

Estimating the breeding population of black-billed gulls *Larus bulleri* in New Zealand, and methods for future count surveys

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Abstract A national census of breeding black-billed gulls (*Larus bulleri*) conducted across New Zealand in 1995–98 estimated 48,000 nests, however the methodology used was unclear. In 2013, the New Zealand threat status for the endemic black-billed gulls was changed to Nationally Critical, based on estimates of recruitment failure causing population decline. To inform future threat classification, the breeding population was re-estimated using aerial surveys to locate, photograph, and count breeding black-billed gulls across New Zealand in 2014–2016. Large spatial gaps in nest count data during 2014/15 and 2015/16 did not allow for annual variability to be taken into account across the 3 seasons, but the 2016/17 survey successfully covered the entire country. Ground counts of nests were conducted at 16 colonies to determine a correction factor of 0.90 to apply to aerial photograph counts of apparently occupied nests. A total of 60,256 nests were found, with 33,703 nests in Southland and 20,675 nests in Canterbury. The North Island was surveyed on the ground and had 992 nests. Historical survey methods were reviewed, highlighting the inaccuracies of using nest densities or applying factors of gulls/nest to total bird counts based on photographs, as well as only counting individual birds on aerial photographs. Historical data likely overestimated numbers of breeding birds, and the inconsistencies of previous surveys make trend analyses difficult. Key recommendations for future counts include: (i) carrying out ground surveys before flights to determine the breeding stage of birds and hence the optimal time to fly; (ii) taking high resolution and zoomed in photos; (iii) carrying out ground nest counts immediately after flights to determine a correction factor; and (iv) using the same observers for all counts to maintain consistency.

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INTRODUCTION

Several bird species in New Zealand, such as the black-billed gull (*Larus bulleri*), are considered braided riverbed specialists that rely on these rivers for breeding (Maloney *et al.* 1997; Forest & Bird 2014; O'Donnell *et al.* 2016). Anthropogenic alterations such as gravel extraction, flow regulation and the introduction of weeds, such as Russell lupin (*Lupinus polyphyllus*) and broom (*Cytisus scoparius*), have reduced the dynamic nature of braided rivers

(Tockner *et al.* 2006), thereby affecting the availability of nesting habitats of river birds (Hughey 1997). Mammalian predators such as feral cats (*Felis catus*), European hedgehogs (*Erinaceus europaeus*), stoats (*Mustela erminea*), and ferrets (*Mustela furo*) also pose threats to braided river bird specialists (Craig *et al.* 2000; Dowding & Murphy 2001; Sanders & Maloney 2002; Keedwell 2005; Caruso *et al.* 2013; O'Donnell *et al.* 2015). Avian predators, such as southern black-backed gulls (*Larus dominicanus*) and swamp harrier (*Circus approximans*), can have significant impacts on productivity and survival of braided river birds (Steffens *et al.* 2012). Consequently, the need for

conservation of river birds is well documented (Maloney 1999; Dowding & Murphy 2001; Sanders & Maloney 2002; Keedwell 2005; O'Donnell *et al.* 2016).

Black-billed gulls are a small slender gull endemic to New Zealand (Higgins & Davies 1996). They primarily rely on braided rivers in the South Island for breeding, but also nest at lake edges, estuaries, lagoons, swamps, harbours, geothermal terraces and sandy coasts (Beer 1966; Higgins & Davies 1996; Taylor 2000). Nests are close together, and colonies vary from a few to several thousand pairs (Higgins & Davies 1996). Coastal colonies can be mixed with red-billed gulls (*Larus novaehollandiae*) or white-fronted terns (*Sterna striata*; Higgins & Davies 1996). Black-billed gulls prefer to forage on ploughed farmland to gather worms and insects, but also feed on fish and crustaceans (Higgins & Davies 1996). During the non-breeding season, birds are generally found along the coast, but continue to feed at inland farms (Taylor 2000).

Due to the unstable habitat the black-billed gulls rely on for breeding, they have adapted by minimizing the time spent at colonies (Beer 1966). They lay eggs within a few days of settling at a colony, and the chicks are highly mobile a few days after hatching, allowing them to crèche and family groups to move if necessary, such as in the case of floods (Beer 1966). The gulls are also quick to desert a colony if nearby food supplies are not sufficient (Evans 1982a). These adaptations make colony surveys quite difficult, as the time for counts is short and colonies often move between years due to changes in substrate (Beer 1966). Consequently, very few studies have been conducted on black-billed gulls (Taylor 2000; McClellan 2008).

As has been noted for other species (Puetz *et al.* 2003; Wienecke *et al.* 2009; Gaston *et al.* 2012; Petersen *et al.* 2015), historical counts of black-billed gulls are difficult to interpret due to inconsistent methods, calculation inaccuracies and data gaps (McClellan 2008). Documented, repeatable and rigorous methodologies are important as future studies and management decisions are based on trends (Puetz *et al.* 2003; Wienecke *et al.* 2009; Petersen *et al.* 2015). The only national census for this species estimated 48,000 nests, or 96,000 breeding birds (Powlesland 1998). Black-billed gulls are classified as Endangered by the International Union for Conservation of Nature (IUCN) due to a rapid population decline over the past 3 generations (BirdLife International 2016). The New Zealand Threat Classification System lists the gulls as Threatened (Nationally Critical) due to a high ongoing, or predicted population decline (Robertson *et al.* 2013, 2017).

Due to the most recent census of black-billed gulls having been completed almost 20 years ago, and combined with the change of threat

classification by Robertson *et al.* (2013) to Nationally Critical, the objectives of the current study were to: i) calculate a national breeding population estimate using data collected over the course of 3 seasons from 2014/15 and 2016/17 to account for annual variability; ii) compare the results to the census conducted between 1995/96 and 1997/98; and iii) make recommendations for future count methodologies.

MATERIALS AND METHODS

Birds New Zealand census 1995/96 to 1997/98

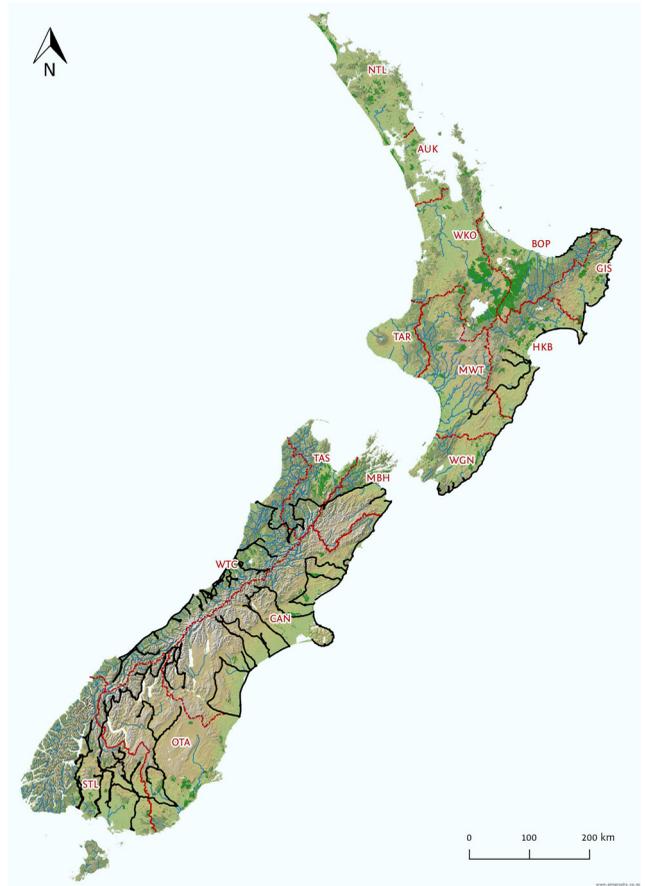
The only national survey of black-billed gulls was conducted by the Ornithological Society of New Zealand (OSNZ, now Birds New Zealand (Birds NZ)) in 1995/96, 1996/97, and 1997/98. Birds NZ regional newsletters, classified summarised notes and nest record scheme cards were searched to access survey methods and specific results; however, precise methods used could not be fully determined. It appears that known North Island breeding sites were visited on the ground to obtain a nest count, and aerial surveys were done in parts of the South Island to locate colonies (Hawkins & Powlesland 1995). Information regarding which rivers were flown, the timing of flights, or which rivers were surveyed on foot could not be found. Once located, the number of pairs/nests were counted on the ground, recorded on Colonial Nest Record (CNR) cards, and submitted to the respective Regional Representative (Hawkins & Powlesland 1995). These CNR cards were requested, but the ones specific to the national survey could not be located and hence the results outlined in Powlesland (1998) were used for comparisons to the present study.

National breeding population estimate, 2014/15 to 2016/17

North Island records for 2014/15, 2015/16, and 2016/17 are from independent observers. These were directly reported to the author by the observers or Birds NZ regional representatives, or found online using eBird (2012).

A mixture of aerial and ground surveys of the 6 South Island regions (Fig. 1) were conducted over the 3 years (Table 1). Rivers were chosen by closely examining each region on Google maps to locate braided sections of rivers, and by using historical records of colony locations. If there was any uncertainty associated with suitable habitat, the river was flown to minimize the risk of missing colonies. Canterbury, Marlborough, Tasman, Otago and Southland were aerially surveyed in 2014/15, and Canterbury and West Coast in 2015/16. All 6 regions were flown in 2016/17. Ground surveys were done in Marlborough and Tasman in 2015/16.

Fig. 1. Tracks of flights undertaken during the 2016/17 census of black-billed gulls in New Zealand. Black lines represent rivers and coastlines flown. Red lines represent regional boundaries. North Island: AUK – Auckland, BOP – Bay of Plenty, GIS – Gisborne, HKB – Hawke’s Bay, MWT – Manawatu-Wanganui, NTL – Northland, TAR – Taranaki, WGN – Wellington, WKO – Waikato. South Island: CAN – Canterbury, MBH – Marlborough, OTA – Otago, STL – Southland, TAS – Tasman, WTC – West Coast. Canterbury tracks are from 2015/16 season.



Ground counts following aerial surveys were conducted in Marlborough and Tasman in 2014/15, West Coast in 2015/16, and all regions except Canterbury in 2016/17 (Table 1). Both aerial and ground survey methods were consistent across the 3 years. Apparently occupied nests (AON), defined as birds sitting on substantial nests or standing within touching distance of a nest (Simeone *et al.* 2003) or sitting in incubation posture, were counted from aerial photographs. Ground counts of nests were completed systematically by 2 observers splitting the colony into 1–2 m wide transects using ropes, counting all nests (maintained empty or with eggs/chicks) within the transect, and then moving the ropes to the adjacent transect. This was repeated until the entire colony was counted, and a colony of about 350 nests could be surveyed by experienced observers in less than 5 minutes. Risk to birds was minimized by counting colonies which were estimated to contain less than 500 nests, experienced observers were used to ensure counts were done quickly and efficiently, and counts were restricted to dry weather.

2014/15

A R22 helicopter was used to conduct flights on rivers in Marlborough and Tasman regions at 150 m above ground (Mischler 2015). Three rivers were surveyed (Tables 2 and 3), all black-billed gull colonies were photographed, and birds on AONs were counted from the photographs. Nest counts on the ground were done on the same or following day to compare to aerial photograph counts.

Details of braided river surveys within Canterbury are available from McClellan (2015). The survey covered 21 rivers (Table 2; see McClellan (2015) for a map of all rivers flown), colonies were located with a fixed wing aircraft, photographed, and number of individual birds counted on the photograph. AONs were not counted separately, and ground counts were not conducted.

In Otago, 8 rivers were flown, colonies located, and photographs taken. Rivers surveyed included Clutha, Shotover, Dart, Rees, Matukituki, Makarora, Hunter and Manuherikia. In Southland, 7 rivers were surveyed for gull colonies while carrying out weed surveys. Rivers surveyed included Eyre,

Table 1. Type of surveys conducted for breeding black-billed gulls during summers of 2014/15, 2015/16, and 2016/17 in regions of the South Island, New Zealand. References correspond to reports summarizing specific surveys. *Aerial surveys were carried out but no counts were completed due to low resolution photographs.

Year	Region	Survey Type	Reference
2014/15	Canterbury	Aerial	McClellan 2015
	Marlborough	Aerial and ground	Mischler 2015
	Tasman	Aerial and ground	Mischler 2015
	Otago	Aerial	.*
	Southland	Aerial	.*
2015/16	Canterbury	Aerial	Mischler & Bell 2016
	Marlborough	Ground	Mischler 2016a
	Tasman	Ground	Mischler 2016a
	West Coast	Aerial and ground	Mischler 2016b
2016/17	Canterbury	Aerial	Bell 2017
	Rest of South Island	Aerial and ground	Current study

Mataura, Aparima, Waikaia, Oreti, Mararoa and Waiau. Photographs were taken for both regions, but no counts were done due to the low resolution of the photographs. No ground counts were completed.

2015/16

No flight surveys were conducted in Marlborough or Tasman, but the same methods used for nest counts as described above were conducted for all known colonies located during ground searches (Mischler 2016a). Braided sections of all rivers in the West Coast region were surveyed by a Cessna 180 plane at 150 m above ground for black-billed gull colonies (Mischler 2016b). A total of 31 rivers were flown (see Mischler 2016b for a map of all rivers flown), and AONs were counted from the photographs. Nest counts on the ground were done the same or following day on a subset of colonies to compare to aerial photograph counts, following the methods described above (Mischler 2016b).

The Canterbury survey was repeated, and the same 21 rivers were flown (Mischler & Bell 2016). AONs were counted from photographs, but no ground counts were done. No flights were conducted in Otago and Southland, and all additional breeding information from other regions was provided by independent observers.

2016/17

A national census was completed following methods used by McClellan (2015), Mischler (2016a, b), and Mischler & Bell (2016). In early to mid-October, a ground search was started in Southland

to determine the stage of breeding. To capture the largest number of breeding birds, the flights of the selected 9 rivers with suitable habitat needed to be conducted between mid-incubation and hatching (Table 3; Fig. 1). A total of 13 colonies were located using ground surveys, and were used to determine a flight date of 20 October 2016.

All flights were done at 150 m above ground at approximately 200 km/h using a Cessna 185. The plane flew along the edge of the river to allow the photographer to see the entire river bed. If a section of river was particularly wide, several sweeps were done to ensure the whole width was covered. Two observers were on board to minimize colonies being missed. Once a colony was found, the plane slowed and circled while the photographer took photographs of all birds. A Garmin GPSMap 64st unit tracked the flight paths, and was used to mark individual colony locations. A Canon 5D camera with a 70–300 mm f5.6 lens was used to take the photographs.

On 21 October 2016, 10 rivers in Otago were flown with the same plane and pilot (Table 3; Fig. 1). Using the aerial photographs, colonies in Southland and Otago estimated to have $\leq 1,000$ breeding pairs were selected. On 22–24 October 2016, ground counts of these selected colonies were conducted in accessible locations to compare to aerial photograph counts, and followed the same nest count methods as outlined above.

Marlborough, Tasman, and the West Coast counts were conducted on 18 and 19 November 2016. One river in Marlborough, 2 rivers in Tasman, and 16 in the West Coast were covered (Tables 2

Table 2. Black-billed gull nests counted in Canterbury (CAN) and Marlborough (MBH) regions of South Island, New Zealand. Data from 2014-16 are summarized, and 2016/17 was a full census. Number of colonies is shown in parentheses. Location are rivers unless stated otherwise. Cor – corrected value using factor of 1.05 for 2014/15 and 0.90 for 2015/16 and 2016/17. Count type: A – aerial photo, G – ground, GP – ground photo. NC – colony/colonies found but nests not counted, 0 – location checked and colony absent, and “-” – no data found on presence/absence of colony. ^Correction not applied due to observers varying from the rest of the South Island. *One additional colony located but nests not counted. **In early November, there were 3 colonies on the Wairau, 2 were washed out and/or depredated before the flight.

Region	Location	2014/15			2015/16			2016/17		
		Count	Cor	Type	Count	Cor	Type	Count	Cor	Type
CAN	Ahuriri	-	-	-	610 (2*)	-	G	491 (2)	^	A, G
	Ashburton	NC	-	A	774 (2)	727	A	4686	^	A
	Ashley	140	-	G	3	-	G	340	-	G
	Cass	-	-	-	55	-	G	75	-	G
	Clarence	187	197	A	139	-	G	0	-	-
	Conway	0	-	-	0	-	-	0	-	-
	Godley	-	-	-	55	-	G	0	-	-
	Hopkins	-	-	-	-	-	-	9	^	A
	Hurunui	NC (2)	-	A	1497	1405	A	1195 (3)	^	A
	Kaitorete Spit	-	-	-	NC	-	G	-	-	-
	Kekerengu	0	-	-	0	-	-	20	-	G
	Opihi	NC	-	A	0	-	-	0	-	-
	Orari	NC	-	G	0	-	-	0	-	-
	Pareora, South	-	-	-	-	-	-	2139	-	G
	Rakaia	NC	-	A	274	257	A	1400 (2)	^	A
	Rangitata	NC	-	A	9279 (3)	8711	A	3171 (2)	^	
	Tasman	-	-	-	41	-	G	62 (2)	-	G
	Tengawai, paddock	NC	-	G	-	-	-	-	-	-
	Timaru Golf	-	-	-	NC	-	G	-	-	-
	Waiau	0	-	-	1258	1181	A	511 (3)	^	AP
Waihao	-	-	-	337	316	A	-	-	-	
Waimakariri	1501 (2)	-	G	1840 (2)	-	G	2985 (4)	^	A, G	
Waipapa Bay	-	-	-	28	-	G	-	-	-	
Waipara	-	-	-	NC	-	G	-	-	-	
Waitaki	NC	-	A	2608 (2)	2448	A	3591 (3)	^	A	
Washdyke Lagoon	-	-	-	3	-	G	-	-	-	
<i>CAN total</i>		1828	1838	-	18,801	17,819	-	20,675	-	-
MBH	Awatere	54	-	G	0	-	-	0	-	-
	Ure	0	-	-	0	-	-	0	-	-
	Wairau	354 (2)	372	A	184	-	G	413	370	A
	(Wairau)**	-	-	-	-	-	-	880 (3)	-	G
<i>MBH total</i>		408	426	-	184	-	-	413	370	-
South Island annual total		-	-	-	22,481	21,404	-	63,433	59,264	-
New Zealand annual total		-	-	-	23,156	22,079	-	64,425	60,256	-

Table 3. Black-billed gull nests counted in Otago (OTA), Southland (STL), Tasman (TAS), West Coast (WTC) regions of South Island, New Zealand. Data from 2014-16 are summarized, and 2016/17 was a full census. Number of colonies is shown in parentheses. Abbreviations and correction factors applied are the same as outlined in Table 2. *Colony on paddock next to artificial pond, disturbed by vehicles with numerous flattened nests and chicks present. Only nests with eggs on ground were counted.

Region	Location	2014/15			2015/16			2016/17		
		Count	Cor	Type	Count	Cor	Type	Count	Cor	Type
OTA	Clutha	NC (2)	-	A, G	NC (2)	-	G	911 (2)	-	A, GP
	Ettrick, paddock	-	-	-	-	-	-	462	-	G
	Lake Dunstan	-	-	-	-	-	-	308	276	A
	Makarora	NC	-	G	-	-	-	-	-	-
	Matukituki	-	-	-	-	-	-	780	701	A
	Pomahaka	-	-	-	-	-	-	456	410	A
	<i>OTA total</i>	-	-	-	-	-	-	2,917	2,760	-
STL	Aparima	NC (3)	-	A	NC	-	G	5,574 (6)	5,006	A
	Eglinton	-	-	-	-	-	-	225 (2)	202	A
	Eyre Creek	NC	-	AP	-	-	-	2187	1,964	A
	Five Rivers*	-	-	-	-	-	-	86	-	G
	Mararoa	NC (2)	-	A, G	2,400	-	G	1,800 (2)	1,616	A
	Mataura	NC (4)	-	A	-	-	-	10,338 (9)	9,285	A
	Oreti	NC (6)	-	A	-	-	-	4,622 (6)	4,151	A
	SH94	-	-	-	-	-	-	335	-	GP
	Tomogalak	-	-	-	-	-	-	845	758	A
	Waiau	NC (3)	-	A	-	-	-	3,398 (10)	3,051	A
	Waiau	-	-	-	-	-	-	172 (2)	-	G
	Waikaia	NC	-	A	-	-	-	4,335	3,893	A
Whitestone	-	-	-	-	-	-	3,546	3,184	A	
<i>STL total</i>	-	-	-	2,400	-	-	37,472	33,703	-	
TAS	Buller	182	191	A	150	-	G	0	-	-
	Matakitaki	0	-	-	-	-	-	204	183	A
	Motueka River/Spit	-	-	-	-	-	-	15	-	G
	Soper's Sandspit	-	-	-	10	-	G	-	-	-
	Totara, Waikato	-	-	-	1	-	G	-	-	-
<i>TAS total</i>	182	191	-	161	-	-	219	198	-	
WTC	Arawhata	-	-	-	12	-	G	0	-	-
	Cook	-	-	-	289	260	A	0	-	-
	Dolomite Point	-	-	-	0	-	-	-	-	-
	Grey	-	-	-	0	-	-	110	98	A
	Hokitika	-	-	-	6	5	A	0	-	-
	Maruia	411	-	G	462	414	A	264 (2)	237	A
	Taramakau	-	-	-	0	-	-	325	291	A
	Whataroa	-	-	-	166	149	A	1,038 (2)	932	A
<i>WTC total</i>	411	-	-	935	840	-	1,737	1,558	-	
South Island annual total	-	-	-	22,481	21,404	-	63,433	59,264	-	
New Zealand annual total	-	-	-	23,156	22,079	-	64,425	60,256	-	

and 3; Fig. 1). The timing was chosen as outlined above, with ground surveys conducted 7–10 days preceding the flights. All but 1 inaccessible colony in the West Coast were counted on the ground following the flights, on 19 and 20 November 2016. The methods used during 2014/15 and 2015/16 were applied to the Canterbury region, and flown on 7 and 8 November 2016 (see Bell 2017). No ground counts were conducted. AON counts for Canterbury referred to in this study were adapted from Bell (2017). Canterbury flight tracks shown in Fig. 1 are from the 2015/16 season.

The North Island was mostly surveyed on the ground (Fig. 1). Flights of 3 rivers in Hawke's Bay were conducted on 4 December 2016, and another flight along the East Coast from Cape Palliser to Opotiki was conducted on 20 December 2016 (Fig. 1). Ground surveys preceding flights were not done. The Ruamahanga River in the Wellington region was ground surveyed on 6 January 2017. All North Island rivers and coastlines flown are shown in Fig. 1.

The clearest photos were chosen for counting using Microsoft Paint. Dispersed colonies usually required the use of more than 1 photograph, and sections were delineated to avoid double counting. At a magnification of 100–200%, each AON was counted and marked with a coloured dot. AONs were counted using visible nesting material as well as based on knowledge about behaviour and incubation posture from multiple years of field experience. To allow for observer differences in counting AONs, all photographs were counted by the same 2 independent observers. These same 2 individuals also counted all AONs in photographs from the 2015/16 season, and 1 of the 2 observers had counted all AONs in 2014/15 photos.

The mean of photograph AON counts from the 2 observers for each river were calculated. To account for potential sources of error, mainly overestimates of AONs from aerial photographs, a correction factor using the ground nest counts was calculated. This was done using methods outlined by Mittelhauser *et al.* (2016) where the correction factor was equal to ground count divided by photo count. To avoid errors from observers, the correction factor was applied to all aerial photograph counts where surveys and counts had been conducted by the same individuals; therefore, the AON counts from Canterbury 2016/17 did not have the correction factor applied as the observers were different from the rest of the country and previous years.

RESULTS

Birds New Zealand census: 1995/96 to 1997/98

Locations for the North Island colonies found in 1995/96, 1996/97, and 1997/98 are outlined in Table

4 (Powlesland 1998). Seven colonies with 322 nests were found and counted in 1995/96, 7 colonies with 547 nests in 1996/97, and 3 colonies with 389 nests in 1997/98. The Auckland region had the highest number of colonies ($n = 3$) in 1995/96 and 1996/97, but Bay of Plenty had the most nests in 1995/96 ($n = 166$) and Hawke's Bay in both 1996/97 and 1997/98 ($n = 246$ and 250, respectively; Table 4).

Locations of the South Island colonies found were restricted to names of rivers rather than specific locations on the river (Powlesland 1998; Table 5). Canterbury had 20 colonies with a total of 12,719 nests in 1995/96, and 17 colonies with 13,589 nests in 1996/97. Southland had 18 colonies with 29,569 nests in 1995/96, and 12 colonies with 33,474 nests in 1996/97. The remaining 4 regions of Marlborough, Otago, Tasman, and West Coast had a minimal number of 1–2 colonies, and a range of 20

Table 4. Black-billed gull nests counted in the North Island, New Zealand during the 1995–97 census (adapted from Powlesland 1998). Number of colonies is shown in parentheses. AUK – Auckland, BOP – Bay of Plenty, HKB – Hawke's Bay, MWT – Manawatu-Wanganui, WKO – Waikato. 0 – location checked and colony absent, “–” – no data found on presence/absence of colony.

Region	Location	1995/96	1996/97	1997/98
AUK	Kidds, Manukau Harbour	26	0	-
	Mataitai, Wairoa Bay	-	10	-
	Miranda	80	130	-
	Papakanui Spit, Kaipara Harbour	0	0	12
	Rat Island, Kaipara Harbour	3	18	0
<i>AUK total</i>		109	158	12
BOP	Ohiwa Harbour	0	30	-
	Rotorua	166	95	127
<i>BOP total</i>		166	125	127
HKB	Napier Wharf	20	0	-
	Portland Island	17	246	-
	Waitangi Estuary	0	0	250
<i>HKB total</i>		37	246	250
MWT	Manawatu River	10	-	-
	<i>MWT total</i>		10	-
WKO	Tongariro Delta	-	18	0
	<i>WKO total</i>		-	18
North Island annual total		322	547	389

Table 5. Black-billed gull nests counted in the South Island, New Zealand during the 1995–97 census (adapted from Powlesland 1998). Number of colonies is shown in parentheses. Location are rivers unless stated otherwise. 0 – location checked and colony absent, “-” – no data found on presence/absence of colony.

Region	Location	1995/96	1996/97	1997/98
Canterbury	Ahuriri	195 (2)	-	-
	Ashburton	3,865 (3)	7,686 (4)	4,637
	Ashley	383	257 (2)	-
	Cass	10	-	-
	Conway	1,000	649	0
	Hurunui	278	-	-
	Opihi	3,824 (2)	1,063 (3)	432
	Opuha Dam	-	1409	-
	Orari	1,200	-	0
	Peacock Springs	0	78	-
	Rakaia	4	732 (2)	-
	Tasman	10	-	-
	Tekapo	25	-	-
	Waiau	973 (3)	1,624 (2)	-
	Waimakariri	-	91	-
Waitaki	952 (2)	-	711	
<i>Canterbury total</i>		12,719	13,589	5,780
Marlborough	Ure	5	-	0
	Wairau	200	-	0
<i>Marlborough total</i>		205	-	-
Otago	Clutha	0	0	200
	Matukituki	-	296	-
<i>Otago total</i>		-	296	200
Southland	Aparima	12,030 (10)	7,785 (3)	2,500
	Eyre Creek	-	-	2,009
	Mararoa	178	-	1,000
	Mataura	-	11,963	8,830
	Oreti	16,737 (5)	9,091 (5)	6,691
	Upukerora	178	-	-
	Waiau	446	4,635 (3)	-
Whitestone	-	-	1,000	
<i>Southland total</i>		29,569	33,474	22,030
Tasman	Buller	80	-	-
	Matakitaki	10	-	-
	Motueka River/Spit	-	70	-
<i>Tasman total</i>		90	70	-
West Coast	Dolomite Point	0	20	0
West Coast total		-	20	-
South Island annual total		42,583	47,449	28,010
New Zealand annual total		42,905	47,996	28,399

Table 6. Black-billed gull nests counted in the North Island, New Zealand. Data from 2014–16 are summarized, and 2016/17 was a full census. Number of colonies shown in parentheses. NC – colony found but nests not counted, 0 – location checked and colony absent, “-” – no data found on presence/absence of colony.

Region	Location	2014/15	2015/16	2016/17
Auckland	Awhitu Peninsula, Manukau Harbour	-	-	20
	Clark’s Bay, Manukau Harbour	-	-	22
	Mataitai, Wairoa Bay	-	170	260
	Miranda	100	120	100
	Papakanui Spit, Kaipara Harbour	-	-	51 (2)
	Te Atatu Peninsula, Waitemata Harbour	-	-	23
<i>Auckland total</i>		100	290	476
Bay of Plenty	Maketu Spit	-	36	36
	Ohiwa Harbour	-	39	5
	Rotorua	75	22	184
<i>Bay of Plenty total</i>		75	87	225
Gisborne	Young Nick’s Head Station	NC	NC	63
<i>Gisborne total</i>		-	-	63
Hawke’s Bay	Ahuriri Estuary	-	-	15
	Napier Wharf	-	150	0
	Portland Island	-	-	4
	Tukituki River	53	-	0
<i>Hawke’s Bay total</i>		53	150	19
Manawatu-Wanganui	Manawatu River	-	-	11
<i>Manawatu-Wanganui total</i>		-	-	11
Northland	Mangawhai Heads	40	-	0
	Waipu Rivermouth	-	4	-
<i>Northland total</i>		40	4	-
Wellington	Henley Lake, Masterton	46	-	0
	Ruamahanga River	-	-	78
	Tauherenikau Delta, Lake Wairarapa	-	54	0
<i>Wellington total</i>		46	54	78
Waikato	Motuoapa, Lake Taupo	-	-	120
	Tokaanu Power Station, Taupo	-	80	0
<i>Waikato total</i>		-	80	120
North Island annual total		314	675	992

to 296 nests. There were ≥ 23 rivers listed as either “Not Counted” or for which nest counts were never reported (Powlesland 1998).

Overall, the New Zealand nest totals were 42,905 for 1995/96, 47,996 for 1996/97, and 28,399 for 1997/98. The results from Powlesland (1998) showed that approximately 30% of black-billed gulls nested in Canterbury during 1995/96 and 28% in 1996/97, while 69% nested in Southland during 1995/96 and 70% in 1996/97. The remaining 1-2%

were in Marlborough, Otago, Tasman, West Coast, and the North Island.

National breeding population estimate: 2014/15 to 2016/17

All North Island nest counts from 2014/15 to 2016/17 are summarized in Table 6 and shown in Fig. 2a. The highest number of colonies ($n = 16$) was located and counted in 2016/17, and this also amounted to the largest number of total nests ($n = 992$). By

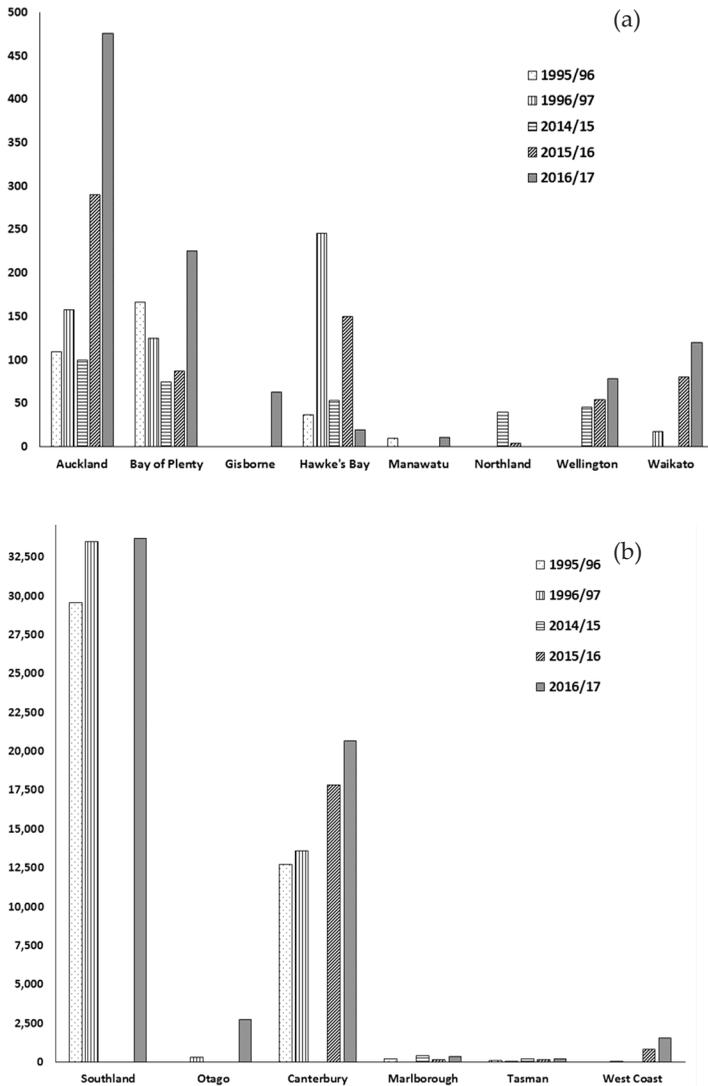


Fig. 2. Number of black-billed gull nests shown per region across the (a) North Island, and (b) South Island of New Zealand during 1995–97 census (adapted from Powlesland 1998), surveys in 2014–16, and full census in 2016/17. Gaps for (a) represent: Gisborne – 1995/96 and 1996/97 not surveyed, 2014/15 and 2015/16 not counted; Manawatu – 1996/97, 2014/15, 2015/16 not surveyed; Northland – 1995/96 and 1996/97 not surveyed, 2016/17 was 0 nests; Wellington – 1995/96 and 1996/97 not surveyed; Waikato – 1995/96 and 2014/15 not surveyed. Gaps for (b) represent: Southland – 2014/15 not counted, 2015/16 not surveyed; Otago – 1995/96 and 2015/16 not surveyed, 2014/15 not counted; Canterbury – 2014/15 not counted; Marlborough – 1996/97 not surveyed; West Coast – 1995/96 and 2014/15 not surveyed.

contrast, 2014/15 had the lowest number of colonies and nest counts ($n = 6$ and 314, respectively), and this was also the lowest number of nests counted across both censuses (Table 6). The Auckland region had the most colonies ($n = 7$) in 2016/17, but Bay of Plenty had the most ($n = 3$) in 2015/16 (Table 6; Figs. 3b, c). The highest number of nests were counted in Auckland during all 3 breeding seasons surveyed from 2014/15 to 2016/17.

Nest ground counts done immediately following flights, to determine a correction factor to apply to aerial photograph counts, are summarized in Table 7. Since errors in counting aerial photographs are specific to individual observers, 2 correction factors were calculated. The first 5 colonies in Table 7 were

counted by the author, both on the aerial photos and on the ground. The remaining 16 colonies were counted by 2 observers, both on the aerial photos and on the ground. Ground counts were done ≤ 5 days after the flights. To avoid skewing the data, three colonies were excluded from calculating the mean correction factors as they were outliers ($n = 1.40, 3.24, \text{ and } 4.49$), likely due to substrate or photo quality; consequently, the remaining four and 14 colonies were used to calculate the factors of 1.05 and 0.90. These factors were applied to all aerial photographs over the past 3 seasons for which methods of both photos and ground counts were consistent, and for which the same observers counted (Tables 2 and 3).

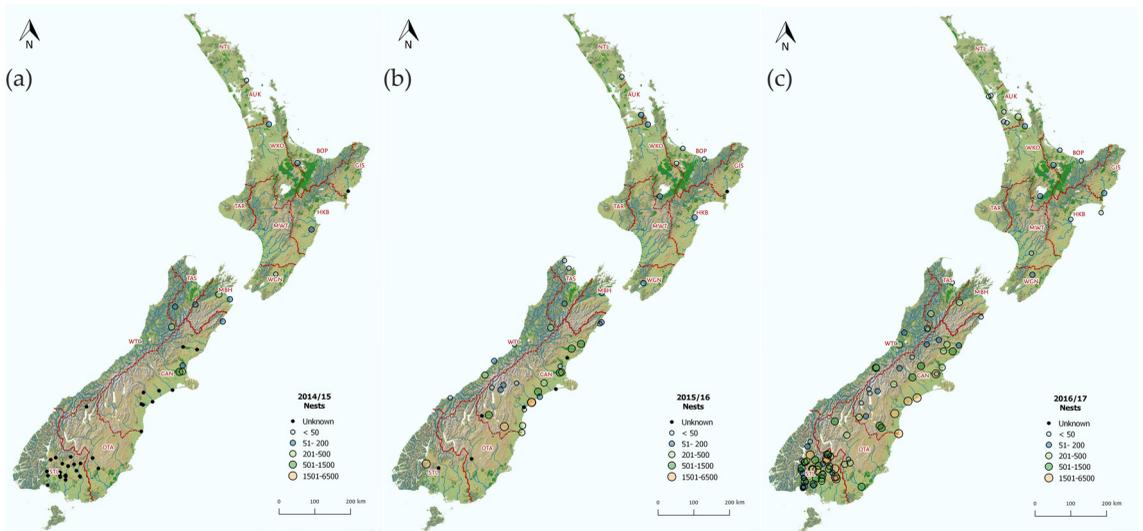


Fig. 3. Number and size of black-billed gull nests in colonies across New Zealand located during (a) 2014/15, (b) 2015/16, and (c) 2016/17.

Although flight surveys were conducted in Canterbury, Otago, and Southland during 2014/15, nest counts in these regions were sparse (Fig. 2b, 3a). Thirteen colonies were found in Canterbury, of which 4 were counted. Three colonies in Otago and 20 in Southland were found but none were counted. The resolution of Canterbury aerial photos was not high enough for a nest count, and the resolution of Otago and Southland photos was insufficient for any count at all. With only Marlborough and Tasman fully surveyed, it is impossible to estimate total number of breeding birds for the 2014/15 season. During 2015/16, Canterbury had 25 colonies of which 4 did not have a nest count (Fig. 3b). The West Coast region was fully surveyed for the first time, and 5 colonies were found with a total of 840 nests. The most colonies ($n = 3$) for the Tasman region were found during 2015/16, but the total number of nests ($n = 161$) was lower than for both 2014/15 and 2016/17 ($n = 191$ and 198 , respectively). Otago and Southland were not surveyed, thereby also omitting a large portion of the South Island population in 2015/16.

All regions were fully surveyed and all nests counted in 2016/17 (Fig. 3c). Canterbury had a total of 27 colonies, the most recorded for the region. The number of nests counted was also the region's highest ($n = 20,675$). In October, Marlborough had 3 colonies with the highest nest count ($n = 880$) for the region recorded (M. Bell, *pers. comm.*); however,

since only 1 of those colonies remained during the flight survey, the count from the survey ($n = 370$) was used to maintain consistency. Six colonies in Otago were found, which is twice the number located during the 2014/15 flights. Southland remained the stronghold for black-billed gulls with 43 colonies and 33,703 nests. Although the Waiarau River had the largest number of colonies ($n = 10$), the Mataura River had the most nesting birds ($n = 9,285$ nests), followed by the Aparima River at 5,006 nests. In 2016/17, both Tasman and West Coast had the highest count of nests ($n = 198$ and $1,558$ respectively) recorded for these regions.

The mean annual variability was calculated from regional totals where full nest counts from 2 consecutive seasons between 2014 and 2016 were available ($n = 7$). This resulted in a mean of 42.2% variability in AON within regions when sampled 2 years apart (range = 14.8 to 79.3%; $se = 10.0\%$).

Overall, the 2016/17 breeding season was the most complete for nest counts, with a total of 60,256 nests found. Southland had 55.9% of the breeding population, Canterbury had 34.3%, Otago had 4.6%, West Coast had 2.6%, North Island had 1.6%, and the remaining 1.0% was in Marlborough and Tasman. The proportion of breeding birds in Canterbury is likely different from 34.3% since no ground counts were done to develop a correction factor, and the factors used in Table 7 could not be applied since the Canterbury photos were counted

by other observers than the rest of the South Island.

DISCUSSION

Origins and challenges of historical black-billed gull counts

The results provide a full census of breeding black-billed gulls for 2016/17. To determine population trends, historical data are needed. However, methods used for historical surveys in the South Island are largely undocumented, and it is therefore unclear how well the historic counts represent the true past population size. McClellan (2008) summarized and reanalyzed Southland counts, and commented that ground counts between 1974 and 1986 were primarily done by using nest densities calculated from 3 colonies for which clear methods were not documented. Densities used for nest calculations varied between 1.79 nests/m² and 4.5 nests/m² (McClellan 2008). A survey on the Aparima River in 1985 shows that some colonies had the area multiplied by 1.5 nests/m² and others 4.5 nests/m², resulting in an estimate of 25,235 nests or 50,470 individuals (L. Esler, *pers. comm.*). For flight surveys, the number of birds visible in all aerial photos taken between 1995 and 2006 were counted, and all data transformed into a number of breeding birds (McClellan 2008). This was done by using a correction factor calculated from an estimate of nests compared to the number of individuals counted on aerial photo (McClellan 2008). Despite a gap of up to 3 weeks between ground nest counts and aerial photos during 2004 and 2005, these values were used along with better timed counts in 2006 to calculate the ratio of gulls/nest, ranging between 0.9 and 3.95 gulls/nest (McClellan 2008). Using unclear methods, a factor of 0.56 gulls/nest was calculated, and applied to all aerial photo counts upon which subsequent trend analyses were based (McClellan 2008). These transformed historical numbers were used to evaluate the threat status for black-billed gulls (McClellan 2008; Robertson *et al.* 2013), but it is likely that the population values generated from such calculations over-estimated the actual population on Southland rivers. Puetz *et al.* (2003) found a similar situation in historical counts of rockhopper penguins (*Eudyptes chrysocome*) where counts in the 1930s had been over-estimated by extrapolations of the colony area, and Wienecke *et al.* (2009) found discrepancies in the timing of data collection as well as count methods and units thereby leading to a poor understanding of trends in southern giant petrels (*Macronectes giganteus*) populations.

Nest density and calculating gulls per nest are inaccurate methods of estimating black-billed gull populations. For nest density, it is common for a colony to consist of several clusters of nests with

several metres in-between clusters (Beer 1966; *pers. obs.*). To obtain accurate estimates, the area of these clusters would have to be individually measured, in which case it may be just as efficient to do an actual nest count. The substrate on which the colony is placed will also influence the density, where larger stones result in reduced densities than smaller stones (*pers. obs.*). It is also common to see nests being built around clumps of “driftwood” (Beer 1966) or logs, which would also affect calculations using density.

Applying a factor for calculating gulls per nest can also lead to large inaccuracies in colony counts. Gulls are highly mobile, and attendance in colonies fluctuates with time and weather (Nisbet 2001; *pers. obs.*). For example, 2 week intervals between flights on a Southland river during 2006 showed fluctuations in number of gulls counted from aerial photographs between 3.7% and 49.3% (McClellan 2008). Six surveys during a 2-month period on 4 rivers in Canterbury had substantial fluctuations in numbers of birds present (McClellan 2015). Diurnal observations during pre-breeding of the closely related red-billed gull also show that occupancy rates vary throughout the day (Mills 1970). Evans (1982b) found that in black-billed gull colonies, leaders call out when leaving a colony to forage, and this encourages followers to depart as well. The proportion of birds at the colony versus away feeding is not understood; consequently, the number of individuals at a colony is continuously changing, whereas at least 1 of the 2 birds in a breeding pair will always be present on the nest. The same inaccuracies apply if only individual birds are counted with no regard to breeding, as that particular count is simply a sample of birds at that present time and cannot be used in population trend analyses without understanding how proportions of birds present are affected by temporal and geographic factors (Link & Sauer 1998).

The proportion of non-breeders in the population is also unknown as the variables required to calculate this would need to be derived from a long-term banding study, similar to Mills *et al.* (2008) on red-billed gulls, or Klomp & Furness (1992) on great skuas (*Catharacta skua*). Black-billed gulls also do not breed until 2–4 years old (Higgins & Davies 1996), and the plumage of older non-breeding birds is indistinguishable from breeding birds. As is the case with other long-lived species, survival of breeding adults plays a key role in population dynamics (Schreiber & Burger 2002; Jenouvrier *et al.* 2005) hence breeders should be counted.

Since black-billed gulls started to breed at Miranda, Firth of Thames, for the first time in 1968, a northward breeding range expansion has

been suggested with gulls nesting at the Kaipara Harbour, Northland, in the 1990s (Gleeson *et al.* 1972; Powlesland 1998; Taylor 2000). Records show that gulls have been breeding at Rotorua since 1932 (Reid & Reid 1965), and these gulls were believed to move to the Firth of Thames, or Bay of Plenty coast, during the winter (Black 1955). Consequently, some of them may have remained there. Similarly, banded birds from Rotorua were also seen at Taupo (Innes *et al.* 1999), and these could also have become breeding residents. In addition to the Rotorua colony, black-billed gulls have been breeding at Hawke's Bay since 1945 and Gisborne since 1954 (Reid & Reid 1965), and it is possible that some of the newly recruited birds have been moving to other North Island colonies. Even if there is a range expansion, it remains small in the large scale of New Zealand.

Comparisons between 2014/15–2016/17 and 1995/96–1997/98

In 2016/17, 60,256 nests were counted, which is higher than the 42,905 and 47,996 nests that were counted during the seasons of 1995/96 and 1996/97, respectively, during the last attempt to complete a national census (Powlesland 1998). The 28,399 nests counted in 1997/98 were much lower than the previous 2 seasons (Powlesland 1998), and this is likely due to reduced search and count efforts in the key regions of Canterbury and Southland (Table 5). The number of colonies in Canterbury was 20 and 17 in 1995/96 and 1996/97 respectively, and this increased to 25 and 27 in 2015/16 and 2016/17 respectively. In Southland, there were 18 and 12 colonies in 1995/96 and 1996/97 respectively, compared to 22, 20, and 24 colonies found in 2004/05, 2005/06, and 2006/07 respectively (McClellan 2008). In 2016/17, there were 43 colonies.

However, the omission of the West Coast from the 1995–98 census and the large number of count gaps in significant rivers, such as the Whitestone, Eyre, Rangitata, and Waimakariri, suggest that the 1995/96, 1996/97, 1997/98 counts underestimated the total national breeding population. The aim of the present study had been to calculate a national breeding population based on 3 seasons of data, 2014–16. This was not possible due to the lack of nest counts during 2014/15, and the lack of surveys in Southland and Otago in 2015/16. Consequently, the data gaps along with unclear and undocumented survey methods for the 1995–98 census, and the previously-mentioned challenges in regards to historical data, makes long-term analyses of population trends difficult. It emphasizes that patchy data must be treated with caution, and highlights the importance for the need of consistent and well documented methods for future surveys.

Recommendations for future counts

With the present-day technology, aerial surveys can be quick, efficient, and cost effective, and have been widely used for gull surveys elsewhere (Dolbeer *et al.* 1997; Johnson & Krohn 2001; Mallory *et al.* 2009). Sources of error that need to be acknowledged, as outlined by Barbraud & Gelinaud (2005), include the number of visits, synchronicity, breeding frequency, observer bias, and nest detectability.

Nisbet (2001) highlighted the importance of calibration between photo counts and ground counts. Because 1 full count per season is done, it is important to ensure that the majority of colonies are at peak breeding by conducting ground surveys before flights. Black-billed gulls are synchronous breeders (Beer 1966; McClellan 2008), and pairs spend very little time at colonies before laying (Beer 1966); consequently, empty nests were counted as these may be early failed breeding attempts or late birds that have yet to lay. O'Connell *et al.* (1997) found that 27% of empty lesser black-backed gull (*Larus fuscus*) nests were never laid in; however, such data do not exist for black-billed gulls and it was therefore assumed that an empty nest is equal to 1 breeding pair. Data on the frequency of breeding for black-billed gulls may help explain the inter-annual variation in counts if, for example, black-billed gulls are biennial rather than annual breeders.

For aerial photograph counts, it is important to have observers with experience in gull behaviour to aid in the identification of birds on nests. In the current study, consistency was maintained by keeping the observers the same across all counts, and errors were further reduced by the correction factor of the ground counts. Although Bell (2017) suggests that there was less variability in photo counts of individual birds than AONs by 3 observers, there was no significant difference in counts between observers using either method in Bell's (2017) report. Consequently, I suggest it is more appropriate to accept slightly higher variability to calculate AONs, which provides useful information in regards to numbers of breeding birds, instead of a slightly less variable count of individuals which provides uncertain information on minimum population size. Since black-billed gulls nest on open rivers on flat ground with little or no vegetation, it is assumed that the nest detection probability on the ground is close to 1 (Barbraud & Gelinaud 2005). It should be noted that colonies at river mouths need to be checked on the ground, as red-billed gulls may be present and indistinguishable in photos. This was not done in the 2016/17 survey of Canterbury (Bell 2017) and this may have resulted in over-estimates of coastal colonies in Canterbury.

To minimize error, the following key recommendations for future black-billed gull

breeding population surveys are made: 1) conduct ground surveys at the start of the breeding season to locate colonies and ensure aerial surveys are undertaken when the nesting stage is between mid-incubation and hatching; 2) when taking photographs from the aircraft, ensure that the photographer zooms in as much as possible to be able to clearly see nests in a high quality image; 3) identify colonies of $\leq 1,000$ nests from photographs and attempt to count as many of those colonies as possible on the ground to determine a correction factor to apply to aerial photograph count; 4) conduct ground counts as soon after the flights as possible, preferably within 5 days; 5) use the same observers to count all photographs to avoid bias and to be able to use the correction factor; and 6) aim to repeat the same surveys over at least 2 seasons to account for annual variability.

Overall, the 2016/17 national census showed positive results in regards to the black-billed gull population. The number of breeding birds is higher than expected, and the trend since the 1990s does not fit the predicted decline of >70% over 3 generations which had warranted the Nationally Critical threat assessment (Robertson *et al.* 2017). However, although the breeding population appears to have increased from 47,996 in 1996/97 to 60,256 in 2016/17, it is important to recall that the omission of key rivers, such as the Whitestone and Eyre in Southland, the Rangitata and Waimakariri in Canterbury, as well as the entire West Coast region during the 1995–98 census likely under-estimated the breeding population. Also, the correction factors and extrapolations, such as nest densities and gulls/nest, used for counts in Southland during historical surveys probably vastly over-estimated the population between the 1960s and 1980s.

In summary, it is likely that the black-billed gull numbers are stable; however, another census in 10 years is needed to assess the long-term population trends.

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