

Population status and trends of selected seabirds
in northern New Zealand



Motutara Rock

Photograph courtesy of Oliver Nicholson

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Introduction

The Department of Conservation is investigating the possible indirect effects of commercial fishing on surface- and near surface-feeding seabirds. Shoals of predatory fish species such as kingfish (*Seriola lalandii*), kahawai (*Arripis trutta*) and trevally (*Pseudocaranx georgianus*) often concentrate their prey—small fish and krill—close to the sea surface, producing ‘boil-ups’ that attract large numbers of surface-feeding seabirds. In New Zealand, these include several shearwater, petrel, and prion species, Australasian gannet (*Morus serrator*), red-billed gull (*Larus novaehollandiae*), white-fronted tern (*Sterna striata*), and grey noddy (*Procelsterna albivitta*¹). Most these species seem to depend on these boil-ups to obtain much of the high-quality food needed to rear their chicks successfully. There is some concern that the frequency, size and duration of these events may be declining due to changes in fish stocks, for whatever reason. If so, then this could reduce the birds’ overall foraging efficiency and compromise breeding success.

One part of the study is to gather past and present information on the location and size of breeding colonies of the main non-procellariform seabirds attracted to these boil ups: Australasian gannet, red-billed gull, white-fronted tern, grey noddy and spotted shag (*Stictocarbo punctatus*). It aims to:

- identify the breeding sites for these species in the northern half of the North Island, from Cape Egmont on the west to East Cape in the east;
- collate the available information on population numbers and any trends through time, both at individual sites and overall within the region of interest, over at least the past 75 years;
- summarise what is known about each species’ breeding biology—timing of breeding cycle, incubation shifts and length and chick rearing period—and what is known about the birds’ diet during chick rearing; and
- assemble any other relevant information on the diet and foraging ecology of these species.

This report presents and discusses the results of this review.

Population review

Data have been collated from several sources (Table 1). The primary source of historical information has been the *Classified Summarised Notes* (CSN) of the Ornithological Society of New Zealand (OSNZ, now Birds New Zealand), published more-or-less annually in the journal *Notornis* between 1939 and 1962. These annual summaries initially listed sightings mentioned by OSNZ members in their reports and were aimed mainly at recording bird species’ distributions. In 1963 the OSNZ started a centralised recording scheme in which unpublished information was assembled in species’ files that could be made available to members on request. These records are all on paper in the Society’s archives, housed in the Auckland Museum, and must be consulted on-site. It has not been possible to do this in the time available. A summary of selected material submitted to this scheme between 1963 and 1970 was published in a special issue of *Classified Summarised Notes* in 1972, and then annually thereafter until 2003 in a continuation of the CSN series. I assume that all important information on the focal species, specifically breeding records and localities, is included in these reports.

¹ Referred to as *P. cerulea albivitta* by Gill *et al.* (2010) but now widely accepted to be a separate species.

With the publication of *The Atlas of Bird Distribution in New Zealand* (Bull *et al.* 1985) and its successor, *Atlas of Bird Distribution in New Zealand, 1999-2004* (Robertson *et al.* 2007), the incentive to document species' distributions gradually diminished and publication of CSNs ended in 2003. A brief but unsuccessful attempt was made to revive the essence of the scheme in 2007 but that was eventually abandoned. Nevertheless, the information collated during that exercise was also reviewed.

Information on breeding, which had originally been incorporated in the CSNs, was increasingly redirected to the Society's nest record card scheme from the mid-1960s onwards. Nevertheless, general notes on breeding, particularly of colonial-nesting birds, continued to be published in the CSNs. These form the bulk of the information collated here. Detailed breeding records held on cards in the OSNZ nest record card scheme have not yet been reviewed because of difficulties accessing them. The cards are currently housed in boxes in the convenor's garage (Roger Sharp, *personal communication*). Very few cards have been submitted over the past decade or more, although there may be some useful historical information. Again, however, based on reports published in the CSNs, I assume that there is likely to be considerable overlap between these data sets, with the nest record cards providing more, but not necessarily more useful, detail for this review.

Table 1. Primary sources of information on breeding seabirds in New Zealand consulted to date

Data set	Source
Classified Summarised Notes	Published in <i>Notornis</i> 1943–2003 (listed separately in Appendix 1)
OSNZ News (issues 34-93)	Published by the Ornithological Society of New Zealand between 1985 and December 1999
New Zealand Bird Report 2007	Unpublished report kindly provided by D.A. Onley
OSNZ tern survey	Powlesland (1998)
Te Papa breeding seabird database	Kerry-Jane Wilson (pers. comm.)
NZ Coastal and Inland Sites IBA database	World Bird Database (Birdlife International) through Chris Gaskin/ Kathryn Hand
New Zealand eBird checklists	Cornell Lab of Ornithology and Birds New Zealand
Birds New Zealand red-billed gull survey database	Birds New Zealand
Atlas of Bird Distribution in New Zealand [1969-1976]	The Ornithological Society of New Zealand (original data on recorded microfiche)
Atlas of Bird Distribution in New Zealand [1999–2004]	The Ornithological Society of New Zealand
Species accounts	Papers published in various scientific journals, primarily <i>Notornis</i>
Individual records	Kindly provided by knowledgeable observers (see Acknowledgements)

Records were also obtained from eBird, an Internet-based recording system set up and hosted by the Lab of Ornithology at Cornell University (<http://ebird.org/>). The scope of this scheme is international, with over 34,400,000 checklists having been submitted to date. Birds New Zealand is a partner in this initiative and is promoting the use of eBird as a replacement for its *Classified Summarised Notes* for recording casual observations. The underlying assumption, like the CSNs, seems to be that capturing extremely large amounts of information will override any variations in reporting rates and inconsistencies in the data recorded, allowing analysts to uncover noteworthy ecological patterns. The few results published to date support this view, although much probably depends on the kind of analysis being done, with data on geographic distribution and seasonal occurrence being most useful (Chandler & King 2011; Scofield *et al.* 2012; Hurlbert & Liang 2012; Taylor *et al.* 2014; Clark 2017).

In addition to extracting information from journals and the above databases, photographs of colonies of some species were analysed as part of this study to provide more quantitative assessments of colony size. These included counts of gannets at five colonies on the Three Kings Islands, from photographs taken in December 2014; five colonies on White Island, photographed in November 2015; and the large but somewhat fragmented colony at Muriwai and adjacent Motutara Rock, photographed in October 2016. Counts were also made from photographs of several white-fronted tern and red-billed gull colonies.

All information has been put on to Excel spreadsheets and then into a geographic information systems (QGIS). Where the data allowed, an estimate of the annual rate of population change (r) in the number of breeding pairs of a species at a site was calculated assuming exponential growth or decline across time intervals (Gasaway *et al.* 1986). The percentage rate of population change per annum was calculated as $100(e^r - 1)$.

Species accounts

Australasian gannet *Morus serrator*

The Australasian gannet is primarily a coastal species, generally occurring close to the New Zealand and south Australian coasts and adjacent islands (Marchant & Higgins 1990). The birds feed over the continental shelf on fish and squid, caught by plunging from the air and pursuing their prey underwater in characteristic V-shaped or U-shaped dives. Although individuals occasionally go as deep as 15–20 m (Ismar 2010), most dives are no deeper than 6 m (mean depth of V-shaped dives, 2.9 ± 2.5 m; U-shaped dives, 4.0 ± 1.5 m; Machovsky-Capuska *et al.* 2011). Much of this foraging appears to be associated with dense schools of fish ('bait balls') driven to the sea surface by predatory fish and dolphins, which in turn create the surface boil ups that attract gannets and other surface-foraging seabirds.

Regurgitations of fish brought back to nest sites at eight northern New Zealand colonies show that, during the breeding season, gannets feed predominantly on pilchard (*Sardinops neopilchardus*: 59% of 344 regurgitations), with anchovy (*Engraulis australis*: 12%), saury (*Scomberesox saurus*: 9%), jack mackerel (*Trachurus novaezelandiae*: 8%), and squid (*Nototodarus* spp: 6%), making up the bulk of the rest (Robertson 1992). Kahawai, yellow eyed mullet (*Aldrichetta forsteri*), cubiceps (*Cubiceps caeruleus*), blue mackerel (*Scomber australasicus*), and garfish (*Hyporhamphus ihi*) are minor components (Fig. 1). Average feeding range of birds at a colony on Motukaramarama I. in the Hauraki Gulf, estimated from time away from the colony, was around 268 km (range: 86–450 km, Wingham 1985). This means that for areas such as the Hauraki Gulf, with five major colonies supporting around 10,000 pairs, there must be considerable overlap in areas used for foraging.

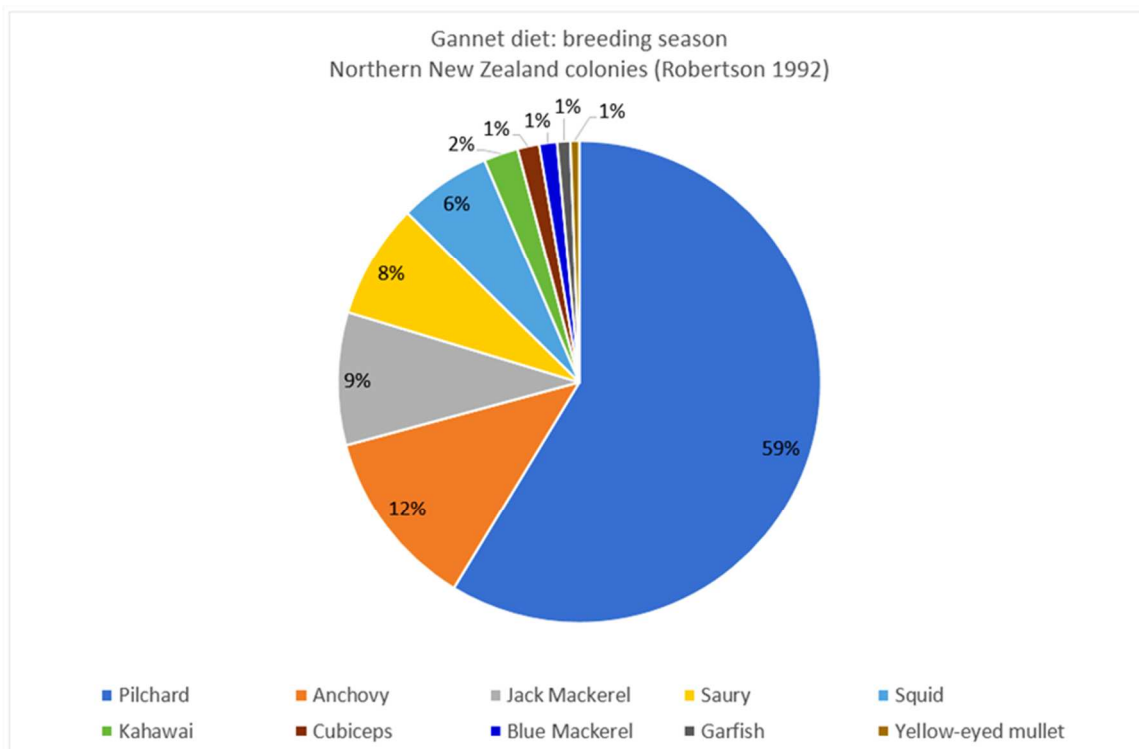


Fig. 1. Composition of the diet, by number, of Australasian gannets at eight northern New Zealand colonies, as determined from 344 regurgitations by birds returning to their colonies to feed young, calculated from data given in Robertson (1992).

Australasian gannets breed in dense colonies on mainland headlands and adjacent coastal stacks and islands in New Zealand, as well as on islands off the south-eastern Australian and Tasmanian coasts. Basic details of the species' breeding biology are given in Table 2. The breeding season extends from July, when colonies are re-occupied, to April when the last chicks fledge. Males arrive before females, re-occupying or establishing and defending a nest site. Both sexes incubate and rear the single egg and chick. Post-breeding juveniles and some adults leave New Zealand waters in autumn to winter in coastal Australian waters (Ismar *et al.* 2011).

Around 87% of the population breeds in New Zealand, with the rest breeding in Australia. The New Zealand population was estimated to be 46,004 breeding pairs in 1980-81 (Wodzicki *et al.* 1984), up from 21,033 pairs in 1946-47 and 37,774 pairs in 1960-61. These figures were derived largely from analyses of aerial photographs and are reasonably reliable. There have been no subsequent published national surveys, although aerial photographs were apparently taken of all major colonies in November 2000 (Stephenson 2005) but do not seem to have been analysed in detail. The present whereabouts of these photographs is not known. Stephenson (2006) estimated that the New Zealand population then was around 55,000 pairs.

Most New Zealand gannet colonies are situated on or around the North Island (Figs 2-4). The largest mainland colonies, about 5,000 breeding pairs, are at Cape Kidnappers and nearby Black Reef islets. The other substantial mainland breeding site is at Otakamiro Point, Muriwai, established in 1979 apparently as an over flow from nearby Motutara (Pinnacle) Rock and Oaia Island (Greene 1999). The largest offshore colonies have historically been on the Three Kings Islands (five colonies totalling 9855 breeding pairs in 1980-81), Karewa/Gannet Island (8003 pairs in 1980-81) and White Island (three colonies totalling 6793 pairs in 1980-81: Wodzicki *et al.* 1984). Another nine colonies on offshore stacks and islands reportedly supported a further 15,004 pairs in 1980-81. (The South Island population is tiny by comparison, consisting of just 104 pairs at three colonies in 1980-81: Wodzicki *et al.* 1984).

Table 2. Basic data on the breeding biology of the seabird species considered in this study: Australasian gannet (*Morus serrator*), spotted shag (*Stictocarbo punctatus*), red-billed gull (*Larus novaehollandiae*), white-fronted tern (*Sterna striata*), and grey noddy (*Procelsterna albivitta*). Data sources: Higgins & Davies (1996), Ismar (2013), Mills (2013a, b), Szabo (2013a, b), BirdLife International (2017).

	Australasian gannet	Spotted shag	Red-billed gull	White-fronted tern	Grey noddy
Conservation status	Not Threatened	Not Threatened	Threatened: Nationally Vulnerable	At Risk: Declining	At Risk: Naturally Uncommon
Pair bond	Monogamous	Monogamous	Monogamous	Monogamous	Monogamous
Social organisation when nesting	Colonial	Colonial	Colonial	Colonial	Colonial
Breeding season	Aug-Mar	Jul-Jun	Sep-Jan	Oct-Jan	Aug-Feb
egg laying	Aug-Jan	all-year round	Sep-Jan	Oct-Dec	Aug-Dec
chicks	Oct-Mar	all-year round	Sep-Jan	Nov-Jan	Sep-Feb
Nest type	raised mound or vegetation, mud and excreta	stick & seaweed platform	ground-level mound of vegetation	scrape	small mound of grass and seaweed
Nest locations	cliff tops and ledges	cliff ledges, small coastal caves	cliffs, cliff tops, rocks, sandspits, shingle bars	cliff tops, ledges, sand and shingle beaches, islands	cliff ledges, rocky crevasses
Clutch size (range)	1	3-4	2 (1-3)	1-2	1
Interval between eggs in a clutch (days)	NA	2	1	1	N/A
Broods per season (maximum)	1	3	1	1	1
Incubation behaviour	shared	shared	shared	shared	shared
Incubation period (range; days)	45 (43-53)	31	23-26	24	32
Nestling type	altricial	altricial	semi-precocial	semi-precocial	precocial
Age at fledging (days)	119	28	45	50	36
Age at independence (weeks)	17	ND	8	>8	ND
Age at first breeding	3-7	2-4	2-6	3	ND
Generation length (yr)	21.2	8.3	11.5	10.1	9.1
Longevity (yr)	>25	10	30	>18	ND
Food (adults)	fish: e.g. pilchards, Australian anchovies, barracouta, garfish, mackerel, horse mackerel	small fish and marine invertebrates (squid, plankton)	small fish, euphausiids, terrestrial invertebrates, fishing discards, garbage, scavenged food	small fish, fish larvae, meso-plankton	krill, tiny fish, squid and sea-striders
Food (chicks)	regurgitated partly-digested fish.	regurgitated partly-digested fish etc.	primarily euphausiids (krill: <i>Nyctiphanes australis</i>)	small fish (whole)	regurgitated fish
Foraging behaviour	plunge diving; attracted to and aggregate at boil ups	surface dives; usually forage in groups but dive independently	forage in groups; at sea attracted to boil ups; surface feeder	group foraging, often associated with shoaling fish balls (boil ups)	gregarious, foraging in flocks; hover and pick prey from the surface

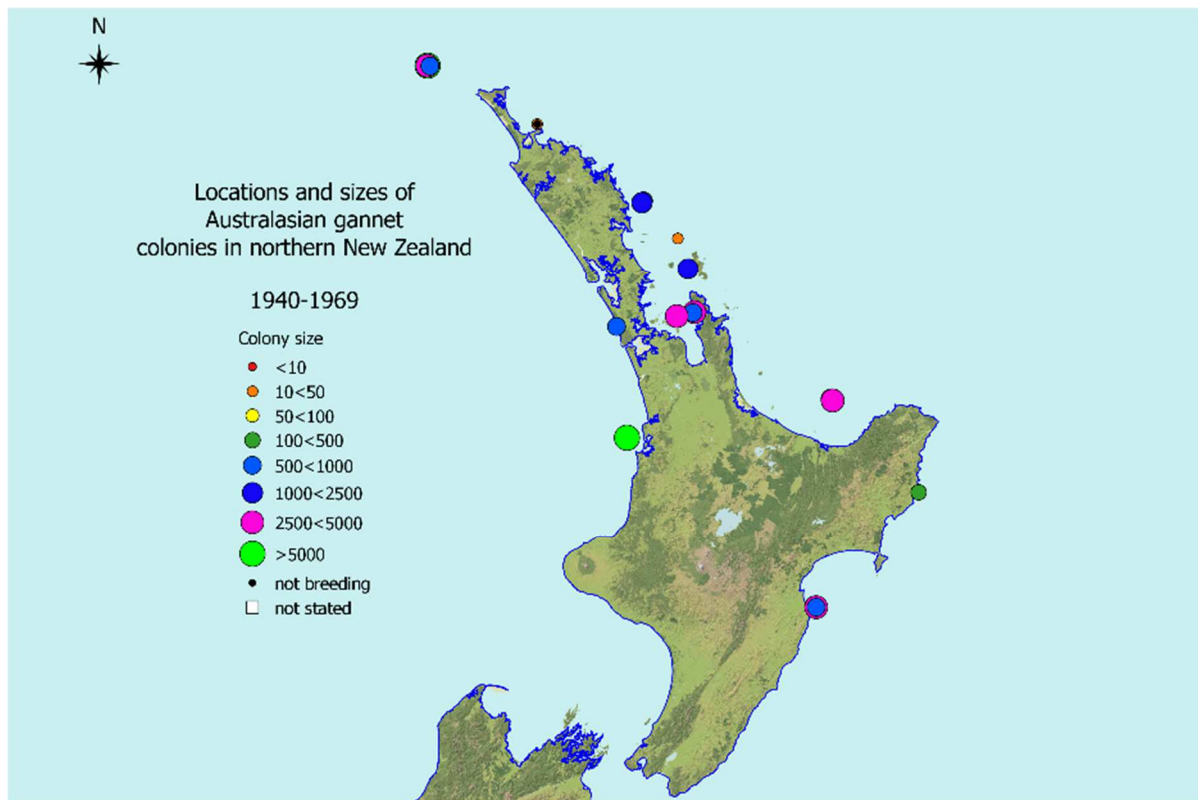


Fig. 2. Locations and comparative sizes of Australasian gannet colonies in northern New Zealand reported during the 30-year period 1940–1969. Few reliable reports exist prior to this.

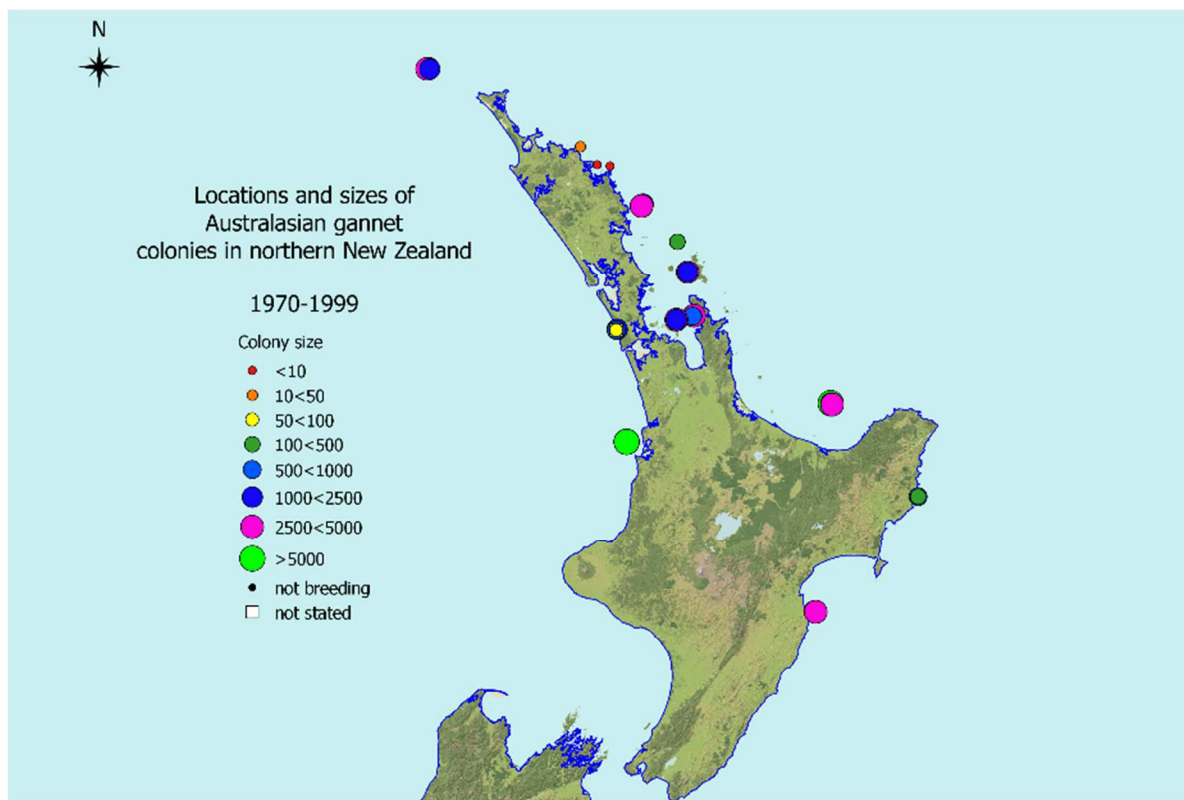


Fig. 3. Locations and comparative sizes of Australasian gannet colonies in northern New Zealand reported during the 30-year period 1970–1999. Note the appearance of additional small colonies in the north-east and west of the North Island, and the increase in size of some others.

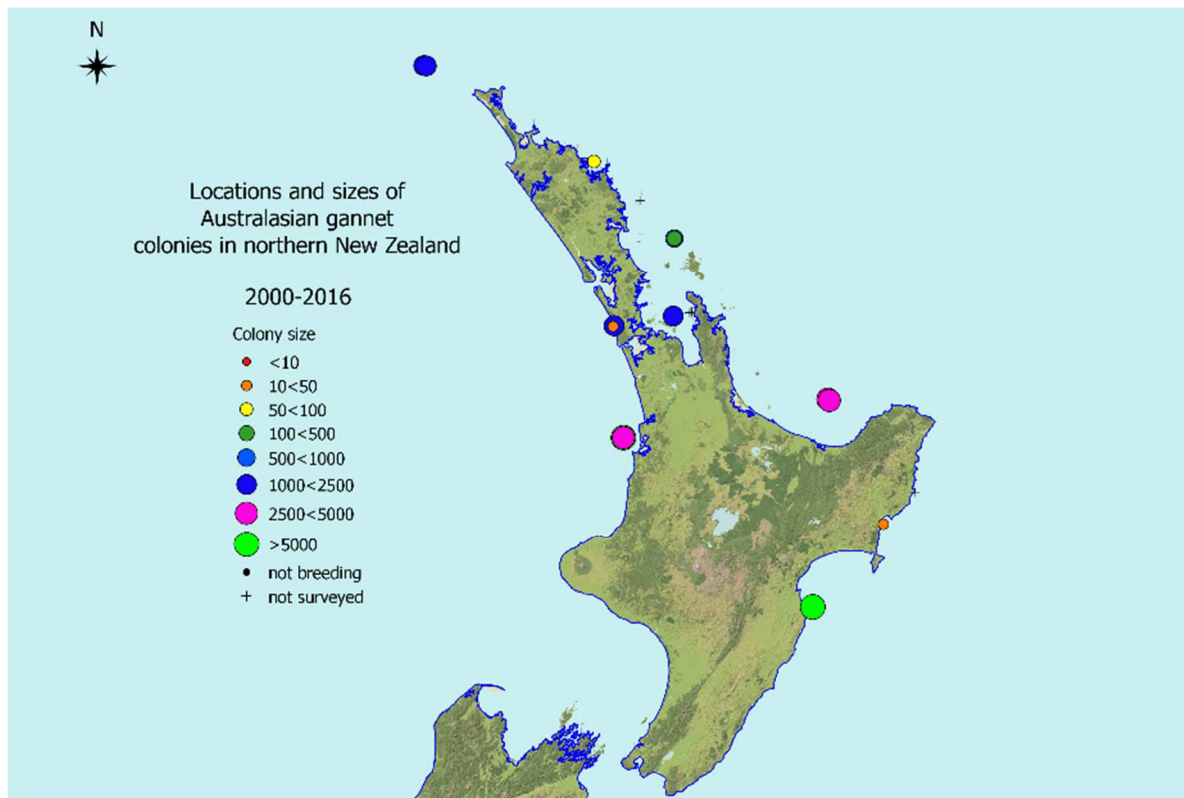


Fig. 4. Locations and comparative sizes of Australasian gannet colonies in northern New Zealand reported during the period 2000–2016. The apparent reduction in both numbers and size is largely artificial, reflecting the absence of recent surveys at some sites known otherwise to be occupied.

Australasian gannets breed preferentially on flat ground rather than on cliffs, usually on the tops of tall, steep-sided islands, stacks or mainland headlands. Except for the two mainland colonies on the North Island, the locations of these colonies make it difficult to count the numbers of nesting pairs from the land or a boat. Even estimates may be quite inaccurate. Moreover, because access to many of these islands is now controlled, the kinds of surveys that were done in the past by casual observers are no longer possible. The result is that there are few reliable recent estimates of the species' breeding population.

Exceptions to this general assessment are suites of aerial photographs of the Three Kings Is and White I. colonies taken during the recently-completed red-billed gull national survey, and photographs of the colony at Muriwai provided by a member of the public. Analyses of these images provide an opportunity to compare current numbers with those recorded during previous surveys of these sites using broadly comparable techniques.

Three Kings Islands

A series of 49 uncatalogued digital photographs showing different parts of the five Three Kings Is colonies were analysed first by grouping the photographs by their time stamps and working out their spatial relationships to each other. Areas of overlap were then identified and marked out. Finally, all incubating or apparently brooding birds visible in separate gridded sections of each photograph were marked and counted. Pairs of birds were counted as one. Areas of overlap were only counted once, on whichever photographs the birds were most visible. Because the photographs were taken from a moving plane, it was generally not possible to create panoramas. By comparing the close-up photographs with more distant views of the islands, it was possible to identify the colony from which the various sets of photographs had been taken. The results are given in Table 3, along with previously published figures for the same colonies.

Table 3. Changes in the numbers of Australasian gannets at colonies on the Three Kings Islands over 70 years, as determined from analyses of aerial photographs. Data for 1946-47 from Fleming and Wodzicki (1952); for 1968-69 and 1980-81 from Wodzicki *et al.* (1984); and 2014-15 from an analysis of photographs taken by L. Feasey (camera: Nikon D4; image size: 4928 x 3280 pixels [16MP]).

Island	Season			
	1946-47	1968-69	1980-81	2014-15
Arbutus Rock	1000	2175	2652	1651
Tutanekai Rock	300	406	402	686
Archway Rock	490	618	1530	774
Hinemoa Rock	1520	3232	4136	2245
South-west Island	824	804	1135	1046
Three Kings Is total	4134	7235	9855	6402
<i>Annual rate of change (%) across periods</i>		+2.57	+4.90	-1.26

Although the population on the Three Kings Is grew substantially from 1946-47 to 1980-81, the recent photographs, taken at the expected peak of the breeding season in December 2014, suggest either a 35% decrease sometime over the past 34 years, for whatever reason, or that 2014-15 was a particularly poor year for breeding, so that many birds failed to nest. If the population has declined, this would not necessarily have started in 1980-81 but could have begun later, in which case the calculated annual rate of change, -1.3%, could be greater.

White Island

High-quality digital photographs (5184 x 3456 pixels [18 MP]) of the three main gannet colonies and their satellites on White Island were taken in November 2015 by J. Fitter, who undertook a helicopter survey of the island, searching for red-billed gull colonies. All the gannet colonies are in the open and birds are all highly visible. Each photograph encompassed one colony or its satellite. The photographs were analysed visually by gridding the scene and working through each grid square marking and counting every individual seen to be incubating eggs or brooding small chicks. Any pairs of birds were counted as one, and birds standing around the fringes of the colony were ignored.

A total of 5306 incubating birds was counted (Table 4). This is a 20% decline from the 6662 pairs recorded from aerial photographs taken in 1980 (Wodzicki *et al.* 1984). Large unoccupied areas were visible on the fringes of the Otaketake colony, the biggest on White I., and to a lesser extent at Te Matawiwi (West Point). Both these colonies had experienced the largest declines. Once again, it is not clear if this fall in numbers is part of a long-term trend or simply a feature of the year in question. Scrutiny of the vacant areas suggests that they have been unused for some time, with patches of re-growing vegetation appearing on them. Nevertheless, such speculation illustrates the difficulty of interpreting change when only sporadic counts are available, especially at long intervals. Assigning cause to such changes is next to impossible, other than as conjecture.

Table 4. Comparison of the number of nesting Australasian gannets recorded on White I. over time. All counts except those made in 1976 (in italics) are based on analyses of aerial photographs. The counts in 2015 were done as part of this study and are unpublished. Others are taken from Wodzicki *et al.* (1984).

Location	Latitude	Longitude	Nests 2015	Comparison with previous counts				
				1946	1969	1976	1980	2015
Te Matawiwi (West Point)	-37.517278	177.168319	621	1254	1419		1419	621
Ohauroa (West)	-37.529162	177.179663	620	1408	1615	1040	1257	1225
Ohauroa (East)	-37.529173	177.181256	605					
Otaketake (West)	-37.529688	177.186184	265	2565	3679	3000	3986	3460
Otaketake (East)	-37.529316	177.187359	3195					
Total			5306	5227	6713	4040	6662	5306
Annual rate of change (%) across periods					+1.09	-0.07		-0.65

Muriwai

The Muriwai gannet colony is the most accessible colony for members of the public to see and appreciate the birds. It is widely photographed and the whole colony can be relatively easily surveyed from selected vantage points. Photographs of the Otakamiro Point cliff-top colony and neighbouring Motutara (Pillar Rock), taken in October 2016 by O. Nicholson, were analysed as described above. A total of 1385 incubating birds was counted on the cliff tops and adjacent sand slip at Otakamiro Point, with a further 187 nesting birds seen on Motutara (front cover photograph). These are shown in Figs 5 and 6 in relation to previous counts made at these sites.

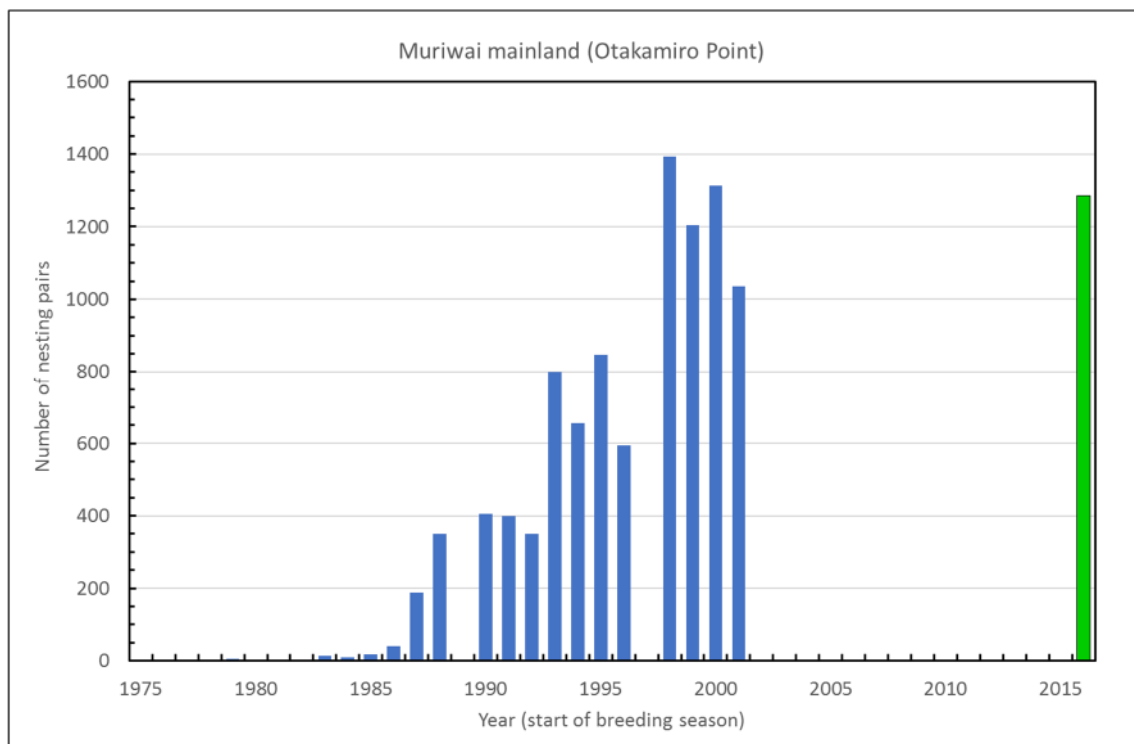


Fig. 5. Counts of Australasian gannets nesting at Otakamiro Point, Muriwai. Other than the most recent count (green), the others come largely from data given in Greene (1999, 2003) and OSNZ records.

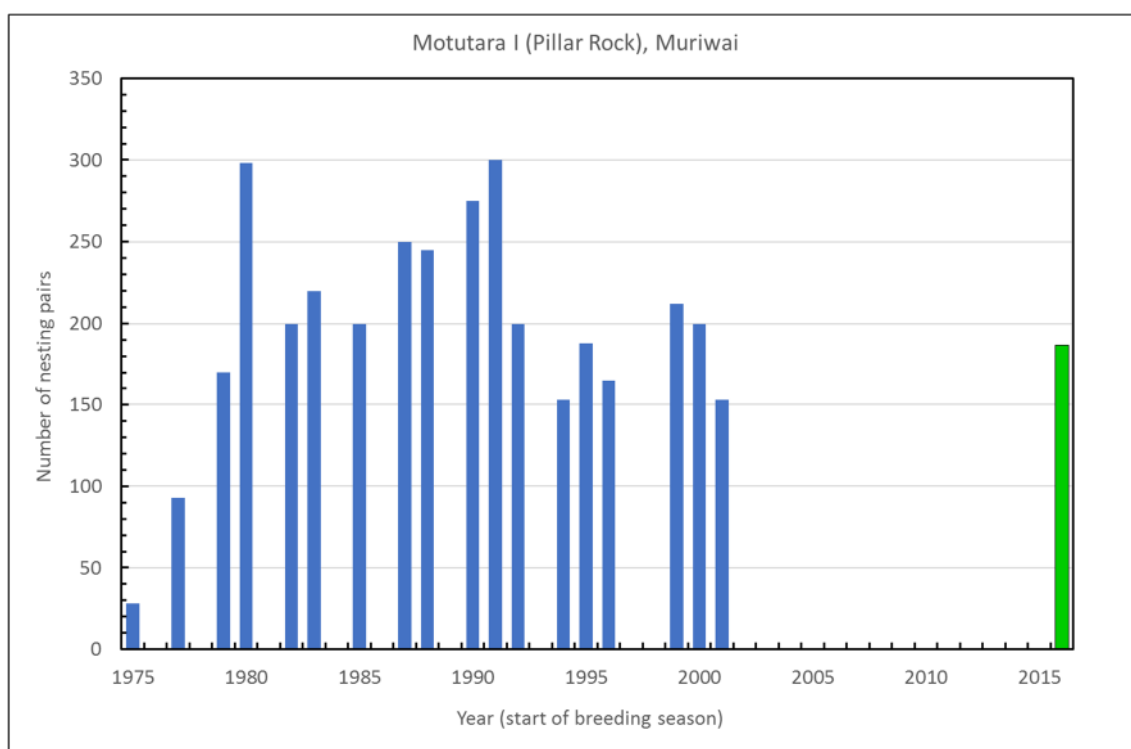


Fig. 5. Counts of Australasian gannets nesting on Motutara, Muriwai. Other than the most recent count (green), the others come largely from data given in Greene (2003) and OSNZ records.

Put in the context of earlier counts, and notwithstanding the long interval between the last published counts (2001) and the latest (2016), these data suggest little change at these two sites. The Motutara colony apparently started as an overflow of birds from those nesting on Oaia I., 1.5 km offshore. That colony, which once supported 892 pairs in 1960-61 and 761 pairs in 1980-81, had only 28-36 pairs present in 2016-17. Potential disturbance by fur seals loafing at the top of the 50-m high island has been suggest to be one reason for the decline of this colony (Oliver Nicholson, *personal communication*).

In contrast to the apparent declines noted above, some new colonies have arisen during the same period, at Tikitiki Rock (Nine Pin) in Northland, and on Young Nick’s Head, south of Gisborne (outside the area of this review). The colony at Tikitiki Rock apparently became established in 2007 (E.F. Kitching in New Zealand Bird Report 2007 [unpublished]) and now supports over 70 pairs. But the size of the rock makes it unlikely that this colony will expand much further. The small colony at Young Nick’s Head was established somewhat artificially, by using model decoys and a sound system to attract passing birds (Sawyer & Fogle 2013).

Overall, it is not possible to say if the Australasian gannet population in New Zealand as a whole is stable, decreasing or increasing. It has long been assumed to have been increasing (Wodzicki *et al.* 1984; Stephenson 2005, 2007; Ismar 2010; Machovsky-Capuska 2012), which may be true for some colonies but perhaps not all. There is some evidence for each trend, depending on what colony is being considered, if recent low counts relative to those recorded historically are not simply one-year aberrations. Given the spectacle provided by colonies of nesting gannets at Muriwai and Cape Kidnappers, and the resulting positive public sentiment this seems to produce, there is merit in getting a better understanding of what is happening to the gannet population in New Zealand, so that any real long-term declines can be addressed.

Spotted shag *Stictocarbo punctatus*

The spotted shag is a distinctive endemic marine cormorant occurring all around the South Island and Rakiura, but which has a more restricted range in the North I. As a breeding species in the North I., it occurs in three general areas: the Hauraki Gulf, south from about 36° 45'S; at a few sites on the west coast, between Bethells Beach (Te Henga) and Ngututura Point, south of the Waikato River mouth; and on Kapiti Island and islands in Wellington Harbour (Robertson et al, 2007). During the non-breeding season, birds from these colonies range more widely. Historically, it is reputed to have bred in the Bay of Islands and at Cape Kidnappers (Turbott 1956), but there have been no records from these sites for the past 80 years. In the first three decades of the last century, spotted shag were persecuted by shooting, and this may account for the disappearance of some colonies (Talbot 1956). Increased recreational boating and fishing pressure have also been suggested as possible causes of population decline in the Hauraki Gulf (Cunningham & Moors 1985).

Spotted shags breed and roost colonially on ledges and in caves on coastal cliffs and stacks. Colonies of up to 700 birds have been recorded, although not all have been breeding at the time. Such aggregations comprise birds at all stages of their breeding cycle as well as non-breeding individuals. Basic information on the species' breeding biology is given in Table 2. Within the Hauraki Gulf, the birds seem to have three breeding peaks, with egg laying occurring in late August-early September, December, and March, whereas west-coast birds nest mostly in spring (Turbott 1956). It is not clear if the multiple peaks of breeding in the Hauraki Gulf represent the same birds nesting for a second or third time in a year, or if nesting is highly asynchronous across the population. Outside the breeding season, spotted shags form large feeding and roosting flocks of up to 2000 birds (Szabo 2013a).

The general inaccessibility of colony sites, let alone the disturbance that access would cause, together with the extended breeding season and presence of many non-breeding birds, makes it difficult to determine colony size accurately. This is reflected in the often-inconclusive information reported in the CSNs. Where a number was given, together with the notes "breeding" or "nesting", it was usually unclear as to whether the number referred to the number of nesting birds (i.e. one bird = one active nest = one pair), or if this was the total number of birds seen, with the actual number nesting being unstated and somewhat less than this.

Spotted shag feed up to 16 km offshore on small fish and marine invertebrates in waters >10 m deep (Stonehouse 1967; Marchant & Higgins 1990). In one South Island study, the principal prey species in the diet of spotted shag for much of the year were ahuru (*Auchenoceros punctatus*) and red cod (*Pseudophycis bachus*), ahuru making up 75% by number and 70% by mass in the species' diet, with red cod contributing a further 20% by mass (Lalas 1983). Sprat (*Sprattus* spp.) and Graham's gudgeon (*Grahamichthys radiata*) were the main prey taken in November–December. Crustaceans were relatively unimportant, except during late spring and early summer, when the pelagic phase of lobster krill (*Munida gregaria*) made up about a quarter of the mass of food fed to nestlings (Lalas 1983). All four species of fish also occur in North Island waters (Francis 1996; McMillan *et al.* 2011), and can be expected to be part of the species' diet there.

The available information on the locations and sizes of spotted shag colonies in northern New Zealand for the periods 1940–1969, 1970–1999, and 2000–2016 are shown in Figs 6–8. Overall, the birds have used the same locations or closely adjacent ones throughout, suggesting considerable fidelity to a breeding site, although this may be due more to a limited number of suitable nesting places than for any other obvious reason.

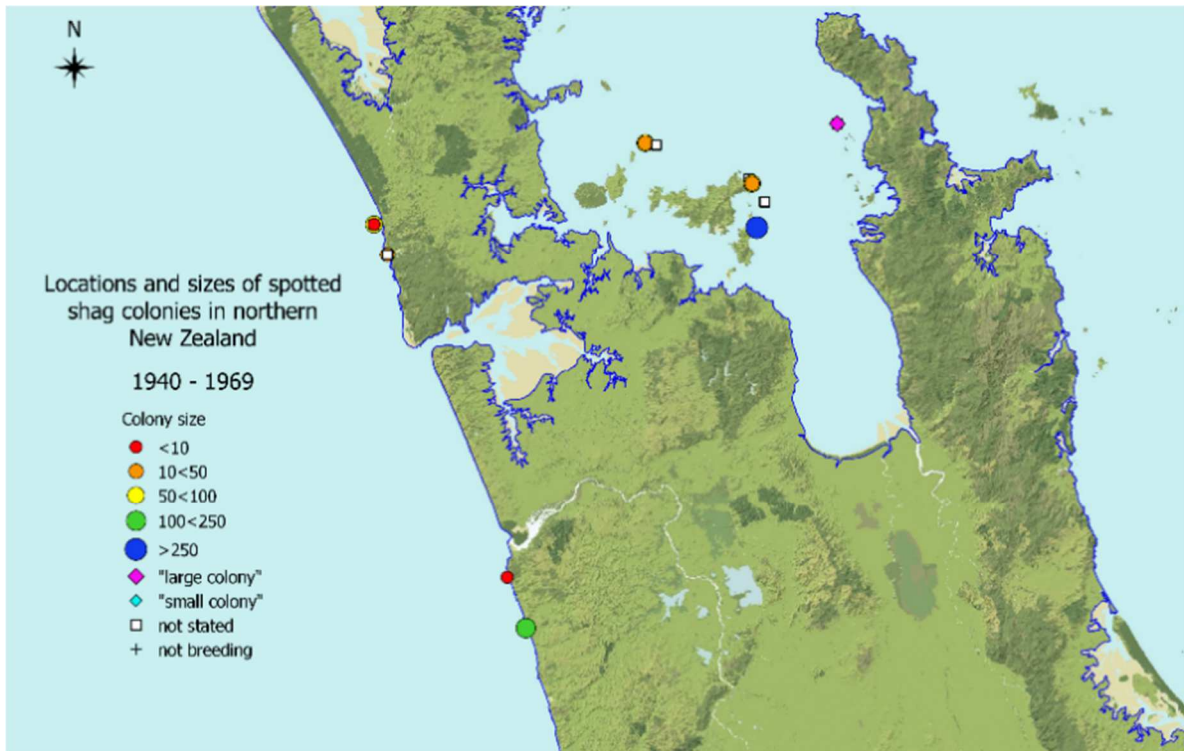


Fig. 6. Locations and comparative sizes of spotted shag colonies in northern New Zealand, 1940–1969.

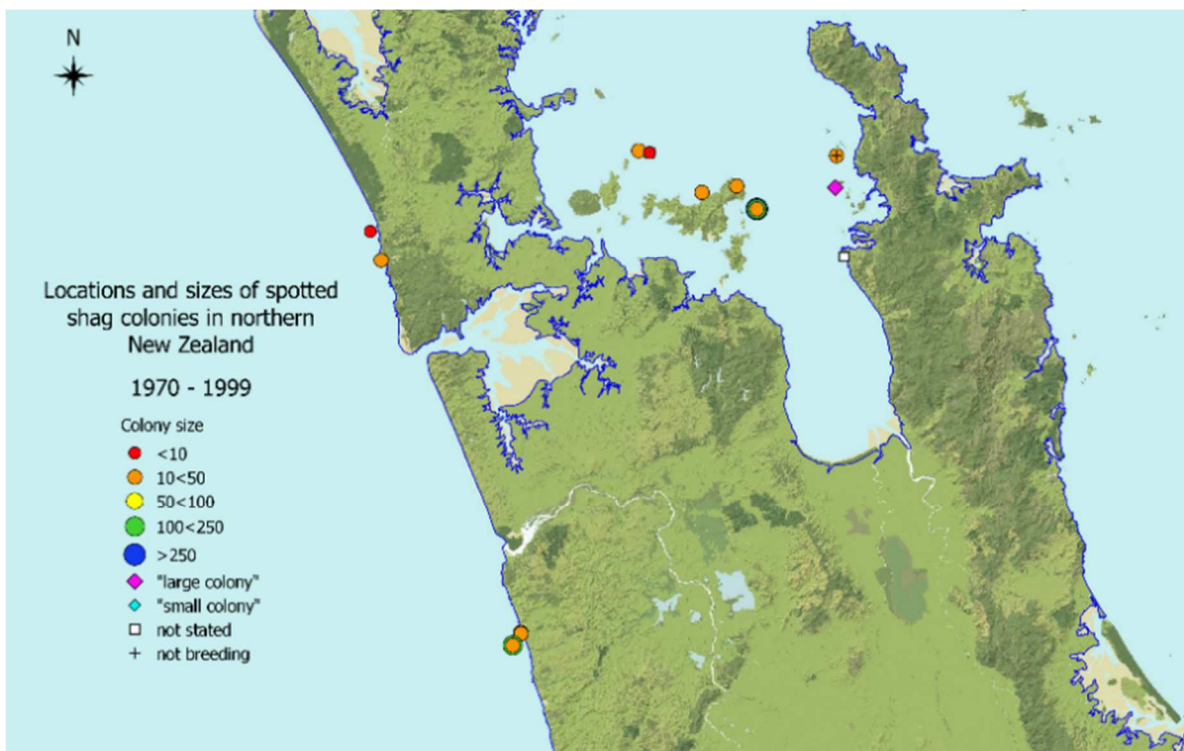


Fig. 7. Locations and comparative sizes of spotted shag colonies in northern New Zealand, 1970–1999.

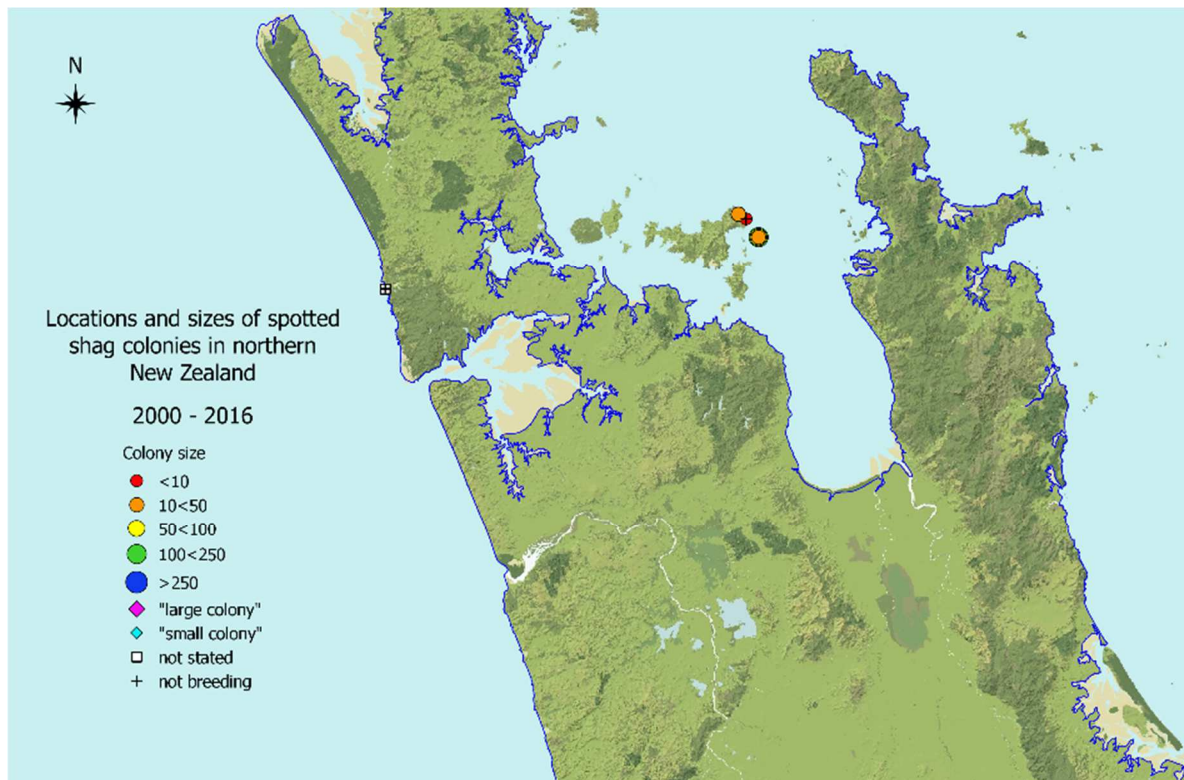


Fig. 8. Locations and comparative sizes of spotted shag colonies in northern New Zealand, 200–2016. The apparent marked reduction in the number of colonies may be due more to a shortage of observers than necessarily to a population decline.

Numbers at most of these North Island colonies have remained relatively small throughout. This may be a legacy of the persecution that the birds faced up until 1931, when the species was afforded some protection (Turbott 1956; Millener 1970; Cunningham & Moors 1985). Although the population recovered somewhat in the following decades, there is some indication of subsequent decline. For example, the colony on Tarahiki I, which in October 1988 had about 700 birds nesting (CSN: Taylor 1990), had only 150-200 nests in September 1990 (CSN: Taylor & Parrish 1992) and 145 nests in October 2000 (CSN: Parrish 2002). In March 2002, this had declined further to c. 80 nests (CSN: Parrish 2003; but note the different time of year), and in November 2015, just 28 old nests (but 315 birds present: Southey & Kitching unpublished).

Declines are also apparent at the Anita Bay colony on Waiheke I., albeit at a smaller scale. In December 1946 and January 1947, the colony had 50-55 occupied nests (CSN: Stidolph 1948), but by November 2002 there were only 8 nests (CSN: Parrish 2006). In November 2015, no nests were seen although there were 53 birds present (Southey & Kitching unpublished). On the west coast, 175 pairs were recorded breeding at Ngatutura (Girdwood) Point in October 1951 (Millener 1970), which had declined to just 10 nests in November 1986 (CSN: Keeley 1988) and 36+ nesting birds in December 1997 (CSN: Tennyson & Lock 2000). On the west coast, the colony at Bethells Beach (Te Henga) has been vacant since 1999 (Graeme Taylor, *personal communication*).

Interpreting changes at other Hauraki Gulf and west-coast colonies is complicated by lack of clarity on just what the reported numbers refer to, and by the paucity of recent counts. Statements such as “breeding” or “nesting”, made without any accompanying information on the size of these colonies, even if only qualitative, further constrains understanding. No doubt this situation reflects the difficulty of visiting the colony sites, something that is certainly further complicated by increased restriction on access to many sites.

Red-billed gull *Larus novaehollandiae*

The red-billed gull is widely considered to be the commonest gull in New Zealand. Its population in 1965 was estimated to be around 40,000 pairs (Gurr & Kinsky 1965). Nevertheless, it is currently classed as Nationally Vulnerable, largely because of reported declines at the three historically largest colonies: Three Kings and Mokohinau Is in the North Island, and the Kaikoura Peninsula in the South Island. Together, these colonies were once thought to support upwards of 20,000 pairs, around half the country's population (for details, see Gurr & Kinsky 1956). Although a regional increase since the early 1990s has been reported in Otago (Perriman & Lallas 2012), when the Kaikoura population was declining, it was unclear if this reflected a country-wide shift in the species' population centres, perhaps with some population dispersion, or was simply a contrary regional trend. In 2014–16, Birds New Zealand and the Department of Conservation undertook a survey of red-billed gull colonies around New Zealand. The resulting estimate of 27,831 breeding pairs nationwide supports the view of an overall decline in the red-billed gull population (Frost & Taylor 2016). Data from that review forms the bulk of the information presented here on the species' current distribution in the northern North Island.

Basic information on the species' breeding biology is given in Table 2. Red-billed gulls mostly breed colonially, although some colonies may only support a few pairs. The frequency distribution of recorded colony sizes (Table 5) is not independent of period. Examining the observed and expected values, assuming independence of colony sizes across periods of years, suggests that prior to 1940 there may have been more colonies over 500 nesting pairs than would be expected by chance, but the result is not significant (G-test for independence: $G = 22.554$, d.f. = 15, $p = 0.094$). Even if it was, it could simply represent a tendency by observers in the past to report the presence of large colonies, rather than anything else.

Table 5. Frequency distribution of recorded red-billed gull colony sizes across different time periods. The corresponding expected values are given in italics. Note that some of the expected values were less than 5, especially for the two largest colony-size classes and the pre-1940 data. This limits any significance in the result.

Period	Colony sizes					
	<10	10<50	50<100	100<500	500<1000	>1000
pre-1940	3	2	3	2	3	2
	<i>2.2</i>	<i>5.2</i>	<i>3.1</i>	<i>3.6</i>	<i>0.6</i>	<i>0.4</i>
1940-69	14	39	28	32	4	4
	<i>18.0</i>	<i>41.5</i>	<i>25.0</i>	<i>28.9</i>	<i>4.4</i>	<i>3.2</i>
1970-99	14	31	26	19	2	1
	<i>13.8</i>	<i>31.9</i>	<i>19.2</i>	<i>22.2</i>	<i>3.4</i>	<i>2.5</i>
2000-16	30	69	28	45	6	4
	<i>27.0</i>	<i>62.4</i>	<i>37.6</i>	<i>43.4</i>	<i>6.6</i>	<i>4.9</i>

In the North Island, red-billed gulls in 2014–16 nested mainly on offshore islands (23% of all reported colonies, excluding the inland ones), coastal cliffs and rocks (19%), and nearshore stacks and islands (19% and 15% respectively). Together these supported just over 63% of the nesting population. Offshore stacks, harbours and breakwaters, and various low-lying coastal and estuarine sites made up the balance. The locations and comparative sizes of these colonies, through time, are illustrated in Figs 9-12. Within the northern half of the North Island, they are noticeably concentrated along the east coast from Cape Reinga southwards, perhaps reflecting the presence many suitable nearshore and offshore islands and stacks where the birds can breed.

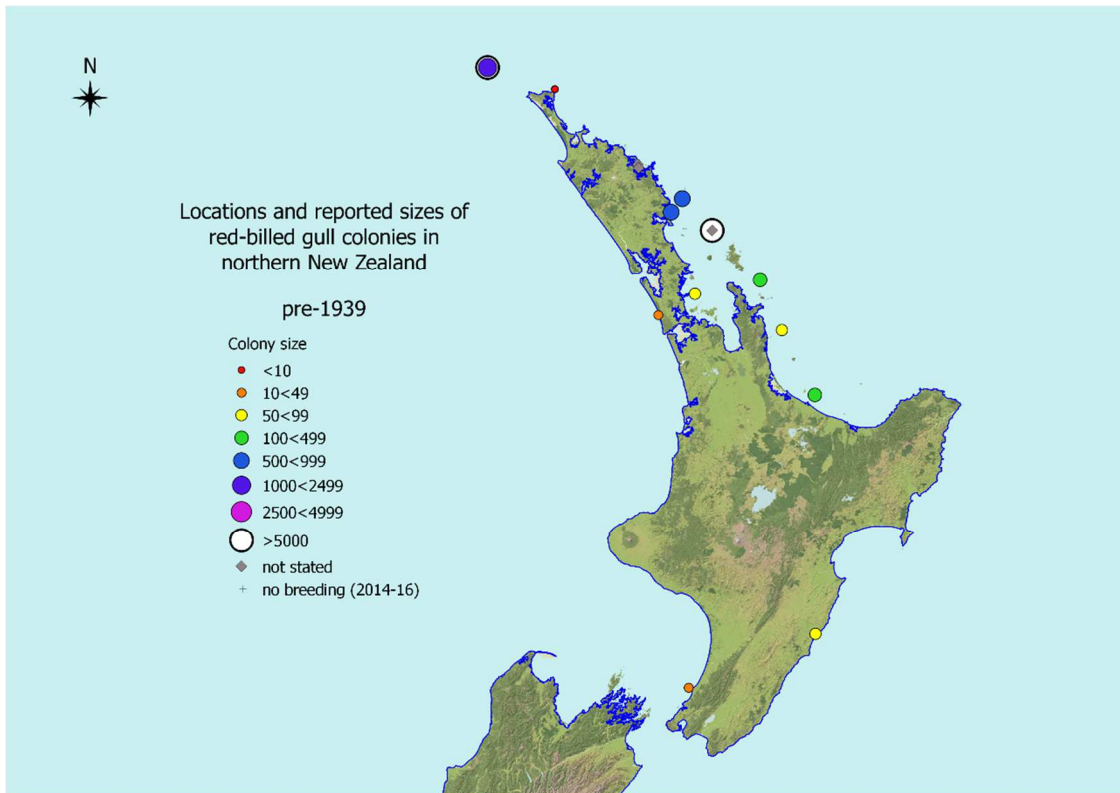


Fig. 9. Locations and comparative sizes of red-billed gull colonies in the North Island prior to 1931. The scarcity of sites probably represents the paucity of reports rather than limited distribution of the species.

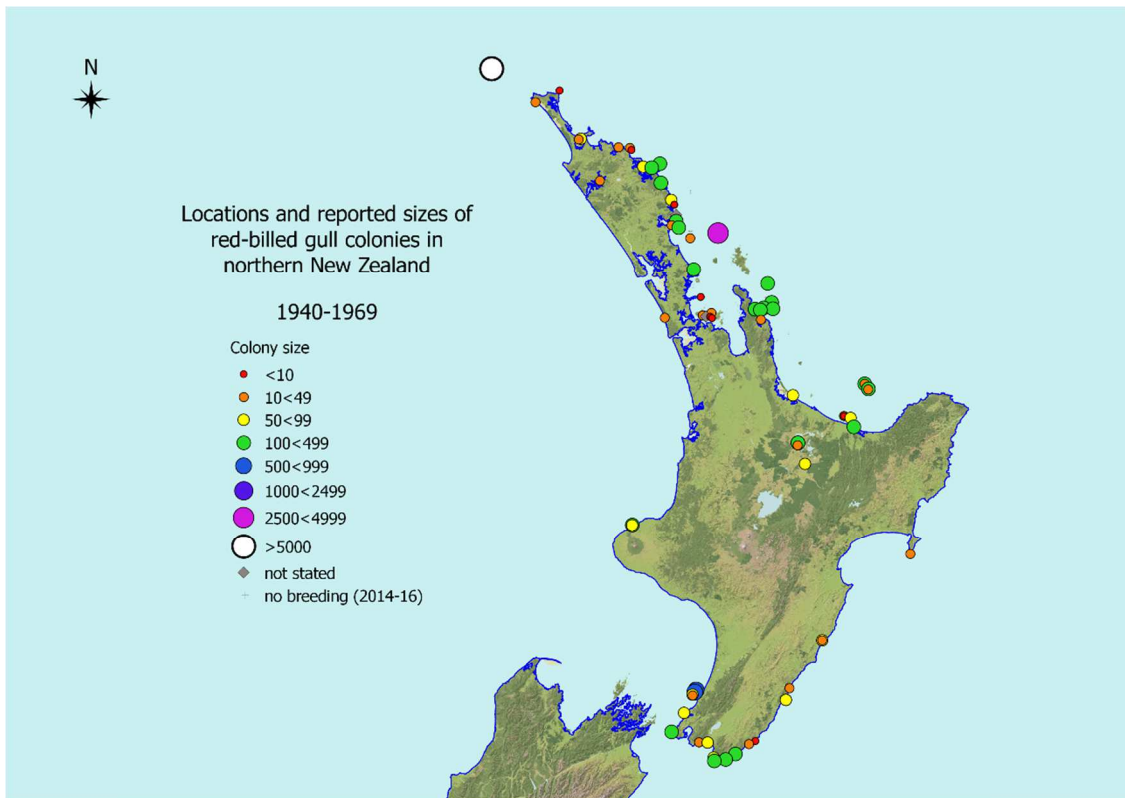


Fig. 10. Locations and comparative sizes of red-billed gull colonies in the North Island reported during the period 1940–1969. Note the presence of large offshore in the Three Kings and Mokohinau islands.

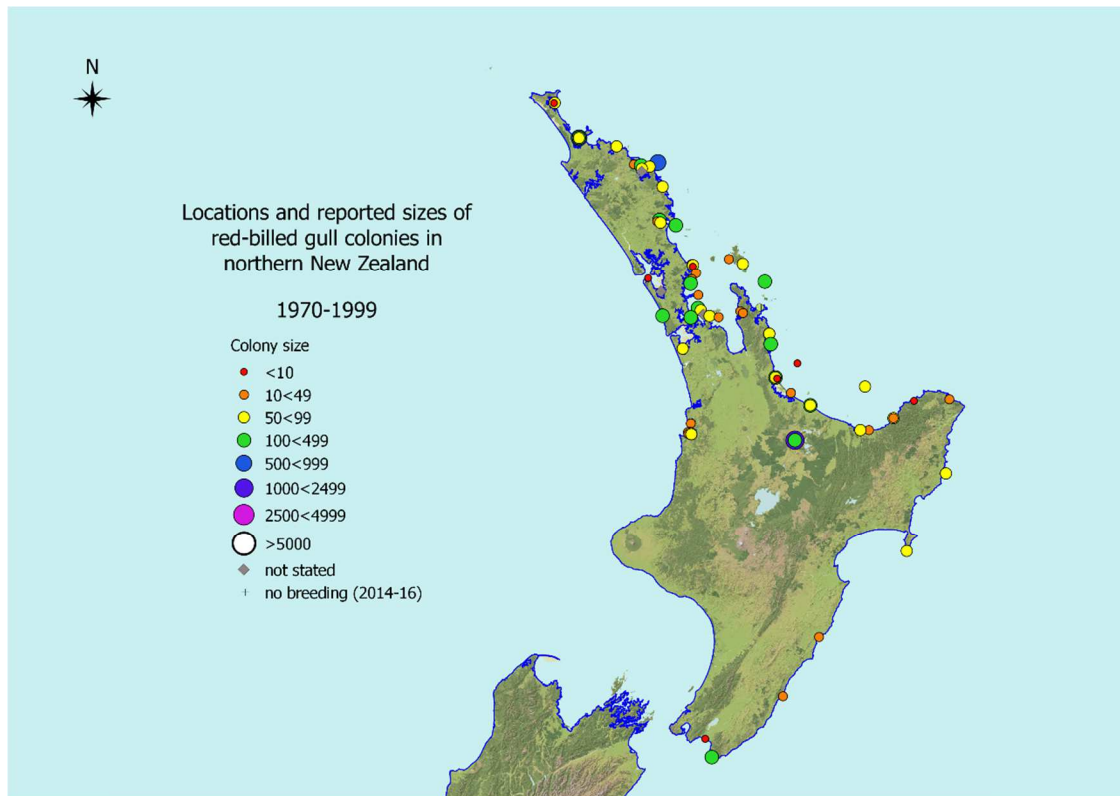


Fig 11. Locations and comparative sizes of red-billed gull colonies in the North Island as reported during 1970–1999. Note the general absence of any particularly large colonies (although the Three Kings Is were not surveyed during this period).

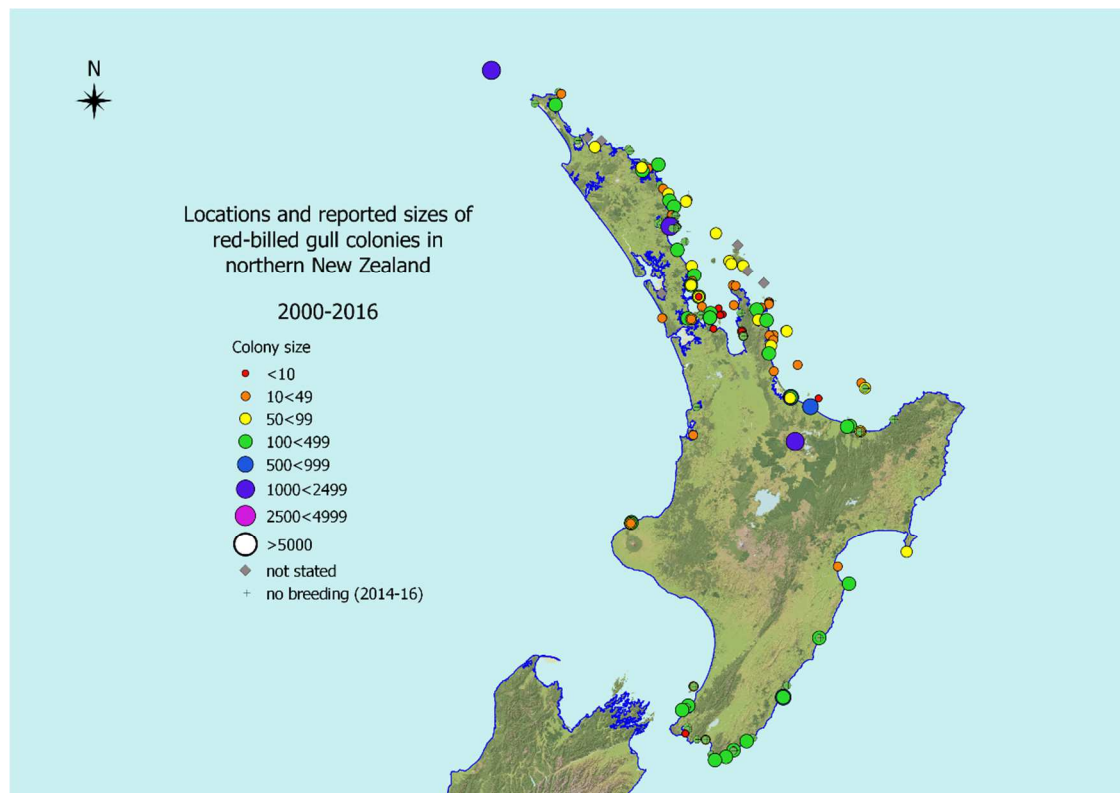


Fig 12. Locations and comparative sizes of red-billed gull colonies in the North Island as reported during 1970–1999. Note the presence of some large colonies on the Three Kings Is; at Marsden Point; and at Rotorua (which lies outside the region of concern here).

In Fig. 9, the apparent scarcity of reported sites probably reflects a low reporting rate, with only the larger or more unusual colonies being noted, rather than showing a limited distribution of red-billed gulls prior to 1940. Even subsequently, reports of red-billed gull colonies have tended to be sporadic, reported on for one or a couple of years only, and then not at all. This complicates interpreting population change, both overall and regionally in the northern North Island. Table 6 summarise the apparent change at a selection of sites (those for which there was reasonably comparable data over time).

Table 6. Summary of broad scale changes in colony size at selected red-billed gull breeding sites across the northern North I. Numbers fluctuated at most sites within the limits shown here.

Locality	pre-1939	1940-59	1960-79	1980-99	2000-16
<i>Increasing</i>					
Tapeka Point	not stated		50<100		100<500
Woolley's Bay, Tutukaka			50<100		100<500
Opakau I				10<50	50<100
Kaitoke Bay islet				10<50	50<100
Goat I.				10<50	50<100
Tiritiri Matangi	50<100	<10		10<50	100<500
Koi I.		<10		50<100	100<500 ¹
Hikunui Rock			10<50	100<500	50<100
Maketu Spit				50<500 ²	500<1000
<i>No change</i>					
Black Rocks, Moturoa			50<100	100<500	50<100
Kautunu		100<500	100<500	not breeding	100<500
Nga Motu, New Plymouth		100<500	100<500		100<500
Cuvier I.	100<500	100<500	100<500		not stated
<i>Declining</i>					
Three Kings Is	"thousands"	>5000			1000<2500
Mokohinau Is	>5000	<5000 ³			50<100
Sugarloaf Rock	500<1000				50<100
Tara Rocks, Motutara				100<500	50<100
West Stack, Green I.		100<500			10<50
Volkner Rocks		100<500	10<50		10<50
Okahu Bay wavebreak				100<500	10<50
Paku, Tairua				50<100	10<50
Kawhia Harbour ⁴				50<100	10<50
Otama Beach			100<500		10<50
Taiharuru Rock	500<1000				not breeding ⁵
Knight I., Whangarei				100<500	not breeding ⁵
White I.		50<100	100<500	50<100	not breeding ⁵
Awarua Rock			100<500		not breeding ⁵
Motuihe [Rock I.]		10<50			not breeding ⁵
Motukaroro [Reotahi]			10<50		not breeding ⁵

¹ But <10 pairs breeding in some years

² Colony expanded through the 1980s, with some fluctuations

³ 1950-59: 50<100 pairs

⁴ Various sites

⁵ 2015-16

Although numbers seem to have increased at some smaller colonies, marked declines have been noted at others, especially at once-large colonies (e.g. Three Kings Is, Mokohinau Is, Sugarloaf Rock, Taiharuru Rock). At only a few colonies have numbers remained reasonably stable, or have fluctuated around some long-term average. But caution should be exercised with these data, however, because the assessment of colony size within any given period is often based on a single observation, which may or may not be accurate. Nonetheless, the scale of change at some sites is large enough that they probably override any inaccuracies in assessment, leaving little doubt that the red-billed gull populations at these sites have changed substantially.

The classic case study of population change in this species comes from the ongoing long-term study started by J.A. Mills at Kaikoura in 1964 (Mills 1989). The number of nesting pairs have been counted in 43 of the 52 years of the study, and show a pattern of initial population increase, with some marked fluctuations, from 4380 pairs in 1964 to over 7500 pairs in 1991, followed by prolonged decline to as few as 2635 pairs in 2011 (Mills *et al.* in prep.). Such well-documented changes illustrate the value of long-term surveys using consistent methods, and provide some substance to the more qualitative changes noted in northern New Zealand.

The causes of change in the Kaikoura population are complex: predation; variations in food availability; weather-related losses; ectoparasite loads; and internal demographic factors, principally higher survival of females than males, leading to a skewed sex ratio. Among these factors, food availability stands out, with the start of the decline coinciding with an increase in fishing for kahawai offshore (Mills *et al.* in prep.). Although red-billed gulls have a catholic diet outside the breeding season (Table 2), during it they depend greatly on the coastal planktonic euphausiid *Nyctiphanes australis* (krill), both to reach peak physiological condition prior to breeding, and for provisioning their chicks (Mills 1969; Mills *et al.* 2008). Adult body mass, number of pairs breeding, clutch size, egg volume, and number of chicks fledged per breeding pair are all positively related to euphausiid availability (Mills *et al.* 2008).

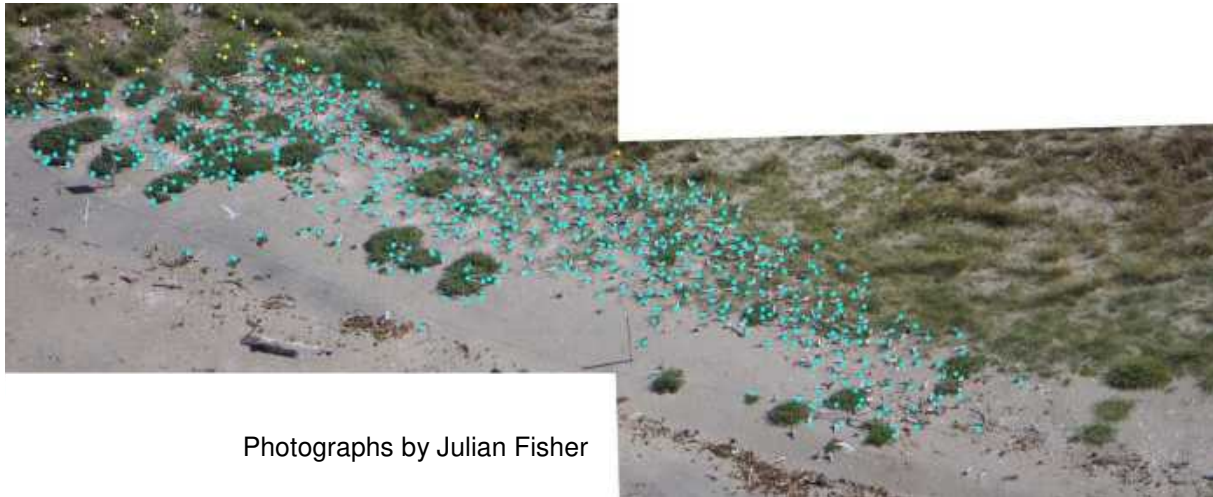
The abundance of *Nyctiphanes* is linked to variations in the Southern Oscillation Index, being highest in years when the index is positive (La Niña conditions: Mills *et al.* 2008). Fluctuations in this index over decadal timescales could drive variations in red-billed gull numbers if reproductive deficits incurred during periods of low krill availability are not offset by higher reproductive output during good years. An analysis of data from Kaikoura by Cury *et al.* (2011) suggests that this may be the case, showing a near-asymptotic relationship between normalised annual breeding success and normalised euphausiid availability, with breeding success declining rapidly below long-term mean euphausiid abundance but rising only slowly above that point (Fig. 3 in Cury *et al.* 2011). But there is considerable unexplained variation in this model, suggesting the influence of other factors.

Mills *et al.* (in prep.) identify predation at the Kaikoura colony as a major factor, a viewpoint somewhat supported by increases at colonies in Otago where predators are controlled (Perriman & Lallas 2012) and at a similarly well-protected colony inside the oil refinery at Marsden Point. But some of the large declines noted in northern New Zealand (Table 6) have occurred on islands and offshore rocks where introduced predators are absent or have been eradicated, so predation cannot be the sole reason for the declines.

Long-term declines could reflect either progressive deterioration in ocean conditions (e.g. changing sea temperatures gradually negatively affecting ocean productivity) or some other unidirectional systemic change, such as changes in fish populations potentially leading to reductions in the incidence, extent or duration of boil ups over which red-billed gulls and other seabirds feed. If this is happening, then it could reduce the ability of the gulls to obtain sufficient amounts of high quality food needed for optimal egg laying, incubation and chick rearing. That in turn could lower breeding success, perhaps below the necessary replacement rate. It is a critical question requiring research into the relevant ecological and demographic processes.

White-fronted tern *Sterna striata*

The white-fronted tern is the most abundant and widespread tern in New Zealand, found around both main islands. It also occurs along the south-east Australian coast. Some New Zealand birds, both adults and juveniles, disperse to Australia but the numbers and age classes of these birds are not well known (Higgins & Davies 1996). The birds are highly gregarious, often occurring in large flocks of hundreds to thousands of birds. They breed colonially on rocky offshore islands and stacks, exposed reefs, ledges on cliffs or on steep slopes, and on sand spits, shingle banks and shell-sand islands in estuaries and along the coast (Fig. 13). They also nest on groynes, harbour piles and dredgings (Higgins & Davies 1996; Szabo 2013).



Photographs by Julian Fisher

Fig. 13. A count of 518 nesting white-fronted terns on Maketu Spit, made from aerial photographs taken in November 2015. The positions of nesting birds are marked in blue (nearby nesting red-billed gulls are marked yellow). This count is considerably higher than the 300 nesting birds estimated in a ground-count made a few days before this photograph was taken (John Lewis, eBird checklist S25843709). Only 1–3 pairs were reported nesting on this spit in the 1980s and 1990s, indicating a marked increase in colony size since then, although it is unclear if this is due to relocation of birds from nearby sites or is a genuine increase in the local population, perhaps because of better predator control.

Although some birds will nest for the first time when 3-years old, most defer breeding until they are 6 years or older. Breeding is highly synchronized, although young birds, 3–5 years old, breed 10.7 days later than older birds in the 12–14-year age group. In contrast, 10–11-year old birds bred 2.9 days earlier than these older birds (Mills & Shaw 1980). Single-egg clutches predominate early in the season, with the proportion of 2–3-egg clutches increasing as the season progresses. Clutch size is unrelated to age. Birds will relay after nest failure. Consequently, towards the end of the breeding season, a colony will include chicks of widely differing ages, and even some birds still incubating late-laid eggs. Other features of the species' breeding biology are summarised in Table 2.

White-fronted terns feed predominantly on small fish (clupeids, engraulids, galaxiids and retropinnids), but will also take fish larvae and small planktonic crustaceans from the upper 0.5 m of the sea surface. There have been no detailed studies of diet. Most prey are obtained by plunge-diving (Higgins & Davies 1996). Foraging flocks apparently follow shoals of kahawai and kingfish as they hunt for and feed on shoals of smaller fish and crustaceans (Higgins & Davies 1996). These predatory fish encircle and trap their prey close to the sea surface, thereby creating the boil ups over which terns and other seabirds feed. The association of white-fronted terns with these fish has led to the birds being called kahawai birds.

The distribution and reported sizes of white-fronted tern colonies at different times are shown in Figs 14–16. Colonies are widely distributed around the northern North Island coast, with some concentration in natural harbours, large estuaries, and regions with many offshore islands and stacks. There is a marked disparity in the number of records through time, however, with just 58 reports of breeding colonies during 1940–1969, and 87 reports since 2000, contrasting with 334 in the period 1970–1999. That reflects a concerted effort in the mid-1990s to survey the white-fronted tern breeding population nationally (Powlesland 1998).

Several sites were monitored annually for 4–5 years during the 1990s. None of them show any trend over time. The same applies to one site in the Bay of Islands, which has been monitored for eight successive years (2009–2016). What these counts do reveal, however, is the considerable year-to-year variation in the number of pairs nesting, with coefficients of variation in the range 40–138%. Most other records are isolated observations or repeated counts over just 2–3 years, or separate reports from one site but long intervals. In part this may be due to the species' own instability in site occupancy, with birds often shifting colony locations from year to year, but mostly it reflects the ad hoc nature of such records.

An analysis of the frequency distribution of the number of sites in different colony-size categories does suggest a trend, however (Fig. 17). Colony size is not independent of time, with many more smaller colonies (10<50 pairs) and fewer large colonies (100<500 pairs) than expected in the period 2000–16, and the reverse for the period 1940–69 (G-test for independence, excluding 'no breeding' and 'unstated' categories, and applied to original numbers, not percentages: $G = 18.45$, $d.f. = 6$, $p = 0.0052$). This suggests that colony size has declined over time, possibly reflecting an overall decline in white-fronted tern numbers since the end of the 1960s.

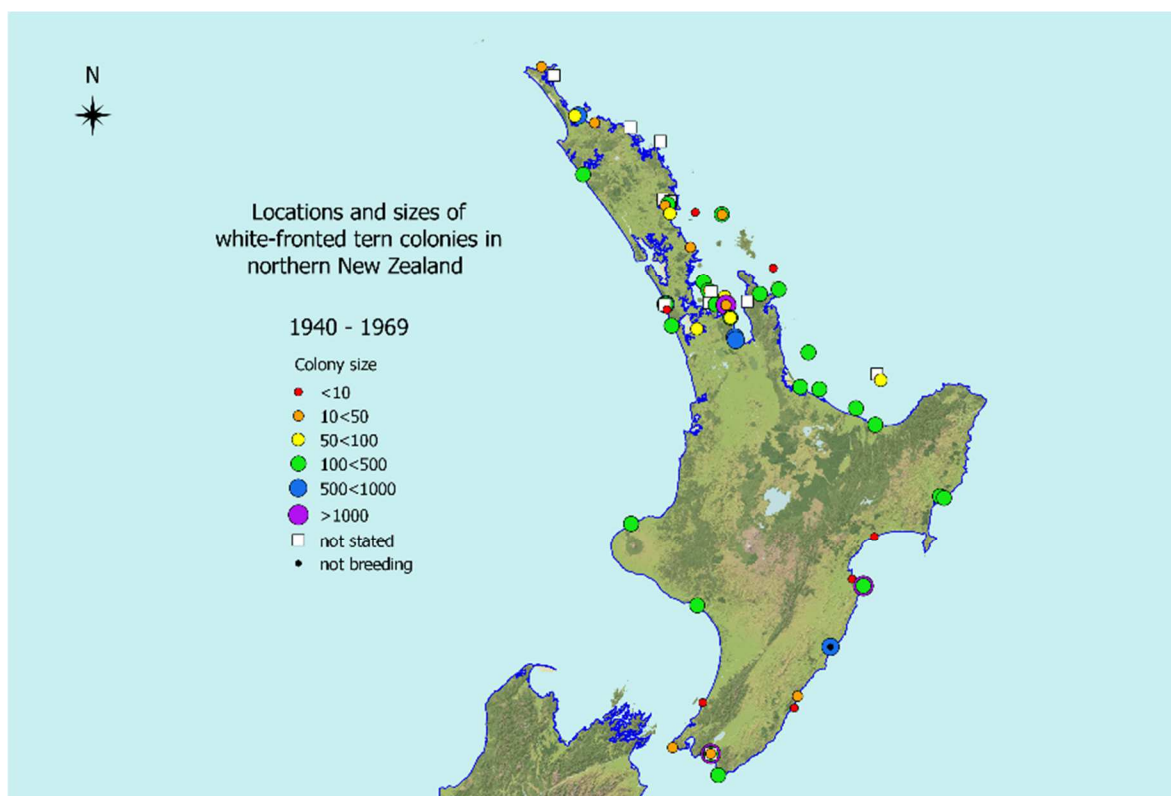


Fig. 14. Locations and comparative sizes of white-fronted tern colonies in northern New Zealand, 1940–1969. The apparent paucity of records may reflect the limited number and geographic distribution of observers rather than any scarcity of birds.

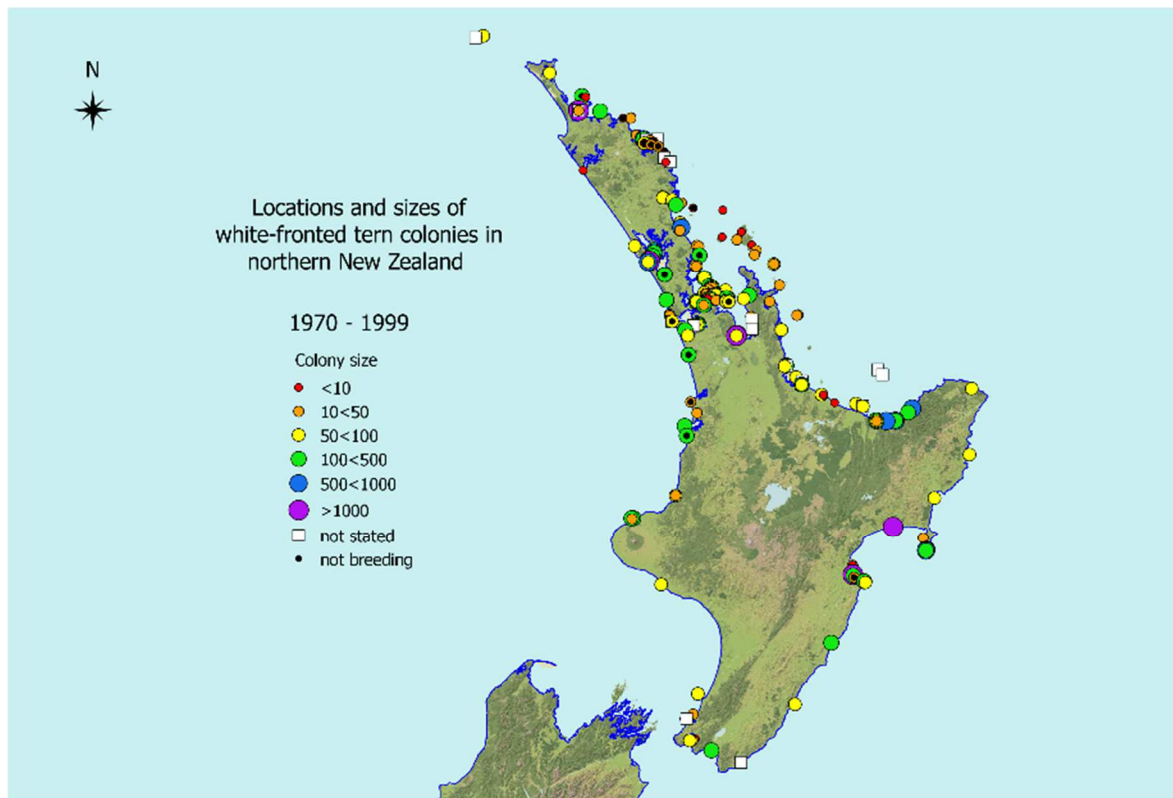


Fig. 15. Locations and comparative sizes of white-fronted tern colonies in northern New Zealand, 1970-1999. Note the concentration of colonies around the west coast and Bay of Plenty natural harbours and estuaries, and in the Hauraki Gulf.

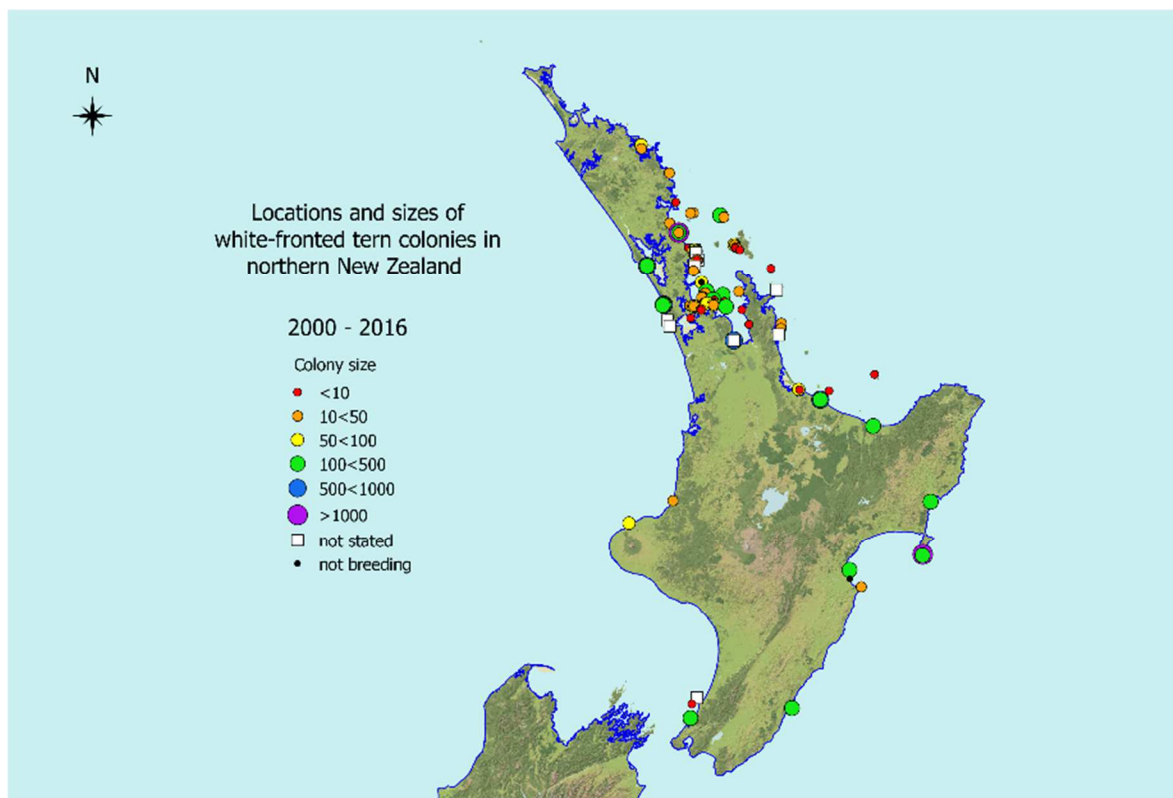


Fig. 16. Locations and comparative sizes of white-fronted tern colonies in northern New Zealand, 2000–2016. The scarcity of records in the Far North and from some of the west coast harbours is notable, but this may reflect more a shortage of observers and observations than anything else.

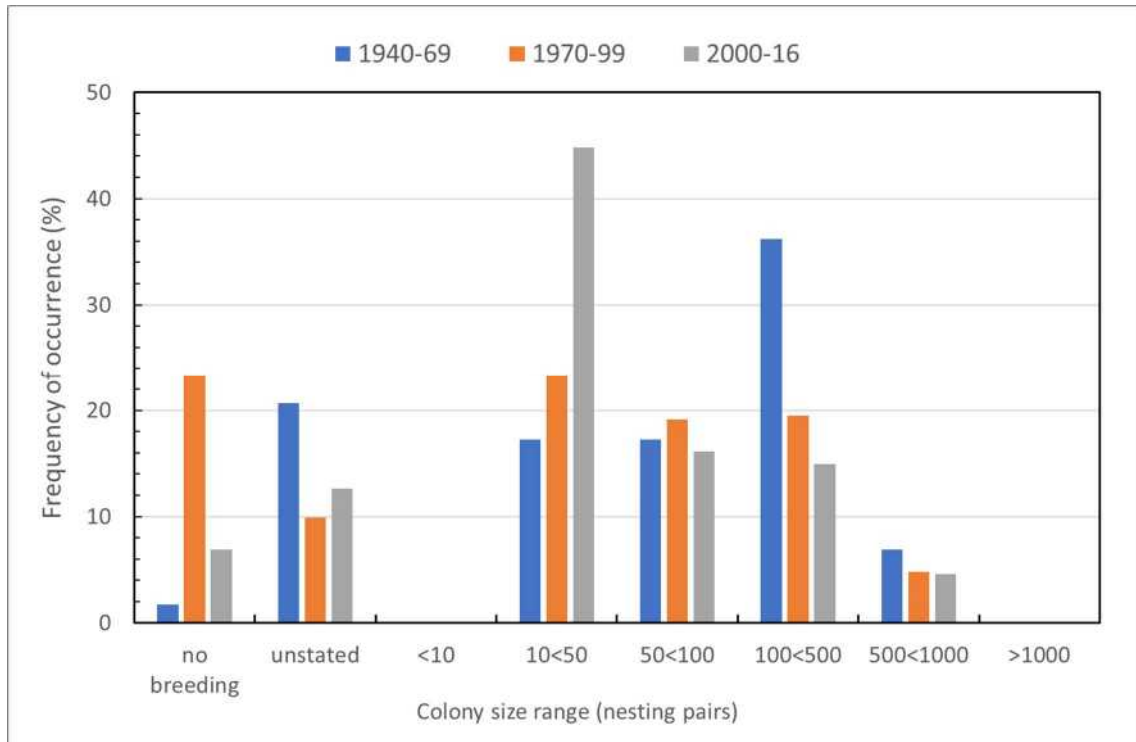


Fig. 17. Frequency distribution of recorded colony sizes during three different time periods: 1940–1969 (58 records); 1970–1999 (334 records); and 2000–2016 (87 records). Note the absence of colonies of <10 breeding pairs. Note also the increase in the frequency of reports of small colonies (10<50 nesting pairs) and the apparent decline in the number of large colonies (100<500 pairs) in the period 2000–2016, relative to their frequency in 1940–1969.

The trend suggested by these data are consistent with the general perception of a marked decline in the species' population overall in the past 40 years or more (Mills 2013b). It is currently regarded as 'at risk' with a predicted decline of 10–50% over the next 30 years (three generations). This is buffered somewhat by an apparent large estimated population size of 20,000–100,000 mature individuals, although the quality of the data used in this formal assessment is poor (Robertson *et al.* 2013).

The reasons for the change in status of the white-fronted tern in northern New Zealand are not known. Many reports noted the loss of shoreline colonies during storms or exceptionally high tides, especially when driven by strong onshore winds. Some mention both deliberate and inadvertent disturbance by people. Predation by introduced mammals is likely to be a major factor at some mainland colonies and perhaps on some islands where predators have not been eradicated or controlled. The black-backed gull (*Larus dominicanus*) also takes eggs and chicks, especially from smaller colonies where the number of terns is often insufficient to defend the colony against such predators. If the ability of terns to mount a communal defence against predators is related to colony size, then as average colony size declines, the risk of predation may increase, especially if the relationship is non-linear. This can feedback in time to yet smaller colonies and increased risk of predation.

The high year-to-year variation in colony size, including some years when the birds do not appear to breed or when a colony is abandoned early in the breeding cycle, suggests that the birds may be susceptible to changes in food availability, for whatever reason. The species' diet, both during the breeding season and outside it, is poorly known. Understanding how sensitive white-fronted terns may be overall to variations in food supply, and what may be driving these fluctuations, urgently needs to be studied.

Grey noddy *Procelsterna albivitta*

The grey noddy is a small, pelagic tern that occurs across the south Pacific between about 21° S and 40° S, extending from the east coast of Australia to southern Chile. Within New Zealand, it breeds in the Kermadec Is, particularly on Macauley and Curtis. Prior to 1970, it was largely seen as a vagrant, with fewer than a dozen records between 1882 and 1970 (Cunningham 1950; Falla 1970; Latham 2003). In early 1970, D. Pomeroy reported an estimated 1000 birds at Volkner Rocks, off White Island in the eastern Bay of Plenty, and a lesser number at Sugarloaf Rock in the Alderman Is less than a week later (Falla 1970). Since then, the species has been recorded regularly in New Zealand, mostly in offshore waters or close to rocky islands from the Bay of Plenty north to the Three Kings Is, often in considerable numbers (Latham 2003; CSNs; numerous eBird records <http://ebird.org/ebird/newzealand/map/grynod1>). The locations of sightings made during in the periods 1970–1989, 1990–2009, and from 2010 onwards are shown in Figs 18–20.

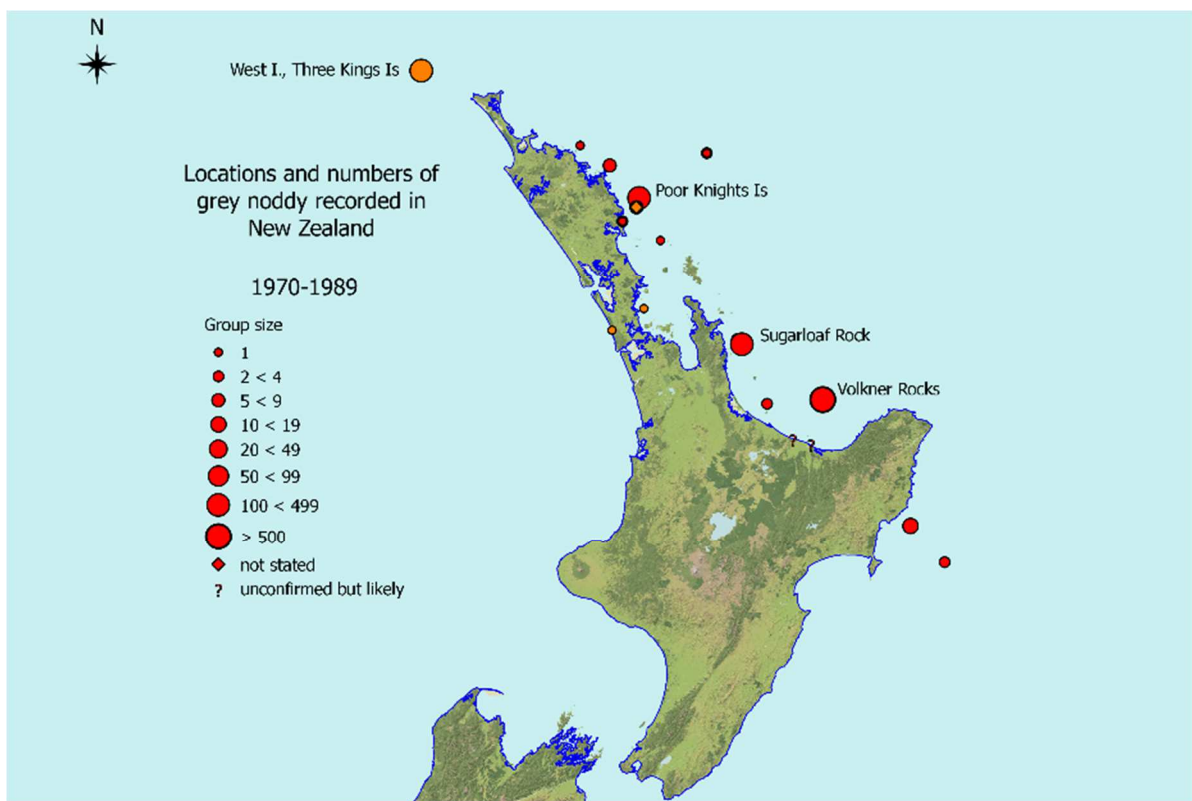


Fig. 18. Locations and comparative numbers of grey noddy seen in New Zealand, 1970–1989. Four sites where grey noddy are either known to have bred (Volkner Rocks) or suspected to have bred are labelled. In all cases these coincide with large numbers of birds being recorded.

The upsurge in sightings since 1970 may be linked to the eradication of goats on Macauley I. in the Kermadec Group in the late 1960s–early 1970s, one of the species’ main breeding sites (Graeme Taylor, *personal communication*). Prior to this, goats probably severely disrupted breeding of this species. Following the eradication of goats, breeding success could have improved, expanding the grey noddy population in the Kermadecs and triggering dispersal to and colonisation of new areas, including northern New Zealand. There is only one definite breeding record in northern New Zealand, although others have been suspected. In March 1993, c.50 old nests, some abandoned eggs, and 10 dead birds were found on the Volker Rocks (Latham 2003). Breeding had earlier been suspected on Sugarloaf Rock in the Alderman Is in 1970 (Falla 1970); on the Poor Knights Is in 1978–79 (CSN: Sibson 1979); and the Three Kings Is in the 1980s (Powlesland 1990), a place where grey noddies are now regularly seen.

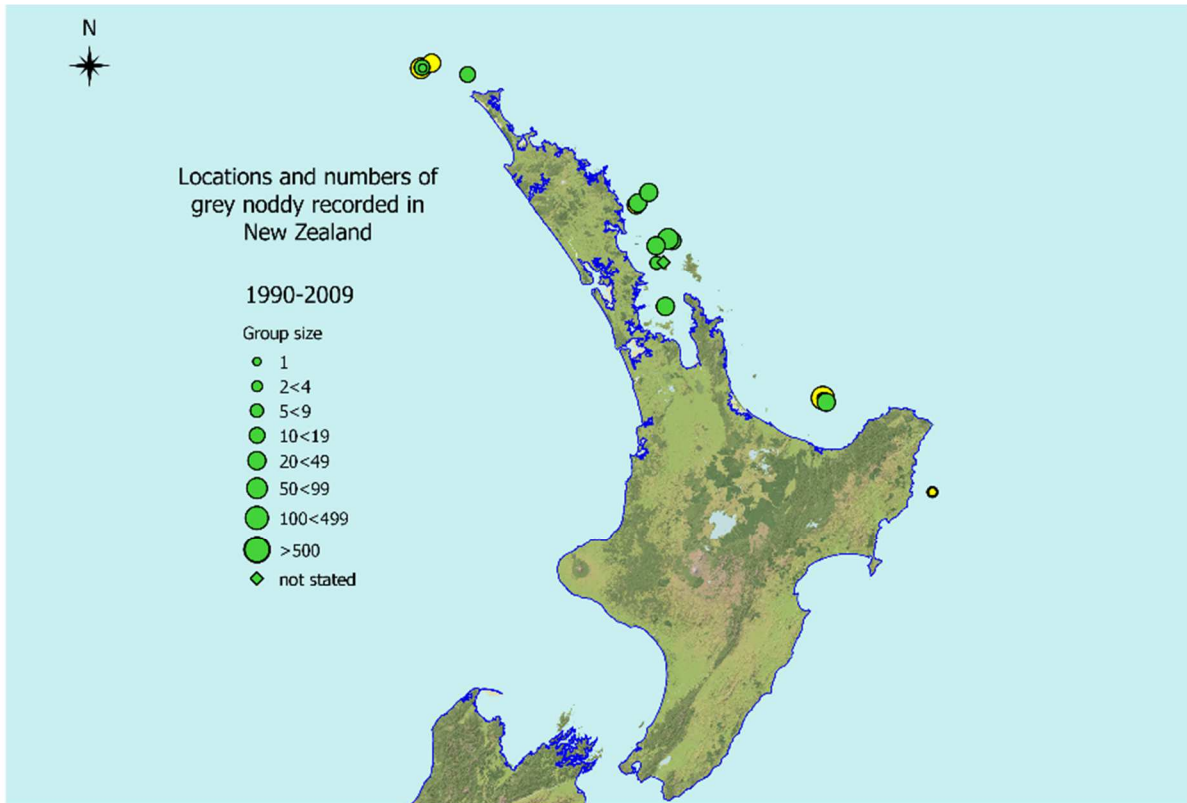


Fig. 19. Sightings of grey noddy in northern New Zealand water during 1990–2009. The yellow circles refer to sighting made during 2000–09, the green circles to sightings made during the preceding decade. The scales are the same.

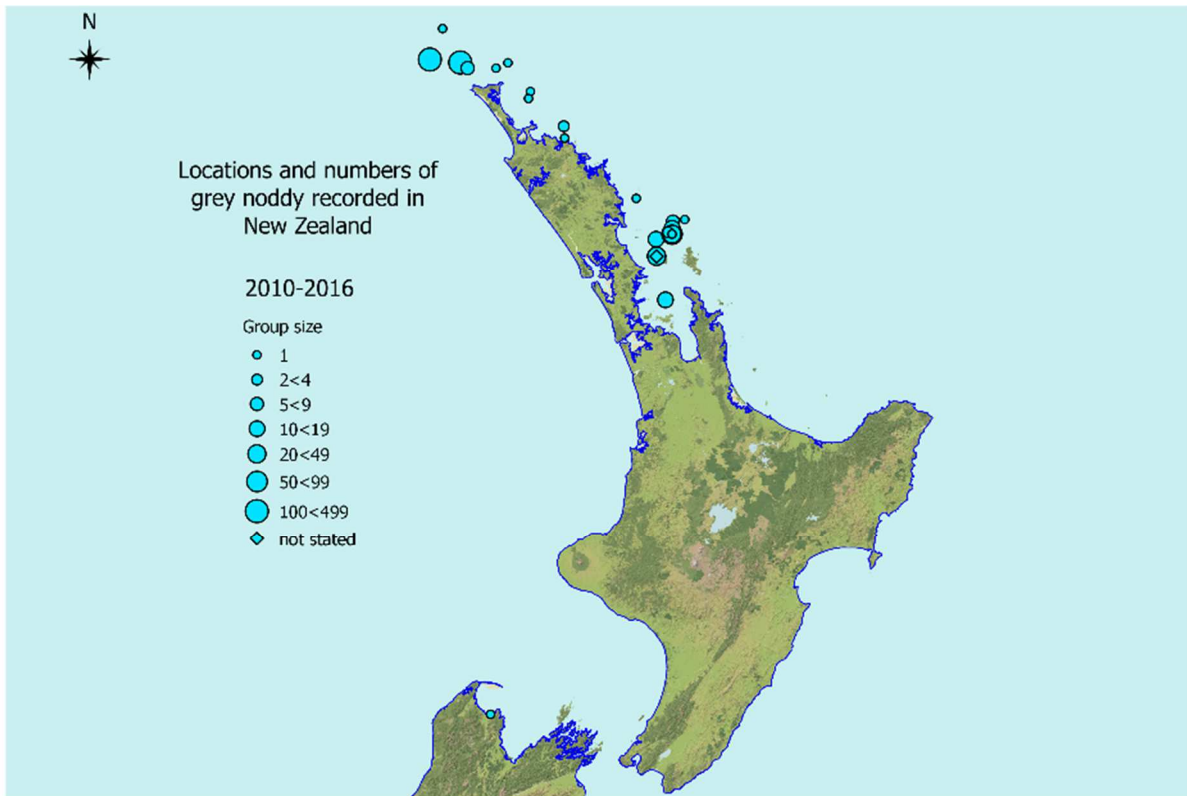


Fig. 20. Sightings of grey noddy in northern New Zealand waters since 2010. The increase in at-sea sightings largely reflects an increase in the number of pelagic bird-watching trips now being undertaken, particularly in the Hauraki Gulf and in the Far North region.

Grey noddy breed colonially on rocky islands, making rudimentary nests of seaweed and grass placed in sheltered spots in crevices or hollows, between boulders, or under vegetation (Table 2). Nests placed in hollows on steep-sided stacks and rocky islands would not only be difficult to access but also hard to see from a boat. This probably explains why there is uncertainty over whether, where and when grey noddy nest in mainland New Zealand. Nevertheless, given the frequency of sightings, it seems likely that the species does breed locally, albeit currently in small numbers.

Grey noddy has the narrowest gape of all terns and feeds on euphausiids, small fish (average size: 17 mm), squid larvae, and sea striders (*Halobates* spp.), which they pick from the sea surface (Higgins & Davies 1996). Their attraction to seabird feeding frenzies around boil ups is probably the opportunity to pick up any scraps left over by other seabirds and predatory fish. How important this association is in the overall foraging ecology of this species needs research, although it may be difficult to do. Do the terns actively seek out and follow these boil ups, or do they exploit them opportunistically? What proportion of the birds' energy and nutrient budget comes from feeding around boil ups? Given the apparent abundance of suitable nest sites on various islands and stacks around New Zealand, what other factors might determine an area's suitability for breeding?

Discussion

The information collated in this review provides a reasonable picture of the breeding distributions of these five species in northern New Zealand. The sites of all major colonies have probably been identified, at least as they existed historically. Some questions remain about whether we know the current locations of all white-fronted tern colonies, a species that seems to shift colony locations often, for reasons that are still unclear. We also do not know if the grey noddy is fully established as a breeding species within this region.

The data on the numbers of birds breeding at these colonies, and what changes may have occurred through time, are generally poor. Many statements about colony size were either qualitative ("big colony", "a few breeding") or, if numbers were given, unclear as to whether these referred to actual counts of active nests or nesting birds; assessments of the number of breeding pairs (not all of which may be nesting); or estimates of the number of birds present. The numbers are perhaps best characterised as conjecture, especially for red-billed gull and white-fronted tern colonies.

This uncertainty is compounded by the often long and irregular intervals between reports on a colony. Not many counts extended over more than a few years in succession. The longest run found in this review was only 8 years, although some longer data sets may reside in people's notebooks (e.g. Black Rocks, C.J. Ralph, *personal communication*). Overall, the available time-series were too short to show any distinct trends. What they do reveal is considerable inter-annual variation in the numbers of apparently nesting pairs, which raises the question: do isolated counts made at long intervals have much merit? Moreover, why do some birds not breed every year, and what drives that behaviour? Could it reflect limited food availability, as Mills *et al.* (2008) have shown for red-billed gull at Kaikoura, and Bunce *et al.* (2005) have suggested for age-related variations in breeding performance in the Australasian gannet in Australia? Could it relate to food quality, as suggested by Mills *et al.* (2008), with breeding birds requiring high-quality food to come into breeding condition and rear their chicks successfully, and yet being drawn to feed on more easily accessible low-quality food, such as discards from fisheries, and consequently failing (Grémillet *et al.* 2008)? Clearly, it is as important to comprehend the driving forces as to understand numbers and trends.

Despite the paucity of data suitable for trend analysis, there are indications of decline in at least some Australasian gannet, spotted shag, red-billed gull and white-fronted tern populations. (A few show the opposite trend, but perhaps not enough to offset the apparent declines.) The reasons for these declines are not known, although predation, disturbance and changes in food supply have all been implicated. Apart from the ongoing long-term study of red-billed gulls at Kaikoura, outside this region, evidence for a decline in this species rests largely on the accuracy of assessments of colony size made over 70 years earlier. Some of these estimates are an order of magnitude larger than more recent counts, suggesting that the declines are real even if their scale is uncertain. Predation and fluctuations in food supply have both been implicated as drivers of change at Kaikoura (Mills *et al.* 2008; Mills *et al.* in prep.), but we do not know if this is representative of what may be happening elsewhere.

For gannets, intermittent aerial surveys of their populations carried out over the past 70 years suggest a 20–35% decline at some colonies, but possibly not nationwide (Fleming & Wodzicki 1948; Wodzicki *et al.* 1984; and counts made of a few colonies as part of this study). Although it is still widely believed that the gannet population in New Zealand is increasing, there is no compelling recent evidence for this. Nevertheless, the species has increased markedly in Australia, thought to be due to a combination of changes in ocean conditions associated with more frequent and intense El Niño events, warmer summer sea surface temperatures, and increased discards from an expanding pilchard (*Sardinops sagax*) fishery (Bunce *et al.* 2002). In contrast, populations of the closely related Cape gannet (*Morus capensis*) have declined by 85–98% in Namibia over 50 years, and fluctuated markedly in South Africa (Crawford *et al.* 2007). This is due largely to changes in the distribution and abundance of its main prey, pilchard and anchovy (*Engraulis encrasicolus*), fish species that make up the bulk of the catch in southern Africa's purse-seine fishery (Crawford 2007). Given the interactions between gannets, fish stocks and fisheries elsewhere, and the resulting major changes in gannet populations, closer monitoring of the New Zealand population would seem prudent, because similar changes could be happening here.

Recommendations

Establish a national seabird monitoring programme

Given our limited knowledge of the status of these species' populations, and even less about their trends, we need closer tracking of them. Even though the species seem reasonably abundant, this is no guarantee of future security, nor a reason to delay monitoring until circumstances deteriorate more obviously. Evidence from monitored seabird populations globally shows that many are experiencing sharp declines (Paleczny *et al.* 2015). The reasons are varied but pervasive: competition with commercial fisheries; added mortality caused by fishing gear, pollution, and alien invasive predators; habitat degradation; and human disturbance (Croxall *et al.* 2012). The extent to which these and other pressures are affecting local seabird populations should be urgently addressed, beyond monitoring those species currently part of New Zealand's threatened species programme.

The aims and organisation of such a programme need discussion with and agreement among all interested parties (government agencies, conservation organisations, the fishing industry, research institutes, and other stakeholders). To be effective, monitoring must address clear and answerable key questions: what is the direction and magnitude of change in these species' breeding populations, and what are the drivers? Because the species considered here are almost all long-lived (average maximum longevity >21 years), slow-reproducing, and with long life cycles (generation times across the species average 12 years [range 8–21 years]), answering these questions will require multi-decadal monitoring.

Provided a monitoring programme is robustly designed, it should not be either necessary to monitor these species' populations everywhere. It certainly will not be economically feasible. But it should be possible to identify certain key colonies and monitor them. For the Australasian gannet, whole colonies can be photographed from the ground (e.g. Muriwai) and from the air (e.g. White I., Three Kings Is). Surveying the Three Kings Is annually may be too expensive, but should be possible for White I., where surveys could be arranged in conjunction with commercial operators who organise regular scenic flights to the island. The annual cost could be less than \$2500, including that of analysing the photographs.

For spotted shag, the practicability of regularly surveying the Tarahiki I. and Waiheke I. colonies needs exploring. Whereas this requires a boat, it should not be a major constraint, given the number of vessels that sail around the region. For both red-billed gull and white-fronted tern, which breed at many sites, there are numerous colonies that could be monitored. Black Rocks (Bay of Islands), Tiritiri Matangi (Hauraki Gulf) and Maketu Spit (Bay of Plenty) are already being censused regularly. Collaborating with those carrying out these censuses would be a useful starting point. This would include agreeing on aims and objectives, adopting standardising protocols, offering joint analysis of the data, and linking the outputs to other environmental information, so that sense can be made of the patterns. Providing feedback to all parties, to maintain interest and long-term commitment, would be essential.

Although Birds New Zealand has proposed using eBird (<http://ebird.org/content/newzealand/>) for monitoring bird populations, and some conservation bodies promote the use of NatureWatch NZ (www.naturewatch.org.nz/) as a repository for similar information across a wider range of taxa, neither of these are formal monitoring programmes in the sense envisioned here. Incidental data collection is not monitoring, although monitoring involves [targeted] data collection. In brief, monitoring is feasible but will need organising. It will not happen of its own accord.

Long-term monitoring requires institutional support

Sustained institutional support is essential for long-term monitoring, both in securing the funds needed to cover the management and costs of periodic surveys, and in enabling timely and effective data collation, analysis and production of results. Some tasks that are best done within a unified framework would be to:

- develop appropriate monitoring protocols;
- plan and coordinate surveys, especially important if some of the work needs to be contracted out or involves groups of volunteers;
- establish and maintain appropriate data repositories, including checking inputs for any gaps or inconsistencies, and seeking clarification or correction from the observer concerned;
- provide regular feedback to those doing the surveys, both to reinforce the need to keep to agreed protocols (or to modify them, if necessary), and to encourage ongoing involvement;
- undertake or commission timely periodic analyses to identify and track emerging trends;
- liaise with other environmental monitoring programmes to integrate and place the findings in a broader environmental context; and
- communicate the results to decision-makers so that appropriate action can be taken, where possible.

Develop seabird population models

Because monitoring essentially produces insights about what has happened, it does not necessarily fully serve the purpose of anticipating what could happen, or what the consequences of that may be. Modelling is one way of exploring this, not only in showing the possible outcomes of present trends, but in identifying areas and variables for which more information is needed. For instance, we have only limited data on key demographic variables for most of the species considered here. We urgently need information on age-specific survival rates; movement among colonies (immigration/emigration rates); age at first reproduction; probability of breeding each year (at least some of the species considered here seem to reproduce intermittently); breeding success; etc. Collating what information exists beyond what has been possible here, and encouraging others to collect whatever demographic data are still outstanding, is an urgent task.

Population modelling can also help explore the possible outcomes of different management options. Expanding existing models, which in New Zealand have been developed primarily for albatrosses facing direct threats from commercial fishing (see <https://docnewzealand.shinyapps.io/seabirdmodelling/>), to cover a wider range of seabirds with different demographic profiles and facing a wider range of pressures, should be explored.

Integrate seabird monitoring with other marine ecosystem programmes (including fisheries)

Seabird population dynamics are driven by both internal and external factors and processes. To make sense of these dynamics, they need to be put into their wider environmental contexts. Developing integrated population models for these and other species, linking both demographic and count data, and combining these with outputs from broader marine-ecosystem monitoring programmes, is crucial if any significant changes to these populations are to be properly understood and counteracted. Without monitoring, there is no sound basis for management, either in knowing when we need to act, or if that action is being effective.

Maintain a database of seabird colonies

Although questions can be raised about the accuracy and consistency of the data reviewed here, the information has some merit. There are few if any alternative sources of historical data, so they provide a useful if sometimes imperfect view of the past, something against which the results of future surveys can be compared, if only qualitatively. These data should form the nucleus of a seabird colony database, to which new observations can be added. Basic frameworks already exist in the NZ Coastal and Inland Sites IBA database maintained by Birdlife International in its World Bird Database, and the draft Te Papa Breeding Seabird Database, the present status of which is not known. Even eBird could be used, if careful consideration is given to ensuring that the data on colony size is properly included. Linking future data collection efforts with these historical data sets is essential to ensuring continuity of information on the locations, composition and sizes of seabird colonies through time.

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Note: these include some sources from which information was obtained for the review but which are not cited specifically in the text. The references to the *Classified Summarised Notes*, from which much of the information was obtained, are listed separately in Appendix 1.

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Appendix 1

List of the Classified Summarised Notes published in *Notornis* and *New Zealand Bird Notes* between 1943 and 2003 (listed in chronological order)

- Anonymous 1940. Summarised reports. *Reports and Bulletins*, 2(1), 37-53.
- Anonymous 1943. Summarised classified notes. *Notornis*, 1(3), 17-32.
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