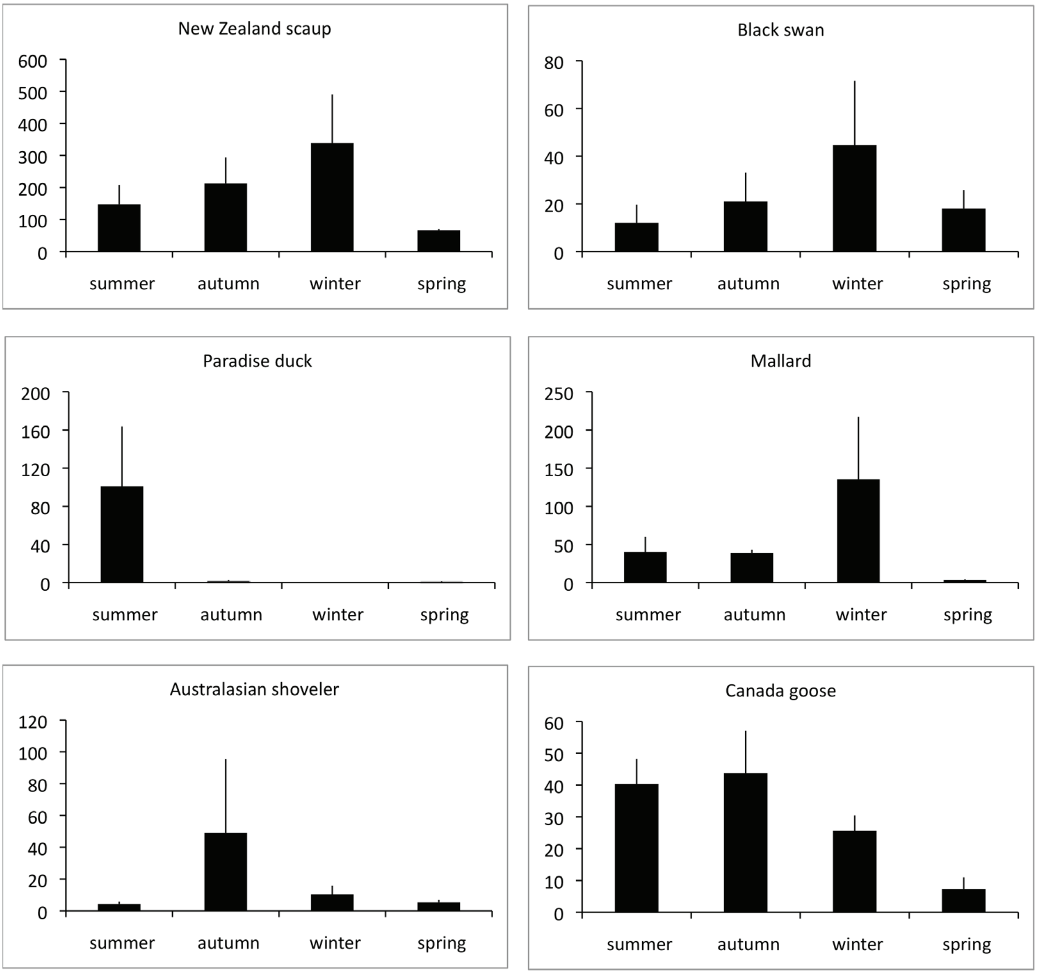

Figure 3. Comparison of pattern of seasonal numbers of waterfowl counted at Sinclair Wetlands 2015–2018. Counts were done in summer (January), autumn (April), winter (July) and spring (October) (Table 1). Bars show mean and whiskers show standard error of mean of counts for the top six most abundant species. Note scales are different for each species.

Table 3. Seasonal counts of fernbirds at Sinclair Wetlands 2015–2018. Total numbers encountered along the 750 m transect, covering 7.5 ha. *counted by a different observer from the other surveys.

	Summer			Autumn			Winter			Spring		
	2016	2017	2018	2016	2017	2018	2015	2017	2018	2015	2016*	2017*
Fernbird counts	32	14	15	14	12	6	6	13	4	19	7	4
Mean ± standard error	20.3 ± 5.8			10.6 ± 2.4			7.7 ± 2.7			10.0 ± 4.6		
Density (mean number/ha ± standard error)	2.70 ± 0.78			1.42 ± 0.32			1.02 ± 0.36			1.33 ± 0.61		

Table 4. Seasonal counts of shag species at Sinclair Wetlands 2015–2018.

	Summer			Autumn			Winter			Spring		
	2016	2017	2018	2016	2017	2018	2015	2017	2018	2015	2016	2017
Black shag	1	1	2	0	0	0	1	0	0	1	0	0
Little pied shag	1	3	1	3	8	8	3	1	1	1	3	2

regionally and nationally. The data presented here support the contention that the Sinclair Wetlands is sufficiently large enough to provide a variety of habitats for significant numbers of native species of waterfowl, with the endemic New Zealand scaup being the dominant species by numbers year-round. In addition, it supports a viable population of South Island fernbird. The Sinclair Wetlands also potentially provides suitable habitats for threatened birds such as bitterns and crakes.

Waterfowl

Interpreting our results for the waterfowl is complex as each species uses the wetlands to different extents for feeding, breeding, moulting and shelter depending on their seasonal cycles. For example, the use of the Sinclair Wetlands by Australasian shoveler is within the context of having one population that moves nationally within a period of weeks (Caithness *et al.* 2002; Sutton *et al.* 2002). Some of our methods would not be fit to investigate these patterns. Nevertheless, baseline counts using standardised repeatable methods have value in determining the overall contribution of the Sinclair Wetlands to the national pattern of mobile species of waterfowl and as a basis for more species-specific studies.

The findings reported here underline the value of the Sinclair Wetlands for native species of waterfowl. Native species made up 68% of total numbers counted. In many other wetlands, mallard (including grey duck, and mallard x grey hybrids), and Canada goose dominate (e.g. Gill & West 2016; Williams 2017), but here they were less than 23% of the total waterfowl counted. The overall low numbers of birds on the open water in spring could be because birds were hidden in reeds nesting, or they could have moved away to breed. The method used for the survey would not have located any nesting birds so the spring count is assumed to be an underestimate. Evidence of breeding was observed for all the waterfowl but the current survey was not designed to measure the extent or success of breeding and this should be the subject of future studies.

New Zealand scaup, the endemic diving duck, was present in high numbers and was over 50% of all waterfowl counted in all seasons. This appears to be an invasion into this wetland as summary reports from four decades ago indicate that New Zealand scaup were rarely seen in the Waihola and Waipori wetlands at that time (Drey 1990). Twenty years later, when another survey was done in summer New Zealand scaup were present, but in low numbers (Kissling 2002). The presence of New Zealand scaup throughout the year suggests they have now colonised these wetlands and occupy them as resident year-round. The numbers were highest in winter, which may indicate these wetlands are a site to which inland birds also migrate for over-wintering, though this needs further investigation.

Paradise shelduck were only seen once in large numbers and this was in summer, and it is hypothesised to have coincided with moulting. However, it is unlikely that the Sinclair Wetlands is a regionally important moult site for paradise shelduck as there was no obvious communal flocking of these birds seen during the summer counts done in Janaury. To determine if the Sinclair Wetlands is a moult site for paradise shelduck would require more counts during the moulting season.

The other native duck species present, Australasian shoveler and grey teal, were also not in great numbers, but these species are highly mobile during autumn and winter, and migrate to and from coastal areas (e.g. Caithness *et al*. 2002; Sutton *et al*. 2002), and probably use the wetlands irregularly. The Otago coast has extensive estuarine habitat that is used by Australasian shoveler and grey teal in winter (eBird 2020).

The numbers of black swan were not as high as expected because, at times, they are very numerous on the nearby open water of Lakes Waihola and Waipori (eBird 2020). The highest consistent counts were in winter, which may indicate the use of the Sinclair Wetlands complex as a wintering site before dispersing for nesting in spring. The data do not support the contention that the Sinclair Wetlands is a significant moulting or breeding site for black swan as may be the case for neighbouring Lakes Waihola and Waipori (Cromarty & Scott 1995). Canada goose are present throughout the year and in slightly greater numbers than swans but also appear to disperse in spring.

Although the aim of the present survey was to provide baseline counts for subsequent surveys, it is relevant to compare the current survey with a previous survey done at the Sinclair Wetlands during the summer of 2001/2002 (Kissling 2002).

The methodologies were slightly different, but it is possible to compare the numbers of waterfowl on the lagoons in the summer of 2002 with the summers of 2015–2018. There is a notable increase from 46–67 birds then, to 159–628 (mean 348) now. Then as now, in the summer New Zealand scaup were the most numerous, making up 64% of all waterfowl in 2002 and 42% now. It appears that more waterfowl are using the lagoons now than 15 years ago. Increased numbers of all the native waterfowl species would indicate the continued value of the wetlands for them. Although none of these native waterfowl species currently using the wetlands has a conservation status of threatened (Robertson *et al.* 2017) it is important to maintain suitable wetland habitat for them to continue to thrive.

Fernbird

Fernbirds were noted at most of the count sites along the transect, which was through an area of sedgeland with emergent coprosma bushes and flaxes, typical of the preferred habitat of fernbird (Best 1979; Harris 1986). The estimated densities ranged from 1 to 2.7 birds/ha depending on season. The variability of the counts is likely related to detectability, as it has been noted that at times fernbird are quiet for no apparent reason (Barlow 1983). The apparently lower count in winter was probably due to the less territorial behaviour of the birds in this season so that they did not respond so readily to call play-back and were therefore less conspicuous. The higher count in summer may include juveniles still present in the parents' territory.

A previous study of fernbird breeding ecology in a comparable area of the Sinclair Wetlands mapped fernbird territories at an average of 1.35 hectares per pair (range 0.46–3.73) (Harris 1986); this would give an estimated density of 1.48 birds/ha, which is similar to that of the current study during spring (1.33 birds/ha). In another study (Kissling 2002), fernbird were surveyed over the 2001/2002 summer along the same transect as our study. The mean density reported was 1.15 birds/ha. The comparable summer density of fernbird for the current survey was 2.7 birds/ha. Overall, these results indicate that the Sinclair Wetlands have maintained a healthy population of fernbirds over the last four decades and is a valuable site for fernbird conservation. Currently the fernbird has a threat classification of 'at risk, declining' (Robertson *et al.* 2017).

It is difficult to extrapolate from our counts to an estimate of the total population of fernbird in the whole of the wetland as the current study did not sample all the available habitat, nor was territory mapping used. Nevertheless, an estimate of the area of suitable habitat made from examination of aerial views suggest that the Sinclair Wetlands could provide about 200 hectares of suitable habitat, giving an estimate of about 130 territories of about 1.5 ha each (260 breeding fernbirds). Smaller fernbird territory sizes have been reported at other locations, e.g. 0.15 ha/pair (Barlow 1983), 0.52 ha/pair (Parker 2002), and 0.67 ha/pair (Elliott 1978). If enhanced wetland habitat leads to a decrease in territory size, then these wetlands would have the potential to support a higher population of fernbird. Factors determining population density include resource availability, predation, and competition with other species. In the Sinclair Wetlands there is potentially competition for invertebrates during the breeding season from numerous introduced bird species that also use the area such as chaffinch (*Fringilla coelebs*), dunnock (*Prunella modularis*), common redpoll (*Carduelis flammea*), yellowhammer (*Emberiza citronella*), and common starling (*Sturnus vulgaris*). Additionally, fernbirds may come to avoid the habitat available to them near the walking tracks as these become busier. This could be assessed in future studies by comparing transects through undisturbed areas of the wetland with those along the walking track.

Other wetland species

The Sinclair Wetlands does not appear to be used to any great extent by shags, nor by wading birds such as herons and stilts, which primarily inhabit the tidal mudflats at the northern end of the main lakes (eBird 2020). Three native species that are cryptic (i.e. rarely seen even if present) - marsh crake (*Porzana pusilla*), spotless crake (*Porzana tabuensis*), and Australasian bittern - were not target species of this survey nor were they encountered during the surveys. However, because of their threat classification of 'at risk, declining' (crakes) and 'nationally critical' (bittern) (Robertson *et al.* 2017), it is important that future surveys include them as healthy wetlands are crucial to their survival. Different survey methods would be needed to target this group of birds such as those recently proposed (O'Donnell & Williams 2015; Williams 2017). These species have been reported occasionally at the wetlands over the survey period. The presence of Australasian bittern in the Sinclair Wetlands has been confirmed by automatic recording devices that were deployed in the wetlands during October and November each year from 2011 to 2016 (Thompson 2015). These recorded bittern boom trains on up to 70% of nights (MPT *unpubl. data*). A pair of marsh crake successfully fledged two chicks in a pond near the visitor centre during October–December 2017 (Thompson 2017). Further species-specific research is required to establish how important these wetlands are to these threatened native species.

Subsequent surveys carried out every 7–10 years following the same methodology used for this survey would allow trends in waterfowl and fernbird populations to be determined to inform decisions about management of the wetlands and ensure that recreational use, restoration efforts, and predator control continues to support native species.

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SHORT NOTE

New Zealand king shag (*Leucocarbo carunculatus*) with deformed primary feathers

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The New Zealand king shag (*Leucocarbo carunculatus*), endemic to the Marlborough Sounds (New Zealand), is 'nationally endangered' (Robertson *et al*. 2017) with a current population estimate of about 800 birds (Schuckard *et al*. 2015; Bell *et al*. 2019). The species has been little studied, in part due to concerns that it was thought to be highly vulnerable to human disturbance (Taylor 2000). Recognising the urgent need to better understand the ecology of this species to inform future management decisions, the Department of Conservation authorised us to capture and band up to four full-grown New Zealand king shags.

We captured one full-grown juvenile New Zealand king shag at Duffers Reef, Marlborough Sounds (40.9562°S, 174.0379°E) on 19 January 2013 using a fishing pole and noose. The bird appeared to be in good condition, but on detailed examination it was found that the outer four primaries on both wings were abnormal (New Zealand king shags have 11 primaries, but the outermost [remicle] is much reduced and is not included in this account). The ventral base of the rachis (the calamus) was swollen and flaky due to what appeared to be deposits of keratin. On the right wing the outer-most primary (P1) was missing, while P3 (numbered ascendantly) was broken near the base (Fig. 1A); on the left wing the outermost primary was broken near the base (Fig. 1B). Apart from dystrophy of the calamus the other affected primaries were of full length, and appeared normal. The other six primaries on each wing also appeared to be in normal condition, as did the rest of the plumage, including the rectrices, which had some wear at the tips (Fig. 1C); there were no fault-bars (Riddle 1908). There was no evidence of mites on the flight feathers from visual inspection. The only other abnormality that we noted were several small lesions on the webs of both feet (Fig. 2).

At the time of capture we had no opportunity to seek veterinary advice or to contact the Department of Conservation as there was no cell phone coverage of the field site.

We collected some samples by taking feather shaft scrape samples of the waxy keratin tissue from the base of the affected primaries. These were submitted to Wildbase, School of Veterinary

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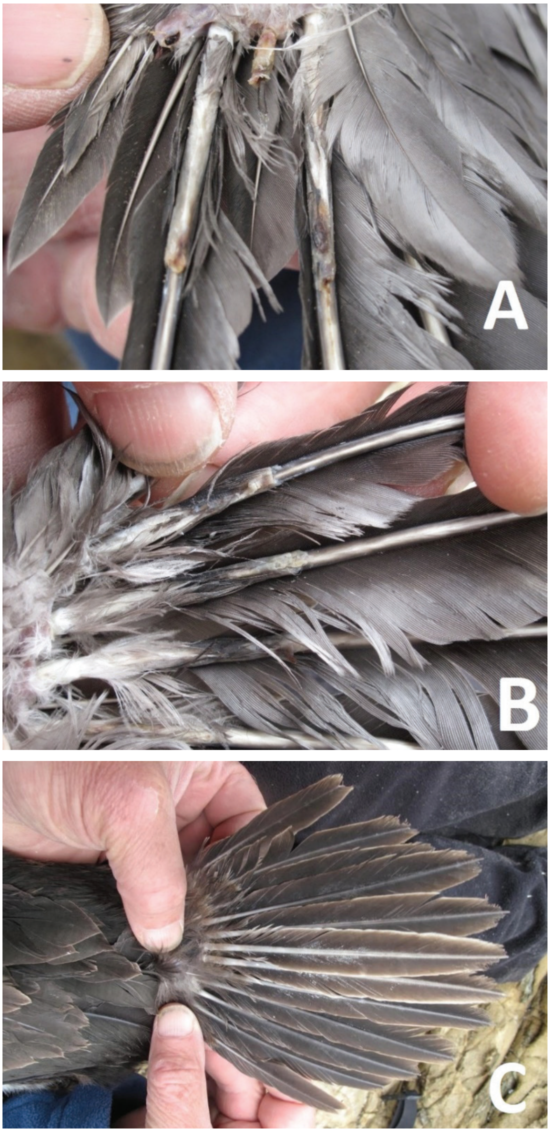

Figure 1. A - Outer primaries of right wing of juvenile New Zealand king shag (from below) showing damaged rachis; P1 (outermost primary) missing, P3 broken. **B** - Outer primaries of left wing of juvenile New Zealand king shag (from below) showing damaged rachis; P1 (outermost primary) broken. (**C**) Rectrices of juvenile New Zealand king shag (from above). These feathers did not show any unusual features

Science, Massey University. The results confirmed hyper-keratinisation of the feather shafts, but no cause could be established (Dr Brett Gartrell, *pers. comm.* via email 30 May 2013). Dr Gartrell advised to submit a feather follicle biopsy for histology and culture in future, as plucked or dropped feathers

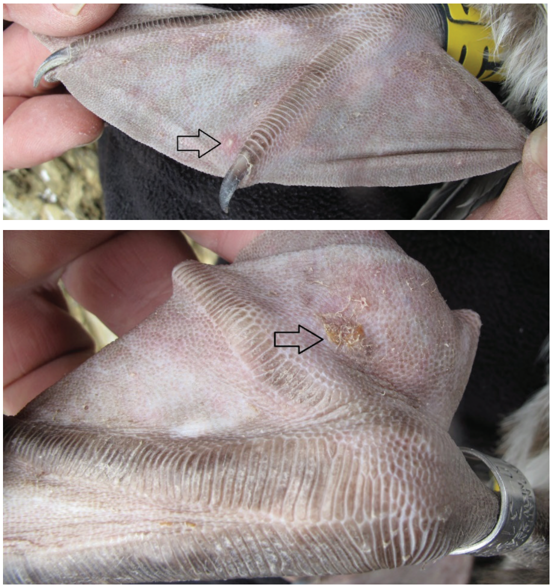

Figure 2. Lesions on the upper surface of the feet of juvenile New Zealand king shag.

are often not diagnostic (Dr Brett Gartrell, *pers. comm.* via email 30 May 2013).

Feather dystrophy, such as that found in our New Zealand king shag, can result from a variety of causes. Psittacine beak and feather disease (PBFD), caused by a circovirus (Todd 2000), can result in feather dystrophy similar that seen in the New Zealand king shag. Whilst primarily recorded in psittacines, PBFD-like symptoms and/or beak and feather disease virus (BFDV) are being recorded in an increasing number of other families and genera of birds (Raidal & Riddoch 1997; Woods & Latimar 2000; Stewart *et al*. 2006; Sarker *et al.* 2015, 2016; Amery-Gale *et al.* 2017). Circoviruses appear to be rarely reported from seabirds, currently only being recorded from three species of gull and two species of penguin (Twentyman 1999; Smyth *et al*. 2006; Morandini *et al*. 2019; Levy *et al*. 2020). The affected primaries appeared to be similar to those affected by 'pinching off syndrome' (POS) (Cooper 1978), which has been recorded in several species of birds of prey in both Europe and North America (Bijlsma & van den Burg 2006; Müller *et al*. 2007a, 2007b; Nemeth *et al.* 2008, 2009; Bijlsma & van de Mortel 2009). The aetiology of POS remains obscure. It was attributed to quill mites (*Harpyrhyncthus* spp.) by Heidenreich (1997), while Cooper (2002) and Redig & Cruz-Martinez (2009) suggested that it might be associated with virus infections; it has been found in various North American raptors infected with West Nile Virus (Nemeth *et al.* 2008, 2009).

Müller *et al*. (2007a, 2007b) were unable to attribute POS to any particular cause in European white-tailed sea eagles (*Haliaetus albicilla*) despite extensive investigation, and concluded that there might be a genetic cause, noting that: 'extremely low genetic drift, possible inbreeding, and the longevity of white-tailed sea eagles may have contributed to the persistence of this disorder' (Müller *et al*. 2007b).

The New Zealand king shag was formerly widespread around the southern coast of the North Island and the northern coast of the South Island (Rawlence *et al*. 2017), but it appears that the population has been restricted to the Marlborough Sounds 'though not in plenty' (Latham 1785), at least since the first specimen was collected in 1773 (Medway 1987). As such, the population may have been subject to a genetic bottleneck, as has been reported in the Stewart Island shag *Leucocarbo chalconotus* (Rawlence *et al.* 2015). If POS is associated with a genetic condition, then it may be found in other individuals within the population.

It seems unlikely that the bird we captured would have been capable of flight, although it did use its wings to help jump from the sea to the rock platform at Duffers Reef. Most New Zealand king shags fly up to 24 km from the colony each day to feed (Schuckard 1994, 2006; Bell 2020); swimming between a colony and a foraging area has been recorded but is uncommon (Bell 2019). Juvenile flight feathers would not normally be replaced until the first complete moult, which Falla (1933) suggests is at about 15 months of age, so it is expected that any juvenile suffering from feather dystrophy would have reduced survival.

Since this initial capture a further 152 New Zealand king shags have been caught and banded (28 adults, 113 chicks, 11 juveniles approximately 2–5 months post fledging) including birds at Duffers Reef. None has shown any evidence of feather dystrophy (Mike Bell *in litt*. 12 July 2021). Vigilance would, however, be advisable. Should any further case of a New Zealand king shag with a plumage disorder be discovered, it is recommended that the live bird be removed from the wild and submitted to an appropriate veterinary facility for detailed examination – future research authorisations should include the ability for such actions.

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SHORT NOTE

Two new radiocarbon ages for Haast's eagle (*Hieraaetus moorei*) (Aves: Accipitridae) and comments on the eagle's past distribution and possible survival into the 19th century

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Haast's eagle (*Hieraaetus moorei*) was the top predator of large vertebrates in the South Island, New Zealand, until its late Holocene extinction (Holdaway 1992; Holdaway, in Worthy & Holdaway 2002). It was never found in the North Island (Holdaway 1992; Holdaway, in Worthy & Holdaway 2002). During the most recent — Weichselian-Otiran — glaciation which lasted from 110,000 to 18,000 years ago, the eagle's distribution included Northwest Nelson (Worthy 1993; Worthy & Holdaway 1994) and the West Coast (Worthy & Zhao 2006). There are no eagle fossils of glacial age known from east of the Main Divide, but this may reflect a shortage of fossil deposits of that age rather than of eagles.

During the Holocene (the past 10,000 years) the situation was reversed. The remains of many eagles have been recovered from both natural and archaeological sites throughout the eastern South Island (Worthy & Holdaway 2002), from the coast to the glacial valleys of Central Otago (Worthy 1998a). So far, only one eagle of Holocene age (Table 1) has been collected from west of the Divide, and that was from near the top of Mt Owen, in SO 209, a 15 m deep pothole at nearly 1,500 m altitude, in a subalpine environment (Worthy & Holdaway 2002).

The eagle's distribution pattern through time has been determined mainly from the association of its remains with the radiocarbon-dated individuals of moa (Aves: Dinornithiformes) and other birds (Holdaway 1992; Holdaway, in Worthy & Holdaway 2002). The five radiocarbon ages measured previously on eagles (Fig. 1; Table 1) fit these patterns in space and time. They also provide the only dated evidence for the Holocene survival of a population west of the Main Divide.

Until now only one radiocarbon age, NZA7912 (2,096 ± 72 ^{14}C years BP) (Fig. 1; Table 1) has been available for an eagle from east of the Main Divide (Worthy 1998b). That was measured on a rib of the larger (female, S2134; Te Papa Museum of New Zealand collection) of two eagles excavated for Augustus Hamilton at Castle Rocks, Southland, in the 1890s (Hamilton 1893, 1894). The chronology of the eagle's presence in the eastern South Island has been assessed otherwise, as noted above, on the basis only of ages of deposits where other taxa have been radiocarbon dated or inferred from the species represented therein (Holdaway 1992).

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Table 1. Radiocarbon ages for Haast's eagle (*Hieraeetus moorei*). CRA, Conventional radiocarbon age (^{14}C years Before Present (BP). Calibrated dates in years (cal BP), based on SHCal20 curve. S, specimen in Museum of New Zealand Te Papa Tongarewa, Wellington. Av, specimen in Canterbury Museum, Christchurch. Mean, weighted mean of measurements; δ^{13}C, AMS measurement, except Pyramid Valley, which are IRMS measurements; C:N, molar carbon to nitrogen ratio of collagen. NA, not available. Sources: 1, Worthy & Holdaway (1994); 2, Worthy (1998a); 3, Worthy & Holdaway (2002); 4, Worthy (1993).

							Calibrated dates (cal BP)			
Site	**Museum**	**Lab. no.**	**CRA**	**SD**	**δ^{13}C**	**C:N**	**Mean**	**SD**	**Median**	**Source**
Hawkes Cave Site 3	S27952 or S28340	NZA3243	16,543	112	-21.4	NA	19,924	175	19,932	1
Hawkes Cave Site 5	S27951	NZA3194	13,175	102	-22.1	NA	15,764	161	15,764	1
Castle Rocks	S2134	NZA7912	2,096	72	-23.3	NA	2,026	100	2,021	2
Mt Owen (SO209)	S27773	NZA905	2,159	196	-22.5	NA	2,124	252	2,110	3
Honeycomb Hill	S22472.13	NZA361	15,541	218	-21.5	NA	18,788	257	18,801	4
Pyramid Valley	Av6177/6178	UBA42949	1,935	25	-22.4	3.28	1,828	44	1,836	This paper
Pyramid Valley	Av6012	UBA42950	2,871	31	-22.7	3.31	2,945	61	2,941	This paper

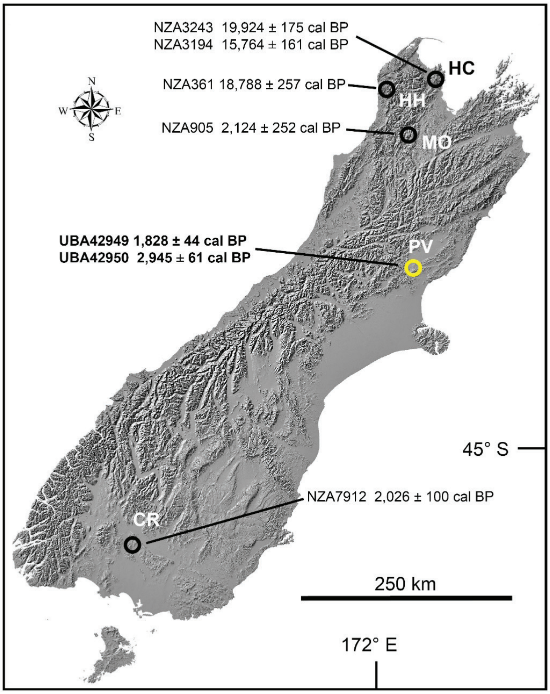

Figure 1. Distribution of radiocarbon-dated specimens of Haast's eagle (*Hieraeetus moorei*), with calibrated dates (weighted mean ± 1SD) cal BP, (calibrated years Before Present, i.e. 1950 CE). Dates in **bold** are reported here for the first time. Sites: HC, Hawkes Cave, Takaka Hill; HH, Honeycomb Hill cave system, Oparara River; MO, Cave SO 209, Mt Owen; PV, Pyramid Valley; CR, Castle Rocks. The distribution of dated individuals does not constitute the known distribution of the eagle. Details of radiocarbon ages and sources in Table 1. Digital Elevation Model courtesy of School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.

At least four eagles (Holdaway & Worthy 1997) have been excavated from the lake bed at Pyramid Valley, North Canterbury, and all must have been deposited there at some time in the past 5,000 years, the duration of deposition at the site (Gregg 1972; Johnston 2014; Johnston *et al*. in press). Two of the four eagles were sampled for dating: non-essential material of the other two was too limited for sampling. The eagle and other large species in the deposit – takahe (*Porphyrio hochstetteri*), adzebill (*Aptornis defossor*), goose (*Cnemiornis calcitrans*), and kakapo (*Strigops habroptilus*) – have been neglected historically in favour of dating the four species of moa (Allentoft *et al.* 2014; Holdaway *et al*. 2014).

All the published radiocarbon ages referred to here were measured by accelerator mass spectrometry (AMS) on bone collagen. Radiocarbon ages for the two eagles were measured (by AMS) at the 14Chrono Laboratory, Queen's University, Belfast, UK, and the conventional ages were calibrated via OxCal4.4 (Bronk Ramsey 1995, 2009), referenced to the SHCal20 curve (Hogg *et al.* 2020). Small (309, 670 mg) bone samples, chosen to avoid features of potential morphological interest, were submitted for dating. Collagen was extracted using a method based on that of Brown *et al.* (1988) but using a Vivaspin® filter cleaning method introduced by Bronk Ramsey *et al.* (2004).

The radiocarbon ages on the Mt Owen and Castle Rocks eagles were measured by the Rafter Radiocarbon Laboratory (now of GNS Science), after 1977, and are reported according to the agreement of that year on Radiocarbon Reporting Conventions (Stuiver & Polach 1977). Before that all ages reported by that laboratory before the 1977 agreement were reported according to best practice at the time, which varied depending on sample type, and evolved over the years. All results have now been recalculated from the original counting data, according to the S&P1977 conventions. Depending on the sample type and original reporting practice, the results may change by up to several hundred years from the original report. The count data were recalculated for this study and no rounding was applied to the error measurement reported. These factors affect ages on moa bones measured before 1977, which are often used in comparison with more recently measured ages.

Both eagles yielded calibrated radiocarbon dates in the past 3,000 years (Table 1). Based on current understanding (Moar 1970; Burrows 1989; Johnston 2014) of the environment surrounding the Pyramid Valley lake, both birds inhabited a lowland forest that hosted an avifauna of nearly 50 species (Holdaway & Worthy 1997), including several ranging in size from Finsch's duck (*Chenonetta finschi*) to moa (Worthy & Holdaway 1996, 2002), that were large enough to have been potential prey for the eagle.

Worthy & Zhao (2006) inferred the presence of the eagle at Kids Cave, near the Nile River, Westland, during the Last Glacial Maximum. They interpreted damage to large bones of species such as kea (*Nestor notabilis*), extinct coot (*Fulica prisca*), paradise shelduck (*Tadorna variegata*), and South Island goose (*Cnemiornis calcitrans*), as beyond the capacity of either the extinct harrier (*Circus eylesi*), whose bones were recovered from the site, or New Zealand falcon (*Falco novaeseelandiae*) but recorded no bones of the eagle itself. The species listed are indeed likely prey for the eagle, but the statement that "This is the first time prey remains have been ascribed to Haast's eagle." (Worthy & Zhao 2006: p. 402) is clearly incorrect. Moa killed by eagles had been identified before (Worthy & Holdaway 1996, 2002; Holdaway 2015) and the eagles are unlikely not to have fed on the moa they had killed.

In contrast to the Pyramid Valley birds, the date for the Mount Owen bird (Table 1) (Worthy & Holdaway 2002: figure 8.23) shows that eagles could also find suitable prey in more open environments, perhaps similar to those available during glacial periods. In addition, its presence there shows that small isolated populations could survive for millennia in rare suitable habitats west of the Main Divide after the climate warmed at the end of the glaciation. The rapid post-glacial spread of lowland rain forest through northwest Nelson quickly surrounded Mount Owen, isolating its high basins. Encircled then by many kilometres of unfavourable wet forest and separated by the central ranges from the eastern populations, at least 400 generations of a tiny population (the area of habitat was limited) of eagles apparently survived there in isolation. The eagle's presence there would also speak to the continued abundance of prey such as weka (*Gallirallus australis*) and takahe in that environment. The upland moa (*Megalapteryx didinus*), South Island giant moa (*Dinornis robustus*), and *Pachyornis australis* were certainly there during the Holocene (Worthy 1989a,b). Remains of a weka were found in SO 209 with the eagle.

Absence of evidence (the absence of eagles from Holocene-aged deposits from west of the Main Divide after 15,000 years BP, with the exception of the much later high-altitude occurrence on Mt Owen), is, of course, not evidence of absence (i.e. eagles were not present in the west Holocene forests). However, two factors support the contention that, in this instance, it does. First, the concept of consilience, where multiple, independent observations yield the same result, which was famously the procedure adopted by Charles Darwin in *On the origin of species*. In the present instance, the absence of eagles from one site with a continuous fossil record might be interesting, the absence of eagles – and of their prey species – from all such sites within the period of interest is information.

Second, west of the Divide the eagle is always associated in the deposits with the same "eastern" fauna of moa and other taxa (Worthy & Holdaway 1993, 1994). The "eastern" fauna vanishes from the deposits, replaced by a wet forest fauna, during the glacial-interglacial transition just as the eagle record ceases too. In major moa sites in the eastern South Island, only the collection from the deposit at Herbert lacks eagles, probably an artefact of the collection philosophy ("collect the moa") adopted at the time. The eagle is otherwise ubiquitous in the presence of the emeid moa during the Holocene east of the Divide and west of the Divide during the glaciation. If the eagle was indeed living in the wet Holocene forests west of the Divide it was living with species such as *Anomalopteryx didiformis*, with which it has never been associated elsewhere.

True forest eagles, especially the largest, the African crowned eagle (*Stephanoaetus coronatus*) and the harpy eagle (*Harpia harpyja*), prey mostly on arboreal mammals (McGraw *et al*. 2006; Swatridge *et al.* 2014; Symes & Antonites 2014; Aguia-Silva *et al*. 2014, 2015; Miranda 2018) that live in the productive canopy biome. The crowned eagle supplements with this diet with antelopes of up to 30 kg killed as they drink at waterholes within the forest (Brown & Amadon 1968). The low productivity at and near the floor of a rain forest limits populations of large herbivores (Cerling *et al*. 2004) and hence, even more so, those of their predators.

The two "large hawks" that European explorer Charles ("Charlie") Douglas shot in the Landsborough Valley, South Westland, in the late 1860s (Pascoe 1957) are unlikely to have been Australasian harriers (*Circus approximans*) as confidently proposed by Sir Robert Falla in a footnote to the quotation. Douglas was a surveyor of note (Nathan 2017) and an astute observer (Holloway 1957): he was unlikely to have measured so badly the birds he shot as to make them twice the size of a harrier. The eagle was discovered after Douglas's observations and he could hardly have been boasting that he had shot living examples of something not known to exist.

The 2,000 year BP date on the Mt Owen female shows that the species was able to survive near the end of the Holocene in subalpine areas. The last area of the South Island that could – and, obviously did, support takahe and other eagle prey – was south of Mt Owen. Takahe survive in mountain valleys farther south today. The landscape of the upper reaches of the Landsborough Valley is not unlike the montane basins on Mount Owen. In the 1860s, before the introduction of deer and other ruminants, the montane basins would have retained much of the character of the pre-human vegetation (Worthy & Holdaway 2002: figure 8.22). Before prey species such as takahe and weka were extirpated or severely reduced in numbers by introduced mustelids after the early 1880s, the area could have provided suitable habitat and prey for a small population of eagles. Douglas's record should not be dismissed out of hand.

The female eagle that died in SO 209 near the summit of Mount Owen just over 2,000 years ago (Holdaway 1992) was unlikely to have been the last bird of its population. Its (almost complete) skeleton does, however, provide an opportunity to test the hypothesis of the long-term survival of a genetically limited population of large raptors. Advances in analysis of ancient DNA mean that the hypotheses of long isolation of the Mt Owen population and a potential genetic shift could be tested against the copious (for a large raptor) material available from east of the Divide (Holdaway 1992) and even the better-preserved bones amongst the much older eagle material from Honeycomb Hill Cave (Worthy 1993) and Takaka Hill (Worthy & Holdaway 1994). The near contemporary individuals from Pyramid Valley would be ideal comparators for the Mount Owen female in such a study.

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SHORT NOTE

A previously unpublished first record of the moa by French naval surgeon/botanist P.A. Lesson

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The timeline of the discovery by Europeans of the prehistoric existence of the moa (Aves: Dinornithiformes) in the 19th century has long been settled. The first remains and accounts of a giant bird in New Zealand found their way to the scientific world from several independent sources, all within the narrow period of 1837 to 1839, and all from the same general locality, the Poverty Bay – East Cape (Tai Rāwhiti) region of New Zealand's North Island.

It will be recalled the first published account was from the trader Joel Polack who reported being shown bones of an *'emu or a bird of the genus Struthio'*, by Māori while living in the Tolaga Bay area in 1835–1836. The bones were said to have been found in the vicinity of the *'mountain of Ikorangi'* (Hikurangi) and that hunting in 'times long past' had caused their extermination. Polack added he was *'assured from the many reports received from the natives, that a species of struthio still exist on that interesting* [South] *Island, in parts, which, perhaps, have never yet been trodden by man'* (Polack 1838: 303, 307-308).

In February 1837, a femur of a very large bird which had come into the possession of John Harris, another trader based at Turanga (now Gisborne), Poverty Bay, was taken to Sydney and left along with some Māori artefacts at the home of Dr John Rule, a former naval surgeon. Harris also left a note stating that the bone and others like it were found buried in riverbanks and by 'tradition' it was from a bird of the 'Eagle kind but which has become extinct' (Anderson 1987).

In January 1838, the missionaries William Williams, brother of Rev. Henry Williams, original author of the authoritative *Dictionary of the Maori Language* and later the first Anglican bishop of Waiapu, William Colenso, James Stack, and Richard Mathews, visited Rangitukia pā, near East Cape where they were told by Ngāti Porou chiefs of a giant bird named 'moa'. This has long been the accepted first record of the name 'moa'. The local people described the bird in semi-mythical terms, maintaining one still lived in the mountainous hinterland to the southwest, in the vicinity of Whakapunake (Williams in Owen 1843, 1879; Colenso 1843).

In 1839 Rule travelled to London where in October he presented Harris' bone to Richard Owen at the Royal College of Surgeons. Owen, after initial scepticism confirmed that the bone was

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indeed the femur a very large bird. The following month November 1839, Owen presented the bone to a meeting of the Zoological Society of London, famously announcing *'I am willing to risk the reputation for it on the statement that there has existed, if there does not now exist, in New Zealand, a Struthious bird nearly, if not quite, equal in size to the Ostrich'* (Owen 1839: 170-171).

In 1842 Rev. Williams sent a consignment of 47 moa bones collected in the Poverty Bay, East Coast area, to Owen via the geologist/palaeontologist Rev. Dr William Buckland of Oxford University. This led to Owen assigning the name *Dinornis novaezealandiae* for the giant moa, as reported in the *Proceedings of the Zoological Society*, 1843, and his subsequent papers which were published together as a compendium in his *Extinct Wingless Birds of New Zealand* (Owen 1879). Since that time a number of debates among scientists about the moa have arisen, including about how and when it became extinct, its systematics, at one stage classified as 28 species in seven genera and two families (Oliver 1955), progressively reduced to the presently accepted nine species in six genera and three families (Bunce *et al.* 2009; Worthy & Scofield 2012), and even its posture. However, the timeline of when Europeans first learnt of the giant New Zealand ratite and of the name 'moa', has never been challenged – until now.

Figure 1. Pierre Adolphe Lesson (1805–1888). Assistant surgeon and botanist in the *Astrolabe* 1826–1829 expedition. Younger brother to ornithologist R.P. Lesson. P.A. Lesson was a career naval surgeon and later medical administrator in French Polynesia where he wrote extensively on Polynesian ethnology. The coastal shrub houpara (*Pseudopanax lessonii*) collected at Whangarei Heads in 1827 was named for him by the famous botanical taxonomist A.P. de Candolle. Portrait in oils by Faustin Betbeder, dated 1869 (n° inv. BA 22-44). ©Musées-municipaux Rochefort 17. Hôtel Hèbre de Saint Clément, Musée d'Art et Histoire de Rochefort.

The *Astrolabe* journal of P.A. Lesson

On 6 February 1827 the French naval corvette *L'Astrolabe* under the command of J.-S.-C. Dumont d'Urville was off the east coast of New Zealand, on a scientific and hydrographic expedition. Having just departed Tolaga Bay (Uawa), it was sailing northwards towards East Cape when it was intercepted by a sailing canoe or waka, flying a flag atop its mast. The waka which hailed the French ship with a musket shot, was under the command of a rangatira whose name d'Urville wrote as 'Ourua' and his assistant surgeon recorded as 'Orua'.

The late-19th/early-20th century ethnologist S. Percy Smith identified this rangatira as 'Te Rere Hourua, a great chief and warrior of Tokomaru Bay' (Smith 1896). According to historian Monty Soutar his correct name was Te Rerehorua; tribal tradition recalling Rerehorua as 'the last of the principal chiefs, and a man of great passionate nature who would kill a man anywhere …'(Soutar 2000: 83). D'Urville invited Te Rerehorua, who evidently knew some English, to dine with him and was impressed by his table manners and his knowledge of the words of the northern lament for the dead, the Pihe, with which d'Urville had become fascinated during his visit to the Bay of Islands in 1824 (Dumont d'Urville 1830: 111–113; Wright 1950: 125–126). At the time the intertribal Musket Wars were raging across New Zealand. Te Rerehorua anxious to obtain muskets and ammunition and evidently wishing to befriend the powerful outsiders, persistently urged d'Urville to call in at Tokomaru Bay. The *Astrolabe*'s assistant surgeon, was 20-year-old Pierre Adolphe Lesson, the younger brother of the surgeon/naturalist René Primevère Lesson who had visited New Zealand in 1824 in *La Coquille* (the original name of the *Astrolabe*), making major contributions to New Zealand ornithology (Andrews 1986; Lee 2016, 2018, 2020; Lee & Bruce 2019a,b). The younger Lesson, a botanist who would co-author the voyage botany volume, part 1 (Lesson & Richard 1832), was a junior member of d'Urville's distinguished team of naturalists which included the surgeons Jean-René-Constant Quoy, Joseph Paul Gaimard and d'Urville himself. The successful partnership of Quoy and Gaimard had already won them a reputation as world-leading field zoologists. During the *Astrolabe* expedition they were to undertake important work in New Zealand, collecting specimens and naming and describing bird and mollusc species in particular (Quoy & Gaimard 1830–33).

P.A. Lesson's journal, which has lain unpublished for 194 years, most of this time in the municipal library in Rochefort, France, reveals some remarkable information about New Zealand's natural history, in particular what appears to be the first record of the name 'moa' applied to the giant New Zealand flightless bird. Lesson's journal entry for 6 February 1827 includes the following:

'Dans la Baie Tolaga, en voyant la bordure d'un manteau en poil d'oiseau, on nous avait donné le nom de Kiwi pour celui qui produisait un pareil plumage ; ici, en voyant les plumes qui ornaient la Pirogue d'Orua, ce chef nous avait appris que c'étaient des plumes d'un autre oiseau, qui ne volait pas mais courait seulement et était appelé par eux Moa. Il avait ajouté qu'on ne le trouvait que dans l'intérieur à assez grande distance de la côte, qu'il y en avait de fort gros, et que si on voulait attendre, il promettait d'en rapporter assez promptement. Un instant même il put croire que cela déciderait le Commandant plus que tout le reste, mais rien ne devait y faire, la baie Tokomarua [*sic*], *quoique grande* était *encore trop peu connue pour qu'on s'y risquât'* (Lesson 1827: 540).

In translation: 'At Tolaga Bay, when we saw the feathered border of a chief's cloak, we had been given the name of 'Kiwi' for the bird which produced such plumage; here, seeing the feathers that adorned the canoe of Orua, this chief led us to understand that these were the feathers of another bird, which did not fly but only ran, and was called by them 'Moa'. He added that it was only found in the interior at a considerable distance from the coast, that there were very large ones, and that if we wished to wait, he promised to bring some back fairly quickly. For a moment he was convinced that this would decide the Commander more than all the other reasons, but there was nothing doing. Tokomarua [*sic*] Bay, although large was still too little known for us to risk it.'

Unfortunately d'Urville's *Histoire du Voyage* makes no mention of this incident.

Two days later on 8 February, having doubled East Cape, *Astrolabe* was intercepted by three waka rigged with inverted triangular sails, the finest under the command of a rangatira from a pā or fortified village called 'Awatere' near Te Araroa, whose name d'Urville recorded as 'Shaki' ('Jack'). The carved bows or tauihu of these waka, Lesson reported, were decorated with the likenesses of two human heads, with tongues protruding, eyes of *Haliotis* (pāua) shell, adding 'these heads were generally surmounted with *quelques plumes de Moa'* – 'a few moa feathers' (Lesson 1827: 546). Unfortunately, on neither occasion did Lesson describe or measure these feathers. This was the same day that Quoy and Gaimard collected what proved to be two specimens of the New Zealand storm petrel (*Fregetta maoriana*) which are still held in the Muséum national d'Histoire naturelle in Paris. This episode Lesson recorded, along with the name *Procellaria pelagica* (the European storm petrel).

The missing journals of the *Astrolabe* expedition

The long-standing confusion about the origins of the Paris New Zealand storm petrel specimens only resolved in 2004 in this journal by Medway and Bourne *et al.*, raises questions about the contents of Quoy and Gaimard's *Astrolabe* journals. More so because in regard to the 'moa' feathers, Lesson would have almost certainly consulted his senior zoologist colleagues, the eminent J.-R.-C. Quoy in particular. In regard to the kiwi, the feathers of which they had examined in the aforementioned cloak, Lesson wrote, '*M. Quoy nous dit que c'etait l'Apteryx'*. 'Mr Quoy tells us that this is the Apteryx' (Lesson 1827: 531). Unfortunately Lesson's unpublished diary is the only officer's journal from the *Astrolabe* (1826–1829) expedition known to still exist. This is because d'Urville at the end of the expedition in April 1829 collected all his officers' journals, selecting excerpts from some to include in his *Histoire du Voyage* volumes. After d'Urville's untimely death in 1842 attempts to locate these journals were unsuccessful (Leclerc 2008: 122). The exception being that of Lesson, who while keeping numerous journals dedicated to botany, medicine, surgery, shipboard alimentation, and nautical matters, did not surrender the journal he had kept as his personal diary. Instead towards the end of his life in 1888, he donated it along with the rest of his papers and those of his brother, to the Bibliothèque municipale in the Lesson family's home town of Rochefort.

Māori accounts of the moa

Nineteenth century accounts by Māori relating to the moa collected by for instance Sir George Grey, John White and Walter Buller (Berentson 2012), have tended to be dismissed by scholars principally because they were suspected of being compromised by leading questions from European inquirers (Brewster 1987). Anderson observed 'as soon as scientific reports about moa became available Europeans used them to prompt Maori 'recollections'' (Anderson 1989a).

This scepticism extends to doubts about the authenticity of the name 'moa' itself (Anderson 1989a; Worthy & Holdway 2002). The ethnologist Roger Duff went as far as to remark, 'If the Maoris of the eighteenth and nineteenth centuries had actually found a live moa, they would not have known what to call it!' (In McCulloch & Cox 1992: 36).

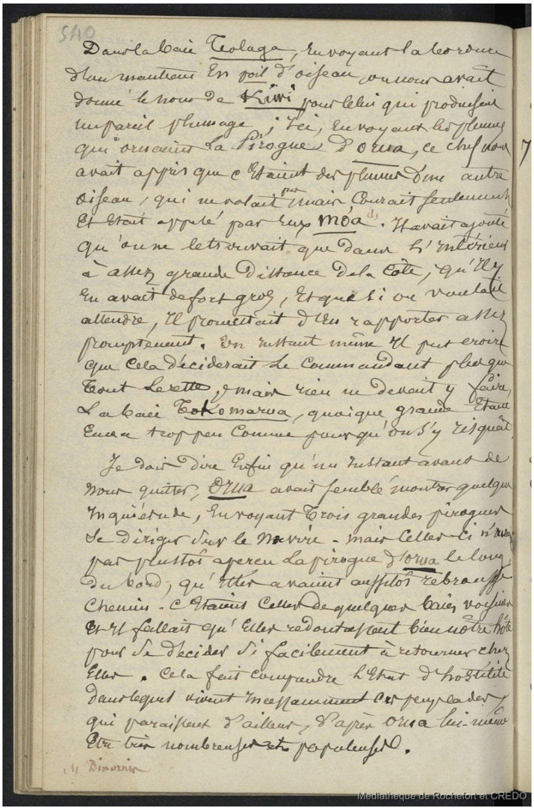
In February 1827, however, there was absolutely no possibility of leading questions or prompting about moa because no-one onboard *Astrolabe*, nor anyone else outside of the Māori world, knew of the moa's existence.

The skepticism about the authenticity of the name 'moa', appears to be reinforced by the fact that it was and still is, widely used across island Polynesia as the name for the domesticated red junglefowl (*Gallus gallus*). For some reason fowls were not brought to New Zealand by the original Polynesian colonists or did not survive their translocation (Wood *et al.* 2016). Why the early Māori called the large flightless birds this name is a question often remarked on by scholars. Of these Lesson was the first. In March 1827 at the end of the *Astrolabe*'s New Zealand visit, in a wide ranging essay, and in the context of introduced domestic fowls that he'd seen in the Bay of Islands, he wrote:

'*Ce qui doit faire admettre qu'ils y étaient tout à fait inconnus, c'est que les Naturels actuels ne désignent pas les poules sous leur nom polynésien de Moa, et que comme leurs ancêtres, ils appliquent pourtant le même nom à un oiseau Gigantesque à ailes courtes, qui autrefois, était très commun mais qui dès à présent est assez rare, tant ils sont pourchassés pour s'en nourrir d'abord et pour les plumes ; ensuite, lesquelles leur servent, comme on a vu, à orner leur tête et leurs pirogues*' (Lesson 1827: 797).

In translation: 'What must make [us] admit that [domestic fowls] were completely unknown here, it is that the present day natives do not designate the fowls under their Polynesian name of Moa, and that like their ancestors, they however apply the same name to a Gigantic bird short-winged, which in the past was very common, but which is now quite rare, as they are hunted down to feed on it first and for the feathers next, which serve them, as we have seen, to adorn their heads and their canoes.'

Lesson's recorded observations, apart from being the earliest written account of the moa, predating those of Polack, Harris, Williams, Colenso, and Taylor by at least eleven years, raise other questions. Te Rerehoroa's claim that very large species of flightless bird called 'moa' could still be found and hunted in the remote interior was evidently made after Lesson expressed interest in the feathers and was likely motivated by his determination to have the French stay as long as possible at Tokomaru Bay. (His anxiety can be understood when it is learned his pā, Tuatini was besieged the following year, [or 1829 according to Laurie 1991] by a coalition of enemy tribes and Te Rerehorua killed and eaten, his head preserved and sold for gunpowder) (Soutar 2000: 85). That being said, the missionary Richard Taylor in his journal entry of 26 April 1839 reported being told by local Māori of a valley near Tokomaru Bay where 'the great bird moa was said to exist.' (Taylor 1839 in Wolfe 2003: 56). However, in regard to Te Rerehorua's initial response to questioning about the feathers on his waka, Lesson's curiosity prompted by the kiwi feathers that he and his colleagues including d'Urville, had examined at Tolaga Bay the previous day, it is difficult to find a reason not to take what could only have been an ingenuous response at face value.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Dans la baie Tolaga, en voyant la bordure d'un manteau en poil d'oiseau on nous avait donné le nom de Kiwi pour celui qui produisait un pareil plumage ; ici, en voyant les plumes qui ornaient la Pirogue d'Orua, ce chef nous avait appris que c'étaient des plumes d'une autre oiseau, qui ne volait pas mais courait seulement et était appelé par eux moa (1). Il avait ajouté qu'on ne le trouvait que dans l'intérieur à assez grande distance de la côte, qu'il y en avait de fort gros, et que si on voulait attendre, il promettait d'en rapporter assez promptement. Un instant même il put croire que cela déciderait le commandant plus que tout le reste, mais rien ne devait y faire, la baie Tokomarua, quoique grande était encore trop peu connue pour qu'on s'y risquât.

Je dois dire enfin qu'un instant avant de nous quitter, Orua avait semblé montrer quelque inquiétude, en voyant trois grandes pirogues se diriger sur le navire - mais celles-ci n'eurent pas plutôt aperçu la pirogue d'Orua le long du bord, qu'elles avaient aussitôt rebroussé chemin. C'étaient celles de quelques baies voisines et il fallait qu'elles redoutassent bien notre hôte pour se décider si facilement à retourner chez elles. Cela fait comprendre l'état d'hostilité dans lequel vivent incessamment ces peuplades qui paraissent d'ailleurs, d'après Orua lui-même être très nombreuses et populeuses.

(1) Dinornis

Figure 2. Lesson Journal p.540. 6 February 1827 which records the name 'moa' communicated to Lesson by the Ngāti Porou rangatira Te Rerehorua. This is the first known record of the word 'moa'. Note the footnote 'Dinornis' in lighter ink which must have been added after Richard Owen's 1843 paper published in the *Proceedings of the Zoological Society of London*. ODSAS https://www.odsas.net/scan_sets.php?set_id=1157&doc=111910&step=72 Médiathèque de Rochefort et CREDO.

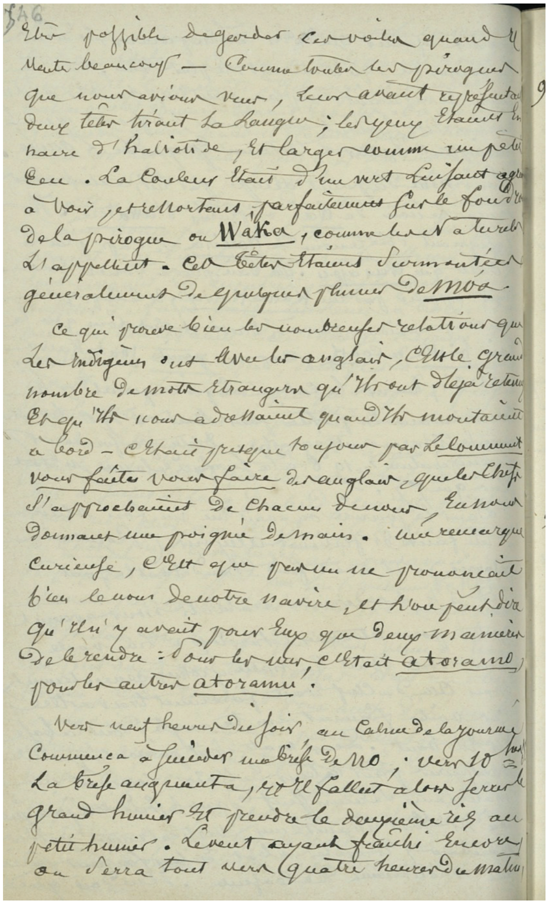
Authenticity of the Lesson journal

Lesson's reports about the moa are so extraordinary that it is not unreasonable to question the journal's authenticity. On this subject the scholar France Herjean de Briançon who rediscovered the Lesson journal and wrote her thesis on it for her Sorbonne Master's degree in history (and on the *Astrolabe* expedition for her doctorate in 1992), had this to say:

'Nous pouvons affirmer sans presque aucun doute, que c'est Pierre Adolphe Lesson qui a rédigé ce journal. A la fin du récit du voyage, se trouve une signature très lisible sous la date du 3 Avril 1829. De plus, il mentionne à plusiers reprises son frère René Primevère et raconte des anecdotes qui lui sont arrivées personnellement' (Herjean de Briançon 1986: 22).

In translation: 'We are able to affirm almost without doubt, that it was Pierre Adolphe Lesson who wrote this journal. At the end of his account of the voyage is found a signature very legible under the date 3rd of April 1829. Furthermore, he mentions his brother René Primevère several times and recounts anecdotes that happened to him personally.'

The Lesson journal is in three volumes, written in black ink, on double-sided pages, *'recto-verso,'* comprising 800 to 900 pages, each volume bound in leather, covering the voyage from 1826 to 1829 (Herjean de Briançon 1986: 18). It is finally in the process of being published in France under the title *L'Astrolabe - Récit du Voyage* with an introduction by Anne Di Piazza. Publication, originally intended in 2020, has been delayed by the Covid 19 pandemic, but is planned for December 2021 (A. Di Piazza *pers. comm.*). However the handwritten original of the Lesson journal is available on-line at the Médiathèque de Rochefort: https://www.odsas.net/scan_sets.php?set_id=1157&doc=111335&step=0



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Etre possible de garder ces voiles quand il
vente beaucoup — Comme toutes les pirogues
que nous avions vues, leur avant représentait
deux têtes tirant la langue; les yeux étaient en
nacre d'haliotide, et larges comme un petit
écu. La couleur était d'un vert luisant agréable
à voir, et ressortaient parfaitement sur le fond rouge
de la pirogue ou Waka, comme les naturels
l'appellent. Ces têtes étaient surmontées
généralement de quelques plumes de moa.

Ce qui prouve bien les nombreuses relations que
les indigènes ont avec les anglais, c'est le grand
nombre de mots étrangers qu'ils ont déjà retenus
et que ils nous adressaient quand ils montaient
à bord — c'était presque toujours par le comment
vous faites vous faire des anglais, que les chefs
s'approchaient de chacun de nous, en nous
donnant une poignée de mains. Une remarque
curieuse, c'est que pas un ne prononçait
bien le nom de notre navire, et l'on peut dire
qu'il n'y avait pour eux que deux manières
de le rendre: pour les uns, c'était atoramo,
pour les autres atoramu.

Vers neuf heures du soir, au calme de la journée
commença à succéder une brise de NO; vers 10 h
la brise augmenta, et il fallut alors serrer le
grand hunier et prendre le deuxième ris au
petit hunier. Le vent ayant fraîchi encore
on serra tout vers quatre heures du matin,

Figure 3. Lesson Journal p.546. 8 February 1827, off East Cape. Here Lesson describes the bow carvings (tauihu) of sailing waka decorated with 'a few moa feathers'. (The Māori name for the *Astrolabe* is reported as 'Atoramo'). ODSAS https://www.odsas.net/scan_sets.php?set_id=1157&doc=111910&step=72 Médiathèque de Rochefort et CREDO.

Implications for the historiography of the moa

So, just as the older brother René Primevère Lesson in 1824 was the first European naturalist to record the existence of the North Island brown kiwi (*Apteryx mantelli*), introducing its now famous name to ornithology (Mathews 1935 in Lee & Bruce 2019b), three years later, the younger brother Pierre Adolphe Lesson, became the first outsider to record the existence of the New Zealand moa and to record the name in writing. Concomitantly the Ngāti Porou rangatira Te Rerehorua of Tokomaru Bay is revealed to be the first person to have reported the existence of the moa to the outside world. Lesson's record must, however, be considered within the context of the consensus (albeit noting Richards 1986) that all species of moa had been driven to extinction across New Zealand by AD 1500 or earlier. (e.g. Anderson 1989a,b; Worthy & Holdaway 2002; Tennyson & Martinson 2006; Bunce *et al*. 2009; Worthy & Scofield 2012; Holdaway *et al.* 2014; Perry *et al*. 2014; Gill *et al.* 2020). That being said the unprompted account of a very large flightless bird, and the claimed use of moa feathers, notably in the decoration of sea-going waka in the 1820s on the East Coast of New Zealand, the first locality where moa bones were shown to Europeans, but since then figured comparatively rarely in moa-related research (albeit noting Huynen *et al*. 2008; Walter *et al.* 2010; McCallum *et al.* 2013). This at the least suggest Māori memory of the moa in this region was still vivid in 1827. It also suggests a reconsideration of Anderson's conclusion, 'The very lack of an unequivocal association between the term 'moa' and any straight forward account

Figure 5. Moa feathers. R.P. Lesson's journal entries for 6 February & 8 February 1827, record what he was told were moa feathers (probably similar to these) used to decorate carvings on sailing waka which visited *l'Astrolabe*. For further information on moa feathers see Rawlence *et al.* (2012). The feathers in the photo are of Upland Moa, *Megalapteryx didinus*, collected 1949, Takahe Valley, Fordland, New Zealand. CC BY 4.0. National Museum of New Zealand Te Papa Tongarewa.

of large birds hunted and eaten by Maoris…[is] the main flaw exploited throughout the long debate, about what if anything the Maoris had known about Dinornithiformes' Anderson (1989a: 90).

Lesson's journal references are undoubtedly the earliest account of the moa, including the name itself, confirming it was in use, at least among East Coast Māori, along with the claimed use of moa feathers and the provision of an unmistakable description provided by a recognised historical figure, Te Rerehorua. It must be considered therefore a significant addition to the historiography of the moa. It also underscores the remarkable contribution of early 19th century French naval scientists, the Lesson brothers in particular, to the natural history of New Zealand.

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SHORT NOTE

Did Molly Falla observe an instance of active tactical deception in the kea (*Nestor notabilis*)?

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Kea (*Nestor notabilis*) are a species of large parrot from New Zealand exhibiting a variety of unusual adaptations. These include cold tolerance, and (partial) carnivory (Diamond & Bond 1999). They are also known for their exceptional intelligence, and are used as a model organism in the study of so-called 'technical' intelligence in birds, which encompasses a suite of flexible behaviours allowing for goal-directed problem solving, via means-end reasoning, the appropriate application and coordination of psychomotor skills, understanding of the relationships between objects and functions, and probabilistic reasoning (among other faculties) (see Huber & Gajdon 2006; O'Hara *et al.* 2012; Bastos & Taylor 2020). Kea are adept at social learning also, being able to (rapidly) learn solution rules to problems once solved (O'Hara *et al.* 2012).

One potential corollary of 'technical' intelligence is the capacity for active (or intentional) tactical deception. This form of tactical deception involves an animal utilising behaviour to actively manipulate another via misrepresentation in order to gain an advantage (McNally & Jackson 2013). This is distinct from what could be termed passive tactical deception, where instinctual adaptations (such as sound mimicry and other behavioural fixed-modal action patterns) or features of morphology (such as in the case of Batesian mimicry) can be used to deceive predators or competitors. Active tactical deception has been studied in various primates in both naturalistic and experimental contexts (Whiten & Byrne 1988; Hare *et al.* 2006). Moreover, recent phylogenetic comparative examinations have found strong correlations between physical-technical and social cognitive abilities, such as tactical deception in non-human primates (Reader *et al.* 2011; Fernandes *et al.*

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2014; Fernandes *et al.* 2020). These results strongly suggest that technical and social intelligence coevolved as part of a domain general cognitive dimension. Among birds, the use of strategic interference against opportunities to observe the location of cached food has been studied as a possible instance of active tactical deception in the common raven (*Corvus corax*) (Bugnyar & Kotrschal 2002). Similarly, field experiments with piping plovers (*Charadrius melodus* and *C. wilsonia*) have found that these species "feigned" having wing injuries when confronted with intruders, in order to draw attention away from nesting sites (Ristau 2013). Although, it could be argued that feigning an injury operates as a fixed-modal action pattern, the experimental evidence indicates that the birds actively monitor the intruders' activity, thus, this behaviour features at least moderate flexibility (Ristau 2013).

Thus far, the capacity for active tactical deception among kea has not (to our knowledge) been studied; however, an anecdotal report of this behaviour that is evidently extremely obscure was recently bought to our attention. The report is sourced from a very brief book written by Elayne Mary (Lady) Falla (1903–1978) in the 1970s about the (tragically short) life of her pet kea. Molly (as she preferred to be known) was the wife of noted New Zealand ornithologist Sir Robert Alexander Falla (1901–1979). She was a talented wildlife artist (Falla 1966, 1970), although her work is relatively obscure today. The book, entitled *A kea on my bed* concerns the life and antics of a hand-raised kea collected by her husband in 1948 . The bird was retrieved from a nest burrow in the New Zealand Southern Alps at an altitude of 1,380 m a.s.l. The bird was estimated to be three-weeks old at time of capture and appeared to have been abandoned (it was found to be sharing its nest with a dead sibling at the time). The bird was then presented by Robert to Molly as a pet, subsequently to be named "Mr Kea" (although judging from the photographs the bird was almost certainly a hen, given its relatively small upper mandible), whereupon Molly proceeded to document the bird's life up until its death some five months later from unknown causes (although poisoning was suspected). The book is richly illustrated and chocked full of interesting, albeit somewhat embellished observational accounts of the young kea's behaviour. It also includes a plea to end the persecution of kea, which at the time was ongoing (kea were not fully protected in New Zealand until 1986; Diamond & Bond 1999).

Among the observations made by Molly Falla, one in particular stands out, as it is suggestive of active tactical deception. The relevant description is as follows:

> "One morning, Bob accidentally trod on his foot and Mr Kea's reaction was most vociferous. After being caressed and comforted, however, he apparently quite forgot about the sore foot, such as a child might have done when it has been kissed and "made better". That evening, he began to run as usual to the door to welcome his master home. Suddenly, a few feet from the door, he pulled up and scowled at Bob and, lifting one foot, came limping back to me. As he had shown no sign whatever of limping during the day, the family's mirth was prodigious – it became more so when we realised he was holding up *the wrong foot*!" (Falla 1975, p.35, italics in original).

Clearly there is a heavy dose of anthropomorphism in this report, e.g. "scowled at Bob", and it is even conceivable that the report was fabricated in order to enliven the author's reverie; however, the intriguing possibility also exists that this might be a sincere (if embellished) report of what could potentially be a manifestation of active tactical deception on the part of this kea. In this instance, it is presumed that the bird came to associate its (very mild) injury at the feet of Bob with significantly increased attention from Molly, so opted to affect the outward appearance of being injured upon encountering Bob again in order to subsequently manipulate Molly into giving it more attention. Being mindful of Morgan's canon, another simpler explanation is that the bird simply learned to contingently associate the foot lifting behaviour with attention from Molly. This alternative account would not require the action of more elaborate cognitive processes such as those that subserve active tactical deception. Additional caution should be exercised in interpreting anecdotal reports such as these given the problem of the lack of standardization among observational case reports of behavioural rarities (Sándor & Miklósi 2020). Relevant to this is a recent debate surrounding a possible instance of spontaneous tool use in the Atlantic puffin (*Fratercula arctica*) which was based on a single second of footage (Fayet *et al.* 2020). This observation proved highly controversial and was the subject of vigorous criticism (Auersperg *et al.* 2020; Dechaume-Moncharmont 2020; Farrar 2020; Sándor & Miklósi 2020; von Bayern *et al.* 2020).

Nevertheless, the plausibility of the hypothesis that Falla (1975) documents an actual instance of active tactical deception in a kea is enhanced when considered in the context of data indicating that kea are highly cooperative (Huber *et al.* 2008). This is because cooperation seems to be a major source of selection favouring this behaviour (McNally & Jackson 2013). The presence of such behaviour in kea would also further strengthen the presumed comparative psychological convergence between this species and other highly intelligent taxa such as primates (Huber & Gajdon 2006), as these are also known active tactical deceivers (Whitten & Byrne 1988; Hare *et al.* 2006).

In re-reporting this possible instance of active tactical deception in kea we have attempted to follow as many of the suggestions put forward for standardizing case reports of behavioural rarities by Sándor and Miklósi (2020) as possible. These researchers also suggest proposing protocols for exploring these behaviours under experimental conditions. Given the possibility of cognitive and behavioural convergence between kea and primates (Huber & Gajdon 2006), it may be possible to generalise an active tactical deception experimental protocol designed for the latter to the study of this behaviour in the former. One such protocol involves competition between humans (*Homo sapiens*) and experimental subjects over an item of food. In experiments involving chimpanzees (*Pan paniscus*) it was found that a number of chimpanzees approached the contested item indirectly in ways that were hidden from the human participant's view, sometimes even taking highly elaborate routes to the item (Hare *et al.* 2006). Hare and colleagues (2006) note that "[t]hese findings not only corroborate previous work showing that chimpanzees know what others can and cannot see, but also suggest that when competing for food chimpanzees are skillful at manipulating, to their own advantage, whether others can or cannot see them." (p.495). Such an experimental paradigm could conceivably be adapted to study this behaviour in the context of both human-kea interactions and possibly also conspecific interactions among kea (involving birds exhibiting different degrees of social dominance).

The Falla (1975) observation also serves to highlight the significance of behavioural insights gained from birds raised in captivity, which can yield substantively novel ethological data owing to the opportunities for close observation that such context affords. Examples of this include the work of Lambert *et al.* (2015) and Woodley of Menie *et al.* (2021) on spontaneous tool use and physical cognition respectively in captive greater vasa parrots (*Coracopsis vasa*), the work of Auersperg *et al.* (2021) on spontaneous tool use in a captive Goffin's cockatoo (*Cacatua goffini*), the work of Cory (2012) on rule governance in a captive white-necked raven (*Corvus albicollis*), and various instances of tool use in captive kea (Auersperg *et al.* 2011; Bastos *et al.* 2021), to list but a few relevant examples. Indeed, virtually everything that is known of the behaviour of the (now extinct) Norfolk Island kaka (*Nestor productus*) comes from observational records made by John Gould (1865) of a captive bird in the possession of a Major Anderson, of Sydney, in about 1838.

Finally, it is hoped that this note will also raise awareness of Molly Falla, who was evidently a most talented individual with a keen naturalist's eye, and who is sadly very little known relative to her eminent husband. It is possible that she was the very first to record a remarkable behaviour in a remarkable species of bird.

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SHORT NOTE

Mind the gap: potential implications of the chronology of the South Island adzebill (*Aptornis defossor*) (Aves: Aptornithidae) at Pyramid Valley, North Canterbury,

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The extinct South Island adzebill (*Aptornis defossor*) (Aves: Aptornithidae) is relatively abundant in the collections from the Pyramid Valley lake bed deposit (42˚58′22.54″S, 172˚35′50.12″E, Fig. 1) (Holdaway & Worthy 1997). The minimum of 11 individuals excavated so far represent 2.6% of the total non-passerine avifauna, and 5.5% of the non-passerines excluding the four species of moa (Aves: Dinornithiformes) (Holdaway & Worthy 1997). The species was third-equal with the brown teal (*Anas chlorotis*) (5.5%) among non-passerines after the New Zealand pigeon (*Hemiphaga novaeseelandiae*) (34.7%), and kaka (*Nestor meridionalis*) (6%).

Such numerical comparisons can be misleading, however, as recovery of material from the lake bed sediments was heavily biased towards large birds by the methods employed in early (pre-1970) excavations. Before 1949, individual pits were dug where probing with steel rods revealed the presence of large bones (Holdaway & Worthy 1997). From 1949, excavations were undertaken in an array of 3.66 × 3.66 m squares dug to 1.5–1.8 m, initially across the width of two squares with "spoil" shovelled back into the previous squares (Eyles 1955). Although it was claimed that "even the fragile bones of forest birds were easily detected", that the "average time for the recovery of each [moa] skeleton… was estimated at 75 minutes" (Eyles 1955: 259) suggests that much if not most of the smaller material was missed.

The number of adzebills recovered reflects their common presence as more or less intact skeletons (Holdaway & Worthy 1997) in comparison to, for example, Haast's eagle (*Hieraaetus moorei*), a bird of about the same body mass (Holdaway 1989; Holdaway 1992). Four eagles were represented by just 22 bones, whereas collections hold well over 517 adzebill bones (Holdaway & Worthy 1997). In light of the mode of excavation – which seems to have concentrated on 'mining' moa skeletons – it is perhaps remarkable that bones of at least nine tui (*Prosthemadera novaeseelandiae*), a much smaller bird than any of the above, were also recovered (Holdaway & Worthy 1997).

The Pyramid Valley fossil avifauna was deposited during the second half of the Holocene (Gregg 1972; Johnston 2014). Deposition chronologies within that time frame are available only for the four species of moa (Holdaway *et al.* 2014; Allentoft *et al.* 2014). Radiocarbon ages on others in the non-moa avifauna are only now becoming available (Holdaway 2021a,b; Johnston *et al*. In press). However, as it is apparent that the deposition conditions and local environment have varied significantly over the past 5,000 years (Johnston 2014; Johnston *et*

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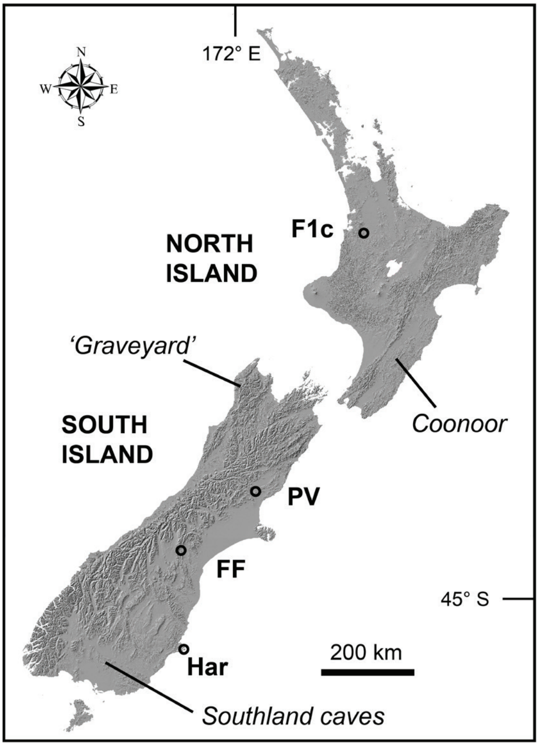

Figure 1. Location of sites for which radiocarbon ages on *Aptornis defossor* (South Island) and *A. otidiformis* (North Island) are now available. F1c, Cave F1c, Waitomo District; PV, Pyramid Valley, North Canterbury; FF, Finsch's Folly Cave, South Canterbury; Har, Harwood, Otago Peninsula. Locations in italics, sites with large samples of *Aptornis* spp. of potential use in testing the LALIA gap hypothesis. Digital Elevation Model courtesy of the School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.

al. submitted), interpretations of the habitat and biology of species in the avifauna depend heavily on when the birds were present. Pyramid Valley is particularly important in this regard because the local environment is better understood from *in situ* studies than for any comparable site in New Zealand (Harris 1955; Moar 1970; Gregg 1972; Burrows 1980a, 1980b, 1989; Holdaway & Worthy 1997; Johnston 2014; Johnston *et al*. In press).

To move beyond the present concentration on moa, radiocarbon ages for individuals of five species of the "smaller megafauna" were measured to investigate relationships between their presence and contemporary conditions (Holdaway 2021a,b; Johnston *et al.* In press; this paper). Of these species, the biology of the adzebills (North and South Island) has attracted recent interest (Holdaway 1989; Holdaway & Worthy 1997; Worthy & Holdaway 2002; Wood *et al.* 2017) because they are the sole representatives of an unusual endemic family in the Gruiformes (rails, cranes, and their relatives) and appear to have been high trophic level predators (Holdaway, in Worthy & Holdaway 2002; Wood *et al.* 2017) in the pre-human ecosystem. Here I report and discuss high resolution accelerator mass spectrometry radiocarbon ages for seven of the 11 adzebills (seven of the 10 held at Canterbury Museum) from Pyramid Valley and also discuss the radiocarbon ages previously available for both the South Island and North Island (*A. otidiformis*) adzebills (Table 1).

All the ages were calibrated using the SHCal20 curve (Hogg *et al.* 2020) in OxCal4.4 (Bronk Ramsey 2009). The probability distributions of the calibrated calendar dates corresponding to the conventional radiocarbon age measurements for the Pyramid Valley birds fell into two groups, separated by a gap of several centuries in the second half of the First Millennium of the Common Era (CE) (Fig. 2A), lessened only slightly by another adzebill age (see below), from a site in South Canterbury (Fig. 2B). The more recent cluster of three was very tight, with two birds having essentially identical dates at the end of the 11th century CE (Table 1, Fig. 2). Both birds were recovered in 1948, but from different pits dug in different parts of the lake bed (Table 1) (Holdaway & Worthy 1997).

The gap in adzebill deposition began just before a period between 536 CE and 660 CE known variously as the "Dark Ages" (Helama *et al.* 2017) and the Late Antique Little Ice Age (Büntgen *et al.* 2016). This period followed two major volcanic eruptions, in 536 and 540 CE, and was characterised by a reduction in insolation and environmental disruption (Büntgen *et al.* 2016; Helama *et al.* 2017; Helama *et al.* 2018). Effects of these eruptions have not been reported before in New Zealand but the gap in deposition characterised below suggests that the adzebill population in the eastern South Island may have indeed been affected. The species could therefore be a useful environmental proxy if more ages were available.

The gap in deposition at Pyramid Valley was nearly three times longer between mean calibrated dates (762 versus 327, 239, and 298 years) than the intervals between the first four ages (Fig. 2C), the difference being significant (One-way ANOVA, $F = 83.79$, $F_{crit} = 18.513$, $P = 0.012$). Before the late First Millennium gap, deposition in Pyramid Valley was regular at 0.37 birds per century ($Y = 0.0037*X + 3.0638$; $R^2 = 0.9595$) (Fig. 2D). Addition of the Finsch's Folly date did not alter the pattern or the regression (Fig. 2D). After the gap, deposition was much more frequent, at 2.7 per century ($Y = 0.0268*X – 26.911$) (Fig. 2C, D). There was no break in the deposition of the four moa taxa at Pyramid Valley concurrent with that of the adzebill (Fig. 2E).

Table 1. Conventional radiocarbon ages and calibrated (SHCal20, (Hogg *et al.* 2020) calendar date ranges for South Island adzebills (*Aptornis defossor*) from Pyramid Valley (this paper), Finsch's Folly Cave and Harwood (Wood *et al.* 2017), and a North Island adzebill (*A. otidiformis*) from F1c Cave, Waitomo (Worthy & Swabey 2002). CRA, conventional radiocarbon age; SD, standard deviation of the measurement; 1σ CI, 68.3% confidence interval for calibrated date.

							Calibrated dates – BCE/CE and BP		
Site	**Square**	**Museum**	**Lab. no.**	**CRA**	**SD**	**$\delta^{13}C$**	**Mean**	**SD**	**1σ CI**
Pyramid Valley	56,58,59	Av6019	UBA42960	2,487	24	-18.6	584 BCE	105	747–419 BCE
Pyramid Valley	VIIA	Av6025	UBA42948	2,217	26	-18.5	257 BCE	75	352–156 BCE
Pyramid Valley	62	Av6016	UBA42946	2,060	26	-19.3	18 BCE	35	56 BCE – 21 CE
Pyramid Valley	VIIB	Av6031	UBA42947	1,810	30	-19.0	280 CE	47	225–338 CE
Pyramid Valley	65	Av6018	UBA42955	1,058	34	-18.5	1042 CE	51	991–1128 CE
Pyramid Valley	48.10e	Av6032	UBA42945	977	22	-19.1	1098 CE	39	1049–1154 CE
Pyramid Valley	48.9A	Av6021	UBA42961	981	28	-19.3	1098 CE	41	1045–1152 CE
Finsch's Folly Cave	-	2013.2	Wk33991	1,645	25	-19.2	465	38	417–522 CE
Harwood, Otago	-	?	Wk23833	737	35	-19.5	1323	41	1280–1381 CE
25% marine	-	-	-	-	-	-	1389	36	1329–1429 CE
50% marine	-	-	-	-	-	-	1508	52	1443–1610 CE
F1c Cave, Layer 8	-	WO63	NZA11601	12,186	60	-19.3	14035 BP	119	14135–13875 BP

The other South Island adzebill mentioned above was from Finsch's Folly pitfall cave, near Kimbell, in South Canterbury (Fig. 1), 197 km southwest of Pyramid Valley (Wood *et al.* 2017). It died just before the start of the Late Antique Little Ice Age/Dark Ages (Fig. 2B). One of several adzebills excavated from the site, its conventional radiocarbon age (Wk33991, measured at University of California at Irvine) of 1,645 ± 25 years Before Present [= 1950 CE]) corresponds to a calibrated (SHCal20 curve) calendar date range (95.4% probability) of 390–535 CE (465 ± 38 CE, mean ± SD) (Table 1, Fig. 2B).

An age (Wk33990, also measured at UC Irvine) on a South Island goose from the same site was nearly identical (at 1,646 ± 25 years BP) (Wood *et al.* 2017). These large flightless birds (an herbivore and a predator) were sympatric there just before the eruptions, and the ensuing climate change. It would have taken some time for the vegetation and other biota to recover after a century of adverse climate, reflected in the interval after the LALIA before the next dates for adzebills from Pyramid Valley in the late 11th century CE (Table 1, Fig. 2).

The only other South Island adzebill dated was from intertidal sand flats at Harwood, on the outer coast of Otago Peninsula (Fig. 1), where the remains may have been eroded from dunes (Wood *et al.* 2017). While not mentioned by the authors, the bone may have been reworked from the Harwood archaeological site (Anderson 1983). The radiocarbon age of 737 ± 35 years BP (Wk23833, measured at UC Irvine) (Table 1) yielded calibrated (95.4%) ranges (if the bird ate only terrestrial organic matter) of 1268–1325 CE (55.1%) and 1346–1390 CE (38.4%), the dual distribution resulting from a major 'wiggle' in the carbon source curve in the 14th century. If, as Wood *et al.* (2017) suggest, the bird included some marine material in its diet, possibly littoral invertebrates, or coastal breeding sea birds, this would of course alter the calibrations so two further calibrations were made, assuming 25% and 50% marine contribution to the diet. The inclusion of 25% marine reservoir material (allowing a local marine offset ΔR of 50 ± 25 years) gave a calendar date of 1388 ± 36 CE; a 50% marine diet moved the calibrated date to 1508 ± 52 CE. Both dates would be unexceptional in the present New Zealand early Polynesian chronology.

The single radiocarbon age presently available for a North Island adzebill (*A. otidiformis*) is on a bird from F1c cave near Waitomo (Worthy & Swabey 2002) (Table 1, Fig. 1), where it lived 14,035 ± 119 calendar years BP. That places it there during the late glacial-interglacial transition, before lowland rain forest returned to the area.

The deposition pattern at Pyramid Valley presented here could be tested by dating further individuals from the site, particularly AMNH 7300, (American Museum of Natural History, New York) which is "an almost complete skeleton" collected by Robert Cushman Murphy in February 1948, and Canterbury Museum Av6033, noted as "not found" by Holdaway & Worthy (1997) and listed as comprising 91+ elements. This bird may have been sent in exchange with another museum, as was a relatively common practice until the 1970s.

Temporal patterns in adzebill distribution could

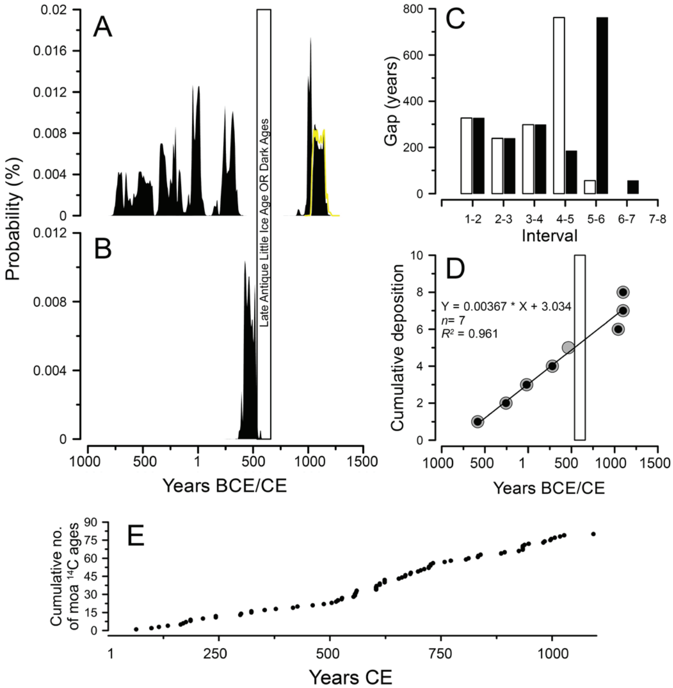

Figure 2. Radiocarbon age calibrated date probability distributions for *Aptornis defossor* in relation to period of the Late Antique Little Ice Age (LALIA). **A**, Seven dates from Pyramid Valley individuals. Note, two almost identical distributions in 11th century CE separated by yellow line. **B**, One age from an individual from Finsch's Folly Cave. **C**, years between mean calibrated dates for (open bars) seven *Aptornis* from Pyramid Valley and (filled bars) including Finsch's Folly cave individual. Interval is spacing between the deposition of individuals. **D**, Deposition (mean calibrated dates against time) of *Aptornis* in Pyramid Valley alone (solid symbols) and including Finsch's Folly cave individual (gray symbols). E, Cumulative deposition of four taxa of moa (Aves: Dinornithiformes) in the Pyramid Valley lake bed (Holdaway *et al*. 2014), showing continuity of deposition through the LALIA period for which no adzebill ages are presently available. Open box, LALIA period.

be better understood by measuring suites of ages on, for example, the 44 adzebills collected from caves in Southland (Worthy 1998). Similarly, ages for the 22 from the Graveyard deposits in the Honeycomb Hill cave system, Oparara, Northwest Nelson (Worthy 1993), would provide a useful adjunct to the small series of ages on moa from there. Again, the North Island species was "relatively common" in the collection removed from the Coonoor pit trap cave in 1914 (Worthy & Holdaway 2002) and ages and other data from those birds might throw some light on when they exercised their apparent preference for ridges, and on other aspects of their biology (Worthy & Holdaway 2002).

The ages on South Island adzebills obtained in this study comprise 70% of those available for the genus. While only hinting at patterns of distribution in spaces and time, in relation to changes in the environment, they highlight the potential value of longer series of ages on species other than moa.

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