# First northern giant petrel (*Macronectes halli*) breeding population survey and estimate for the Auckland Islands, New Zealand

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**ABSTRACT:** This first breeding population estimate of northern giant petrels (*Macronectes halli*) in the Auckland Islands group involved whole-island censuses, apart from the main Auckland Island, in the 2015-16 breeding season, and multi-year repeat visits to a subset of island colonies. Parallel line-transects in giant petrel habitat were used to survey the number and spatial distribution of pre-fledging chicks. The Auckland Islands 2015-16 whole-island census resulted in a count of 216 northern giant petrel chicks on eight of the 15 islands in the group. Applying a simple correction factor, the breeding population in 2015 is estimated as c. 340 breeding pairs (range 310–390). This estimate is higher than historical non-quantitative records of 50–200 breeding pairs. Multi-year counts on Enderby, Rose, Frenchs, Ocean, Disappointment, and Adams Islands showed some inter-annual variability, but other island colonies remained more stable. The northern giant petrel colony on Enderby Island has increased from two chicks in 1988 to 96–123 chicks in 2015–18 (four annual counts undertaken).

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## Introduction

Robust estimates of the size of breeding populations are critical to inform conservation management for species of conservation concern. Determining the conservation status of many species of albatross and petrel is important because these taxa are subject to threats such as incidental by-catch resulting in declines in breeding populations, competition for resources with commercial fisheries, the impacts of introduced mammals at breeding sites, and susceptibility to climate change and pollution (Croxall *et al.* 2012; Phillips *et al.* 2016).

Northern giant petrels (*Macronectes halli*; Fig. 1) are large, southern hemisphere fulmarine petrels that face conservation threats in both their terrestrial and marine environments (Shirihai 2008). Along with the closely related southern giant petrel (*M. giganteus*), northern giant petrels are the most common avian scavengers in subantarctic and Antarctic waters (Brooke 2004), and are also predators of large birds such as great albatrosses and penguins (Cox 1977; Hunter & Brooke 1992; Ryan *et al.* 2008; Dilley *et al.* 2013).



Northern giant petrels forage between 30°S and 64°S (Marchant & Higgins 1990). The species breeds on nine island groups between 44°S and 54°S (ACAP 2010). Over one-third of the total estimated breeding population is on South Georgia, in the South Atlantic (ACAP 2010). In the southern Indian Ocean, breeding takes place on the Prince Edward Islands (Ryan *et al.* 2003) and the Crozet and Kerguelen archipelagos (Weimerskirch *et al.* 1989; Shirihai 2008). In the southern Pacific region, northern giant petrels breed on the Chatham Islands group, Macquarie Island, Campbell Island, the Auckland Islands group, and the Antipodes Islands (Marchant & Higgins 1990).

Introduced mammalian predators at some northern giant petrel breeding sites can cause nesting failures and, in some instances, may also depredate adults. Cats (*Felis catus*) and ship rats (*Rattus rattus*) caused egg and chick failure on Macquarie Island (ACAP 2010) prior to cat eradication in 2000 and rat eradication in 2012 (Robinson & Copson 2014; Hunt 2014). Nest trampling by livestock (sheep *Ovis aries* on Campbell Island, and cattle *Bos taurus* on Enderby, Auckland Islands, before their respective removals) had impacts on large ground-nesting southern royal albatross (*Diomedea epomophora*) (R.H. Taylor 1971) and likely also nesting giant petrels. Giant petrels are also prone to human disturbance (Brooke 2004) and secondary, non-target poisoning in operations to eradicate introduced mammals (Alderman *et al.* 2019). Northern giant petrels were recorded as by-catch mortality by fisheries observers in New Zealand commercial trawl, surface, and bottom longline fisheries during 2002–17, at an average of less than one bird per year (Abraham & Thompson 2015). This does not account for mortalities in unobserved fisheries, nor for cryptic mortality in commercial fishing operations. Giant petrels are recorded as mortalities in commercial fisheries in other areas of the Southern Ocean (Petersen *et al.* 2008; Parker 2012, 2013), with fatal captures in Patagonian toothfish fisheries of particular concern in the past (Nel *et al.* 2002).

Northern giant petrels exhibit strong site fidelity, and pairs generally show long-term pair bonds (from a long-term study during 1966–80 at Île de la Possession, Crozet archipelago; Voisin 1988). The species is surface-nesting, with the age at first breeding averaging *c.* 10 years (Woehler & Johnstone 1988). A single egg is laid mid-Aug to late-Sep (Brooke 2004). Chicks fledge at 110–120 days of age (Johnstone 1977), and females fledge 5–6 days earlier than males (Hunter 1984; Cooper *et al.* 2001). Breeding sabbaticals are common; at Île de la Possession 15–40% of adults did not breed each year (Voisin 1988), and at South Georgia 27–57% took breeding sabbaticals (1978–81; Hunter 1984).

The worldwide northern giant petrel breeding population is estimated to be *c.* 11,800 pairs (ACAP 2010). However, recent quantitative population estimates exist for only four of the nine island groups where the species breeds (ACAP 2010). Local population trends show that some northern giant petrel populations have been increasing and others decreasing (ACAP 2010). At South Georgia the population increased by 60% during 1978–1996, apparently linked to the dramatic increase in Antarctic fur seals (*Arctocephalus gazella*) and the increased availability of commercial fisheries discards (González-Solís *et al.* 2000). On Île de la Possession the population increased between 1966 and 1980 (Voisin 1988), declined during the 1980s, increased in the early- to mid-1990s, and

**FIGURE 1.** Northern giant petrel chick, Disappointment Island, January 2016. *Image: Graham Parker.*



was reportedly decreasing from 1998 (Delord *et al.* 2008). The Marion Island population has had periods of both increase and decrease during 1985–2008, but overall the trend on Marion was for a slight decrease of 0.5% in the breeding population to 2008 (ACAP 2010), and breeding numbers appear to have increased by around 30% over the past decade (P. Ryan, *pers. comm.*, 12 Mar 2019).

The contemporary size and trends of northern giant petrel populations in the New Zealand (NZ) region are not known. The Macquarie Island population experienced large increases from the mid-1990s (ACAP 2010), but was reduced by approximately 30% in 2010–11 due to non-target mortality during the eradication of invasive mammals (Springer & Carmichael 2012). Statistical modelling suggests that the Macquarie population has a high probability of returning to pre-poison levels over the ensuing 10 years (Alderman *et al.* 2019). Single population estimates exist for the Antipodes Islands (230 breeding pairs; Wiltshire & Hamilton 2003) and Campbell Island (234 breeding pairs; Wiltshire & Scofield 2000). These provide a baseline population estimate for those islands but no population estimates have been conducted since, preventing any insight into population trends at Antipodes and Campbell. The Chatham Islands are the stronghold of the species in the New Zealand region. The entire Chatham Islands' population was estimated at 2,000 breeding pairs in 1993, based on extrapolation (Robertson & Sawyer 1994), and 2,150 pairs in 2017, based on counts during the mid-chick phase and adjusted for breeding success with Macquarie Island data (Bell *et al.* 2018). No population trend data exist for the main population in the Chatham Islands, Motuhara/Forty-Fours, which comprises approximately 92% of the northern giant petrel population in the island group (Bell *et al.* 2017). In the Auckland Islands, northern giant petrels reportedly breed throughout the group, but no targeted, island-wide count of breeding birds has been conducted and population estimates

for the Auckland Islands group are based solely on anecdotal evidence. The most recent estimate of approximately 50 pairs dates from the 1980s (G.A. Taylor 2000). This work reports on the first quantitative estimate of the size of the Auckland Islands northern giant petrel breeding population, and describes their spatial distribution in the group.

## Methods

The Auckland Islands (50°44'S, 166°05'E) are located *c.* 450 km south of the New Zealand mainland (Fig. 2). The total area of the island and islets is *c.* 56,800 ha with Mt Dick (705 m a.s.l) the highest point, located on Adams Island. The main Auckland Island comprises the vast majority of the land area (45,889 ha), but due to invasive pigs (*Sus scrofa*), cats, and mice (*Mus musculus*), the native vertebrate biodiversity on the main island is lower than on islands free of introduced mammalian predators (Miskelly *et al.* 2020 – Chapter 2 in this book; Russell *et al.* 2020 – Chapter 6 in this book).

The vegetation of the Auckland Islands consists of southern rātā (*Metrosideros umbellata*)-dominated low forest at sheltered lower altitudes, interspersed with *Coprosma foetidissima*, *Myrsine divaricata*, *Pseudopanax simplex*, and *Dracophyllum cockayneanum* and *D. longifolium*. The rātā-dominated forest turns to *Coprosma* spp., *Veronica elliptica*, *Myrsine divaricata*, and *Dracophyllum* spp. shrubland at mid-elevations, with tussock grasslands of *Chionochloa antarctica*, *Poa litorosa*, and *P. foliosa* followed by herb-fields at higher elevations.

To ensure that all areas on the Auckland Islands with historical records of northern giant petrel breeding were surveyed, published and unpublished records were collated prior to field work in the 2015-16 summer. In the single year of the island-wide survey, KRH and GCP operated from a 15 m yacht on 2–4 Dec 2015 to survey the islands in Port Ross in the north of the Auckland Islands.



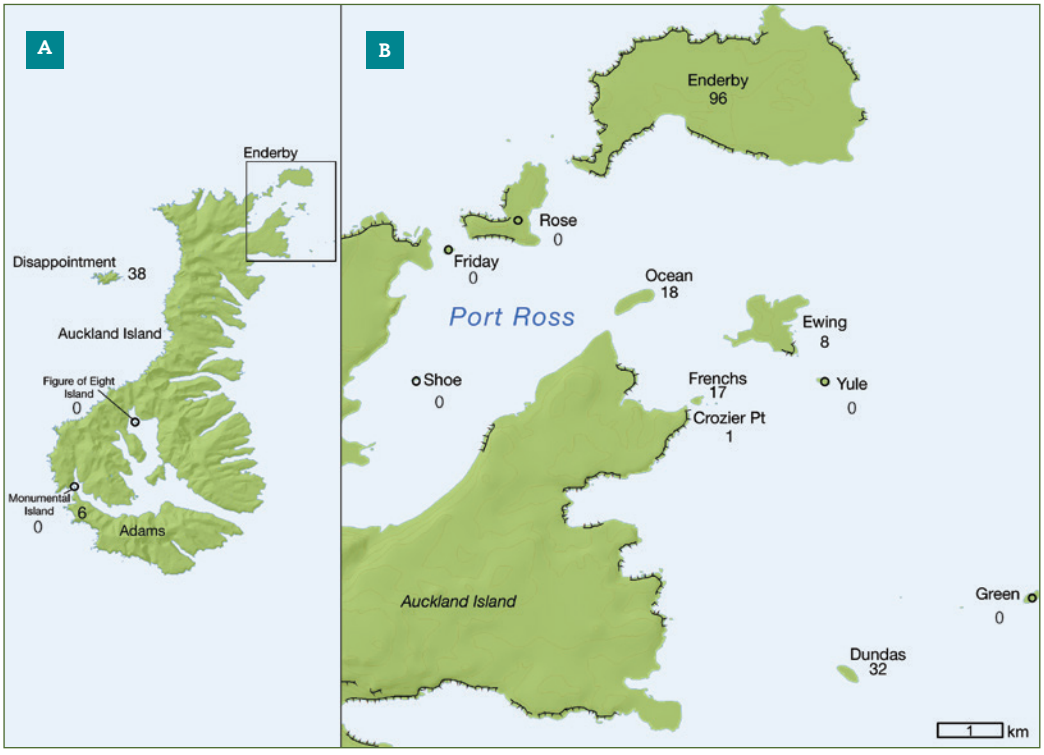


**FIGURE 2.** Location and number of northern giant petrel chicks detected in surveys during the 2015 breeding season, Auckland Islands. Small open circles mark islands where no breeding was recorded. **A.** Giant petrel counts in the wider Auckland Islands group. **B.** Port Ross area giant petrel chick counts.

Islands surveyed were Rose, Friday, Shoe, Ocean, Ewing, Frenchs, Yule, and Green Islands (Fig. 2A). Enderby Island was counted on 5–27 Dec 2015. The only stable colony known on Adams Island, at Fairchilds Garden, was visited on 13 Dec 2015. Northern giant petrel chicks on Disappointment Island were counted on 3–9 Jan 2016. In the following three breeding seasons (2016-17, 2017-18, and 2018-19; referred to from here onwards as 2016, 2017, and 2018), chicks on Enderby and Dundas Islands were counted annually, and there were opportunistic counts at Adams, Ocean, Ewing, Frenchs, and Shoe Islands to provide insight into inter-annual changes in breeding populations at those sites. Due to the presence of pigs, we did not think that northern giant petrel breeding would occur on the main Auckland Island; there was therefore no systematic survey undertaken of this, the largest of the islands. Crozier Point, on Auckland Island, was surveyed after northern giant petrels were noticed displaying aerially above the point, as they do at breeding sites.

On each island, the number of pre-fledging chicks present and their spatial distribution were recorded. Two workers conducted parallel line-transects spaced *c*. 30 m apart to survey the available northern giant petrel nesting habitat. The exceptions were Enderby Island in Jan 2016, and Dundas Island in 2015, 2017, and 2018, where a single person conducted searches of all available habitat. All vegetation classes were treated as available habitat (Marchant & Higgins 1990) apart from the interior of rātā-dominated forest. The edges of thick rātā forest were thoroughly searched, 150 m into the interior. Hand-held GPS units (Garmin Map 62s, Garmin Map 60Cx, or Garmin Etrex Vista HCx) with topographical mapping software were used to record all line-transect surveys and the locations of all chicks detected.

Empty nests that showed signs of having failed in the current breeding season were recorded, but are not included in nest counts reported here. This is because failed nests are less detectable than nests with an adult or chick, and it is not always possible to differentiate between failed nests, old nests, or 'play' nests constructed by non-breeding birds.

We elected to use breeding success data to correct for nesting failure during the egg and early chick stage (e.g. Wiltshire & Hamilton 2003). The total number of northern giant petrels breeding at the Auckland Islands was estimated by applying the average, lowest, and highest records of breeding success from the past 10 years on Macquarie Island (Department of Primary Industries, Parks and Environment Tasmania [DPIPWE], *unpubl. data*) to the number of active nests we found (excluding failed nests detected). Macquarie Island, 650 km south-west of the Auckland Islands, is the nearest northern giant petrel colony where breeding success data has been collected.

# Results

## Whole-island census 2015

In the single year of island-wide survey, 216 northern giant petrel chicks were counted on eight of the 15 islands visited in Dec 2015 and Jan 2016 (Table 1). Enderby Island had the largest breeding population, with 96 chicks counted (45% of the 2015-16 Auckland Islands total; Fig. 2). The second- and third-largest breeding populations were on Disappointment Island (38 chicks, 18% of total) and Dundas Island (32 chicks, 15% of total).



No breeding northern giant petrels were recorded on Rose and Friday Islands, where the species had previously been recorded breeding (Table 1, Fig. 2). Surveys of Shoe, Yule, Green, Monumental, and Figure of Eight Islands confirmed that northern giant petrels were not breeding there in the 2015 season, and there are no previous records of them breeding at any of these islands (Fig. 2). Chicks were counted at two previously unrecorded locations, at Frenchs Island, and also Crozier Point on the main Auckland Island (Fig. 2).

Nesting habitat was primarily partially wind-exposed sites in long tussock (*Chionochloa antarctica*, *Poa foliosa*, *P. litorosa*, *Carex trifida*) bordering forest and shrub edges. Most chicks were in loose colonies ranging in size from two to tens of chicks, but the occasional chick was by itself. The 216 chicks counted is a minimum estimate of the breeding population due to possible earlier breeding failure. To correct for breeding failure, we used Macquarie Island data from the past 10 years, where breeding success averaged 63.8% (range 55.7%–69.8%) (R. Alderman, DPIPWE Tasmania, *pers. comm.*). If Auckland Island breeding success is similar to that on Macquarie,

**TABLE 1.** Northern giant petrel chick counts at the Auckland Islands, Dec 2015 to Jan 2019, and changes relative to historic records. Previous record type is indicated by: B, breeding but no record of number of nests or chicks; C, number of chicks counted; E, number of eggs counted; N, number of nests counted.

| Location | Dates counted (this study) | Nesting year | Number of large chicks | Previous breeding records |
|---|---|---|---|---|
| Enderby Island | 28 Nov–27 Dec 2015<br>7–9 Jan 2017<br>12 Nov 2017–12 Jan 2018<br>24–28 Nov 2018 | 2015<br>2016<br>2017<br>2018 | 96<br>125<br>105<br>123 | B (1972-73)[a]; 11C (1980)[b]; 2C (1988)[c‡]; 'scattered colony' (1989)[d] |
| Rose Island | 2 Dec 2015<br>15, 22–23 Jan 2018<br>30 Nov 2018 | 2015<br>2017<br>2018 | 0<br>0<br>0 | B (1966)[e]; 20+C (1983)[f]; 0C (1988)[c]; 28C (1989)[d] |
| Friday Island | 2 Dec 2015 | 2015 | 0 | Breeding[g] |
| Shoe Island | 2 Dec 2015 | 2015 | 0 | No previous breeding records |
| Yule Island | 3 Dec 2015 | 2015 | 0 | No previous breeding records |
| Green Island | 4 Dec 2015 | 2015 | 0 | No previous breeding records |
| Ocean Island | 4 Dec 2015<br>26 Jan 2018 | 2015<br>2017 | 18<br>2 | 2C (1988)[c]; 18C (1989)[d] |
| Ewing Island | 3 Dec 2015<br>20 Jan 2018 | 2015<br>2017 | 8<br>18 | 30 (1989)[d] |
| Frenchs Island | 3 Dec 2015<br>21 Jan 2018<br>1 Dec 2018 | 2015<br>2017<br>2018 | 17<br>12<br>7 | Breeding (2009)[h] |
| Main Auckland Island: Crozier Point | 4 Dec 2015<br>24 Jan 2018<br>1 Dec 2018 | 2015<br>2017<br>2018 | 1<br>1†<br>2 | No previous breeding records |
| Adams Island: Fairchilds Garden | 17 Dec 2013<br>13 Jan 2015<br>12 Dec 2015<br>26 Dec 2016<br>20 Dec 2018 | 2013<br>2014<br>2015<br>2016<br>2018 | 5<br>6<br>6<br>16<br>11 | c.200N (1942)[i]; 12E (1944)[j]; 22C (1954)[k]; 13C (1978)[k]; 'chicks of various ages' (1983)[f]; 1C (1989)[k]; 35C (2004)[l]; 7+C (2006)[l] |
| Grafton Ridge | 8 Feb 2017 | 2016 | 0 | 6C (1991)[l]; 0C (2004)[l] |

| Location | Dates counted (this study) | Nesting year | Number of large chicks | Previous breeding records |
|---|---|---|---|---|
| Monumental Island | 17 Jan 2015 | 2014 | 0 | 1N (1942)[i] |
| Figure of Eight Island | | | | Annual visits, no breeding records[g] |
| Dundas Island | 18 Jan 2016<br>18 Jan 2017<br>18 Jan 2018<br>18 Jan 2019 | 2015<br>2016<br>2017<br>2018 | 32<br>25<br>9<br>13 | ~30 nests (1943)[m]; B (1972-73)[a]; 0C (1978)[m]; 3C (1980)[n]; 'Lots' (2015)[g] |
| Disappointment Island | 7 Jan 2015^<br>13 Jan 2016 | 2014<br>2015 | 44<br>38 | B (1972-73)[a]; B (1976)[o]; 3C (1983)[f]; 44C (1993)[l] |

*Source of previous breeding records:* [a]Bell (1975); [b]Mitchell & Ensor (1986); [c]G.A. Taylor (1988); [d]Moore & McClelland (1990); [e]R.H. Taylor (1971); [f]Mayhill & Goulstone (1986); [g]S. Childerhouse *pers. comm.*, 13 Nov 2015; [h]Enderby Island hut book; [i]McEwen (2006); [j]Turbott (2002); [k]Buckingham *et al.* (1991); [l]K. Walker *pers. comm.*, 10 Nov 2015; [m]Falla *et al.* (1979); [n]Jenkins (1981); [o]Bartle & Paulin (1986).

^ The 2015 count was possibly not complete due to time restrictions.

‡ Survey 6–15 Feb 1988, after some chicks would have fledged.

† Apparently recently fledged nest.



then the number of large chicks counted represent about two-thirds of the productivity in 2015. Applying these correction factors to our estimates, and assuming that the number of large chicks we counted represents the number that fledged, we estimate the breeding population in 2015 to be 340 (range 310–390) breeding pairs.

### Island recounts

Seven of the Auckland Island northern giant petrel breeding sites were counted again in the 3-year period following 2015: Enderby, Adams, Dundas, Rose, Frenchs, and Ocean Islands, and Crozier Point on Auckland Island (Table 1). The Enderby Island chick counts over a 4-year period were fairly similar (96 in 2015, 125 in 2016, 104 in 2017, 123 in 2018; Table 1). This pattern did not hold for chick counts on Dundas Island (32 in 2015, 25 in 2016, 9 in 2017, 13 in 2018). Five years of chick counts at Fairchilds Garden on Adams Island suggests a small breeding population there (5 in 2013, 6 in 2014, 6 in 2015, 16 in 2016, 11 in 2018).

## Discussion

This first quantitative estimate of the breeding population of northern giant petrels in the Auckland Islands revealed that *c.* 340 (range 310–390) pairs bred there in 2015. Repeat chick counts from some locations in the following three breeding seasons indicate that the population may have been of a similar size in each of those years, although the repeat surveys were not as comprehensive as those undertaken in 2015. Our estimate is higher than the four historical non-quantitative records, which documented the population as 50 breeding pairs on three occasions (Bell 1975; G.A. Taylor 1988, 2000) and once as 200 breeding pairs (C.J.R. Robertson *in* Hunter 1986).

Many more northern giant petrels bred on Enderby Island than expected, with numbers comprising approximately half of the Auckland Islands population. This is a recent change: G.A. Taylor (1988) conducted a comprehensive survey of the island and counted just two chicks in 1988. The other three records we found also suggest much smaller numbers than the 96 large chicks recorded in the first year of this survey (Bell 1975; Moore & McClelland 1990), although neither record was based on a full survey. The current status of Enderby Island as the major Auckland Island breeding site could be due to a number of factors, particularly the abundant food available from placentas and dead pups during the New Zealand sea lion (*Phocarctos hookeri*) breeding season, (a large proportion of the Auckland Islands' sea lion population breeds at Enderby Island: 18.6% and 17.8% in the 2015 and 2016 breeding seasons respectively; Childerhouse *et al.* 2017). In the past 20 years, sea lion pup mortality has been higher than previously (Department of Conservation 2017), providing a sizeable scavenging opportunity for giant petrels. The Enderby Island subantarctic skua (*Catharacta antarctica*) population was severely reduced during a rabbit (*Oryctolagus cuniculus*) and mouse eradication campaign there in 1993 (Torr 2002). Lower skua numbers may benefit giant petrels by lowering nest depredation rates from skuas, and reducing competition for animal carcasses. Enderby Island also now has much greater *Chionochloa antarctica* and *Poa foliosa* tussock cover than when cattle and rabbits were present on the island, when tussock was confined to cliff areas (Russell *et al.* 2020 – Chapter 6). When cattle and rabbits were present, open swards of low-cropped grass and herb-field may not have provided very suitable breeding areas for northern giant petrels on Enderby Island, perhaps because in open areas, small chicks may have been more vulnerable to skua predation during brood-guard changeovers by parents. Breeding giant petrels may also have been disturbed, and nests destroyed, by feral cattle on Enderby Island.

The spatial distribution of breeding sites for northern giant petrels has changed in the Auckland Islands, but this is not a recent phenomenon and nor is it rare for the species. Moore & McClelland (1990) visited Ewing Island, Enderby Island, Rose Island, and Ocean Island, and recorded that *'the northern giant petrel population may have expanded or changed its distribution, as several colonies were found that were not present in 1972–73'*. This has also been found on other island groups. Wiltshire & Scofield (2000) suggest that a perceived population decline in northern giant petrels on Campbell Island was, instead, the result of a change in local breeding locations. The islands in the Auckland Islands group that previously had records but no longer support breeding northern giant petrels may indicate shifting breeding-site locations by giant petrels. Giant petrels bred on Rose Island in 1944 and 1966 (R.H. Taylor 1971; Turbott 2002), and 28 chicks were counted in 1989 (Moore & McClelland 1990). However, no nests and no loafing adults were found in the current study over several visits, despite what appeared to be comparable breeding habitat to their nest sites on Enderby Island.

Breeding northern giant petrels on Dundas Island were recorded in four out of five visits between 1943 and 2015 (Falla *et al.* 1979; Jenkins 1981; Bartle & Paulin 1986). The single year when no breeding was recorded was 1978, despite the species having been recorded 5 years prior in 1972-73. Previous records do not state chick numbers. This study counted 32 chicks in Jan 2016 (2015 breeding season) and slightly fewer in 2016 (25 chicks), and 9 and 13 chicks in 2017 and 2018, respectively. As for Enderby Island, it is likely that the presence of breeding sea lions supports the population of breeding northern giant petrels. However, Dundas is a very small island and so northern giant petrels breeding there compete for space with sea lions, and likely suffer from at least occasional disturbance. This is exacerbated in mid- to late-January when sea lions move inland from the beach (CGM, *pers. obs.*), although that time coincides with fledging and when the giant petrel chicks are much more mobile. Adult northern giant petrels were not observed feeding chicks when sea lions were very close to chicks, and so chick provisioning may have been affected by sea lion presence. As Dundas Island contains the majority of breeding sea lions in the Auckland Islands (79% in the 2016 season; Childerhouse *et al.* 2017), northern giant petrels from Enderby Island may feed there but nest on Enderby, where more nesting space is available and disturbance is less.

Due to logistical constraints on the timing of our work, this study is based on counts of chicks. Nest failures during incubation and the early chick phase are likely to have occurred before study count dates. To correct chick counts and account for nest failures when estimating the number of breeding pairs, we used breeding success data from Macquarie Island. No local nest-failure data are available because there has been no monitoring of northern giant petrel breeding at any of the New Zealand subantarctic islands. Ideally we would use a stage-specific nest failure correction factor (e.g. incubation only) as this would give a more accurate estimate of breeding numbers for the Auckland Island group, but such data are not available. It is assumed that the Macquarie Island data would be comparable to northern giant petrel breeding success in the Auckland Islands. However, this may not be the case as Macquarie Island has more food resources due to vastly larger populations of colonial penguins (*Aptenodytes patagonicus*, *Pygoscelis papua*, *Eudyptes schlegeli*, *E. filholi*) and fur seal rookeries (*Arctocephalus gazella*, *A. tropicalis*, *A. forsteri*), which are common prey and scavenged species for northern giant petrels (Hunter & Brooke 1992).

A variable proportion of northern giant petrel adults take breeding sabbaticals (15–47%; Hunter 1984; Voisin 1988), and so the size of the breeding population may change markedly between years. We can gain some insight into inter-annual variability in the Auckland Islands northern giant petrel population, with some indication of biennial breeding in chick counts on Enderby Island, where counts on alternate years were similar in size. This could be due to breeding sabbaticals or to fluctuating breeding success. To accurately gauge the degree of biennial breeding, if any, and potential variation in breeding success in the Auckland Islands' northern giant petrel population, annual counts of incubating adults at the peak laying period are required, or a capture-mark-resight study.

Since nests can be isolated or clustered in loose groups over 1 km inland, and favoured nesting locations on a given island can shift by hundreds of metres, comprehensive survey coverage is crucial to find all nests. However, comprehensive coverage can be challenging on larger islands, potentially decreasing detection rates (Ryan *et al.* 2009). In this study, using historical records and a thorough survey design minimised non-detection of breeding birds as a source of error (Wolfaardt & Phillips 2011). In addition, the small size of most islands and their relatively open vegetation made comprehensive coverage of all potential habitat possible, giving further confidence in detection of giant petrels. However, since detection rates were not quantified and Adams Island is a large and mountainous island, counts should be taken as minima.

Population changes in giant petrels could be driven by prey changes, interactions with fisheries at sea, and disturbance or predation at the breeding island (ACAP 2010). Very little is known about the diet of northern giant petrels breeding on New Zealand islands, and so documenting population fluctuations relative to the abundance of key prey species is not possible. The extent of incidental mortality of northern giant petrels in commercial fisheries in other nations' territorial waters and in international waters remains unknown. Giant petrels can be vulnerable to human disturbance around nesting areas and are known to abandon breeding sites (Brooke 2004). Enderby Island is the most-visited island in the Auckland Islands group, and so it is encouraging that the breeding population on Enderby Island has increased compared with the only previous comprehensive survey, when just two northern giant petrel chicks were recorded on the island (G.A. Taylor 1988). Approximately half the northern giant petrel nests on Enderby Island are found in the tussock to the west of the boardwalk where tourists are not permitted to go. Given that northern giant petrels are prone to human disturbance and the Enderby population is such a large proportion of the Auckland Island population, future monitoring of the Enderby Island northern giant petrel breeding population should be considered, particularly if visitor numbers increase or new areas are opened to tourists.

The discovery of northern giant petrels breeding on the main Auckland Island was surprising. We assumed that the species would be excluded from this largest island in the group due to depredation by pigs, as white-capped mollymawks (*Thalassarche cauta steadi*) are depredated in areas accessible to pigs at Southwest Cape (Flux 2002; Peat 2009). The single live northern giant petrel

chick found at Crozier Point on the main island in 2015 was accompanied by a single dead chick, recently killed, and with pig faeces, prints, and rooting throughout the area. In 2018, two large chicks were present, with pig sign similar to that observed in 2015. Although some northern giant petrel breeding attempts persist on the main Auckland Island, pigs ensure that it is not ideal habitat for surface-nesting seabirds like giant petrels.

In conclusion, the Auckland Island giant petrel population numbers *c*. 340 breeding pairs and appears relatively stable, with some inter-annual variability. Further work is needed to uncover whether variability is due to biennial breeding or to fluctuating breeding success perhaps linked with prey availability, fisheries by-catch, predation, or visitor pressure. Enderby Island is now the stronghold for northern giant petrels in the Auckland Islands. Monitoring should focus at Enderby Island, but with periodic surveys of other islands since breeding sites are known to shift between islands.

As there are no trend data for northern giant petrels for any location in the New Zealand region, we strongly recommend that the Antipodes and Campbell Islands populations are re-counted in the next 2–5 years to enable trend analysis using previous counts (Wiltshire & Scofield 2000; Wiltshire & Hamilton 2003).



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