

# A review of the distribution and size of prion (*Pachyptila* spp.) colonies throughout New Zealand

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**ABSTRACT:** Prions are among of the most numerous birds of the Southern Ocean, and yet their populations are poorly documented. New Zealand has breeding populations of four of the six recognised species, all with large population sizes. The remaining two species occur naturally in the New Zealand zone but do not breed there. This review reports data collated from the scientific literature, government archives and unpublished information about the population sizes of prions gathered since earliest scientific records in New Zealand (1773, during James Cook's second voyage) until the present day. The study focuses on breeding populations, and reports data about population size and presence or absence of prion populations from sites throughout the New Zealand region. The summary presented provides a solid baseline for future population assessments and identifies priority sites where future surveys are warranted.

**KEYWORDS:** prions, *Pachyptila*, population sizes, population distribution, Procellariiformes, range, seabirds, New Zealand.

## Introduction

Seabirds are one of the most globally threatened groups of birds (Croxall *et al.* 2012). They face a multitude of pressures, such as interactions with commercial fisheries, pollution, climate change, plastic ingestion and disturbances on the breeding grounds, from both humans and invasive species (Carney & Sydeman 1999; Gregory 2009; Hilton & Cuthbert 2010; Anderson *et al.* 2011). For many seabird species, adequate knowledge of their distribution is lacking (Croxall *et al.* 2012). This paucity of the most basic of data inhibits the conservation of these species. Furthermore, a poor understanding of a species' range makes it difficult to

collect the baseline data necessary for robust evaluations of its population trends and conservation status.

Many seabird species rely on remote islands for breeding and nest in burrows, making the collection of even the most basic data challenging. Further, in New Zealand access to many of the southern nearshore islands is severely restricted to anyone other than traditional owners or occupiers, and then often limited to the March–May muttonbirding season (Moller *et al.* 2009), a period that does not coincide with the breeding season of many seabird species, including prions.

Prions (*Pachyptila* spp.) are small petrels (120–200 g average weight; Miskelly 2013a,b), are nocturnal on land, and nest in burrows or crevices, mostly on remote

predator-free islands. Globally, there are six species of prion, all of which breed on islands in the Southern Ocean: broad-billed prion (*P. vittata*), Salvin's prion (*P. salvini*), Antarctic prion (*P. desolata*), thin-billed prion (*P. belcheri*), fairy prion (*P. turtur*) and fulmar prion (*P. crassirostris*). Although they are one of the most abundant groups of seabirds (up to 95 million individuals; Brooke 2004) and are all listed by the International Union for Conservation of Nature as of 'Least Concern' (IUCN 2016), they still face significant population threats.

First, prions are among the most common species of seabird to succumb to beach-wreck (e.g. Harper 1980; Post 2007; Powlesland 1989). For example, during a severe weather event in July 2011, approximately 250,000 prions (approximately 200,000 of which were broad-billed prions) blew ashore and died along the west coast of New Zealand (Miskelly 2011a; Tennyson & Miskelly 2011). Climate-change models forecast that such storms are likely to increase in both frequency and intensity (Easterling *et al.* 2000; Alley *et al.* 2003). This could have significant detrimental effects on population numbers of prions. Second, prions are surface-feeders that rely on planktonic crustaceans, molluscs and fish. It has been predicted that over the next 90 years there will be a 6.3% decline in ocean productivity (Yool *et al.* 2013). Much of this decline will be due to a significant decrease in key nutrient levels in surface waters, resulting in large-scale effects on the lower trophic levels. In turn, this could resonate throughout the ecosystem (Yool *et al.* 2013) and lead to diminished feeding opportunities for surface-feeding birds. Monitoring even abundant species such as prions for assessing changes in marine ecosystems is thus clearly important; as apex predators, prions are sensitive indicators of change throughout these systems. And third, introduced mammalian predators have extirpated populations of small seabirds from many islands in New Zealand since scientific records began 250 years ago (Taylor 2000a).

Accurate and detailed information about the distribution and abundance of seabirds from the earliest days of scientific recording to today would enable these changes to be documented and their impact on species' conservation status to be assessed (Warham 1996). However, globally there is a lack of baseline data for most prion populations, with just a few exceptions (e.g. Catry *et al.* 2003; Taylor 2011). The first step in determining prion population trends is establishing the distribution of the species, which is best done during the breeding season, when they are ashore.

In this paper we collate data from a wide variety of sources to describe the distribution of prions breeding within the New Zealand region, and if the data were available, we report information on population numbers and trends. From this information we make recommendations for monitoring prion populations with the aim of identifying colonies that cover the geographic range of each species, but also those that are the most practical to monitor owing to relative accessibility. Our priority list includes those sites that have already had some history of monitoring. We also recommend that the population size for each recorded colony is estimated. As initial counts of all colonies are completed, other priority sites for long-term monitoring will become apparent. This review does not provide information about the biology of prions, nor their distributions outside of New Zealand. While we have attempted to include both published and unpublished records to provide a comprehensive overview, it is inevitable that some information will have been missed.

## Methods

A literature review was conducted using primary, secondary and unpublished sources (sources and methods are described in Waugh *et al.* 2013). Raw data were also gleaned from the authors' personal field notebooks and those of other contributing researchers. We follow the taxonomy and nomenclature of Gill *et al.* (2010) and present the results in taxonomic order.

We report records of birds on land only, omitting observations of birds on the water, in the air or reported as beach-wrecks. We assumed that the presence of birds ashore signified breeding; however, birds found in skua middens may have been killed elsewhere (e.g. on the water) and transported to land. Depending on the information available in the original source, we described records as individuals (when no information on breeding status was given), breeding pairs (when some indication of breeding was provided and we note the presence of eggs or chicks) or burrows (when we had information only on the nesting structures themselves, with no information on bird occupancy; note that most prion nests are in soil burrows, and while in some cases the birds also nest in crevices, such nests are usually also reported as burrows, as most authors did not distinguish between nest types). If some level of systematic surveying was conducted, then the sampling protocol was described as a 'count', otherwise it was recorded as an 'observation'. A few individual records of live birds on islands well outside their

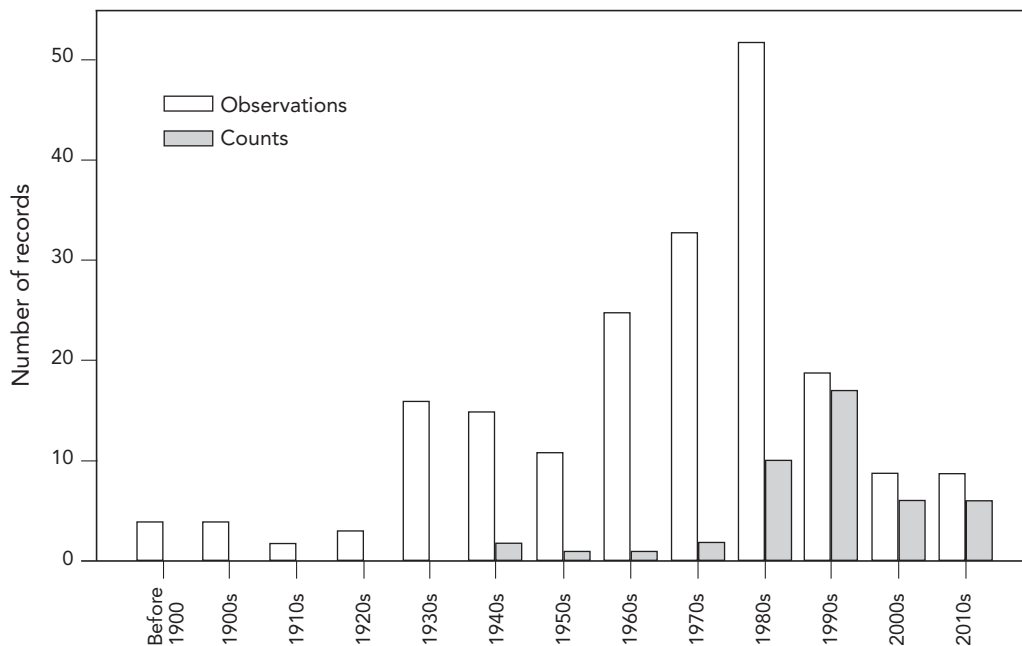


Fig. 1 Temporal distribution of population records for prion (*Pachyptila* spp.) colonies within New Zealand.

known breeding range (e.g. a broad-billed prion on Motunau I., Canterbury (Cox *et al.* 1967) and an Antarctic prion on Houruakopara I., Chatham Is (Imber 1994)) were considered to be vagrants. Brief observations that did not add any significant data to more comprehensive observations were not listed (e.g. there are some records of a species being present on an island when there are other records of actual population estimates from a similar time).

We used the names of localities as they are reported by Land Information New Zealand (Land Information New Zealand 2012; Harriss 2016). Island and islands are abbreviated to 'I.' and 'Is', respectively. In some cases, text in parentheses after the site name gives information to indicate the location of a small islet, or to reduce ambiguity about the location, such as where multiple sites with the same name exist.

The data set associated with this research, including detailed latitude and longitude information of the sites, is available to researchers and management groups on request from Susan Waugh at the Museum of New Zealand Te Papa Tongarewa (Te Papa; susan.waugh@tepapa.govt.nz).

## Results

We located 304 records of prion colony observations in the New Zealand region from the literature and data review; half of these related to fairy prions. We report 100, 21, 152 and

31 records for broad-billed, Antarctic, fairy and fulmar prions, respectively. Prions were found on all major offshore island groups except the Kermadec Is. There were no records of Salvin's or thin-billed prions breeding on New Zealand islands. This was expected, as they are not known to breed in the southwest Pacific Ocean (Marchant & Higgins 1990), but it is noted that thin-billed prions were recorded as possibly breeding at Macquarie I. (Brothers 1984). Fairy prions had the most expansive New Zealand range, spanning 1650 km in distribution from north to south. Antarctic prions had the most restricted range; they were found almost exclusively at the Auckland Is. 'Observations' far outnumbered 'counts' (251 versus 51; Fig. 1). The number of 'observations' peaked during the 1980s, and 'counts' peaked during the 1990s, after which the number of each decreased (likely due to limited resources), but the casual observations were as numerous as formal counts after the 1990s (Fig. 1).

### Broad-billed prion

We report broad-billed prions at 48 different locations (Table 1). Their colonies spanned from the Chatham Is to the Snares Is/Tini Heke, a distance of *c.* 1400 km. Of the 100 records for broad-billed prions, only seven colonies had total population estimates based on counts.

There were very few repeated observations at any one site over time, but the few that there were suggested population

Table 1 Population data for broad-billed prions (*Pachyptila vittata*) nesting in New Zealand (FLD = Fiordland; STW = Stewart I./Rakiura and Foveaux Strait; CIS = Chatham Is; SNI = Snares Is/Tini Heke; dash = no data or comments; see 'Methods' for sampling protocol).

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Haweia I., Breaksea Sound <sup>a</sup>	FLD	Mar–Apr 1986	10s	Burrows	Norway rats ( <i>Rattus norvegicus</i> ) eradicated Apr 1986	Observation	G. Taylor, unpub. data
Wairaki I., Breaksea Sound <sup>a</sup>	FLD	Mar–Apr 1986	10s	Burrows	Seals limiting	Observation nesting sites	G. Taylor, unpub. data
Gilbert Is (western island), Breaksea Sound <sup>a</sup>	FLD	Mar–Apr 1986	100s	Burrows	Dense colony	Observation	G. Taylor, unpub. data
Dusky Sound	FLD	1986	–	Pairs	Breeding	Observation	K. Morrison <i>in</i> Gaze 1988
Petrel Is, Dusky Sound	FLD	1785	–	Pairs	–	Observation	Begg & Begg 1968
Anchor I., Dusky Sound	FLD	Mar–May 1773	1000s	Pairs	–	Observation	Medway 2011
		1785	–	Individuals	Immense numbers	Observation	Medway 2002
		Apr 1900	0	Individuals	–	Observation	Medway 2011
Seal Is, Dusky Sound	FLD	1773	1000s	Pairs	–	Observation	Medway 2011
Chalky Inlet	FLD	1986	–	Pairs	Breeding	Observation	K. Morrison <i>in</i> Gaze 1988
Solander I. (Hautere)	FLD	Jul 1948	–	Burrows	Adults 'in numbers'; weka patrolling	Observation	Falla 1948
		Nov 1973	2	Individuals	Corpses	Observation	Cooper <i>et al.</i> 1986
		Feb 1996	100s	Pairs	Many weka killed	Observation	A. Tennyson & G. Taylor, unpub. data
Little Solander I.	FLD	Jul 1985	Several	Individuals	Seen in flight	Observation	Cooper <i>et al.</i> 1986
Raratoka I. (Centre I.)	STW	Oct 1989	–	Pair	1 chick	Observation	Cooper 1991
Codfish I./ Whenua Hou	STW	Dec 1934	–	Pairs	Small numbers	Observation	Wilson 1959: 75
		Dec 1966	–	Pairs	–	Observation	Blackburn 1968
		2000s	10s	Burrows	At least 10s of scattered burrows	Observation	G. Taylor, unpub. data
Sealers Bay stacks, Codfish I./ Whenua Hou	STW	1935	–	Pairs	–	Observation	E. Stead <i>in</i> Blackburn 1968
		Dec 1966	–	Pairs	–	Observation	Blackburn 1968

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Table 1 Population data for broad-billed prions (*Pachyptila vittata*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Sealers Bay stacks, Codfish I./ Whenua Hou [ <i>contd</i> ]		Nov 1991	1000–2000	Burrows	–	Observation	G. Taylor & A. Tennyson <i>in</i> O'Donnell & West 1998
Trig I.	STW	Dec 2011	500	Burrows	Mostly inactive	Count	Miskelly 2011b
		Dec 2011	10	Pairs	10 chicks	Count	Miskelly 2011b
Green I., nr Ruapuke I.	STW	Nov–Dec 1941	1000s	Pairs	Many thousands	Observation	Stead 1953
		Dec 2012	–	Pairs	Reported to be present; weka present	Observation	Miskelly 2013c, unpub. data
Bird I., nr Ruapuke I.		Mar 1965	–	Individuals	Large numbers	Observation	Blackburn 1965
North I., Titi/Muttonbird Is	STW	Oct 1911	–	Individuals	–	Observation	Guthrie-Smith 1914
Jacky Lee I. (Pukeokaoka)	STW	Dec 1932	'fairly plentiful'	Pairs	Many chicks taken by weka	Observation	Wilson 1959
		Dec 1940	'a mere handful'	Individuals	Decimated by weka	Observation	Wilson 1959
Herekopare I. (Te Marama)	STW	Oct 1911	1000s	Individuals	–	Observation	Guthrie-Smith 1914
		May 1942	100s	Individuals	Cat predation observed	Observation	Richdale 1944a
		Dec 1968	0	Individuals	–	Observation	Adams & Cheyne <i>in</i> Fitzgerald & Veitch 1985
		Apr–May 1970	1	Individual	–	Observation	Fitzgerald & Veitch 1985
Halfmoon Bay Islet	STW	1939/40	16	Individuals	Skua midden	Observation	B. Marples <i>in</i> Anonymous 1953
Whero Rock	STW	1941	50	Pairs		Count	Richdale 1942
		1942/43	200	Individuals	–	Count	Richdale 1944a
		Nov 2010	0	Individuals	Nesting site destroyed by shags	Count	Peat 2011
Pukeweka I.	STW	1931	–	Individuals	–	Observation	Wilson 1959
Kundy I.	STW	Nov 1929	–	Pairs	–	Observation	Wilson 1959
		Mar 2011	50	Individuals	Also 52 in skua middens	Observation	C. Miskelly, unpub. data
Big I.	STW	Mar 1965	–	Individuals	Common	Observation	Blackburn 1965
Mokiiti/. Little Moggy I	STW	2006	–	Pairs	–	Observation	M. Charteris, unpub. data

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Table 1 Population data for broad-billed prions (*Pachyptila vittata*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Mokinui/ Big Moggy I.	STW	2007	–	Pairs	–	Observation	M. Charteris, unpub. data
Putauhinu I.	STW	Mar 2011	1	Individual	Heard at night	Observation	C. Miskelly, unpub. data
Tamaitemioka I.	STW	Mar 1965	–	Individuals	Skua middens	Observation	Blackburn 1965
Rerewhakaupoko I. (Solomon)	STW	Nov 1931 Mar 2012	– 7	Pairs Individuals	– At night	Observation Observation	Wilson 1959 C. Miskelly, unpub. data
Pohowaitai I.	STW	Mar 1965	–	Individuals	Skua middens	Observation	Blackburn 1965
Weka I.	STW	Nov 1931	–	Pairs	–	Observation	Wilson 1959
Taukihepa/ Big South Cape I.	STW	Jun 1955– May 1956	–	Individuals	–	Observation	Falla <i>in</i> Blackburn 1965
The Sisters (Rangitatahi) (middle island)	CIS	Oct 1973 Sep 1976	1 1	Pair Pair	1 chick 1 egg	Observation Observation	Imber 1994 Imber 1994
S of Owenga, Chatham I.	CIS	Apr 1983	–	Burrows	15 adults killed by cats	Observation	Imber 1994
Stack off Cascades	CIS	Apr 1981	15	Burrows	–	Count	Imber 1994
Blyth's Stack	CIS	Nov 1983	18	Pairs	Chicks	Observation	Imber 1994
Houruakopara I.	CIS	Aug 1980 Nov 1987	2 300	Pairs Pairs	– –	Observation Count	Imber 1994 Plant 1989
Pitt I. (Rangiauria)	CIS	1871/72 1923/24 1937 1951–53 Apr 1967 Apr 1993	> 100 – – – – – 5	Individuals Pairs Pairs Pairs Individuals Individuals	Preyed upon by cats – – Preyed upon by cats – – Appeared to be killed by cats (A. Tennyson, pers. obs.)	Observation Observation Observation Observation Observation Observation	Travers & Travers 1872 Archey & Lindsay 1924 Fleming 1939 Bell 1955 Imber 1994 AV36939, Canterbury Museum
Star Keys	CIS	1960s–70s Feb 1988	25 Many	Individuals Individuals	– Killed by skuas; probably few nesting	Observation Observation	Imber 1978 A. Tennyson, unpub. data
Rabbit I.	CIS	Nov 1980	> 100	Pairs	–	Observation	Imber & Lovegrove 1982

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Table 1 Population data for broad-billed prions (*Pachyptila vittata*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Kokope I.	CIS	–	–	–	Breeding	Observation	Imber 1994
		Dec 1997	150	Pairs	Heavily preyed on by weka	Observation	A. Tennyson, unpub. data
Mangere I.	CIS	1871/72	–	Burrows	?Breeding	Observation	Tennyson & Millener 1994
		1923/24	–	Burrows	–	Observation	Archey & Lindsay 1924
		1937	–	Pairs	Abundant	Observation	Fleming 1939
		1957 <sup>b</sup>	–	Pairs	–	Observation	Tennyson & Millener 1994
		1981/82	–	Pairs	Many large chicks	Observation	D. Crouchley <i>in</i> Booth 1983
		1987/88	10,000	Pairs	–	Count	Tennyson 1989
Little Mangere I. (Tapuaenuku) The Fort	CIS	1937	–	Pairs	Abundant	Observation	Fleming 1939
Rangatira (South East I.)	CIS	Dec 1937	–	Pairs	Abundant	Observation	Fleming 1939
		Jul 1975	–	Individuals	Huge numbers	Observation	Imber 1994
		1981/82	–	Pairs	Many large chicks	Observation	D. Crouchley <i>in</i> Booth 1983
	CIS	1989/90	330,000	Pairs	–	Count	West & Nilsson 1994
		1989/90	0.34/m <sup>2</sup>	Burrows	Assumed prion burrows	Count	West & Nilsson 1994
		1989/90	1.34/m <sup>2</sup>	Burrows	All burrows	Count	West & Nilsson 1994
		Apr 1993	–	Individuals	Huge numbers	Observation	Imber 1994
		Mar 1999	0.31/m <sup>2</sup>	Burrows	Assumed prion burrows	Count	Sullivan & Wilson 2001
		Apr 2002	1.19±0.10/m <sup>2</sup>	Burrows	All burrows	Count	Roberts <i>et al.</i> 2007
Western Nugget, Murumuru Is	CIS	Dec 1987	20	Pairs	Densely burrowed; partial count	Observation	Tennyson <i>et al.</i> 1993
North East I.	SNI	Jan 1977	–	Pair	1 chick	Observation	Sagar 1977a
		1986	2000–5000	Pairs	–	Observation	Miskelly <i>et al.</i> 2001
		1986	265	Individuals	Skua middens	Count	Tennyson 2013
		Dec 2013	103	Individuals	Skua middens	Count	Tennyson 2013
(South Bay)		Feb 1986	350	Individuals	–	Observation	Miskelly <i>et al.</i> 2001
		Nov 1986	60	Pairs	Chicks; partial count	Observation	Miskelly <i>et al.</i> 2001
		Dec 2013	6	Pairs	Chicks; partial count	Count	Tennyson 2013
Rocky Islet	SNI	1971/72	3	Pairs	–	Observation	Horning & Horning 1974
		Dec 1976	2	Pairs	2 chicks	Observation	Sagar 1977a
		Dec 1984	1	Pair	1 chick	Observation	Miskelly <i>et al.</i> 2001

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Table 1 Population data for broad-billed prions (*Pachyptila vittata*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Alert Stack	SNI	Feb 1985	1	Individual	–	Observation	Miskelly <i>et al.</i> 2001
Broughton I.	SNI	Nov 1976	–	Individuals	Killed by skuas	Observation	P. Sagar <i>in</i> Edgar 1977
		Feb 1984	–	Individuals	–	Observation	Miskelly <i>et al.</i> 2001
Toru Islet <sup>c</sup>	SNI	Dec 1984	2	Pairs	2 chicks	Observation	Miskelly 1997
		Jan 1986	3	Pairs	1 egg, 2 chicks	Observation	Miskelly <i>et al.</i> 2001

(a) Gaze (1988) and Marchant & Higgins (1990) noted breeding observations from unspecified locations in Breaksea Sound; we provide more detailed observations from this area.

(b) Apparently, the year was incorrectly given as 1961 in Tennyson & Millener (1994: table 1), as Lindsay visited in 1957 (Lindsay *et al.* 1959). However, Lindsay's diary of this trip, supposedly held in Te Papa's archives (Tennyson & Millener 1994), could not be located in 2015 (J. Twist, pers. comm.).

(c) Note that while broad-billed prions have been reported from skua middens on Rima Islet (Snares Is/Tini Heke; Sagar 1977b), there is no evidence that the species breeds there (C. Miskelly, unpub. data).

declines. For example, thousands of birds were believed to have been nesting on Anchor I. in Dusky Sound, Fiordland, during James Cook's visit in 1773; however, by 1900 a breeding population was no longer present there (Medway 2011). Similar declines resulting in localised extinction are suspected at the colony on the neighbouring Seal Is (Medway 2011). To the east on Kokope I. (Chatham Is), and at Solander I. (Hautere) and Jacky Lee I. (Pukeokaoka) (both in the Stewart I./Rakiura region), the populations were being heavily depredated by weka (*Gallirallus australis*). Prions trying to nest on Chatham I. were reported to be heavily preyed upon by cats (*Felis catus*; Imber 1994). On Herekopare I. (Te Marama), off Stewart I./Rakiura, the population went from thousands of individuals in 1911 to a single individual in 1970, reportedly due to cat predation (Guthrie-Smith 1914; Fitzgerald & Veitch 1985). The entire population on Whero Rock was extirpated after colonisation by the New Zealand endemic Stewart Island shag (*Leucocarbo chalconotus*), whose nesting activity destroyed the small cap of vegetation on the islet (Richdale 1944a; Peat 2011). The Chatham Is host the largest portion of New Zealand's breeding population of broad-billed prions, yet there have not been any repeated counts at the large colony at Mangere I. and only a limited number of counts conducted at Rangatira (South East I.), the most recent being in 2002. Despite huge colonies of prions formerly being present in southern New Zealand, the largest known documented remaining colonies in recent times are at the Snares Is/Tini Heke (2000–5000 pairs in 1986) and on the

Sealers Bay stacks off Codfish I./Whenua Hou (1000–2000 burrows in 1991; Table 1). However, the number of birds in the Fiordland and Stewart I./Rakiura regions is poorly known and more detailed surveys are warranted there.

## Antarctic prion

The Auckland Is are the stronghold of Antarctic prions breeding in New Zealand (Table 2); the species has been reported from eight different islands in the group. However, there are no substantive data from which to assess population size among the 19 records for the species in the group, and so we are unable to draw conclusions about their population status or trends.

## Fairy prion

With numbers of breeding pairs in the millions, fairy prions are among the most common seabird species nesting in New Zealand (sooty shearwater, *Puffinus griseus*, is the most abundant; see Waugh *et al.* 2013 for a population assessment). They are also one of the most widespread New Zealand seabird species, with a geographic range extending from the Poor Knights Is in Northland to Stewart I./Rakiura and the Antipodes Is. (Table 3). The largest colony within New Zealand, and likely the world, is on Stephens I./Takapourewa in the Marlborough Sounds, which has about 1.4 million pairs (Craig 2010). The limited information available suggests that the second-largest colony in the New Zealand region is on Mangere I. in the Chatham Is, with



Table 2 Population data for Antarctic prions (*Pachyptila desolata*) nesting in New Zealand (AKI = Auckland Is; CBL = Campbell I./Motu Ihupuku; dash = no data or comments; see 'Methods' for sampling protocol).

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Auckland Is <sup>a</sup>	AKI	1984	100,000–1,000,000	Pairs	–	Unknown	Robertson & Bell 1984
		1990	350,000–750,000	Pairs	–	Unknown	Marchant & Higgins 1990
Enderby I.	AKI	1944	–	Pairs	Common	Observation	Turbott 2002
		Jan 1966	–	Burrows	–	Observation	Taylor 1971
		Dec 1976	–	Individuals	Skua middens	Observation	Bartle & Paulin 1986
		Feb 1988	–	Pairs	Calling from burrows, 1 adult seen in burrow	Observation	G. Taylor, unpub. data
Rose I.	AKI	Jan 1966	–	Burrows	–	Observation	Taylor 1971
Auckland I.	AKI	1907	–	Burrows	Common <sup>b</sup>	Observation	Waite 1909
		1944	–	Pairs	Common	Observation	Turbott 2002
		Feb 1973	–	Pairs	Most common petrel	Observation	Challies 1975
		Feb–Mar 1982	100+	Individuals	Killed by cats	Observation	Thompson 1986
		Feb 1988	–	Individuals	Many birds killed by cats outside burrows	Observation	G. Taylor, unpub. data
Ocean I.	AKI	1972	4	Individuals	–	Observation	K.-J. Wilson, unpub. data
		Feb 1988	–	Pairs	Calling from burrows	Observation	G. Taylor, unpub. data
Shoe I.	AKI	1903	–	Burrows	–	Observation	Waite 1909
Disappointment I.	AKI	Nov 1907	–	Individuals	Remains only	Observation	Waite 1909
Adams I.	AKI	1944	–	Pairs	Common	Observation	Turbott 2002
		Nov 1989	–	Pairs	–	Observation	Buckingham <i>et al.</i> 1991
Masked I.	AKI	Nov 2013	2	Pairs	–	Count	K.-J. Wilson, unpub. data
Northwest Bay stack	CBL	Jan 1986	1	Individual	Found in a burrow; probably this species	Observation	D. Cunningham, pers. comm. to G. Taylor
Eboulé Peninsula, Campbell I./Motu Ihupuku	CBL	Jan 2006	1	Individual	Fledgling in skua midden; not clear evidence of breeding at this site	Observation	Miskelly & Fraser 2006

(a) Te Papa holds specimens of Antarctic prions that indicate additional or probable breeding islands in the Auckland Islands group: 1 egg (NMNZ OR.14749, collected 4 Dec 1943) and 1 chick (NMNZ OR.13031, collected 14 Jan 1943) from Figure of Eight Island; 2 adults (NMNZ OR.17547 and OR.17548, both collected 8 Jan 1973) from Ewing Island; 1 complete skeleton (NMNZ OR.19794, collected 21 Feb 1973) from Monument Island.

(b) Waite (1909) was uncertain if the burrows were created by Antarctic or broad-billed prions; the latter have never been observed in AKI, so we have assumed the burrows were made by Antarctic prions. Also, Antarctic prions were reported by Waite (1909) as being on the Antipodes Is but likely a case of misidentification, as only fairy prions have been sighted there by other observers (Tennyson *et al.* 2002).

Table 3 Population data for fairy prions (*Pachyptila turtur*) nesting in New Zealand (NL = Northland; KAP = Kapiti coast; MLS = Marlborough Sounds; WCN = west coast, North I.; WCS = west coast, South I.; CTC = Canterbury coastal; OTC = Otago coastal; FLD = Fiordland; STW = Stewart I./Rakiura; CIS = Chatham Is; SNI = Snares Is/Tini Heke; ANT = Antipodes Is; dash = no data or comments; see 'Methods' for sampling protocol).

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Poor Knights Is	NL	1930s	–	Pairs	Burrows and eggs	Observation	Falla 1934
Tawhiti Rahi I., Poor Knights Is	NL	Jan 1943	–	Pairs	Small numbers	Observation	Buddle 1946
		Aug 1958	–	Individuals	Moderate numbers	Observation	Kinsky & Sibson 1959
		Dec 1958	1	Pair	Downy chick	Observation	Kinsky & Sibson 1959
		Sep 1980	1000s	Pairs	Many thousands	Observation	McCallum 1981
Aorangi I., Poor Knights Is	NL	Nov 1940	–	Pairs	Vast numbers	Observation	Buddle 1941
		Aug 1958	–	Individuals	Moderate numbers	Observation	Kinsky & Sibson 1959
		1964–75	40,000	Individuals	Extrapolation from plot surveys	Count	Harper 1976
		Nov 1990	–	Pairs	Many; some eggs	Observation	R. Parrish <i>in</i> Taylor & Parrish 1992
		Dec 2011	–	Pairs	Widespread	Observation	G. Taylor & A. Tennyson, unpub. data
Te Haupa I. (Saddle I.), off Great Barrier I. (Aotea I.)	NL	Prior to 1934	–	Pairs	Chicks	Observation	Falla 1934
		Apr 1990	0	Individuals	Ship rats present	Observation	G. Taylor & A. Tennyson, unpub. data
		Nov 1994	0	Individuals	Ship rats present	Observation	A. Tennyson & K. McConkey, unpub. data
Hauturu/ Little Barrier I.	NL	1886	–	Individuals	–	Observation	Reischek 1887
		Nov 1960	1	Individual	Presumed vagrant	Observation	Bishop 1963
		Dec 1962	1	Individual	Presumed vagrant	Observation	Bishop 1963
		1978–2015	0	–	No recent sightings	Observation	A. Tennyson, G. Taylor & C. Miskelly, unpub. data
Mana I.	KAP	2005	1	Nest	–	Count	Miskelly & Gummer 2013
		2008	3	Pairs	–	Count	Miskelly 2010
		2012	6	Pairs	–	Count	Miskelly & Gummer 2013
Stephens I. (Takapourewa)	MLS	1925	100,000s	Burrows	–	Observation	Guthrie-Smith 1936
		May 1974– Apr 1975	0.2– 4.5/m <sup>2</sup>	Burrows	Range	Count	Walls 1978
		1985	1,000,000	Individuals	–	Unknown	Harper 1985
		1990	500,000	Individuals	–	Unknown	Daugherty <i>et al.</i> 1990
		Jun–Dec 1994	0.5±0.3– 1.4±0.2/m <sup>2</sup>	Burrows	Varied by habitat (means ± SEs)	Count	Markwell 1997

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Table 3 Population data for fairy prions (*Pachyptila turtur*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Stephens I. (Takapourewa) [ <i>contd</i> ]		Jun–Dec 1994	0.4±0.1– 1.1±0.2/m <sup>2</sup>	Pairs	Varied by habitat (means ± SEs)	Count	Markwell 1997
		Aug 1994	0.095/m <sup>2</sup> (0–0.371/m <sup>2</sup> )	Burrows	Mean (range)	Count	Craig 2010
		Aug 1994	1,830,523	Burrows	–	Count	Craig 2010
		Aug 1994	1,418,665 <sup>a</sup>	Pairs	Occupancy rate 0.775 (Craig 2010: table 14)	Count	Craig 2010
		1998	0.84/m <sup>2</sup> (0–3/m <sup>2</sup> )	Burrows	Mean (range)	Count	Mulder & Keall 2001
Jag Rocks	MLS	1961	–	Individuals	–	Observation	B. Bell, unpub. data
		Apr 1987	–	Burrows	Abundant	Observation	G. Taylor, unpub. data
Middle Trio I., Trio Is (Kuru Pongi)	MLS	Apr 1963– Jan 1964	–	Pairs	Numerous	Observation	Campbell 1967
		1990	–	Individuals	–	Observation	Daugherty <i>et al.</i> 1990
Sentinel Rock	MLS	Apr 1987	–	Individuals	Feathers common in crevices	Observation	G. Taylor, unpub. data
Ninepin Rock, nr Chetwode Is	MLS	Aug 1993	–	Burrows	Numerous	Observation	D. Brown <i>in</i> O'Donnell 1995
The Haystack (Moturaka), nr Chetwode Is	MLS	Aug 1993	–	Burrows	Numerous	Observation	D. Brown <i>in</i> O'Donnell 1995
North Brother I.	MLS	Aug 1950– Feb 1951	–	Pairs	In great numbers	Observation	Sutherland 1951
		Oct 1990	1000	Pairs	–	Count	Gaston & Scofield 1995
		Oct 1990	0.03/m <sup>2</sup> (0–5/m <sup>2</sup> )	Pairs	Mean (range)	Count	Gaston & Scofield 1995
		Oct 1990	1.4/m <sup>2</sup> (0–14/m <sup>2</sup> )	Burrows	Mean (range)	Count	Gaston & Scofield 1995
		Feb 1993	1750	Burrows	Medium reliability	Count	K.-J. Wilson, unpub. data
South Brother I.	MLS	Early 1960s	–	Individuals	–	Observation	B. Bell & I. Crook, unpub. data
The Twins	MLS	1961	–	Individuals	–	Observation	B. Bell, unpub. data
Motungarara I.	MLS	1961	–	Individuals	–	Observation	B. Bell, unpub. data
Wall I.	WCS	Dec 2013	1255	Pairs	–	Count	R Lane & M. Charteris <i>in</i> R. Lane, unpub. data
		Dec 2015	1400	Pairs	–	Count	R. Lane, unpub. data

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Table 3 Population data for fairy prions (*Pachyptila turtur*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Motukiekie Rocks (islet)	WCS	2000	–	Burrows	–	Observation	G. Wood, unpub. data
		Jan 1995	8	Nests	8 chicks	Observation	B. Stuart-Menteath <i>in</i> O'Donnell & West 1996
Murphy Beach stacks	WCS	Mar 2010	2	Nests	1 egg, 1 chick	Observation	OR.029176 and OR.029213, Te Papa
Arnott Point islet	WCS	Mar 2010	1	Nest	1 chick	Observation	OR.029177, Te Papa
Taumaka I., Open Bay Is	WCS	1907	–	Nests	See note b	Observation	Waite 1909
		Feb 1973	–	Nests	Uncommon	Observation	K.-J. Wilson, unpub. data
		Oct 1980	–	Nests	Uncommon	Observation	K.-J. Wilson, unpub. data
		Aug 1986	10s	Nests	Some weka predation	Observation	A. Tennyson, unpub. data
		1994/95	–	Nests	Chick remains	Observation	Miller 1997
Barn Is	WCS	Mar 2011	–	Burrows	Numerous	Observation	Lettink <i>et al.</i> 2013
Motunau I.	CTC	1958	9900	Burrows	–	Observation	Cox <i>et al.</i> 1967
		1962	14,000	Burrows	–	Count	Cox <i>et al.</i> 1967
		1961–63	27,500	Individuals	Very rough estimate	Count	Cox <i>et al.</i> 1967
		Dec 1983	–	Pairs	Many	Observation	J. Fennell & P. Sagar <i>in</i> Gaze 1985
		Dec 1996– Jan 1997	14,000	Burrows	–	Count	Beach <i>et al.</i> 1997
2004	–	Individuals	Harrier midden	Observation	Hawke <i>et al.</i> 2005		
Crown I. (Le Bons Bay to Pompeys Pillar)	CTC	1960	–	Pairs	Nesting densely	Observation	B. Bell <i>in</i> Wilson 2008 <sup>c</sup>
		Dec 2000	255	Burrows	–	Count	Wilson 2008
Islet, Redcliffe Nook	CTC	Dec 2000	30	Pairs	–	Count	Wilson 2008
Islet, Island Nook	CTC	1960	–	Pairs	–	Observation	B. Bell <i>in</i> Wilson 2008
		Dec 2000	150	Pairs	–	Count	Wilson 2008
Islet, Island Bay	CTC	1960	–	Pairs	–	Observation	B. Bell <i>in</i> Wilson 2008
		Dec 2000	300	Pairs	–	Count	Wilson 2008
Wharekakahu	OTC	Nov 1983	2000–3000	Burrows	Occupancy rate 70% at plot examined	Count	Ward & Munro 1989
Gull Rocks	OTC	1990s	–	Pairs	–	Observation	Loh 2000

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Table 3 Population data for fairy prions (*Pachyptila turtur*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Green I.	OTC	1980s	–	Pairs	Important breeding area	Observation	Ward & Munro 1989
		No date	–	Pairs	–	Observation	Loh 2000
Tunnel Beach (Prion Cave) (Prion Cleft) (Prion Cliff)	OTC	Feb 1997	8	Burrows	–	Count	Loh 2000
		Aug 1996	–	Individuals	–	Observation	Loh 2000
		Jan 1993	70	Individuals	14 potential nests	Count	Loh 2000
		Oct 1998	160	Individuals	Artificial nests installed from 1994	Count	Loh 2000
Rock stacks, Catlins	OTC	No date	–	Pairs	‘Small colonies’	Observation	Loh 2000
Solander I. (Hautere)	FLD	Jul 1948	–	Burrows	Weka patrolling	Observation	Falla 1948
		Jan 1973	–	Individuals	Bones	Observation	Wilson 1973
		Nov 1973	–	Pairs	Small colony	Observation	Cooper <i>et al.</i> 1986
		Nov 1976	–	Individuals	Small numbers	Observation	Cooper <i>et al.</i> 1986
		Feb 1996	100s	Pairs	Many killed by weka	Observation	A. Tennyson & G. Taylor, unpub. data
Jul 1997	–	Pairs	Scattered in areas inaccessible to weka	Observation	G. Taylor, unpub. data		
Little Solander I.	FLD	Jul 1948	–	–	Remains in ‘skua and (or) hawk castings’	Observation	Falla 1948
		Nov 1976	–	Individuals	Small numbers	Observation	Cooper <i>et al.</i> 1986
		Jul 1985	1	Individual	Seen in flight	Observation	Cooper <i>et al.</i> 1986
Codfish I./ Whenua Hou	STW	Dec 1934	–	Pairs	Small numbers	Observation	Wilson 1959: 75
		1991–2011	0	–	No recent sightings	Observation	G. Taylor, A. Tennyson & C. Miskelly, unpub. data
Green I.	STW	Nov 1941	1,000,000 (<1/m <sup>2</sup> )	Burrows	–	Count	Stead 1953
		Nov 1941	1,500,000 <sup>d</sup>	Pairs	–	Count	Wilson 1959
		Dec 2012	–	Individuals	Only 6 corpses; weka present	Observation	Miskelly 2013c, unpub. data
North I., Titi/ Muttonbird Is	STW	Oct 1911	–	Individuals	–	Observation	Guthrie-Smith 1914
Jacky Lee I. (Pukeokaoka)	STW	Dec 1932	–	Pairs	‘Fairly plentiful’; many taken by weka	Observation	Wilson 1959
		Dec 1940	–	Individuals	‘A mere handful’; decimated by weka	Observation	Wilson 1959
Herekopare I. (Te Marama)	STW	Oct 1911	1000s	Individuals	–	Observation	Guthrie-Smith 1914
		Aug 1941	10s	Individuals	Some dozens	Observation	Richdale 1944b
		Dec 1968	–	Pairs	A very large population	Observation	Adams & Cheyne in Fitzgerald & Veitch 1985

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Table 3 Population data for fairy prions (*Pachyptila turtur*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Halfmoon Bay Islet	STW	1939/40	44	Individuals	Skua midden	Observation	Anonymous 1953
Bench I.	STW	Nov 1971	1	Individual	–	Observation	K.-J. Wilson, unpub. data
Whero I.	STW	1940s	1000	Individuals	–	Count	Richdale 1965
		1941	400	Pairs	–	Count	Richdale 1942
		2010	0	Individuals	–	Count	Peat 2011
Kundy I.	STW	Nov 1929	–	Pairs	–	Observation	Wilson 1959
		Mar 2011	1000s	Individuals	Also 44 in skua middens	Observation	C. Miskelly, unpub. data
Mokiiti/ Little Moggy I.	STW	2007	–	Pairs	NW and NE headlands	Observation	M. Charteris, unpub. data
Big I.	STW	Mar 1965	–	Individuals	Carcasses	Observation	Blackburn 1965
Kaimohu I.	STW	Feb 1965	–	Individuals	Skua middens	Observation	Blackburn 1965
Putauhinu I.	STW	Mar 2011	1	Individual	Heard at night	Observation	C. Miskelly, unpub. data
Tamaitemioka I.	STW	Mar 1965	–	Individuals	Skua middens	Observation	Blackburn 1965
Rerewhakaupoko I. (Solomon)	STW	Nov 1931	–	Pairs	–	Observation	Wilson 1959
		Jan 1955– May 1956	–	Individuals	–	Observation	Falla <i>in</i> Blackburn 1965
Pohowaitai I.	STW	Dec 1929	–	Pairs	In burrows	Observation	E. Stead diary (C. Miskelly, unpub. data)
		Mar 1965	–	Individuals	Skua middens	Observation	Blackburn 1965
Taukihepa/ Big South Cape I.	STW	Jun 1955– May 1956	–	Individuals	–	Observation	Falla <i>in</i> Blackburn 1965
		Apr 1961	–	Individuals	Common	Observation	Bell & Merton <i>in</i> Blackburn 1965
		Aug 1964	–	Individuals	–	Observation	Bell & party <i>in</i> Blackburn 1965
Chatham Is	CIS	1871/72	–	Pairs	‘Immense numbers’	Observation	Travers & Travers 1872
The Sisters (Rangitatahi) (western island) (middle island)	CIS	No date	–	Pairs	–	Observation	Imber 1994
		Jan 1954	2	Pairs	–	Observation	Dawson 1955; Marchant & Higgins 1990
		Jan 1974	1	Nest	1 chick	Observation	Imber 1994
Star Keys	CIS	1960s–70s	25	Individuals	–	Observation	Imber 1978
		Feb 1988	Many	Individuals	Killed by skuas; probably few nesting	Observation	A. Tennyson, unpub. data

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Table 3 Population data for fairy prions (*Pachyptila turtur*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Rabbit I.	CIS	Oct–Nov 1980	100s	Individuals	Eggs noted	Observation	Imber & Lovegrove 1982; Imber 1994
		Apr 1981	–	Individuals	Many visiting	Observation	Imber 1994
Kokope I.	CIS	No date	–	Pairs	–	Observation	Imber 1994
		Dec 1997	0	Individuals	–	Observation	A. Tennyson, unpub. data
Mangere I.	CIS	1871/72	–	Individuals	Probably in ‘immense numbers’	Observation	Travers & Travers 1872
		1923/24	–	Burrows	Numerous	Observation	Archey & Lindsay 1924
		1937	–	Pairs	–	Observation	Fleming 1939
		Jul 1975	–	Individuals	Abundant	Observation	Imber 1994
		Oct 1980	1000s	Pairs	Some thousands	Observation	T.G. Lovegrove <i>in</i> Booth 1982
		1987/88	30,000	Pairs	–	Count	Tennyson 1989 <sup>e</sup>
Little Mangere I. (Tapuaenuku) The Fort	CIS	1937	–	Pairs	–	Observation	Fleming 1939
Western Nugget, Murumuru Is	CIS	Dec 1987	1	Nest	Partial count	Observation	Tennyson <i>et al.</i> 1993
Daption Rocks (north)	SNI	Feb 1977	–	Individuals	Killed by skuas	Observation	Miskelly <i>et al.</i> 2001
		(south) Nov 1976	–	Pairs	–	Observation	Miskelly <i>et al.</i> 2001
North East I.	SNI	1985–87	3500	Pairs	–	Count	Miskelly <i>et al.</i> 2001
Rocky Islet	SNI	Dec 1971	3	Individuals	–	Observation	K.-J. Wilson, unpub. data
		Dec 1976	–	Pairs	–	Observation	Miskelly <i>et al.</i> 2001
		Dec 1984	3	Pairs	3 eggs	Observation	Miskelly <i>et al.</i> 2001
Alert Stack	SNI	Dec 1976	–	Pairs	–	Observation	Miskelly <i>et al.</i> 2001
Broughton I.	SNI	Feb 1984	–	Individuals	–	Observation	Miskelly <i>et al.</i> 2001
		Mar 1992	500	Pairs	–	Observation	Miskelly <i>et al.</i> 2001
Antipodes Is (all islands)	ANT	Jan–Mar 1969	0	Individuals	Unable to find any on land	Observation	Warham & Bell 1979
		Apr 2001	–	Individuals	Scores	Observation	Imber <i>et al.</i> 2005
Antipodes I.	ANT	Nov–Dec 1978	20+	Pairs	Not in large numbers	Observation	Imber 1979, 1983
		Nov 1995	1000–5000	Pairs	–	Observation	Tennyson <i>et al.</i> 2002
Bollons I.	ANT	Nov–Dec 1978	–	Pairs	–	Observation	Imber 1979, 1983

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Table 3 Population data for fairy prions (*Pachyptila turtur*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Archway I.	ANT	Nov–Dec 1978	–	Individuals	–	Observation	Imber 1979

- (a) This value differs from the population total of 2,160,017 pairs in Craig (2010). Craig's total assumes that burrow count equals nesting population, but values from her table 14 suggest a burrow occupancy rate of 0.775, and hence a population of 1,418,665 breeding pairs ( $1,850,523 \times 0.775$ ) is more accurate.
- (b) Listed as probably Antarctic prions but assumed to be fairy prions as they are the only species to have been recorded nesting in the area by other observers.
- (c) A fledgling was collected by E. Stead and A. Brooks Jr. in 1935 at an 'Islet near Akaroa Inlet' (Museum of Vertebrate Zoology, Berkeley (MVZ Birds 72373), retrieved on 9 April 2014 from <http://arctos.database.museum/guid/MVZ:Bird:72373>) – this location is probably one of the islets discussed by Wilson (2008).
- (d) Assumed to be primarily fairy prions, although there are likely to be some broad-billed prions included in this count as Stead (1953) estimated a ratio of one broad-billed prion to every 12 fairy prions.
- (e) An estimate of 40,000 pairs (Taylor 2000b; Aikman & Miskelly 2004) is based on a misquotation of Tennyson (1989), which states 30,000 pairs.

30,000 pairs (Tennyson 1989), followed by Aorangi I. in the Poor Knights Is, with 40,000 individuals (Harper 1976), then Motunau I. in Canterbury, with 14,000 burrows (Cox *et al.* 1967), although admittedly some of these data are decades old and the current sizes of these colonies may have changed significantly. More than 2000 pairs are also likely to nest on Tawhiti Rahi I. in the Poor Knights Is (McCallum 1981), Wharekakahu in Otago (Ward & Munro 1989), Herekopare I. (Te Marama) and Kundy I., both in the Stewart I./Rakiura region (Guthrie-Smith 1914; C. Miskelly, unpub. data), North East I. in the Snares Is/Tini Heke (Miskelly *et al.* 2001) and Antipodes I. (Tennyson *et al.* 2002).

Although the species was reported in 66 locations from 152 records, population trends can be estimated at only nine colonies. The largest apparent increase was at Stephens I. (Takapourewa), where reported numbers went from 1 million individuals in 1985 to 1.4 million pairs in 1994 (Harper 1985; Craig 2010; this study). A five- to sixfold increase in population size over nine years is highly improbable, so these differences presumably reflect differing methodologies. However, a more detailed examination of data reported by Walls (1978) and Mulder & Keall (2001) does indicate that the population on Stephens I. (Takapourewa) has grown over time. Both studies conducted surveys in the same area of the island (Keeper's Bush), and found that the density of burrows increased from 0.70/m<sup>2</sup> in 1975 to 0.95/m<sup>2</sup> in 1998 (note that the numbers reported in Table 3 are for the entire island, not just Keeper's Bush). This population increase is

presumably happening as a result of land being retired from farming and the habitat improvements associated with extensive planting of new forest areas (currently coordinated by the Department of Conservation). Stock trampling of burrows in the past would have reduced burrow densities over large parts of the island (Taylor, pers. obs.).

Fairy prion numbers appear to have remained stable at Wall I. in Westland, with between 1255 and 1400 pairs recorded in 2013 and 2015 (R. Lane, unpub. data). The tiny Mana I. colony has been slowly growing after it was established using translocated chicks (Miskelly & Gummer 2013). The Motunau I. population appears to have remained stable from 1962 to 1996 (Cox *et al.* 1967; Beach *et al.* 1997). In contrast, six other colonies appear to have decreased in size or been extirpated.

The most substantial decline occurred on Green I., northeast of Stewart I./Rakiura. An estimated 1.5 million pairs were nesting on the island in November 1941 (Wilson 1959), yet in December 2012 there was very little sign of any nesting prions (Miskelly 2013c). Weka are present on the island (Miskelly 2013c), but it is unclear if weka predation could have caused such a massive decline in prion numbers. On nearby Jacky Lee I. (Pukekoaka), where weka were not harvested by muttonbirders, the dense weka population all but extirpated fairy prions within a few decades (Wilson 1959). On neighbouring Whero I., the population declined from 1000 individuals in the 1940s to a total absence in 2010 after an expanding colony of Stewart Island shags destroyed the vegetation on the islet (Richdale 1965; Peat

Table 4 Population data for fulmar prions (*Pachyptila crassirostris*) nesting in New Zealand (CIS = Chatham Is; BIS = Bounty Is; SNI = Snares Is/Tini Heke; AKI = Auckland Is; dash = no data or comments; see 'Methods' for sampling protocol).

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Chatham Is (total for all islands)	CIS	1984	1000– 5000	Pairs	–	Unknown	Robertson & Bell 1984
Motuhara (Forty-Fours)	CIS	1974	–	Individuals	–	Observation	Imber 1994
		Dec 1983	–	Pairs	Many	Observation	Imber 1994
The Pyramid (Tarakoikoia)	CIS	Dec 1937	–	Pairs	Numerous carcasses, 2 nests	Observation	Fleming 1939
		Nov 1974	–	Pairs	–	Observation	Imber 1994
		Dec 1987	7	Pairs	Partial count	Observation	Tennyson <i>et al.</i> 1993
Bounty Is (total for all islands)	BIS	1888	–	Nests	See note a	Observation	A. Reischek <i>in</i> Robertson & van Tets 1982
		1907	–	Nests	See note a	Observation	Waite 1909
		Nov 1978	76,000	Pairs	'Impossible to census'	Observation	Robertson & van Tets 1982
		1997	29,354	Pairs	Medium reliability	Count	Booth & Schmechel <i>in</i> Taylor 2000a
		1997	0.21/m <sup>2</sup>	Nests	Medium reliability	Count	Booth <i>in</i> Taylor 2000a
Proclamation I.	BIS	Dec 1997	1235	Pairs	Good reliability	Count	Booth <i>in</i> Taylor 2000a
Toru Islet	SNI	Dec 1972	–	Pairs	–	Observation	Fleming & Baker 1973
		Nov 1976	–	Pairs	–	Observation	Sagar 1977b

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2011). In 1934, a small fairy prion colony was apparently present on Codfish I./Whenua Hou (Wilson 1959), but weka and Pacific rats (*Rattus exulans*) were also present and the species has not been reported since, despite extensive research and management work at the site.

In 1886, fairy prions were reported to be present on Hauturu/Little Barrier I. (Reischek 1887), but again they have not been reported since. Cats and Pacific rats were present, so the colony may have been extirpated by them. The population on Te Haupa (Saddle I.), off Great Barrier I. (Aotea I.) appears to have been extirpated (reportedly by ship rats, *Rattus rattus*), although there are no data on the initial size of the population (Falla 1934). This suggests that the geographically isolated population currently nesting on the Poor Knights Is is a remnant of a more widespread northern New Zealand population. A fairy prion colony supposedly on the Marotere Is

in Northland in the nineteenth century was probably misreported or a mis-identification of another petrel species (see Falla 1934; Skegg 1964).

Breeding fairy prions were reported on Kokope I. in the Chatham Is by Imber (1994), but the species was not found ashore in 1997 and there was considerable evidence of predation on other petrel species by weka (A. Tennyson, unpub. data).

## Fulmar prion

Fulmar prion colonies were reported on the Chatham Is, Bounty Is, Snares Is/Tini Heke and Auckland Is (Table 4), but from only eight individual islands within these groups, and with counts from just two sites of the total 31 records. The Bounty Is are home to the largest population of breeding birds (29,354 pairs in 1997; Booth & Schmechel *in* Taylor 2000a). This was a significant decline from the

Table 4 Population data for fulmar prions (*Pachyptila crassirostris*) nesting in New Zealand. *Continued from previous page*

Locality name	Area	Dates	Counts	Status	Occurrence comments	Sampling protocol	Reference
Toru Islet [ <i>contd</i> ]		Feb 1984	300–400	Pairs	Later doubted by author	Observation	Miskelly 1984; Miskelly <i>et al.</i> 2001
		Dec 1984	4	Pairs	2 eggs, 2 chicks	Observation	Miskelly <i>et al.</i> 2001
		Jan 1986	6	Pairs	2–6 eggs and chicks	Observation	Miskelly <i>et al.</i> 2001
		Sep–Oct 2010	–	Individuals	Low numbers, widely distributed	Observation	Carroll & Charteris 2010
		Nov 2013	100s	Pairs	–	Observation	A. Tennyson & C. Miskelly, unpub. data
Rima Islet	SNI	Nov 1976	–	Pairs	–	Observation	Sagar 1977b
		Feb 1984	100–200	Pairs	–	Observation	Miskelly 1984
		Sep 2010	–	Individuals	Low numbers, widely distributed	Observation	Carroll & Charteris 2010
Auckland Is (total for all islands)	AKI	1984	1000–5000	Pairs	–	Unknown	Robertson & Bell 1984
		1998	<1000	Pairs	–	Observation	Tennyson & Bartle 2005
Rose I.	AKI	1943	–	Pairs	Small numbers	Observation	Taylor 1971
		Nov 1972–Mar 1973	–	Individuals	–	Observation	Bell 1975
		1998	Few 100	Pairs	Estimate based on densities nearby	Observation	Tennyson & Bartle 2005
Ocean I.	AKI	Jun 1998	<100	Pairs	–	Observation	Tennyson & Bartle 2005
Ewing I.	AKI	Nov 1972–Mar 1973	–	Individuals	–	Observation	Bell 1975
		Nov 1989	–	Individuals	–	Observation	Moore & McClelland 1990
		Jun 1998	100–400	Pairs	–	Observation	Tennyson & Bartle 2005

(a) Listed as *Pachyptila turtur* [= fairy prion] in Robertson & van Tets (1982) and *Prion desolatus* [=Antarctic prion] in Waite (1909) but assumed to be fulmar prions as they are the only species to have been recorded nesting at this island group by other observers.

1978 population estimate of 76,000 pairs, although as the researchers described them as ‘impossible to census’ (Robertson & van Tets 1982) it is difficult to be certain that the apparent decline is real. Apart from the colony at Proclamation I., the distribution of nesting islands within the Bounty Is group has not yet been reported. The population nesting on the Auckland Is in 1984 was estimated to be 1000–5000 pairs, but less than 1000 pairs 14 years later (Robertson & Bell 1984; Tennyson & Bartle 2005). Because such a wide range was reported for the 1984

estimate (and no information was given about the sampling protocol used), this difference cannot be considered real, and clearly there is a need for new and accurate surveys of the prion populations for this island group.

## Discussion

We located 304 records of prions breeding on islands throughout New Zealand and its subantarctic and offshore islands, except the Kermadec Is. There are no population

Table 5 Population sizes and trends, and quality of information for four species of prion (*Pachyptila* spp.) nesting in the New Zealand region.

Species	Total population estimate (breeding pairs)	Estimated number of breeding sites (number of sites with population estimates or counts since 1995)	Trend information	Quality of information
Broad-billed prion	350,000	44 (6)	Unknown	Poor
Antarctic prion	350,000–1,000,000	8 (0)	Unknown	Poor
Fairy prion	1,500,000	64 (1)	Unknown	Poor
Fulmar prion	31,000–36,000	8 (4)	Unknown	Poor

estimates or counts for the majority of prion breeding sites and the data consist of five times more ‘observations’ than ‘counts’. Moreover, there were very few sites where repeat counts have been conducted. For fairy and broad-billed prions, only 17% and 14% of colonies, respectively, have had their breeding populations estimated within the last 20 years (Table 5). No Antarctic prion colony estimates exist other than broad overall population estimates from more than 25 years ago, with no reference to how these numbers were attained.

This lack of data severely limited our ability to draw any conclusions about population sizes or to assess population trends. The paucity of information emphasises the need to collect baseline data. Without reliable information on population size and trend, decisions about management of threats are problematic. It is concerning that the number of population records has decreased since the 1980s–1990s, but offsetting this is the fact there has been an increase in the accuracy and repeatability of surveys since the 1980s.

There was evidence of population declines at several of the few broad-billed prion colonies where data allowed us to assess population trends. Population declines were due to both predation and habitat destruction by other seabirds. For example, the population on Anchor I. was likely to have been extirpated by stoats (*Mustela erminea*; see Medway 2011). On Herekopare I. (Te Marama), cats extirpated the broad-billed prion population (Fitzgerald & Veitch 1985), and cats continue to cause significant damage to wildlife populations at other sites, such as Chatham I. (Imber 1994). The populations of both broad-billed and fairy prions on Whero Rock were extirpated due to habitat destruction caused by Stewart Island shags (Peat 2011). However, the

causes of decline are not always obvious. For instance, Rangatira (South East I.) is free of introduced predators (Aikman & Miskelly 2004), yet the density of broad-billed prion burrows between 1989 (0.34/m<sup>2</sup>) and 1999 (0.31/m<sup>2</sup>) has decreased by 8% and the rate of decline is even steeper if burrows of all sizes (1.34/m<sup>2</sup> in 1989, 1.19/m<sup>2</sup> in 2002) are included (11%). There are no obvious reasons for this change. Western Gilbert I. (Fiordland), Sealers Bay stacks and Trig I. (Stewart I./Rakiura region), Mangere I. and Rangatira (South East I.) (Chatham Is), and North East I. (Snares Is/Tini Heke) may be good candidates for establishing regular long-term survey plots. They are widely dispersed throughout the broad-billed prion’s New Zealand range. Furthermore, each site already has some level of baseline data and most are regularly visited by seabird researchers.

Due to the lack of data, it is impossible to estimate the current size of the New Zealand’s breeding population of Antarctic prions. Estimates as high as 750,000 (Harper *in* Marchant & Higgins 1990) and 1 million pairs (Robertson & Bell 1984) have been published, but neither of these accounts provides any information about how the figures were determined. Within the New Zealand region, Antarctic prions have been confirmed nesting only on the Auckland Is. In the nineteenth century, these islands saw the arrival of sealers and whalers. This led to the introduction of mammals such as European rabbits (*Oryctolagus cuniculus*), cats, house mice (*Mus musculus*) and pigs (*Sus scrofa*) (Taylor 1971), which today remain predators of ground-nesting birds or cause significant habitat destruction. Some islands in this group (including Adams I. and Disappointment I.) have remained free of introduced mammals. Enderby I. and Rose I. had diverse introduced mammal communities, but these

mammal species were eradicated in the early 1990s (Torr 2002). Auckland I. is the most heavily impacted by introduced mammals of all the islands in the group, and is the only island still supporting introduced mammals (pig, cat and house mouse) (Taylor 1968; Taylor 2000a). Monitoring Antarctic prions on Enderby I. and Adams I. is considered a high priority, particularly as these sites are regularly visited by researchers, while at Ewing I. the recent expansion of the *Olearia* forest (K.-J. Wilson, pers. obs.) indicates changes occurring at the site, which have potential to impact on the prion numbers.

Fairy prions are the most numerous and widespread species of prion nesting in New Zealand. The largest population, on Stephens I. (Takapourewa), numbers approximately 1.4 million pairs and appears to be growing (Craig 2010). While a few smaller colonies have declined or been extirpated, the vast majority of colonies lack data that would allow assessment of population trends. However, on Green I., near Stewart I./Rakiura, which was reported to have a population of more than a million pairs in the 1940s (Stead 1953; Wilson 1959), densities had declined to low levels by 2012 (Miskelly 2013c, unpub. data). This is likely to have been the largest single population in the region, and so it can be assumed that the number of fairy prions nesting around Stewart I./Rakiura is also likely to be small compared with populations of 70 years ago.

It is recommended that regular surveys of sites throughout the fairy prion's range are implemented. These are best done at Aorangi I. (Northland), Stephens I. (Takapourewa) (Marlborough Sounds), North Brother I. (Marlborough Sounds), Wall I. (West Coast), Motunau I. (Canterbury), Wharekakahu I. (Otago), Tunnel Beach (Otago), Mangere I. (Chatham Is), North East I. (Snares Is/Tini Heke) and Antipodes I. These islands provide geographic coverage throughout the range of colonies where quantitative data exist. Ideally, at least two populations in the Stewart I./Rakiura region should be monitored (e.g. Kundy I. and Herekopare I. (Te Marama)) as this region holds the most important fairy prion populations for the southern part of the species' New Zealand range. These are both traditional muttonbirding islands with restricted access; monitoring at these sites could potentially be undertaken by people with muttonbirding rights on the islands, but would require visits outside the March–May muttonbirding season.

Fulmar prion populations are poorly known. Brooke (2004) suggests a global population of 50,000–100,000 pairs, with all but the 1000–10,000 pairs estimated to be

nesting on Australia's Heard I. nesting in New Zealand (Tennyson & Bartle 2005). However, our analysis suggests that the global population estimate is likely to be too high: the Bounty Is, where most fulmar prions breed, are estimated to have a nesting population of approximately 30,000 pairs (Taylor 2000a). The only other colonies of significant size are in the Chatham Is and Auckland Is, both of which Robertson & Bell (1984) estimated at 1000–5000 pairs. Robertson & Bell (1984) gave no information about how these numbers were arrived at, and more recent work by Tennyson & Bartle (2005) suggests that the Auckland Is population is less than 1000 pairs. The remaining site where the species is known to breed is the Western Chain of the Snares Is/Tini Heke, which is thought to hold less than 1000 pairs, resulting in a maximum global population of less than 47,000 pairs. This lower population estimate cannot be attributed to a population decline and the data are not accurate enough to enable trends to be determined – quantitative information about population sizes has only been collated since the 1990s. Further, there are significant challenges in surveying fulmar prions, which – unlike the other New Zealand nesting prion species – nest mostly in crevices and caves on very remote, seldom-visited islands, making them extremely difficult to survey. However, efforts should be made to monitor at least one colony at each island group where the species occurs in numbers, e.g. The Pyramid (Tarakoikoia) (Chatham Is), Proclamation I. (Bounty Is), Toru Islet (Snares Is/Tini Heke) and Ewing I. (Auckland Is).

While historical and recent counts reveal several significant changes in numbers at prion colonies, the Late Pleistocene/Holocene fossil record reveals some longer-term changes for fairy and broad-billed prions. There is evidence of prehistoric fairy prion colonies on the mainland of New Zealand, with abundant fossils at some South I. sites (Holdaway *et al.* 2001). All except a handful of birds nesting on the coast of Otago (Loh 2000) have been extirpated, presumably by introduced mammalian predators. While there is evidence for broad-billed prions formerly breeding on mainland South I., there is a suggestion that the species may be a recent colonist at the Chatham Is (Tennyson & Millener 1994; Holdaway *et al.* 2001).

Our review of published and unpublished data revealed that very little is known about the population status of any species of prion nesting in New Zealand, which is particularly concerning in light of the loss of 250,000 birds during the 2011 wreck (see above). For each species reviewed, the



conclusions are similar – there is a lack of reliable data on which to assess the population size, status or trends. There is a need for population monitoring, even at large colonies, to ensure that further localised extinctions are not occurring. We strongly encourage baseline data to be collected at all major colonies, and the initiation of regular monitoring programmes for all species. This is particularly important for fulmar prions due to their small population size and sub-specific diversity (Tennyson & Bartle 2005). We recommend that surveys employ the methodologies promoted by the Population and Conservation Status Working Group of the Agreement on the Conservation of Albatrosses and Petrels (Wolfaardt & Phillips 2013). In brief, we consider that delineating permanent quadrats at representative habitat types throughout key colonies is necessary. Repeated estimates are needed every 5–10 years, counting all burrows within each quadrat and checking each burrow's occupancy. These data will allow for the calculation of habitat-specific density estimates, which can then be used to assess population trends and determine conservation statuses.

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