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Data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability: Synthesis of population and demographic work

New Zealand Aquatic Environment and Biodiversity Report No. 228.

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ISSN 1179-6480 (online)
ISBN 978-1-99-000839-9 (online)
September 2019

New Zealand Government

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EXECUTIVE SUMMARY

Thompson, D.R. (2019). Data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability: synthesis of population and demographic work.

***New Zealand Aquatic Environment and Biodiversity Report No. 228.* 15 p.**

This report synthesises the results of population and demographic work undertaken as part of a multi-year, multi-species project (the data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability: PRO200601). Originally, the project was reported in a series of annual 'final research reports', National Institute of Water and Atmospheric Research (NIWA) reports and other ad hoc reports.

The five-year project commenced in the austral summer of 2006–07, with data collected through to 2010–11, and comprised work on white-chinned petrel *Procellaria aequinoctialis*, grey petrel *P. cinereal* (Antipodes Island), Salvin's albatross *Thalassarche salvini* (Western Chain, The Snares and Bounty Islands), and northern royal albatross *Diomedea sanfordi*, Chatham albatross *T. eremita*, northern Buller's albatross *T. bulleri platei* and northern giant petrel *Macronectes halli* (Chatham Islands), although not all species were studied in each of the five years of the project. It should be noted that in addition to the summary of data collected and reported here, tracking and at-sea distribution data were also collected for all but two species-site combinations (Salvin's albatross at the Bounty Islands and northern giant petrel at the Chatham Islands). The tracking and distribution data collected as part of project PRO2006-01 are not included as part of this synthesis.

Population estimates, and demographic parameter estimates, have been compiled, and, in the case of white-chinned petrel and grey petrel breeding at Antipodes Islands, new population estimates were generated. Where possible, these metrics have been compared with population and demographic parameter estimates from studies carried out since project PRO200601 was completed.

1. INTRODUCTION

The data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability project (hereafter referred to as PRO2006-01) was a multi-year, multi-site and multi-species project.

Project PRO2006-01 commenced in the austral summer of 2006–07 (for two species), with data collected through to 2010–11 (for four species), and comprised work on white-chinned petrel *Procellaria aequinoctialis*, grey petrel *P. cinereal* (Antipodes Island), Salvin's albatross *Thalassarche salvini* (Western Chain, The Snares and Bounty Islands), and northern royal albatross *Diomedea snafordi*, Chatham albatross *T. eremita*, northern Buller's albatross *T. bulleri platei* and northern giant petrel *Macronectes halli* (Chatham Islands), although not all species were studied in each of the five years of the project. Additionally, tracking and at-sea distribution data were collected for all but two species-site combinations (Salvin's albatross at the Bounty Islands and northern giant petrel at the Chatham Islands). The tracking and distribution data collected as part of project PRO2006-01 are not included as part of this synthesis.

The primary research provider for the project was the National Institute of Water and Atmospheric Research Ltd (NIWA), collecting data for white-chinned and grey petrels at Antipodes Island and Salvin's albatross at the Western Chain, with Canterbury Museum sub-contracted to provide data for species and sub-species breeding at the Chatham Islands: Chatham albatross, northern Buller's albatross, northern royal albatross and northern giant petrel. Additionally, Latitude 42 Environmental Consultants Pty Ltd provided a population estimate for Salvin's albatross at the Bounty Islands, based on an aerial survey, for the 2010–11 breeding season.

The research objectives for the synthesis of information from project PRO2006-01 were as follows:-

1. To prepare an Aquatic Environment and Biodiversity Report (AEBR), which summarises all work undertaken by NIWA under the PRO2006-01 A to E MFish contracts including species and sites of study:

a. White-chinned petrel and grey petrel on Antipodes Island
    i. Population trend
    ii. Range and foraging tracking
    iii. Burrow occupancy and progress towards a total population estimate for the island

b. Salvin's albatross on Snares Western Chain
    i. Population census
    ii. Survival
    iii. Breeding frequency
    iv. Range and foraging tracking

c. Northern Buller's albatross, northern royal albatross and northern giant petrel on Forty-Fours and Sisters
    i. Population monitoring of northern Buller's albatross, northern royal albatross and northern giant petrel
    ii. Range and foraging tracking

d. Chatham Island albatross on the Pyramid
    i. Population census and trend analysis
    ii. Survival
    iii. Range and foraging tracking

As noted above, this report synthesises the 'population' work carried as part of PRO2006-01, and so within Objective 1.1 covers ai and aiii, bi, bii and biii, ci and di and dii.

2. METHODS

Table 1 summarises the species, breeding sites and years of data collection included in PRO2006-01. Data collected are further subdivided into those that contributed towards population estimates and those that were used to estimate demographic parameters (adult survival and breeding success).

Table 1: Species, locations and population and demographic data collected during PRO2006-01 across five austral summers. P – population estimate data collection, D – demographic parameter data collection, * - grey petrel breeds during the austral winter (such that the entire breeding season occurs within a calendar year), and population estimates were obtained for the 2009 and 2010 breeding seasons, ** - northern royal albatross, additional aerial survey data were acquired for this species between 2006–07 and 2009–10, inclusive, that produced population estimates and breeding success estimates for populations breeding at the Forty Fours, Big Sister and Middle Sister, Chatham Islands.

Species	Location	Breeding Season				
		2006–07	2007–08	2008–09	2009–10	2010–11
White-chinned petrel	Antipodes Island	P, D	P, D	P, D	P, D	P, D
Grey petrel*	Antipodes Island			P	P	
Salvin's albatross	Western Chain, The Snares			P, D	P, D	P, D
	Bounty Islands					P
Chatham albatross	Pyramid, Chatham Islands		P, D	P, D	P, D	P, D
Northern Buller's albatross	Forty-Fours, Chatham Islands		P	P	P	
Northern royal albatross**	Forty-Fours, Chatham Islands		P			
Northern giant petrel	Forty-Fours, Chatham Islands		P	P	P	

Detailed methodologies can be found in the various annual reports produced as part of PRO2006-01. A summary of the reports produced is provided here:

Information on white-chinned petrels at Antipodes Island has been summarised from five unpublished annual research reports: Sagar & Thompson (2008), Sommer et al. (2008, 2009, 2010, 2011). Of these, Sagar & Thompson (2008) was produced as a NIWA report (as opposed to a NIWA client report), Sommer et al. (2008) appears to be a 'plain' summary document, while Sommer et al. (2009, 2010, 2011) were produced as Ministry of Fisheries Final Research Reports.

Information on grey petrels at Antipodes Island has been summarised from two unpublished annual research reports: Sommer et al. (2009, 2010), both of which were produced as Ministry of Fisheries Final Research Reports.

Information on Salvin's albatross at the Western Chain, The Snares has been summarised from three unpublished annual research reports: Charteris et al. (2009), Carroll et al. (2010) and Sagar et al. (2011), which were produced as Ministry of Fisheries Final Research Reports.

Information on Chatham albatross at the Pyramid, Chatham Islands has been summarised from four unpublished annual research reports: Scofield et al. (2008a), Fraser et al. (2009a, 2010a, 2011). Of these, Scofield et al. (2008a) appears to be a 'plain' summary document, while Fraser et al. (2009a, 2010a, 2011) were produced as Ministry of Fisheries Final Research Reports.

Information on northern Buller's albatross at the Forty-Fours, Chatham Islands has been summarised from three unpublished annual research reports: Scofield et al. (2008b), Fraser et al. (2009b, 2010b). Of these, Scofield et al. (2008b) appears to be a 'plain' summary document, while Fraser et al. (2009b, 2010b) were produced as Ministry of Fisheries Final Research Reports.

Information on northern royal albatross at the Forty-Fours, Chatham Islands has been summarised from two unpublished annual research reports: Scofield et al. (2008b) and Scofield (2011). Of these, Scofield et al. (2008b) appears to be a 'plain' summary document, while Scofield (2011) was produced as Ministry of Fisheries 'final research report'. Scofield et al. (2008b) covers ground-based work in 2007–08, while Scofield (2011) covers aerial photographic survey work carried out annually between 2006–09 and 2009–10 (Table 1).

Information on northern giant petrel at the Forty-Fours, Chatham Islands has been summarised from three unpublished annual research reports: Scofield et al. (2008b), Fraser et al. (2009b, 2010b). Of these, Scofield et al. (2008b) appears to be a 'plain' summary document, while Fraser et al. (2009b, 2010b) were produced as Ministry of Fisheries Final Research Reports.

3. RESULTS AND DISCUSSION

3.1 White-chinned petrel

Work on white-chinned petrels at Antipodes Island spanned all five years of the project, from 2006–07 through to 2010–11, although timing of trips differed from year to year, and fieldwork in 2008–09 and 2009–10 also incorporated work on grey petrels (see Section 3.2). Table 2 summarises the timing of fieldwork on white-chinned petrels at Antipodes Island.

Table 2: PRO2006-01 fieldwork periods and breeding phase across five austral summers for white-chinned petrel and grey petrel at Antipodes Island.

Breeding Season	Fieldwork Period	Breeding Season Phase
2006–07	9 Jan – 27 Feb 2007	White-chinned petrel: late incubation, early chick rearing
2007–08	13 Jan – 29 Feb 2008	White-chinned petrel: late incubation, early chick rearing
2008–09	24 Jan – 20 Apr 2009	White-chinned petrel: early chick rearing Grey petrel: incubation
2009–10	8 Dec – 13 Jan 19 Mar – 30 Apr	White-chinned petrel: incubation Grey petrel: incubation
2010–11	3 Jan – 16 Feb	White-chinned petrel: early chick rearing

For white-chinned petrels, the focus of the fieldwork was to establish permanent study areas in which burrow density, burrow occupancy and mark-recapture work on banded individuals was carried out,

and to determine burrow densities and occupancies from additional transects placed across the island, from which population estimates were to be determined. During the first breeding season, three study plots were established towards the northern end of Antipodes Island: A ('North Plains') and B ('Banana Ridge') were both 50 × 100 m, and C ('Polar Front') was 160 × 110 m. These three plots were monitored each breeding season and occupancy by breeding white-chinned petrels determined (Table 3). The number of burrows detected in the first year of the study (2006–07) appear low across all three study plots, with increased and relatively consistent numbers found in subsequent years (Table 3). It is likely that this pattern reflects relatively low burrow detection in the first year, rather than a genuine increase in white-chinned petrel burrows over time. Additionally, a study population of individually banded white-chinned petrels was established, and resighting of banded individuals was carried out in each of the 2007–08 to 2010–11 breeding seasons. In all, 366 breeding white-chinned petrels were banded across the three study plots, and resighting work extended to 10 m buffer zones around all study plots (to check for birds that may have moved relatively short distances to burrows beyond the study plot perimeters).

Burrow occupancy was relatively low across all study plots and all years, ranging from 15% in two years in plot A up to 37% in 2010–11 in plot C (Table 3). These occupancy values are consistent with those in white-chinned petrel burrows detected in 2 m-wide transects at various sites across Antipodes Island in 2008–09 (29 transects), 2009–10 (20 transects) and 2010–11 (31 transects): mean occupancy values in transects were 19%, 28% and 25% in the three breeding seasons, respectively (Table 4). These occupancy values were much lower than those for white-chinned petrels at Disappointment Island (mean 73%) and at Adams Island (mean 69%) reported by Rexer-Huber et al. (2017), for the closely-related spectacled petrel *Procellaria conspicillata* at Inaccessible Island (mean 81%, Ryan & Ronconi (2011)) and slightly lower than values for Westland petrel *P. westlandica* near Punakaiki, South Island, with mean occupancy values ranging from 21% to 52% between 2001 and 2014 (Waugh et al. 2015).

Table 3: White-chinned petrel burrow occupancy values (expressed as the percentage of white-chinned petrel burrows with an active breeding attempt in a particular breeding season) and the total number of burrows identified as white-chinned petrel burrows for each of three study plots at Antipodes Island over five austral summers. All three study plots were inland to the southwest of Anchorage Bay at the northern end of Antipodes Island: A, 'North Plains', B, 'Banana Ridge', and C, 'Polar Front'.

Quadrat	Breeding Season									
	2006–07		2007–08		2008–09		2009–10		2010–11	
A	17%	24	15%	39	26%	35	24%	34	15%	34
B	19%	52	18%	66	22%	66	22%	65	20%	65
C	27%	184	26%	204	25%	204	30%	196	37%	197

White-chinned petrel burrow density could similarly be determined from the three permanent study plots and from transects located across the island. Considering the study plots (A–C) and ignoring the first year (2006–07) when burrow numbers were relatively low in all three plots (Table 3), burrow density remained fairly constant across all three study plots (A: 68–78 burrows ha^{-1}, B: 130–132 burrows ha^{-1}, C: 111–116 burrows ha^{-1}). In transects, which were located in different parts of the island and were conducted at slightly different times of the breeding season in different years, mean burrow density values were 178 burrows ha^{-1}, 115 burrows ha^{-1} and 133 burrows ha^{-1} in 2008–09, 2009–10 and 2010–11, respectively (Table 4).

Table 4: Population estimate information for white-chinned petrels breeding at Antipodes Island.

Breeding Season	Number of Transects	Burrow Density ha^{-1} (mean ± sd)	Burrow Occupancy % (mean ± sd)	Population Estimate (mean ± sd)	95% CI
2008–09	29	177.7 ± 144.4	19.2 ± 18.0	45 135 ± 36 208	31 957 – 58 313
2009–10	20	115.3 ± 63.0	27.8 ± 15.8	44 924 ± 44 626	25 366 – 64 482
2010–11	31	133.3 ± 76.0	24.7 ± 20.5	39 670 ± 43 960	24 195 – 55 145

Considering only the transect data from 2008–09 to 2010–11 and using the proportion of burrows occupied by other species (notably white-headed petrel *Pterodroma lessonii*), to correct numbers of burrows that were either empty or which couldn't be fully checked to produce an estimate of 'total-potential white-chinned petrel burrows' for each transect, population estimates were generated (Table 4). These estimates are relatively simple, multiplying the likely area of Antipodes Island with suitable white-chinned petrel habitat that was covered by the transects with mean burrow density and mean burrow occupancy. Bell (2002) noted that habitat used by breeding white-chinned petrels and grey petrels was largely exclusive and that grey petrels occupied approximately 510 ha of the total area of Antipodes Island (2015 ha). Further, transects were not placed in particularly swampy areas of the island, estimated at approximately 204.2 ha, reducing assessed white-chinned habitat to approximately 1310.8 ha.

The mean population estimates for white-chinned petrel at Antipodes Island of approximately 40–45 000 pairs over 2008–09 to 2010–11 (Table 4) are lower than those noted by Sommer et al. (2011) of 91 125 and 58 725 for 2009–10 and 2010–11, respectively. Sommer et al. (2010, 2011) did not appear to adjust occupancy values to include a proportion of empty burrows as white-chinned petrel burrows based on the proportion of positively identified burrows belonging to other species of seabird. However, had they done so, their population estimates would have been larger than those noted above. It is likely, therefore, that the discrepancy between the estimates produced by Sommer et al. (2011) and those noted here is due to the area of suitable white-chinned petrel habitat on Antipodes Island used in the calculations. Sommer et al. (2011) used the entire area (2025 ha) of Antipodes Island as being suitable for white-chinned petrels, whereas the estimates here exclude 510 ha as being predominantly grey petrel habitat (Bell 2002) and a further 204.2 ha as swamp habitat that was not surveyed during PRO2006-01.

The estimates of 40–45 000 breeding pairs of white-chinned petrel at Antipodes Island are much lower than the suggested 'at least 100 000 pairs' noted by Taylor (2000), and also much lower than the estimated 153 000 (119 700–195 700) breeding pairs at Disappointment Island in the Auckland Islands (Rexer-Huber et al. 2017). Rexer-Huber et al. (unpublished data) suggested a further 28 000 breeding pairs on Adams Island (Auckland Islands) with an overall Auckland Islands population of approximately 184 000 breeding pairs of white-chinned petrels. Rexer-Huber et al. (unpublished data) also suggested approximately 20 000 breeding pairs of white-chinned petrels at Campbell Island and associated stacks and islets (it should be noted that the Campbell Island population of white-chinned petrels is very likely increasing following the eradication of rats *Rattus norvegicus* from the islands in 2001).

It is noteworthy that the white-chinned petrel population at Disappointment Island (area approximately 300 ha) is perhaps three times the size of that at Antipodes Island, despite being nearly seven times smaller in area. At a superficial level, the difference in population size between the two sites is driven by much higher burrow density and burrow occupancy values at Disappointment Island compared to Antipodes Island (see above), but the underlying causes of these differences remain to be identified. It would be interesting to explore whether the eradication of mice *Mus musculus* from

Antipodes Island (confirmed in 2018) will have any beneficial effects for the white-chinned petrel population there.

Using the resighting data from the three study plots (A-C) and the simple Cormack-Jolly-Seber model in Program MARK, survival estimates for white-chinned petrels were 0.79 (se 0.05, 95% CI 0.69–0.87) between 2006–07 and 2007–08, 0.86 (se 0.04, 95% CI 0.75–0.92) between 2007–08 and 2008–09 and 0.91 (se 0.05, 95% CI 0.76–0.97) between 2008–09 and 2009–10, although given the relatively few years of resighting data these estimates should be considered very preliminary.

3.2 Grey petrel

Work on grey petrels at Antipodes Island occurred in 2008–09 and 2009–10. See Table 2 for a summary of the timing of fieldwork on grey petrels at Antipodes Island. The two periods of fieldwork coincided with the incubation phase of the breeding season in both years and consisted of determining the number of grey petrel burrows and the occupancy rate for these burrows along a series of 2 m-wide transects. In 2008–09, transects were located towards the northern end of Antipodes Island, whereas in 2009–10 transects were located more towards the southern end of the island. There was no overlap of transect locations between the two breeding seasons. As for white-chinned petrel, the proportion of burrows that were occupied by species other than grey petrel was used to assign empty burrows and burrows that were impossible to check fully as 'grey petrel burrows' in order to determine grey petrel burrow density and occupancy estimates. Following Bell (2002), grey petrel habitat was assumed to cover 510 ha of Antipodes Island.

Estimates of the numbers of breeding grey petrels on Antipodes Island are presented in Table 5: mean estimates were 87 573 and 60 147 in 2008–09 and 2009–10, respectively. These estimates are slightly higher than the estimate of 53 000 breeding pairs in 2001, based on the number of breeding grey petrels detected in four census grids (Bell 2002). Antipodes Island remains the stronghold for this poorly-studied species, with most other breeding sites supporting a few hundreds to thousands of pairs. Perhaps only Gough Island, south Atlantic Ocean, supports a few tens of thousands of pairs (see https://www.acap.aq/). Within New Zealand, the only other confirmed breeding site for grey petrel, Campbell Island, supports approximately 100 pairs, but in the absence of rats this population is likely to be recovering, albeit slowly (Parker et al. 2017).

Table 5: Population estimate information for grey petrels breeding at Antipodes Island.

Breeding Season	Number of Transects	Burrow Density ha^{-1} (mean ± sd)	Burrow Occupancy % (mean ± sd)	Population Estimate (mean ± sd)	95% CI
2008–09	16	485.3 ± 365.5	31.0 ± 30.0	87 573 ± 93 218	41 896 – 133 250
2009–10	38	450.3 ± 349.0	20.0 ± 19.5	60 147 ± 68 849	38 256 – 82 038

3.3 Salvin's albatross

3.3.1 Western Chain, The Snares

Counts of the number of breeding pairs of Salvin's albatross were made in all three years the islands were visited and are summarised in Table 6 (see also Sagar et al. (2011)). Totals of 1195 and 1116 breeding pairs were counted on Toru and Rima islets in 2008 and 2009, respectively (Table 6). Wha Islet was visited in October 2009 but no evidence of breeding by Salvin's albatross was recorded. Similarly, no breeding Salvin's albatrosses were observed through binoculars on Tahi and Rua islets.

Table 6: Numbers of breeding pairs of Salvin's albatross on Toru, Rima and Wha islets, Western Chain, Snares Islands. A failed nest was assessed as containing fresh egg fragments from a breeding attempt in that year.

Islet	Breeding Season	Date of Count	Adult + Egg	Failed Nest	Total
Toru	2008–09	6–7 Oct 2008	828	70	898
	2009–10	2 Oct 2009	783	51	834
	2010–11	28–29 Sep 2010	780	49	829
Rima	2008–09	16 Oct 2008	279	18	297
	2009–10	30 Sep 2009	265	17	282
Wha	2009–10	7 Oct 2009	0	0	0

Sagar et al. (2014) reported counts of breeding Salvin's albatross at the Western Chain in 2014 (count date: 17 September 2014) and found 898 and 315 breeding pairs on Toru and Rima, respectively. The overall total in 2014 of 1213 breeding pairs was similar to the totals of 1195 and 1116 for 2008 and 2009, respectively (Table 6, Sagar et al. 2011), perhaps indicating a relatively small but stable population. An aerial, photographic survey of breeding Salvin's albatrosses at the Western Chain was also carried out on 17 September 2014 (Baker et al. 2015). Adjusting for the proportion of birds actually incubating an egg (as opposed to birds sitting on empty nests), using data obtained by the ground-based field team (Sagar et al. 2014), Baker et al. (2015) recorded 1486 breeding pairs (not including nests with broken eggs), compared to 1125 breeding pairs from the ground count (Sagar et al. 2014). Baker et al. (2015) suggested that double-counting of birds in photographs, although unlikely, was possible, and that the aerial counts could have recorded birds that were not recorded from the ground counts as potential explanations for the difference in totals.

Previous counts of breeding Salvin's albatross at the Western Chain have generally been made later in the breeding season or on either Toru or Rima, but not both (see Sagar et al. (2011) for a summary), making direct comparisons with summarised counts difficult. However, Clark (1996) reported 1021 nests with eggs on Toru on 5 October 1995, slightly higher than the counts noted here for Toru (Table 6).

Sagar et al. (2011) calculated survival rate estimates based on band resighting data gathered over the three years of fieldwork at the Western Chain. These resighting data included birds banded as chicks in 1986 and birds banded as adults in 1995, as well as adult birds banded and resighted as part of this study. Sagar et al. (2011) reported an adult survival rate of 0.967 and an apparent survival rate of chicks from 1986 of 0.939, some of the highest survival estimates for annually-breeding albatrosses.

3.3.2 Bounty Islands

Baker et al. (2012), an unpublished client report produced for the Ministry of Fisheries, summarised the findings of an aerial photographic survey of breeding pairs of Salvin's albatross at all the Bounty Islands in October 2010 (Table 1). The results from that survey, and additionally those from a subsequent aerial survey in October 2013, were updated and collated in a report to the Department of Conservation (Baker et al. 2014). A third complete count, also using aerial photography, ground-truthed by researchers at the Bounty Islands, was completed in October 2018 (Baker & Jensz 2019).

Table 7 summarises raw and corrected totals of Salvin's albatrosses at the Bounty Islands (see Baker et al. 2014, Baker & Jensz 2019). Raw totals (all birds counted in photographs) have been corrected for the proportion of nests (or apparently occupied sites) that contained an egg and for 'loafing' birds (those birds attending the breeding colony but which were not obviously associated with a nest) as

determined through ground-truthing. No ground-truthing occurred in 2010, so the raw count for that year was corrected using ground-truthing data from 2013 (Baker et al. 2014).

Table 7: Numbers of Salvin's albatrosses (raw) and breeding pairs (adjusted) on the Bounty Islands as determined from aerial photography carried out in October 2010, 2013 and 2018.

Year					
2010		2013		2018	
Raw	Adjusted	Raw	Adjusted	Raw	Adjusted
42 832 ± 207	31 786 ± 232	53 893 ± 178	39 995 ± 200	60 419 ± 246	26 955 ± 164

While the raw totals for Salvin's albatrosses at the Bounty Islands showed an increasing trend across the three years surveys were completed, the totals adjusted for non-breeding birds on nests and for loafing birds peaked in 2013 and then declined to 2018 (Table 7). It should be noted however that the 'correction factor' (the mean proportion of birds counted in photographs that were actually incubating an egg) differed markedly between 2013 (0.74) and 2018 (0.47), and that 2010 data were corrected using the 2013 correction factor. Given the relatively large difference between the two correction factors used, it would be prudent to approach the adjusted totals reported by Baker et al. (2014) and Baker & Jensz (2019) with caution.

Sagar et al. (2015), in a paper describing a declining trend in the Salvin's albatross population, summarised ground-based counts of breeding Salvin's albatross at Proclamation Island within the Bounty Islands and reported totals of 3065 and 2634 breeding pairs in 1997 and 2004, respectively. Baker et al. (2014) reported Proclamation Island totals of 2116 and 4880 breeding pairs in 2010 and 2013, respectively, and Baker & Jansz (2019) reported a total of 2978 breeding pairs at Proclamation Island in 2018, all based on aerial photography. Further work is required to resolve how best to report estimates of breeding Salvin's albatrosses at the Bounty Islands. It is clear, however, that within New Zealand, the Bounty islands support more than 95% of the Salvin's albatross population, with the remainder at the Western Chain (see above).

3.4 Chatham albatross

Work on Chatham albatross consisted of ground-based nest counts (population estimates) and band resighting for demographic parameter estimates. Chatham albatross is the subject of a current Fisheries New Zealand project (PRO2017-05B) that aims to synthesise all available population estimate and mark-recapture information in order to determine population trajectory and to quantify a range of key demographic parameters. The reader is directed to the outputs for project PRO2017-05B for a more comprehensive and sophisticated treatment of all the available data. Here the nest count data acquired between 2007 and 2010 are summarised.

Table 8: Numbers and percentages (in parentheses) of nests of Chatham albatross on the Pyramid, Chatham Islands. Active nests are those defined as 'egg', 'chick' and 'failed' (see Scofield et al. (2008a) and Fraser et al. (2009a, 2010a, 2011)).

Breeding Season	Date of Counts	Active Nests	Empty Nests	Total Nests
2007–08	19–29 Nov 2007	5 025 (96%)	222 (4%)	5 247
2008–09	22 Nov–7 Dec 2008	5 209 (96%)	198 (4%)	5 407
2009–10	9–12 Dec 2009	5 028 (97%)	166 (3%)	5 194
2010–11	24–30 Nov 2010	5 087 (97%)	158 (3%)	5 245

Table 8 provides details of nest counts of Chatham albatross carried out across four breeding seasons within PRO2006-01. For three areas of the Pyramid, it was not possible to delineate between an empty nest and a nest that had failed (and which contained egg fragments, an abandoned egg or a dead chick). For these three areas, the number of failed nests has been determined by applying the mean percentage of failed nests for the remaining 11 areas for which empty and failed nests were recorded separately (% failed nest = number failed / number failed + number empty × 100). Table 8 summarises the number and percentage of 'active' nests (those nests defined as 'chick', 'egg' and 'empty' combined, see Scofield et al. (2008a) and Fraser et al. (2009a, 2010a, 2011)) and empty nests each year. It is striking that the total number of nests and the number and proportion of nests that were active or empty in each year are relatively stable: over these four breeding seasons, the total number of nests ranged from 5194 to 5407 and of these 96–97% were classified as active. Bell et al. (2017a) provided a compilation of Chatham albatross nest count data spanning 1999 to 2016: even over this extended timeframe, total nest counts ranged from 5194 (in 2009) to 5407 (in 2008) noted above, with the mean number of nests across all eight years being 5294.

3.5 Northern Buller's albatross

Work on northern Buller's albatross consisted of ground-based nest counts (population estimates). Table 9 provides summary information on the numbers of northern Buller's albatross nests, and, based on sub-samples of nests, nest contents for each of the three breeding seasons 2007–08 to 2009–10.

Table 9: Numbers of nests and mean proportions of nests by nest contents (as percentages) of northern Buller's albatross on the Forty-Fours, Chatham Islands. Nest + Egg = nest with an adult incubating an egg, Nest + Adult, no Egg = an adult sitting on an empty nest, Empty Nest = a nest with neither an adult or an egg present and Failed Nest = nest with broken egg or fresh eggshell, or eggshell beside a nest with or without an adult present. * Counts of failed nests were incomplete in 2007 (see Scofield et al. (2008b) and Fraser et al. (2009b, 2010b)).

Breeding Season	Date of Counts	Total Nest Count	Nest + Egg (%)	Nest + Adult, No Egg (%)	Empty Nest (%)	Failed Nest (%)
2007–08	13–19 Nov 2007	15 238	61	24	11	*
2008–09	9–18 Nov 2008	14 674	61	28	5	6
2009–10	1–8 Dec2009	14 185	76	13	8	3

Total numbers of nests ranged from 14 185 in 2009 to 15 238 in 2007 (Table 9), with the percentage of nests with an incubating adult increasing from 61% in 2007 and 2008 to 76% in 2009. This increase in the proportion of nests with an incubating adult in 2009 may reflect the slightly later timing of the count in this year (early December in 2009 compared to mid-November in 2007 and 2008: Table 9), when the breeding season would have been more advanced and with a greater number of adults having completed egg-laying (Fraser et al. 2010b).

Based on a ground-count, the total number of northern Buller's albatross nests at the Forty-Fours in December 2016 was 17 682 with at least 16 492 of these classified as being an adult incubating an egg or having already failed (Bell et al. 2017b). While these totals were higher than those for 2007–2009 (Table 9), Bell et al. (2017b) noted that this probably reflected improved methodology rather than a genuine increase in the population size. Additionally, Baker et al. (2017) reported a total of 13 771 breeding northern Buller's albatrosses at the Forty-Fours from a photographic aerial survey, adjusted based on ground-truthing data. The difference between this lower total (13 771: Baker et al. 2017) and the ground-count total of 16 492 (Bell et al. 2017b) may reflect an inability to detect all breeding pairs from the air.

The Forty-Fours support approximately 84% of the breeding population of northern Buller's albatross at the Chatham Islands, with the remainder (3158 nests with an egg or having failed in December 2017) located on Big and Middle Sister islands (Bell et al. 2018).

3.6 Northern royal albatross

Scofield et al. (2008b) summarised ground-based counts of nesting northern royal albatrosses at the Forty-Fours, Chatham Islands between 13 and 19 November 2007. A total of 1070 nests were recorded with birds incubating eggs or sitting on empty nests, as egg-laying was incomplete at the time of the survey.

Scofield (2011) summarised the results of four aerial photographic surveys of northern royal albatrosses at the Forty-Fours and at Big Sister and Middle Sister islands. Table 10 presents counts of breeding pairs across all four breeding seasons and at all three islands. Total counts for the Chatham Islands ranged from 5388 in 2006–07 to 5744 in 2009–10 (Scofield 2011). It should be noted that Scofield (2011) compared the results of the aerial survey of the Forty-Fours from 2007–08 with the ground count from the same breeding season: the aerial survey found 2212 breeding pairs of northern royal albatross (Table 10), compared to a ground count of 2125 breeding pairs. It is not clear why the ground count total of 2125 pairs for the Forty-Fours in 2007–08 (Scofield 2011) differs from the count of 1070 reported by Scofield et al. (2008b).

Table 10: Numbers of breeding pairs of northern royal albatross on the Forty-Fours, Big Sister and Middle Sister islands, Chatham Islands.

Breeding Season	Forty-Fours	Big Sister	Middle Sister	Chatham Islands Total
2006–07	1 879	2 128	1 381	5 388
2007–08	2 212	2 018	1 371	5 601
2008–09	2 055	2 081	1 316	5 452
2009–10	2 692	1 893	1 159	5 744

Scofield (2011) also summarised breeding success data, based on counts of chicks near fledging that resulted from breeding attempts initiated earlier in the breeding season and captured in photographs taken at different times of year, for northern royal albatrosses at the Forty-Fours, Big Sister and Middle Sister islands. Breeding success appeared higher at the Forty-Fours, ranging from 40% to 54% across the fours breeding season studied, whereas at Big Sister breeding success was as low as 14% in 2007–08 and was highest in 2006–07 at 41%. Breeding success at Middle Sister ranged from 32% in 2007–08 to 49% in both 2006–07 and 2009–10 (Scofield 2011).

Bell et al. (2017b) reported a total 1400 northern royal albatross nests containing an egg at the Forty-Fours in December 2016. Even adding the 121 failed nests noted in 2016 (Bell et al. 2017b) to this total would still result in an overall breeding pairs total (1521) that was considerably lower than the 1879–2692 breeding pairs reported by Scofield (2011) across 2006–07 to 2009–10 (Table 10). Similarly, ground counts of Big and Middle Sister islands in December 2017 found lower numbers of breeding northern royal albatrosses compared to totals reported by Scofield (2011). There were 1391 nests with an egg or which had already failed at Big Sister in 2017 (Bell et al. 2018), compared to totals that ranged from 1893 to 2128 (Scofield 2011) across 2006–07 to 2009–10 (Table 10), and 864 nests at Middle Sister, compared to 1159 to 1381 (Scofield 2011) across 2006–07 to 2009–10 (Table 10).

An aerial photographic survey in December 2016 reported a total of 1581 breeding pairs of northern royal albatrosses at the Forty-Fours, whereas a count based on satellite imagery found 2533 pairs (Baker et al. 2017). For the Sisters, Baker et al. (2017) reported an aerial count of 2824 breeding pairs and a satellite-based count of 2578 breeding pairs. Some of the discrepancies between ground, aerial and satellite counts may be due to timing of when counts were carried out, but further ‘truthing’ of these approaches is warranted.

3.7 Northern giant petrel

Northern giant petrels nest relatively early in the summer breeding season, such that at the time of visits to the Forty-Fours (November to December) breeding birds were at the chick-rearing phase of the breeding season. Scofield et al. (2008b) reported a total of 483 nests with northern giant petrel chicks within four areas of the Forty-Fours in 2007–08. In the subsequent two breeding season, nest totals were limited to the areas identified as 'Sample 1' and 'Sample 2' by Scofield et al. (2008b), which had a combined nest total of 431 in 2007–08. In 2008–09 and 2009–10, the combined 'Sample 1' and 'Sample 2' nest estimates were 349 and 270, respectively (Fraser et al. 2009b, 2010b). An earlier count, from 1993, found 273 northern giant petrel nests (Robertson & Sawyer 1994).

In December 2016, Bell et al. (2017b) reported 424 northern giant petrel nests (with chicks or which had failed) in areas 'Sample 1' and 'Sample 2', and, based on extrapolation from an estimated breeding success rate of 60.1%, suggested a total breeding population of 1977 pairs for the Forty-Fours. Using a similar approach, Bell et al. (2018) reported breeding population totals for northern giant petrel of 46 and 110 pairs at Big Sister and Middle Sister islands, respectively, in December 2017.

The Chatham Islands remain the stronghold for northern giant petrels with perhaps 2000–2200 breeding pairs spread across the Forty-Fours and the Sisters islands (see above). By comparison, Parker et al. (2016) reported approximately 340 pairs of northern giant petrels at the Auckland Islands in 2015–16, Wiltshire & Hamilton (2003) reported 230 pairs at Antipodes Island and Wiltshire & Scofield (2000) reported 234 pairs at Campbell Island.

4. ACKNOWLEDGMENTS

This work was supported by Ministry of Fisheries project PRO2006-01 and Fisheries New Zealand project SEA2017-08. Many thanks to all those researchers involved with data collection in the field and with the production of the project annual reports, upon which this synthesis is based. Thanks also to Kalinka Rexer-Huber for discussions around population estimates for white-chinned petrel and to Ian Tuck for reviewing an earlier version of this report.

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