# NOTORNIS

# Ornithology of the Southern Pacific



Volume 69 Part 2 June 2022 Journal of the Ornithological Society of New Zealand

## NOTORNIS

**Scope** Notornis is published quarterly by the Ornithological Society of New Zealand Inc. The journal publishes original papers and short notes on all aspects of field or laboratory ornithology, and reviews of ornithological books and literature, student research, and reports of specialist ornithological events. Notornis concentrates on the birds of the ocean and lands of the Southern Pacific, with special emphasis on the New Zealand region. It seeks to serve professional, amateur and student ornithologists alike, and to foster the study, knowledge and enjoyment of birds.

#### Editor: CRAIG T. SYMES

#### Assistant Editor: PAUL M. SAGAR

**Submission of manuscripts** Manuscripts submitted for consideration for publication in *Notornis* should be prepared in accordance with the Instructions to Authors obtainable from the web page *http://osnz.org.nz* (abbreviated instructions are on the inside back cover of each issue). Submissions may be sent by email to The Managing Editor, *Notornis*, E-mail: *Notornis.Editor@gmail.com* 

The Ornithological Society of New Zealand Inc. exists to create a nation-wide study group with individual members or groups working on different aspects of ornithology as suits their interests or circumstances and all contributing to the sum of ornithological knowledge. This aim cannot be achieved in a day or a decade but each year brings a variety of new accomplishments and insights into the biology of birds.

President: BRUCE McKINLAY Secretary: LYNNE ANDERSON

#### The objects of the Society are:

- To encourage, organise and promote the study of birds and their habitat use particularly within the New Zealand region.
- To foster and support the wider knowledge and enjoyment of birds generally.
- To promote the recording and wide circulation of the results of bird studies and observations.
- To produce a journal and any other publication containing matters of ornithological interest.
- To effect co-operation and exchange of information with other organisations having similar aims and objects.
- To assist the conservation and management of birds by providing information, from which sound management decisions can be derived.
- To maintain a library of ornithological literature for the use of members and to promote a wider knowledge of birds.
- To promote the archiving of observations, studies and records of birds particularly in the New Zealand region.
- To carry out any other activity which is capable of being conveniently carried out in connection with the above objects, or which directly or indirectly advances those objects or any of them.

Notornis, Vol. 4, No. 1 (July 1950) (ISSN 0029-4470)

In continuation of Reports and Bulletins (1939-1942) and New Zealand Bird Notes (1942-1950)

Vol. 69, No.2 (June 2022) (Published June 2022)

© *Ornithological Society of New Zealand Inc.* Reproduction of full or part articles for non-commercial, scholastic purposes is permitted. For all other purposes, written permission of the Editor is required.

Full details of the **Ornithological Society of New Zealand** can be obtained from the Secretary, PO Box 834, Nelson 7040, New Zealand, New Zealand or from the Society web page at *https://www.birdsnz.org.nz Notornis* is on-line at *https://www.notornis.osnz.org.nz/publications* 

# NOTORNIS

Journal of the Ornithological Society of New Zealand

Volume 69 Part 2 June 2022

Notornis, Vol. 1, No. 1 (July 1950) (ISSN 0029-4470)

In continuation of Reports and Bulletins (1939-1942) and New Zealand Bird Notes (1942-1950)

Vol. 69, Part 2 (June 2022) (Published June 2022)

#### Editor: CRAIG T. SYMES Assistant Editor: PAUL M. SAGAR

#### Ornithological Society of New Zealand, Inc.

#### President: BRUCE McKINLAY

#### Secretary: LYNNE ANDERSON

#### Treasurer: PAUL GARNER-RICHARDS

The Ornithological Society of New Zealand, Inc. exists to create a nation-wide study group with individual members or groups working on different aspects of ornithology as suits their interests or circumstances and all contributing to the sum of ornithological knowledge. This aim cannot be achieved in a day or a decade but each year brings a variety of new accomplishments and insights into the biology of birds.

#### The aims and objectives of the Society are:

- To encourage, organise and promote the study of birds and their habitat use particularly within the New Zealand region.
- To foster and support the wider knowledge and enjoyment of birds generally.
- To promote the recording and wide circulation of the results of bird studies and observations.
- To produce a journal and any other publication containing matters of ornithological interest.
- To effect co-operation and exchange of information with other organisations having similar aims and objects.
- To assist the conservation and management of birds by providing information, from which sound management decisions can be derived.
- To maintain a library of ornithological literature for the use of members and to promote a wider knowledge of birds.
- To promote the archiving of observations, studies and records of birds particularly in the New Zealand region.
- To carry out any other activity which is capable of being conveniently carried out in connection with the above objects, or which directly or indirectly advances those objects or any of them.

© The Ornithological Society of New Zealand, Inc.

# Continued increase in red-billed gulls (*Larus novaehollandiae scopulinus*) at Otago, southern New Zealand: implications for their conservation status and the importance of citizen science

CHRIS LALAS\* PO Box 31, Portobello, Dunedin, New Zealand

SALLY CARSON New Zealand Marine Studies Centre, Department of Marine Science, University of Otago, PO Box 8, Portobello, Dunedin, New Zealand

LYNDON PERRIMAN 1 Kaleb Place, Helensburgh, Dunedin, New Zealand

**Abstract:** A published national survey of red-billed gulls (*Larus novaehollandiae scopulinus*) in 2015 recorded about 28,000 nests in New Zealand, a 30% decrease in 50 years. We compared nest numbers in 2020 at Otago, south-eastern South Island, with published records for 1992–2011 and 2015. In contrast to trends further north, numbers at Otago have increased but the average annual rate of increase dropped from 6–10% for 1992–2011 to 2% for 2011–2020. Citizen science provided a valuable input in 2020 with records of breeding at previously undocumented urban locations. The about 6,000 nests at Otago in 2020 probably account for 20% of the national total.

Lalas, C.; Carson, S.; Perriman, L. 2022. Continued increase in red-billed gulls (*Larus novaehollandiae scopulinus*) at Otago, southern New Zealand: implications for their conservation status and the importance of citizen science. *Notornis* 69(2): 81–88.

Keywords: red-billed gull, tarāpunga, Larus novaehollandiae scopulinus, Otago, nest numbers, conservation status, citizen science

#### INTRODUCTION

Although widespread and apparently numerous around New Zealand, red-billed gulls (tarāpunga, *Larus* [*Chroicocephalus*] novaehollandiae scopulinus) are currently assigned as 'At Risk–Declining' in the New Zealand Threat Classification System (Robertson *et al.* 2021). Frost & Taylor (2018) recorded about 28,000 nests from a nationwide survey in 2015, and concluded that there has been a likely one-third decrease through 50 years from the estimated 40,000 nests since the only previous comprehensive survey by Gurr & Kinsky (1965).

Contrary to the nation-wide trend of decline, red-billed gull nest numbers increased at Otago, south-eastern South Island, at an average annual increase of 6–10% through 20 years from 1992 to 2011 (Perriman & Lalas 2012). In particular, this increase at Otago corresponded to the decrease 350–500 km further northeast at Kaikoura,

*Received 6 October 2021; accepted 5 January 2022* \*Correspondence: *ithaki@xtra.co.nz* 

the location with the largest number of nests on South Island. Red-billed gulls are highly philopatric: for 10,851 chicks banded at Kaikoura and later found breeding, 99% nested at or within 25 km of Kaikoura (Mills *et al.* 2008). Perriman & Lalas (2012) found only one marked individual from Kaikoura breeding at Otago. They concluded that the paucity of breeding red-billed gulls from Kaikoura indicated that the concomitant population increase at Otago and decrease at Kaikoura was not caused by a southward emigration of birds from Kaikoura.

We have continued the annual counts of redbilled gull nests at Otago begun by Perriman & Lalas (2012). In 2020, we sought additional help to find any previously unknown nesting locations through the development of a citizen science project to encourage the wider community to share information about where the gulls are nesting. Citizen science, where the wider community is engaged in various aspects of the scientific process (Bonney *et al.* 2009), is a well know practice among the birding community and has contributed to much of our knowledge of avian species distributions (Sullivan *et al.* 2014).

Here we update trends for Otago and compare and contrast trends among locations within this region. Frost & Taylor (2018) made two major recommendations for the future monitoring of redbilled gulls: nation-wide trends could be deduced from monitoring several representative locations; and census data should be entered into a central repository. We report the outcomes from Otago for the selection of an appropriate representative location, and review the value of engaging with the wider community to detect previously-unknown nesting locations.

#### **METHODS**

Annual counts of red-billed gull nests at Otago begun by Perriman & Lalas (2012) for 2007 to 2010 were continued through the 10 years from 2011 to 2020. Our annual survey area encompassed a linear distance of about 200 km of the Otago coast from Waitaki River, the Otago regional boundary with Canterbury, south to Nugget Point (Fig. 1). Not all nesting locations were surveyed every year. Consequently, we concentrated our assessment of trends on the three years with reliable nest counts for the entire coast: for 2011 from data presented in Perriman & Lalas (2011); for 2015 from data collected by Chris Lalas and Lyndon Perriman and presented in Frost & Taylor (2018); and for 2020, the most recent survey year.

Red-billed gulls are colonial breeders but the number of nesting locations depends on the designation of minimum distance between neighbouring groups of nests. Frost & Taylor (2018)



**Figure 1.** Maps of South Island, New Zealand, and the Otago coast from Moeraki to Dunedin showing locations mentioned in the text. The Otago coast extends about 250 km from Waitaki River to Makati (Chaslands Mistake).

did not address this issue in their recent assessment of the status of red-billed gulls. Instead, they applied four terms: 'sites', 'locations', 'colonies' and 'aggregations'. They designated locations with <500 nests as 'colonies' but designated locations with ≥500 nests as 'breeding aggregations' because these largest numbers could consist of several closely-spaced 'colonies'. To keep things simple we followed Perriman & Lalas (2012) and used 'location' as the only spatial term: at Otago we allocated nests to the nearest named location, with neighbouring nesting locations at least 1 km apart.

We made nest counts from land, sea or air using eye, binoculars, spotter scope or photographs, with most counts were made from land. Counts from a small boat were done from the vicinity of Doctors Point south along Otago Peninsula to Te Wharekaiwi (Fig. 1). Our surveys in 2020 included a flight on 20 November 2020 from St Clair south to Makati (Chaslands Mistake), the Otago regional boundary with Southland (Fig. 1). This survey provided our only accurate assessment of nest numbers along a linear distance of about 40 km of the Otago coast south of Nugget Point.

Nest counts were allocated to the calendar year of the start of the breeding season. We attempted to time annual nest counts to coincide with maximum nest numbers by following breeding activity at Taiaroa Head and at Katiki Point. Survey dates typically ranged from 20 November to 10 December and were restricted to one count per location with nearby locations counted on the same day. The stage of breeding during the nest count at each location typically ranged from adults sitting tight on nests (presumably on eggs) to chicks aged up to 2-3 weeks. Values for annual counts at each location were presented as a best estimate bounded by a (non-statistical) likely range in an attempt to account for imprecision and ambiguity in counts. Consequently, the values we present as best estimates for nest numbers are approximations rather than exact numbers.

In mid 2020, a citizen science project was created by the Otago Peninsula Trust's education team at the Royal Albatross Centre and funded by the Otago Participatory Science Platform (http://scienceintoaction.nz/current-projects/). The purpose of this project, entitled Red-billed *Gulls—love them or lose them,* was to involve the wider community in caring for and gathering data that could help inform population size and management of the species at Otago. This project was promoted through a range of media (public talks, newspaper and newsletter articles, social media, posters) and the wider community was asked to report sightings of red-billed gulls nesting to inform our understanding about current and historic nesting locations. People were encouraged to share their observations through personal discussions, email, or to upload photographs to the Red-billed Gull Nests in Otago website, a 'project' we created on iNaturalist (https://inaturalist.nz/ projects/red-billed-gull-nests-in-otago). iNaturalist, a citizen science platform for identification and recording of biodiversity, was promoted over eBird as it caters for species-specific projects and is used by a broad range of people. eBird, although well known to avid birders, is not as well-known and typically is used for site-specific multispecies bird counts. We reviewed entries for red-billed gulls at Otago from both eBird and iNaturalist for evidence of nesting. We downloaded and analysed records for red-billed gulls at Otago on 4 June 2021 from the eBird website (http://ebird.org/media/catalog ?taxonCode=silgul2&mediaType=p&regionCode =NZ-OTA&q=Silver%20Gull) and on 24 June 2021 from the iNaturalist website (https://inaturalist. nz/observations?order=asc&order\_by=observed on&place id=6839&subview=table&taxon id=144507). After the completion of our analyses we added photos of breeding locations in Otago for 2020 in the *Red-billed Gull Nests in Otago* iNaturalist project website.

Our calculations for temporal trends in nest numbers followed Perriman & Lalas (2012). Trends were derived from exponential curves of best fit in the form  $N_t \propto e^{\lambda t}$  (where  $N_i$  = number of nests in year t, and  $\lambda$  = average annual exponential rate), and presented as average annual arithmetic rates =  $e^{\lambda}$ -1.

#### RESULTS

#### Trends in nest numbers at Otago

The best estimate for total number of red-billed gull nests from Waitaki River to Nugget Point dropped from 4,898 in 2011 to 4,611 in 2015 then rose to 5,957 in 2020 (Table 1). Nest numbers increased by 22% (=[5,957–4,898]/4,898) overall through the 10 years 2011–2020, an annual increase of 2.2%. We surveyed the Otago coast south of Nugget Point only in 2020 and found red-billed gulls nesting at two locations: False Islet with 27 nests and Frances Pillars, Tautuku Peninsula, with 30 nests (Fig. 1). Consequently, the 5,957 nests documented in Table 1 account for 99% of the Otago total 6,014 nests in 2020.

The number of locations at Otago with at least 1,000 nests increased from one in 2011, Taiaroa Head (at the mouth of Otago Harbour) with 2,423 nests, to three in 2020: Taiaroa Head with 2,800 nests, Katiki Point with 1,315 nests, and Otago Yacht Club Marina (in the Dunedin metropolitan area at the head of Otago Harbour, 19 km southwest of Taiaroa Head) with 1,250 nests. The likelihood of predation by introduced mammals has been mitigated by trapping at each of these three most important sites. Predator control at Taiaroa Head by Department of Conservation and at Katiki Point by Penguin Rescue and Te Rūnanga o Moeraki were instigated before gulls began breeding there (Perriman & Lalas 2012). In contrast, predator control at Otago Yacht Club Marina by Dunedin City Council was instigated in 2017, several years after gulls began breeding there (Aalbert Renergan, pers. comm.).

The distribution and abundance of red-billed gull nests at Otago displayed two major changes since 2011, with both more distinct through the most recent five years. First was an increased numbers of nests concentrated into fewer locations. Here gulls nested at 19 locations in 2011 and in 2015, with respective averages of 258 and 243 nests per location. Nesting subsequently reduced to 10 locations by 2020 with more than doubling in the average size to 596 nests per location (Table 1). The most dramatic change was the initiation and rapid increase in nests at Otago Yacht Club Marina, most likely beginning in 2010 with eight nests on a boat (Benson 2010), and rising by 2020 to 1,250 nests, practically all on a breakwater.

The second major change was a northward movement in both the relative and absolute abundance of red-billed gull nests at Otago from Waitaki River to Nugget Point. The proportion of **Table 1.** Locations and best estimates for annual numbers for red-billed gull nests at Otago from Waitaki River to Nugget Point for 2011 (updated from Perriman & Lalas 2012), 2015 (updated from Perriman & Lalas data in Frost & Taylor 2018) and 2020 (this study); and the maximum best estimate recorded for each location through the 14 consecutive breeding seasons from 2007 to 2020.

Leading	Calendar year	(start of breedi	ng season)		
Location	2011	2015	2020	Maximum	Year
Waitaki River at river mouth	116	0	0	936	2019
Waitaki River 4–5 km from mouth	105	0	0	721	2018
Oamaru Harbour	0	150	0	239	2017
Oamaru town, on buildings	0	0	250	250	2018–20
Kakanui, north end	0	0	48	48	2020
Maukiekie Island	49	0	42	49	2011
Katiki Point	317	535	1,315	1,315	2020
Shag Point	274	304	0	502	2012
Hawksbury Lagoon	25*	25*	25	25	2020
Karitane Peninsula	21	6	0	152	2007
Karitane Beach islets	114	39	0	114	2011
Doctors Point	8	25	0	38	2017
Taiaroa Head	2,423	2,145	2,800	2,863	2019
Onekapua	0	120	0	120	2015
Rerewahine Point	0	120	0	120	2015
O te Ukuuku Tuku	153	60	0	208	2007
Te Wharekaiwi	0	0	0	15	2018
Otago Yacht Club Marina	20*	250*	1250	1,250	2020
Wharekakahu Island	50	0	0	80	2007
Gull Rocks and Harakeke Point	50	18	120	120	2020
Maori Head and Bird Island	15	26	0	499	2007
Lawyers Head	238	274	19	306	2010
St Clair cliff and islet	120	30	0	120	2011
Black Head	280	10	9	420	2018
Tirohanga islets	0	1	79	180	2018
Nugget Point mainland and islets	520	473	0	520	2011
Total number of nests: Best estimate	4,898	4,611	5,957		
Range	Not done	4,252–5,298	5,373–6,751		
Total number of breeding locations	19	19	10		
Average number of nests per location	258	243	596		

\*Not counted: these entries are interpolated from earlier and/or later counts (see text).

nests in North Otago (nests from Waitaki River to Doctors Point) rose from 21% (=1,029/4,898) in 2011 to 28% (=1,680/5,957) in 2020; the proportion of nests in the vicinity of Dunedin and Otago Peninsula (nests from Taiaroa Head to Black Head) rose from 68% (=3,349/4,898) in 2011 to 70% (=4,198/5,957) in 2020; but the proportion of nests in the vicinity of Nugget Point (mainland and islets at Nugget Point and islets at nearby Tirohanga) fell from 11% (=520/4,698) in 2011 to 1% (=79/5,957) in 2020. The corresponding nest numbers and average annual changes in nest numbers through the 10 years 2011–2020 were for North Otago an increase from 1,029 to 1,680 nests at 5.6% annually; for the vicinity of Dunedin and Otago Peninsula an increase from 3,349 to 4,198 nests at 2.5% annually; and for Nugget Point a dramatic decrease from 520 to 79 nests at 18.9% annually.

#### **Inconsistencies in use of locations**

We found that use of red-billed gull nesting locations could vary unpredictably, a feature best indicated by three examples from North Otago (Table 1). First, discontinuous use of locations—we did not find any nests at Waitaki River in our 2015 or 2020 surveys but recorded up to almost 1,000 nests in intervening years on shingle islands at the river mouth and/or 4–5 km upstream. Here an absence of nesting in some years might be related to high water flow. Second, creation of new locations-prior to 2015 we did not record any nesting along the about 55 km of coast between Waitaki River and Moeraki: our first record for nesting here was at Oamaru Harbour in 2015 where nesting was abandoned after only three years; all nesting since 2018 has been about 1 km away on buildings in the town centre (our only records for nesting on buildings). Third, abandonment of established locationsthe large increase in nest numbers at Katiki Point between 2015 and 2020 coincided with the decrease and subsequent cessation of nesting 9 km further south at Shag Point. Our first record for nesting at Shag Point was 274 nests in 2011 (Perriman & Lalas 2012), numbers peaked in 2012 with 502 nests, with the last record in 2018 with six nests (Table 1).

#### Contribution from citizen science

From the eBird website we verified nesting by redbilled gulls at Otago in 44 records from six locations, with records spread through all 11 years from 2010 to 2020. Taiaroa Head (around the Royal Albatross Centre, a major tourist destination) predominated with 38 records of nesting, followed by two records for Katiki Point and one record for each of the other four locations: Oamaru Harbour, Kakanui, Shag Point, and Black Head. From the iNaturalist website we verified nesting by red-billed gulls at Otago in 48 records from four locations, with records spread through 12 of the 17 years from 2004 to 2020. Taiaroa Head again predominated with 41 records of nesting, followed by five records for Katiki Point and one record for each of the other two locations; Lawyers Head and Nugget Point. Our Red-billed Gull Nests in Otago project on iNaturalist failed to raise a substantial response: there were only four entries of which three were trial entries by us. None of the records from eBird or iNaturalist provided nest numbers.

Only one record downloaded from eBird or iNaturalist was not already accounted for in our data for the 14 consecutive years from 2007 to 2020: Robin Corcoran depicted red-billed gulls nesting at Shag Point on 27 October 2010 (http://ebird.org/ checklist/S49839254) but these must have deserted because we (CL) recorded none nesting there during our North Otago census day on 12 November 2010. Consequently, our record for initiation of nesting at Shag Point in 2011 (Perriman & Lalas 2012) is one year late. We have one other definitive record for red-billed gulls deserting nests here. Two years later during our North Otago census day on 25 November 2012 we recorded a total of 491 nests in four groups at Shag Point. Subsequently, on 5 December 2012 we recorded partial desertion (one group of 71 nests) at Shag Point and the creation of a new group of about 20 nests 9 km further north at Katiki Point.

Discussions with the wider community during 2020 revealed two nesting locations at Otago previously unknown to us. One location was relatively small: Aalbert Renergen (Dunedin City Council) reported about 25 nests for Hawkesbury Lagoon Table 1). The other location, Otago Yacht Club Marina with 1,250 nests, turned out to the be the third largest number of nests in Otago in 2020 (Table 1). Although the presence of the birds was well known to the yacht club members, they regarded them as a pest and had no idea anyone might be interested in recording the number of nests. Input from others improved the accuracy of the records for two other locations in 2020: Tom Waterhouse (Department of Conservation) for Oamaru, where red-billed gulls have been nesting on buildings since 2018, and Francesca Cunninghame (Forest & Bird) for Harakeke Point (Table 1).

#### Precision in records of nest counts

Perriman & Lalas (2012) recorded only exact numbers, the best estimates, for red-billed gull nests from Waitaki River to Nugget Point in 2011. We recorded nest numbers for the subsequent two surveys in 2015 and 2020 not only as best estimates but also as likely ranges for each location. The best estimate of 4,611 nests in 2015 was bounded by a likely range from 4,252 to 5,298 nests (Table 1). This equated to a range from 8% less (=[4,252-4,611,4,611) to 15% more (=[5,298-4,611],4,611) than the best estimate. The best estimate of 5,957 nests in 2020 was bounded by a likely range from 5,373 to 6,751 nests (Table 1). This equated to a range from 10% less to 13% more than the best estimate. Here the lower likely limit of 5,373 nests for 2020 was only slightly higher than the upper likely limit of 5,298 nests for 2015, and could indicate that the number of nests did not increase substantially from 2015 to 2020.

The accuracy of our pre-2020 records in Table 1 was further lessened because we had to guess at nest numbers for Hawksbury Lagoon and Otago Yacht Club Marina, the two nesting locations previously unknown to us. For Hawksbury Lagoon we entered a best estimate of 25 nests (range 19–29) from photos and descriptions by Aalbert Renergen for 2020. We retained this best estimate of 25 nests for the backdated entries for 2011 and 2015 but

broadened the range to 0–50 nests. Following advice from Otago Yacht Club members we were able to trace the first record of nesting here to a report in the local newspaper (*Otago Daily Times*) eight nests on a boat moored at the Otago Yacht Club Marina in 2010 (Benson 2010). From this we guessed at 20 nests for the next year, 2011. From a photo and descriptions by Aalbert Renergen for 2017 we concluded that nest numbers had about tripled in the three years from 2017 to 2020. Extrapolating this trend back two years from 2017, we settled on a best estimate of 250 nests for 2015 (Table 1) and went broad with a range of 50–500.

#### Dispersion of nests within locations

The three locations with the largest number of redbilled gull nests at Otago in 2020, Taiaroa Head, Katiki Point and Otago Yacht Club Marina, showed the greatest differences in dispersion of nests. Nests at Taiaroa Head (best estimate 2,800, range 2,615-2,995) were spread through about 2.5 ha (roughly a square with 150 m sides) in 22 distinct groups that varied in size from three (range 3-4) to 602 (range 560-645) nests. Nests at Katiki Point (best estimate 1,315, range 1,076-1,554) were divided into two groups; 539 (range 444–634) were spread through 0.2 ha along about 150 m of the west side of the mainland, and separated by about 150 m from 776 (range 632–920) nests on a 0.3 ha islet 30 m off the southern tip of the mainland. Nests at Otago Yacht Club Marina (best estimate 1,250, range 1,171-1,490) were separated between 1,220 (range 1,156– 1,430) along the outer 280 m of the 350 m southern breakwater bordering the 3.2 ha marina, and 10 (range 5–30) on posts and 20 (range 10–30) on 2–3 boats within the marina.

#### DISCUSSION

The trend of increase in red-billed gull nest numbers at Otago documented by Perriman & Lalas (2012) has continued but the average annual rate of increase has dropped from 6-10% for 1992 to 2011 (Perriman & Lalas 2012) to 2% for 2011 to 2020. Locations from Waitaki River south to Nugget Point totalled 5,957 nests in 2020. This accounted for 99% of the entire Otago regional total of 6,014 nests for the linear distance of about 250 km from Waitaki River to Makati (Chaslands Mistake). Recent patterns of change in nest numbers differed within the region, with North Otago increasing at an average 5.6% annually to 1,680 nests in 2020; the vicinity of Dunedin and Otago Peninsula increasing at an average 2.5% annually to 4,198 nests in 2020; but, further south, the vicinity of Nugget Point decreasing at an average 19.8% annually to 79 nests in 2020.

The continued increase in red-billed gull nests at Otago contrasts with the overall nation-wide decline in New Zealand reported by Frost & Taylor (2018). Comparisons of trends within and between locations are complicated by likely incompatibilities in use of terms. Following Perriman & Lalas (2012), we separated nesting locations by applying a nominal spacing of at least 1 km between locations. In contrast, Frost & Taylor (2018) did not apply a spatial factor and instead regarded nesting locations (or sites) either as individual colonies or aggregations of colonies. These ambiguities preclude detailed comparisons but one trend is clear—the number of locations/colonies with >1,000 red-billed gull nests at Otago tripled from one of six nation-wide in 2015 (Frost & Taylor 2018) to three by 2020.

The importance of citizen science was exemplified by public input leading to our embarrassing discovery of substantial nesting by red-billed gulls at a previously undocumented location. Here in Otago Harbour at Otago Yacht Club Marina, within the Dunedin city metropolitan area, 1,250 nests were hiding in plain sight and accounted for 21% of the Otago total. As observed in other studies (Ward et al. 2015), the citizen science data proved to be useful to complement existing data sets and filling in data gaps when other surveys are absent. As scientists often concentrate their biodiversity survey efforts in natural habitats (Martin et al. 2012), it was interesting to note that the two nesting locations we missed were in urban settings, highlighting where the contribution of citizen science may be most valuable (Sánchez-Clavijo et al. 2021).

We found that personal communication was more effective than the on-line platforms for gathering information from the public. This in part was due to our unfamiliarity with the specific iNaturalist 'project' function to record nesting locations of red-billed gulls in Otago. For for a 'project' to be effective, participants need to know it exists (Kirchhoff et al. 2021) and so we plan to increase awareness with more-targetted promotion through media. The lack of engagement in the 'project' function may also reflect the observation that participants are less likely to engage with more complex and lengthy data collection and entry protocols (Davis et al. 2019). Feedback through the 'journal' function on iNaturalist has been shown to be an effective way to keep project participants updated about the results of a project (Kirchhoff et al. 2021) and so we plan to implement this in the future. Uploading of the data to iNaturalist ensures open access to both scientists and citizen scientists, a critical component to the success of citizen science projects (Bonney et al. 2009).

Two features of chronological trends among red-billed gull nesting locations at Otago precluded meaningful intra-regional or inter-regional comparisons among individual locations. First, our records dating back to 1992 (Perriman & Lalas 2012) indicate that few if any locations are used consistently each year. Second, through recent years the increasing number of nests have condensed into fewer locations, thus inflating the growth rate at locations with the largest number of nests. Frost & Taylor (2018) recommended that nation-wide trends for the red-billed gull population could be deduced from monitoring several representative locations. Unfortunately, the lack of consistency in trends among locations means that Otago lacks this shortcut. Instead, for Otago we recommend using total nest numbers from Waitaki River to Nugget Point (99% of Otago total nests) for inter-regional comparisons.

Predation by introduced mammals has been considered a major cause for the decline in redbilled gulls nation-wide (Frost & Taylor 2018), and more specifically for the decline at Kaikoura beginning in 1994 (Mills et al. 2018), and both studies emphasised the importance of predator control. Predation has not been a major problem at Otago since control measures were implemented at the important nesting locations but this alone is unlikely to account for increases at Otago coinciding with decreases further north. Frost & Taylor (2018) attributed the greatest contribution towards the nation-wide decline in red-billed gulls since the 1960s to massive decreases in nest numbers at Three Kings Islands and Mokohunau Islands off northern North Island. Both these island groups now lack predatory mammals: none were introduced to Three Kings Islands (Bellingham et al. 2010) and Mokonau Islands only had kiore (Rattus exulans), with the last eradicated 30 years ago (McFadden & Greene 1994). Consequently these northern declines in nest numbers cannot be attributed to predation.

The recent update for the conservation status of New Zealand birds added 'Climate Impact' as a potential cause for decreases in populations and allocated this as the only qualifier for the national population decline in red-billed gulls (Robertson *et al.* 2021). Perriman & Lalas (2012) found that increases at Otago coincided with changes in the marine environment and so continued monitoring of red-billed gulls here may prove worthwhile as a test for the effect of climate change on New Zealand seabirds.

#### ACKNOWLEDGEMENTS

This research was supported in part by Curious Minds (NZ Ministry of Business, Innovation and Employment, the Ministry of Education, and the Office of the Prime Minister's Chief Science Advisor) through the Otago Participatory Science Platform, and the Otago Peninsula Trust. Special thanks to Francesca Cunninghame (Forest & Bird), Aalbert Renergen (Dunedin City Council), and Tom Waterhouse (Department of Conservation) for their contributions towards nest numbers, and to Otago Yacht Club members for their gull recollections. Chris Lalas thanks Sanford Ltd for logistic support and Adrian Hodgson for assistance on field trips. We thank the reviewers for their comments.

#### LITERATURE CITED

- Bellingham, P.J.; Wiser, S.K.; Wright, A.E.; Cameron, L.J.; Forester, L.J. 2010. Disperser communities and legacies of goat grazing determine forest succession on the remote Three Kings Islands, New Zealand. *Biological Conservation* 143: 926–938.
- Benson, N. 2010. Trimaran's feathered shipmates. Otago Daily Times 20 December 2010.
- Bonney, R.; Ballard, H.; Jordan, R.; McCallie, E.; Phillips, T.; Shirk, J.; Wilderman, C.C. 2009. Public participation in scientific research: defining the field and assessing its potential for informal science education. Washington, Center for Advancement of Informal Science Education.
- Davis, A.; Taylor, C.E.; Martin, J.M. 2019. Are proecological values enough? Determining the drivers and extent of participation in citizen science programs. *Human Dimensions of Wildlife* 24: 501–514.
- Frost, P.; Taylor, G. 2018. The status of the red-billed gull (*Larus novaehollandiae scopulinus*) in New Zealand, 2014–2016. *Notornis* 65: 1–13.
- Gurr, L.; Kinsky, F.C. 1965. The distribution of breeding colonies and status of the red-billed gull in New Zealand and its outlying islands. *Notornis* 12: 223–240.
- Kirchhoff, C.; Callaghan, C.T.; Keith, D.A.; Indiarto, D.; Taseski, G.; Ooi, M.K.J.; Le Breton, T.D.; Mesaglio, T.; Kingsford, R.T.; Cornwell, W. K. 2021. Rapidly mapping fire effects on biodiversity at a large-scale using citizen science. *Science of The Total Environment* 755: 142348.
- McFadden, I.; Green, T. 1994. Using Brodifacoum to eradicate kiore (*Rattus exulans*) from Burgess Island and the Knights Group of the Mokohinau Islands. *Science & Research Series* 19. Wellington, Department of Conservation.
- Martin, L.J.; Blossey, B.; Ellis, E. 2012. Mapping where ecologists work: biases in the global distribution of terrestrial ecological observations. *Frontiers in Ecology and the Environment* 10: 195–201.
- Mills, J.A.; Yarrall, J. W.; Bradford-Grieve, J.M.; Morrissey, M.; Mills, D.A. 2018. Major changes in the red-billed gull (*Larus novaehollandiae scopulinus*) population at Kaikoura Peninsula, New Zealand; causes and consequences: a review. *Notornis* 65: 14–26.

- Mills, J.A.; Yarrall, J.W.; Bradford-Grieve, J.M.; Uddstrom, M.J.; Renwick, J. A.; Merilä, J. 2008. The impact of climate fluctuation on food availability and reproductive performance of the planktivorous red-billed gull *Larus novaehollandiae scopulinus*. *Journal of Animal Ecology* 77: 1129–1142.
- Perriman, L.; Lalas, C. 2012. Recent increase in population size of red-billed gulls (*Larus* novaehollandiae scopulinus) at Otago, southern New Zealand. Notornis 59: 138–147.
- Robertson, H.A.; Baird, K.; Elliott, G.P.; Hitchmough, R.A.; McArthur, N.J.; Makan, T.D. Miskelly, C.M.; O'Donnell, C.F.J.; Sagar, P.M.; Scofield, R.P.; Taylor, G.A.; Michel, P. 2021. Conservation status of birds in Aotearoa New Zealand, 2021. New Zealand Threat Classification Series 36. Wellington, Department of Conservation.

Sánchez-Clavijo, L.M.; Martínez-Callejas, S.J.;

Acevedo-Charry, O.; Diaz-Pulido, A.; Gómez-Valencia, B.; Ocampo-Peñuela, N.; Ocampo, D.; Olaya-Rodríguez, M.H.; Rey-Velasco, J.C.; Soto-Vargas, C.; Ochoa-Quintero, J. M. 2021. Differential reporting of biodiversity in two citizen science platforms during COVID-19 lockdown in Colombia. *Biological Conservation* 256: 109077.

- Sullivan, B.L.; Aycrigg, J.L.; Barry, J.H.; Bonney, R.E.; Bruns, N.; Cooper, C.B.; Damoulas, T.; Dhondt, A.A.; Dietterich, T.; Farnsworth, A. 2014. The eBird enterprise: an integrated approach to development and application of citizen science. *Biological Conservation* 169: 31–40.
- Ward, E.J., Marshall, K.N.; Ross, T.; Sedgley, A.; Hass, T.; Pearson, S.F.; Joyce, G.; Hamel, N. J.; Hodum, P. J.; Faucett, R. 2015. Using citizenscience data to identify local hotspots of seabird occurrence. *PeerJ* 3: e704.

# Hosts of the long-tailed cuckoo (*Eudynamys taitensis*) and museum specimens of the cuckoo's egg

B.J. GILL Auckland War Memorial Museum (retired), Auckland, New Zealand

**Abstract:** The description of the long-tailed cuckoo's (*Eudynamys taitensis*) egg was uncertain until the 1930s. Edgar Stead published evidence in 1936 that it was white with darker (red-brown or purplish) speckles, and therefore mimetic in colour and pattern (as well as size) to the eggs of many small song-birds in New Zealand. In reviewing eggs in museum collections, I find that only one (Auckland Museum LB8968) is certainly long-tailed cuckoo, and only eight other eggs are "probable" (with another eight "possible"). Average dimensions of the nine most likely eggs are 24.1 x 17.4 mm. Field observations of long-tailed cuckoo nestlings, or dependent fledglings receiving food, mostly involve whiteheads, yellowheads, and brown creepers (all in the genus *Mohoua*, Mohouidae), the principal biological hosts. There are single credible reports of a long-tailed cuckoo nestling being raised in a nest of South Island robin (*Petroica*; 1880s), silvereye (*Zosterops*; 1946, plus a vague record from the 1980s), and fantail (*Rhipidura*; 1963). The scarcity of secondary hosts is extremely rare. Seven other New Zealand song-birds have been cited as hosts of the long-tailed cuckoo, nestling being raised by the species concerned.

Gill, B.J. 2022. Hosts of the long-tailed cuckoo (*Eudynamys taitensis*) and museum specimens of the cuckoo's egg. *Notornis* 69(2): 89–98.

Keywords: brood-parasitism, passerine hosts, egg morphology, museum collections, historical records, New Zealand

#### INTRODUCTION

The migratory long-tailed cuckoo (koekoea, *Eudynamys taitensis* Cuculidae: Cuculinae) occurs seasonally on tropical and temperate islands of the south-west Pacific in a fan-shaped range extending some 11,000 km from west to east (Gill & Hauber 2012) and about 7,000 km from north to south. However, it breeds only in the far south of the range (New Zealand) where it parasitises principally the three species of *Mohoua* (Family Mohouidae), i.e. whitehead (*M. albicilla*) in the North Island, and in

*Received 7 December 2021; accepted 15 January 2022* Correspondence: *adiantum@outlook.co.nz*  the South Island, yellowhead (*M. ochrocephala*), and brown creeper (*M. novaeseelandiae*) (Higgins 1999).

The breeding of the long-tailed cuckoo remains poorly known. The events attending laying, hatching, nestling development, and eviction of eggs or nest-mates, are either unknown or have been seen and described at very few nests. This is mainly because the mohouid hosts nest in dense forest and scrub. In these habitats, systematic study of nesting is difficult and passing birdwatchers seldom find nests casually. The best information on the cuckoo's breeding comes from Elliott (1990), who collected important incidental notes on parasitism during a study of yellowheads. However, only six of 95 yellowhead nests were parasitised, and observations were restricted by the nests being in cavities and often in tall trees. An enquiry to the Nest Record Scheme in November 2021 revealed that there were no records for longtailed cuckoo.

Bad luck has perpetuated our ignorance of longtailed cuckoos, because two studies that might have shone light on parasitism did not. In the most detailed study of brown creepers (Cunningham 1985), 52 nests were observed near Kaikoura during 1979–1982, but long-tailed cuckoos were absent or rare in the area (Hunt & Gill 1979; Powlesland 1979) and so no parasitism was reported. In a study of whiteheads on Little Barrier Island during 1984-1989 (McLean & Gill 1988; Gill & McLean 1992), 72 nests were found in low-elevation areas in the southwest of the island. Unfortunately, none of these nests was parasitised despite whiteheads being seen feeding long-tailed cuckoo fledglings at higher elevations in the same summers (McLean 1988).

Long-tailed cuckoo eggs are rare in museum collections. Egg collections in New Zealand museums are fairly small, comprising c. 11,000 eggs or clutches of local and foreign species as against 30,000 study-skins (Gill 2006). Egg collections are low-quality for New Zealand native birds, containing many isolated eggs or partial clutches salvaged from nests that failed. The best New Zealand egg material was assembled by a handful of private collectors whose collections have now, thankfully, passed into public ownership. The Edgar Stead collection (Canterbury Museum) contains seven probable or possible long-tailed cuckoo eggs. At Auckland Museum, two small collections, those of J.C. McLean (Gill & Taylor 2010) and G.A. Buddle (Gill & Taylor 2012) contain no long-tailed cuckoo eggs. Even in the Stead collection there is no instance of an entire host clutch, with an interposed long-tailed cuckoo egg, having been collected. We do not yet have an image of a host clutch containing the parasite's egg (unless we photograph Egg 21 and the two eggs found with it – see Results).

There are literature records, reviewed by Cunningham (1949) and McLean (1988), suggesting that the long-tailed cuckoo has hosts in passerine families other than the Mohouidae. Brooker & Brooker (1989) used the term "biological host" for a successful host species for which there are multiple, independent records of parasitism involving more than one observer, more than one location, and more than one year. Records of parasitism may be egg records, nestling records (including those followed through to fledging) and records of fledglings being fed.

One aim of this study was to again re-assess the evidence for the long-tailed cuckoo's hosts. The cuckoo is believed to have a mimetic egg, i.e. whitish with dark (usually reddish-brown) speckling (Stead 1936), which is a good match for the eggs of many New Zealand native song-birds. Another aim of the study was to re-examine the evidence for what the cuckoo's egg looks like, and in doing that make an inventory of museum specimens.

#### METHODS

I searched the literature to trace back to their earliest sources all records of host species and eggs of the long-tailed cuckoo. To locate long-tailed cuckoo eggs in museum collections I searched on-line catalogues or made enquiries to museum curators. I visited collections to examine all such eggs in New Zealand museums. I listed in chronological order the more detailed published descriptions of eggs reported to belong to long-tailed cuckoos (including obvious mis-identifications). They are given consecutive numbers to form a catalogue. I have incorporated into this list the long-tailed cuckoo eggs preserved in museum collections at Auckland War Memorial Museum (AIM), Museum of New Zealand Te Papa Tongarewa (NMNZ, Wellington), Canterbury Museum (CMC, Christchurch) and The Natural History Museum (BMNH, Tring, United Kingdom). Many of the likely long-tailed cuckoo eggs that Stead (1936) examined and described, were collected or obtained by him, and several of his descriptions of individual eggs now cross-reference to CMC specimens. Where a museum egg did not have a published description or measurement, I have given these here from my own examination (measurements with vernier callipers).

Ås far as I can tell, there are no long-tailed cuckoo eggs at Otago Museum (Dunedin), or at the principal natural history museums in Sydney (Australian Museum), Melbourne (Museum Victoria), New York (American Museum of Natural History), Washington D.C. (National Museum of Natural History) or Paris (Muséum National d'Histoire Naturelle). It seems unlikely that any genuine long-tailed cuckoo eggs are held overseas.

The early writers on New Zealand ornithology often reported second-hand accounts of bird observations from correspondents. Some of these early reports were imprecise, inaccurate, or unlikely to be true. Bogert (1937) credited Stead (1936) with the first credible descriptions of the eggs of the long-tailed cuckoo and considered previous accounts erroneous. I have annotated each egg in the following list as "rejected", "possible", "probable" or "certain" in terms of its likelihood of belonging to a long-tailed cuckoo. "Rejected" eggs seem obviously wrong for long-tailed cuckoo. "Possible" is for eggs without good information to support such an attribution (e.g. evidence for the identity of the nest-maker and details of laying). "Probable" is where the visual appearance of the egg seems right for long-tailed cuckoo and the nesting observations or circumstances add plausibility. The only "certain" egg was recovered from the oviduct of a dead cuckoo.

#### RESULTS

#### Catalogue of putative long-tailed cuckoo eggs

The following list shows that of eggs ascribed to long-tailed cuckoo, eight are possible (Eggs 12–14, 16–20), eight are probable (Eggs 7–11, 15, 21, 22) and only one is certain (Egg 23).

**Eggs 1 & 2.** Ramsay (1865) gave one description common to two eggs he had, one from a bellbird (*Anthornis melanura*) nest and one from a New Zealand fantail (*Rhipidura fuliginosa*) nest. They were "of a pale yellowish salmon-colour, freckled indistinctly with marks of a deeper hue" and "10 lines long by  $7\frac{1}{2}$  lines broad" (21.2 x 15.9 mm). Accuracy must have suffered if one description and set of measurements could apply to two eggs. The dimensions seem too small for the cuckoo. REJECTED.

**Egg 3.** Buller (1873: 76; 1888, 1:131) received an egg "some years ago" from Rev. R. Taylor (Wanganui; no host species stated) who had obtained it from someone else. It was "almost spherical in shape, with a slightly rough or granulate surface" and "of a pale buff or yellowish-brown colour". It measured 1:25 inches long by 1:15 inches broad (31.8 x 29.2 mm), and was "now in the Colonial Museum", Wellington (NMNZ; currently missing). Buller (1873: 76) admitted that the "authenticity cannot be considered quite certain". Potts (1885) referred to the same egg. It seems too big to be a long-tailed cuckoo's and is the wrong colour; Stead (1936) thought it was probably a pullet's egg. REJECTED.

**Egg 4.** Buller (1888, 1:131) referred to an egg in Canterbury Museum (currently missing) from a grey warbler (*Gerygone igata*) nest (Oamaru, Mr Smith, Nov. 1885) that "corresponds exactly with mine", i.e. Egg 3, "except that it is slightly narrower". REJECTED.

**Egg 5.** Nehrkorn (1879) reported an egg in the Godeffroy Museum (Hamburg, Germany) from Mr. Kleinschmidt (no locality). It measured  $35 \times 21$  mm, and was very shiny, olive-brown, with a wreath of black-smeared spots at the blunt end, and pear-shaped. Finsch (1901) clarified that this

egg was from Fiji, which makes it unlikely to be a long-tailed cuckoo's. Timmermann (1931) corrected the size to 32.9 x 20.5 mm and the location to Viti Levu. REJECTED.

**Egg 6.** Oates & Reid (1903) listed an egg in BMNH (1902.10.25.502) from the collection of W. Radcliffe Saunders. They described it as "spherical in shape, rough in texture, and pale buff in colour". Oates & Reid gave the size as  $1.1 \times 0.85$  inches (27.9 x 21.6 mm). Schönwetter (1964) considered this to be a dwarf egg of the domestic chicken and gave the dimensions as  $25.3 \times 21.4$  mm. I examined the egg at Tring (2011) and confirmed Schönwetter's measurements. The egg is marked "From Potts colln. 91" indicating its New Zealand origin from T.H. Potts. REJECTED.

**Egg 7.** Fulton (1904) received a nest of the tomtit (*Petroica macrocephala*), containing four fresh eggs, collected in the Milford–Te Anau area by the Ross brothers. Three eggs were small ( $0.75 \times 0.55$  inches = 19.1 x 14.0 mm), and tomtit eggs are about 18 x 15 mm (Heather & Robertson 1996). The fourth, which Fulton surmised to be a long-tailed cuckoo's, was larger ( $0.94 \times 0.7$  inches =  $23.9 \times 17.8$  mm). It was "white with purplish-brown speckles, becoming thicker and darker at the larger end" and "ovoido-elliptical" in shape. Stead (1936) accepted this record. PROBABLE.

**Egg 8.** Stead (1936) found an egg in a deserted whitehead nest (Silverstream; 19 Sep. 1909) that he suspected was a long-tailed cuckoo's. The "ground-colour was creamy white with purplish brown markings more thickly distributed at the larger end". It was measured by Stead: 23.5 x 17.0 mm. CMC AV4991 (Stead no. 234d). PROBABLE.

**Egg 9.** CMC AV4988 (Stead no. 234h); white with reddish-brown blotches concentrated at the blunter end; Kapiti Island; coll. A.S. Wilkinson 1936 from a whitehead nest. Part of the shell is missing but the egg is still measurable at about 25 x 17 mm. PROBABLE.

**Egg 10.** Stead (1936) observed a brown creeper nest with two eggs (Jacky Lee Island, off Stewart Island); "last year" = Dec. 1932. One egg ( $19.5 \times 15.0$  mm; CMC AV4496, Stead no. 284c) was assumed to be a creeper's. Brown creeper eggs are about  $18.5 \times$ 14 mm (Heather & Robertson 1996). The other egg (22.8 x 17.5 mm; coll. 16 Dec. 1932) was assumed to be a long-tailed cuckoo's; this is CMC AV4993 (Stead no. 234a). The latter was "creamy white in groundcolour with purplish brown markings – more numerous at the larger end and with underlying markings of grey". PROBABLE.

**Egg 11.** Stead (1936) found a deserted brown creeper nest with one egg when in February (= Feb. 1933) he re-visited Jacky Lee Island. The egg (23.5 x 17.0 mm) was assumed to be a long-tailed cuckoo's. It was similar in colouring to Egg 10, but the "creamy tint of its ground colour was slightly more pronounced". CMC AV4994 (Stead no. 234e). PROBABLE.

**Egg 12.** CMC AV4990 (Stead no. 234g); white with reddish-brown and grey blotches concentrated at the blunter end; "Dunedin Museum"; 24.1 x 17.8 mm. Identity of source nest not recorded. Little observational information to support its identity. POSSIBLE.

**Egg 13.** CMC AV4989 (Stead no. 234f); similar colour to Egg 12; Dunedin; coll. A. Portman; 22.5 x 18.0 mm. From a European greenfinch (*Carduelis chloris*) nest. Stead (1936) reported three cuckoo eggs that Mr Portman obtained in a Dunedin gully, two from song thrush (*Turdus philomelos*) nests and one from a greenfinch nest. Greenfinch eggs are about 22 x 14.5 mm (Heather & Robertson 1996). Little observational information to support its identity. POSSIBLE.

**Egg 14.** CMC AV4992 (Stead no. 234b); cream with red-brown speckles; no data; 26.3 x 16.9 mm. No observational information to support its identity. POSSIBLE.

**Egg 15.** Cunningham (1949) described an egg from a deserted silvereye (*Zosterops lateralis*) nest (Wairarapa) as "very pale pink in ground colour, slightly darker at the larger end, thickly blotched at that end and more sparingly at the smaller end, with purplish brown; size, 24 x 17.8 mm". Silvereye eggs are immaculate pale blue and about 17.5 x 13 mm (Heather & Robertson 1996), so a larger, spotted egg in a silvereye's nest could well be a long-tailed cuckoo's. PROBABLE.

**Egg 16.** Stidolph (1949) gave measurements of an egg from a deserted silvereye nest (Wairarapa) as  $23.7 \times 18.0 \text{ mm}$  (no description of colour and pattern). Although Stidolph was a trusted observer, he provided little observational information on the nest or egg to support their identities. This was a different egg from Egg 15 (further details given under 'Secondary hosts' below). POSSIBLE.

**Egg 17.** CMC AV17568; shape rounded, background colour pinkish with red-brown speckles and blotches concentrated at the blunter end; Kokiri, Westland; coll. J.G. Penniket Jan. 1958; 20.8 x 16.9 mm (reported as Jan. 1957 in Anon. 1958: 199). Found addled in abandoned tomtit nest with fragments of tomtit eggshell "thinner, glossier white, spots greyer and browner" (CMC label). Tomtit eggs are 18 x 15 mm (Heather & Robertson 1996), so this egg is not much bigger. POSSIBLE.

**Egg 18.** NMNZ OR7258; white with reddish-brown speckles; no data; 23.2 x 17.6 mm. No observational information to support its identity. POSSIBLE.

**Egg 19.** NMNZ OR11260; white with reddish-brown speckles; York Bay, Wellington; coll. P.J.H. Purvis 26 Nov. 1964; 22.4 x 17.3 mm. No observational information to support its identity. POSSIBLE.

**Egg 20.** CMC AV25598; white with a slight bluegreen tinge, grey and red-brown blotches and speckles concentrated at the blunter end; no data; Robin Francis-Smith colln., pres. 1971; 23.1 x 15.7 mm. No observational information to support its identity. POSSIBLE.

**Egg 21.** NMNZ OR17353; pale, speckled with red-brown, particularly towards the blunter end; Orongorongo Valley, Wellington; coll. P.C. Bull 16 Feb. 1973; 25.0 x 17.5 mm. From an abandoned whitehead nest containing three eggs. The other two eggs, presumed to be whitehead's, were also collected. One is pale beige-pink without spots; 19.4 x 14.8 mm. The other is pale without evident markings; damaged, but *c*. 21 mm long. Whitehead eggs are about 20 x 15 mm (Heather & Robertson 1996). PROBABLE.

**Egg 22.** AIM LB864; white with brown and grey speckles spread over most of the egg; Urewera; coll. 2 Feb. 1978; 24.2 x 18.0 mm (Fig. 1). From a whitehead nest; identified by S.M. Reed. PROBABLE.

**Egg 23.** AIM LB8968; white with small brown speckles mostly towards the blunter end; East Coast, North Island; no collector or date (but before May 1998); 25.0 x 16.6 mm. I removed this egg from the oviduct of an adult long-tailed cuckoo during dissection (spread wing of this female preserved as LB8981). The bird was received frozen and unlabelled in April 1998 from the East Coast Conservancy, Department of Conservation. The abdomen had been torn open during collision-trauma or predation. I checked the gonads for



**Figure 1.** A probable egg of the long-tailed cuckoo taken from a whitehead's nest. Egg 22 (AIM LB864); 24.2 x 18.0 mm. Photo: B. Gill.

sexing and discovered the egg in the oviduct, cracked on one side along the long axis. After cleaning and drying the egg I stabilised it by gluing the broken edges with a stiff solution of Paraloid B-72 dissolved in acetone. This egg seems pale and poorly spotted, likely because its time in the oviduct was insufficient for full pigmentation. One end is very pointed. It is currently the only long-tailed cuckoo's egg whose identity is beyond doubt (Fig. 2). CERTAIN.

#### General description and size of eggs

Stead (1936), who saw many long-tailed cuckoo eggs while they were fresh, summed up their appearance as "ground colour white, tinted with cream or creamy pink, freely spotted and streaked with purplish-brown and having underlying spots of grey, the markings being larger and more numerous at the larger end". He described the egg as having a thick, hard shell and a surface that is smooth and slightly lustrous.



**Figure 2.** An undoubted egg of the long-tailed cuckoo removed from the oviduct of an adult during dissection. Egg 23 (AIM LB8968); 25.0 x 16.6 mm. This egg probably had insufficient time in the oviduct to develop full spotting. Photo: B. Gill.

In his text, Stead (1936) gave measurements of *three* presumed long-tailed cuckoo eggs (Eggs 8, 10 and 11) in the course of describing them. Eggs 8 and 11 had the same dimensions. He summed up at the end by giving measurements of *four* eggs. Unfortunately, things do not match up. Egg 8 or 11 is given only once (why not twice, making *five* eggs?). Egg 10's length and width are listed, but measurements for two other eggs are unexplained and not previously mentioned. There may be errors in this final listing, so, to be conservative, I have attributed only three egg measurements to Stead (1936), as given in his text describing each egg.

The nine probable or certain long-tailed cuckoo eggs (Eggs 7–11, 15 and 21–23) have a mean length of 24.1 mm (sd = 0.78, range = 22.8–25.0), and a mean width of 17.4 mm (sd = 0.48, range = 16.6–18.0). Figure 3 plots the dimensions of these eggs alongside the approximate values for eggs of known and potential hosts. The cuckoo eggs cluster tightly with similar dimensions. Long-tailed cuckoo eggs are close in size to those of the yellowhead and South Island robin, but larger than those of the whitehead and brown creeper. They are much larger than silvereye or fantail eggs.

#### **Principal hosts**

There is good evidence for the three species of *Mohoua* being regular "biological hosts" (as used by Brooker & Brooker 1989) of the long-tailed cuckoo. This evidence includes the feeding of nestling cuckoos. Observations of the feeding of fledgling cuckoos do not prove parasitism (discussed further below). However, parasitism is the most likely explanation when fledgling feeding by the three mohouids is seen, and such records reinforce the conclusion that parasitism of these species is the norm throughout New Zealand.



Figure 3. Length and width (mm) of nine probable or certain eggs of long-tailed cuckoos (black diamonds; see text). Two eggs have the same dimensions so only eight symbols show. The approximate sizes (from Heather & Robertson 1996) of the eggs of known and potential hosts are shown: fantail (Fan), silvereye (Sil), brown creeper (BC), whitehead (WH), yellowhead (YH), and South Island robin (SIR).

#### Whitehead

Fulton (1904: 141) had a third-hand report of a cuckoo nestling in a whitehead's nest. Wilkinson (1927) stated that on Kapiti Island the whitehead was the "principal victim" of the long-tailed cuckoo and the only species seen feeding the parasite. In February 1925 he had climbed to a whitehead nest and found "a young Long-tailed Cuckoo the sole occupant, and even at this early stage nearly filling the nest" (Wilkinson 1927). Again on Kapiti, a whitehead nest with a long-tailed cuckoo nestling as the sole occupant was observed during 16 days in January 1936 until it fledged (Wilkinson & Stidolph 1947). Wilkinson & Wilkinson (1952) provided two photographs of a well-feathered cuckoo being fed in the nest by a whitehead on Kapiti (one of these images was also reproduced in Oliver 1955: 540). On Little Barrier Island in three summers (1984– 1987), McLean (1988) found one late-term cuckoo nestling and 16 cuckoo fledglings. All were fed by whiteheads, showing that this species is the principal host on the island. A fledgling cuckoo was being fed by whiteheads at Mt Climie, Upper Hutt, in April 1991 (Taylor & Parrish 1992), and at Boundary Stream, Hawkes Bay, in February 2003 (Parrish 2006).

#### Yellowhead

Fulton (1904: 141) had a report from R. Riddle of Orepuki (Southland) of a young long-tailed cuckoo in a yellowhead's nest. Elliott (1990) provided details of parasitism at six yellowhead nests at Knobs Flat, Eglinton Valley, Fiordland.

#### Brown creeper

R. Riddle of Orepuki sent a report to Fulton (1904: 141) of a brown creeper feeding a young long-tailed cuckoo. Edgar Stead and Robert Wilson visited Jacky Lee Island, off Stewart Island, in December 1932 (Wilson 1959), where brown creepers and long-tailed cuckoos were common. Wilson found a creeper nest containing a "half fledged" cuckoo being fed by creepers (Stead 1936; Wilson 1959). One of them found a brown creeper's nest with two eggs, one of which (Egg 10) they considered to be a long-tailed cuckoo's. The eggs were being incubated but were soon deserted with the clutch remaining at two. In February 1933, Stead (1936) was on the island again and found a deserted brown creeper's nest with one egg (Egg 11) that he considered to be a cuckoo's from the similarity in size and colouring to Egg 10.

In March 1978, Paddy Latham saw a juvenile long-tailed cuckoo being fed by a pair of brown creepers at Franz Josef (Sibson 1978). In January 1988, Ralph Powlesland watched two long-tailed cuckoo fledglings, each at a separate location on Codfish Island, being fed by brown creepers (McLean 1988; R.G. Powlesland, *pers. comm.* to BJG Nov. 2021). In February 1991, Colin O'Donnell saw three separate cuckoo fledglings being fed by brown creepers (and another by yellowheads) at Knobs Flat (O'Donnell & West 1992).

#### Secondary hosts

For three other species there is credible evidence that nestling long-tailed cuckoos were once or twice seen in nests, but no case gave evidence of the species raising the cuckoo to fledging and independence. These species cannot be considered biological hosts. The records are from the 1880s, 1946 and 1963, with an additional vague report from before 1988.

#### New Zealand fantail

Ramsay (1865) reported that a Mr Huntley in December 1862 forwarded him a fantail nest, probably from Wellington, containing four fantail eggs and an egg said to belong to a long-tailed cuckoo. We might discount this dubious record had not Roberts (1963) published a stunning monochrome photograph that he took at Pye's Pa Bush, near Tauranga, showing a fantail feeding a long-tailed cuckoo nestling in what is clearly a typical fantail nest. The fantail, presumably with food in its bill, is advancing towards the open gape of the chick. The cuckoo nestling is well-feathered, at least two-thirds of the way through its nestling period, and shows the pale dorsal spots typical of an immature long-tailed cuckoo. The gape is much larger than a fantail chick's would be. The cuckoo fills the nest and appears to be the sole occupant. Unfortunately, Roberts, who perhaps visited the nest only once, provided no details beyond the photo caption.

#### South Island robin

Buller (1888, 1:131) reported observations by W.W. Smith of an "undoubted case" of an egg of the longtailed cuckoo being hatched out by a South Island robin Petroica australis. On 29 October (no year or locality given) the nest had two eggs, and four eggs on 31 October. On 3 November, Smith found an "egg of Eudynamis taitensis placed among the rest" making five eggs. By 24 November, all eggs had hatched, the young cuckoo was "of enormous" size compared to its mates" and one robin chick was dead. Smith's observation on 2 December was that the cuckoo "will soon be too large for the nest, and already has to lie on top of the young Robins". On 9 December, Smith removed two robin chicks leaving one, which the next day was nearly ready to fly. On 11 December, Smith placed mesh over the nest through which the chicks could be fed. On 15 December, he released the robin chick and brought the cuckoo home ("now in fine plumages, spotted with white or greyish white on a brown ground"), where he fed it but it was dead by 22 December. This nest was under close observation, and we have to accept that Smith, a well-known naturalist, correctly identified the cuckoo chick. However, it is suspicious that the cuckoo did not evict the robins to be raised alone.

Stead (1936) and Wilson (1959) reported finding what they considered to be a long-tailed cuckoo's egg in a robin nest on Jacky Lee Island, Stewart Island, in December 1932. It was the only egg in the nest, and disappeared next day, so the evidence is weak.

#### Silvereye

On 5 January 1946, Cunningham (1949) found a speckled egg (Egg 15) that he believed to be a long-tailed cuckoo's in a deserted silvereye nest at Kiriwhakapapa, in the Tararua foothills north of Masterton. On 27 February 1949, at the same location, Mrs Stidolph found an old silvereye nest from a previous season containing a supposed long-tailed cuckoo's egg (Egg 16; Stidolph 1949). Neither account described the nest, or stated whether any pale blue silvereye eggs were also present, information that could have corroborated the identification.

Stidolph (1949) had visited the same locality on 20 January 1946, when his wife found a silvereye's nest containing "a large chick, with the eyes just opening, of a long-tailed cuckoo". It had "a yellow gape, dark feathers were appearing on the back and yellowish ones on the sides of the underparts". Stidolph removed the chick for examination but made no comment on the beak, legs or tail. He noted that "the adult" silvereyes were "in attendance" (i.e. in the vicinity?) and uttered the alarm note, but he did not stand back to confirm that silvereyes were bringing food to the nestling. At the next inspection, seven days later, before the chick would have been old enough to fledge, the nest was empty. (This did not surprise Stidolph because he felt it impossible that a silvereve's delicate cradlelike nest, suspended at the rim, could ever take the weight of a fully grown long-tailed cuckoo nestling.) If it really was a long-tailed cuckoo chick, then it is possible that it merely occupied an atypical whitehead nest, the species being present at the location though "somewhat scarce". Whiteheads can build atypical nests "suspended from light twigs, after the habit of the Silvereye" (see Plate 2 of Buddle 1951). However, Stidolph was a trusted observer and we must accept his record as credible.

P. Harper reported to McLean (1988) an observation of a long-tailed cuckoo nestling being raised by silvereyes in the Waikato, but no corroborating details were given.

#### Unlikely hosts

Records of the following species as successful hosts are dubious. They involve putative cuckoo eggs laid or thought to have been laid in nests, but they give no firm evidence of a cuckoo egg hatching, or a cuckoo nestling being raised, in the nests concerned.

#### Grey warbler

The long-tailed cuckoo plate in the second edition of Buller's *A History of the Birds of New Zealand* (1888) shows a grey warbler feeding the cuckoo fledgling. At this time the warbler was thought to be host to long-tailed cuckoos ("as many witnesses can testify"), as well as to shining cuckoos, but Buller gave no strong evidence for parasitism by the former. Potts (1885) cited observations of fledglings being fed by grey warblers in Canterbury. Mr W.W. Smith, at Oamaru in November 1885, took an egg (Egg 4) thought to be a long-tailed cuckoo's from a grey warbler's nest (Buller 1888, 1:131), but this egg was plain and spherical, so not likely to be a longtailed cuckoo's.

Andersen (1926) reported that a Mr Overton of Otago saw a long-tailed cuckoo lay an egg on the ground and carry it in its beak to place it in a grey warbler's nest. This is not credible since where the act of egg deposition has been seen in other parasitic cuckoos the female typically sits on the nest to lay (e.g. Wyllie 1981: 124). St Paul (1976) claimed to have seen two grey warblers "by the Wanganui River" bringing food to a big long-tailed cuckoo nestling. He did not confirm that it was in a grey warbler's nest – it could have been a case of passing warblers feeding a chick in another species' nest.

Moncrieff (1949), defending her inclusion (in Moncrieff 1948) of grey warbler as a long-tailed cuckoo host, wanted to keep an open mind on the subject. Fulton (1904), Stidolph (1949), and Oliver (1955) thought that records of grey warblers hosting long-tailed cuckoos were mistaken.

#### Bellbird

Ramsay (1865) was given a batch of birds' nests and eggs by Mr R. Huntley of Wellington. These included an egg said to be a long-tailed cuckoo's taken from the nest of a bellbird, a species that Ramsay believed was "frequently the foster-parent of the Long-tailed Cuckoo". Fulton (1904) thought it "probable" that the bellbird is parasitised because it chases and harries the long-tailed cuckoo.

#### Tui

Higgins (1999) cited a cuckoo's egg being found in a tui's nest (*Prosthemadera novaeseelandiae*) but I cannot trace the original report.

#### Tomtit

Fulton (1904) had a letter from Mr J.C. Buckland (November 1903) stating that a Mr Westenra of Akaroa found a nearly fledged long-tailed cuckoo in a tomtit's nest, but this third-hand observation lacks corroborating detail on how the nest was identified (McLean 1988). Fulton received a tomtit nest from Fiordland with four fresh eggs, one of which was larger and thought by Fulton to be a long-tailed cuckoo's (Egg 7). J. Penniket also found a supposed cuckoo's egg (Egg 17) in an abandoned tomtit nest at Kokiri, Westland, in January 1957 (Anon. 1958: 199). These last two egg records are possible or probable but not firmly established.

#### Song thrush

Smith (1931) stated that eggs of the long-tailed cuckoo have "occurred in the nest of the English Thrush" but gave no details. Stead (1936) saw two eggs collected from two song thrush nests by A. Portman, of Ravensbourne, Dunedin. Stead considered them to be long-tailed cuckoo eggs based on their size, colour, and pattern being similar to that of long-tailed cuckoo eggs Stead had seen. These eggs have not been found in any museum collection.

#### House sparrow

Kinsky (1957) saw a long-tailed cuckoo visit a house sparrow (Passer domesticus) nest on Kapiti Island in January 1957, pushing its head and half its body into the nest for "a short while". The nest was checked and contained four eggs, "three of them normal sparrow's eggs and the fourth somewhat smaller and lighter in colour". Next day the nest contained five eggs, "four normal sparrow eggs and the mysterious egg of the day before". Kinsky believed the latter to be a cuckoo's egg from its size and colour and because atypical lighter sparrow eggs are usually the last egg laid, not the penultimate. This record seems unlikely, not least because sparrow eggs are about 22 x 16 mm (Heather & Robertson 1996) and the cuckoo's egg would be bigger than this, not smaller. McLean (1988) credited P. Jenkins with an account of a long-tailed cuckoo laying in a house sparrow's nest on Kapiti Island. This may be the same Kinsky observation, whose paper McLean did not cite, rather than a second such record on the same island.

#### European greenfinch

Stead (1936) saw an egg (Egg 13) collected from a greenfinch nest by A. Portman, of Ravensbourne, Dunedin, that Stead considered was a long-tailed cuckoo egg. The identity was based on its size, colour, and pattern being similar to that of other presumed long-tailed cuckoo eggs seen by Stead.

#### Unparasitised species feeding cuckoo fledglings

Nestlings and fledglings of parasitic cuckoos in general, with their large size (relative to hosts), large gape and noisy begging, can represent a super-stimulus to passing birds of any species (e.g. Davies 2000: 80–81). The mobility of dependent fledgling cuckoos within the host territory puts them in the path of many other birds. It seems that unconnected birds, even of species that are never parasitised, may get diverted to feeding the begging cuckoo fledgling if they pass by while carrying food intended for their own offspring.

On Little Barrier Island in 1982, McLean (1982) saw a group of three whiteheads feeding two longtailed cuckoo fledglings. The assumption here is that two adjacent whitehead groups, each with a cuckoo fledgling as a result of parasitism, merged briefly and one group accidentally "adopted" the second cuckoo ending up with two to feed. It shows the effect of the super-stimulus operating within a parasitised species. McLean (1988), while following long-tailed cuckoo fledglings on Little Barrier Island, saw them begging to passing stitchbirds (*Notiomystis cincta*), tui, bellbirds and red-crowned parakeets (*Cyanoramphus novaezelandiae*), species that are unlikely to be parasitised.

It is unsurprising that there are many records of long-tailed cuckoo fledglings being fed by a diversity of species. These observations of course are not proof that the species concerned was parasitised. New Zealand pigeon. R. Riddle Southland) saw this species (Hemiphaga (of novaeseelandiae) feeding a fledgling cuckoo (Fulton 1904: 141), an improbable record (Oliver 1955) given that the cuckoo is an insectivore and the pigeon a herbivore. **Grey warbler.** Cases of grey warblers feeding long-tailed cuckoos were reported by Potts (1874: 148, 1885: 477) and Buller (1888). Oliver (1955: 540) mentions grey warblers feeding a long-tailed cuckoo on the ground. Tui. Alfred Reynolds of Riverton reported to Fulton (1904: 141) a tui feeding a "young cuckoo". This was considered improbable by Oliver (1955). Tomtit. J.C. Buckland (of Akaroa) reported to Fulton (1904) a fledgling long-tailed cuckoo being fed by a tomtit. North Island robin. On Little Barrier Island a fledgling cuckoo "was fed by a female Robin [Petroica longipes] at least twice" (McLean 1986, 1988). South Island robin. R. Riddle

(of Southland) reported a fledgling long-tailed cuckoo being fed by this species (Fulton 1904: 141).

#### DISCUSSION

Good evidence establishes the whitehead, vellowhead, and brown creeper as principal biological hosts of the long-tailed cuckoo. It makes evolutionary sense for this cuckoo to be a specialist brood-parasite of mohouid passerines. The mohouids form an endemic family (Aidala et al. 2013) and their association with a broodparasite endemic to New Zealand (in terms of breeding) at the specific, or perhaps even generic level (as Urodynamis; Payne 2005), suggests a long co-evolutionary relationship (Fleming 1982). This brood-parasitic interaction is likely to be older than that between the shining cuckoo (Chrysococcyx *lucidus*), which is only subspecifically endemic to New Zealand, and its hosts the grey warbler and Chatham Island warbler (Gerygone albofrontata), which are New Zealand endemics at just the species level.

There is evidence from a very few nests that long-tailed cuckoo nestlings can be reared by South Island robins (1880s), silvereyes (1946), and fantails (1963), but the use of secondary hosts is extremely rare. In the past 60 years there has been a big upsurge in professional field-work on songbirds throughout New Zealand, and an increase in amateur bird-watching. Yet there are no reports during this time of long-tailed cuckoos parasitising species other than mohouids, except for a poorly documented silvereye record (*c.* 1980s; McLean 1988).

The Roberts photograph (1963) seems to give evidence that fantails can raise a long-tailed cuckoo nestling to an advanced stage of development. Assuming that fantails can also raise the cuckoo fledgling to independence one wonders why the cuckoo does not parasitise fantails regularly across the country. That they do not implies that the association is suboptimal in some way. It might be, for example, that the cuckoo's egg, so much bigger than the fantail's (Fig. 3), is frequently rejected.

The survey of eggs in museum collections revealed one certain long-tailed cuckoo egg and 16 that are probable or possible. None has been collected in the field since 1978 (Egg 22, Fig. 1). A useful next step would be to settle the identities of the uncertain eggs from DNA extracted by a minimally destructive method. Stead's (1936) general description of the colour and pattern of the long-tailed cuckoo's egg is still accurate.

#### ACKNOWLEDGEMENTS

For access to eggs in museum collections I thank Alan Tennyson and Gillian Stone (NMNZ, 2009), Douglas Russell (BMNH, 2011) and Paul Scofield (CMC, 2020). I am grateful to Colin Miskelly (NMNZ) and Paul for checking my list of eggs and providing important corrections and background information. Julie Senior and Susan Tolich (AIM Library) helped me to obtain old journal articles and Roger Sharp checked the Nest Record Scheme for long-tailed cuckoo records.

#### LITERATURE CITED

- Aidala, Z.; Chong, N.; Anderson, M.G.; Ortiz-Catedral, L.; Jamieson, I.G.; Briskie, J.V.; Cassey, P.; Gill, B.J.; Hauber, M.E. 2013. Phylogenetic relationships of the genus *Mohoua*, endemic hosts of New Zealand's obligate brood parasitic long-tailed cuckoo (*Eudynamys taitensis*). *Journal* of Ornithology 154: 1127–1133.
- Andersen, J.C. 1926. *Bird-song and New Zealand song birds*. New Zealand, Whitcombe & Tombs.
- Anonymous 1958. Classified Summarised Notes. Notornis 7: 191–200.
- Bogert, C. 1937. Birds collected during the Whitney South Sea Expedition. 34. The distribution and the migration of the long-tailed cuckoo (*Urodynamis taitensis* Sparrman). *American Museum Novitates* 933: 1–12.
- Brooker, M.G.; Brooker, L.C. 1989. Cuckoo hosts in Australia. Australian Zoological Reviews 2: 1–67.
- Buddle, G.A. 1951. *Bird secrets of New Zealand*. London, Allen & Unwin.
- Buller, W.L. 1873. *A history of the birds of New Zealand*. 1st edition. London, John van Voorst.
- Buller, W.L. 1888. *A history of the birds of New Zealand*. 2nd edition. London, The author.
- Cunningham, J.B. 1985. Breeding ecology, social organisation and communicatory behaviour of the brown creeper (*Finschia novaeseelandiae*). Ph.D. thesis. University of Canterbury, Christchurch.
- Cunningham, J.M. 1949. Rearing of long-tailed cuckoo. *New Zealand Bird Notes* 3: 176–178.
- Davies, N.B. 2000. *Cuckoos, cowbirds and other cheats*. London, Poyser.
- Elliott, G.P. 1990. The breeding biology and habitat relationships of the yellowhead. Ph.D. thesis. Victoria University, Wellington.
- Finsch, O. 1901. Zur Catalogisirung der ornithologischen Abtheilung. I. Cuculi [Catalogue of the ornithological division]. Notes from the Leyden Museum 22: 75–125.
- Fleming, C.A. 1982. George Edward Lodge. The unpublished New Zealand bird paintings. Wellington, Nova Pacifica.
- Fulton, R. 1904. The kohoperoa or koekoea, longtailed cuckoo (*Urodynamis taitensis*): an account of its habits, description of a nest containing its (supposed) egg, and a suggestion as to how the

parasitic habit in birds has become established. *Transactions of the New Zealand Institute 36*: 113–148.

- Gill, B.J. 2006. Birds in Australian and New Zealand museums—a major resource for ornithology. *New Zealand Journal of Zoology* 33: 299–315.
- Gill, B.J.; Hauber, M.E. 2012. Piecing together the epic transoceanic migration of the long-tailed cuckoo (*Eudynamys taitensis*): an analysis of museum and sighting records. *Emu 112*: 326–332.
- Gill, B.J.; McLean, I.G. 1992. Population dynamics of the New Zealand whitehead (Pachycephalidae)—a communal breeder. *Condor* 94: 628–635.
- Gill, B.J.; Taylor, M.J. 2010. J.C. McLean's collection of New Zealand and foreign birds' eggs. *Records* of the Auckland Museum 47: 75–88.
- Gill, B.J.; Taylor, M.J. 2012. G.A. Buddle's collection of New Zealand and Canton Island birds' eggs. *Records of the Auckland Museum* 48: 29–44.
- Heather, B.D.; Robertson, H.A. 1996. *The field guide* to the birds of New Zealand. Auckland, Viking.
- Higgins, P.J. (Ed.) 1999. Handbook of Australian, New Zealand and Antarctic birds. 4. Parrots to dollarbird. Melbourne, Oxford University Press.
- Hunt, D.H.; Gill, B.J. (*Eds.*) 1979. *Ecology of Kowhai Bush, Kaikoura*. Christchurch, Biological Society, University of Canterbury.
- Kinsky, F.C. 1957. Long-tailed cuckoo and house sparrow. *Notornis* 7: 112–113.
- McLean, I.G. 1982. Whitehead breeding, and parasitism by long-tailed cuckoos. *Notornis* 29: 156–158.
- McLean, I.G. 1986. [Long-tailed cuckoo record in Classified Summarised Notes]. *Notornis* 33: 115.
- McLean, I.G. 1988. Breeding behaviour of the longtailed cuckoo on Little Barrier Island. *Notornis* 35: 89–98.
- McLean, I.G.; Gill, B.J. 1988. Breeding of an islandendemic bird: the New Zealand Whitehead *Mohoua albicilla*; Pachycephalinae. *Emu 88*: 177–182.
- Moncrieff, P. 1948. New Zealand birds and how to identify them. 3rd edition. New Zealand, Whitcombe & Tombs Ltd.
- Moncrieff, P. 1949. Grey warbler and cuckoos. *New Zealand Bird Notes* 3: 111–112.
- Nehrkorn, A. 1879. Mittheilungen über nester und eier des Museums Godeffroy zu Hamburg [Reports on nests and eggs from the Godeffroy Museum in Hamburg]. *Journal für Ornithologie* 27: 393–410.
- Oates, E.W.; Reid, S.G. 1903. Catalogue of the collection of birds' eggs in the British Museum (Natural History). Volume III. Carinatae (Psittaciformes– Passeriformes). London, British Museum (Natural History).

- O'Donnell, C.F.J.; West, J.A. 1992. Classified Summarised Notes, South and Chatham Islands 1 July 1990 to 30 June 1991. *Notornis 39*: 211–232.
- Oliver, W.R.B. 1955. New Zealand birds. 2nd edition. Wellington, Reed.
- Parrish, G.R. 2006. Classified Summarised Notes, North Island, 1 July 2002 to 30 June 2003. *Notornis* 53: 240–247.
- Payne, R.B. 2005. *The cuckoos*. Oxford, Oxford University Press.
- Penniket, J.G. 1958. [Long-tailed cuckoo record in Classified Summarised Notes]. Notornis 7: 199.
- Potts, T.H. 1874. On the birds of New Zealand [Part 4]. *Transactions of the New Zealand Institute* 6: 139–153.
- Potts, T.H. 1885. Oology of New Zealand [Part 4]. New Zealand Journal of Science 2: 475–484.
- Powlesland, R.G. 1979. [Long-tailed cuckoo record in Classified Summarised Notes]. Notornis 26: 416.
- Ramsay, E.P. 1865. On the nests and eggs of some New Zealand birds. *Ibis 7*: 154–157.
- Roberts, P.M. 1963. Plate XV [Nestling long-tailed cuckoo in fantail nest; photograph only]. *Notornis* 10: 173.
- St. Paul, R. 1976. A bushman's seventeen years of noting birds. Part D. Shining cuckoo and longtailed cuckoo. *Notornis* 23: 289–298.
- Schönwetter, M. 1964. *Handbuch der Oologie*. Vol. 1. Part 9. Berlin, Akademie Verlag.
- Sibson, R.B. 1978. Classified Summarised Notes. Notornis 25: 332–349.
- Smith, W.W. 1931. Feeding habits of the shining bronze-cuckoo. *Emu* 30: 217–218.
- Stead, E.F. 1936. The egg of the long-tailed cuckoo (Eurodynamis taitensis). Transactions of the Royal Society of New Zealand 66: 182–184.
- Stidolph, R.H.D. 1949. Long-tailed cuckoo victimising silver-eye. *New Zealand Bird Notes* 3: 175.
- Taylor, G.A.; Parrish, G.R. 1992. Classified Summarised Notes, North Island 1 July 1990 to 30 June 1991. *Notornis* 39: 161–210.
- Timmermann, G. 1931. Mittheilungen ueber einige vogeleier aus Zentralpolynesien [Reports about some bird eggs from central Polynesia]. Beiträge Fortpflanzungsbiologie der Vögel mit Berücksichtigund der Oologie 7: 104–109, 139–141.
- Wilkinson, A.S. 1927. Birds of Kapiti Island. *Emu* 26: 237–258.
- Wilkinson, A.S.; Stidolph, R.H.D. 1947. A cuckoo in the nest. *New Zealand Bird Notes* 2: 77–79.
- Wilkinson, A.S.; Wilkinson, A. 1952. Kapiti bird sanctuary. A natural history of the island. Masterton, Masterton Printing Co.
- Wilson, R.A. 1959. *Bird islands of New Zealand*. Christchurch, Whitcombe & Tombs Ltd.
- Wyllie, I. 1981. The cuckoo. London, B.T. Batsford Ltd.

# The detection, breeding behaviour, and use of mangroves (*Avicennia marina australasica*) by banded rails (*Gallirallus philippensis assimilis*)

A.J. BEAUCHAMP 17 Bellbird Ave, Onerahi 0110, New Zealand

**Abstract:** This study assessed how tall mangroves were used by a pair of banded rails with dependent young during three breeding seasons and the intervening periods. Banded rails were territorial and resident all year, raised their young under the mangrove canopy predominantly in dense pneumatophores, and sub-canopy seedlings and saplings. Foraging rails did not follow the tide as it covered and uncovered the flats. Young less than 20 days old were left in cover and delivered food. Young then followed parents as they strolled throughout the site, swam, flew short distances, and climbed mangroves. Rails bathed in and drank saline water and ate worms and crabs. The dependence period of broods was 45–49 days, and in one season, a young bird stayed within the natal site until it was 59 days old.

Beauchamp, A.J. 2022. The detection, breeding behaviour, and use of mangroves (Avicennia marina australasica) by banded rails (Gallirallus philippensis assimilis). Notornis 69(2): 99–111.

Keywords: Rallidae, weka, weasel, breeding, mangroves

#### INTRODUCTION

Banded rail (*Gallirallus philippensis assimilis*) is frequently cited as a volant relative of the weka (*Gallirallus australis*) and used in morphological and physiological comparisons between flightless and flighted forms (McNab 1994; Lamb 2004). The *Gallirallus* group of rails is thought to colonise offshore islands repeatedly and evolve flightless forms (Livezey 2003; Kirchman 2009, 2012; Garcia-R *et al.* 2017). Flightlessness evolves where genetic changes produce morphologies that can be selected for and confer physiological and ecological advantage (McNab 1994; Kirchman 2009; Shen *et al.* 2009; Sackton *et al.* 2019). However, flightless Gallirallus species have frequently died out when people have colonised islands (Kirchman 2012; Sayol et al. 2020), while flighted rails have remained, or established, including the Gallirallus philippensis group on Tonga (Kirchman & Steadman 2005). In New Zealand, humans and a suit of humanassisted introduced mammalian predators have reduced the distribution of weka (Beauchamp et al. 1999; King 2017) and banded rails (Guthrie-Smith 1925; Elliott 1983). However, it is unclear why flighted banded rails are now more habitat constrained than flightless weka (Bull et al. 1985; Beauchamp et al. 1999) and why saltmarsh and mangrove forests (Avicennia marina australasica) comprise the remaining habitats of most of the New Zealand banded rail population (Bellingham 2013).

*Received 1 September 2019; accepted 3 June 2021* Correspondence: *wekaman@xtra.co.nz* 

Historically, banded rails utilised the widespread terrestrial wetland habitats in New Zealand (Guthrie Smith 1925; Oliver 1955; Turbott 1967). However, during the 1930s, rail distribution declined (Oliver 1955), and by the 1970s, the mainland population was predominantly restricted to coastal wetlands in Golden Bay, South Island, and coastal wetlands, especially mangroves, in the North Island (Bull *et al.* 1985). Nevertheless, banded rails continued to use terrestrial habitats on Aotea/ Great Barrier Island, where mustelids are absent.

Observing banded rails in mangrove forests is difficult because New Zealand mangrove forests can be structurally complex (Lundquist *et al.* 2017), and banded rails are cautious and cryptic, and blend into tall (15 cm high) pneumatophores or patches of mangrove seedlings and saplings. The actual level of use of mangroves by rails has not been determined (Morrisey *et al.* 2010; Boffa Miskell Ltd 2017), but Botha (2011) found that mangroves had up to three times the footprint density of saltmarshes at Ohiwa Estuary. Banded rail home ranges are estimated to be 1.5 ha per pair in Nelson saltmarshes (Elliott 1983) and up to 4 ha per pair in mangroves (Bellingham 2013).

The breeding biology of banded rails is well known until the week after chicks leave the nest (Elliott 1983). Banded rails use grassed sites for nesting, incubate from the last laid egg, and the egg hatching is synchronous. The young leave the nest within 24 hours, and brood nests are used (Elliott 1983). Chicks feed independently at 5–7 days old in saltmarsh and when they are also provided with supplementary food (Dunlop 1970; Elliott 1983). After that time, there are anecdotal records about the biology of the chicks and parents but no detail on parental care and relationships with habitat use (Dunlop 1970).

Dunlop (1970) identified six call types associated with pair communication, breeding and territorial defence. A "sharp squeak, *kuk/chik, coo, coo-aw-oo-ooaw*" was used for warning, post-chase advertisement and chick communication, and partner/chick location, respectively. Dunlop (1970) also described sharp squeaks repeated at 15–20 seconds associated with walking as a "mating call". Other studies have described a low pitched and potentially angry growly *coo*, a grunt given during nest defence and explosive hisses from adults when chicks are chased (Marchant & Higgins 1993). Downy chicks also *peep* and are communicated with by soft cooing by parents (Dunlop 1970).

Year-round breeding takes place in the tropics (Robinson 1994; Tarburton 2018), and seasonal breeding occurs in temperate climates (Dunlop 1970; Marchant & Higgins 1993), with an estimated two clutches per year in Nelson, New Zealand (Elliott 1983). One pair in Samoa hatched on average 4.2 (range 3–5, n = 5) chicks per clutch, of which

1.3 (range 1–3) fledged (Robinson 1994). Eviction of these broods averaged 44 days (range 34–63 days; Robinson 1994). At Little Goat Island, Pumicestone Channel, Queensland, Australia, pairs were seen with 1–6 young (n = 12) per clutch when young appeared at 2–21 days old (Dunlop 1970). At Nelson, New Zealand, one clutch became independent at 29 days after both parents died (Elliott 1983).

Infrequently, a group or pair of rails living in mangroves is more tolerant of humans than others. For example, during 2005 and 2006, walkers often saw a bird at the boardwalk behind the public baths in central Whangarei (AJB *unpubl. data*). At Sandspit, near Warkworth, during 2013–2021, 2–14 rails foraged within 10 metres of the mangrove margin after long-term predator control occurred around the mangroves (AJB *unpubl. data*). From late 2015, a more tolerant pair lived around the Limeburners Creek boardwalk.

In this paper, I provide information on the habitat use by this pair and developing banded rail chicks, the parental behaviour and care of those young, and the calling of both the adults and young during three breeding attempts and intervening periods.

#### METHODS

#### Study Area

This study took place near Whangarei sewerage ponds (Fig. 1), beside a 186 m long boardwalk in mangroves at mid-Limeburners Creek, Kioreroa Road (35.745°S, 174.322°E). The Limeburners Creek boardwalk extended from the southern section of the rest area to the stream margin over a tidal flat occupied by eight-metre-tall c. 60–80-year-old mangroves (Fig. 2). Much of the open understory was covered with 0.1–0.15 m high pneumatophores and seedlings up to 0.2 m tall in winter, and visibility was 15-50 m. Beside the creek, part of the tidal flats bed was up to 0.3 m higher and was covered in 0.5-2.0 m sapling and seedling mangroves. The visibility within these mangrove seedlings and saplings was 2–7 metres. The tidal flats were covered and re-exposed about 1–2 hours before and after high tide via channels west of the boardwalk (Fig. 2). The raised tidal flat margin along the creek remained exposed during the lowest high tides (2.3 m chart datum at Marsden Point) and was heavily holed with tunnelling mud crab (Helice crassa) burrows. The inner margin between the boardwalk entrances also contained dense seedling and saplings (Fig. 2C). In addition, there were two small (c. 100 m<sup>2</sup>) areas with oioi (Leptocarpus similis), one on the western margin near the road and the other between the boardwalk entrances. The remaining creek banks were planted with low native shrubland and flax (Phormium tenax) and included the weed pampas (Cortaderia selloana).



Figure 1. The location of banded rail breeding and survey sites in Whangarei Harbour, New Zealand.



**Figure 2.** The habitat and location at first detection of adult banded rails at Limeburners Creek, Whangarei. A) during young dependency 2018–19; B) after young dependency; C) during young dependency 2019–20; D) during young dependency in 2020–21. Filled squares are where birds were first seen, and filled dots are where birds were first heard. Open squares are where birds of the southern pair were seen, and open dots heard in November 2020. In C, the ++ regions show the extent of the sapling understory.

ed, juv	tected	
detecte	first de	
= not	pen = j	
ion; nil	ility; o	
detect	or visib	
ei. For	eak. Fo	
nangar	nbs Bu	
ek, Wł	warni	
ers Cre	ueak =	
neburn	and sq	
s at Lin	al call	
: young	erritori	
endent	terr = t	plings
ad dep	t calls,	ea of se
they h	d <i>chit-i</i> i	n an ar
when	<i>chit</i> and	ected in
ed rails	hit-it =	rst dete
f band	calls, c	sed = fi
ation o	cation	gs, clos
and loc	nmuni	seedlin
ection a	IS = COI	thout s
ort, dete	, comm	h or wi
rey effc	young	rea wit
1. Surv	endent	ipen ai
ble	dep	an (

				:			000		:			000		:	
		201	8–2019 Bree	eding season			20	19-2020 Bree	ding seaso	-		202	0–2021 Bree	eding seaso	с
Young age (day)	Start time	Detection	contact, total time (mins)	visibility	location	Start times	Detection	contact, total time (mins)	visibility	location	Start times	Detection	contact, total time (mins)	visibility	location
1	16:40	seen	10, 16	open	middle	1	I	1	1	ı	17:20	nil	0, 42	1	1
2	'	I	I	·	ı	17:40	squeak	7, 34	closed	outer	17:30	seen	7, 32	open	outer
3	1	'	ı	'	'	ı		ı	ı	'	16:40	seen	10, 72	closed	middle
4	'	I	I	·	ı	18:00	squeak	0, 51	closed	outer	17:05	seen	53, 86	closed	outer
υ	ı	'	'	'	·	ı	'	ı	ı	'	18:20	comms	1, 40	closed	outer
9	'	'		'	'	ı	'	ı	ı	'	10:47	terr	4, 73	closed	middle
7	'	'		'	'	ı	'	ı	ı	'	07:35	seen	37, 60	open	middle
8	ı	ı	ı	'	'	17:00	nil	0, 20	ı	'	ı	'	'	ı	'
6	17:20	lin	0, 20	'	'	ı		ı	ı	'	12:30	nil	0, 53	ı	ı
6	ı	ı	ı	'	'	ı		ı	ı	'	16:40	seen	22, 78	closed	inner
10	ı	ı	ı	'	'	17:00	nil	0, 20	ı	'	18:40	squeak	1, 40	closed	inner
11	ı	ı	ı	'	'	17:05	nil	0, 47	ı	'	12:30	nil	0, 60	ı	'
11	'	'		'	'	ı	'	ı	ı	'	17:50	seen	1, 67	closed	inner
12	ı	'	ľ		'	14:00	seen	70, 75	open	middle	10:45	seen	3, 55	open	outer
13	ı	1	ľ		'	14:45	nil	0, 69	ı	'	17:20	seen	22, 40	closed	inner
14	ı	'	'	'	'	ı	ı	ı	'	'	ı	ı	'	ı	'
15	17:55	lin	0, 20	'	'	10:15	seen	28, 75	open	middle	17:05	squeak	2, 60	open	middle
15	'	I	ı	ı	ı	15:27	seen	77, 93	closed	outer	17:05	squeak	3, 87	closed	inner
16	I	ı	ı	ı	ı	17:36	seen	22, 74	open	middle	ı	ı	ı	ı	ı
17	I	ı	ı	1	ı	ı	1	ı	ı	ı	07:40	seen	30, 40	open	inner
17	I	ı	ı	ı	ı	ı	1	I	ı	ı	17:30	comms	44, 65	open	outer
18	'	ı	ı	'	ı	ı	ı	ı	ı	·	16:55	seen	3, 20	closed	outer
19	ı	1	ľ		'	ı		ı	ı	'	17:05	nil	0, 70	ı	ľ
20	'	I	ı	'	ı	ı	ı	I	I	ı	07:40	squeak	15, 50	closed	outer
20	'	I	1	ı	I	I	1	I	I	ı	17:00	nil	0, 60	I	I
21	14:10	squeak	80, 90	closed	outer	16:15	seen	22, 95	open	outer	I	1	1	I	ı
22	17:00	seen	17, 30	closed	outer	14:30	lin	0, 63	I	ı	07:35	nil	0, 30	I	ı
22	I	I	I	1	ľ	ı	1	I	I	ı	17:35	nil	0, 26	I	ı
23	15:40	nil	0, 100	1	ı	17:45	seen	1, 55	open	middle	I	I	1	1	T

102 Beauchamp

Table 1.	contine	d													
		2018-	-2019 Breed	ing season			201	[9-2020 Bree	eding seaso	u		202	0-2021 Bree	ding season	
Young age (day)	Start time	Detection	contact, total time (mins)	visibility	location	Start times	Detection	contact, total time (mins)	visibility	location	Start times	Detection	contact, total time (mins)	visibility loc	ation
24	1		ı		ı	17:23	seen	5, 47	closed	inner	16:35	lin	0, 80		'
25	16:40	juv & comms	54, 56	closed	outer	15:25	seen	6, 45	closed	inner	11:15	lin	0, 63		I
26	17:20	seen	8, 25	open	middle	15:20	seen	25, 85	closed	inner	I	ı	ı		I
27	16:48	seen	10, 100	closed	inner	16:50	squeak	1, 58	closed	outer	I	ı	ı	ı	'
28	13:00	squeak	20, 90	closed	inner	16:10	lin	0, 73	ı	ı	17:10	lin	0,45	ı	ī
29	ľ	1	ı	ı	ı	16:26	seen	19, 79	closed	outer	I	ı	ı		ī
30	ı		'	'	ı	16:10	seen	32, 60	open	outer	I	ı	'	·	ī
31	18:20	squeak	12, 20	closed	inner	16:30	seen	43, 63	open	middle	I	ı	ı	·	ī
32	17:30	juv & comms	5, 60	closed	outer	13:23	squeak	0, 12	closed	outer	15:15	lin	09'0	·	ī
32	ı		'	'	'	16:40	squeak	10, 62	open	outer	ı			·	I
33	19:00	juv & comms	70, 75	closed	outer	19:15	squeak	43, 45	open	inner	I	ı	'	·	ī
34	10:15	squeak	2, 34	closed	inner	19:02	squeak	63, 63	open	middle	I	ı	'	·	ı
34	19:40	nil	0, 35	'	'	'	'	'	'	'	ı			·	ľ
35	07:30	nil	0, 30	'	ı	14:05	lin	0, 46	'	'	I	ı	'	·	ı
35	17:18	squeak	10, 72	closed	inner	19:10	lin	0, 36	'	'	ı			·	ľ
36	1		1	ı	I	18:22	seen	7, 61	open	inner	I	I	I	ı	1
37	1	1	'	'	1	14:23	seen	9, 67	closed	inner	I	ı	'	·	1
38	I	1	'	·	ı	17:48	seen	44, 83	open	outer	I	ı	'	ı	ī
39	I	1	'	·	ı	11:02	lin	0, 38	'	'	12:56	lin	0,72	ı	1
41	18:30	squeak	10, 30	closed	inner	18:40	seen	26, 60	open	inner	I	·	'	ı	ī
42	12:40	nil	0,60	ı	ı	18:35	seen	48, 80	open	inner	I	I		ı	1
42	15:58	squeak	25, 62	closed	inner	ı	1			ı	I	I		ı	1
43	16:00	seen	55, 110	closed	outer	'	'			'	ı	'	ı	·	1
44	15:40	chit-it	19, 45	closed	inner	17:10	comms	13, 53	open	middle	18:28	lin	0,41	·	1
45	18:00	nil	0, 20	ı	ı	17:02	seen	25, 128	open	outer	I	I		ı	1
46	16:20	squeak	66, 90	closed	outer	18:10	squeak	41, 49	closed	outer	ı	·	'	ı	'
47	'	ı	'	'	·	19:00	seen	26, 50	open	middle	ı	·	'	ı	ľ
48	'	ı	'	'	'	18:10	chit-it	4, 70	closed	middle	'	·	'		ľ
49	'	ı	'	'	'	18:50	seen	24, 75	open	middle	'	·	'		ľ
50	14:08	squeak	4, 60	closed	inner	17:00	seen	6, 52	open	outer	ı	'	ı		ı

103

Banded rail in mangroves

#### Survey method

I visited the Limeburner Creek boardwalk and neighbouring sediment ponds (Fig. 2) at least weekly from 10 October 2015. I walked the boardwalk at <2 km/hr, 1–8 times per survey, stopped at all corners and searched out to 50 m using Nikon 8x20 binoculars. Banded rails were only detected ten times in 145 single-pass surveys until November 2018. Then, after chicks were seen on 5 November 2018, I increased the number of times the boardwalk and pond margins were checked to 2–6 times each survey.

In the 2018–19 parental care period, surveys occurred when the mangrove-covered flats were submerged by the tide when the young rails were 15, 31, 33, 35, 42, 43, 44, and 45 days old (Table 1). All other surveys occurred when the mudflats were exposing, exposed, or covering.

I noted the location of detection, the duration of observation, the routes undertaken by the birds, the number of birds present, the behaviours of adults and young, the food items eaten, and the calls given. I also recorded the calls from birds when they were 3–10 metres from the boardwalk on an Olympus Linear PCM recorder LS-10 and the characteristics of the calls were assessed on Raven Lite (Charif *et al.* 2010).

I visited the site 29 times each year to record the behaviour and calls given after young fledged and until moult commenced (until the 28 February 2019 and 24 March 2020) to determine if there were further breeding attempts (post-breeding period). This time was chosen because a pair and two halfgrown young were seen near the boardwalk on 28 March 2016 (AJB *unpubl. data*). I also visited the site 19 times between 1 April 2019 and 31 August 2019 and 18 times between 19 April 2020 and 28 August 2020 (non-breeding period) to assess whether the site was permanently occupied.

The chicks were aged using the presence/ absence of an egg tooth, colour of downy plumage and size (Dunlop 1970), and chick mobility and behaviour. Notes were kept on the plumage of the first young as they developed and used to check later clutches. The larger adult was assumed to be the male (Marchant & Higgins 1993).

#### RESULTS

#### **Detection and habitat**

Rail parents with 4, 1, and 3 young were seen from the Limeburners Creek boardwalk during 22, 29, and 16 days of the parental care period in the 2018–19, 2019–20, and 2020–21 seasons, respectively (Table 1). When detected, a pair was present with the young 26 times and one parent 23 times. The only time I saw three adults with young was on a territorial boundary where all three birds were calling because a weasel (*Mustela nivalis vulgaris*) was *c*. 5 m from them.

Rails were detected significantly more often than not during the chick dependency periods ( $\chi^2$ = 16.50, *df*. = 1, *P* < 0.001, *n* = 83) and before moult started at 1 March 2019 and 3 February 2020 ( $\chi^2$  = 5.76, *df*. =1, *P* < 0.025, *n* = 34). However, during the two non-breeding period rails were equally likely to be detected or missed ( $\chi^2$  =0.017, *df*. = 1, *P* < 0.01, *n* = 61).

The average time to detection of the breeding birds with chicks 21-50 days old during the 2018-2019 breeding season (mean = 10.4 minutes, SD =9.65, n = 21) did not differ from that in the 2019–2020 season (mean = 14.1 minutes, SD = 14.3, n = 36; t =-1.03, df = 55, P = 0.31). During the three parental care periods banded rails were first seen or heard in similar proportions ( $\chi^2 = 7.89$ , *df*. =5, *P* > 0.05, *n* = 65); however, rails were initially located significantly more often in saplings ( $\chi^2 = 11.88$ , df. =5, P < 0.05, n = 65) until I learned how to approach the birds without unduly disturbing them. Consequently, when first seen in the open, parents continued activity without apparent distress (n = 11, 41%), but also gave the warning squeak when near young (n = 10, 37%) or when they entered the sapling margins (n = 4, 14%), or when they returned to sites where young were resting and I was present (n = 2, 7%).

#### Parental care when young were 1-20 days old

It was difficult to find rails when they had young that were less than 20 days old. In 2018–19 chicks were only seen once, on 5 November 2018 at 1650h (Table 1). Then, four small black downy chicks were seen. They were assumed to be 1–2 days old due to their size, the presence of egg teeth on their bills, and their stumbling walking when led by a parent eight metres into saplings. The chicks were fed three times on crabs and brooded for 12 minutes. The other parent gave a warning squeak, disappeared into saplings and circled back in silence to the brooding bird, and the family moved into the mangrove saplings.

On 21 December 2019, I saw a chick beside a preening adult in saplings. The chick was downy grey-black with no egg tooth. The parent remained silent and only moved when the chick exposed itself. The chick followed the parent and swam a five-metre water gap that the parent had flown over. The parents and chick had not been located during five visits to the site after the predicted hatch date (Table 1). The chick was only seen three times in the remaining first 20 days and was left in saplings and fed by parents. Adults walked past me in the open in silence but then gave many warning squeaks as they entered the saplings. They also gave low volume *chit* and communication calls during movements.

Three 2-day-old chicks were seen with parents on 22 October 2020 (Table 1) and seven subsequent occasions. Both parents generally raised the chicks in silence but gave very soft communication calls (purr) when the chicks were two and 18 days old. Rails left chicks in three sunny hiding spots in dense saplings or fallen logs, and delivered food to them from within the surrounding c. 20 m. The chicks were brooded/covered by the female on day seven when disturbed in open habitat, and while the male attempted to lure me away from them, giving warning squeaks. At other times the male moved throughout the territory, only gave single warning squeaks to indicate threats (n = 3). These calls were not responded to by female or chicks. At 17 days old, the chicks ran to cover when they heard steps or other people on the boardwalk and without any calling by parents. The chicks were not following foraging parents when they were all lost to either a weasel or an extreme rainfall and hail event when between 18 and 20 days old.

#### Parental care days 21-50 days old

Parents and young were more visible when young exceeded 21 days old (Table 2). At this time, young rails were still downy-grey, but the wing overcoverts were visible. Then, parents and young always walked while foraging and often covered 20 or more metres a minute. Young moved behind and within 1-3 m of feeding parents and fed from the parent's bill and on food that the parent dropped. Adults gave soft calls, and occasionally low amplitude warning grunts when they passed within 10 m of me (Fig. 3C). Foraging was most often from within the mangrove sapling area and its margins (Fig. 2) and only once targeted the tidal margin of the covering flats. When chicks were inactive, adults foraged up to 50 m from them within the sapling area. Young started to forage for themselves at 21–23 days old, and from day 42, the young fed over 20 metres from parents (Table 2).

**Table 2.** The timing of behaviours by parent and juvenile banded rails in two breeding periods at Limeburners Creek, Whangarei. Records in brackets are less certain due to a lack of sightings in the period specified.

Activity	Juve	enile age (day)
	2018-2019	2019–2020
Chick brooding	2	not seen
Juveniles started to feed alone	23	21
Juveniles swam between sites	31, 43	12, 33
Juveniles last fed by adults	25	36
Juveniles started foraging independently	23	21
Juveniles started wing flap and dash	21	15
Juveniles climbed mangroves	31, 32, 33	not seen
Juveniles gave last <i>peep</i> calls	43	42
Juveniles gave wavering calls	21–43	15-42
Juveniles deliberately drinking seawater	not noted	21–50
Juveniles last foraged with adults	43	44
Juveniles last interacted with adults	46-(49)	45
Juveniles last foraged at natal site	50	59
Juveniles tail flicking started	25	30
Juveniles gave <i>chit-it</i> call	not heard	(50)–54
Juvenile gave warning squeak	not heard	(57)–59
Adult gave food calls	21–34	13–34
Adult lead away display and soft calling ends	21	16
Adult gave close deep distress calls	not heard	15–21
Adult chased young	not seen	45
Adult climbed mangroves	21, 33	not seen
Adult swam in the creek channel	21, 31	not seen
Adult courtship chase and feeding	not seen	51, 52
Adult territorial activity southern boundary	not seen	45-58
Adult flying in the understory	21, 25	12, 33, 42, 48



Figure 3. Spectrogram of the calls given by banded rails at Limeburners Creek. A, communication call; B, *chit-it;* C, close warning grunt call; D, chick later wavering call; E, chick out of site peep call; F, Warning call; and G, rapid territorial calls.

Adults and young bathed in seawater on the incoming tide (n = 7) and deliberately drank seawater (n = 6). In the 2018–19 breeding season, when young were 31 and 33 days old, adults and young climbed six-metre-high mangroves, and when young were 31 and 43 days old, they swam along the mangrove creek margin. Each time, the young swam with their head, upper back and tail out of the water, while the parents swam with a third of their body above the water. On day 33, the family of rails remained in the outer mangroves and called there until half an hour after sunset.

Young rails jumped while flapping their wings over the outer drainage channels when they were 25 days old. Wing-stretching showed that the remiges were *c*. 80–90% of total length at 37 days old.

In 2018–19, four young rails were last seen with parents when 27 days old and when young foraged predominantly independently of parents. Then, from 31–47 days old, only two young were seen with parents. In 2019–20, only one chick was seen with parents, and from 45–59 days old, it remained in the natal area with little interaction with its parents (Table 2).

Young at 47 days old, had a red-brown nape and grey front band and resembled small adult weka. Then, from 52 days old, the upper unbanded breast developed light bars and the pale orange-brown patch typical of independent young rails. By day 59, the nape cap became a light rusty colour on the margin, and the wings appeared fully developed. The mid proximal upper mandible changed from dark grey to maroon grey at 37 days old to reddishbrown at 59 days old. I assumed the parents of all three clutches were the same because of their tameness, consistent use of the same areas between seasons (Fig. 2), consistent number and size of young seen during the season, and the location of sites of territorial defence. However, I did not see the parents or young of the third clutch after 10 November 2020, during what should have been the remaining dependency period of these young (from 20–50 days old; n = 9 surveys, Table 1).

#### Foraging and food use

Mud crabs were the most sought-after food, and rails ate 18 of them during eight surveys. Crabs were the only food item that rails ran to catch, and were caught on exposed mudflats and within the water in the stream channel. When young were less than 15-days-old parents took crabs to dry areas and broken them up for the chicks. After this, crabs were given whole to young.

Worms were the principal food item consumed. Chicks and juveniles ate 44 worms during 13 surveys. Adult's raised worms in their bills *in situ* so that the following young could catch up and take them at adult's side. Adults always carried worms to <20 day-old young, and sometimes carried worms over 50 m to sites where older young were resting (n = 5).

When the 2019–20 juvenile was 52 days old, it searched with an open bill in dirty shallow waterfilled pools for worms and appeared to be using its tongue for detection. Small items, likely snails, were also taken by adults and the juvenile from the tide-moistened bases of mangrove trunks and boardwalk supports.

#### Call use by adults and young

Adults gave four long-distance call types as part of territorial defence, pair and chick communication (Tables 3 & 4). There was also an additional call syllable *cheo* (not recorded, likely the *coo aw oo oow*, Dunlop 1970) given throughout the year before multiple repeat *chit* calling.

During parental care, the most frequent call was a single warning squeak which carried at least 120 m (Tables 3 & 4; Fig. 3F). The squeak was given when I was detected on-site but had not first located the birds, when I moved erratically near the adults, and when adults entered dense saplings after they were previously seen in the open. This call was only responded to three times by the partner, and then with communication and *chit-it* calls (Fig. 3A & B). The warning squeak never resulted in young rails running or freezing. Groups of warning squeaks repeated at *c*. 0.3–30 second intervals also occurred after territorial disputes and when a weasel was

	I	Warning	squeak	Comm	nunicatio	ns call	С	<i>hit-it</i> cal	ls	Territor	ial calls
Activity	Pair contact	Danger nearby	Response to other stimulus	Pair contact	Young contract	Post defence	Pair contact	Young contact	Post defence	Physical conflict	Vocal defence
Incubation	0	0	0	0	0	1	1	0	1	1	0
Parental care	2	25	10	13	10	4	8	17	2	2	4
Breeding season lacking young	2	5	6	8	0	7	7	1	7	1	7
Non-breeding period	0	0	2	4	0	2	2	0	3	0	6

**Table 3.** Number of banded rail calls groups where the activity could be assigned at Limeburners Creek, Whangarei. Danger nearby, included people and dogs on the boardwalk and mustelids. Response to other stimulus, included other bird species distress calls, emergency services alarms, heavy truck breaking.

**Table 4.** Presence of calls types (% of surveys) given by banded rail adults during the breeding season where dependent young were present at that site, where dependent young were absent during the breeding season, and in the non-breeding period at Limeburners Creek, Whangarei. January 2019 – October 2020. n = number of surveys.

		Surveys calls type	s heard (%	<b>5</b> )	Surveys la	cking calls (%)	
	Warning Squeak	Communication calls	Chit & chi-it	Territorial calls	Rails not detected	Rails seen but not calling	Surveys (n)
Breeding season 1 September – 31 March							
Incubation	0	8	17	8	67	0	12
Young <20 days old	37	9	23	11	34	9	35
Young ≥21–50 days old	38	22	27	3	19	9	64
Other times	14	19	19	10	41	9	80
Overall breeding season	25	17	22	8	34	8	191
Non-breeding season 1 April – 31 August	8	17	14	17	44	8	36

nearby. These calls continued for up to 25 minutes after I left the immediate vicinity.

Groups of communication calls were given every *c*. 1–5 seconds when pairs were together in dense saplings (Fig. 3A; Table 3), and while pairs were separated when each tending part of the brood. These calls ceased when the pair reestablished visual contact (when the young were 1, 23, and 33 days old).

The only other adult call that carried more than 30 m was a *chit-it* call (Fig. 3B; Table 3). This call was given by a separated parent trying to locate its partner and young, or as a response to warning squeak calls from neighbours or partners.

Parents gave repeated soft contact calls every few seconds when walking with older young. A short-range food call (increasing frequency *geer*) was given by adults when presenting food, and a parent gave a *guik* call every second as it swam in front of two 31-day-old young to the shoreline. Warning grunt calls (Fig. 3C) were also given by the adult when feeding juveniles 3–10 metres from me beside the boardwalk (Table 2).

From 15 days old, young gave a call like the wavering jerky end of dependence period calls of weka (Fig. 3D; Table 2; Table 5), initially only when presented with food by parents, and then from days 21–34 continuously when parents were present. Louder *peeps* were given by young while foraging with adults (Fig. 3E). These calls carried over 50 metres and were given almost continuously along with parental communication calls as rails fed in dense saplings.

## Calls used in response to a neighbour calling and territorial behaviour

The boardwalk pair only responded seven times (n = 227 surveys) to the immediate calls by neighbours between 25 November 2018 and 18 February 2021.

Activity	Banded rail call	Weka call
Territorial defence	"Chi-dik", 'kuk" "cick"* chit, chit-it #	Booming doon-doon-doon repeated
Pair or individual spacing	A rapidly repeating group of communication calls #	Spacing call duet, <i>coo-eet</i> , repeated up to 40 times
Warning calls	<i>Kuk</i> *, or high intensity and modulating high pitched squeak #	<i>Kuk, Squeak</i> often repeated multiple times where dependent young are present
Partner close contact calling	soft coo or communications calls #	Contact call and boom and soft <i>uh</i>
Nest and breeding reediness	Guttural rising Urrrrrrr repeated	Guttural rising Urrrrrrr repeated
Chick leading	Soft <i>coo</i> *, <i>chit-it</i> , <i>guik</i> repeated and adult to chick food call	put-put-call
Adult to chick food calling	Chit* and food call uuurha	Food call rising uuurha
Chick out of sight	Peep	Peep or silence
Chick late foraging with parents	#	Wavering calls constant when near parents
Chick close contact defence	Loud coo* growl #	growl repeated grrrrh

Table 5. Calls used by banded rails and weka during equivalent activities

\* Dunlop 1970, not heard in this study, #, see Fig 3.

Two of these responses were associated with police sirens, one to a drone flying over the site and three with close conflict on the western boundary (Fig. 2D).

In the post-breeding period between 20 January 2020 and 9 March 2020, there was considerable activity in the western margin of the home range. This activity included call groups, with six or more combined communication call or *chit* notes repeated together three to a second (territorial calls; Fig. 3G) before and after chases. The behaviour was indicative of a boundary dispute but may have also included a pair challenge, because it was associated with courtship feeding and a courtship chase.

No pair duet or individual calling took place at dawn or the early evening through the year.

#### DISCUSSION

Most data collected in this study derive from observations of three broods with the same parents, so may not represent how all banded rails behave within mangroves. The other breeding pair present in the 2020–21 season, only occupied saplings.

This study showed that banded rails were generally secretive and extremely mobile groundbased foragers. There was little leaf litter under mangroves, so foraging was predominantly undertaken by investigating under objects, probing at objects, fishing about in small puddles or dashing at visible food items. Some foraging occurred within the water of the creek margin, but most foraging was from the exposed mangrove forest floor. Banded rails delivered worms and crabs to young. The territories were submerged twice a day by the tide and were always moist. There was no apparent competition for food resources on the mangrove forest floor with New Zealand kingfishers (*Todiramphus sanctus*), Eurasian blackbirds (*Turdus merula*), song thrush (*Turdus philomelos*), or mallards/grey ducks (*Anus platyrhynchos/superciliosa*). Rats (*Rattus norvegicus*) emerged from hollow standing mangrove trunks in the late evenings.

Food appeared to be abundant. Banded rails did not follow the flush or ebbing tide or were pressed for foraging areas or time. Rails were first detected near the creek margin 30 or more minutes after tidal-flat exposure. Up to one metre long short-finned eels (*Anguilla australis*) were always near the head of newly advancing flushing tides and could have been a predation issue for young rail chicks (McDowall 1990). Adult rails generally flew over drains and channels and only swam when chicks could not fly or would not see where adults hand flown. On most occasions, adults and young moved inland in advance of the tide.

The noisiest and potentially the riskiest time for banded rail young at Limeburners Creek was when they were 18–43 days old, when they could not fly, and communication between young and parents lasted up to 80% of the time. Similar long periods of noisy calling occurred between parents and young during the hour before sunset at Awaroa River (75– 77% of the time) on 9 and 12 February 2019 (AJB *unpubl. data*). Five of the eight young I followed at Limeburners Creek disappeared during this time. The appearance of a weasel in the mangroves two days before the loss of the chicks and adults in 2020–21, suggests that predation was the cause. It is likely that the two young that disappeared in early December 2018, at 27 days old, died; because young of this age were still dependent on some parental feeding, and independent young would still have been expected to be within the parental territory.

Banded rails, like weka, had specific locations where they left chicks while they foraged for food. All of these sites were near or within logs or dense sapling cover. During the first 20 days, the pair foraged within 20 metres of young and carried food to them instead of calling them from cover. The male roamed more widely and only called when there was another person on the boardwalk or to locate the female if she had moved chicks on. The female answered these calls with a single communication call. Unlike weka, banded rails did not call when they met after separation, and there were no equivalents of the territorial boom or the spacing call (Table 5, Beauchamp 1987), which are used in pair greetings and to define ownership of space (Beauchamp 1987; Beauchamp & Chambers 2000).

At Limeburners Creek, the banded rails used a similar group of calls during pair communication and territorial defence to those described in Queensland (G. p. mellori, Dunlop 1970). These included the "kuk" or "chik" calls, which like the chit and *chit-it* calls in my study were associated with keeping other rails away, partner communication and boundary defence (Table 5). In addition, banded rails used a call, like the distant food calls and breeding readiness calls in weka (Table 5), while breaking up crabs near chicks (Dunlop 1970). Dunlop (1970) also described the sharp squeak, given every 15–20 seconds, as associated with mate finding and warning of an unexpected factor. This description appears to cover both the warning squeak and the communication calls. Rails in both areas gave calls that started with a burst of squeaks up to three a second and then slowed to 20 or more seconds apart. Calls like this occurred during and after territorial defence.

Dunlop (1970) reported that the single squeak given when birds were surprised was a directed warning call to the group, not the partner alone, and seldom induced a response. The banded rail young in my study did not appear to treat this call as an indication of imminent danger. Multiple repeated warning squeaks and communication calls occurred when the weasel was present, but chicks only moved when the parents sort cover. Similar warning squeaks and multiple communication calls occurred on 20 November, 12 December, 22 December 2019, and 7 & 28 February, 9 March, and 28 August 2020 at adjoining banded rail sites, but chick presence was only confirmed once (AJB *unpubl. data*). The lack of any speedy reaction to predators is considered a reason for losses in other rail populations (Bunin & Jamieson 1995).

In contrast, North Island weka (G. a. greyi) often gave similar harsh warning squeaks, once when surprised, but multiple times when dependent young were present but frequently up to 100 m away. This call was also occasionally taken up by nearby non-paired weka and pairs with and without young (AJB unpubl. data). Young between 3-41 days old ran and occasionally hid. However, the South Island weka (G. a. australis) and those of a mixed population on Kapiti Island (Beauchamp 1987; Trewick et al. 2017) very occasionally gave this call when weka were surprised, and seldom gave it when they had dependent young unless those young were hiding a few metres away (Marchant & Higgins 1993). This call was never taken up by neighbouring pairs (AJB *unpubl. data*).

The study indicated that adult banded rails also reduced their vulnerability by reducing actions that would make them visible. For example, no banded rails foraged on the margin of the oxidation ponds in daylight. Also, rails foraged within 6–10 metres of cover at Sandspit where mammalian predator control was present (AJB *unpubl. data*), and at Ohiwa Harbour when it was not (Botha 2011).

Most of the calls described by Dunlop (1970) in Queensland, Australia, were given by New Zealand banded rails and appeared to have similar functions. However, in both populations there was no equivalent to the loud spacing calls, or mate finding calls of weka which are often heard in the evenings (Table 5; Beauchamp 1987, 1997). There was calling that would allow predators to find banded rails within the mangroves. However, this calling appears to be of less than that described for other populations of banded rails (Lachish & Goldizen 2004) and the related terrestrial Roviana Rail (*Gallirallus roviane;* Kirchman 2012) that give lengthy territorial calls (Frank Lambert, XC404084. Accessible at www.xeno-canto.org/404084.).

In conclusion, banded rails in New Zealand are vulnerable to nest and chick predation from introduced rats and mustelids in saltmarsh and swamp habitats (Guthrie-Smith 1925; Elliott 1983). Even when predator control occurs, banded rails tend to stay within 10 m of cover. There is limited competition for the resources under mangroves, and banded rails can use mangroves because they can drink saline water, eat saline foods, and utilise a habitat with predictable food supplies. In mangroves, rails have limited calling behaviour that may further reduce the attention of mammalian predators near that habitat, especially outside of the time that young are between 18 and 43 days old.

#### ACKNOWLEDGEMENTS

I thank Katrina Hansen, Neil Fitzgerald, an anonymous reviewer and Craig Symes for comments on earlier drafts of the paper, which substantially improved this paper.

#### LITERATURE CITED

- Beauchamp, A.J. 1987. A population study of the weka *Gallirallus australis* on Kapiti Island. Unpubl. PhD thesis. Victoria University of Wellington, Wellington, New Zealand.
- Beauchamp, A.J. 1997. The decline of the North Island weka (*Gallirallus australis greyi*) in the East Cape and Opotiki Regions, North Island, New Zealand. Notornis 44: 27–35.
- Beauchamp, A.J.; Butler, D.J.; King, D. (Eds). 1999. Weka (Gallirallus australis) recovery plan 1999– 2009. Department of Conservation Threatened Species Recovery plan 29. Wellington.
- Beauchamp, A.J.; Chambers, R. 2000. Density changes of adult North Island weka in the Mansion House Historic Reserve, Kawau Island: 1992–1999. Notornis 47: 82–90.
- Bellingham, M. 2013. Banded rail. In Miskelly, C.M. (ed.) New Zealand Birds Online. www. nzbirdsonline.org.nz Accessed: 25 September 2020.
- Boffa Miskell Ltd. 2017. Use of mangrove habitat by banded rail (*Gallirallus philippensis assimilis*). Waikato Regional Council Technical Report 2017/24.
- Botha, A. 2011. Foraging distances and habitat preferences of banded rails in the Ohiwa Harbour. Bay of Plenty Regional Council Environmental Publication 2010/06. Whakatane, Bay of Plenty Regional Council.
- Bull, P.C.; Gaze, P.D.; Robertson, CJ.R. 1985. The atlas of bird distribution in New Zealand. Wellington, The Ornithological Society of New Zealand.
- Bunin, J.S.; Jameson, I.G. 1995. New approaches toward a better understanding of the decline of takahe (*Porphyrio mantelli*) in New Zealand. *Conservation Biology* 9: 100–106.
- Charif, R.A.; Waack, A.M.; Strickman, L.M. 2010. Raven Pro 1.4 User's Manual. Ithaca, New York, Cornell Lab of Ornithology.
- Dunlop, R.R. 1970. Behaviour of the banded rail, *Rallus philippensis. The Sunbird* 1: 3–15.
- Elliott, G.P. 1983. The distribution and habitat requirements of the banded rail (*Rallus philippensis*) in Nelson and Marlborough. Unpubl. MSc thesis, Victoria University of Wellington. Wellington, New Zealand.
- King, C.M. 2017. Contemporary observations of predation on buff weka (*Gallirallus australis hectori*) by ferrets in the South Island during the nineteenth century. *Notornis* 64: 52–55.

- Garcia-R, J.C.; Joseph, L.; Adcock, G.; Reid, J.; Trewick, S.A. 2017. Interisland gene flow among populations of the buff-banded rail (Aves: Rallidae) and its implications for insular endemism in Oceania. *Journal of Avian Biology* 48: 679–690.
- Guthrie-Smith, H. 1925. *Bird life on island and shore*. London, William Blackwood & Sons.
- Kirchman, J.J. 2009. Genetic tests of rapid parallel speciation of flightless birds from an extant volant ancestor. *Biological Journal of the Linnean Society* 96: 601–616.
- Kirchman, J.J. 2012. Speciation of flightless rails on islands: a DNA-based phylogeny of the tropical rails of the Pacific. *The Auk* 129: 56–69.
- Kirchman, J.J.; Steadman, D.W. 2005. Rails (Aves: Rallidae: Gallirallus) from prehistoric sites in the Kingdom of Tonga, including a description of a new species. Proceedings of the Biological Society of Washington 118: 465–477.
- Lachish, S.; Goldizen, A.W. 2004. Responses to neighbours and non-neighbours in the buffbanded rail (*Gallirallus phillipensis*): no dearenemy relationships. *Australian Journal of Zoology* 52: 369–378.
- Lamb, J.M. 2004. Changes in feather microstructure associated with the occurrence of flightlessness. Unpubl. MSc thesis. Portland State University, USA.
- Livezey, B.C. 2003. Evolution of flightlessness in rails (Gruiformes: Rallidae) phylogenetic, ecomorphological and ontogenetic perspectives. Ornithological Monographs 53: 1–654.
- Lundquist, C.; Carter, K.; Hailes, S.; Bulmer, R. 2017. *Guidelines for managing mangrove (m*ānawa) expansion in New Zealand. NIWA Information Series No. 85. National Institute of Water & Atmospheric Research Ltd.
- Marchant, S.; Higgins, P.J. 1993. (eds). Handbook of Australian, New Zealand, and sub-Antarctic Birds. Vol. 2, Raptors to Lapwings, [Gallirallus philippensis Buff-banded rail.] Pp 495–506, Melbourne, Oxford University Press.
- McDowall, R.M. 1990. New Zealand freshwater fishes, A natural history and guide. Auckland, Heinemann Reed MAF publishing group.
- McNab, B.K. 1994. Energy conservation and the evolution of flightlessness in birds. *American Naturalist* 144: 628–642.
- Morrisey, D.J.; Swales, A.; Dittmann, S.; Morrison, M.A.; Lovelock, C.E.; Beard, C.M. 2010. The ecology and management of temperate mangroves. Oceanography and Marine Biology: An Annual Review 48: 43–160.
- Oliver, W.R.B. 1955. New Zealand Birds. Wellington, A.H. & A.W. Reed.
- Robinson, A.C. 1994. Breeding pattern in the banded rail (*Gallirallus philippensis*) in Western

Samoa. Notornis 42: 46-48.

- Sayol, F.; Steinbauer, M.J.; Blackman, T.M.; Antonelli, A.; Faurby, S. 2020. Anthropogenic extinctions conceal widespread evolution of flightlessness in birds. *Science Advances 6*: eabb6095. doi: 10.1126/sciadv.abb6095
- Shen, Y-Y; Shi, P.; Sun, Y-B.; Zang, Y-P.; 2009. Relaxation of the selective constraints on avian mitochondrial DNA following the degeneration of flight ability. *Genome Research* 19: 1760–1765.
- Sackton, T.B; Grayson, P.; Cloutier, A.; Hu, Z.; Liu, J.S.; Wheeler, N.E.; Gardner, P.P.; Clarke, J.A.; Baker, A.J.; Clamp, M.; Edwards, S.V. 2019. Convergent regulatory evolution and the loss

of flight in paleognathous birds. *Science 364*: 74–78.

- Tarburton, M.K. 2018. Evidence for year-round breeding of birds in the Samoan Islands in the context of the Australasian and South Pacific regions. *Notornis* 65: 92–108.
- Trewick, S.A.; Pilkington, S.; Shepherd, L.D.; Gibb, G.C.; Morgan-Richards, M. 2017. Closing the gap: Avian lineage splits at a young, narrow seaway imply a protracted history of mixed population response. *Molecular Ecology 26(16)*: 4197–4210. doi: 10.1111/mec.14323
- Turbott, E.G. 1967. *Buller's birds of New Zealand*. Christchurch, Whitcoulls Publishers.

Notornis, 2022, Vol. 69: 112-115 0029-4470 © The Ornithological Society of New Zealand Inc.

#### SHORT NOTE

# Radiocarbon ages for two of the three South Island takahe (*Porphyrio hochstetteri*; Aves: Rallidae) from Pyramid Valley, North Canterbury, New Zealand

RICHARD N. HOLDAWAY Palaecol Research Ltd, PO Box 16 569, Hornby, Christchurch 8042, New Zealand

Eleven bones of the South Island takahe (*Porphyrio hochstetteri*), seven representing a minimum of two adults and four from an immature bird, were excavated from the Pyramid Valley lake bed deposit (42° 58' 22.54"S, 172° 35' 50.12"E), near Waikari in the north-eastern South Island. Their presence in the deposit has been used as evidence that the big, flightless rail inhabited, or at least could inhabit, the lowland mixed forest/shrubland that surrounded the lake (Worthy & Holdaway 1996; Holdaway & Worthy 1997). This interpretation conflicts with the general view that the takahe is a relict glacial grassland specialist (Mills *et al.* 1984).

However, the undated presence of a species in a site whose environmental context may have changed with time does little to define that species' habitat preference(s). Takahe were among a minimum of 46 species of bird, whose habitat requirements ranged from forest to shrubland, grassland, wetlands, and open water, recovered from Pyramid Valley during excavations conducted periodically from the late 1930s to 1972 (Holdaway & Worthy 1997; Holdaway 2015). Until recently, radiocarbon ages had been measured on only the four species of extinct moa (Aves: Dinornithiformes) from the site (Allentoft *et al.* 2014; Holdaway *et al.* 2014). Without radiocarbon ages, even the relative dates of individuals are unknown because of the crude excavation methods, the fluidity of the sediments, and the lack of records of the recovery depths for the non-moa avifauna. The uncertainties of the chronology of species presence and an assumption of stasis in the vegetation make interpretations of when and in what habitat(s) the Pyramid Valley takahe may have lived difficult at best.

Radiocarbon ages on individuals are crucial because they allow species' occurrences to be referenced directly to their ambient vegetation. To provide a baseline for interpretation of habitat of takahe in the area around Pyramid Valley, I submitted bone samples from three individuals from the site - two adults, Av5922 (1.07 g), and Av15039 (0.41 g) (both from right femora), and the one juvenile, Av6041 (0.31 g) (tip of immature mandible) - for high precision accelerator mass spectrometry (AMS) radiocarbon analysis to the 14 Chrono Laboratory, Queen's University, Belfast, UK. The samples were chosen to avoid features of potential morphological interest. 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 conventional radiocarbon ages were calibrated to calendar date ranges via OxCal4.4, referenced to the SHCal20 curve (Hogg et al. 2020). The radiocarbon ages on the Waikari Cave and Takahe Tomo takahe (Table 1) were measured by the Rafter

*Received 3 August 2021; accepted 21 November 2021* Correspondence: *turnagra@gmail.com* 

**Table 1.** Details of available conventional radiocarbon ages (CRA) on South Island takahe (*Porphyrio hochstetteri*), with calibrated (SHCal20 terrestrial calibration curve, Hogg *et al.* [2020]) mean and median dates Before Present (BP, 1950 CE), Before Common Era/Common Era (BCE/CE), and confidence intervals for the calibrated dates of the Pyramid Valley individuals. Av, Canterbury Museum accession number; S, Te Papa Tongarewa Museum of New Zealand accession number. Age, bird's estimated ontogenetic age at death. SD, standard deviation of radiocarbon measurement.  $\delta^{13}$ C, carbon stable isotope ratio used in calibrating measurement. Radiocarbon age sources: NZA, Rafter Radiocarbon Laboratory, GNS Science, Lower Hutt, New Zealand; UBA, 14Chrono laboratory, Queen's University, Belfast, United Kingdom. References: W & H, Worthy & Holdaway (1996); W, Worthy (1997).

								Cali	brated date	es BP
Site	Age	Museum no.	<sup>14</sup> C Lab no.	CRA	SD	$\delta^{13}C$	Mean	SD	Median	Source
Pyramid Valley	Imm	Av6041	UBA42952	1,680	26	-20.5	1,533	41	1,540	This paper
Pyramid Valley	Ad	Av15039	UBA42953	2,054	29	-22.6	1,963	37	1,960	This paper
Pyramid Valley	Ad	Av5922	UBA42954	Failed	-	-	-	-	-	This paper
Waikari Cave	?	S33717	NZA4612	3,480	100	-21.93	3,708	135	3,705	W & H (1996)
Takahe Tomo	?	S334493/S33495	NZA6970	12,210	110	-20.5	14,154	246	14,108	W (1997)
							C	alibr	ated dates	BCE/CE
Site		Museum no.	<sup>14</sup> C Lab no.	CRA	SD		Mean	SD		Median
Pyramid Valley	Imm	Av6041	UBA42952	1,680	26	-	417 CE	41		410 CE
Pyramid Valley	Ad	Av15039	UBA42953	2,054	29	-	14 BCE	37		11 BCE
Waikari Cave	?	S33717	NZA4612	3,480	100	-	1759 BCE	135		1756 BCE

				Confidence intervals	for Pyramid Valley ra	adiocarbon ages	
				В	Р	BC	E/CE
<sup>14</sup> C age no.		CRA	SD	68.3%	95.4%	68.3%	95.4%
UBA42952	Imm	1680	26	1,583–1,518	1,589–1,452 (91.0%); 1,444–1,427 (4.4%)	368-432 CE	362–498 (91.0%); 507–523 (4.4%)
UBA42953	Ad	2054	29	2,004–1,983 (19.9%); 1,975–1,927 (48.4%)	2,043–2,030 (2.4%); 2,017–1,888 (93.1%)	55–34 BCE (19.9%); 26 BCE–23 CE (48.4%)	94–81 BCE (2.4%); 68 BCE – 63 CE (93.1%)

Radiocarbon Laboratory (now of GNS Science). All ages are reported by that laboratory according to the 1977 agreement on Radiocarbon Reporting Conventions (Stuiver & Polach 1977).

The radiocarbon age of  $2,054 \pm 29$  <sup>14</sup>C years before present (BP) (UBA42953) was measured on one of the adults (Av15039, Table 1). Unfortunately, insufficient bone gelatin was recovered from the other adult's (Av5922) sample for measurement. As noted before (Holdaway & Worthy 1997), the immature bird confirms that takahe had bred at or very near the site: its radiocarbon age of 1,680 ± 26 <sup>14</sup>C years BP (UBA42952, Table 1) means that it lived 400 years after the adult (350–500 years taking the extreme upper and lower errors of both calibrated dates (Table 1)).

Only one other radiocarbon age on a takahe from the eastern South Island has been published. This was on an individual recovered from Waikari Cave, a small cavern at the south-eastern edge of the Hawarden Basin, North Canterbury, and 12.34 km east of Pyramid Valley. The Waikari Cave takahe was, at *c.* 3,700 calendar years BP (Table 1), also of Holocene age, but almost twice as old as those at Pyramid Valley (Table 1). The Waikari Cave fossil fauna included taxa with widely different habitats, from forest (e.g. New Zealand pigeon, Hemiphaga novaeseelandiae); South Island saddleback, Philesturnus carunculatus; South Island kokako, Callaeas cinerea) to shrubland/grassland (e.g., New Zealand quail, Coturnix novaezelandiae), and small shore and water birds (e.g., shore plover, Thinornis novaeseelandiae; New Zealand dabchick (Poliocephalus rufopectus) (Worthy & Holdaway 1996). Of the other radiocarbon ages for birds from Waikari Cave, two (NZ1723, NZ4166) can be ignored as they were measured on mixed bulk samples of small bones (Worthy & Holdaway 1996). However, an AMS age of  $3,837 \pm 71$  <sup>14</sup>C years BP (NZA4613) on an extinct coot (Fulica prisca) (Worthy & Holdaway 1996) from Waikari Cave is almost indistinguishable from that on the takahe.

As none of other species from the site has been radiocarbon dated, they cannot be employed as indicators of the local habitat(s) available to the takahe. The variety of species (Worthy & Holdaway 1996) and their range of body sizes suggests that the deposit is an accumulation of the prey remains of either or both the extinct harrier (*Circus eylesi*) and extinct laughing owl (*Sceloglaux albifacies*). The smaller birds could have been captured some distance from the site and might not reflect the vegetation near at hand occupied by larger species such as takahe, which are unlikely to have been carried far.

The Pyramid Valley (330 m) and Waikari Cave (220 m) deposits record faunas from relatively low altitude vegetation. The only other radiocarbon age for a South Island takahe is  $12,210 \pm 110^{14}$ C years BP (NZA6970) (Table 1) for one of six individuals identified in Takahe Tomo, a cave in the Hodges Creek cave system, at c. 940 m in northwest Nelson (Worthy 1997). The present vegetation in that area is southern beech (Fuscospora, Lophozonia, both formerly Nothofagus) forest. The bird is geologically much older than those from North Canterbury and was deposited during the period of warming following the most recent (Weichselian-Otiran) glaciation so its habitat probably included subalpine shrubland as well as grassland, fellfield, and encroaching beech forest, much as that occupied by the relict Fiordland populations.

The environmental context of the deposit at Pyramid Valley has been thought to be well understood (Moar 1970; Gregg 1972; Burrows 1989; Holdaway & Worthy 1997) and relatively constant. Recent work on the lake bed sediments and the fossil microflora has shown, however, that the present 1 ha lake is a remnant of a much larger (c. 50 ha) and deeper lake (Johnston 2014; Johnston et al. 2022). From c. 3,500 to 2,100 calendar years BP, the present Pyramid Valley lake was, apart from two brief intervals, a small shallow bay on the southeastern periphery of a larger lake that filled the entire valley. The two dated Pyramid Valley takahe were deposited, one at the onset of, and the other at the termination of, the major change in the local vegetation that accompanied the lake's sudden drainage just over 2,000 years ago (Johnston 2014; Johnston et al. 2022).

The presence and disappearance of the lake means that the surrounding vegetation was not constant in extent or composition during the 3,500 years represented in the lake sediments (Johnston 2014; Johnston *et al.* 2022). The draining of the large lake exposed nearly 50 ha of the larger lake bed. In addition, the avulsing outbreak flood waters would have damaged or destroyed several square kilometres of forest in the outwash valley to the west and beyond that on the wide terraces along the upper Waipara River (Johnston *et al.* 2022).

The abrupt change in vegetation is recorded in pollen diagrams (Harris 1955; Moar 1970) but its significance was misinterpreted. Moar (1970) attributed the sudden rise in grass (Poaceae) and sedge (Cyperaceae) pollen at c. 400 mm depth to the replacement of forest by grassland after Polynesian firing (McWethy et al. 2010; McWethy et al. 2014), despite the continued abundance of forest tree pollen. A new age-depth model (Johnston 2014; Johnston *et al.* 2022) places the 400 mm depth at *c*. 2,000 BP and not at Polynesian settlement over 1,000 years later. At 400 mm, a spike in the terrestrial fern Microsorum (also known as Phymatosorus) (Harris 1955) was followed by another of bracken (Pteridium). The new date for the increase in grass pollen, along with the persistence of forest pollen (Moar 1970), suggests the colonisation of a significant new area of open ground within surrounding forest and recovery of forest destroyed further afield.

This new vegetation sequence means that the takahe adult was present when seral grassland and shrubland occupied the former lake bed and the regenerating forest to the west. In contrast, the immature bird lived 400 years later, by which time the succession to forest would have been complete and the entire valley forested. The species was therefore then breeding near Pyramid Valley – albeit unsuccessfully for the parents concerned – in lowland dry forest.

The calibrated dates for the two takahe suggest, but obviously cannot prove, that the species was present between the drainage of the large lake until forest had covered the former lake bed. The seral succession over those four centuries would have provided the species with a range of habitats from closed forest, to grassland near forest (as occupied by the birds surviving in Fiordland), and seral shrubland. The radiocarbon ages on these birds suggest that eastern populations of takahe were not restricted to "Pleistocene grasslands" but were flexible in their habitat requirements.

The source of the takahe population at Pyramid Valley, if indeed it was not present throughout the 5,000 years of the deposit's history (Johnston 2014), is unknown. As the species was present at Waikari Cave less than 15 km away 1,400 years before the first Pyramid Valley individual died, the South Island takahe may have been a regular, if uncommon, component of the North Canterbury Holocene avifauna.

#### ACKNOWLEDGEMENTS

I thank the Brian Mason Scientific & Technical Trust for providing the funds under grant 2019/08 for the radiocarbon dating programme for the Pyramid Valley "minimegafauna". Paul Scofield (Canterbury Museum) kindly facilitated my sampling of the Pyramid Valley specimens in the Canterbury Museum collections. The MS benefited from the comments of an anonymous referee.

#### LITERATURE CITED

- Allentoft, M.E.; Heller, R.; Oskam, C.L.; Lorenzen, E.D.; Hale, M.L.; Gilbert, M.T.; Jacomb, C.; Holdaway, R.N.; Bunce, M. 2014. Extinct New Zealand megafauna were not in decline before human colonization. *Proceedings of the National Academy of Sciences, USA 111*: 4922–4927.
- Bronk Ramsey, C.; Higham, T.; Bowles, A.; Hedges, R. 2004. Improvements to the pretreatment of bone at Oxford. *Radiocarbon* 46: 155–163.
- Brown, T.A.; Nelson, D.E.; Vogel, J.S.; Southon, J.R. 1988. Improved collagen extraction by modified Longin method. *Radiocarbon* 30: 171–177.
- Burrows, C.J. 1989. Moa browsing: evidence from the Pyramid Valley mire. *New Zealand Journal of Ecology* 12: 51–56.
- Gregg, D. 1972. Holocene stratigraphy and moas at Pyramid Valley, North Canterbury, New Zealand. *Records of the Canterbury Museum* 9: 151–158.
- Harris, W.F. 1955. Progress report on pollen statistics from Pyramid Valley Swamp. *Records* of the Canterbury Museum 6: 279–290.
- Hogg, A.; Heaton, T.; Hua, Q.; Bayliss, A.; Blackwell, P.; Boswijk, G.; Bronk Ramsey, C.; Palmer, J.; Petchey, F.; Reimer, P. 2020. SHCal20 Southern Hemisphere calibration, 0–55,000 years cal BP. *Radiocarbon* 62: 759–778.
- Holdaway, R.N. 2015. *Pyramid Valley and beyond: Prehistoric life in North Canterbury*. Christchurch, Turnagra Press.
- Holdaway, R.N.; Allentoft, M.E.; Jacomb, C.; Oskam, C.L.; Beavan, N.R.; Bunce, M. 2014. An extremely low-density human population exterminated New Zealand moa. *Nature Communications* 5: 5436.
- Holdaway, R.N.; Worthy, T.H. 1997. A reappraisal of the late Quaternary fossil vertebrates of Pyramid Valley Swamp, North Canterbury, New Zealand. *New Zealand Journal of Zoology* 24: 69–121.
- Johnston, A.G. 2014. A high resolution, multiproxy analysis of the palaeolimnology of Pyramid Valley, North Canterbury. Unpubl. MSc Thesis, Department of Geological Sciences, University

of Canterbury, Christchurch, New Zealand

- Johnston, A.G.; Duffy, B.M.; Holdaway, R.N. 2022. When the lonely goose? Implications of a revised history of Pyramid Valley lake, South Island, New Zealand, and its surrounding vegetation for a radiocarbon age for the only South Island goose (*Cnemiornis calcitrans*) from the Pyramid Valley lake bed deposit, New Zealand. *Notornis* 69(1): 19–36.
- McWethy, D.B.; Whitlock, C.; Wilmshurst, J.M.; McGlone, M.S.; Fromont, M.; Li, X.; Dieffenbacher-Krall, A.; Hobbs, W.O.; Fritz, S.C.; Cook, E.R. 2010. Rapid landscape transformation in South Island, New Zealand, following initial Polynesian settlement. *Proceedings of the National Academy of Sciences, USA 107*: 21343–21348.
- McWethy, Ď.B.; Wilmshurst, J.M.; Whitlock, C.; Wood, J.R.; McGlone, M.S. 2014. A highresolution chronology of rapid forest transitions following Polynesian arrival in New Zealand. *PLoS One* 9: e111328.
- Mills, J.A.; Lavers, R.; Lee, W.G. 1984. The takahe—a relict of the Pleistocene grassland avifauna of New Zealand. *New Zealand Journal of Ecology* 7: 57–70.
- Moar, N.T. 1970. A new pollen diagram from Pyramid Valley swamp. *Records of the Canterbury Museum 8*: 455–461.
- Stuiver, M.; Polach, H.A. 1977. Discussion: Reporting of <sup>14</sup>C data. *Radiocarbon* 19: 355–363.
- Worthy, T.H. 1997. Fossil deposits in the Hodges Creek Cave System, on the northern foothills of Mt Arthur, Nelson. South Island, New Zealand. *Notornis* 44: 111–108.
- Worthy, T.H.; Holdaway, R.N. 1996. Quaternary fossil faunas, overlapping taphonomies, and palaeofaunal reconstruction in North Canterbury, South Island, New Zealand. *Journal* of the Royal Society of New Zealand 26: 275–361.
- **Keywords:** South Island takahe, *Porphyrio hochstetteri*, radiocarbon, Pyramid Valley, habitat, adaptability

#### SHORT NOTE

### Successful use of intraspecific parental fostering in the management of an endemic threatened bird: New Zealand's hihi (*Notiomystis cincta*)

RACHEL E. SELWYN\* Zealandia Centre for People and Nature, PO Box 9267, Wellington 6141, New Zealand

BAUKJE LENTING The Nest Te Kōhanga, Wellington Zoo, 200 Daniell Street, Wellington 6021, New Zealand

KARI C. BEAVEN ELLEN T. IRWIN Zealandia Centre for People and Nature, PO Box 9267, Wellington 6141, New Zealand

Intraspecific fostering of nestlings occurs naturally in some avian species (Hitchcock & Mirarchi 1985; Berggren 2006; Kazama et al. 2012) and is used by conservation practitioners to bolster breeding success in threatened species, or to re-introduce reared chicks into managed populations (Cade 1980; Fentzloff 1984; Synder et al. 1987; Romer 2000; Saint Jalme 2002; Lobo & Marini 2013; Hahn & Yosef 2020; Vigo-Trauco et al. 2021). Introducing chicks into surrogate nests is not a suitable option for all species as some have a higher risk of siblicide, aggression, or rejection from foster parents, or abandonment following management interventions (Synder et al. 1987; Vigo-Trauco et al. 2021). There are few documented cases of intraspecific fostering in a New Zealand passerine species (notably the North Island robin, Petroica longipes; Berggren 2006). Here we report the use of a surrogate nest and induced fostering to successfully raise and release a wild hihi (stitchbird, Notiomystis cincta) nestling at Zealandia Te Māra a Tāne sanctuary (henceforth Zealandia), Wellington. To our knowledge, the potential to use fostering or surrogate nests as a management tool has not been previously trialled with this species.

Hihi are a cavity-nesting passerine species that

were previously common in forests across North Island of New Zealand (Buller 1888; Department of Conservation & Zoological Society of London 2021). Due to habitat destruction, disease, and introduced mammalian predators, the species became restricted to one offshore island (Te Hauturu-o-Toi/ Little Barrier Island) by the 1880s (Taylor *et al.* 2005; Innes et al. 2010). In 2005, 64 hihi were translocated to Zealandia, in the first mainland reintroduction of this species; this is one of seven re-introduced managed populations (Ewen et al. 2013; Salvador et *al.* 2019). The population is now *c.* 120 adults, aided by supplementary feeding, predator exclusion, and provisioning of artificial nest boxes to mimic suitable tree-cavities that would be found in oldgrowth forests (Department of Conservation & Zoological Society of London 2021).

Hihi are the sole members of their phylogenetic family, Notiomystidae (Driskell *et al.* 2007), and have an atypical breeding ecology (Castro *et al.* 1996). They have an unusually long nestling period of 28–31 days, and parental care continues for a further 7–14 days post-fledging (Higgins *et al.* 2001; Castro *et al.* 2003). Females often provide most of the parental care with males, sometimes multiple, contributing towards occasional feeds (Castro *et al.* 1996, 2003; Low *et al.* 2006, 2012). Although hihi typically form breeding pairs, a mixture of

Received 22 October 2021; accepted 31 January 2022 \*Correspondence: Rachel.Selwyn@visitzealandia.com

monogamy, polygyny, polyandry, polygynandry, and extra-pair copulations are commonplace in hihi populations (Castro *et al.* 1996; Low 2005).

In December 2020, during routine breeding season monitoring of nest boxes, an 11-day-old hihi chick was found to be suffering from a large airfilled swelling on the left side of its neck. The chick was the sole nestling from its nest where the other two eggs had failed to hatch. Due to the severity of the chick's condition, it was removed from its nest and immediately taken to the Nest Te Kohanga at Wellington Zoo for veterinary treatment. Veterinary treatment was successful, although the cause of the air-filled swelling remained undetermined. The most likely causes of the swelling were air sac rupture resulting in air leaking into subcutaneous tissues, or obstruction of airflow out of the cervical air sac causing it to hyperinflate. Within 10 days the chick had recovered fully. The chick (henceforth referred to as the introduced chick) was slightly underdeveloped for its age but had gained several grams of mass from hand-rearing and was in good condition. Continuing to hand-rear was not considered to be a viable option as a release into the wild population following weeks of hand-rearing was thought to have a high likelihood of failure, behavioural abnormalities, or failure to successfully re-integrate into the wild population.

A nearby active nest had a breeding female and two male partners raising a lone chick (henceforth referred to as the natural chick) of similar age, and thus was potentially compatible as a surrogate nest. Both social males associated with the nest had been observed attending the nest and feeding the chick alongside the breeding female. Previous research has shown that hihi nestlings can naturally exhibit body size differences linked to hatch order without impacting their survival after fledging, suggesting that slight asynchrony in development between the two chicks would not be an issue (MacLeod et al. 2016). The introduced chick was 18 days old with a mass of 33.1 g. The natural chick was 21 days old with a mass of 37.0 g. The spread of pathogens between the introduced chick and the surrogate nest was a concern; however, as the chick had been treated with antibiotics, some of this risk had been minimised. Further pathogen screening would have delayed the release by several days, thus missing the window for re-introduction.

In January 2021, 10 days after the introduced chick had been removed from its original nest, it was transported to Zealandia to be introduced into the foster nest. The chick was fed immediately prior to being transported. To minimize disturbance and to ease the transition the introduction took place with the natural chick being removed for banding. Upon arriving at the nest site, one of the social males associated with the nest was observed entering the nest box and feeding sounds were heard. The female was observed in the vicinity and remained nearby for the duration of banding. The introduced chick was placed into the nest while the natural chick was removed for banding. The introduced chick was continually vocalizing, and the female showed interest in the nest box as well as the chick we were banding. Following banding, both chicks were placed together in the nest box and appeared to settle quickly. The female entered the nest box two minutes later and remained inside for four minutes. The nest was observed for several hours following banding to look for any signs of rejection or aggression. During this time, the female and both social males were seen separately attending the nest multiple times and both chicks could be heard responding vocally each time. A trail camera (Browning Patriot) was set up to continue observing the nest box entrance. Footage showed ongoing and consistent attendance by the female and the two social males. Both chicks fledged successfully nine days later and were resighted the following week being fed by one of the males. To our knowledge, the original breeding pair that provided the introduced chick did not renest during the remainder of the breeding season. The foster trio had an additional successful breeding attempt with three chicks fledging in March 2021.

There are many factors that must be considered before taking significant wildlife management actions such as the surrogacy used here. This includes minimising the risk of disease transmission and risks to existing nestlings and the surrogate. Further, the case described here provided many situational factors necessary for testing the approach and ultimately supporting its success; nests at Zealandia are intensively monitored, the surrogate nest had a sole nestling of similar age, limiting the risk to the other nestling's survival, and three parents were present possibly providing a greater pool of resources. However, our case study shows that fostering and nest surrogacy could be considered a feasible management option for hihi. Further investigation is required to determine if this approach remains successful under different circumstances, e.g. younger chicks or with more nestmates. Future research could also investigate the potential of using nest surrogacy, possibly alongside artificial incubation, to improve breeding success in hihi populations that struggle from low embryo and nestling survival (Low & Pärt 2009).

#### ACKNOWLEDGEMENTS

We are grateful to the team at the Nest Te Kōhanga for their excellent care in bringing the chick back to health. Thank you to Andrew Hawke for being a fast-thinking and dedicated hihi nest monitor, to the team at Zealandia Te Māra a Tāne for jumping into action and thinking outside of the box, and to the Hihi Recovery Group for providing guidance and advice. This management focused research was conducted under Wildlife Act Authority 53918-CAP.

#### LITERATURE CITED

- Berggren, Å. 2006. Intraspecific adoption and foster feeding of fledglings in the North Island robin. *New Zealand Journal of Ecology* 30(2): 209–217.
- Buller, W.L. 1888. *A history of the birds of New Zealand*. 2<sup>nd</sup> edn, London, The Author.
- Cade, T.J. 1980. The husbandry of falcons for return to the wild. *International Zoo Yearbook 20(1)*: 23–35.
- Castro, I.; Minot, E.O.; Fordham, R.A; Birkhead, T.R. 1996. Polygynandry, face-to-face copulation and sperm competition in the hihi *Notiomystis cincta* (Aves: Meliphagidae). *Ibis* 138: 765–771.
- Castro, I.; Brunton, D. H.; Mason, K. M.; Ebert, B.; Griffiths, R. 2003. Life history traits and food supplementation affect productivity in a translocated population of the endangered Hihi (stitchbird, Notiomystis cincta). Biological Conservation 114(2): 271–280.
- Department of Conservation Te Papa Atawai, Zoological Society of London 2021. *Hihi Conservation 2021*. www.hihiconservation.com. Accessed: 6 October 2021.
- Driskell, A.; Christidis, L.; Gill, B.J.; Boles, W.E.; Barker, F.K.; Longmore, N.W. 2007. A new endemic family of New Zealand passerine birds: adding heat to a biodiversity hotspot. *Australian Journal of Zoology* 55(2): 73–78.
- Ewen, J.G.; Renwick, R.; Adams, L.; Armstrong, D.P.; Parker, K.A.; North, N.Z.D. 2013. 1980– 2012: 32 years of re-introduction efforts of the hihi (stitchbird) in New Zealand. pp. 68–73 In: Global Re-introduction Perspectives: 2013. Further case studies from around the globe. Abu Dhabi, IUCN/SSC Re-introduction Specialist Group & Environment Agency.
- Fentzloff, C. 1984. Breeding, artificial incubation and release of white-tailed sea eagles: *Haliaeetus albicilla*. *International Zoo Yearbook* 23(1): 18–35.
- Hahn, A.; Yosef, R. 2020. Induced alloparental care in common swifts (*Apus apus*): alloparental care. *European Journal of Ecology* 6(2): 18–22.
- Higgins, P.J.; Peter J.M.; Steele W.K.; 2001. Stitchbird (hihi). pp. 954–966 In: Handbook of Australian, New Zealand and Antarctic birds. Melbourne, Oxford University Press.
- Hitchcock, R.R.; Mirarchi, R.E. 1985. Surrogate feeding and adoptive behavior in mourning doves. *The Journal of Wildlife Management* 49(2): 502–504.
- Innes, J.; Kelly, D.; Overton, J.M.; Gillies, C. 2010. Predation and other factors currently limiting New Zealand forest birds. *New Zealand Journal of Ecology* 34(1): 86–114.
- Kazama, K.; Niizuma, Y.; Watanuki, Y. 2012.

Intraspecific kleptoparasitism, attacks on chicks and chick adoption in black-tailed gulls (*Larus crassirostris*). *Waterbirds* 35(4): 599–607.

- Lobo, Y.; Marini, M.A. 2013. Artificial incubation, egg replacement and adoptive parents in bird management: a test with lesser elaenia *Elaenia chiriquensis. Bird Conservation International* 23(3): 283–295.
- Low, M. 2005. Factors influencing mate guarding and territory defence in the stitchbird (hihi) *Notiomystis cincta. New Zealand Journal of Ecology* 29(2): 231–242.
- Low, M.; Joy, M. K.; Makan, T. 2006. Using regression trees to predict patterns of male provisioning in the stitchbird (hihi). *Animal Behaviour* 71(5): 1057–1068.
- Low, M.; Pärt, T. 2009. Patterns of mortality for each life-history stage in a population of the endangered New Zealand stitchbird. *Journal of Animal Ecology* 78(4): 761–771.
- Low, M.; Makan, T.; Castro, I. 2012. Food availability and offspring demand influence sexspecific patterns and repeatability of parental provisioning. *Behavioral Ecology* 23(1): 25–34.
- MacLeod, K.J.; Brekke, P.; Ewen, J.G.; Thorogood, R. 2016. Minutes matter: brief hatching asynchrony adversely affects late-hatched hihi nestlings, but not life beyond the nest. *Animal Behaviour* 119: 111–118.
- Romer, L. 2000. Management of the doubleeyed or red-browed fig parrot *Cyclopsitta diophthalma macleayana* at Currumbin Sanctuary, Queensland. *International Zoo Yearbook* 37(1): 152–158.
- Salvador, R.B.; Tomotani, B.M.; Miskelly, C.M.; Waugh, S.M. 2019. Historical distribution data of New Zealand endemic families *Callaeidae* and *Notiomystidae* (Aves, Passeriformes). *Check List* 15: 701–727.
- Saint Jalme, M. 2002. Endangered avian species captive propagation: an overview of functions and techniques. Avian and Poultry Biology Reviews 13(3): 187–202.
- Snyder, N.R.R.; Wiley, J.W.; Kepler, C.B. 1987. The Parrots of Luquillo: Natural History and Conservation of the Puerto Rican Parrot. Los Angeles, California, Western Foundation of Vertebrate Zoology.
- Taylor S.; Castro I.; Griffiths R. 2005. Hihi/stitchbird (Notiomystis cincta) Recovery Plan 2004–09. pp. 31 In: Threatened Species Recovery Plan 54. Wellington, Department of Conservation.
- Vigo-Trauco, G.; Garcia-Anleu, R.; Brightsmith, D.J. 2021. Increasing survival of wild macaw chicks using foster parents and supplemental feeding. *Diversity* 13(3): 121–135.
- Keywords: hihi, *Notiomystis cincta*, intraspecific fostering, surrogate nest, alloparental care

#### SHORT NOTE

#### Unmanned Aerial Vehicle (UAV) activity elicits little to no response from New Zealand forest birds during wildlife monitoring

ZOË L. STONE\* Zoology and Ecology Group, School of Natural Sciences, Massey University, Palmerston North, New Zealand

KEVIN A. PARKER Parker Conservation Ltd. PO Box 130, Warkworth, New Zealand

Drones, or UAVs (unmanned aerial vehicles) are increasingly popular for wildlife monitoring because they offer a relatively cheap and fast means to monitor wildlife (Chabot & Bird 2015; Gallego & Sarasola 2021). However, there is concern about how UAVs influence wildlife behaviour. Most studies investigating bird responses to UAVs have focused on open habitats (e.g. Weston et al. 2020) where these bird assemblages, including raptor species, have demonstrated sensitivity to UAV activity (Lyons et al. 2017), but few studies have examined how forest species respond. In Aotearoa New Zealand, wildlife monitoring within forest landscapes is often challenging, and UAVs have been touted as a means for improving monitoring in these complex habitats. However, forest bird responses to UAVs are largely unknown. Here we outline observations of forest bird responses from sustained UAV use within rich and diverse forest sites during recent monitoring.

Turitea reserve is the main water catchment for Palmerston North and consists of broadleaf/

podocarp forest at lower elevation (80-300 m a.s.l.) dominated by a tawa (Beilschmiedia tawa)/ rewarewa (Knightia excelsa) canopy with emergent rimu (Dacrydium cupressinum)/miro (Pectinopitys ferruginea), transitioning into regenerating submontane horopito (Pseuduowintera colorata) scrub. The site has a diverse bird assemblage typical of New Zealand broadleaf forests (Table 1) and includes large populations of uncommon species such as popokotea (whitehead, Mohoua Acanthisitta albicilla), tītitipounamu (rifleman, chloris), miromiro (North Island tomtit, Petroica *macrocephala*), korimako (bellbird, Anthornis melanura), and kārearea (New Zealand falcon, Falco novaeseelandiae). The two reservoirs also provide habitat for a range of aquatic birds, including tētēmoroiti (grey teal, Anas gracilis).

We conducted 48 flights (*c*. 15 hours) using a large (4 kg) UAV (DJI Matrice 200) to track the dispersal of 40 toutouwai (North Island robin, *Petroica longipes*) reintroduced to Turitea reserve (Fig. 1). A commercial-sized UAV capable of carrying a custom receiver was required for toutouwai monitoring. These larger UAVs are louder than smaller recreational drones which are commonly used for

*Received 1 December 2021; accepted 2 February 2022* \*Corresponding author: *Z.Stone@massey.ac.nz* 



Figure 1. Location of observation sites in New Zealand, with aerial views of the landscape where UAV monitoring was conducted (upper image – UAV above Turitea reserve; lower image – Close up image of canopy from UAV camera used for helping identify bird responses).

wildlife surveys. For instance, similar commercial UAVs produce noise emissions ranging from 80–90 dB compared to smaller recreational UAVs, which produce 50–80 dB of noise (Schäffer *et al.* 2021). This noise level is comparable to heavy traffic and far above the ambient noise level of typical rural/forest environments (Torija *et al.* 2020). As a result, we expected our observations to reflect the higher end of potential forest bird responses to UAVs.

Monitoring was conducted by a Part 101 licensed operator (ZLS) which meant the UAV was always within line of sight and bird responses to the UAV could be observed. Noise emissions were generally heard at all times by the operator except at the furthest distances (e.g. >1 km). Volunteers undertaking toutouwai ground monitoring were also occasionally below the UAV during flights and could clearly hear it from beneath the canopy (D. Armstrong & K. Macdermid *pers. comm.*).

In addition to the sound and flight associated disturbance from the UAV, we attached additional navigation strobe lighting to the unit to assist with visibility during monitoring. These strobe lights (Firehouse Technology Arc "V" Drone Strobe Navigation Light – in red and white) produce 1,000 lumens of output which may also disturb birds. UAV flights followed a lawnmower pattern with gridlines 60 m apart and lasted on average 12 minutes and covering 2.2 km per flight. The UAV was flown at speeds of 14-16 km/h (3.8-4.4 m/s) at an altitude of 70 m a.g.l. (above ground level). Prior to monitoring calibration flights were also flown at 45 m a.g.l. - the lowest possible altitude that allowed canopy clearance, 50, 60, 75, and 100 m a.g.l. While this speed and altitude were specific to toutouwai monitoring, it likely reflects a higher potential disturbance to forest species as the transmitters used (Lotek Picopip Ag376) are small and require the UAV to be flown close to the canopy for best detection. Take-off was generally 100 m from the forest edge but sometimes occurred within 10-20 m.

During monitoring almost all of the observed 33 species (Table 1) showed no discernible response to the UAV (April – July 2021) based on approximately 2,259 anecdotal observations. Observations were taken from the ground by the pilot and observers, and from video footage retrieved from the UAV. Of the few species that did display an identified response (8), these appeared to be relatively minor or very brief.

<b>Table 1.</b> List of all bird species recorde according to Gill <i>et al.</i> 2010; E = Exotic). clearly UAV triggered (? = 4) or if specie been estimated based on visual observe	ed in Turitea reserve (Manawatu, N UAV response column indicates w se was never directly observed duri ations per flight (e.g. average of fiv	Vew Zealand) d hether a respon ng flights (- = 10 e tūī observed p	uring annu se was obse ). Number o er flight = 24	I bird monitoring by Palmerston North City Council (ordered ved $(Y = 8)$ , not observed (N = 21), if observed response was not of observations for each species that were clearly identifiable has to observations).
Common name	Scientific name	Number of observations	UAV response	Response type
PHASIANIDAE				
Peafowl (E)	Pavo cristatus	0	ı	1
ANATIDAE				
Black swan (E)	Cygnus atratus	5	Z	
Canada goose (E)	Branta canadensis	5	Z	1
Tētē moroiti/Grey teal	Anas gracilis	10	Υ	Minor displacement
Mallard (E)	Anas platyrhynchos	300	Z	1
Putangitangi/Paradise shelduck	Tadorna variegata	120	Y	Take-off, circling & displacement
I I A LA L				
Kawau/Black shag	Phalacrocorax carbo	15	ć	Possible take-off/displacement
Kāruhiruhi/Pied shag	Phalacrocorax varius	48	ć	Possible take-off /displacement
ACCIPITRIDAE				
Kahu/Swamp harrier	Circus approximans	70	Z	
FALCONIDAE				
Kārearea/New Zealand falcon	Falco novaeseelandiae	15	Z	1
RALLIDAE				
Pukeko	Porphyrio melanotus	0	ı	
CHARADRIIDAE				
Spurwinged plover	Vanellus miles	15	Y	Take-off & displacement (only when UAV very close)
LARIDAE				
Black-backed gull	Larus dominicanus	0	ı	1
COLUMBIDAE				
Kererū	Hemiphaga novaeseelandiae	240	Z	1
STRIGOPIDAE				
Kaka	Nestor meridionalis	0	ı	
CACATUIDAE				
Sulphur crested cockatoo (E)	Cacatua galerita	20	Y	Take-off/displacement, circling (Bushy Park)

Short note 121

Table 1. continued				
Common name	Scientific name	Number of observations	UAV response	Response type
PSITTACIDAE				
Eastern rosella (E)	Platycercus eximius	£	Y	Stopped singing (UAV directly overhead)
CUCULIDAE				
Koekoeā/Longtailed cuckoo	Eudynamys taitensis	0	ı	
Pipīwharauroa/Shining cuckoo	Chrysococcyx lucidus	5	Z	-
STRIGIDAE				
Ruru/Morepork HALCYONIDAE	Ninox novaeseelandiae	0	I	
Kotare/Sacred kingfisher	Todiramphus sanctus	0		-
ACAN I HISI I I I DAE				
Tititipounamu/Rifleman ACANTHIZIDAE	Acanthisitta chloris	15	Z	
Riroriro/Grey warhler	Gernoone joata	06	>	Stonned singing mossible take-off/displacement (UAV directly overhead)
MELIPHAGIDAE		2	1	
Korimako/Bellbird	Anthornis melanura	380	Z	
Tūī	Prosthemadera novaeseelandiae	240	Z	
PACHYCEPHALIDAE				
Pōpokatea/Whitehead	Mohoua albicilla	06	Υ	Stopped singing (UAV directly overhead)
ARTAMIDAE				
Australian magpie (E)	Gymnorhina tibicen	Э	Z	(Bushy Park)
RHIPIDURIDAE				
Piwakawaka/New Zealand fantail	Rhipidura fuliginosa	150	Z	
PETROICIDAE				
Toutouwai/North Island robin*	Petroica longipes	15	Z	
Miromiro/North Island tomtit	Petroica macrocephala toitoi	40	Z	
ALAUDIDAE				
Skylark (E)	Alauda arvensis	10	Z	
ZOSTEROPIDAE				
Tauhou/Silvereye	Zosterops lateralis	60	ć	Possible take-off/displacement (UAV directly overhead)

Table 1. continued				
Common name	Scientific name	Number of observations	UAV response	Response type
HIRUNDINIDAE				
Warou/Welcome swallow	Hirundo neoxena	30	Υ	Changed course (only when UAV very close)
TURDIDAE				
Eurasian blackbird (E)	Turdus merula	80	Z	
Song thrush (E)	Turdus philomelos	15	Z	
STURNIDAE				
Common starling (E)	Sturnus vulgaris	20	Z	
MOTACILLIDAE				
Pihoihoi/New Zealand pipit	Anthus novaeseelandiae	0	ı	
PRUNELLIDAE				
Dunnock (E)	Prunella modularis	0	·	
FRINGILLIDAE				
Chaffinch (E)	Fringilla coelebs	20	ć	Possible take-off/displacement
European goldfinch (E)	Carduelis carduelis	60	Ζ	
European greenfinch (E)	Carduelis chloris	50	Z	
Common redpoll (E)	Carduelis flammea	0	·	
EMBERIZIDAE				
Yellowhammer (E)	Emberiza citrinella	20	N	
TOTAL		2,259		

In general, native forest birds showed little or no reaction to the UAV, with some minor responses observed such as brief pauses in singing by smaller species (K. Macdermid pers. comm.) or possible displacement from perches when the UAV was directly overhead. The UAV often flew directly over perching kererū (New Zealand pigeon, Hemiphaga novaeseelandiae) which could be seen in the canopy from both ground and UAV camera footage, and no individuals were observed moving or being alarmed when the UAV flew or hovered above. Kererū can be sensitive to ground disturbance, e.g. from hikers and walkers (Mander et al. 1998). However, it was reassuring that kererū did not appear to respond to UAV activity and seemed to move naturally below it (including performing breeding displays). Tūī (Prosthemadera novaeseelandiae) and korimako were also often seen undertaking general movements and foraging activities, and singing and being territorial within the canopy prior to UAV take-off. As the UAV approached during monitoring (c. 40 m), individuals appeared to maintain these behaviours and did not appear to alter their movement patterns.

Predatory birds can respond aggressively to UAVs (e.g. Junda *et al.* 2016); however, we noted no response by kārearea and kahu (swamp harrier, *Circus approximans*) which often flew past or directly above the UAV without changing behaviour.

All other forest bird species showed no response to UAV activity directly above. This included the recently released toutouwai; a pair observed at a nest when the UAV passed directly above did not alter their behaviour and the nestlings remained vocal while being fed (K. Macdermid *pers. comm.*). This nest was located in a tall tawa (20–30 m), so the UAV would have been within 40 m at the time.

The main responses observed were from aquatic birds found at the reservoirs. Pūtangitangi (paradise shelduck, Tadorna variegata) reacted to UAV take-off and fly-bys, with individuals responding almost every time to take-off. When the UAV was in flight and crossed a reservoir, responses could be observed at a distance. For example, pūtangitangi disturbed from the water (or a perch) circled the UAV a few times and then left the reservoir while alarm calling. In some instances, individuals would return to their original location before being disturbed, but most were displaced, settling out of range of the UAV. Various shags were also seen flying during UAV flights; however, these individuals were only observed from a distance, and it is unclear whether the displacement was in response to the UAV or not. On the few occasions where tētē-moroiti were close to a UAV take-off, they did move away from the dam edge but did not take flight. These responses were consistent with observed responses to general human presence.

During preliminary testing at Bushy Park

Tarapuruhi - a fenced sanctuary 20 km north-east of Whanganui which has a similar bird assemblage to Turitea but with the addition of tieke (North Island saddleback Philesturnus carunculatus) and hihi (Notiomystis cincta) - we also witnessed no notable responses to the UAV by native species. Hihi continued to use the supplementary feeders when the UAV was directly above, and no change in tieke behaviour occurred. However, during these flights, we did witness our only major response by a forest bird - sulphur crested cockatoos (Cacatua galerita). Soon after UAV take-off, a small flock (c. 10 birds) of this non-native species rose from the canopy and flew towards the UAV, calling loudly. This response happened on two occasions with the flock circling the UAV a few times before returning to their original perches. This reaction was provoked from over 100 m away. Native parrots (Strigopidae & Psittaculidae) were not observed at our sites (although kaka Nestor meridionalis has been recorded rarely in Turitea reserve) so we are unable to evaluate their response. Based on the cockatoo response, we recommend testing prior to the use of UAVs within sites where they occur.

Our UAV flew at consistent flight speeds on autopilot, occasionally pausing briefly at waypoints to change direction or adjust altitude. Bird responses to UAVs may vary depending on whether the UAV is stationary or mobile, so different responses to those identified here could be possible for different flight patterns. During their research, Muller *et al.* (2019) filmed nesting penguins and found that sudden changes in UAV acceleration triggered more head tilts than smooth flight patterns. We never witnessed this during our monitoring, where the use of autopilot software meant flight paths were smooth and continuous. We therefore suggest the use of autopilot software, for future monitoring, to reduce bird disturbance by UAVs.

A benefit of the receiver system we used during monitoring (Muller et al. 2019) was that the aerial array was custom-designed to sit as a box protruding wider and higher than the rotors. We believe this may provide a solid barrier that birds are able to see compared to bare spinning rotors which could be difficult to see. This meant that in the few instances when birds did get close to the UAV, they were kept away from potential harm. During our monitoring, we only observed one incident where a pūtangitangi had to change course to avoid a collision. This occurred during preliminary test flights during the breeding season (November), and it was suspected a nest may have been nearby, prompting the pair to display more defensive behaviour. We suggest utilising a similar barrier/guard to our aerial array that sits outside the rotors or using propellor guards that are available for some UAV models to avoid harm to individuals.

Our observations at sites with a wide assemblage of New Zealand forest bird species present a scenario where UAV disturbance can be assessed. While these observations are anecdotal, they provide evidence that many of New Zealand's forest dwelling birds are unlikely to be negatively affected by UAVs during wildlife monitoring research. Our monitoring used automated piloting software for smooth and consistent, and predictable flight paths, which may provide less disturbance to birds. However, aquatic birds, particularly ducks responded to the UAV take-off, flybys, and hovering in a similar way as to human presence. UAVs for tracking wildlife, therefore, likely provide low disturbance to birds in forest settings. However, additional testing of specific species responses during breeding, and for particular groups (e.g. native parrots) would be beneficial to identify and minimise any potential negative responses.

#### ACKNOWLEDGEMENTS

Thank you to Doug Armstrong for the initial comments on this paper and to Kara Macdermid and Chris Muller for their input and field assistance. This study was funded by Ministry of Business and Innovation (MBIE) under contract C09X1805 'More Birds in the Bush' and in accordance with approved animal ethics practice (MUAEC Protocol 20/17) and the Wildlife Authority Act permissions (permits 69360-FAU and 68060-FAU).

#### LITERATURE CITED

- Chabot, D.; Bird, D.M. 2015. Wildlife research and management methods in the 21st century: where do unmanned aircraft fit in? *Journal of Unmanned Vehicle Systems* 3(4): 137–155. doi: 10.1139/juvs-2015-0021
- Gallego, D.; Sarasola, J.H. 2021. Using drones to reduce human disturbance while monitoring breeding status of an endangered raptor. *Remote Sensing in Ecology and Conservation* 7: 550–561. doi: 10.1002/rse2.206
- Gill, B.; Bell, B.; Chambers, G.; Medway, D.; Palma, R.; Scofield, R.; Tennyson, A.; Worthy, T.H. 2010. Checklist of the birds of New Zealand, Norfolk and Macquarie Islands, and the Ross Dependency,

Antarctica. (4th Edition) Ornithological Society of New Zealand and Te Papa Press, Wellington.

- Junda, J.H.; Greene, E.; Zazelenchuk, D.; Bird, D.M. 2016. Nest defense behaviour of four raptor species (osprey, bald eagle, ferruginous hawk, and red-tailed hawk) to a novel aerial intruder – a small rotary-winged drone. *Journal* of Unmanned Vehicle Systems 4(4): 217–227. doi: 10.1139/juvs-2016-0004
- Lyons, M.; Brandis, K.; Callaghan, C.; McCann, J.; Mills, C.; Ryall, S.; Kingsford, R. 2017. Bird interactions with drones, from individuals to large colonies. Cold Spring Harbor Laboratory. doi: 10.1101/109926
- Mander, C.J.; Hay, J.R.; Powlesland, R. 1998. Monitoring and management of kereru (*Hemiphaga novaeseelandiae*). Department of Conservation Technical Series, no. 15. Wellington, New Zealand, Department of Conservation.
- Muller, C.G.; Chilvers, B.L.; Barker, Z.; Barnsdale, K.P.; Battley, P.;F.; French, R.K.; McCullough, J.; Samandari, F. 2019. Aerial VHF tracking of wildlife using an unmanned aerial vehicle (UAV): comparing efficiency of yellow-eyed penguin (*Megadyptes antipodes*) nest location methods. *Wildlife Research* 46(2): 145–153. doi: 10.1071/WR17147
- Schäffer, B.; Pieren, R.; Heutschi, K.; Wunderli, J.M.; Becker, S. 2021. Drone noise emission characteristics and noise effects on humans – a systematic review. *International Journal of Environmental Research and Public Health* 18(11): 5940. doi: 10.3390/ijerph18115940
- Torija, A.J.; Li, Z.; Self, R.H. 2020. Effects of a hovering unmanned aerial vehicle on urban soundscapes perception. *Transportation Research Part D: Transport and Environment 78*: 102195. doi: 10.1016/j.trd.2019.11.024
- Weston, M.A.; O'Brien, C.; Kostoglou, K.N.; Symonds, M.R.E. 2020. Escape responses of terrestrial and aquatic birds to drones: towards a code of practice to minimize disturbance. *Journal of Applied Ecology* 57: 777–785. doi: 10.1111/1365-2664.13575
- Keywords: UAV, drone, wildlife monitoring, birds, New Zealand

Notornis, 2022, Vol. 69: 126-129 0029-4470 © The Ornithological Society of New Zealand Inc.

#### SHORT NOTE

### Polygyny observed in pāteke (brown teal, Anas chlorotis)

BERNARD MICHAUX PO Box 191, Kaukapakapa 0873, New Zealand

Pāteke (brown teal, Anas chlorotis) is a small, endemic dabbling duck that was once widespread throughout lowland New Zealand (Williams 2013). It suffered a catastrophic population decline following European settlement in the mid-1800s and was reduced to relict populations in Northland, Aotea/Great Barrier Island, and Fiordland by the mid-twentieth century (Hayes & Williams 1982; Parish & Williams 2001; Ferreira & Taylor 2003; Harper 2009). The reasons for this decline are depressingly familiar; introduced mammalian predators combined with the loss of wetland habitat, and possibly disease (McKenzie 1971), reduced the number of wild birds to an estimated 1,500 by the 1970s (Dumbell 1986). Successful captive breeding programmes were established by Ducks Unlimited (Operation Pāteke) and the Mount Bruce Native Bird Reserve, with reared birds being released at suitable predator-controlled sites from the late 1960s (Hayes & Williams 1982). The success of these programmes resulted in a downgrading of the threat level from Nationally Endangered to Recovering in 2008 (Department of Conservation 2022), although the species is still considered vulnerable with an estimated wild population of only 2,000-2,500; mainly in Northland (c. 600), Aotea (c. 700), and the Coromandel (c. 400) (Department of Conservation 2022).

Pāteke are crepuscular and actively feed at night (Williams 2013). They prefer still or sluggishly moving water and ample vegetation cover that provides daytime shelter and secluded nesting sites. As the breeding season approaches in late winter or early spring (July-September; Williams 2013), birds that have congregated at flocking sites pair off and establish breeding territories that they vigorously defend against both conspecifics and other water fowl (Hayes & Williams 1982). This short note reports an example of polygyny in the usually strictly monogamous pāteke, which was observed at the Weiti chéniers, Auckland (Fig. 1) during the 2021/22 breeding season. The Weiti chénier area, a series of shell ridges separated by mangrove swamps, provides ideal habitat for pāteke. A brackish water lagoon (0.6 ha) formed on the landward side of the outer chénier and extensive mudflats on its seaward side provide adequate sources of food (Moore & Battley 2003; Moore *et al.* 2006), and an adjacent vegetated area of 0.4 ha provides daytime shelter and suitable nesting sites. Pest control on and around the chéniers has been carried out since 2013 by a local community group, initially to protect New Zealand dotterel (tūturiwhatu, Charadrius obscurus) and variable oystercatcher (torea pango, Haematopus unicolor) nesting sites, but this has also reduced predator pressure on nesting pāteke and their ducklings.

*Received 4 February 2022; accepted 13 March 2022* Correspondence: *bjmichaux@gmail.com* 



**Figure 1.** The four chéniers are labelled 1–4. M = mangroves. The dashed line on the youngest chénier (4) separates bare shell from vegetated areas. The cover vegetation adjacent to the lagoon is used by pāteke (brown teal, *Anas chlorotis*) for daytime shelter and nesting. Extensive areas of mudflats are available for nocturnal feeding. The Scrub/Coastal Bush vegetation includes grassland, mature macrocarpa (*Cupressus macrocarpa*), regenerating native vegetation, replanted areas and mature põhutukawa (*Metrosideros excelsa*) and pūriri (*Vitex lucens*) along old cliff faces. The lagoon is at 36°38′43″S, 174°43′32″E.

Pāteke have successfully bred at this site since 2017 when a pair raised two offspring (Martin Sanders pers. comm.). The Weiti birds are self-introduced and were originally banded on Motutapu island in the Hauraki Gulf. In the 2021/22 breeding season three birds, a male and two females, were first observed at the lagoon on the 2 July 2021. One of the females was uniquely banded (metal/ white). However, the white band may have faded from an original yellow, as a female with a metal/ yellow band combination was observed at Weiti in 2018. While the birds were usually seen resting together, the unbanded female was observed on several occasions to be aggressive towards the banded female. Two or three adult pāteke were observed on twelve subsequent visits between 2 July 2021 and 11 February 2022 indicating that they were holding a territory; this was confirmed by the aggressive behaviour of the drake towards mallards (A. platyrhynchos) that were also breeding at the lagoon. A brood of four pāteke ducklings (Fig. 2) was first seen on the 9 December 2021 (pers. obs.) and based on shape and size were about four weeks old (Barker & Williams 2002). The four ducklings were observed until 21 December 2021 (Martin Sanders pers. comm.) after which the unbanded female and four juveniles vacated the territory and

were not observed again. This was coincidental with a new brood of three ducklings, estimated to be a week or so old, observed with the banded female on the 22 December 2021. It is likely that these two events are linked and that the maturing juveniles were old enough to survive in the wider environment as they became progressively more independent from the adults, leaving their more protected natal habitat for the younger brood. Whether the banded female and male ejected the unbanded female and her brood or it was a natural progression as the ducklings matured is not known. The three juveniles and parents were still present at the lagoon on 27 January 2022 when they were almost adult size.

Monogamy is the primary mating system in dabbling ducks, with pāteke males protecting nesting females, defending feeding territory, and helping to care for ducklings, but three southern hemisphere species – Cape teal (*A. capensis*), speckled teal (*A. flavirostris*), and white-cheeked pintail (*A. bahamensis*) frequently exhibit polygyny (McKinney 1985). Polygyny has also been observed occasionally in northern hemisphere species such as the Eurasian wigeon (*A. penelope*) (Jacobsen & Ugelvik 1995). McKinney (1985) suggested that polygyny may be favoured in dabbling duck species



Figure 2. Unbanded female pāteke (brown teal, *Anas chlorotis*) with four ducklings resting on the vegetated margin of the Weiti lagoon and about to take to the water in response to the approaching photographer. Photograph: Martin Sanders.

that have extended and/or irregular breeding seasons, as is the case with pāteke, which might produce asynchrony in breeding and moult timing resulting in a skewed sex ratio thereby relaxing constraints on strict monogamy. If this is the case, one may expect to find polygyny in dabbling duck population where the sex ration is skewed for other reasons. Wingfield (1984) demonstrated that polygyny could be induced in monogamous species by artificially increasing testosterone. Because pāteke are known to exhibit territorial aggression, even towards species as large as black swans (Cygnus atratus) (Hayes & Williams 1982), we can assume that testosterone levels are high enough in males during the breeding season to create a potential for polygyny in this species. Whether this potential is realised will depend on circumstances (Emlen & Oring 1977).

Perhaps the polygyny observed this breeding season at Weiti was simply a result of the trio's isolation from other pāteke. The staggered breeding times observed allowed the male to protect both females while they were nesting and to provide for both sets of ducklings, and perhaps could best be described as serial monogamy rather than true polygyny. To my knowledge, this is the first report of multiple mating by a male pāteke and has implications for the conservation of this species. Provided there is no significant difference in survival of young to fledging age between monogamous and polygynous pairings, polygyny could increase the potential for pāteke to self-spread and that reintroductions could be successful even if only few individuals were translocated.

#### ACKNOWLEDGEMENTS

I would like to thank Martin Sanders, a Stillwater stalwart, for providing feedback and photographs, Malin Undin for her review, and Craig Symes for his editorial assistance.

#### LITERATURE CITED

- Barker, D.; Williams, M. 2002. Breeding of brown teal (*Anas chlorotis*) at Okiwi, Great Barrier Island. *Notornis* 49: 199–208.
- Department of Conservation 2022. Brown teal/pāteke. Accessed: 2 February 2022. https://www.doc.govt.nz/nature/nativeanimals/birds/birds-a-z/brown-teal-pateke/
- Dumbell, G. 1986. The New Zealand brown teal: 1845–1985. Wildfowl 37: 71–87.
- Emlen, S.T.; Oring, L. W. 1977. Ecology, sexual selection, and the evolution of mating systems.

Science 197(4300): 215–223.

- Ferreira, S.M.; Taylor, S. 2003. Population decline of brown teal (*Anas chlorotis*) on Great Barrier Island. *Notornis* 50: 141–147.
- Harper, G.A. 2009. The native forest birds of Stewart Island/Rakiura: patterns of recent declines and extinctions. *Notornis* 56: 63–81.
- Hayes, F.N.; Williams M. 1982. The status, aviculture and re-establishment of brown teal in New Zealand. *Wildfowl* 33: 73–80.
- Jacobsen, O.W.; Ugelvik, M. 1995. A case of polygyny in the Eurasian Wigeon Anas penelope. Wildfowl 46: 72–75.
- McKenzie, H.R. 1971. The brown teal in the Auckland Province. *Notornis* 18: 280–286.
- McKinney, F. 1985. Primary and secondary male reproductive strategies of dabbling ducks. Pp. 68–82 In: Gowaty, P.A.; Mock, D.W. (eds) Avian Monogamy, Ornithological Monographs 37. Washington, American Ornithological Union.

- Moore, S.J.; Battley, P.F. 2003. Cockle-opening by a dabbling duck, the brown teal. *Waterbirds* 26: 331–334.
- Moore, S.J.; Battley, P.F.; Henderson, I.M.; Webb, C.J. 2006. The diet of brown teal (*Anas chlorotis*). *New Zealand Journal of Ecology* 30: 397–403.
- Parrish, R; Williams, M. 2001. Decline of brown teal (Anas chlorotis) in Northland, New Zealand, 1988–99. Notornis 48: 131–136.
- Williams, M.J. 2013 [updated 2020]. Brown teal. In Miskelly, C.M. (ed.) New Zealand Birds Online. www.nzbirdsonline.org.nz
- Wingfield, J.C. 1984. Androgens and mating systems: testosterone-induced polygyny in normally monogamous birds. *The Auk* 101: 665–671.
- Keywords: pāteke, brown teal, polygyny, dabbling duck

Notornis, 2022, Vol. 69: 130-134 0029-4470 © The Ornithological Society of New Zealand Inc.

#### SHORT NOTE

# Opportunistic predation of non-native species by pūkeko (*Porphyrio melanotus melanotus*)

AILEEN P. SWEENEY\* KRISTAL E. CAIN School of Biological Sciences, University of Auckland, Auckland 1010, New Zealand

When species are introduced to, or naturally colonise, new areas they may encounter either novel prey or novel predators or, in some cases, both. Conversely, they may present as either novel prey or novel predators to the local fauna (e.g. McLennan et al. 1996; Yorio et al. 2020). Whether or not a species establishes a self-sustaining population in a newly invaded region, as well as the impacts they may have on the invaded ecosystem, depends on numerous factors (Williamson 1999; Duncan et al. 2003). One of the factors dictating a successful establishment in a new region may be the behavioural flexibility of the introduced species and their responses to novel situations, predators, and prey (Sol et al. 2002). For example, an invasion event may involve the partial or total loss of the species native diet, such that, without sufficient dietary flexibility, the establishment of the species may be unsuccessful (Sol & Lefebvre 2000).

Therefore, it is reasonable to predict that dietary generalists are better equipped to establish in new regions compared to dietary specialists. Generalist omnivores may be opportunistic feeders and therefore can utilise available novel food sources which specialists cannot. Indeed, some of the most successful and widespread species in the world are opportunistic generalists, for example house sparrows (*Passer domesticus*), common cockroaches (Periplaneta americana), and brown rats (Rattus norvegicus) (Case 1996; Sax & Brown 2000; Cassey 2001). It is unsurprising that these cosmopolitan species are also associated with humans in both their native and introduced ranges, but it obscures whether their invasiveness is due to diet or being a human commensal (Barrett et al. 2019). In other words, successful invaders are often passengers of human driven habitat modification (Grarock et al. 2013). However, a number of other very successful invasive species are less dependent on humans, but are still very flexible in diet, such as the Asian carps (a number of species of cyprinid fishes) and cane

*Received 22 December 2021; accepted 30 March 2022* \*Correspondence: *aswe261@auckanduni.ac.nz* 

toads (Rhinella marina), suggesting diet is important.

Non-native species introductions have long been considered one of the main threats to biodiversity and ecosystem composition. Indeed, there are many examples to support this, particularly in New Zealand (Aotearoa) where introduced predators have been responsible for historical extinctions and severe population declines for many endemic species, and are still a driving force in many current population declines (O'Donnell 1996; Dowding & Murphy 2001; Duncan & Blackburn 2004; Innes et al. 2010; Tennyson 2010; Remeš et al. 2012; Garcia-R & Di Marco 2020). However, it has become increasingly apparent that non-native introductions may have neutral and/or positive effects on native species, particularly if the invading species in question can become prey for natives (e.g. Rodriguez 2006; Goodenough 2010; Pintor & Byers 2015; Carlson et al. 2017; Yorio et al. 2020). If native predators can take advantage of novel prey (i.e. successfully identify and capture the prey), and if these novel prey become relatively abundant, then the native predators may obtain fitness benefits from the presence of this nonnative species (Carlsson et al. 2009). In a metaanalysis of introduced species studies, Pintor and Byers (2015) found that the focus on predatorprey interactions involving introduced species is largely one-sided (i.e. focused on introduced predators rather than introduced prey). However, it appears that native predator populations typically increase significantly following the introduction of non-native prey. Thus, introduced prey may indirectly benefit native prey by offering new targets and diluting the risk. Understanding these native predator/introduced prev dynamics may be fundamental in protecting native prey species from severe competition or even displacement by introduced prey species. Native predators may aid in limiting or entirely prohibiting the expansion of introduced prey species populations through biotic resistance (deRivera et al. 2005; Cheng & Hovel 2010).

Pūkeko (*Porphyrio melanotus melanotus*) are a highly successful New Zealand subspecies of the purple swamphen. Estimates date their selfintroduction from Australia to ~1,000 years ago, and today they are widespread across mainland New Zealand, as well as offshore islands (Worthy & Holdaway 1996; Trewick 1996a, 1996b; 1997; Trewick & Worthy 2001). It was not until the 1800s, during European colonisation, that additional species were introduced to New Zealand, including mammalian predators and various avifauna, particularly British species (see Duncan 1997 for a full list of British passeriforms released in New Zealand).

Pūkeko diet is primarily plant material such

as stems, shoots, leaves, and seeds of numerous varieties of grass, sedge, rush, and clover (Carroll 1966; Dey & Jamieson 2013; Rodgers & Cain 2019). In addition, they are also opportunistic feeders and a portion of their diet consists of animal material (Trewick 1996a). However, how large and how frequent a portion is unclear. In one Australian population, animal matter was found in 51 of 234 animal (22%), but made up only 1% of the contents by volume (Norman & Mumford 1985). The animal matter in pūkeko diet is primarily invertebrates. However, reports of larger vertebrate prey exist (Carroll 1966; McKenzie 1967; Fogarty 1968; Wright 1978; Dey & Jamieson 2013). These include New Zealand reports of predation on species such as pied stilt eggs (Himantopus leucocephalus), Eurasian blackbird chicks (Turdus merula), mallard (Anas platyrhynchos) ducklings, pāteke ducklings (brown teal, Anas chlorotis), as well as reports in Australia on species such as common starlings (Sturnus vulgaris), noisy miner chicks (Manorina melanocephala), black swan eggs and cygnets (Cygnus atratus), and various waterfowl species ducklings (Van Tets, 1965; Lowe 1966; McKenzie 1967; Fogarty 1968; Wright 1978; Nixon 1983; Egan 1992; Morgan et al. 2006; Balasubramaniam & Guay 2008; Rickett 2010). Craig (1974) reported that pukeko mainly took prey during the breeding season to feed chicks. This presents a unique situation in which pūkeko are a self-introduced (and now considered native) predator and prey species. Further, this species has experienced the introduction of further new predator and prey species since this initial colonisation event.

We monitored a North Island population of pūkeko from September 2017 – October 2020 in Māngere, Auckland (36.95052°S, 174.76543°E), as part of a larger project on the species (Sweeney 2022). Regular census counts (on average once a fortnight) and *ad libitum* observations occurred throughout the study period, in addition to other experiments. Over the course of three years, pūkeko were observed opportunistically depredating five non-native species, three avian and two mammalian, involving a total of eight events (Table 1). All events involved significant commotion, with three-nine members of the pūkeko social group involved. The bird which caught the prey typically ran around with it, while other members of the group vocalised loudly and gave chase. In four of the eight observations, we observed the situation immediately preceding the event. In all four cases the depredating bird was not observed "stalking" the prey, instead each event appeared to happen spontaneously (i.e. opportunistically) when the prey item suddenly appeared near the attacking individual. In the case of the European greenfinch (Chloris chloris), it flew to join the pukeko feeding

Species	Age	Observations	Time of Year
Brown rat ( <i>Rattus norvegicus</i> )	Juvenile	1	Breeding Season
Mouse (Mus musculus)	Adult	3	Breeding Season
European Greenfinch (Chloris chloris)	Adult	1	Breeding Season
European Goldfinch (Carduelis carduelis)	Adult	1	Breeding Season
Mallard (Anas platyrhynchos)	Duckling	2	Breeding Season

**Table 1.** Non-native species observed being opportunistically predated on by pūkeko (*Porphyrio melanotus melanotus*)from September 2017 – October 2020.

on some grass seed and the pūkeko almost immediately caught it.

It is worth noting that over the course of the study, pūkeko were regularly observed foraging in close proximity to the avian species listed in Table 1, without any attempted predation events being observed. Further, these species did not appear to consider pūkeko a threat; they fly towards them intentionally and do not alarm or engage in any other anti-predator behaviour, until attacked. It is also worth noting that though other observers have reported seeing pūkeko attacking native species, no predation of any native species was observed over the course of this 3 year study, despite many native avifauna species occurring in the area, which is of international importance for migratory species (>35 native species (eBird 2022)).

On one occasion the pūkeko were observed feeding the prey item (a mouse (Mus musculus)) to offspring. In all other cases (n = 7), they moved into dense vegetation out of the observers view shortly after capturing the prey, so the fate of the prey item was unknown. However, all observed predation events occurred during the peak breeding season (August – February), which supports Craig (1974) and Wright's (1978) arguments that pūkeko mainly take larger prey opportunistically during the breeding season to provide extra protein to offspring during their critical development stage (growth). Overall, in line with previous studies, pūkeko in the study population were observed to be predominantly herbivorous. However, these observations of predatory behaviour indicate that they are capable of opportunistically exploiting a food source beyond their typical diet range, potentially to benefit their offspring and thereby increase reproductive output.

Behavioural flexibility facilitates rapid responses to novel conditions, and species demonstrating dietary flexibility should be able to exploit novel food resources more readily than specialised species which maintain foraging behaviours from their native range (Sol & Lefebvre 2000; Wyles *et al.* 1983). When a flexible species invades a new region, its ability to modify and develop behaviours should facilitate identifying and utilising novel food resources, and therefore increase its success establishing a self-sustaining population. in The ability of pūkeko to opportunistically depredate non-native prey is further evidence of the species' dietary flexibility. This is perhaps unsurprising given how well established pūkeko have become since self-introduction. Sol et al. (2011) predicted that in regions where species often encounter novel feeding opportunities, and where risks associated with native predators are low, the species in question should favour approaching novel resources (neophilia) over avoidance (neophobia). Pūkeko are an excellent example of this process. Though they are a very common species, understanding their behaviour and foraging decisions has important and wideranging consequences. A recent paper showcases this possibility, finding that pukeko readily consume native threatened freshwater mussels (Echyridella spp. (Farnworth 2021)). Together, these findings illustrate how understanding the diet and behaviour of common species can have very real conservation implications, and that even infrequent food choices may have large effects on prey populations. Perhaps more importantly, it shows us that even our most familiar species still have some secrets for us to learn.

#### ACKNOWLEDGEMENTS

This work was supported by a University of Auckland Doctoral Scholarship, University of Auckland Postgraduate Research Student Support funding, University of Auckland PhD Output Award and University of Auckland Faculty Research Development Fund. Thanks to tangata whenua, Watercare and Ambury Regional Park for permission to work on the land. Specifically, thanks to L. Templeton, R. Crooks and J. Nillesen for their help and support. Also, thanks to H. Davis, N Haerewa, A. Heswall, S. Lorimer and K. Mansfield for assistance in the field.

#### LITERATURE CITED

- Balasubramaniam, S.; Guay, P.J. 2008. Purple swamphens (*Porphyrio porphyrio*) attempting to prey upon black swan (*Cygnus atratus*) eggs and preying upon a cygnet on an urban lake in Melbourne, Australia. *The Wilson Journal of Ornithology* 120(3): 633–635.
- Barrett, L.P.; Stanton, L.A.; Benson-Amram, S. 2019. The cognition of 'nuisance' species. *Animal Behaviour* 147: 167–177.
- Carlson, N.V.; Healy, S.D.; Templeton, C.N. 2017. Hoo are you? Tits do not respond to novel predators as threats. *Animal Behaviour* 128: 79–84.
- Carlsson, N.O.; Sarnelle, O.; Strayer, D. L. 2009. Native predators and exotic prey – an acquired taste? *Frontiers in Ecology and the Environment* 7(10): 525–532.
- Carroll, A.L.K. 1966. Food habits of pukeko (*Porphyrio melanotus* Temminck). *Notornis* 13(3): 133–141.
- Case, T.J. 1996. Global patterns in the establishment and distribution of exotic birds. *Biological Conservation* 78(1–2): 69–96.
- Cassey, P. 2001. Determining variation in the success of New Zealand land birds. *Global Ecology and Biogeography* 10(2): 161–172.
- Cheng, B.S.; Hovel, K.A. 2010. Biotic resistance to invasion along an estuarine gradient. *Oecologia* 164(4): 1049–1059.
- Craig, J.L. 1974. The social organization of the pukeko, *Porphyrio porphyrio melanotus*, Temminck, 1820. Unpubl. PhD thesis, Massey University, Palmerston North, New Zealand.
- DeRivera, C.E.; Ruiz, G.M.; Hines, A.H.; Jivoff, P. 2005. Biotic resistance to invasion: native predator limits abundance and distribution of an introduced crab. *Ecology* 86(12): 3364–3376.
- Dey, C.J.; Jamieson, I.G. 2013. Pukeko New Zealand Birds Online. Pukeko. http://www. nzbirdsonline.org.nz/species/pukeko. Accessed: 29 March 2022.
- Dowding, J.E.; Murphy, E.C. 2001. The impact of predation by introduced mammals on endemic shorebirds in New Zealand: A conservation perspective. *Biological Conservation* 99(1): 47–64.
- Duncan, R.P. 1997. The role of competition and introduction effort in the success of passeriform birds introduced to New Zealand. *The American Naturalist* 149(5): 903–915.
- Duncan, R.P.; Blackburn, T.M. 2004. Extinction and endemism in the New Zealand avifauna. *Global Ecology and Biogeography* 13(6): 509–517.
- Duncan, R.P.; Blackburn, T.M.; Sol, D. 2003. The ecology of bird introductions. Annual Review of Ecology, Evolution, and Systematics 34(1): 71–98.
- eBird. 2021. eBird: An online database of bird distribution and abundance [web application]. eBird, Cornell Lab of Ornithology, Ithaca,

New York. Available: http://www.ebird.org. Accessed: 29 March 2022.

- Egan, K. 1992. Purple swamphen's predation on European starling. *Australian Birds* 26: 84.
- Farnworth, B. 2021. First evidence of avian predation of threatened freshwater mussels (*Echyridella spp.*) in New Zealand: Predation patterns, prey characteristics and prey selectivity of a native wading bird (*Porphyrio porphyrio melanotus*). *Wildlife Research*. doi: 10.1071/WR20209
- Fogarty, S. 1968. Some hazards for early nesting pied stilts. *Notornis* 15(4): 266-266
- Garcia-R, J.C.; Di Marco, M. 2020. Drivers and trends in the extinction risk of New Zealand's endemic birds. *Biological Conservation* 249: 108730.
- Goodenough, A.E. 2010. Are the ecological impacts of alien species misrepresented? A review of the "native good, alien bad" philosophy. *Community Ecology* 11(1): 13–21.
- Grarock, K.; Tidemann, C.R.; Wood, J.T.; Lindenmayer, D.B. 2014. Are invasive species drivers of native species decline or passengers of habitat modification? A case study of the impact of the common myna (*Acridotheres tristis*) on Australian bird species. *Austral Ecology* 39(1): 106–114. doi: 10.1111/aec.12049
- Innes, J.; Kelly, D.; Overton, J.M.; Gillies, C. 2010. Predation and other factors currently limiting New Zealand forest birds. *New Zealand Journal* of Ecology 34(1): 86–114.
- Lowe, V.T. 1966. Notes on the musk-duck. *Emu* 65(4): 279–290.
- McKenzie, H.R. 1967. Foods of the pukeko. *Notornis* 14: 41–42.
- McLennan, J.A.; Potter, M.A.; Robertson, H.A.; Wake, G.C.; Colbourne, R.; Dew, L.; Joyce, L.; McCann, A.J.; Miles, J.; Miller, P.J. 1996. Role of predation in the decline of kiwi, *Apteryx* spp., in New Zealand. *New Zealand Journal of Ecology* 20(1): 27–35.
- Morgan, D.; Waas, J.R.; Innes, J. 2006. The relative importance of Australian magpies (*Gymnorhina tibicen*) as nest predators of rural birds in New Zealand. New Zealand Journal of Zoology 33(1): 17–29.
- Nixon, C. 1983. Ducked, by a purple swamphen! Bird Observer 623: 114.
- Norman, F.I.; Mumford, L. 1985. Studies on the purple swamphen, *Porphyrio porphyrio*, in Victoria. *Wildlife Research* 12(2): 263–278. doi: 10.1071/wr9850263
- O'Donnell, C.F.J. 1996. Predators and the decline of New Zealand forest birds: An introduction to the hole-nesting bird and predator programme. *New Zealand Journal of Zoology* 23(3): 213–219.
- Pintor, L.M.; Byers, J.E. 2015. Do native predators benefit from non-native prey? *Ecology Letters* 18(11): 1174–1180.

- Remeš, V.; Matysioková, B.; Cockburn, A. 2012. Nest predation in New Zealand songbirds: Exotic predators, introduced prey and longterm changes in predation risk. *Biological Conservation* 148(1): 54–60.
- Rickett, J. 2010. The dispersal and survivorship of pateke (*Anas chlorotis*) in relation to experimental release techniques; supplementary feeding and wing-clipping. Unpubl. MSc thesis, Massey University, Palmerston North, New Zealand.
- Rodgers, R.M.R.; Cain, K.E. 2019. No evidence for side preference or handedness in a New Zealand rail species with habitual foot-usage, the pukeko. *Behavioural Processes* 167: 103910. doi: 10.1016/j.beproc.2019.103910
- Rodriguez, L.F. 2006. Can invasive species facilitate native species? Evidence of how, when, and why these impacts occur. *Biological Invasions 8*(4): 927–939.
- Sax, D.F.; Brown, J.H. 2000. The paradox of invasion. *Global Ecology and Biogeography* 9(5): 363–371. doi: 10.1046/j.1365-2699.2000.00217.x
- Sol, D.; Lefebvre, L. 2000. Behavioural flexibility predicts invasion success in birds introduced to New Zealand. *Oikos* 90(3): 599–605.
- Sol, D.; Timmermans, S.; Lefebvre, L. 2002. Behavioural flexibility and invasion success in birds. *Animal Behaviour* 63(3): 495–502.
- Sweeney, A.P. 2022. Adaptability and responses to threats in a highly successful rail, the pūkeko, *Porphyrio melanotus melanotus*. Unpubl. PhD thesis, University of Auckland, Auckland, New Zealand.
- Tennyson, A.J.D. 2010. The origin and history of New Zealand's terrestrial vertebrates. *New Zealand Journal of Ecology* 34(1): 6–27.
- Trewick, S.A. 1996a. The diet of kakapo (*Strigops habroptilus*), takahe (*Porphyrio mantelli*) and pukeko (*P. porphyrio melanotus*) studied by faecal analysis. *Notornis* 43(2): 79–84.
- Trewick, S.A. 1996b. Morphology and evolution of two takahe: flightless rails of New Zealand. *Journal of Zoology* 238(2): 221–237.

- Trewick, S.A. 1997. Flightlessness and phylogeny amongst endemic rails (Aves: Rallidae) of the New Zealand region. *Philosophical Transactions: Biological Sciences* 352(1352): 429–446.
- Trewick, S.A.; Worthy, T.H. 2001. Origins and prehistoric ecology of takahe based on morphometric, molecular, and fossil data. *In* Lee, W.G.; Jamieson I.G. (*Eds*) *The takahē: fifty years of conservation management and research*. Dunedin, N.Z., University of Otago Press.
- Van Tets, G.F. 1965. Eastern swamphen takes a downy from a pair of Chestnut Teal. *Emu* 64(2):100.
- Williamson, M. 1999. Invasions. *Ecography* 22(1): 5–12.
- Worthy, T.H.; Holdaway, R.N. 1996. Quaternary fossil faunas, overlapping taphonomies, and palaeofaunal reconstruction in North Canterbury, South Island, New Zealand. Journal of the Royal Society of New Zealand 26(3): 275–361.
- Worthy, T.H.; Holdaway, R.N. 2002. The lost world of the moa: prehistoric life of New Zealand. Indiana University Press. Bloomington, IN.
- Wright, J.D. 1978. The time budget and feeding ecology of the pukeko (*Porphyrio porphyrio melanotus*, Temminck 1820). Unpubl. MSc thesis, Massey University, Palmerston North, New Zealand.
- Wyles, J.S.; Kunkel, J.G.; Wilson, A.C. 1983. Birds, behavior, and anatomical evolution. *Proceedings* of the National Academy of Sciences 80(14): 4394– 4397.
- Yorio, P.; Suárez, N.; Kasinsky, T.; Pollicelli, M.; Ibarra, C.; Gatto, A. 2020. The introduced green crab (*Carcinus maenas*) as a novel food resource for the opportunistic kelp gull (*Larus dominicanus*) in Argentine patagonia. *Aquatic Invasions* 15(1): 140–159.
- Keywords: pūkeko, *Porphyrio melanotus*, predation, opportunistic omnivore, diet flexibility, nonnative prey

#### **OFFICERS 2022**

Please refer to the Birds New Zealand website (www.birdsnz.org.nz/contact/) for up-to-date contact details and email addresses.

President:	BRUCE McKINLAY
Vice-President:	NATALIE FORSDICK
Secretary:	LYNNE ANDERSON
Treasurer:	PAUL GARNER-RICHARDS
Council Members:	MEL GALBRAITH
	COLIN MISKELLY
	ELEANOR GUNBY
	KEITH WOODLEY
	JOSIE GALBRAITH
	IAN ARMITAGE

**EXECUTIVE OFFICER** INGRID HUTZLER

#### EDITORS

NOTORNIS	CRAIG T. SYMES
NOTORNIS (Assistant)	PAUL SAGAR
Birds New Zealand:	MICHAEL SZABO
Book Reviews:	TRISH WELLS

#### **CONVENORS & ORGANISERS**

Beach Patrol:	LLOYD ESLER
Moult Records:	MICAH SCHOLER
Nest Records:	ROGER SHARP
Records Appraisal	
Committee:	COLIN MISKELLY
Scientific Committee:	GRAEME TAYLOR
Banding Liaison Officer:	JOHN STEWART
Checklist Convenor:	COLIN MISKELLY
Membership Secretary:	KURIEN (KOSHY) YOHANNAN
Wader Counts:	ANDREW CROSSLAND
	ADRIAN RIEGEN
Web Support Officer:	ROGER SHARP

#### LIBRARIANS

Books & Journals:	TRINA SMITH
Publications purchasing:	PAUL CUMING

#### **REGIONAL REPRESENTATIVES 2022**

Please refer to the Birds New Zealand website (www.birdsnz.org.nz/contact/) for up-to-date contact details and email addresses.

Far North:	VACANT
Northland:	Ilse Corkery Ph: 027 343 5884 birds.northland@birdsnz.org.nz
Auckland:	Ian McLEAN Ph: 021 535 121 imclean@southernworld.com
South Auckland:	Sue FROSTICK Ph: 09 267 2495 birds.sth.auckland@birdsnz.org.nz
Waikato:	Bruce POSTILL Ph: 07 849 1944 or 027 849 1944 brucepostill@gmail.com
Bay of Plenty/Volcanic Plateau:	Paul CUMING Ph: 07 571 5125 <i>birds.bop.volcanic@birdsnz.org.nz</i>
Gisborne/Wairoa:	Geoff FOREMAN Ph. 06 868 8826 gaforeman@xtra.co.nz
Taranaki:	Peter FRYER Ph. 06 754 7434, 027 271 4150 <i>pj.fryer@xtra.co.nz</i>
Manawatu:	Phil BATTLEY Ph: 021 072 1216 p.battley@massey.ac.nz
Whanganui:	Peter FROST Ph: 06 343 1648 birds.whanganui@birdsnz.org.nz
Hawke's Bay:	Bernie KELLY Ph: 06 870 0837 birds.hawkesbay@birdsnz.org.nz
Wairarapa:	Oliver DRUCE Ph: 06 304 9854 or 027 334 5705 <i>birds.wairarapa@birdsnz.org.nz</i>
Wellington:	Johannes FISCHER Ph: 022 134 6676 <i>birds.wellington@birdsnz.org.nz</i>
Nelson:	Paul GRIFFITHS Ph: 021 029 93509 birds.nelson@birdsnz.org.nz
Marlborough:	Kristin RUWHIU Ph: 021 022 40762 kristin.ruwhiu@hotmail.com
Canterbury / West Coast:	Don GOODALE Ph: 027 224 4441 birds.canterbury@birdsnz.org.nz
Otago:	Mary THOMPSON Ph: 03 464 0787 <i>birds.otago@birdsnz.org.nz</i>
Southland:	Neil ROBERTSON Ph: 03 249 9595 neilgrobertson@yahoo.co.uk

#### Abbreviated Instructions to Authors

#### Please consult the full instructions at http://osnz.org.nz

manuscripts: Submission of Manuscripts may be submitted by e-mail to the Managing Editor, Dr Craig Symes Notornis.Editor@gmail.com. The submission should be in MS Word format. To facilitate the review process, a single document should be submitted, with Tables and Figures (preferable .jpg format) included in the document, but following the main text and references. Large embedded files should be compressed sufficiently so that the final document size is no larger than 10MB, yet image quality is retained. Should the manuscript be accepted, the Editor will request separately submitted files for images in the relevant format and in suitable resolution. Consult a recent issue for general formatting procedures. A brief covering letter must accompany the submission, confirming that the paper or material in it has not been published previously and is not under consideration with another publication. If the manuscript contains information provided to the author as a personal communication, confirmation that the author has permission to publish this information is required. Authors are strongly advised to have their manuscript read, and critically reviewed, by friends or colleagues. Although this is not a formal requirement of the journal, it may influence the treatment of the manuscript. Complying with any administrative requirement of the author's workplace or supporting agency is a matter between those parties; such matters are not checked by the editors and OSNZ accepts no responsibility in case of any dispute.

**Ethics:** Papers reporting experimental work on animals should include a reference to the code of practice adopted and relevant animal ethics approval. While the review process may highlight certain issues in this regard it is the responsibility of the author/s to ensure that the relevant procedures are followed and acknowledged when, 1) working on and handling animals, and 2) accessing land where permission is required.

Editorial process: All manuscripts are acknowledged upon receipt. The Managing Editor will make an initial assessment of the manuscript to confirm its subject, content, scope, and quality are appropriate for the journal. The Managing Editor will approach potential referees to review the paper; two reviewers for an original paper, and one reviewer for a short note. The Managing Editor will decide on acceptance for publication following receipt of the reviewers' reports.

#### Manuscript styles:

*Full papers:* The main sections of the manuscript should be: 1) Title page containing the title, authors' names, affiliation/s, a suggested short title, and corresponding authors contact e-mail. The title should be as short as possible while still reflecting the content of the paper. 2) Abstract (~150 words) that provides a succinct summary of the main findings of the study, followed by up to seven Keywords. 3) The major parts (Introduction, Materials and Methods, Results, Discussion, Acknowledgments, Literature cited) should follow continuously. Avoid footnotes. Headings: There are three levels of headings. First level is BOLD CAPITALS; second level is Bold initial capitals; third level is Italic capitals and lower case. If necessary, a fourth level of Capitals and small capitals can be invoked. Text continues on the same line for third and fourth level headings. Use only those levels that are appropriate: main sections are first level headings.

Short notes: These are generally of <2,000 words and report a single item of ornithological interest. The text is without subdivision with results and discussion combined and the only first level headings used are 'Acknowledgements' and

'Literature cited'. Authors' names and affiliation/s are placed at the beginning and keywords at the end of the manuscript. *Book reviews:* Publishers of books are invited to contact the Managing Editor in this regard.

Editorial conventions: The most recent edition of the *Checklist of New Zealand birds* should be taken as the prime reference of taxonomy and nomenclature for both scientific and common names of bird species in the New Zealand region (see: *http://nzbirdsonline.org.nz/*). Use a similar authoritative source for other regions. Use of other nomenclature can be adopted where necessary, as in taxonomic papers or where explained or justified in the text. At first mention, both the common and the scientific names (italicised and in brackets) of a species must be given; thereafter one or other may be used, but not both. Subspecific names should be given only if relevant to the content of the paper. Authorities for species names are not required, unless dictated by the subject matter.

Literature cited: Authors are responsible for the accuracy of all references. All citations in the text must be on the list of references; all on the list must be cited. Cite references in the text chronologically and list alphabetically in full at the end of the paper. In the text, names of two authors should be linked by '&'; for three or more, the first author's name should be followed by 'et al.' Use of transitory reference sources, e.g. web sites, is not encouraged. Journal titles or titles of other periodicals or series must be cited in full.

*Tables:* Each table should begin on a separate page, numbered in Arabic numerals in the order as referred in the text, and accompanied by a title at the top. Horizontal lines should appear only between the title and the table body, and below the last line of tabulated data. In some instances, clarity may be improved by short horizontal lines over column heads that are logically linked. Do not use vertical lines anywhere in the table.

Figures: Check image quality and legibility by photocopying at the necessary reduction. Lettering should be in sansserif type (e.g. Helvetica or Arial), not bold, and only initial letters of axis labels capitalised. The preferred symbols are those that are readily available on word processor packages. Photographs must be sharp and of good contrast. Identify necessary details with appropriate labelling. Colour photographs can be printed, but please enquire before submitting. Maps should be simple enough to present the relevant context of the study. Avoid copying poor quality and/ or over-detailed images from, for example, Google Earth or institutional reports, etc. Captions should be prefaced by Figure in bold and referenced sequentially in the text by Fig. 1, etc. (not Figure). Provide appropriate legends, or list the meanings of shading or other details in the caption. Captions should contain enough information to explain the figures without reference to the text.

*Copyright:* The Ornithological Society of New Zealand assumes copyright of the printed script. The author/s, by "signing off" the final version of their manuscript, are assigning copyright to the Society. The assumption of copyright is to protect authors from having their publication subjected to commercial exploitation without their knowledge and agreement and does not confer any financial gain to OSNZ.

Page charges: There are currently no page charges for authors.

Revised and updated December 2018

### NOTORNIS Journal of the Ornithological Society of New Zealand Inc. Volume 69, Part 2, June 2022

#### CONTENTS

#### Papers

Continued increase in red-billed gulls ( <i>Larus novaehollandiae scopulinus</i> ) at Otago, southern New Zealand: implications for their conservation status and the importance of citizen science	Lalas, C.; Carson, S.; Perriman, L.	81
Hosts of the long-tailed cuckoo ( <i>Eudynamys taitensis</i> ) and museum specimens of the cuckoo's egg	Gill, B.J.	89
The detection, breeding behaviour, and use of mangroves ( <i>Avicennia marina australasica</i> ) by banded rails ( <i>Gallirallus philippensis assimilis</i> )	Beauchamp, A.J.	99

Short notes Radiocarbon ages for two of the three South Island takahe ( <i>Porphyrio hochstetteri</i> ; Aves: Rallidae) from Pyramid Valley, North Canterbury, New Zealand	Holdaway, R. N.	112
Successful use of intraspecific parental fostering in the management of an endemic threatened bird: New Zealand's hihi ( <i>Notiomystis cincta</i> )	Selwyn, R. E.; Lenting, B.; Beaven, K.C.; Irwin, E.T.	116
Unmanned Aerial Vehicle (UAV) activity elicits little to no response from New Zealand forest birds during wildlife monitoring	Stone, Z.L.; Parker, K.A.	119
Polygyny observed in pāteke (brown teal, Anas chlorotis)	Michaux, B.	126
Opportunistic predation of non-native species by pūkeko (Porphyrio melanotus melanotus)	Sweeney, A.P.; Cain, K.E.	130