Aerial Survey of the Distribution and Abundance of Australasian Gannet, Red-billed Gull and White-fronted Tern Populations, Northern New Zealand, November 2017

Peter G.H. Frost

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Indirect effects on seabirds in northern North Island (POP2017-06)

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Cover photograph

The Australasian Gannet colony on Mahuki Island, off Great Barrier Island, taken on 23 November 2017, showing the layout of the colony and some of the sub-colonies within it. This is currently the largest gannet colony in northern New Zealand (photo: P.G.H. Frost)

Author contact details

Peter G.H. Frost
Science Support Service,
87 Ikitara Road,
Whanganui 4500
pghfrost@xtra.co.nz

Executive Summary

Objective 4(a) of the Department of Conservation's Conservation Services Programme-funded project *Indirect effects on seabirds in northern North Island* (POP2017-06) is to collect baseline population data on three surface-nesting seabirds: Australasian Gannet (*Morus serrator*), Red-billed Gull (*Larus novaehollandiae* = *Chroicocephalus scopulinus*) and White-fronted Tern (*Sterna striata*). All three species nest colonially aboveground, making them potentially suitable for aerial monitoring.

To cover the number and diversity of potential colony sites, especially at remote locations, an aerial photographic survey of selected islands off the northern North Island was undertaken on 23rd November 2017. Forty sites on 37 islands and island groups were surveyed, extending the southern Hauraki Gulf, up the east coast to the Three Kings Islands in the north, then down the west coast to Karewa (Gannet) Island, off Kawhia Harbour. The aims of this survey were:

a) to determine the current status and size of several red-billed gull colonies, known to have been active in the past but not surveyed in the 2014–15 Birds New Zealand national survey of red-billed gull (Frost & Taylor 2018);

b) to resolve the exact locations and sizes of red-billed gull colonies on the Three Kings Is, photographed in 2014 and 2015 but without precise location data; the Three Kings Is are reputed to have once supported the largest number of nesting red-billed gulls in New Zealand;

c) to survey previously known Australasian gannet colonies, which in the 1980s contained just over 33,300 nesting pairs, and to identify and determine the size of new ones known to have become established since then; and

d) to locate and determine the size of any large breeding colonies of white-fronted tern, given some evidence that numbers have declined on the North Island mainland in recent decades (Frost 2017).

From the resulting 1740 photographs, taken with a range of cameras, a selection was chosen visually for clarity, resolution then processed using Photoshop Elements to enhance the features of nesting birds.

A total of 30,757 nesting pairs of Australasian Gannets were counted at 18 colonies. This is 135 % and 21 % higher than the numbers recorded in 1946 and 1969 respectively, but about 8 % lower than that recorded in 1980, the last complete census. It is probably within the margin of error of both censuses. Nevertheless, big changes were apparent at several colonies. Those at Mahuki and Muriwai were substantially larger than in 1980, whereas the colonies on Horuhoru, Mahenotakapu, Motukaramarama and Oaia I. had declined markedly. It is suggested that these changes represent movements between colonies because, at a subregional scale, the total numbers show little change over the past 37 years. The same pattern is apparent at Sugarloaf (decline) and the High Peaks Rocks (increase), and among the five colonies on the Three Kings Islands.

In addition to the likelihood of inter-colony movements, it is possible that some of the variation in numbers may reflect some birds skipping breeding in a year if conditions for successful reproduction are unfavourable. If these features are a major source of variation in numbers through time, they could complicate the interpretation of the results of any long-term monitoring.

Red-billed Gull colonies were found at 25 of 40 surveyed sites, supporting 3172 nesting pairs. Two of the colonies had not previously been reported (Mahuki and Te Anaputa in the Cavalli Is). Using the latest available data since 2000 for all known sites in northern New Zealand, this brings the estimated overall regional breeding population to 8343 pairs. Almost 80 % of the nesting pairs counted were on the Three Kings Islands. This count, aggregated across all Three Kings Is colonies, was 43 and 129 % above counts from aerial photographs taken in 2014 and 2015 during the national Red-billed Gull survey. Although there are queries about the completeness of coverage of the 2014 and 2015 surveys, it is also possible that substantial numbers of gulls did not breed in those years, if conditions for breeding were unfavourable. Even during the 2017 survey, large numbers of apparently non-breeding birds were seen, although it is not clear if these were all immatures and sub-adults, or if some were mature birds skipping breeding in 2017. Whatever the case, large inter-annual variations in the numbers of breeding birds complicates long-term monitoring unless the variation can be explained and factored out.

Only 1106 pairs of nesting White-fronted Tern were recorded, concentrated in two main areas, the Three Kings Is and around Muriwai. Taking the latest counts since 2000 for all known White-fronted Tern colonies, this brings the overall regional breeding population to around 5025 pairs. In general, White-fronted Terns were difficult to see from the air, so that isolated small colonies and individuals could easily have been missed. Given this, and what is known about the transient nature of many White-fronted Tern colonies, the species is probably unsuitable for monitoring by aerial survey, at least from aircraft. The use of drones, however, should be investigated.

Overall, whereas aerial surveys are useful in helping to inventory the location and general size of the colonies of some species, most notably gannets, they may not be suitable for long-term monitoring of these species unless the often large variation in numbers counted annually can be accounted for. Instead, it may be better to focus on measures of reproductive performance, particularly if the aim is to have early warning of population decline or if a species is being used as an indicator of the integrity and vitality of marine ecosystems.

Several recommendations are made about how to improve the efficiency of aerial surveys.

Introduction

In 2017, the Department of Conservation's Conservation Services Programme initiated a project, *Indirect effects on seabirds in northern North Island* (POP2017-06), to study the possible indirect effects of commercial fishing on seabirds, including those species regularly attracted to fish bait balls ('work-ups'). These are created by predatory fish forcing their prey—small fish and krill—close to the sea surface where they become available to surface- and near-surface feeding seabirds. Many seabirds seem to depend on these short-lived aggregations to obtain the high-quality food needed for successful chick-rearing. There has been growing concern that the frequency, size and duration of these events may be declining, for whatever reason, and that this could reduce the birds' overall foraging efficiency, compromising breeding success. Objective 4(a) of this project was therefore to collect baseline population data on several of these species, including Australasian Gannet (*Morus serrator*), Red-billed Gull (*Larus novaehollandiae* [= *Chroicocephalus scopulinus*]), and White-fronted Tern (*Sterna striata*). All three species nest colonially on the surface, although both Red-billed Gull and White-fronted Tern can nest individually or in small, loose groups.

Concern for the status of these species stemmed from several sources. First, between June 2014 and March 2016, members of Birds New Zealand, the Department of Conservation and the public, took part in a national survey of breeding Red-billed Gulls aimed at documenting the distribution and abundance of all colonies of this species (Frost & Taylor 2018). The results of this survey were then compared with an earlier collation, carried out in the mid-1960s (although those records went back many years: Gurr & Kinsky 1965). This comparison suggested that not only had the Red-billed Gull population declined nationally, perhaps by as much as 30 %, but also that breeding colonies were, on average, smaller and more dispersed. Nevertheless, these conclusions were tempered by the recognition that earlier estimates and geographic coverage encompassed high uncertainty. (The 2014–16 estimates are also uncertain, but this may be less because colonies were surveyed more systematically and rigorously, with greater use being made of both aerial and ground-level photography.)

Second, the study drew attention to the potential indirect effects of fishing, including the possibility of changes in the frequency, size and duration of the occurrence of fish 'work-ups'. Accordingly, a desk-top study was carried out to collate all information on the past and present locations and size of breeding colonies of the main non-procellariform seabirds attracted to these work-ups. In addition to Red-billed Gull, the review covered Australasian Gannet, White-fronted Tern, Spotted Shag (*Stictocarbo punctatus*) and Grey Noddy (*Procelsterna albivitta*[1]). Information was obtained from numerous sources, including the Classified Summarised Notes (CSN) of the Ornithological Society of New Zealand (OSNZ); OSNZ Nest Record Cards; New Zealand eBird checklists; the 1995-1998 OSNZ gull and tern survey (Powlesland 1998); Birds New Zealand Red-billed Gull survey database; species accounts published in various scientific journals; and individual records provided by knowledgeable observers. Few clear trends were found, other than a marked regional decline in the distribution and abundance of Spotted Shag (Frost 2017). Common problems with all data sets included: inconsistency in survey methods; lack of clarity as to what the reported numbers denoted—birds, pairs, or active nests; exact location of colonies poorly specified; a likely bias in only reporting large colonies; and no sustained monitoring (Frost 2017).

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

The lack of regular monitoring, and the need to identify the most cost-effective ways of monitoring seabird populations in different circumstances, prompted a plan to conduct an aerial survey of islands with colonies of surface-nesting seabirds in the northern North Island. In addition to photographing the colonies for later analysis, this flight would also provide first-hand experience from which lessons could be learned that could be applied to improve later surveys. The objectives of this survey were:

e) to conduct an aerial photographic survey of several past-known Red-billed Gull colonies that were not assessed in the original Birds New Zealand study, particularly on offshore islands from the Hauraki Gulf northwards;

f) to resolve the exact locations and sizes of the gull colonies on the Three Kings Is, which had been surveyed aerially in 2014 and 2015, but with some uncertainty around the precise location of the colonies photographed and the completeness of coverage;

g) to survey all previously known Australasian gannet colonies, which in the 1980s contained just over 33,300 nesting pairs, and to identify and determine the size of new ones known to have become established since then; and

h) to locate and estimate the size of any large breeding colonies of white-fronted tern, given some evidence that numbers have declined on the North Island mainland in recent decades (Frost 2017).

Approach

The survey was organised in conjunction with the Northern New Zealand Seabird Trust (NNZST). The Trust had been contracted by the Conservation Services Programme (CSP) of the Department of Conservation (DOC) to undertake further study of the indirect impacts of changes in fish populations on seabirds in the north-east North Island region (project POP2017-06). Effective aerial surveys of surface-nesting seabirds depend on getting high-quality photographs at a range of scales. This usually requires the services of experienced photographers using top-quality equipment. Such persons are normally professionals and require some compensation for their time. The NNZST built this provision into its proposal to DOC-CSP. A grant from Birds New Zealand covered some of the flight and land-transport costs, while that to NNZST covering the balance of flight costs and professional time.

The flight was organised through FlyStark Airlines Ltd (www.flystark.com), a company based in Whitianga but also flying out of Ardmore airport, Auckland. That company operates Gippsland GA8 single-engine, high-wing aircraft equipped to fly over sea with properly qualified pilots. It has large windows suitable for aerial observation. The Gippsland GA8 is also used for skydiving, among other things, and has a large rear door that can be opened in flight by suitably qualified personnel. We were unable to get permission to do this, so all photographs had to be taken through acrylic windows, a substantial drawback.

A detailed 18-page flight plan was drawn up, containing the geographic locations of the 35 islands or island groups to be surveyed. The vegetation and elevation of each island was described and, if known, the positions or suspected positions of Red-billed Gull and Australasian Gannet colonies on them. The flight plan also included a map showing the proposed route. The purpose of all this was to give both the pilot and the photographers forewarning of what to expect at each location, as well as the target species there. A set of guidelines for the aerial survey of seabird colonies, covering aims, sources of error in counting, and suggested optimal approach to planning, preparation and performance of a survey, was also circulated.

The flight path was tracked by three GPS units (2 Garmin GPSMap 62s, 1 Garmin GPSMap 64s). One Garmin GPSMap 62s was under the control of the navigator (myself, PGHF), while the other was monitored by Olivia Hamilton (OH), who tracked the flight on computer in real time and made notes of any significant features during the flight, including sightings of marine mammals and fish work-ups. Neil Fitzgerald also kept track of the flight on his Garmin GPSMap 64s. The navigator's unit was placed on the aircraft dashboard throughout and had the clearest view of the sky. It gave the most accurate information on the track, at least when judged against written notes and memory of the flight paths around the islands. All cameras and watches were synchronised to the nearest second with the time shown on the GPS units. In addition to myself as navigator, the personnel involved in the survey were:

- Richard Robinson (Depth – Underwater Photography, Snell's Beach, https://www.depth.co.nz/about)
- Neil Fitzgerald (Neil Fitzgerald Photography, Pirongia: https://www.neilfitzgeraldphoto.co.nz/profile.html)
- Olivia Hamilton (Institute of Marine Science, The University of Auckland, studying the spatial ecology of marine mammals and birds at sea)

RR and NF were the photographers, while PGHF and OH tracked the flight by GPS.

The flight took place on 23 November 2017, departing from Ardmore airport at 08h46 and ending eventually, 9.4 hr and 1,465 km later at 18h09. Weather conditions were ideal with an almost cloudless sky and windless conditions up and down both coasts. Total time in the air was 8.2 hr, somewhat longer than had been anticipated because insufficient allowance was made in the plan for the time taken to circle and photograph each location. This came to 86 min overall, an average of just under 3 min at each point. Track data were imported from the GPS's to OziExplorer® as *.gpx files and from there to Excel, where the time was corrected from UTC to local time. The data were then exported to both Google Earth (as *.kml files) and QGIS (as shape files). The flight path of the survey is shown in Figure 1 and operational details of the flights around each island are given in Table 1.

In all, 1732 photographs were taken with three different cameras: Canon EOS 5DS R with EF24-70mm f/2.8L II USM lens at shutter speed 1/1000 s and aperture F5.6 at focal lengths varying from 38-70 mm (700 images); Canon EOS-1D X Mark II with an EF300mm f/2.8L IS USM lens, at shutter speed 1/2500 s, aperture F5.0 (215 images); and a Canon EOS-1D Mark IV with an EF70-200mm f/4L USM lens at 1/1000 to 1/8000 (817 images). The Exif data for each image (camera make and model, date and time of each image, shutter speed, ISO rating and lens focal length) were bulk extracted using Picture Information Extractor 6.99.10.61, Picmeta Systems (http://www.picmeta.com).

In addition to aerial photographs of the gannet colonies, almost the whole mainland colony at Muriwai was photographed by PGHF the previous day (22 November 2017). Only a few small areas of the colony were out of sight. From the aerial photographs, these hidden areas contained 31 nesting pairs. The ground-level photographs were therefore used to verify the accuracy of the counts of nesting gannets made from the same areas visible on the aerial photographs. The ground-level photographs also showed nesting White-fronted Terns and the few visible nesting Red-billed Gulls. They therefore also served as a check on the counts of these species made from the aerial photographs.

Figure 1. Flight path and location of sites surveyed on 23 November 2017.

Table 1. Operational details of the aerial photographic survey carried out on 23 November 2017 from the inner Hauraki Gulf to the Three Kings Islands (A), around the Three Kings Islands (B), and from the Three Kings Islands south to Karewa Island (C).

A. North Island East Coast Sites

Locality	Survey type (number of circuits)	Start time	End time	Duration (min)	Distance (km)	Ave. speed (kph)	Min. altitude (m)	Max. altitude (m)
Horuhoru	Circle (3)	8:58:30	9:04:13	5:42	13.25	139.1	137	208
Motutakupu	Circle (3)	9:10:04	9:13:30	3:25	7.86	137.3	140	205
Motukaramarama	Circle (3)	9:14:03	9:18:06	4:03	9.37	138.7	144	266
Islet W of Motuwi	Circle (1)	9:18:11	9:19:29	1:18	3.00	138.3	146	204
Mahuki Island (& Junction I. stack)	Circle (2)	9:35:11	9:39:40	4:28	10.24	137.0	142	219
Stack east of Opakau I.	Flypast	9:40:51	9:41:15	0:24	0.94	141.1	164	189
Maori Rocks, Mokohinau Is	Circle (2)	9:51:58	9:54:32	2:33	5.85	136.8	132	165
Sugarloaf, Poor Knights Is	Circle (2.5)	10:13:11	10:15:25	2:13	5.07	136.2	212	235
High Peaks Rocks, Poor Knights Is	Circle (2)	10:16:26	10:18:57	2:31	5.82	138.6	177	254
Otuwhanga/Cape Brett/Motukokako	Circle (1)	10:35:10	10:36:55	1:45	5.92	203.1	300	350
Mahenotakapu (Bird Rock)	Circle (2)	10:37:32	10:39:52	2:20	5.37	138.0	160	217
Tikitiki Rock (9-Pin)	Circle (3)	10:44:23	10:47:48	3:24	7.8	137.0	148	222
Te Anaputa Island	Circle (1)	11:39:09	11:40:15	1:06	2.64	144.0	161	194
Motutakupu & outer Cavalli Is	Circle (1) & flypast	11:40:56	11:43:12	2:16	5.63	149.1	131	180
Kaitirehe Rock	Flypast	11:44:16	11:44:39	0:22	0.96	149.9	150	167
Rocky Island	Circle (3)	12:00:32	12:04:28	3:56	9.12	139.1	114	221
Karikari Stacks	Circle (1) & flypast	12:05:05	12:10:14	5:09	12.62	147.0	121	197
North Cape (Otou, Murimotu)	Circle (1)	12:24:05	12:25:17	1:11	2.78	138.9	137	208

B. Three Kings Islands

Locality	Survey type (number of circuits)	Start time	End time	Duration (min)	Distance (km)	Ave. speed (kph)	Min. altitude (m)	Max. altitude (m)
Manawatāwhi/Great I. (part NW-NE)	Flypast	12:49:34	12:53:16	3:42	8.58	139.2	175	249
North-east Island	Flypast	12:53:41	12:55:32	1:50	4.5	146.1	129	180
Farmer Rocks	Circle (1)	12:56:12	12:57:40	1:27	3.48	142.4	156	175
Manawatāwhi/Great I. (part SE-SW)	Flypast	12:57:40	12:59:25	1:45	4.58	157.0	139	174
South-west Island	Circle (1.5)	13:01:32	13:06:12	4:40	10.87	139.7	155	215
Rosemary Rock Arbutus Rock Tutanekai Rock Archway Rock Hinemoa Rock Stella Rock West I.	Circle (3-4)	13:06:46	13:19:18	12:31	29.80	142.7	139	293

C. North Island West Coast sites

Locality	Survey type (number of circuits)	Start time	End time	Duration (min)	Distance (km)	Ave. speed (kph)	Min. altitude (m)	Max. altitude (m)
Matapia I.	Flypast	13:46:30	13:46:57	0:25	1.07	153.4	181	253
Oaia Island, Muriwai	Circle (1)	15:46:58	15:48:33	1:34	3.57	135.4	153	200
Otakamiro Point, Muriwai Muriwai stack (Motutara), Muriwai Maukatia Bay clifftop, Muriwai	Flypast (2)	15:49:18	15:51:03	1:45	1.89	64.9	164	184
Karewa (Gannet I.)	Circle (3)	17:21:48	17:27:50	6:01	13.67	136.0	128	176
Ngatutura Point (Waikato Coast)	Circle (1)	17:46:43	17:49:07	2:24	8.4	209.9	193	235

Images for analysis were selected visually for clarity, resolution and coverage then processed using Photoshop Elements. A few images were processed initially in RAW format, especially those presenting a unique but overexposed view, but this was time-consuming. In most cases, colour balance, contrast, brightness and sharpness could be more quickly and quite adequately addressed in Photoshop Elements. Objects were selected and counted using the Multi Point selection tool in ImageJ 1.52.

In most cases, a colony or area to be counted spread over more than one image. To be useful for counting birds and ensure that the whole colony or area can be covered, the images must show enough overlap to allow discrete zones to be demarcated from neighbouring areas viewable in adjacent images. This involved mapping common boundaries visible in two or more overlapping images on all sides. The adjoining images in turn must have their own distinct zones distinguishable from the next images in sequence, and so on until all areas in which nesting birds occurred had been covered without overlap or gaps (Figure 2).

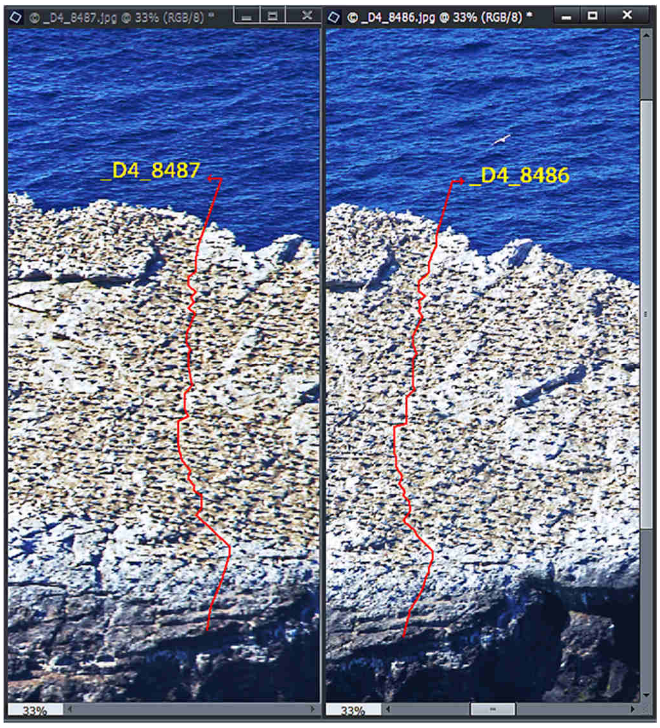

Figure 2. Delineation of discrete areas on adjacent images ensures that there are no gaps or overlapping areas in which birds are being counted (gannets on Karewa I.). Nesting birds were counted to the left on image 8487 and right on 8486 up to the next demarcation lines to the left and right respectively where these overlap with the adjoining images.

To express the uncertainty in these counts, 95 % confidence intervals were calculated for each (and summed for the totals), using the *poisson.exact* function in the R package *exactci* (Fay 2017), with the parameter settings *alternative* = "two-sided", *tsmethod* = "central", and *conf.level* = 0.95. This calculates the exact Poisson confidence limits and corresponds to the exact central confidence interval of Garwood (1936), a widely used method for calculating this parameter in a one-sample case. The fundamental assumption is that these counts are products of a Poisson process, as shown by Baker et al. (2013) for the White-capped Mollymawk (*Thalassarche steadi*) and applied later to other colonial nesting seabirds (e.g., Baker et al. 2017).

Results and discussion

A total of 40 sites on 37 islands or island groups were surveyed (Table 1). Most involved flying circuits around the islands to check visually for any colonies or large groupings of surface-nesting seabirds. Any seen were photographed. A few localities (e.g., Junction I. and the stack off Opakau I.) were simply flown past while a visual check was made to see if there were any large Red-billed Gull colonies on them. Aggregations of gulls had been reported on these islands during the 2014–2015 national Red-billed Gull survey, but there was no evidence of any breeding there in 2017. The counts for all three key species are given in Table 2.

Australasian Gannet

All known gannet colonies were successfully photographed. A total of 30,757 (95 % confidence limits: 29,512–32,055) apparently occupied sites were counted at 18 colonies (Figure 2). These sites were ones with a bird either incubating an egg or brooding a small chick, or with a large downy chick, usually with an adult standing nearby. Partners of nesting birds were not counted. Compared with earlier aerial censuses (Table 3), this total is 135 % and 21 % above the numbers counted in 1946 and 1969 (71 and 48 years earlier respectively), but 7.6 % below that of the same colonies when censused in 1980, 37 years ago. This net decline, however, encompasses substantial apparent increases and declines at individual colonies (Table 3). For example, the gannetry on Mahuki I. increased by almost 130 % over 37 years, which seems substantial but corresponds to just under 2.3 % annual growth rate, assuming a constant rate of increase. A similar rate has been reported for the Northern Gannet (*Sula bassana*) during periods of population expansion (Nelson 1966; Wanless et al., 2006).

A much greater increase has occurred at the mainland colony at Muriwai. This site was first occupied around 1980, coincident with an apparent shift from the colony on nearby Oaia I., initially to the Motutara stack, just off Muriwai, and then on to mainland, where fencing and pest control provided some protection (Greene 1999). Once established, the mainland colony grew rapidly, particularly after the original fence was moved, creating more space for nesting birds (Greene 2003). Meanwhile, the Oaia I. colony declined further, while that on Motutara remained reasonably stable (Figure 4). The cause of the initial shift from Oaia I. is thought to have been due to increased disturbance from an expanding New Zealand Fur Seal (*Arctocephalus forsteri*) population (G.A. Taylor, pers. comm.), although the small size of the island was probably also beginning to be a limiting factor in the 1960s and 1970s.

In October 2016, Oliver Nicholson photographed the Muriwai and adjacent Motutara (Pillar Rock) colonies. He also photographed Oaia I. from a distance, but the gannet colony there could still just be seen. A clip from a YouTube 4k video of the small Oaia I. colony, taken from a drone flown (illegally) in January 2016 (https://www.youtube.com/watch?v=FxLV_FK0Mjk), was processed to give a figure of about 12 breeding pairs for the 2015–16 breeding season. A total of 1500 nesting gannets were counted on the 2016 ground-level photographs: 187 nesting birds on Motutara; 1285 on the Muriwai cliff tops and the adjacent sand slip at Otakamiro Point; and 28 on Oaia I. (Frost 2017). Compared with the 209 pairs recorded on Motutara and 1,904 pairs nesting on the Muriwai mainland in November 2017, the number of pairs breeding at the two larger sites in 2017 was 12 % and 48 % higher than in 2016, well above any increase stemming from intrinsic growth.

Table 2. Numbers of apparently occupied nest sites of Australasian Gannet, Red-billed Gull and White-fronted Tern counted on photographs covering 40 sites on various islands in November 2017. The exact 95 % confidence limits are also given, assuming the counts come from a Poisson process (see text for details).

A. North Island East Coast Sites

Locality	**Australasian Gannet**	**Red-billed Gull**	**White-fronted Tern**	**Note**
Horuhoru	988 (*927–1052*)	4 (*1–10*)	0	
Motutakupu	464 (*423–508*)	0	0	
Motukaramarama	1956 (*1870–2045*)	0	0	
Islet W of Motuwi	130 (*109–154*)	0	0	
Mahuki I.	6160 (*6007–6316*)	72 (*56–91*)	0	
Maori Rocks, Mokohinau Is	383 (*346–423*)	16 (*9–26*)	0	
Sugarloaf, Poor Knights Is	1101 (*1037–1168*)	267 (*236–301*)	0	
High Peaks Rocks, Poor Knights Is	2245 (*2153–2340*)	54 (*41–70*)	0	
Cape Brett (Motukokako)	0	0	0	*1*
Cape Brett (Tiheru I.)	0	6 (*2–13*)	0	*2*
Mahenotakapu (Bird Rock)	0	0	0	*3*
Tikitiki Rock (9-Pin)	107 (*88–129*)	21 (*13–32*)	0	
Outer Cavalli Is (Te Anaputa I.)	0	182 (*157–210*)	7 (*3–14*)	
Kaitirehe Rock	0	0	0	*4*
Rocky I. & Karikari Stacks	0	0	0	*5*
North Cape (Otou, Murimotu)	0	0	0	
	13,534 (*12,960–14,135*)	622 (*515–753*)	7 (*3–14*)	

Table 2 (cont.)

B. Three Kings Islands

Locality	Australasian Gannet	Red-billed Gull	White-fronted Tern	Note
Manawatāwhi/Great I. (Tapatu Bay)	0	7 (*3–14*)	0	*6*
Manawatāwhi (Crater Head)	0	327 (*293–364*)	34 (*24–48*)	
Manawatāwhi (Patea Bay)	0	384 (*347–424*)	2 (*0–7*)	
Manawatāwhi (Petu Point)	0	331 (*296–369*)	36 (*25–50*)	
Manawatāwhi (Maratea Shoals)	0	0	13 (*7–22*)	
North-east I.	0	0	0	
Farmer Rocks	0	0	0	
South-west I.	1267 (*1198–1339*)	512 (*469–558*)	38 (*27–52*)	
Rosemary Rock	0	176 (*151–204*)	139 (*117–164*)	
Will Watch Rock	0	39 (*28–53*)	0	
Lion Head	0	106 (*87–128*)	0	
Top Hat	0	26 (*17–38*)	0	
Arbutus Rock	2687 (*2586–2791*)	0	0	
Tutanekai Rock	654 (*605–706*)	54 (*41–70*)	0	
Archway Rock	1362 (*1291–1436*)	270 (*239–304*)	0	
Hinemoa Rock	3402 (*3289–3518*)	102 (*83–124*)	0	
Stella Rock (including offshore stack)	0	60 (*46–77*)	0	
West I.	0	134 (*112–159*)	51 (*38–67*)	*7*
	9372 (*8969–9790*)	2528 (*2212–2886*)	313 (*238–410*)	

Table 2 (cont.)

C. North Island West Coast sites

Locality	Australasian Gannet	Red-billed Gull	White-fronted Tern	Note
Matapia I.	0	0	0	
Oaia I., Muriwai	25 (*16–37*)	10 (*5–18*)	463 (*422–507*)	
Muriwai (Otakamiro Pt & Maukatia Bay)	1904 (*1819–1991*)	5 (*2–12*)	226 (*197–257*)	
Muriwai stack (Motutara), Muriwai	209 (*182–239*)	0	20 (*12–31*)	
Karewa (Gannet I.)	5713 (*5566–5863*)	6 (*2–13*)	0	
Ngatutura Point (Waikato Coast)	0	1 (*0–6*)	77 (*61–96*)	
	7851 (*7583–8130*)	22 (*9–49*)	786 (*692–891*)	
Total offshore northern North I.	30,757 (*29,512–32,055*)	3172 (*2736–3688*)	1106 (*933–1315*)	

Notes

1 Steep-sided, forested island with sheer vertical cliffs; little suitable habitat for surface-nesting seabirds

2 Nesting gulls poorly resolved on grainy image

3 134 roosting WFT; no sign of breeding

4 1 dead gannet but no evidence of recent mass occupancy of this islet by gannets

5 1013 RBG in 4 feeding aggregations offshore; 81 roosting on island

6 934 RBG in 5 groups roosting on water; 127 WFT roosting on rocks

7 Around 750 birds loafing on water close to island

Table 3. Changes in estimated numbers of Australasian Gannet pairs nesting at various colonies in the northern North Island, New Zealand, 1946–2017 (Fleming & Wodzicki 1952; Wodzicki et al., 1984; this report).

Location	1946	1969	1980	2017	% change 1980–2017	Annual % change
Tutanekai Rock, TKI	300	406	402	654	62.7	1.3
South-west I., TKI	824	804	1135	1267	11.6	0.3
Archway Rock, TKI	490	618	1530	1362	-11.0	-0.3
Arbutus Rock, TKI	1000	2175	2652	2687	1.3	0.0
Hinemoa Rock, TKI	1520	3232	4136	3402	-17.7	-0.5
Tikitiki Rock (9-Pin Rock)	0	0	0	107		
High Peaks Rocks	100	528	1553	2245	44.6	1.0
Sugarloaf	1410	2462	2617	1101	-57.9	-2.3
Maori Rocks, Mokohinau Is	12	49	344	383	11.3	0.3
Mahuki I., Aotea/GBI	325	1869	2681	6160	129.8	2.3
Motuwi	5	50	96	130	35.4	0.8
Motukaramarama I	1513	2834	3530	1956	-44.6	-1.6
Motutakupu, Coromandel	288	777	925	464	-49.8	-1.8
Horuhoru Rock	1228	2526	2647	988	-62.7	-2.6
Muriwai mainland	0	0	8	1904		
Motutara, Muriwai	0	0	298	209	-29.9	-1.0
Oaia I., Muriwai	338	892	761	25	-96.7	-8.8
Karewa (Gannet I.)	3715	6132	8003	5713	-28.6	-0.9
Totals	13,068	25,354	33,318	30,757	-7.6	-0.2

Even considering those birds not visible in the photographs taken in October 2016, estimated to be about 8% of the total Muriwai mainland population, the higher number of birds recorded in 2017 suggests that a sizeable proportion of the population did not breed in 2016, for whatever reason, or there was immigration from elsewhere. Being long-lived and slow reproducing, it is possible that some individual Australasian Gannets forego breeding in unfavourable years, sacrificing a potentially only small reproductive gain for long-term survival (Dobson & Jouventin 2010). This might also explain some of the other inter-annual irregularities recorded at Muriwai and Motutara (Figure 4). This needs further investigation.

Apart from the marked decline recorded on Oaia I., other notable declines were recorded at Horuhoru (-63 %), Sugarloaf in the Poor Knights group (-58 %), and Motutakapu and Motukaramarama islands in the Coromandel (-50 % and -45 % respectively). Lesser declines were recorded at several other sites, including within the Three Kings islands (-5 %). The declines in the colonies on Horuhoru, Motutakapu and Motukaramarama all occurred within the southern sector of the Inner Hauraki Gulf while, within the same region, numbers at Mahuki grew substantially and on Motuwi marginally. Within the southern Hauraki Gulf overall, there was minimal change between 1980 (9879 nesting pairs) and 2017 (9698 nesting pairs), a difference of -181 pairs, well within the likely counting errors in both surveys. Similarly, the decline on Sugarloaf is partly offset by an increase at the nearby High Peaks Rocks colony, leaving only a small net decline of -824 pairs. This also is well within the likely margin of error in detecting and counting nesting birds on these steep-sided, deeply fissured islands.

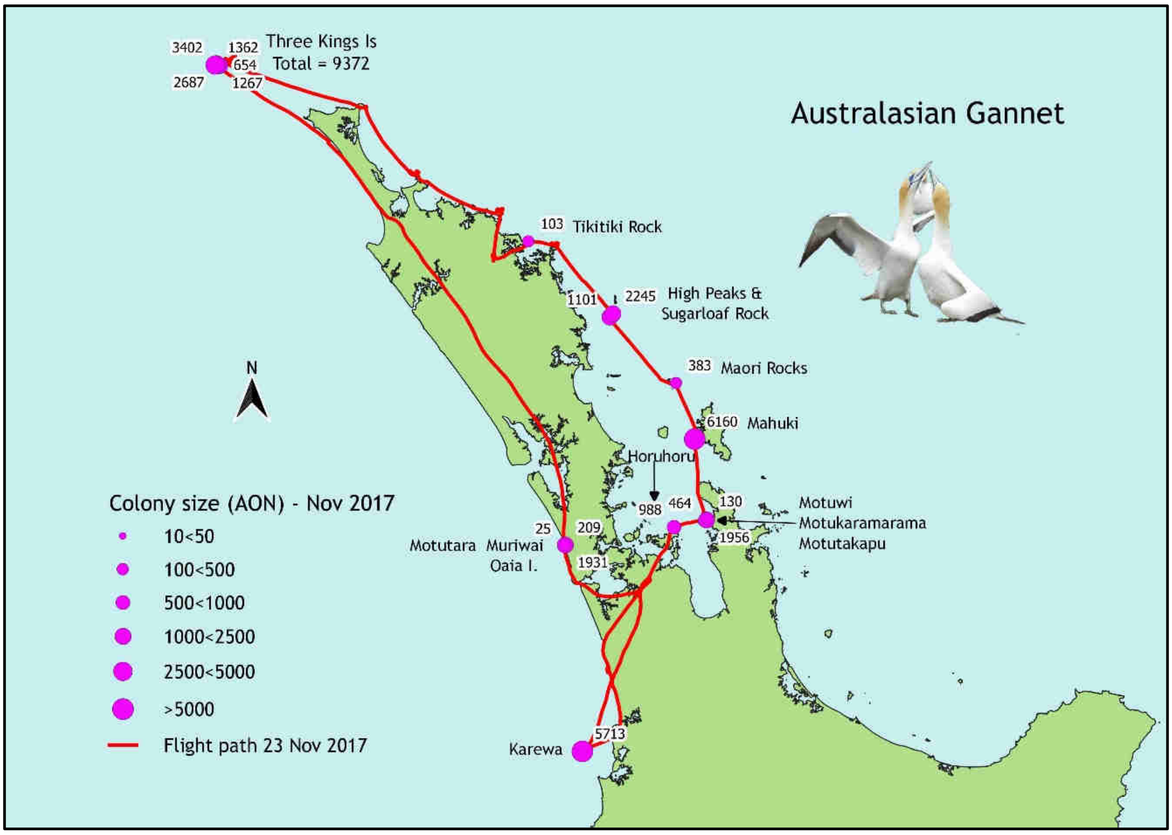

Figure 3. Location and sizes of Australasian Gannet colonies in northern New Zealand, November 2017. Islands in the Bay of Plenty were not surveyed.

The shifts among colonies noted in the Muriwai complex and inferred in the southern Hauraki Gulf and Sugarloaf/High Peaks colonies indicate another potentially important cause of change at individual colonies: inter-colony movements of breeding birds. It is not clear if established breeding birds will move to another colony, or if such relocation is led by new recruits to the breeding population establishing themselves at other colonies. Nevertheless, the data from the Muriwai complex indicate that such movements, at least locally, are real. Crawford et al. (2006) have documented large-scale southwards and eastwards shifts in the locus of the Cape Gannet (*Morus capensis*) population in Namibia and South Africa between 1956 and 2005. These were attributed primarily to changes in the distribution and abundance of the Cape Gannet's main fish prey species, sardine (*Sardinops sagax*) and anchovy (*Engraulis encrasicolus*). Whether the Australasian Gannet will undertake similar mass movements over large distances is not known.

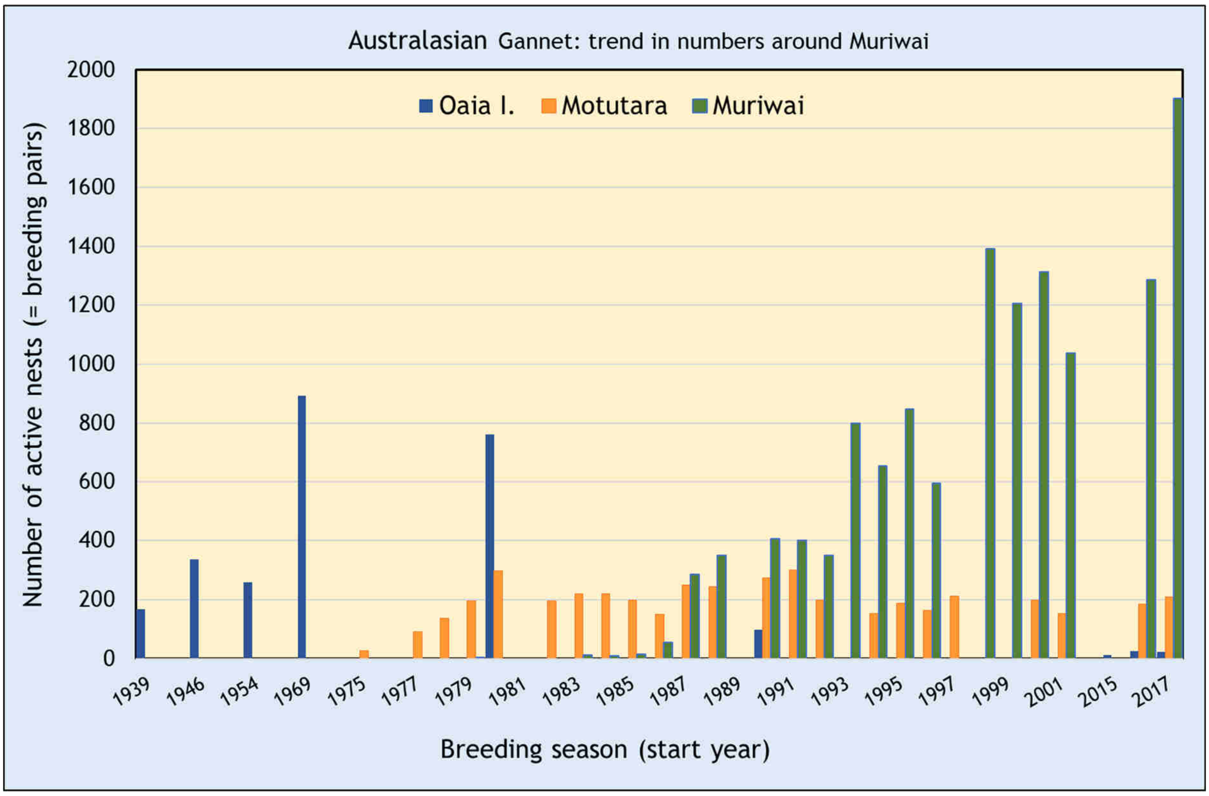

Figure 4. Changes over time in the reported number of pairs of Australasian Gannet nesting at three colonies around Muriwai: Oaia I., Motutara (Pillar Rock) and the Muriwai mainland (Otakamiro Point and Maukatia Cliffs). See text and Frost (2017) for the various sources of these data.

The possibilities of some birds skipping breeding in unfavourable years and moving among colonies, at least sub-regionally, makes any detailed discussion of long-term changes and trends somewhat speculative. Interpretations of change are further complicated by the long intervals between the four whole-population censuses—respectively 23, 11 and 37 years between 1946 and 2017[2]—as well as by the paucity, irregularity and uncertainty of the methods used in any intervening counts.

Overall, the northern North Island population, which in past years has constituted 62–72 % of the total breeding population of the Australasian Gannet in New Zealand, appears to be in good state. Nevertheless, several issues need further detailed work because they complicate attempts to institute a robust long-term monitoring programme. If inter-colony movements are common, then population monitoring will need to be done across the whole population, at least regionally, rather than focusing on only a few sites. This will increase the cost of monitoring, especially if colonies are surveyed more frequently to better understand their short-term dynamics and links to wider ecosystem processes, such as changes in fish abundance and quality.

[2] An aerial survey was also carried out in 2000 but, apart from the colony at Cape Kidnappers (Stephenson 2005), it appears that these were never analysed. Attempts to get the photographs for analysis have been unsuccessful.

Whereas the Australasian Gannet, like other sulids, is one of the easier seabird species to survey nationally, some thought needs to be given to the aims of such surveys and to whether whole-colony counts are adequate for addressing these. Past and present aerial surveys have clearly established the species' distribution and general population status within New Zealand, but may not be suitable for detecting gradual long-term trends driven by changes in the marine ecosystem (e.g., changes in fish composition and abundance, marine pollution, or ocean productivity driven by warming seas). Tracking such changes may be better done by monitoring reproductive performance of the birds at selected colonies (e.g., monitoring nesting success; chick growth and development; food delivery rates; diet; etc., assuming this can be done with minimal disturbance).

Red-billed Gull

Red-billed Gull colonies were found at 25 of 40 sites across the 37 islands or island groups covered in this survey (Table 2, Figure 5). Overall, 3172 apparently nesting pairs were counted (95 % confidence limits: 2736–3688). Almost 80 % of these pairs were located on the Three Kings Is. In addition to these nesting birds, just over 2500 other individuals were recorded in and around the Three Kings Is colonies, some of which would have been partners of nesting birds. A further 1685 birds were counted in six large aggregations roosting on the sea. This is likely to be an undercount because only those birds at sea close to the colonies were counted, most of them photographed inadvertently.

The counts of nesting pairs on the Three Kings Is were 43 and 129 % above the numbers counted in 2014 and 2015 respectively from aerial photographs taken during the national Red-billed Gull survey by Les Feasey. There is some uncertainty about the completeness of coverage of these two surveys so it is difficult to account for the differences if they are real. Nonetheless, the results of the present survey suggest that the Three Kings Is still support a substantial population of Red-billed Gulls. The high numbers reported in 1940s and 1950s may have been overestimates (Frost & Taylor 2018).

Another large aggregation of non-breeding birds was recorded off Rocky Island (1013 in four groups, two of which were feeding over fish boil-ups, plus 81 roosting on an islet). The status of these at-sea aggregations and even most of the additional birds at colonies is not known. Are they all immature or sub-adult birds, or are some of them mature birds that for some reason are skipping breeding? Red-billed Gulls start breeding on average only when 3-4 years old, and then not necessarily annually after that (Mills 1986), the number of pairs breeding annually varying with fluctuations in food supply (Mills et al., 2008, 2018).

Previously unreported colonies were recorded only at Mahuki (72 pairs) and Te Anaputa in the outer Cavalli Is (182 pairs). Larger than previously recorded numbers of nesting gulls were counted on the Sugarloaf and High Peaks Rocks, close to the Poor Knights Is. It is not clear if these latter increases are real or due to previous under-counting (or present over-counting). Both islands can only be surveyed from the air but, even then, locating and counting nesting gulls proved to be difficult because the islands are tall, steep-sided, and covered with broken boulders and deep fissures and hollows in which the gulls breed.

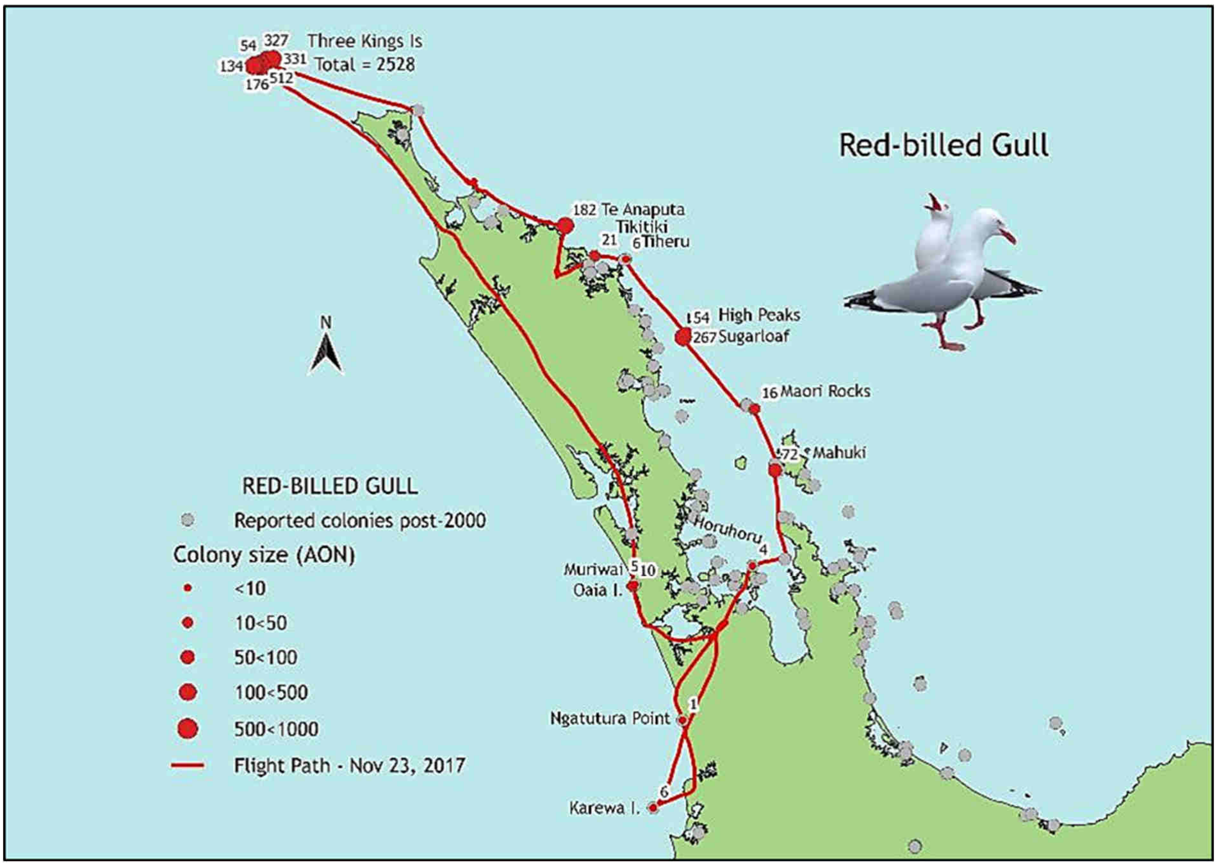

Figure 5. Locations and sizes of Red-billed Gull colonies in northern New Zealand recorded during the November 2017 survey, together with colonies reported since 2000

Red-billed Gulls proved to be difficult to locate consistently from the air. First, unless the nesting birds were well aggregated and relatively numerous, they were easily overlooked. It was only by going back through photographs taken of other more conspicuous species, such as Australasian Gannet, that some isolated nesting individuals of small groups were located. Others were likely missed. Second, even where a nesting colony was identified and photographed, it was difficult to be sure (a) which individuals were nesting (i.e., incubating eggs, brooding or guarding chicks); (b) which ones were standing guard over, or accompanying, a bird on a nest, especially if the latter was wholly or partly out of sight; (c) which ones were incipient pairs, but not yet nesting (i.e., standing together but with no visible nest nearby); and (d) which were sub-adults simply loafing in or around a colony.

At some colonies, the area within which the birds were nesting either contained numerous pale or guano-covered rocks or flowering vegetation that made it difficult to pick out birds sitting low down with only their heads visible. This was particularly noticeable at Crater Head and Patea Bay on Great I. in the Three Kings Group, where the birds were nesting in areas covered with what appeared to be flowering rengarenga (*Arthropodium cirratum*). Because of this, the full extent of these colonies was underestimated at the time. Counts were made later of nesting birds visible in the landscape-scale photographs taken of the general area, but because of potential confusion between nesting birds and similarly coloured inflorescences of rengarenga, there is likely to be considerable uncertainty in these counts.

Using the latest available data since 2000 for all known sites in northern New Zealand, this brings the estimated overall regional Red-billed Gull breeding population to 8343 pairs. Figure 5 shows the location of these colonies, the bulk of them recorded during the 2014–16 national Red-billed Gull survey. Most lie close to or along the mainland coast, but this could have been due to limited surveying of offshore sites, something that this survey set out to rectify. The results presented here, showing a relative paucity of colonies on offshore islands (except those on the Three Kings Group), suggests that the Red-billed Gull may primarily be a coastal species. This should make it easier to monitor breeding, because the colonies are more accessible.

More needs to be known about inter-colony movements of breeding pairs, and how stable some of the smaller colonies are. Observations made during the 2014–16 survey suggest that breeding at some of the smaller colonies is erratic, with birds either not breeding every year or moving to other breeding sites, including larger colonies. More needs to be known about whether Red-billed Gulls exhibit such fission-fusion dynamics before putting in place a robust and effective monitoring programme to track population change in this species. As with the Australasian Gannet, long-term monitoring may be better focused on tracking changes in the reproductive performance of birds at colonies, because this is likely to reflect environmental change, including the quality and abundance of food, more rapidly than such change filtering through to changing population numbers.

White-fronted Tern

A total of 1106 nesting pairs were recorded during this survey (95 % confidence intervals: 922–1290). Most of these were found in just two areas (Table 2, Figure 6). At the Muriwai complex 709 apparently occupied nests were counted, concentrated on Oaia I. (463 pairs) and on the Muriwai mainland (226 pairs); the small balance (20 pairs) was nesting on Motutara where suitable nest sites are limited. The other large concentration of breeding birds was on the Three Kings Islands (313 apparently occupied nests spread across seven sites: Table 2). The only other notable colony was at least 77 pairs nesting on stacks off Ngatutura Point.

Like Red-billed Gull, the White-fronted Tern is largely a coastal species (Figure 6). This may be reflected in the apparent paucity of nesting colonies found on the more isolated outer islands (as opposed to a group of islands such as the Three Kings Is). Only one relatively large aggregation of non-breeding birds was recorded, 134 on Mahenotakapu. Taking the latest estimates of size since 2000 for all known White-fronted Tern colonies, the current survey brings the overall regional breeding population to around 5025 pairs.

Because of their relatively small size, nesting White-fronted Terns are difficult to detect from the air unless the colony is reasonably large. November was probably also not the ideal time for censusing this species because, both from ground-level photographs taken at Muriwai the previous day to the aerial survey and for those colonies where the birds could be seen reasonably well from the air, it was obvious that many were feeding chicks. Once the chicks are more than a few days old, they leave the nest and may separate, so seeing one chick at one site and another elsewhere, raises the question of whether they are products of one nest or two.

There is some evidence of inter-annual shifts in colony location in the OSNZ Nest Record Card scheme and the Society's Classified Summarised Notes. It is not known if these are enforced, caused by disturbance or to early failure of a colony (White-fronted Terns breed close to the sea and appear to be particularly susceptible to flooding), or if colonies are established close to where food is most abundant in a particular year. A detailed study of colony dynamics in this species, both within and between years using individually marked birds, may help to understand the changes.

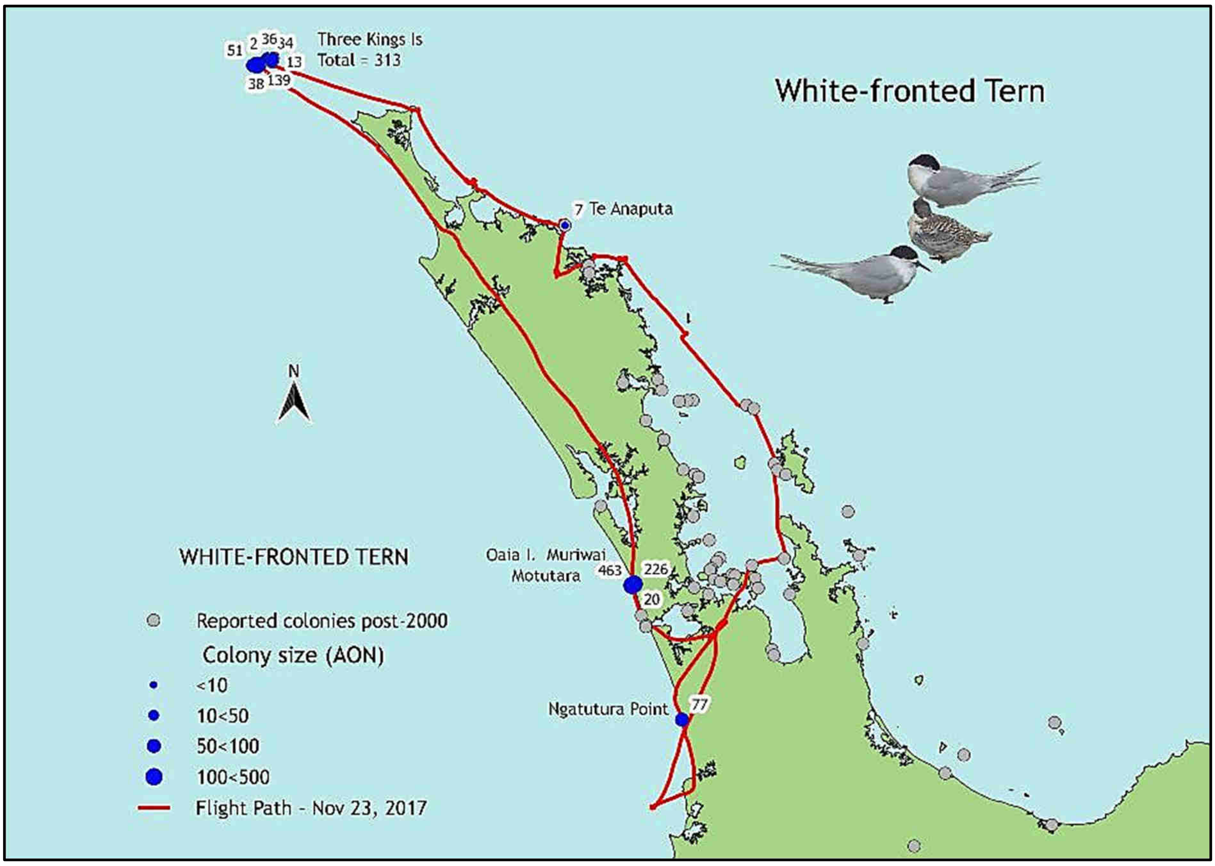

Figure 6. Locations and sizes of White-fronted Tern colonies in northern New Zealand recorded during the November 2017 survey, together with colonies recorded since 2000.

Other species

Buller's Mollymawk

A small population of Buller's Mollymawk (*Thalassarche bulleri*) was discovered nesting on Rosemary Rock in the Three Kings Islands in December 1983 (Wright 1984), and surveyed more completely the next season (1984/85), when 18 birds and 15 nests (13 occupied) were noted (McCallum et al., 1985). Since then, despite intermittent visits by scientists and birders, there has been no subsequent survey, so the present status of this population was unknown. The Department of Conservation had asked that this locality be surveyed. We flew past the islet four times at 156–250 m a.s.l. altitude (average 204 m) and 130–340 m distance (average 230 m). Although no mollymawks were seen on the rock or in the air at the time, later analysis of the photographs taken revealed 38 birds occupying 35 sites (34 with nesting birds: Figure 7). One vacant site was also identified (Frost et al., 2018).

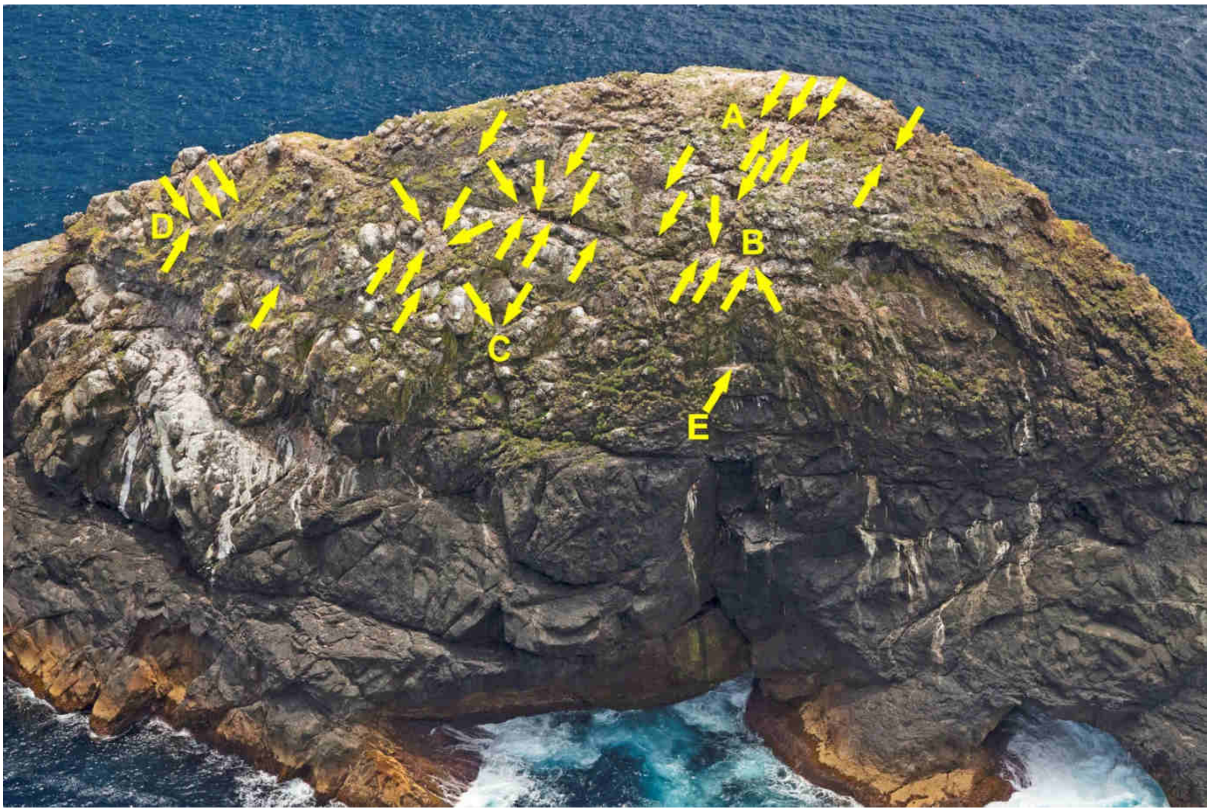

Figure 7. Locations of Buller's Mollymawk nests on Rosemary Rock, Three Kings Is. All nests were on the southern side of the rock (Red-billed Gulls and White-fronted Terns nested on the grassy northern slopes and along the crest of the island). A. The site of the first nests discovered in 1983 by A.E. Wright (1984), which are still being used; B–D, single sites occupied by pairs of birds; E, the only vacant nest site noted. (Photograph by Richard Robinson.)

Southern Black-backed Gull

Surprisingly few nesting Black-backed Gulls (*Larus dominicanus*) were recorded, although this could have been an artefact of the focus on the three key species. No large concentrations were seen, but if they had they would have been photographed. The largest colony was on Moturoa I. west of Cape Karikari, with nine nesting pairs and seven other individuals, assumed to be partners of the nesting birds. Elsewhere, Southern Black-backed Gulls appeared to nest solitarily. One pair was seen nesting on Kaitirehe Stack, and three were nesting on stacks off Ngatutura Point. No doubt there were some isolated nesting individuals at other surveyed sites but these were not noted or counted. As this is predominantly a coastal species, the larger colonies in which it is known to nest would have been bypassed in an aerial survey of offshore islands.

Pied Shag

A small colony of eight nesting Pied Shags (*Phalacrocorax varius*) was seen on a rocky stack off Ngatutura Point, alongside two nesting Southern Black-backed Gulls and an individual, non-nesting Black Shag (*Phalacrocorax carbo*).

Sooty Tern

A vagrant Sooty Tern (*Onychoprion fuscatus*) was seen on photographs of Rosemary Rock taken by Neil Fitzgerald. It was sufficiently unusual to warrant being submitted to Birds New Zealand's Record Appraisal Committee for review. The record was validated (UBR 2018/060) and constitutes only the ninth accepted record for New Zealand outside the Kermadec Islands since the mid-1980s.

Conclusion

The principal conclusion from this survey is that the Australasian Gannet population is little changed from that recorded during the last aerial survey, carried out 37 years previously. The small overall decline noted, just under 8 %, is likely to be within the margins of error of the two surveys. Nevertheless, there have been marked changes at some colonies, most notably increases at Muriwai (mainland) and Mahuki, and decreases at Horuhoru, Motutakapu and Motukaramarama in the southern Hauraki Gulf, and at Sugarloaf off the Poor Knights Islands. In all cases, these increases and declines roughly cancelled out each other. This implies that there has been substantial movement of birds among colonies, at least at sub-regionally, something that needs further study. The other conceivable explanation for annual variation in the numbers of breeding birds, the possibility that some pairs may forego breeding in unfavourable years, should also be investigated.

Two other species—Red-billed Gull and White-fronted Tern—were also surveyed. No major Red-billed Gull colonies were discovered, although two previously unreported small-to-medium sized colonies were found. The complex of colonies in the Three Kings Islands were resurveyed, following recent aerial surveys. The number of nesting birds recorded was 43–129 % higher than in the 2014 and 2015 surveys. It is not clear to what extent this is due to difference in coverage, detection efficiency (partly dependent on photograph quality), or to real interannual differences in the number of pairs breeding, perhaps in response to varying environmental conditions, including food abundance and nutritional quality. In addition to the number of breeding birds, some large aggregations of apparently non-breeding birds were recorded, both around the Three Kings Is colonies and elsewhere.

Few White-fronted Tern colonies were discovered. The largest aggregations were around Muriwai (mainland and nearby offshore islands) and on the Three Kings Islands, none of them individually particularly large. The largest of these would be classed as little more than medium-sized in comparison with size of other known White-fronted Tern colonies. Aerial survey, at least by aircraft, is probably not an efficient means of locating and censusing this species.

In addition to successfully completing the survey as planned, useful lessons were learnt about doing aerial surveys from small airplanes. The guidelines to the aerial survey of seabird colonies, prepared prior to the survey, were generally satisfactory but need modifying to take the following into account.

1. The ideal survey airplane should be one in which it is possible to photograph through open windows or a specially designed photographic port, or through an open door. The two photographers on the flight, both professionals, commented that the acrylic windows, although thoroughly cleaned beforehand, still marred the clarity of the images, something that was obvious when the images were examined later at high resolution. This did not make the images unusable, only more difficult to work with. The

requirements for being able to open the rear door of the Gippsland came too late to be resolve. These included the need for a wind deflector to be fitted; the additional drag and therefore increased fuel consumption during the time the door was open; and having a suitably qualified person to open and close a door in flight (which could mean a higher passenger load if an extra person was onboard, increasing fuel consumption and reducing the flight range). Opening the door in flight also requires CAA certification.

2. On-board communication was difficult because the intercom only worked between the pilot and the navigator. The photographers were not able to communicate directly with the pilot or the navigator, although they could communicate among themselves. Consequently, requests to fly around again, or to fly higher/lower/closer in/further out, were only communicable by a complicated series of hand signals. Moreover, the four-point safety harnesses worn by the pilot and navigator did not allow much lateral movement, such as turning around. The three-point, automotive-style harnesses worn by the passengers allowed more freedom of movement, but still did not make it easy for someone in the passenger seats to lean forward and communicate with the pilot. An air-survey aircraft should ideally have an auxiliary intercom system through which the photographers can communicate at least with the navigator. If not, then a small A4-sized whiteboard should be used to pass messages between the photographers and navigator/pilot.
3. The aircraft flew past or over the colonies faster than expected, especially apparent when flying only a few hundred metres or less from an island. This left little time for decision-making or adjustment. It emphasises the need for an initial look-see circuit, to plan how best to approach the definitive flypasts, so that everything necessary is photographed and documented. This also means being able to communicate these decisions to everyone onboard.
4. Overall, more time needs to be set aside for flying around the survey locations, both to locate colonies and to plan how best to photograph them. This has implications not only for total flying time (and therefore cost) but also for fuel consumption, given that the airplane is frequently banking, which requires additional power to maintain altitude under reduced lift. Increased fuel consumption compromises flight range, as we found out when having to land three times to refuel (partly also because of the number of people on-board likewise increased fuel consumption).

Aerial survey is the only cost-effective way of censusing certain surface-nesting seabirds on remote islands, but this need not necessarily mean surveys from airplanes. Consideration should be given to trialling the use of unmanned aerial vehicles (UAVs or drones). This is a rapidly advancing technology, including uses in the field of seabird monitoring (Sardà-Palomera et al. 2012, Hodgson et al. 2016). This capacity needs to be developed locally, including using professional drone operators who may be able to conduct such surveys more cost-effectively.

Finally, the present survey was geared primarily to locating and mapping the distribution of colonies, and broadly determining their size. But the uncertainties inherent in the counts make it unlikely that anything other than a dramatic collapse or increase can be rapidly detected. If the aim is to have early warning of population decline or if a species is being used to indicate the integrity and vitality of marine ecosystems, it may be better to focus on reproductive performance.

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