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The status of the red-billed gull (*Larus novaehollandiae scopulinus*) in New Zealand, 2014–2016

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Abstract A national survey of breeding red-billed gulls (*Larus novaehollandiae scopulinus*) was carried out during 2014–2016 to establish the present status of the species. Observers were asked to find and report all breeding colonies, starting with a check of previously reported breeding sites. Standardised means of conducting these surveys were developed, publicised, and largely applied. Around 27,831 pairs of red-billed gulls were recorded nesting in New Zealand during the survey: 14,713 pairs at 122 South Island sites; 12,676 pairs at 124 North Island sites; and 442 pairs at 14 sites on the Chatham Islands. Other than colonies on the Three Kings Islands (1,763 pairs) and Takapourewa/Stephens Island (1,250 pairs) there were no large concentrations on offshore islands. The largest mainland concentrations were at Kaikoura (3,210 pairs), Taiaroa Head (2,145), Rotorua (2,277) and Marsden Point (1,190). Although the accuracy of previous estimates is questionable, the red-billed gull nevertheless appears to have declined nationally since the mid-1960s. Possible reasons for the decline are discussed and a proposal for future monitoring of the species is proposed.

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Keywords red-billed gull; *Larus novaehollandiae scopulinus*; colony survey; breeding population; New Zealand

INTRODUCTION

The red-billed gull (*Larus novaehollandiae scopulinus*; taxonomy follows Gill *et al*. 2010) is currently classed in New Zealand as 'At Risk – Declining' (Robertson *et al*. 2017), despite being a widespread and seemingly common species nationwide. Its conservation classification reflects recent growing concern over an apparent marked decline in numbers nationally, especially at some of the historically largest colonies—Three Kings Islands, Mokohinau Islands, Kaikoura—notwithstanding some reported regional increases, such as in Otago (Perriman & Lalas 2012). Fifty years ago, a synthesis of the locations and reported sizes of known breeding colonies from the late-1800s to the mid-1960s led to an estimated national breeding population of around 40,000 pairs (Gurr & Kinsky 1965).

To update this figure and provide a firmer baseline for future threat assessments, Birds New Zealand, in conjunction with the Department of Conservation, organised a national survey over the period 2014–2016 to establish the size of the red-billed gull's breeding population. The overall goal of this study was to better understand the

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current population status of the red-billed gull in New Zealand, to build a solid foundation for future threat assessments, and to set a framework for more appropriate and effective conservation action, if needed.

Answers were sought to the following questions. What is the species' status nationally? Is the population declining, despite some local increases, or is it stable, but with the main population centres shifting, perhaps tracking changes in food supply? Are a few large breeding colonies being replaced by many smaller, more dispersed ones? What are possible reasons for any changes in status of the species? Accordingly, the study had the following five objectives: (1) locate and resurvey as many of the sites as possible where red-billed gulls had been reported breeding historically (Gurr & Kinsky 1965), to determine the nature and extent of any changes that may have occurred since; (2) beyond this, locate and survey as accurately as possible all currently active red-billed gull colonies in New Zealand; (3) collate and map the available information to provide an overall national estimate of the number and distribution of breeding pairs of red-billed gull in mainland New Zealand and the Chatham Islands; (4) along with observations made by participants in the survey and more generally, use this information to evaluate the likely reasons for any change in status of the species; and (5) based on the results of the survey, assess if a national monitoring programme, encompassing selected colonies countrywide, is needed to track long-term changes in the red-billed gull population.

MATERIALS AND METHODS

Survey approach

The survey was done in 2 stages: an initial scoping study followed by a more detailed survey. The scoping study, carried out during the 2014–15 breeding season (October 2014–February 2015), aimed to check all those sites listed by Gurr & Kinsky (1965) to determine which ones are currently still being used, as well as identify any new sites. Just under 61% of the 173 pre-1965 sites in mainland New Zealand and the Chatham Islands were surveyed during this phase. Of these, around half (50) were found still to be active. Reports were received of birds breeding at a further 131 sites, bringing the total number of known occupied sites to 181 (Frost & Taylor 2015).

The second phase was conducted during the 2015–16 breeding season. This was aimed at counting as accurately as possible the number of pairs of gulls breeding at each identified site. The total number of sites to be surveyed during the second phase was expanded to include sites brought to our attention after the scoping study together with information on sites found since 1965, as reported in the Ornithological Society of New Zealand's *Classified Summarised Notes* (CSN) for the period 1972–2005 (extracted by Emma Rowell, Department of Conservation). The final list also encompassed all unchecked pre-1965 sites, and those reported in 2014–15 as being inactive but which may simply reflect inter-annual variation in occupancy.

Observers were asked to find and report all breeding colonies of the species, starting with a check of previously reported breeding sites. A list of all 411 sites was drawn up, giving the name or location of each site, its geographic position in both standard latitude-longitude (WGS 84) and New Zealand Transverse Mercator (NZTM 2000) coordinates, and the species' status at these sites, where known (i.e. whether it has been checked during the past season; if it still supported breeding red-billed gulls; and, if known, the order-of-magnitude size of the colony).

This list was circulated to everyone who had provided information the previous year. As before, the list was also sent to all Birds New Zealand regional representatives and regional recorders with a request that they inform all local Birds New Zealand members of the survey and ask for their inputs. Department of Conservation field staff and many individuals were contacted by email, asking them to participate. Replies were sent to everyone who submitted information, indicating how this fitted into the broader picture. The aim was to stimulate as much further interest and activity as possible.

Information about the survey was publicised on the Birds New Zealand and BirdingNZ.net websites. This included links to the list of sites to be surveyed, and options to view the locations of sites either on NZ Topo Map (http://www.topomap.co.nz/) or on Google Earth, using a downloadable kml file. These allowed observers to zoom into a region to see the precise location of a site.

Survey methods

Guidelines on how to survey a colony were made available through the Birds New Zealand website. The guidelines covered direct counts (done by walking through a colony, although this was not recommended), scan counts (done from a distance either by telescope or binoculars), and counts from photographs, taken either from one or more points overlooking a site, or from a boat or aircraft. For those using photographs, instructions were also given on what to look for and how to count nesting birds systematically. In many cases, however, observers simply chose to submit their photographs uncounted; these were analysed by PGHF. This

Table 1. Numbers of occupied and vacant red-billed gull colony sites in New Zealand, 2014–16, together with the overall numbers of breeding pairs. The number of occupied sites includes discrete subsites within larger aggregations (see text for further explanation).

Region	Known sites	Number of sites checked	Number unoccupied	Number occupied	Number of pairs
North Island	288	214	90	124	12,676
South Island	205	181	59	122	14,713
Chatham Islands	27	22	8	14	442
Total	520	417	157	260	27,831

provided some consistency of interpretation as to which birds were counted as nesting, and which were not. The lack of complementary ground counts meant that no further adjustment could be made for birds on nests but not actually breeding. Copies of both the original and interpreted photographs are available on request through Birds New Zealand and the Department of Conservation.

The following information was requested for all colonies, where possible: (1) colony name (using an established name for the locality, if known); (2) geographic location (latitude/longitude or NZTM 2000 coordinates, obtainable either by GPS or from paper Topo 50 maps, or online at NZ Topo Map or from Google Earth); (3) date and time of census; (4) number of breeding pairs (equivalent to the number of active nests); (5) total number of red-billed gulls present (optional); (6) weather conditions at the time of the census; (7) name(s) of observer(s); (8) file name(s) of any relevant photographs; and (9) a sketch map of the area surveyed. A structured spreadsheet was sent to all Birds New Zealand regional representatives to ensure that their members' observations were recorded systematically.

The results were collated centrally. Colonies reported in 2014–15 but not surveyed in 2015–16 were included in the final analysis. For this, we used either the 2014–15 count, if made, or the mean colony size for the applicable size class, as estimated in 2014–15 (<10, 10<100, 100<1,000 breeding pairs), based on the mean colony size of the corresponding size class in 2015–16.

The nature of the site occupied by a colony was determined either from photographs or from Google Earth, using the geographic coordinates and descriptions of the sites provided by observers. Only broad categories of site and substrate were used. Islands larger than 6,000 ha (i.e. North and South islands, Stewart Island/Rakiura, Chatham Main/Rekohu, Great Barrier Island/Aotea, D'Urville Island/Rangitoto Ki Te Tonga, Waiheke Island, Pitt Island/Rangiauria, and 4 others) were treated as 'mainland'. The distance from land of the smaller islands (>1 ha) and stacks (<1 ha) on which red-billed gull colonies occur was measured on Google Earth to the nearest point on these larger land masses. Nearshore islands and stacks were defined as those <5 km from these land masses; those >5 km away were treated as being offshore. Measures of variation are given as ± 1 standard deviation.

RESULTS

Information was received on 417 sites across New Zealand, 42 of them previously unrecorded either by Gurr & Kinsky (1965) or in the CSN. Of these, 157 (38%) were unoccupied. The 260 occupied sites together supported at least 27,831 pairs of nesting red-billed gulls (Table 1). No reports were received from around 103 sites where gulls had previously been recorded breeding. Some of these are close to other locations where birds were breeding, and therefore were possibly vacant; not all observers clearly reported previously known but currently unoccupied sites.

Colonies of less than 50 pairs made up just over 61% of all those recorded, but contained only 10% of all breeding pairs. Colonies larger than 500 pairs made up under 5% of the total but supported around 42% of the red-billed gull breeding population.

At some sites (e.g. Three Kings Islands, Kaikoura, Sulphur Bay on Lake Rotorua) several colonies were located close to each other, with varying degrees of asynchrony among them in the prevalent stage of breeding at each. Historically, these sites have been referred to as if they were single large colonies. Fig. 1 shows the location where the aggregated numbers of breeding birds at such sites exceeded 500 pairs. At only 5 of the 10 sites were the breeding groups apparently reasonably coherent and are therefore treated as single colonies: Taiaroa Head

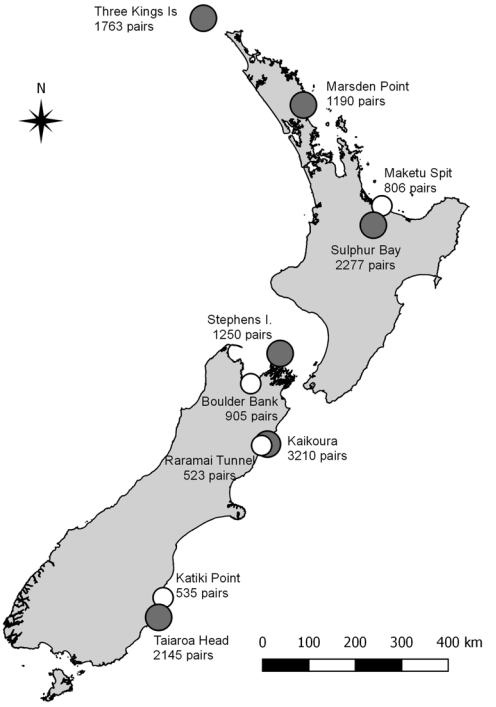

Fig. 1. Locations of the largest breeding aggregations (○ 500<1,000 pairs, ● >1,000 pairs) of red-billed gull in New Zealand, 2014–16. The aggregations on the Three Kings Islands, Sulphur Bay, Stephens I., Boulder Bank and Kaikoura all comprise a series of apparently discrete colonies close to each other but not necessarily nesting synchronously.

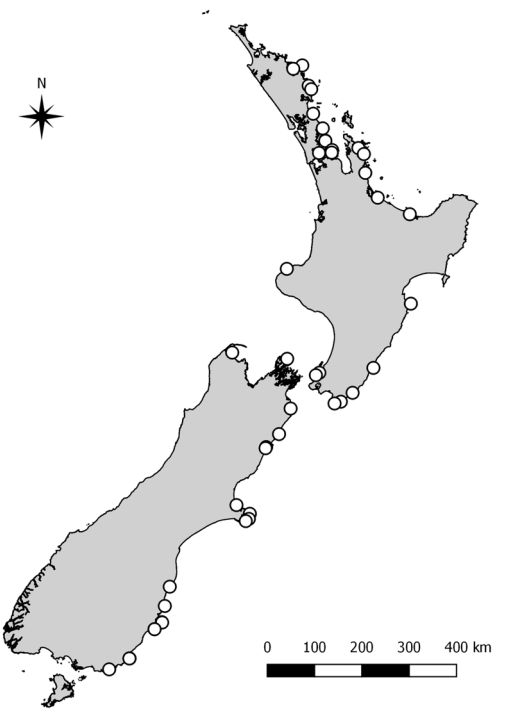

Fig. 2. Locations of medium-sized colonies (○ 100<500 pairs) of red-billed gull in New Zealand, 2014–16, showing a noticeable concentration of colonies along the eastern seaboard of New Zealand and an almost complete absence of such-sized colonies along the west coast. Note that some points overlie others nearby.

(2,145 pairs), Marsden Point refinery (1,190 pairs), Maketu Spit (806 pairs), Katiki Point (535 pairs) and Raramai Tunnel (523 pairs).

Overall, these large aggregations were well spaced through the country. Two were on offshore islands: Three Kings Islands (1,783 pairs across 18 colonies) and Stephens Island (1,250 pairs across 5 colonies). Except for Sulphur Bay on Lake Rotorua (2,277 pairs distributed among 7 colonies), 2 of the 3 other large colonies were on mainland coasts (Kaikoura, 3210 pairs in 11 colonies; Boulder Bank, 905 pairs in at least 3 discrete groups).

The locations of other sites are shown in Figs. 2-4. Apart from the cluster on Ngā Motu on the west coast at New Plymouth, all medium-sized colonies (100<500 pairs) were concentrated on the east coasts of both main islands (Fig. 2). In contrast, small- to medium-sized colonies (<100 pairs) were more widely distributed, including on the west coast of the South Island, but still none on the west coast of the North Island (Figs. 3 and 4).

Relatively few red-billed gulls nest on the Chatham Islands, in contrast to the numbers of other seabird species. Around 600 pairs bred there in 2014–15, distributed among 19 small colonies (Mike Bell and Tansy Bliss, *pers. comm.*), whereas only 302 pairs were recorded at 11 colonies in 2015–16, 1 of them a new site (Fig. 5). A further 8 sites, occupied in 2014–15, were vacant. Three sites, occupied by 140 pairs the previous season, were not checked in 2015–16. Taking these into account, around 442 pairs could have nested in the Chatham Islands in 2015-16. The largest colony, 136 pairs, was at Taupeka Point (150 pairs in 2014–15).

No red-billed gull colonies were found on the Auckland Islands or reported from any other New Zealand sub-Antarctic island. Small numbers of gulls (5–20 individuals) were seen in the various harbours and along the shorelines of the Auckland Islands but no nests were seen, nor was nesting suspected (Graham Parker pers. comm.). Up to 100 red-billed gulls were present in small groups on

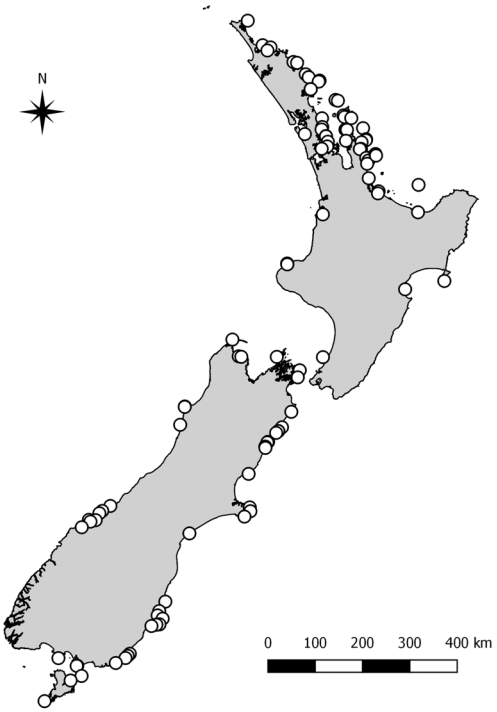

Fig. 3. Locations of medium-small sized colonies (○ 10<100 pairs) of red-billed gull in New Zealand, 2014–16. Although some are situated on the west coast of the South Island, most are still concentrated along the east coasts of both islands. Note that some points overlie others nearby.

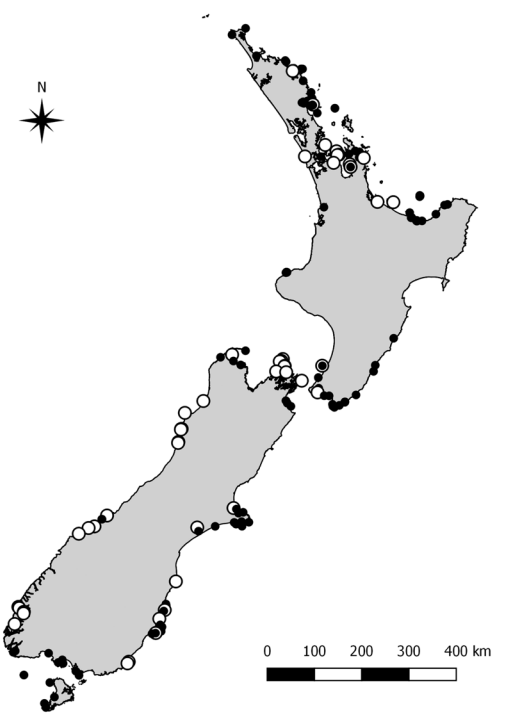

Fig. 4. Location of small colonies (○ <10 pairs) and known vacant sites (●) of red-billed gull in New Zealand, 2014–16. The locations of checked and reported historical sites where no nesting was recorded in 2014–16 are also shown.

Campbell Islands in 1984–87 (Graeme Taylor *pers. obs.*). Red-billed gulls in this region tend to nest solitarily and so breeding birds would be hard to find on precipitous cliffs or under rocks.

Just under 74% of all recorded breeding pairs occurred on the 2 main islands or other large nearby land masses (i.e. islands over 6,000 ha in extent; Table 2). Nearly 63% of these pairs nested on coastal cliffs or rocks. The other mainland breeding gulls were more-or-less equally partitioned among coastal sands or shingle (~11%); silica or salt flats (Rotorua, Lake Grassmere: 12%); and sites close to human habitation (industrial sites, harbours and town roofs: 12%).

Of those colonies on islands and stacks, about 64% were situated <5 km from the nearest large land mass, and contained around 45% of nests on such sites. The rest occurred on sites more than 5 km offshore (Table 2).

The sizes of colonies varied widely and non-systematically across these substrates and locations. Average colony size was largest amongst those colonies situated on salt/silica flats (mean ± 1 standard deviation: 485 ± 564 nests), but this is due largely to their small number and the influence of 2 large colonies at Sulphur Bay, Rotorua. Colonies on freshwater shorelines or islands were the smallest: 24 ± 16 nests. Mainland coastal sites had larger colonies on average (149 ± 295 nests), than either nearshore islands and stacks (40 ± 49 nests) or those further offshore (90 ± 140 nests).

Across all sites, median colony size (50th percentile) was less than 50 nests (Table 2). Nearshore sites comprised predominantly small colonies <100 nests (90th percentile, 99 nests: Table 3), in contrast to offshore sites, where colonies were generally larger (90th percentile, 383 nests: Table 3). There were relatively few inland mainland sites, made up of some small and a couple of large colonies, both situated on salt or silica flats. Coastal mainland sites generally contained the largest colonies, with just over 64% of all nests (Tables 2 and 3).

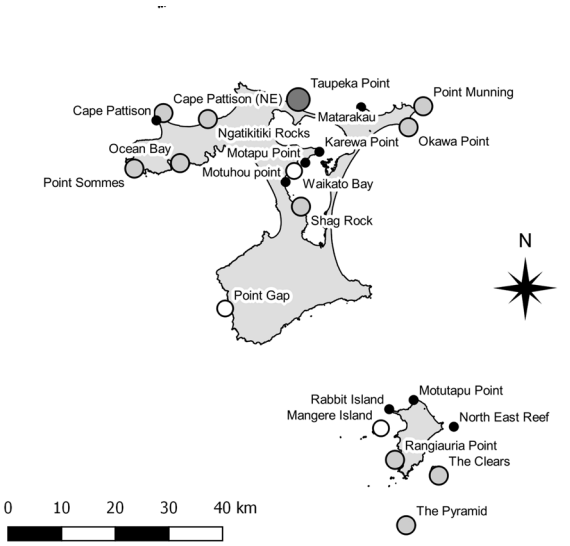

Fig. 5. Locations of active red-billed gull colonies on the Chatham Islands, 2014–16. Note that some sites active in 2014-15 were vacant in 2015-16. The relatively small size of the colonies is notable. Legend: ● 100<500 pairs, ● 10<100 pairs, ○ <10 pairs, ● vacant site in 2016.

Of the 103 sites for which no reports were received and which are assumed mostly not to have been checked, just under 72% were in the North Island, 23% in the South Island, and the balance in the Chatham Islands. Around 52% were mainland sites, mostly coastal ones, 31% on nearshore islands and stacks, and just under 17% offshore. Historical records for these sites, both from Gurr & Kinsky (1965) and the Ornithological Society of New Zealand's *Classified Summarised Notes* published in *Notornis* between 1972 and 2006, show that a few of these sites once supported reasonably large colonies of red-billed gulls. For example, Cape Brett, 300+ in the 1960s, > 2,000 in the 1970s; Rangiputa Bank, Rangaunu Harbour, 200-600 in the mid-1970s, but 50-100 in the decades on either side; Cuvier Island, 'hundreds' in 1950s, *c.*450 in 1979, but <10 pairs between 2001 and 2009 (Graeme Taylor *pers. obs.*); Flat Island, off Opito Point, Coromandel, 200 pairs in the 1960s; Motutara Island, Muriwai, c.200 pairs in the 1990s but <10 pairs in January 2017 (Graeme Taylor *pers. obs.*). Other non-surveyed sites had smaller numbers historically. There is no indication that these unsurveyed sites could still have similar numbers of breeding pairs, if any at all. If they did, this would likely have come to our attention as most such sites are close to others that were visited. Nevertheless, that they have not been surveyed introduces some uncertainty to the estimate of the numbers of red-billed gull currently breeding in New Zealand.

A comparison of the reported locations and relative sizes of red-billed gull colonies pre-1965 (Gurr & Kinsky 1965) and those recorded during the 2014-16 survey suggests that there are now more, generally smaller, colonies (Fig. 6, Table 4).

Table 2. Sizes of red-billed gull colonies across various percentiles show the colony sizes below which the given percentage of colonies occurs in each situation.

Percentile	Mainland (inland)	Mainland (coastal)	Nearshore (<5 km)	Offshore (>5 km)
25	16	15	6	15
50 (median)	37	47	15	34
75	81	142	53	103
90	650	333	99	206
100 (largest colony)	1,496	2,145	261	760
Number of colonies	12	120	83	45
Total number of nests	2,597	17,883	3,283	4,068

Table 3. Numbers of active red-billed gull colonies and nests in different situations on the two main New Zealand islands (and large adjacent ones) and on the Chatham Is.

	North Island			South Island			Chatham Islands			New Zealand
Colony situations	Checked	Active	Nests	Checked	Active	Nests	Checked	Active	Nests	Total nests
Offshore island (>5 km offshore; >1 ha)	35	27	2,156	11	8	1,705	1	1	11	3,872
Offshore stack (>5km offshore; <1 ha)	10	8	193	1	1	3	0	0	0	196
Nearshore island (<5 km offshore; >1 ha)	30	18	1,015	16	8	200	3	2	34	1,249
Nearshore stack (<5 km offshore; <1 ha)	50	23	992	47	31	1,030	2	1	12	2,034
Total offshore	*125*	*76*	*4,356*	*75*	*48*	*2,938*	*6*	*4*	*57*	*7,351*
Coastal cliffs and rocks	46	23	2,426	80	59	10,087	11	8	363	12,876
Coastal sands and shingle	9	4	1,071	10	6	1,137	0	0	0	2,208
Estuary sand islands	12	3	50	10	6	214	0	0	0	264
Freshwater shorelines and islands	5	4	147	3	1	1	5	2	22	170
Salt/silica flats	4	4	2,241	1	1	186	0	0	0	2,427
Harbours and breakwaters	8	7	910	2	1	150	0	0	0	1,060
Industrial sites (including roof tops)	5	3	1,475	0	0	0	0	0	0	1,475
Total on mainland	*89*	*48*	*8,320*	*106*	*74*	*11,775*	*16*	*10*	*385*	*20,480*
Total	214	124	12,676	181	122	14,713	22	14	442	27,831

DISCUSSION

The 27,831 pairs of red-billed gull recorded breeding in 2014–16 is substantially less than the 40,000 pairs estimated by Gurr & Kinsky (1965). Although some sites could have been missed, they are unlikely to have been large colonies, which we assume have all been found and counted. Given that adult birds do not breed every year (Mills 1989), the overall breeding population is probably larger than this, perhaps as much as 30,000 pairs.

Some allowance must be made for uncertainty in Gurr & Kinsky's (1965) overall figure, however, especially for many of the larger breeding aggregations. Aside from Buddle's (1943)

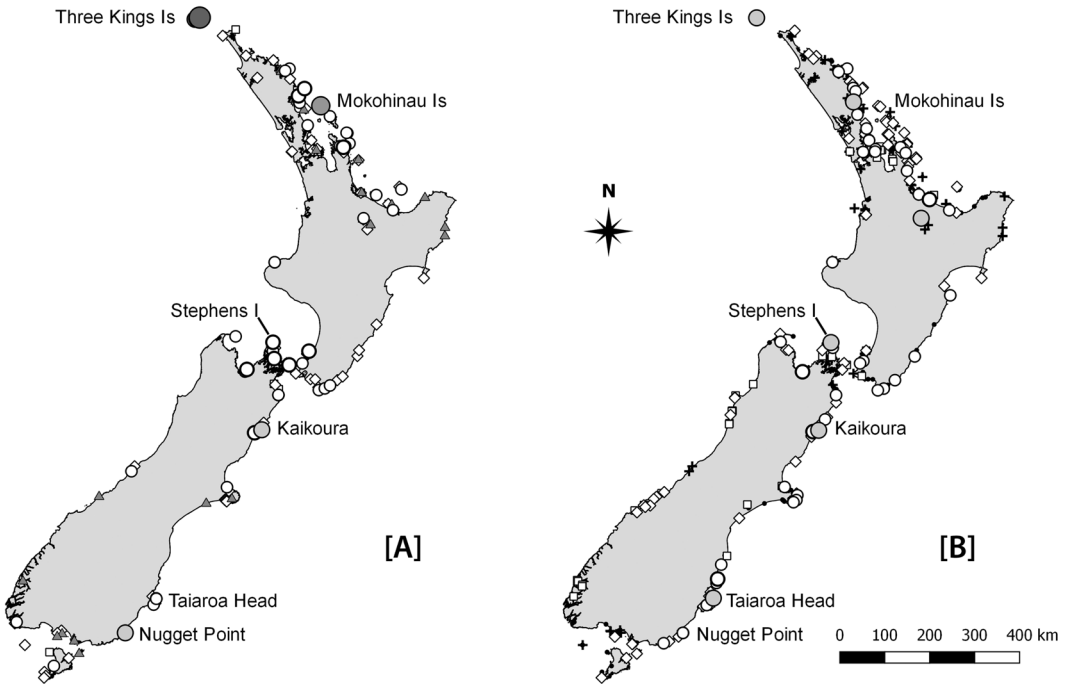

Fig. 6. Comparison of the number, distribution and relative size of reported red-billed gull colonies (A) prior to 1965 and (B) in 2014-16. Legend: ● >10,000 pairs, ● 5,000<1,000 pairs, ● 1,000<5,000 pairs, ○ 500<1,000 pairs, ○ 100<500 pairs, ◇ 10<100 pairs, □ <10 pairs, ▲ no estimate, • no nesting, + not surveyed.

Table 4. Numbers of reported red-billed gull colonies of varied sizes on the 2 main New Zealand islands (and large adjacent ones) prior to 1965 (Gurr & Kinsky 1965), and as recorded in 2014-16. These distributions differ significantly (χ^2, with Williams' correction, 14.833; d.f. = 3; p = 0.002), with proportionately more colonies of 100<1000 pairs and fewer colonies of <10 pairs prior to 1965, relative to those recorded in 2014-16.

Colony size class (number of pairs)	Number of recorded colonies	
	pre-1965	2014–16
<10	14	51
10<100	61	129
100<1,000	55	62
>1,000	6	4

photograph of part of a red-billed gull colony at the Eastern Blowhole Cliffs on Burgess Island, Mokohinau Group, showing about 113 incubating birds and reproduced in Wilson (1959) and by Ismar *et al*. (2014), we have been unable to locate any photographs of the large red-billed gull colonies reported at the time. Nevertheless, mapping of the colonies on Burgess Island by Fleming (1946) and further elaborated on by Buddle (1947), leaves little doubt that substantial numbers of gulls nested there at the time, estimated at 5,000-10,000 birds by Fleming (1946) and 13,000 birds by Buddle (1947). Gillham (1960, 1965) also referred to the presence of large numbers of red-billed gulls on Burgess Island in the late 1950s, although gave no figures.

A review of the Gurr & Kinsky (1965) data set shows that only 123 of the 166 colonies recorded for mainland New Zealand (i.e. excluding the Chatham and sub-Antarctic islands) had been reported as being active in the 15 years (1950-1965) preceding

their assessment. Even then, the records were patchy and numbers sometimes varied considerably at a site from one assessment to the next. It is also unclear to what extent this reflected actual year-to-year variations in colony size, as opposed to differences in the way observers counted or estimated colony size, or when in the breeding cycle the counts were made. In some cases, it is uncertain if the figures refer to the number of incubating birds, nesting pairs, or the total number of birds present at a colony, whether nesting or not. Around 20% of the estimates of colony size were purely qualitative ("large numbers", "hundreds", "several", "few"). Some simply noted that a colony was active. In brief, Gurr & Kinsky's (1965) estimate of 40,000 pairs must have wide confidence limits around it, even if it was made by 2 experienced researchers and informed by many equally knowledgeable contacts.

Concern about the present status and trends in red-billed gull numbers comes from indications of substantial declines at 3 locations that, historically, are reputed to have supported large numbers of breeding red-billed gulls. Tens of thousands of birds were reportedly breeding on the Three Kings Islands in the first half of the last century (summarised by Gurr & Kinsky (1965)). Buddle (1951) estimated as upwards of 100,000 birds in 1948. Even if exaggerated, this suggests numbers in the 10,000–100,000 range. Even as late as December 1995, R.J. Pierce reported 20,000+ birds around these islands (Parrish & Lock 1997). Estimates of the numbers of pairs breeding on the Mokohinau Islands in the late-1940s ranged from 2,000 to more than 6,500 pairs (Fleming 1946; Buddle 1947), with perhaps 20,000–30,000 birds overall (Buddle 1951; Wilson 1959). Finally, 9,212 pairs were recorded nesting at Kaikoura in 1988 (Mills *et al.* 2008).

These numbers contrast markedly with the total of 5,031 breeding pairs recorded in 2014–16 across all three sites: Three Kings Islands, 1,763; Mokohinau Islands, 58; Kaikoura, 3,210. Although numbers have increased at some other localities (e.g. Taiaroa Head, c.80 in 1963 [J. Allen cited by Gurr & Kinsky 1965] rising to 2,145 in 2015–16; Sulphur Bay, Rotorua, *c*.50–430 in the early 1960s [summarised by Gurr & Kinsky (1965)] to 2,277 in 2015–2016), overall numbers seem to have declined, perhaps by as much as 33% if the earlier estimate of 40,000 pairs is broadly accurate. Larger declines have been reported at individual sites (e.g. 51% at Kaikoura between 1983 and 2003: Mills 2013; Mills *et al*. 2018).

Apart from declines in the size of the largest colonies, other changes are also apparent. Before 1965, there were proportionally more colonies in the 100<1,000 pairs size range and fewer recorded with <10 pairs. Many more smaller colonies (<100 pairs) were recorded during 2014–2016 in the Hauraki Gulf, around the Coromandel Peninsula down to the Bay of Plenty, along the Otago and south-east Southland coasts, and along the west coast of the South Island, than prior to 1965. It is uncertain if this represents a real change in colony distribution and size towards more smaller colonies now, or if it is simply a result of more intensive searching for colonies during 2014–16. It is also unclear if, before 1965, observers always sought out and reported small colonies. We suspect not, so the pattern may be an artefact of past partial reporting. The relative paucity of large colonies on the west coasts of both islands is also puzzling. Other than on Ngā Motu, off New Plymouth, the west coasts generally only support clusters of medium-sized and small colonies. This could reflect a shortage of suitable sites for large colonies or less favourable feeding conditions offshore to support large colonies, or both.

What could be the reasons for the decline in the red-billed gull population overall? Predation by introduced mammals—rats (*Rattus rattus* and *R. norvegicus*), stoats (*Mustela erminea*), ferrets (*Mustela furo*) and cats (*Felis catus*)—is clearly a major threat to breeding birds (Mills 2013; Mills *et al*. 2018). Only one occurrence of possible mass predation came to our notice during the survey: 157 dead chicks and 40 dead adult red-billed gulls seen in close-up aerial photographs of one of the colonies at Sulphur Bay, Rotorua (there were still 106 other pairs nesting in this colony, most with small chicks). In the absence of autopsy, it is not possible to be certain of the cause of these deaths. From their splayed-out postures, they looked like shot birds, leading to an initial suggestion of human persecution, but the numbers of dead birds and their proximity to a lakeside walkway and other tourist attractions makes this unlikely. Only 1–2 dead gulls were seen in the nearby colonies, but these were further out from cover and surrounded by softer substrate. Predation seems the most probable cause.

Where there has been sustained pest control, such as some of the sites in Otago, most notably at Taiaroa Head, red-billed gull numbers have increased substantially (Perriman & Lalas 2012). Pest control, and the lack of disturbance by people and uncontrolled dogs, may also explain the large number of red-billed gulls nesting within the restricted zone of Marsden Point oil refinery (1,190 pairs). But some apparently declining colonies are on marine stacks that are either predator-free or where conditions do not favour pest persistence, even though some could arrive seasonally. Several correspondents either mentioned or asked about the possible impact of predation by southern black-backed gulls (*Larus dominicanus*), especially given the large apparent (but poorly documented) increase

in this species' population. More information on the nature and extent of predation as a prime cause of population decline in the red-billed gull is clearly needed from a wider range of sites.

Vegetation change on islands and at mainland sites supporting red-billed gull colonies could also affect gull numbers. Removing goats (*Capra hircus*) from Great Island in the Three Kings Group in 1946 resulted in substantial regeneration of woody vegetation (Cameron *et al*. 1987; Wright & Cameron 1990), potentially reducing the amount of open space for nesting gulls. Likewise, woody vegetation has expanded on several other protected islands: e.g. Kapiti Island (Esler 1967); Tiritiri Matangi (Cameron & Davies 2013); and Burgess Island in the Mokohinau Group (Ismar *et al*. 2014). Whereas this regeneration has increased habitat area and improved habitat quality for many other native species (Bellingham *et al*. 2010; Ismar *et al*. 2014), it must surely have detrimentally affected species that prefer nesting in open habitats. Although red-billed gulls nest under taupata (*Coprosma repens*) and other shrubs on several offshore islands, the density of nesting birds in these situations seems to be substantially less than that of birds breeding in the open. At least on the Three Kings Islands and Burgess Island, the declines in the islands' red-billed gull populations seem broadly coincident with the spread of woody plants. But there are still substantial areas of bare ground and inhabitable cliffs on these islands, suggesting that vegetation change, at best, may only be a partial factor. Moreover, we do not know the status of these populations before the original vegetation was cleared by settlers and regeneration was suppressed by goat and stock browsing. Did the red-billed gull population expand on these islands following partial clearance of the original vegetation cover, then decline as woody plants began to regenerate and spread? More broadly, it raises the question of whether red-billed gull numbers were always high historically, or if the population initially expanded during the last century in response to changes in land use, expansion of the fishing industry, and other human activities.

Human settlement and activity along much of New Zealand's coastline has grown considerably over the past 50 years. This could have disrupted breeding, either through disturbance or displacement, but there is no outright evidence for this, although the exact geographic location of most historical colonies is not known. On the contrary, some developments, such as the construction of harbours and marinas, seem to have provided new nesting sites (e.g. the rock walls of the Whangamata marina, 257 pairs; Whitianga marina, *c*.50 pairs; Tairua marina, 26 pairs).

Disturbance caused by human settlement and industrial development also does not seem to deter red-billed gulls from establishing large breeding colonies (e.g. Marsden Point oil refinery, 1,190 pairs; Tauranga Harbour timber wharf, 471 pairs; Sanford's slipway, St Mary's Bay, Auckland, 166 pairs; The Hub shopping-complex roof, Whakatane, 119 pairs). The breeding success of birds at these colonies is not known, however. It could be below that required to maintain the population, especially if adults are feeding themselves and their chicks on poor-quality food obtained around human settlements. For example, red-billed gulls feeding chicks on Mana Island can sometimes be seen flying to and from nearby Titahi Bay and Porirua City, 5–9 km away, where presumably they are feeding on scraps, possibly when food becomes harder to find at sea. The long-term dynamics of these urban and peri-urban colonies require more detailed study.

Although red-billed gulls are generalist feeders overall, breeding birds feed predominantly on *Nyctiphanes australis*, a coastal planktonic euphausiid (krill) (Mills *et al.* 2008). There are clear positive relationships between euphausiid availability and features such as gull body mass, number of pairs breeding, clutch size, egg volume, and number of chicks fledged per breeding pair (Mills *et al*. 2008). Euphausiid abundance 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). This index fluctuates over decadal timescales and may well drive variations in red-billed gull numbers. Whether it alone accounts for the multi-decadal decline in this species' population is questionable, unless the deficits incurred during periods of low krill availability cannot be offset by the gains in reproductive output during good years. The analysis of data from Kaikoura by Cury *et al*. (2011) suggested that this could be the case. It showed a near-asymptotic relationship between the normalised annual breeding success of red-billed gulls and normalised euphausiid availability, in which breeding success declined rapidly below long-term mean euphausiid abundance but rose only slowly above that point (Fig. 3 in Cury *et al*. 2011). Nevertheless, even within narrower ranges of euphausiid availability, there were large inter-annual variations in breeding success, suggesting the influence of other factors.

A long-term population decline may also reflect either progressive deterioration in ocean conditions (e.g. changing sea temperatures gradually negatively affecting ocean productivity) or some other unidirectional systemic change. Red-billed gulls are seldom recorded in seabird bycatch statistics (Richard & Abraham 2013; Pierre *et al*. 2015). Between 2003 and 2015 only 1 red-billed gull and 6 undetermined 'gull' or 'seagull' were noted among 7,623 seabirds reported in bycatch

statistics from New Zealand's exclusive economic zone (data available at https://psc.dragonfly.co.nz/ 2016v1/ released/explore/). Given that the red-billed gull is predominantly a coastal species, this is not surprising.

Several respondents wondered if the red-billed gull could be affected by changes in the stocks of those fish species that feed on krill and schools of small fish by forcing their prey close to the surface, creating 'boil ups', which in turn attract surface-feeding seabirds, including red-billed gulls. Shoaling fish such as kahawai (*Arripis trutta*), trevally (*Pseudocaranx georgianus*) and barracoota (*Thyrsites atun*), which feed in this manner, are targeted by New Zealand's purse-seine fishery. Any reduction in the incidence, extent or duration of 'boil ups' could potentially reduce the ability of foraging gulls and other surface-feeding seabirds to obtain sufficient high-quality food needed for optimal egg laying, incubation and chick rearing. If so, then long-term impacts on the birds could emerge through lowered breeding success, perhaps below the necessary replacement rate.

Around 100 fish species or species groups, including the above shoaling species, are fished commercially within catch limits set under New Zealand's Quota Management System. These stocks are widely considered by local fisheries managers to be sustainably managed, in that stock levels are at or close to maximum sustainable yield (MSY) (Ministry for Primary Industries 2016). For the above-mentioned species, the MSY target level is 40–52% of the unexploited stock (see the relevant plenary reports on these species at http://fs.fish.govt.nz/Page.aspx?pk=61&tk=212). But stocks can be lower than this, down to a 'soft limit', typically set at 50% of the target level. Fisheries managers still consider fish stocks within this range to be self-recoverable. Only below this lower limit would a stock be considered overfished, triggering a formal, time-bound plan for rebuilding it (Ministry of Fisheries 2011).

Currently, around 83% of managed fish stocks, including shoaling fish species, are judged to be above the 'soft limit' (Ministry for Primary Industries 2016). Although this may seem sustainable from a fisheries perspective, stock levels much less than half the original unexploited biomass could well be affecting other marine species indirectly, including perhaps by reducing the frequency, size and duration of ocean 'boil ups'.

The issue is further complicated because current stock levels are being estimated largely from data on catch and effort, the assumption being that there is an ongoing predictable relationship between the stock level and catch per unit effort (CPUE) (Dunn *et al*. 2000; Taylor 2014). There are few catch-independent estimates. But improvements in technology and skill at finding fish schools (e.g. fish-detection sonar, use of spotter planes, increased boat size and speed) may enable purse seine fishers to maintain high catch rates without much apparent increase in 'effort' (measured as the time spent with nets in the water), perhaps even as a stock is declining. This can confound the relationship between CPUE and abundance over time (Taylor 2014), rendering questionable stock assessments based on catch data alone. These wider issues need more research.

Future directions

The red-billed gull is a long-lived species. Maturity is delayed and individuals do not necessarily breed every year (Mills 1989; Mills *et al*. 2018). In any one year, this produces a mix of immature, sub-adult and non-breeding adult birds alongside those adults that are breeding. Because of this large pool of non-breeding birds—up to half the number of birds at a colony (Mills 1989)—simple counts of the number of individuals present may not accurately reflect the size of a breeding population or, at least in the short term, its dynamics. The only reliable measures are counts of the number of active nests in a season, which generally require several visits to cover variation, together with counts of the number of fledged chicks, to provide a measure of productivity, ideally repeated over many years.

Apart from Dr J.A. Mill's ongoing long-term study of the red-billed gull population at Kaikoura (e.g. Mills 1989; Mills *et al.* 2008; Mills *et al*. 2018) and the more recent regular monitoring of some colonies in Otago (Perriman & Lalas 2012), there have been no consistent long time-series counts of red-billed gull numbers at breeding colonies. Instead, most counts have been sporadic or inconsistent in how and when the colonies were counted, and in what numbers were being reported. Because of this, broader long-term trends and their likely causes are difficult to discern.

Regular nationwide surveys of the red-billed gull population, such as this one, are both costly and complex to do. It may be more feasible to select and closely monitor several representative colonies around the country, including some nearshore and offshore sites, using standardised methods and agreed definitions of what to monitor. The approaches adopted during this study provide a starting point. Exactly which colonies to monitor will need to be decided in consultation with those who commit to carrying out the surveys. The key questions to answer for each monitored colony and overall are: what are the intra- and inter-annual variations in the numbers of nesting red-billed gulls? What is the corresponding variation in breeding success? What are the long-term trends?

A central repository for the data is also needed. One option could be to use eBird as the repository (http://ebird.org/content/newzealand/), as promoted by Birds New Zealand for bird monitoring more generally. But based on experience gained in this study, for this to be effective, it will need someone or a team committed to reviewing the incoming information and provide feedback and encouragement to those submitting it. Rapid feedback is important if third-party monitoring is to be sustained for more than a few years. Without this, it will be difficult to get a sufficiently long and consistent time-series of data on which to start unravelling this long-lived, slow-reproducing species' dynamics nationally.

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