Report on the National Red-billed Gull Survey, 2014-2016

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Abstract

The red-billed gull, *Larus novaehollandiae scopulinus*, is classed as Nationally Vulnerable in New Zealand because of an apparent decline in numbers nationally, especially at some of the largest colonies, and despite some reported regional increases, such as in Otago. A synthesis of known breeding colonies from the late-1800s to the mid-1960s, published in 1965, estimated a national breeding population then of around 40,000 pairs. To update this figure, Birds New Zealand, in conjunction with the Department of Conservation, carried out a national survey during 2014-2016 to establish the current size of the red-billed gull breeding population. Observers were asked to find and report all breeding colonies of the species, starting with a check of previously reported breeding sites. Standardised means of conducting these surveys were developed, publicised, and largely applied. This report summarises the results of this survey and its implications. An estimated 27,831 pairs of red-billed gulls nested in New Zealand in 2014-16 (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 Is (1763 pairs) and Takapourewa/Stephens I. (1250 pairs) there are no large concentrations on offshore islands. The largest mainland concentrations are at Kaikoura (3210), Taiaroa Head (2145), Rotorua (2277) and Marsden Point (1190), some of these close to human habitation. Among the many factors potentially adversely influencing the red-billed gull population, predation and disturbance at breeding colonies, although prevalent, may be less important than changes in food availability offshore during the breeding season. A plan for long-term monitoring of the red-billed gull population is needed beyond the 50-year study ongoing at Kaikoura and the more recent surveys at some colonies in Otago. The red-billed gull is a long-lived, slow-reproducing species in which individual adults do not necessarily breed every year, so any long-term population change is more likely to be revealed by surveys carried out over many years, than by unsystematic counts done at long and irregular intervals. Nationwide surveys, such as this study, are too costly and complex to be done sufficiently regularly to provide accurate and timely information on major population changes. Instead, Birds New Zealand, in conjunction with others, needs to identify several representative colonies around the country, including some nearshore and offshore sites, that are reasonably accessible and for which teams of volunteers are willing and able to survey several times a season over many years using comparable and consistent methods.

Introduction

The red-billed gull, *Larus novaehollandiae scopulinus*, is currently classed as Nationally Vulnerable (Robertson et al. 2013), despite being a widespread and seemingly common species in New Zealand. 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 Is, Mokohinau Is, 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 estimated a 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 current population status of the red-billed gull in New Zealand, to build a solid foundation for future threat assessments and set a framework for more appropriate and effective conservation action, if needed. It was underpinned by 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.
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.
5. Based on the results of the survey, assess if a national annual monitoring programme, encompassing selected colonies countrywide, is needed to track long-term changes in the red-billed gull population.

The survey was done in two 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 Is 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, bring 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.

This report details the steps taken to carry out the survey, the overall results, and some discussion on these and their implications. We conclude with some suggestions for the way ahead.

Methods

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 given 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 (RRs) and Regional Recorders who were ask to inform all local BirdsNZ members of the survey and ask for their inputs. Most RRs either organised, or encouraged others to organise counts of the colonies in their region. Some did the surveys themselves. 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 in to 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 (see National Red-Billed Gull Survey / Phase 2: October 2015 - January 2016 and National Survey of Red-billed Gull, 2014-2016 respectively). This included links to the list of sites to be surveyed, and options to view the locations of sites either on NZ Topo Map or on Google Earth, using a downloadable kml file. These allowed anyone interested to zoom into a region to see the precise location of a site.

Guidelines on how to survey a colony were also developed and made available through these sites (see http://osnz.org.nz/sites/osnz.org.nz/files/Guide_to_Counting_RBG.pdf). The guidelines covered direct counts (done by walking through a colony although 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 aeroplane. For those using photographs, instructions were also given on what to look for and how to count nesting birds systematically. In most cases, however, observers simply chose to submit their photographs uncounted. These were then analysed by PGHF. This provided some consistency of interpretation as to which birds were taken to be nesting, and which were not. 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.

- *Colony name* (using an established name for the locality, if possible);
- *Geographic location* (latitude/longitude or NZTM 2000 coordinates, obtainable either by GPS or from paper Topo 50 maps, or online at http://www.topomap.co.nz/ or from Google Earth);
- *Date and time of census*;
- *Number of breeding pairs* (equivalent to the number of active nests);
- *Total number of red-billed gulls present* (optional);
- *Weather conditions* at the time of the census;
- *Name(s) of observer(s)*;
- *File name(s) of relevant photographs*;
- *A sketch map of the area surveyed*.

A structured spreadsheet was sent to all RRs to record their observations systematically.

For people planning to take aerial photographs of gull colonies, a spreadsheet calculator was developed to assist in determining the optimum height (or distance) from which to take the photographs, contingent on the make and model of the camera being used and the focal length of the lens. These determine the size of the sensor and the camera resolution, and hence the field of view and the ground area being covered, both in total and by each pixel. The aim was to ensure that each nesting gull would fill 1000–3,000 pixels, at which resolution it would be clear if the bird was nesting. (Lower resolution images could be, and sometimes were, interpreted but with much greater uncertainty.)

The results were collated centrally. Colonies reported in 2014-15 but not surveyed in 2015-16 were included in the final analysis, using either the 2014-15 count, if made, or the average colony size for the applicable size class estimated in 2014-15 (<10, 10<100, 100<1000 breeding pairs), based on the corresponding size classes 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 6000 ha (i.e. North and South Is, Stewart I./Rakiura, Chatham Main/Rekohu, Great Barrier I./Aotea, D'Urville I./Rangitoto Ki Te Tonga, Waiheke I., Pitt I./Rangiauria, and four others others) were treated as 'mainland'. The distance offshore 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

Around 166 people provided information on 417 sites across New Zealand, 42 of them previously unrecorded. Of these, 157 (38%) were unoccupied. The 260 occupied sites together supported at least 27,831 pairs of nesting red-billed gulls (Table 1). Some of the sites supported several discrete colonies, with varying degrees of asynchrony among them in the prevalent stage of breeding in each colony. No reports were received from

around 103 sites where gulls had previously been recorded breeding. Some of these are close to others 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, whereas colonies larger than 500 pairs made up under 5% of the total but supported around 42% of the red-billed gull breeding population.

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

At some sites, several colonies were located close to each other. Historically, these sites have been referred to as if they were single large colonies. Figure 1 shows the location where the aggregated numbers of breeding birds at such sites exceeded 500 pairs. At only five of the ten sites were the breeding groups apparently reasonably coherent and are therefore treated as single colonies: Taiaroa Head (2145), Marsden Point refinery (1190 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 Is (1783 pairs across 18 colonies) and Stephens I (1250 pairs across five colonies). Except for Sulphur Bay on Lake Rotorua (2277 pairs distributed among seven colonies), the others were all on mainland coasts.

The locations of other sites are shown in Figures 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 (Figure 2), perhaps reflecting a shortage of suitable sites for large colonies and less favourable feeding conditions offshore. 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 (Figures 3 and 4).

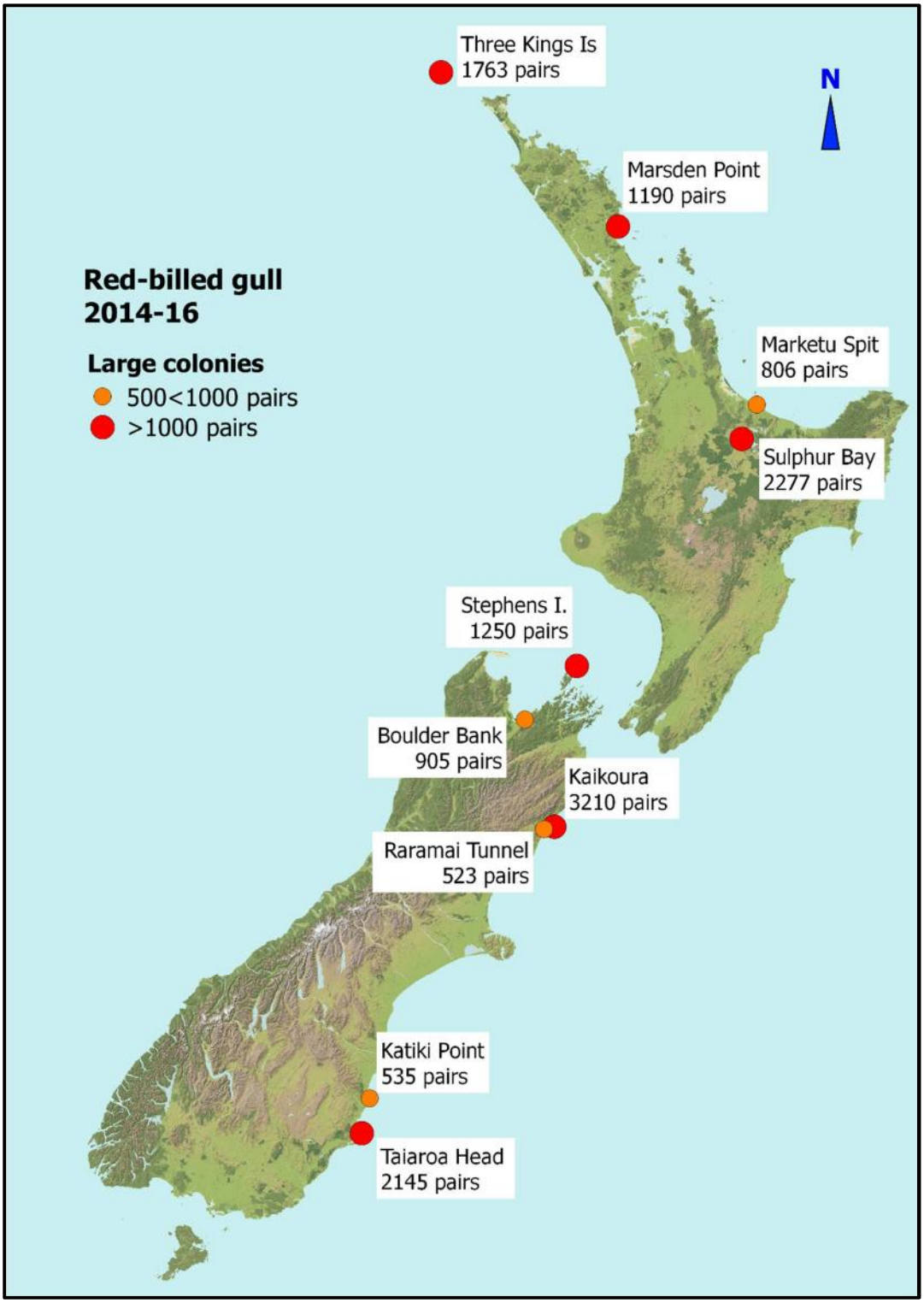

Figure 1. Locations of the largest breeding aggregations (>500 pairs) of red-billed gull in New Zealand, 2014–16. The aggregations on the Three Kings Is, Sulphur Bay, Stephens I., Boulder Bank and Kaikoura all comprise a series of apparently discrete colonies close to each other but not necessarily nesting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

Figure 2. Locations of medium-sized colonies (100<500 pairs) of red-billed gull in New Zealand, 2014–16. This shows 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. Not all sites are named and some points overlie others nearby.

Figure 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. Not all sites are named and some points overlie others nearby.

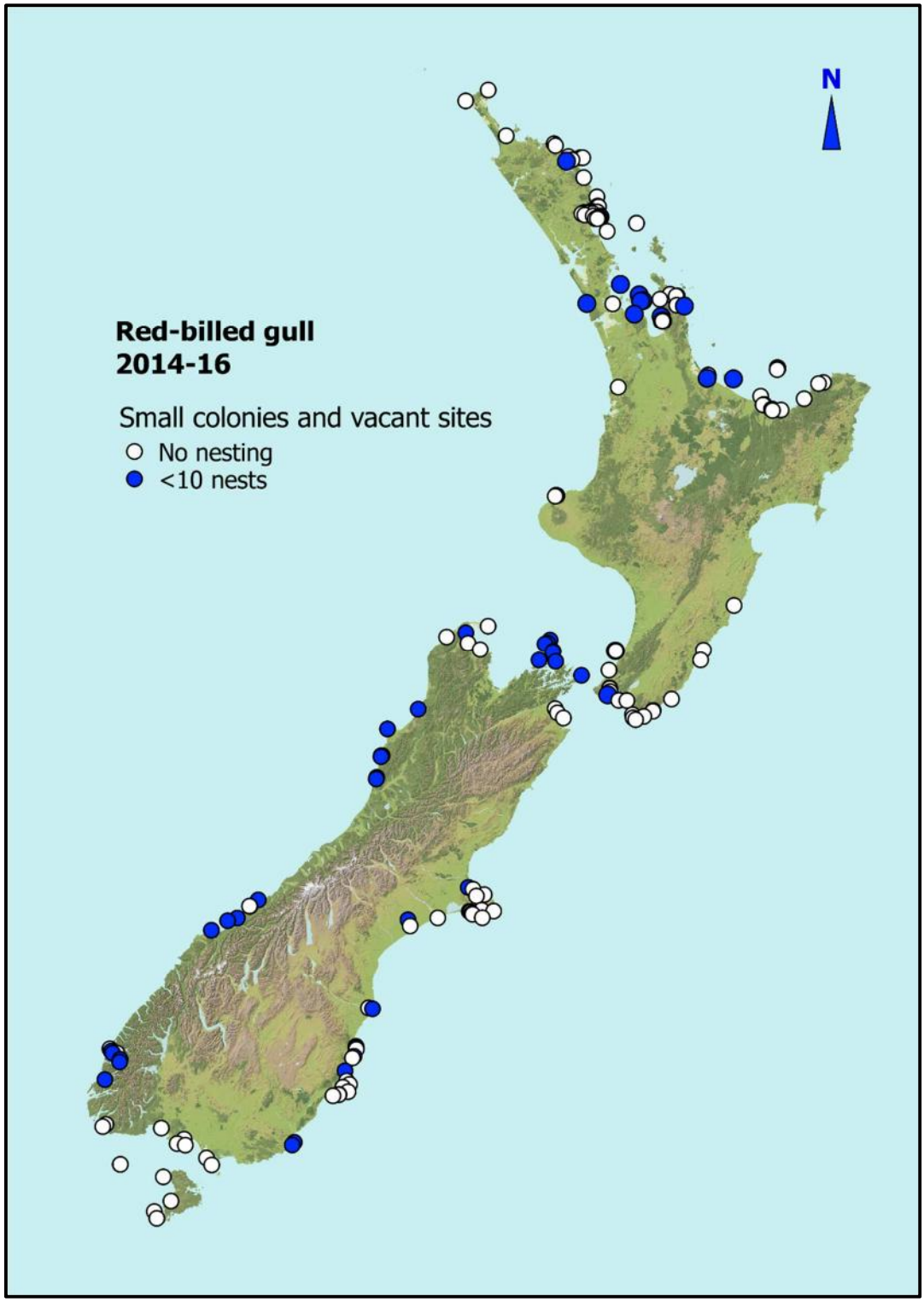

Figure 4. Location of small colonies (< 10 pairs) of red-billed gull in New Zealand, 2014–16. The locations of checked and reported historical sites where no nesting was recorded in 2014–16 are also show.

Relatively few red-billed gulls nest on the Chatham Is, in contrast to the numbers of other seabird species. Around 599 pairs bred there in 2014–15, distributed among 19 small colonies (Mike Bell and Tansy Bliss, pers. comm.), whereas only 302 were recorded at 11 colonies in 2015–16, one of them a new site (Figure 5). A further eight 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 Is in 2015-16. The largest colony, 136 pairs, was at Taupeka Point (150 pairs in 2014-15).

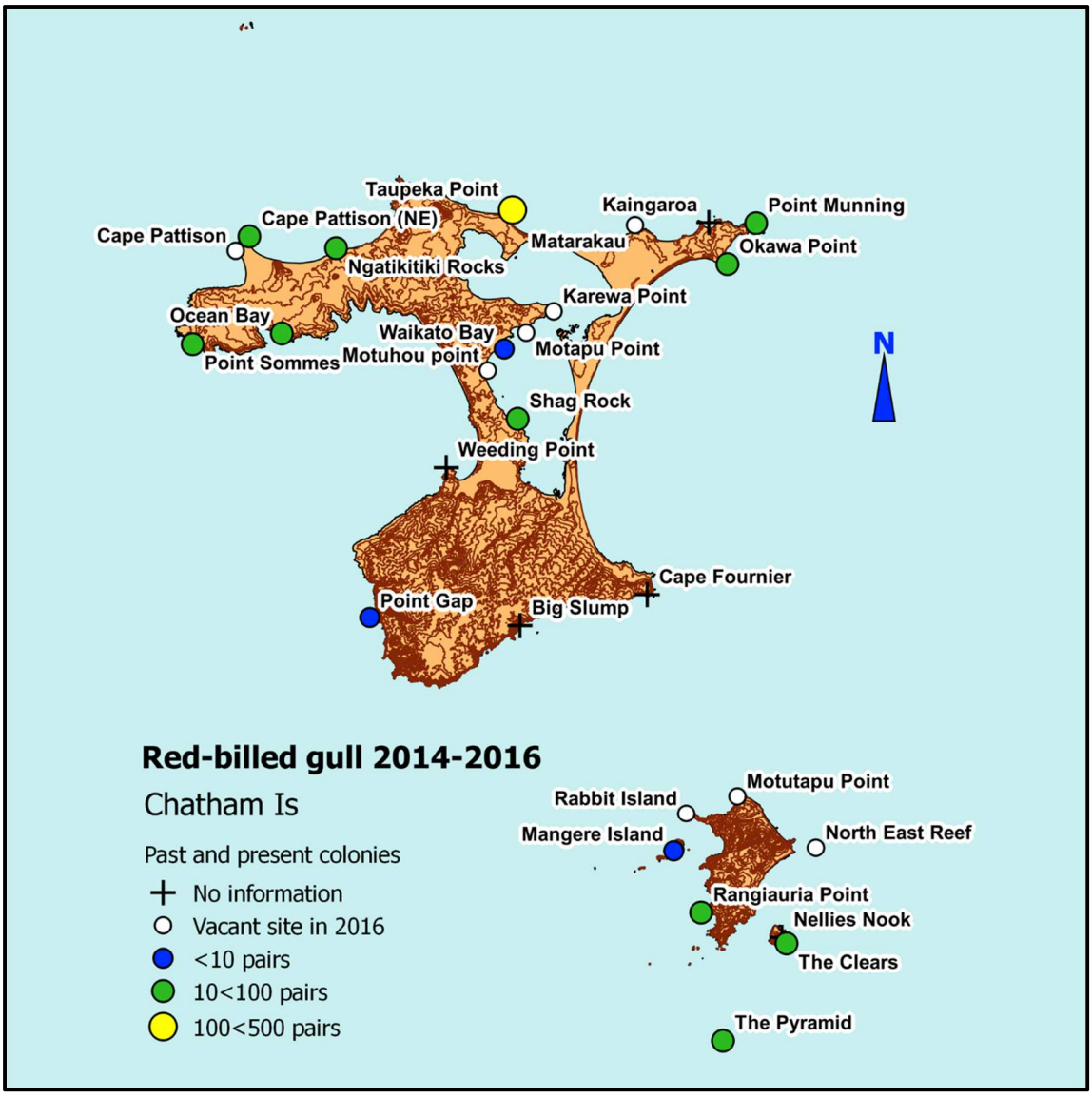

Figure 5. Locations of active red-billed gull colonies on the Chatham Is, 2014–16. Note that some sites active in 2014-15 were vacant in 2015-16. The relatively small size of the colonies is notable.

No red-billed gull colonies were found on the Auckland Is or reported from any other sub-Antarctic island. Small numbers of gulls (5–20 individuals) were seen in the various harbours and along the shorelines of the Auckland Is but no nests were seen, nor was nesting suspected (Graham Parker pers. comm.). Red-billed gulls in this region tend to nest solitarily and so would be hard to find on precipitous cliffs or under rocks.

Just under 74% of all recorded breeding pairs occurred on the two main islands or other large nearby land masses (i.e. islands over 6000 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%); 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 among those colonies situated on salt flats (mean ± 1 standard deviation: 485 ± 564 nests), but this is due largely to their small number and the influence of two large colonies at Sulphur Point, 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 (Figure 6). 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 flats. Coastal mainland sites generally contained the largest colonies, with just over 64% of all nests (Figure 6, Tables 2 and 3).

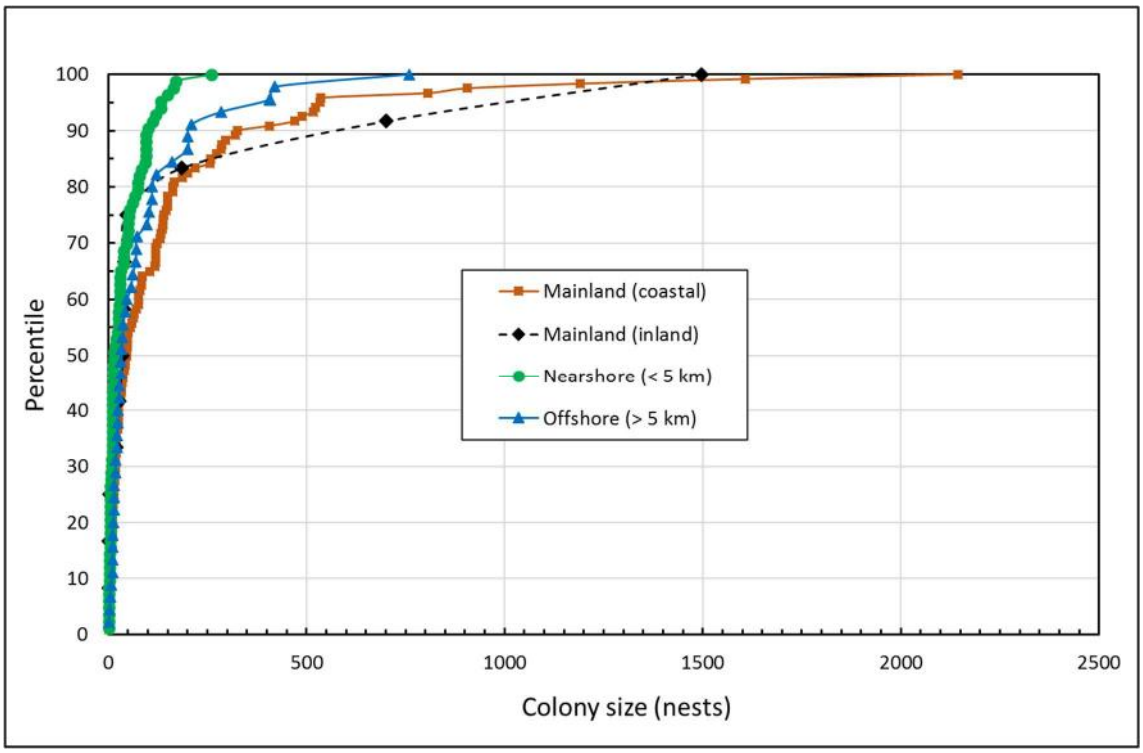

Figure 6. Frequency distribution of different-sized colonies across four main colony positions.

Table 2. 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**	**All 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 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**

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.

	Colony situation			
Percentile	Mainland (coastal)	Mainland (inland)	Nearshore (< 5 km)	Offshore (> 5 km)
25	15	16	6	15
50 (median)	47	37	15	34
75	142	81	53	103
90	333	650	99	206
100 (largest colony)	2,145	1,496	261	760
Number of colonies	120	12	83	45
Total number of nests	17,883	2,597	3,282	4,068

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 I., 23% in the South I., and the balance in the Chatham Is. 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 consolidated 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 19060s, > 2000 in the 1970s; Rangiputa Bank, Rangaunu Harbour, 200-600 in the mid-1970s, but 50-100 in the decades on either side; Cuvier I., 'hundreds' in 1950s, c.450 in 1979; Flat I., off Opito Point, Coromandel, 200 pairs in the 1960s; Motutara I., Muriwai, c.200 pairs in the 1990s. 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 our assessment of the current breeding population of the red-billed gull in New Zealand and this needs to be borne in mind.

Discussion

The 27,841 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 and Kinsky's 1965 figure, however, especially for many of the larger breeding aggregations. A review of their 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 are patchy and sometimes varied considerably at a site from one assessment to the next.

It also is not clear to what extent the numbers reported by Gurr & Kinsky (1965) reflect actual year-to-year variations in colony size, as opposed to differences in the way observers counted or estimated colony size. 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 the 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 estimate of 40,000 pairs must have wide confidence limits around it, although it was made by two well-informed researchers with broad experience and many equally knowledgeable contacts.

Concern about the present status and trend in red-billed gull numbers comes from indications of substantial declines at three 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 Is in the first half of the last century (summarised by Gurr & Kinsky 1965), 2000–6500+ pairs on the Mokohinau Is in the late-1940s (Fleming 1946, Buddle 1947, Wilson 1951), and 9212 pairs nesting at Kaikoura in 1988 (Mills et al. 2008). These numbers contrast markedly with the total of 5031 breeding pairs recorded in 2014–16 for these sites: Three Kings Is, 1763; Mokohinau Is, 58; Kaikoura, 3210. 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 2145 in 2015–16; Sulphur Bay, Rotorua, c.50–430 in the early 1960s [summarised by Gurr & Kinsky 1965] to 2277 in 2015–2016), overall numbers seem to have declined, perhaps 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 2005: Mills 2013).

What could be the reasons for this decline? Predation by introduced mammals (rats, stoats, ferrets and cats) has been cited as a major threat to breeding birds (Mills 2013). Significantly perhaps, the substantial population growth recorded in Otago over the past few decades coincided with increased predator control at some of these sites, most notably at Taiaroa Head (Perriman & Lalas 2012). Pest control may also explain the large number of red-billed gulls nesting within the Marsden Point oil refinery (1190 pairs). But some apparently declining colonies are on marine stacks that are either predator-free or where conditions do not favour their persistence, even though some could arrive seasonally. Several correspondents either mentioned or asked about the possible impact of predation by black-backed gulls, *Larus dominicanus*, especially given the large (but undocumented) 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.

There has been considerable expansion in human settlement and activity along much of New Zealand's coastline over the past 50 years. Could this be disrupting breeding, either through disturbance or displacement? Outright displacement seems to have been a factor at only one site: Tutukaka, Northland, where there is now a marina. Such developments elsewhere have not necessarily stopped red-billed gulls from nesting. The construction of rock walls alongside several marinas may even have facilitated it (e.g. 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, 1190 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 of this long-lived, slow-reproducing species, 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 I. can be seen flying to and from nearby Titahi Bay and Porirua City, where presumably they are feeding on scraps. Both the dynamics of these colonies through time, and year-to-year variations in breeding success 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 fluctuations 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.

To account for a long-term decline more likely requires either progressive deterioration in ocean conditions (e.g. changing sea temperatures gradually negatively affecting ocean productivity) or some other unidirectional systemic change. One suggestion, made by several observers, is that changes in fish stocks being targeted by fisheries could indirectly be affecting red-billed gull breeding success. Foraging gulls and other surface-feeding seabirds frequently associate with 'boil ups' caused by shoaling fish such as kahawai, *Arripis trutta*, trevally, *Pseudocaranx georgianus*, and barracouta, *Thyrsites atun,* feeding on *Nyctiphanes* swarms. These fish force the krill to the surface where they become available to surface-feeding seabirds. Any reduction in the incidence, extent or duration of such events could reduce the birds' abilities to obtain sufficient high quality food needed for optimal egg laying, incubation and chick rearing. If these endure, then long-term impacts on the birds could emerge through lowered breeding success.

Around 100 fish species or species groups, including these shoaling species, are fished commercially within catch limits set under New Zealand's Quota Management System. These stocks are widely considered by fisheries managers to be sustainably managed, in that stock levels are at or close to maximum sustainable yield (MSY). For the above species, this 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, and still be considered self-recoverable. Only below this lower limit would a stock be considered overfished, triggering a formal, time-bound plan for rebuilding the stock (Ministry of Fisheries 2011).

Currently, around 83% of managed fish stocks, including shoaling fish species, are judged to be above the 'soft limit' (Ministry of 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 notion being that there is a predictable relationship between the stock level and catch per unit effort (CPUE). 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, boat size and speed) may enable 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 (Taylor 2014), rendering stock assessments based on catch data questionable. The wider issues need more research.

Future directions

The red-billed gull is a long-lived, slow-reproducing species in which maturity is delayed and individuals do not necessarily breed every year (Mills 1989). 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 measure are counts of the number of active nests in a season, which may entail several visits, complemented by one or more counts of the number of fledged chicks, to provide a measure of productivity, all determined over a long succession of 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) and the more recent regular monitoring of some colonies in Otago (Perriman & Lalas 2012), there is no consistent time-series data on red-billed gull numbers. Counts at most other colonies have been sporadic or inconsistent either in how and when the colonies were counted or in what numbers were being reported, or both. Because of this, it is difficult to discern any clear long-term trends or the likely causes for any changes that may be occurring nationally.

Regular nationwide surveys of the red-billed gull population, such as the one reported here, are both costly and complex to do, especially for an organisation run by volunteers. 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.

Birds New Zealand, in conjunction with others, including the Department of Conservation, should therefore consider mobilising teams of observers who would be both willing and able to survey selected colonies several times a season using pre-set methods. 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 is being promoted by Birds New Zealand for bird monitoring more generally. But based on experience gained in this study, for this to effective, it will need someone or a team committed to reviewing the incoming information and giving feedback and encouragement to those submitting it. Rapid feedback is important if 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 nationally on which to start unravelling this long-lived, slow-reproducing species' dynamics.

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