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ABSTRACT

This report is part of the ongoing study of the black petrel, *Procellaria parkinsoni,* on Great Barrier Island (Aotea Island) that was begun in the 1995/96 breeding season. During the 2014/15 breeding season, 422 study burrows within the 35-ha study area near Mount Hobson/Hirakimata were checked and intensively monitored. Of these, 283 were used by breeding pairs, 100 by non-breeding adults and the remaining 39 burrows were non-occupied. By 28 April 2015, 199 chicks were still present in the study burrows, corresponding to a breeding success of 70.3%. Nine census grids were monitored within the study area and accounted for 159 of the inspected burrows, with 97 burrows being used for breeding. Eighty-nine chicks from earlier breeding seasons were recaptured within the Mount Hobson colony area this season (a total of 194 'returned chicks' have been caught since the 1999/2000 season). Analysis of the stratified census grid and mean transect data estimated that there were 2296 to 2606 birds present in the 35-ha area around Mount Hobson (Hirakimata).

Keywords: black petrel, *Procellaria parkinsoni*, monitoring, population estimate, breeding success, fishing effort, bycatch, Great Barrier Island (Aotea Island), New Zealand

1. INTRODUCTION

The black petrel, *Procellaria parkinsoni*, is a medium-sized endemic seabird which is only known to breed on Hauturu-o-Toi/Little Barrier Island (36°199'S 175°082'E) (LBI) and Great Barrier Island (Aotea Island) (36°187'S 175°4125'E) (GBI), New Zealand (Heather and Robertson 1996).

The main breeding area on GBI is around the summit of Mount Hobson (Hirakimata) (hereafter Mount Hobson). Monitoring work carried out during the 2014/15 breeding season was a continuation of the survey and monitoring study begun in 1995/96 (Bell & Sim 1998a, Bell & Sim 1998b, Bell & Sim 2000a, Bell & Sim 2000b, Bell & Sim 2000c, Bell & Sim 2002, Bell & Sim 2003a, Bell & Sim 2003b, Bell & Sim 2005, Bell *et al.* 2007, Bell *et al.* 2009, Bell *et al.* 2011a, Bell *et al.* 2011b, Bell *et al* 2011c, Bell *et al.* 2013a, Bell *et al.* 2013b, Bell *et al.* 2014), adding to the baseline data on the Great Barrier Island black petrel population. Field work carried out in 2006/07, 2010/11 and 2011/12 seasons was privately funded and has not been reported through the DOC publication process. The annual report for those seasons can be obtained from the lead author (EAB). Mark-recapture, breeding and population data from the 2006/07, 2010/11 and 2011/12 seasons have been included in this (2014/15) report. This study will assist in identifying effects that at-sea and land-based threats may have on the population and build on the earlier population parameter and tracking data (Bell *et al.* 2009, Bell *et al.* 2011a, Bell *et al.* 2011b, Bell *et al.* 2011c, Bell *et al.* 2013b, Bell *et al.* 2014). The population estimate and population trend data has been updated, ensuring that any population changes will be detected in time to implement the appropriate management strategies.

2. OBJECTIVES

The main objective of this study was to estimate the population trend, fecundity and age-class survival of black petrels on GBI. The annual census of the black petrel population on GBI was undertaken via burrow monitoring and the banding of adults and fledglings to establish adult mortality, fecundity, breeding success, recruitment and age-class survival to describe the population trend. Since this study was a continuation of research from previous breeding seasons, we also aimed to provide more data to establish population trends and to determine causes and timing of mortality.

In summary, the study objectives were:

- Collect data that will allow estimation of the black petrel population size and describe the population trend by comparing the estimate to relevant existing data. Key tasks conducted under this objective were:
    - Monitor a sample of black petrel burrows within the main breeding area and band all adults present in the burrows during December 2014 and January/February 2015 and band all remaining fledglings during April 2015.
    - Determine breeding success in the sample of long-term study burrows and record causes of breeding failure.
    - Monitor and re-survey the census grids and study area for new burrows and band and recapture as many breeding and non-breeding birds present as possible.
    - Continue the mark/recapture programme, capturing and banding as many birds as possible during the breeding season to determine juvenile (pre-breeder) survival, fecundity, age of first return to the natal colony, age of first breeding attempt, age of first successful breeding attempt and adult (breeder) survival.
    - Confirm the breeding status of adults during each visit to the colony (i.e. to monitor the study burrows at the beginning, middle and end of the breeding season), and where possible, identify the sex of the resident adult.
    - Determine a population estimate by extrapolating from stratified census grids to the main Mount Hobson breeding area.

3. METHODS

3.1 Study burrows

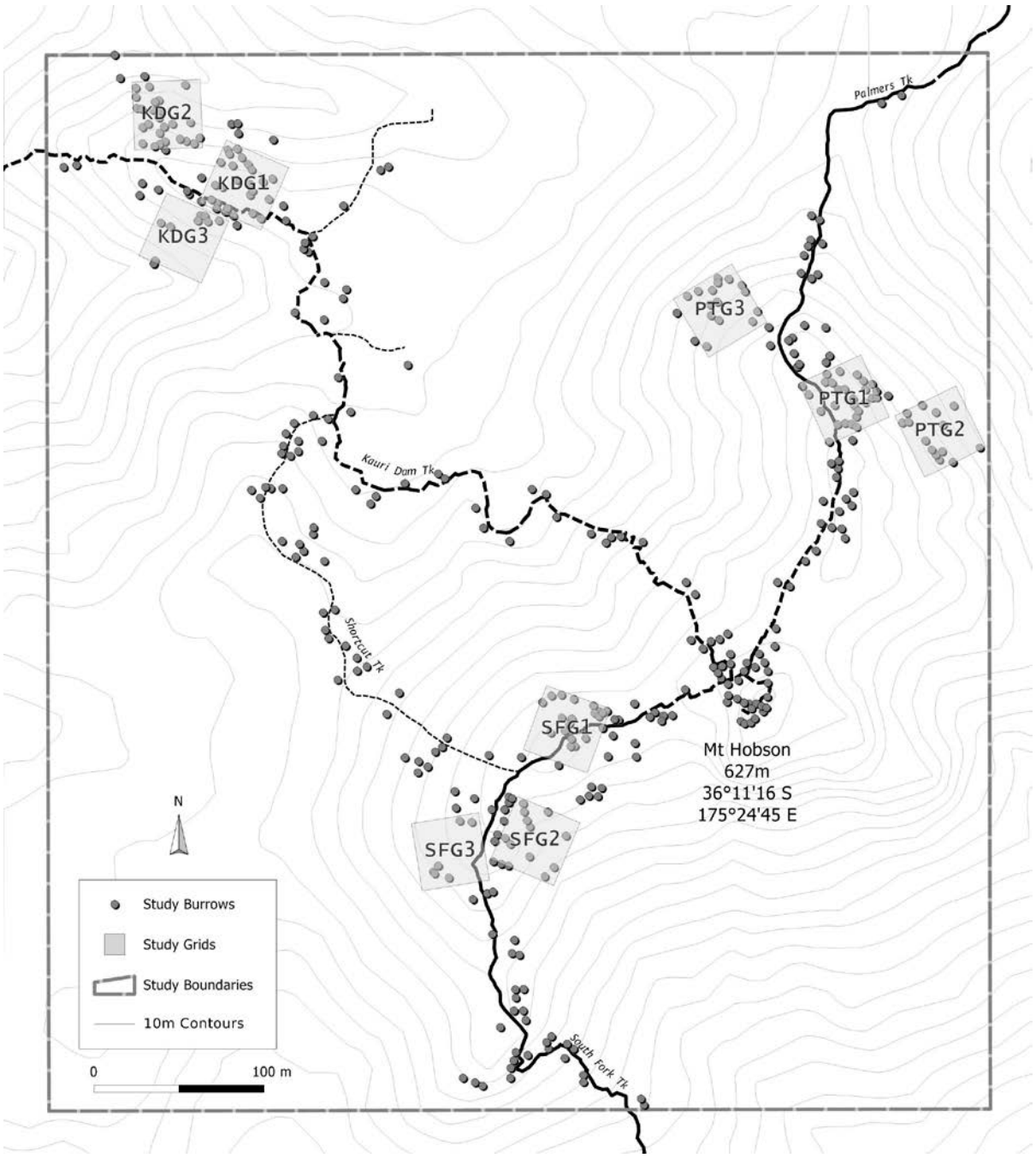
The study area (35 ha at and around the summit of Mount Hobson; Figure 1) was visited three times during the breeding season; 6-15 December 2014. During this visit the study burrows (*n* = 422, Figure 1) were either randomly selected from those along the track system (i.e. within 10 m of either side), burrows that have 'returned chicks' (pre-breeders) resident, or all burrows within the nine census grids. The study burrows have been selected regularly since 1995/96 season (Bell & Sim 1998a, Bell & Sim 1998b, Bell & Sim 2000a, Bell & Sim 2000b, Bell & Sim 2000c, Bell & Sim 2002, Bell & Sim 2003a, Bell & Sim 2003b, Bell & Sim 2005, Bell *et al.* 2007, Bell *et al.* 2009, Bell *et al.* 2011a, Bell *et al.* 2011b, Bell *et al.* 2011c, Bell *et al.* 2013a, Bell *et al.* 2013b, Bell *et al.* 2014). To ensure accurate monitoring, the study burrows were accessible either through the main entrance or via an opening that had been excavated through the burrow roof or wall into the chamber. This opening was covered by a piece of plywood, which was camouflaged with soil and debris. Any occupying adult was removed from the burrow, banded (or the band number recorded if a recapture), sexed by viewing the cloaca (if swollen, the bird is a female — the cloaca is particularly obvious immediately after egg laying) and returned to the burrow. The presence of any egg was noted.

On a second visit to the colony (28 January-25 February 2015) the study burrows were intensively monitored again. As in the December visit, any adults present were identified or banded, and returned to the burrow. The presence of eggs, eggshell fragments or chicks was noted and the absence of this sign was used to identify non-breeding birds.

The study burrows were monitored again (22-28 April 2015). All remaining fledgling chicks were banded. This information was used to determine breeding success.

The locations of study burrows were mapped by entering GPS co-ordinates into GIS-mapping software (Manifold™).

Figure 1 Location of the black petrel (Procellaria parkinsoni) study burrows and census grids within the study area on Great Barrier Island (Aotea Island). Altitude (621 m a.s.l.) is shown. Approximate North is shown (N). KDG = Kauri Dam Grid; SFG = South Forks Grid; PTG = Palmers Track Grid.



3.2 Census grids

The three original grids (KDG1, PTG1 and SFG1) were established in 1996 (Bell & Sim 1998a). These grids were located in areas that had a known historical presence of black petrels, different strata, vegetation types and topography and were near known petrel launch sites (Bell & Sim 1998a) (Figure 1). These original grids were replicated in 1998 (KDG2, PTG2 and SFG2) and in 1999 (KDG3, PTG3 and SFG3) to compare burrow densities between areas and to increase the accuracy of the population estimate (Bell & Sim 2000a, Bell & Sim 2000b).

These nine census grids (each 40 x 40 m) set up around Mount Hobson were systematically searched (at 1 m intervals) during the December 2014 and February 2015 visits by authors (EAB and JS) using Rua and Maddi (Department of Conservation certified bird dogs owned by JS) to locate any new burrows and to determine occupancy rates. The same procedure as for study burrows (see section 3.1) was followed for all birds in the burrows in the grids.

3.3 Night banding

Night work was undertaken during the December 2014 and January/February 2015 visits to the study area. This involved searching the study area by walking the track system and capturing any adult petrel on the surface. Several nights were also spent at known petrel launch sites, where birds were captured at take-off or landing. All birds were banded or had their band numbers recorded. During the December 2014 visit, sex was determined (if possible) by cloacal inspection.

3.4 Preliminary surveys around the island

Ground-based searches using seabird detector dogs were conducted at Mt Heale, Kaiaraara Track Ridge, Maungapiko, Windy Canyon, Whangaparapara Hill, Te Ahumata, Cooper's Castle and Ruahine (Figure 2). These searches were completed to determine whether black petrels were present in other locations on GBI. Search areas were selected from historical records of black petrels. The same procedure as for study burrows (See Section 3.1) was followed for any bird found in a burrow with the search area. Each burrow was mapped using GPS.

Figure 2 Location of black petrel (Procellaria parkinsoni) burrows within random search areas on Great Barrier Island (Aotea Island), February 2015.

3.5 Population estimate

Bell et al. (2007) noted that previous population estimates determined by direct extrapolation from the nine census grids have overestimated the black petrel population size due to the original census grids being established in areas of known high petrel density, whereas the distribution of burrows over the whole 35-ha study area is not uniform.

The population estimate for the 35-ha study area was determined by extrapolating from the earlier transects and census grids after stratification of the 35-ha study area (stratifying the area into the four habitat grades based on burrow density, ranking and splitting the length of the transects and areas of the census grids into those habitat types, and then extrapolating to the habitat areas which make up the 35 ha).

For all estimates, any breeding burrow was treated as having two resident birds present and any non-breeding burrows was treated as having 1.25 birds present (as in any non-breeding burrow there is a 25% chance of capturing more than one bird in the burrow when the resident male attracts a female to that burrow).

3.6 Programme MARK

Adult survival and the corresponding dispersion coefficient (Chat) value were calculated using the Burnham Jolly Seber (Live/Dead) model for adult survival over time and age [S(age) P(age) r(*) F(*) where S = apparent survival, P = probability of recapture, r = reportability and F = fidelity]. Juvenile survival and corresponding Chat values were also calculated, using the Burnham Jolly Seber model.

4. RESULTS

4.1 Study burrows

Within the 422 study burrows (those burrows that could be accessed to determine occupancy out of the 432 numbered burrows in the 2014/15 season), 283 contained breeding birds, 100 contained non-breeding birds and 39 were non-occupied (Appendix 1, Tables 1 and 2). There were 84 failures (e.g. loss of eggs, infertility, predation, etc., Table 2). This corresponds to a breeding success of 70.3% (Table 2, Figure 3). Table 2 shows the failures and overall breeding success rate within the study burrows since 1995/96.

Table 1 shows the percentage of occupied and non-occupied burrows within the study burrows and the percentages of non-occupied, breeding and non-breeding burrows. Data from the past 17 breeding seasons shows the ratio of breeding to non-breeding burrows has averaged 3:1 (± 0.2) with a range of 2.2 to 5.8 over this period, and the number of the burrows used for breeding has decreased over the period (Table 1, Figure 3). Over this same 17-year period, the ratio of occupied to non-occupied burrows has ranged from 5:1 to 19:1; the number of non-occupied burrows has also increased over this time despite a drop in numbers this season (Table 1, Figure 3). The last four seasons have had similar numbers of occupied and non-occupied burrows (Table 1). The number of burrows used by breeding birds has declined overall despite the increase in breeding occupancy from last season (Figure 3). Similarly the number of burrows being used by non-breeding birds have increased overall despite the last three seasons showing a decline (Figure 3). The number of burrows used for breeding this season was higher than last season and the overall mean for the entire study (67.1% compared to 66.6 ± 0.7%, Table 1).

Table 1 Proportions of occupied, non-occupied, breeding and non-breeding burrows, ratio of occupied to non-occupied and breeding to non-breeding burrows, and breeding success, within the black petrel (Procellaria parkinsoni) study burrows on Great Barrier Island (Aotea Island) since the 1998/99 breeding season.

	OCCUPIED (%)	NON-OCCUPIED (%)	RATIO (OCCUPIED TO NON-OCCUPIED)	BREEDING BURROWS (%)	NON-BREEDING BURROWS (%)	RATIO (BREEDING TO NON-BREEDING)	BREEDING SUCCESS (%)
1998/99	93	7	13:1	71	23	3.0:1	77
1999/00	94	6	16:1	72	22	3.3:1	74
2000/01	95	5	19:1	66	29	2.3:1	76
2001/02	92	8	12:1	68	24	2.8:1	70
2002/03	88	12	7:1	63	25	2.5:1	69
2003/04	82	18	5:1	64	18	3.6:1	76
2004/05	86	14	6:1	63	23	2.7:1	80
2005/06	82	18	5:1	70	12	5.8:1	67
2006/07	91	9	10:1	70	21	3.3:1	83
2007/08	85	15	6:1	68	17	4.0:1	77
2008/09	89	11	8:1	69	21	3.3:1	76
2009/10	87	13	7:1	62	25	2.5:1	74
2010/11	85	15	6:1	66	19	3.5:1	61
2011/12	92	8	12:1	63	29	2.2:1	77
2012/13	91	9	10:1	66	25	2.6:1	81
2013/14	89.5	10.5	8.5:1	64.9	24.6	2.6:1	70.3
2014/15	90.8	9.2	10:1	67.1	23.7	2.8:1	70.3
MEAN (± SEM)	89.0 (± 1.0)	11.0 (± 1.0)	9.4:1 (± 1.0)	66.6 (± 0.7)	22.4 (± 1.0)	3.1:1 (± 0.2)	74.0 (± 1.3)

Table 2 Breeding success and causes of mortality in the black petrel (Procellaria parkinsoni) study burrows on Great Barrier Island (Aotea Island) between the 1995/96 and 2014/15 breeding seasons.

Year	Number of study burrows	Eggs									Chick							**OVERALL BREEDING SUCCESS (%)**
		Laid	Predation (rat)	Crushed[1]	Abandoned	Infertile	Dead embryo	Disappeared egg[2]	Unknown[3]	Hatched	Predation (rat)	Predation (cat)	Died (disease)	Died (starvation)	Died (unknown causes)	Disappeared chick[4]	Fledged[5]	
95/96	80	57	1	0	0	0	0	2	0	54	0	0	0	0	0	0	54	**94**[6]
96/97	118	92	6	5	2	6	0	0	0	73	0	0	1	0	0	0	72	**78**
97/98	137	95	1	0	1	4	8	0	0	81	0	0	0	1	0	0	80	**84**
98/99	197	142	2	1	5	12	6	0	0	116	2	2	0	0	3	0	109	**77**
99/00	248	178	9	10	1	6	13	0	0	139	0	2	0	0	6	0	131	**74**
00/01	255	168	6	6	3	8	9	0	0	136	0	1	0	0	7	0	128	**76**
01/02	283	192	5	5	9	3	14	11	0	145	0	2	0	0	8	0	135	**70**
02/03	318	199	1	14	7	2	19	3	5	148	0	3	0	0	8	0	137[7]	**69**
03/04	324	208	2	13	0	7	16	0	0	170	0	2	0	0	10	0	158[7]	**76**
04/05	362	226	3	7	3	4	12	5	0	192	0	0	0	0	7	5	181[7]	**80**
05/06	366	257	15	27	1	0	9	19	0	186	0	2	0	0	12	0	172[7]	**67**
06/07	370	257	0	7	2	1	6	19	0	222	0	0	0	0	10	0	212[7]	**83**
07/08	379	256	5	9	11	4	0	19	0	208	0	0	0	0	9	1	198[7]	**77**
08/09	388	266	5	11	6	3	18	7	0	216	0	0	0	0	15	0	201[7]	**76**
09/10	393	244	8	2	3	3	20	20	0	188	0	0	0	0	8	0	180[7]	**74**
10/11	396	262	8	15	13	3	15	33	0	175	0	1	0	0	13	2	159[7]	**61**
11/12	363[8]	214	6	12	1	0	4	23	0	168	0	0	0	0	0	4	164[7]	**77**
12/13	409	276	2	11	8	4	12	8	0	231	0	0	0	0	5	3	223[7]	**81**
13/14	410	266	6	3	8	8	3	35	0	203	0	0	0	4	0	12	187[7]	**70.3**
14/15	422	283	1	12	6	4	24	15	0	221	0	0	1	0	17	4	199	**70.3**

[1] These eggs have been crushed and only shell fragments were recovered from the burrow. Some may have been predated by rats, infertile or contained an embryo which died.

[2] These eggs were present in December, but were gone when first checked in January. Many of the burrows had been cleaned out and the adults were not caught again.

[3] There were five burrows that were not located in May 2003 and as a result it is not known if the eggs hatched successfully. To determine overall breeding success we have been cautious and assumed that they failed.

[4] These chicks were present in February, but were gone in April. The chicks were too young to have fledged. Some may have been predated by rats or cats, or died due to starvation or disease and removed from the burrow by their parents.

[5] All chicks still present at the end of the April or May trip. It is assumed all will fledge safely.

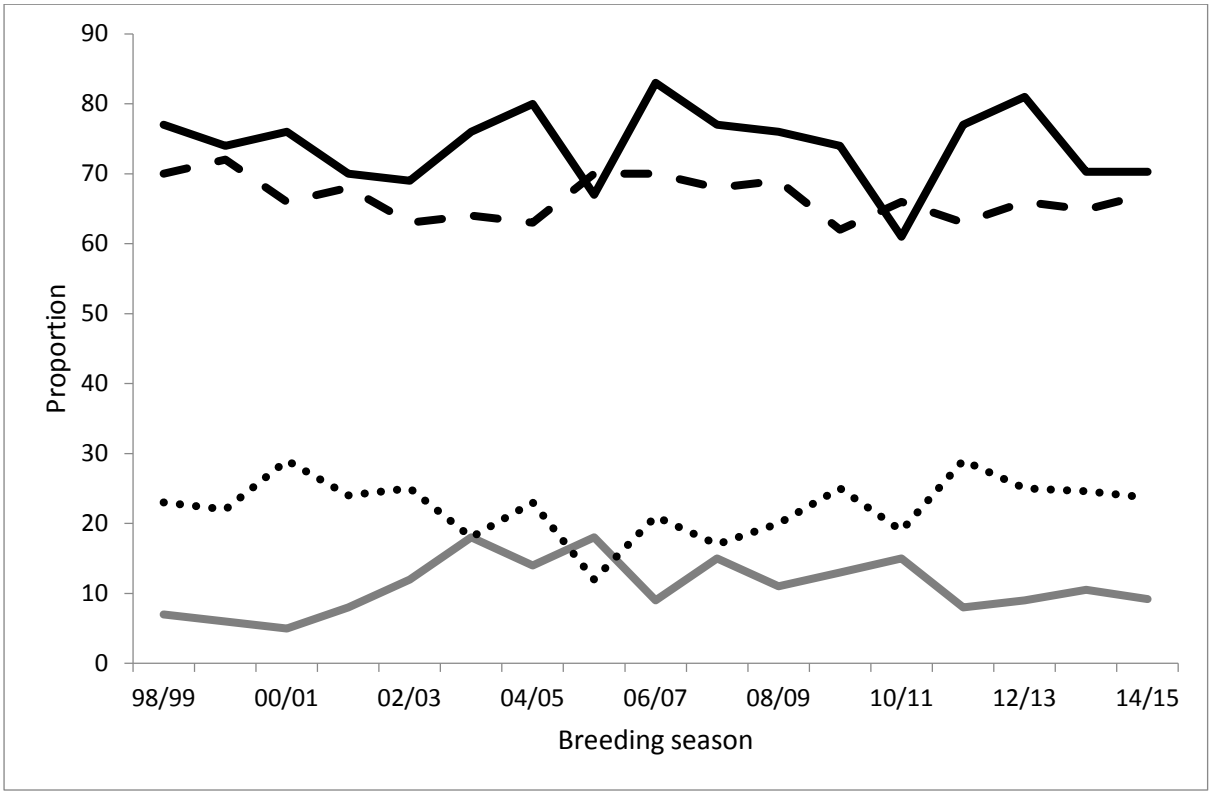
[6] This breeding success rate is biased as most of these 80 study burrows were located in late February when chicks were already present (and these chicks were likely to survive to fledging).

[7] Of these, some chicks had already fledged prior to the banding visit (78 in 2002/03; 50 in 2003/04; 6 in 2004/05; 8 in 2005/06 (plus 24 unbanded due to a lack of bands), 1 in 2006/07, 8 in 2007/08, 2 in 2008/09, 22 in 2009/10, 21 in 2010/11, 6 in 2011/12, 8 in 2012/13 and 2 in 2013/14). The remaining chicks were banded.

[8] There were 401 study burrows checked in December and January, but only 363 were monitored over the complete 2011/12 breeding season (December 2011, January 2012 and April 2012). There were 38 burrows that could not be located by the field team in April 2012.

Figure 3 shows the trend in the proportion of non-occupied, breeding and non-breeding burrows since the 1998/99 breeding season. It appears that breeding success has been relatively stable (with regular fluctuations between years) despite the number of burrows being used for breeding reducing over the same time (Figure 3). The annual breeding success this season was 70.3%, which is lower than the mean annual breeding success (74.0% ± 1.3) for the past 17 years of the study (Tables 1 and 2).

Figure 3 Occupancy and breeding success of study burrows (1998/99 to 2014/15 breeding seasons) by black petrels (Procellaria parkinsoni) on Great Barrier Island (Aotea Island). Solid black line = breeding success; dashed black line = burrows used by breeding birds; dotted line = burrows used by non-breeding birds; solid grey line = unoccupied burrows.



4.2 Number of burrows in the census grids

A total of 159 burrows were found in the nine census grids (Appendix 1, Figure 1, Table 3) in the 2013/14 breeding season. Of these, 97 burrows were used by breeding pairs, 42 were used by non-breeding adults and 20 burrows were non-occupied (Table 3).

Figure 4 shows the trend in the number of non-occupied, breeding and non-breeding burrows in the census grids since the 1998/99 season. It appears that the number of burrows used for breeding in the census grids has decreased over the length of the study, despite a slight increase in burrows used for breeding over the past three seasons. There is also an apparent increase in breeding success since the beginning of the study. Despite lower number of non-breeding burrows and slight increase in non-occupied burrows this season, the overall trend for both non-occupied and non-breeding burrows shows an increase since 1998 (Figure 4).

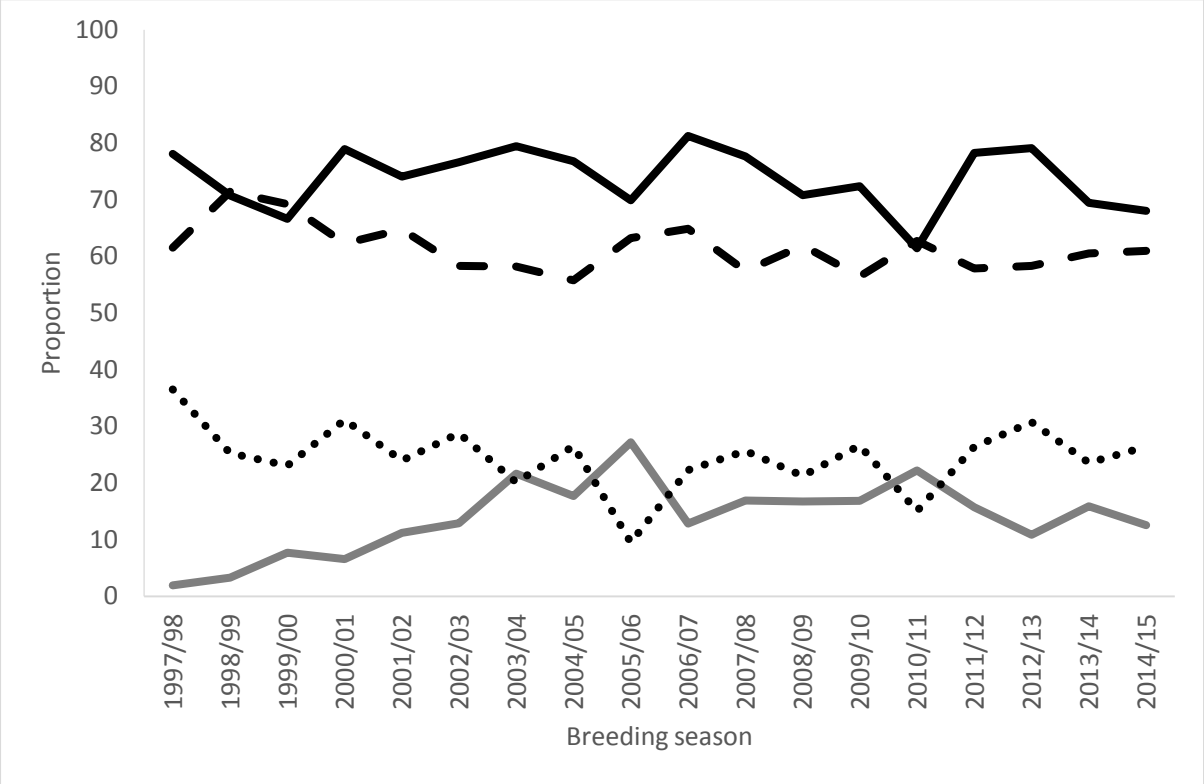
There were also several 'potential' burrows within the grids, which were not included in any burrow estimate, but are annually monitored for activity. 'Potential' burrows are those which had been investigated and/or preliminarily dug out, but were not yet being used by breeding or non-breeding petrels.

Table 3 Type and number of study burrows within the black petrel (Procellaria parkinsoni) census grids (Kauri Dam, Palmers Track and South Forks) in the study area on Great Barrier Island (Aotea Island) between the 1995/96 and 2014/15 breeding seasons.

	YEAR	KAURI DAM				PALMERS TRACK				SOUTH FORKS				**TOTAL**
		Non-occupied	Breeding	Non-breeding	TOTAL	Non-occupied	Breeding	Non-breeding	TOTAL	Non-occupied	Breeding	Non-breeding	TOTAL	
GRID ONE	1995/96	1	10	4	15	3	7	3	13	2	5	4	11	**39**
	1996/97	1	10	5	16	0	13	6	19	1	12	2	15	**50**
	1997/98	0	8	9	17	0	13	7	20	1	11	3	15	**52**
	1998/99	1	12	6	19	1	15	6	22	0	11	5	16	**57**
	1999/00	3	11	8	22	1	18	5	24	1	10	6	17	**63**
	2000/01	1	12	9	22	0	16	9	25	3	10	4	17	**64**
	2001/02	4	11	8	23	1	19	5	25	4	8	5	17	**65**
	2002/03	2	16	5	23	3	15	7	25	4	6	7	17	**65**
	2003/04	3	18	2	23	3	14	8	25	6	7	4	17	**65**
	2004/05	1	17	7	25	5	14	7	26	4	11	3	18	**69**
	2005/06	3	20	2	25	6	16	4	26	5	11	2	18	**69**
	2006/07	3	16	6	25	3	20	4	27	1	13	4	18	**70**
	2007/08	3	15	7	25	6	17	4	27	0	10	8	18	**70**
	2008/09	5	16	5	26	2	20	5	27	3	10	7	20	**73**
	2009/10	4	15	7	26	2	19	9	30	7	8	5	20	**76**
	2010/11	5	16	4	25	3	20	5	28	8	9	3	20	**73**
	2011/12	7	18	1	26	2	17	9	28	5	7	8	20	**74**
	2012/13	4	13	8	25	3	21	7	31	3	11	7	21	**77**
	2013/14	3	16	6	25	4	21	7	32	5	9	7	21	**78**
	2014/15	**2**	**15**	**9**	**26**	**5**	**21**	**5**	**31**	**3**	**16**	**3**	**22**	**79**
GRID TWO	1998/99	0	15	4	19	0	10	1	11	1	2	1	4	**34**
	1999/00	0	16	5	21	0	10	1	11	1	1	2	4	**36**
	2000/01	0	13	9	22	0	10	1	11	1	3	0	4	**37**
	2001/02	1	16	6	23	0	10	1	11	0	3	1	4	**38**
	2002/03	2	16	5	23	2	8	2	12	0	3	6	9	**44**
	2003/04	4	16	4	24	1	7	4	12	5	2	2	9	**45**
	2004/05	3	16	6	25	2	7	4	13	2	4	6	12	**50**
	2005/06	6	15	4	25	3	9	1	13	5	7	0	12	**50**

	2006/07	2	19	4	25	1	9	3	13	1	4	7	12	**50**
	2007/08	5	17	3	25	0	8	5	13	0	6	6	12	**50**
	2008/09	1	20	5	26	2	9	3	14	5	6	1	12	**52**
	2009/10	3	18	5	26	2	8	4	14	2	3	5	11	**51**
	2010/11	3	19	4	26	1	11	2	14	4	8	0	12	**52**
	2011/12	2	19	5	26	1	8	5	14	3	7	3	13	**53**
	2012/13	0	18	7	25	1	7	6	14	0	7	6	13	**52**
	2013/14	1	18	6	25	3	9	2	14	4	6	3	13	**52**
	2014/15	**1**	**17**	**6**	**24**	**1**	**6**	**8**	**15**	**2**	**9**	**3**	**14**	**53**
GRID THREE	1999/00	2	3	0	5	0	9	0	9	1	3	0	4	**18**
	2000/01	1	3	3	7	2	6	2	10	0	3	1	4	**21**
	2001/02	1	4	2	7	3	6	1	10	0	4	1	5	**22**
	2002/03	1	3	3	7	2	6	3	11	1	4	0	5	**23**
	2003/04	2	4	1	7	4	7	1	12	1	3	1	5	**24**
	2004/05	2	4	1	7	6	5	5	16	1	4	0	5	**28**
	2005/06	2	4	1	7	9	7	0	16	1	4	0	5	**28**
	2006/07	1	5	1	7	6	7	3	16	1	3	1	5	**28**
	2007/08	1	4	2	7	9	5	2	16	1	3	1	5	**28**
	2008/09	2	4	2	8	5	6	5	16	1	5	0	6	**30**
	2009/10	2	4	1	7	4	7	4	15	0	5	1	6	**28**
	2010/11	2	4	1	7	7	5	3	15	1	4	1	6	**28**
	2011/12	0	4	4	8	5	8	5	15	0	4	2	6	**29**
	2012/13	2	3	2	7	4	7	4	15	0	4	1	5	**27**
	2013/14	1	4	2	7	3	8	4	15	1	4	0	5	**27**
	2014/15	**1**	**3**	**3**	**7**	**5**	**7**	**2**	**14**	**0**	**3**	**3**	**6**	**27**

Figure 4 Occupancy of census grid burrows (1995/96 to 2014/15 breeding seasons) by black petrels (Procellaria parkinsoni) on Great Barrier Island (Aotea Island). Dashed black line = burrows used by breeding birds; dotted line = burrows used by non-breeding birds; solid grey line = unoccupied burrows.



4.3 Banding data

During the 2014/15 season, 704 adults were identified. Of these, 537 were already banded and 167 were banded this season (Appendix 1, Table 4). There were 199 chicks still present in the study burrows during the April visit and all were banded (Appendix 1, Table 4). An additional 16 chicks were banded in random burrows or on the surface within the study area.

There have been 2982 chicks banded within the study area between 1995 and 2015 (Tables 4, 5 and 6) and these birds have begun to return to the colony as pre-breeders, non-breeders and breeders (*n* (2014/15 season) = 89; *n* (total) = 194, Table 6, Appendix 2). The proportion of 'returned chicks' from each season varies from 0 to 12.9% (mean ± SEM = 7.3 ± 1.0); the greatest number of chicks that have been recaptured is from the 2004/05 breeding season (*n* = 22), but the highest proportion of chicks recaptured were banded in both the 1997/98 and 1998/99 season (12.9%, Table 6). Figure 5 shows the number of chicks banded each season and the proportion of those chicks that have been recaptured in the 35-ha study area. Table 5 shows the number of returned chicks that have been recaptured each season; since the first chicks were banded in 1995/96, the number of recaptures of 'returned chicks' has increased to 92 in 2013/14.

There were 89 'returned chicks' recaptured at the colony this season (Table 5); of these, 72 attempted to breed, with 49 successfully raising chicks of their own. The remaining 17 did not breed, although several males were recaptured while calling to attract a mate. Figure 6 shows the total number of 'returned chicks' and number that was caught breeding and non-breeding each season between 1995 and 2014.

Table 4 Banding, recapture and recovery data from all black petrels (Procellaria parkinsoni) caught within the study area on Great Barrier Island (Aotea Island) for the breeding seasons 1995/96 to 2014/15.

	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	**14/15**
Recaptures of birds banded prior to 1995	19	31	24	23	29	27	27	27	21	22	22	19	19	18	14	13	9	13	11	**10**
Recaptures of birds banded in 1995/96	-	14	14	14	16	14	11	12	12	8	12	10	7	8	11	9	5	5	6	**4**
Recaptures of birds banded in 1996/97	-	-	113	86	84	73	63	57	43	37	39[1]	31	28	30	29	22	12	21	15	**15**
Recaptures of birds banded in 1997/98	-	-	-	32	32	30	28	24	18	27	18	13	13	17	15	11	12	10	9	**5**
Recaptures of birds banded in 1998/99	-	-	-	-	95	82	71	64	49	36	39	33	32	37	39	24	17	29	19	**17**
Recaptures of birds banded in 1999/00	-	-	-	-	-	86	75	66	47	51	52	37	31	39	34	33	20	22	17	**15**
Recaptures of birds banded in 2000/01	-	-	-	-	-	-	51	52	41	22	36	28	29	40	30	21	12	22	18	**15**
Recaptures of birds banded in 2001/02	-	-	-	-	-	-	-	68	88	26	25	22	21	26	36	20	18	24	22	**17**
Recaptures of birds banded in 2002/03	-	-	-	-	-	-	-	-	61	55	57	54	39	56	52	38	26	36	34	**31**
Recaptures of birds banded in 2003/04	-	-	-	-	-	-	-	-	-	22	28	23	21	26	27	24	16	23	19	**15**
Recaptures of birds banded in 2004/05	-	-	-	-	-	-	-	-	-	-	48	31	33	48	59	42	28	47	43	**38**
Recaptures of birds banded in 2005/06	-	-	-	-	-	-	-	-	-	-	-	46	34	49	50	35	23	35	28	**27**
Recaptures of birds banded in 2006/07	-	-	-	-	-	-	-	-	-	-	-	-	27	46	42	35	22	43	45	**38**
Recaptures of birds banded in 2007/08	-	-	-	-	-	-	-	-	-	-	-	-	-	29	20	19	18	32	23	**24**
Recaptures of birds banded in 2008/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	71	55	46	66	54	**53**
Recaptures of birds banded in 2009/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	29	39	40	**33**
Recaptures of birds banded in 2010/11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	39	32	**35**
Recaptures of birds banded in 2011/12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	26	**24**
Recaptures of birds banded in 2012/13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	70	**71**
Recaptures of birds banded in 2013/14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**50**
TOTAL RECAPTURES	19	45	151	155	256	312	326	370	380	306	377	347	334	469	529	412	341	517	531	**537**
Number of new-banded adults	41	179	60	129	145	97	114	179	67	135	108	85	53	183	107	82	49	244	134	**167**
TOTAL ADULTS	60	224	211	284	401	409	440	549	447	441	485	432	387	652	636	494	390	761	665	**704**
Number of new-banded chicks	59	69	85	116	137	137	160	62	110	184	143[2]	215	191	203	171	144	163	219	199	**215**
TOTAL NUMBER OF BIRDS	119	293	296	400	538	546	600	611	557	625	627	647	578	855	807	638	553	980	864	**919**
Number of 'returned' chicks recaptured	0	0	0	0	1	1	9	18	14	20	25	20	28	41	42	43	42	85	92	**134**

[1] This includes the returned "chick" from Little Barrier Island (a female H-30807, banded as a chick in 1996/97 breeding season) and recaptured for the first time on Great Barrier Island in the 2005/06 breeding season; this was the first recorded immigration event.

[2] This does not include the 21 chicks that could not be banded due to a lack of bands (there was a total of 164 chicks still present in the study burrows).

BAND RECOVERIES FROM DEAD BIRDS	0	1	1	0	2	1	2	2	0	0	2	1	1	2	3	2	0	3	0	**0**

Table 5 Number of black petrel (*Procellaria parkinsoni*) 'returned chicks' banded since 1995 that have been recaptured within the study site on Great Barrier Island (Aotea Island) between 1995/96 to 2014/15.

	95/96	96/97	97/98	98/99	99/ 00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15
Recaptures of chicks banded in 1995/96	-	-	-	-	1	1	2	3	2	1	2	1	2	2	2	2	1	1	2	1
Recaptures of chicks banded in 1996/97	-	-	-	-	-	-	2	2	3	2	1	0	0	1	2	2	0	1	0	0
Recaptures of chicks banded in 1997/98	-	-	-	-	-	-	5	6	4	1	2	3	1	4	6	6	3	3	2	2
Recaptures of chicks banded in 1998/99	-	-	-	-	-	-	-	6	3	6	6	6	6	8	5	5	3	8	7	5
Recaptures of chicks banded in 1999/00	-	-	-	-	-	-	-	1	2	10	9	5	5	8	2	1	4	7	6	5
Recaptures of chicks banded in 2000/01	-	-	-	-	-	-	-	-	-	-	4	1	5	2	8	3	1	4	2	2
Recaptures of chicks banded in 2001/02	-	-	-	-	-	-	-	-	-	-	1	2	6	8	2	2	5	10	8	8
Recaptures of chicks banded in 2002/03	-	-	-	-	-	-	-	-	-	-	-	2	2	4	2	4	1	4	3	5
Recaptures of chicks banded in 2003/04	-	-	-	-	-	-	-	-	-	-	-	-	1	3	8	7	3	5	4	4
Recaptures of chicks banded in 2004/05	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	8	9	14	14	12
Recaptures of chicks banded in 2005/06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5	9	15	9
Recaptures of chicks banded in 2006/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	7	11	9
Recaptures of chicks banded in 2007/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	7	6	8
Recaptures of chicks banded in 2008/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	9	11
Recaptures of chicks banded in 2009/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	3
Recaptures of chicks banded in 2010/11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Recaptures of chicks banded in 2011/12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Recaptures of chicks banded in 2012/13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Recaptures of chicks banded in 2013/14	-	-	-	-																-
TOTAL RECAPTURE OF RETURNED CHICKS	0	0	0	0	1	1	9	18	14	20	25	20	28	41	41	43	42	85	92	89

Table 6 Total number of black petrel (*Procellaria parkinsoni*) chicks banded each season since 1995 and the proportion of those chicks that have been recaptured within the study site on Great Barrier Island (Aotea Island) between 1995/96 to 2014/15.

	Total number of banded chicks	Total number of returned chicks	Proportion (%) of returned chicks
1995/96	59	4	6.8
1996/97	69	7	10.1
1997/98	85	11	12.9
1998/99	116	15	12.9
1999/00	137	16	11.7
2000/01	137	9	6.6
2001/02	160	17	10.6
2002/03	62	7	11.3
2003/04	110	8	7.3
2004/05	184	22	12.0
2005/06	143	17	11.9
2006/07	215	17	7.9
2007/08	191	17	8.9
2008/09	203	16	7.9
2009/10	171	6	3.5
2010/11	144	5	3.5
2011/12	163	0	0
2012/13	219	0	0
2013/14	199	0	0
2014/15	215	0	0
TOTAL	**2982**	**194**	**6.5**
MEAN (± SEM)	149.1 ± 11.7	9.7 ± 1.6	7.3 ± 1.0

Figure 5 The number of black petrel (*Procellaria parkinsoni*) chicks banded each season (1995/96 to 2014/15) and the percentage of those chicks that have been recaptured in the study site on Great Barrier Island (Aotea Island). Grey column = the number of chicks banded per season and solid black line = percentage of those chicks that have been recaptured.

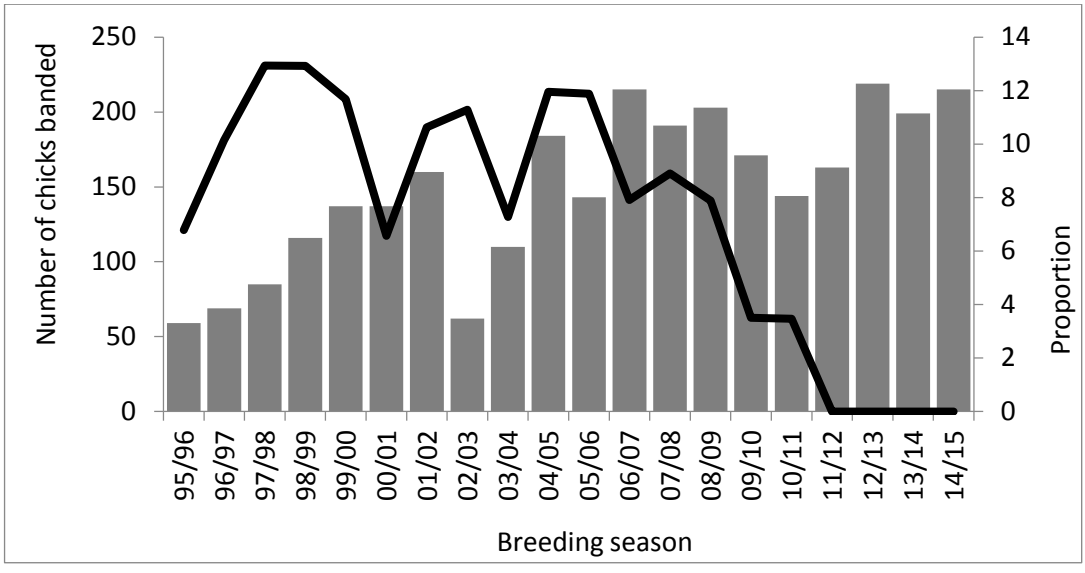


Figure 6 The number of breeding and non-breeding black petrel (Procellaria parkinsoni) 'returned chicks' recaptured each season between 1995/96 and 2014/15 in the study site on Great Barrier Island (Aotea Island). Dotted black line = total number of recaptured 'returned chicks', grey column = the number of non-breeding 'returned chicks' and black column = the number of breeding 'returned chicks'.

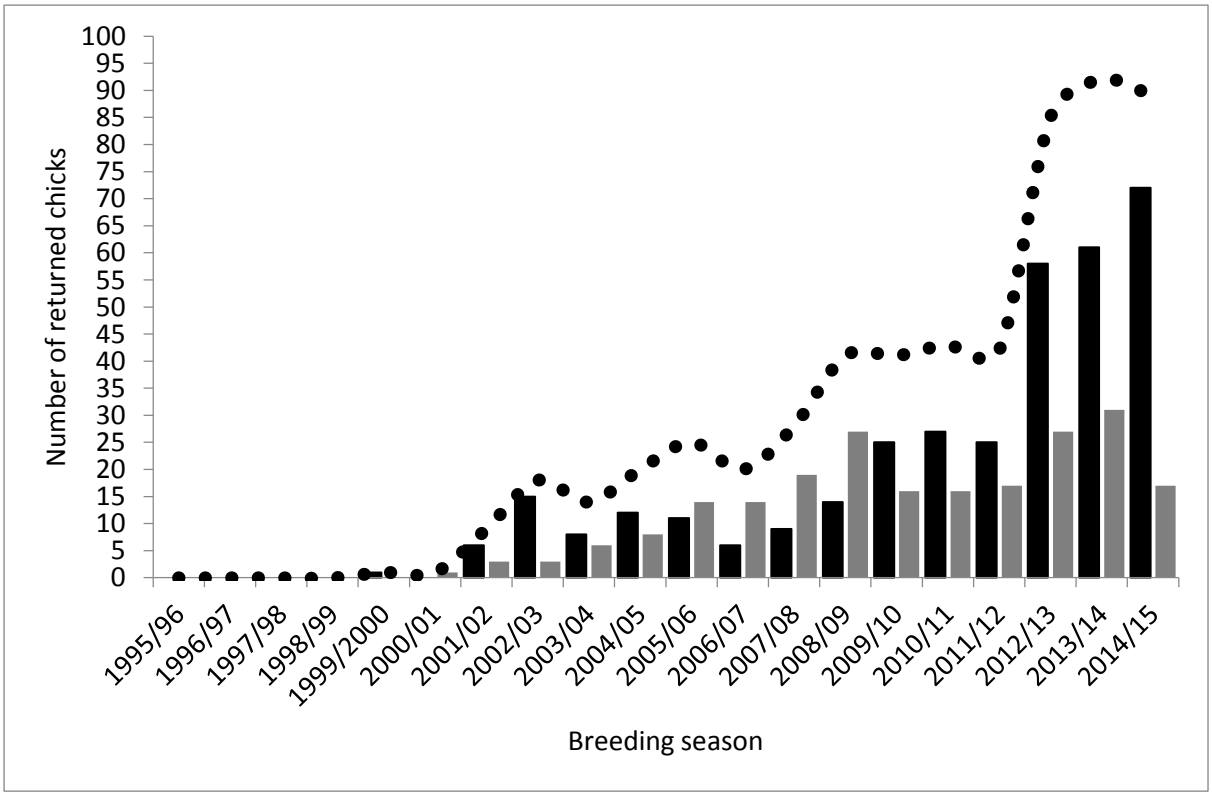
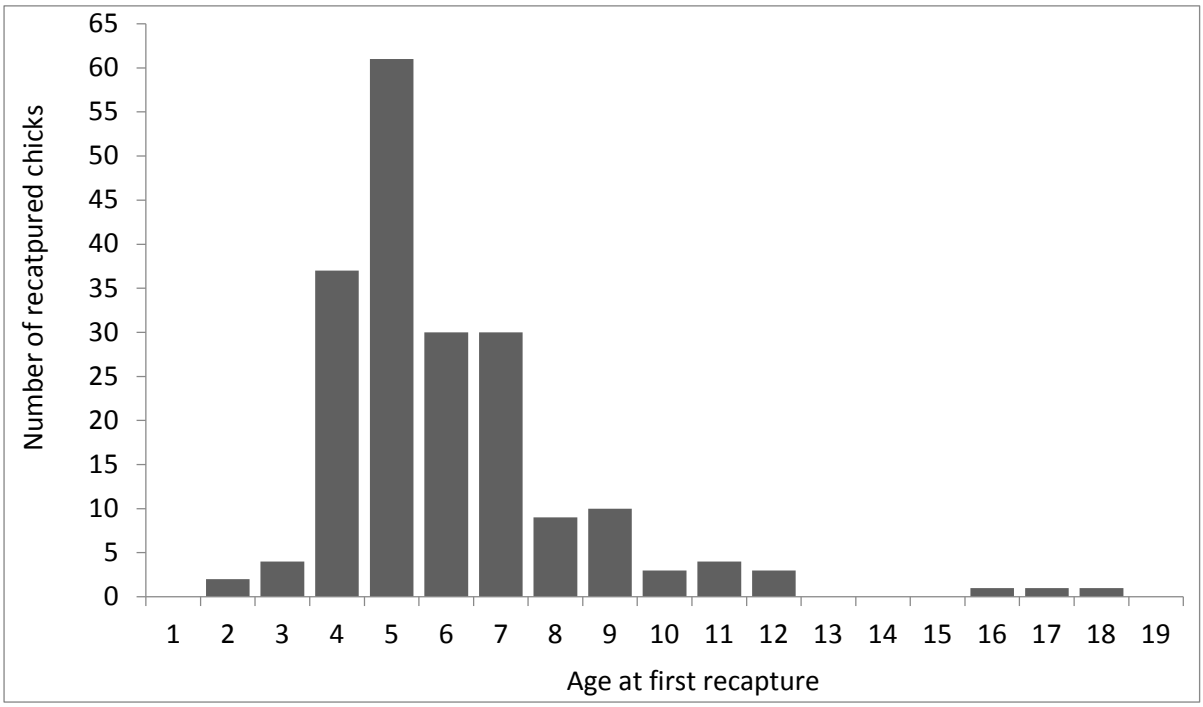


Figure 7 Observed frequency of age of first recapture of returned black petrel (*Procellaria parkinsoni*) 'chicks' to the 35-ha study area on Great Barrier Island (Aotea Island) between 1995/96 and 2014/15.



Since the first returned chick (banded on Great Barrier Island in the 1995/96 season) was recaptured as a pre-breeder in the 1999/00 season, 194 'chicks' have been recaptured as pre-breeders, non-breeders or breeding adults (Table 6); 193 from chicks banded on Great Barrier Island and one from Little Barrier Island (Appendix 2). The number of times 'chicks' have been recaptured ranges from 1 to 15 (mean ± SEM = 2.9 ± 0.2, Appendix 2). The frequency of first recapture of each age class is given in Figure 7. Although the youngest age at first recapture at the colony is 2 years, the mean age ± SEM at first return is 6.0 ± 0.2 (range 2 to 18 years, Appendix 2). Two birds have been caught and released alive at sea in South America at age 2, but have not been recaptured at the colony to date (Appendix 2).

Since returning to the Great Barrier Island (Aotea Island) colony, 118 of these 'returned chicks' have attempted to breed, with 94 breeding successfully over this period (Appendix 2). This means the age at first breeding attempt ranges from 4 to 17 years (mean ± SEM = 7.3 ± 0.2) and the age at first successful breeding also ranges from 4 to 17 years (mean ± SEM = 7.6 ± 0.2) (Appendix 2)

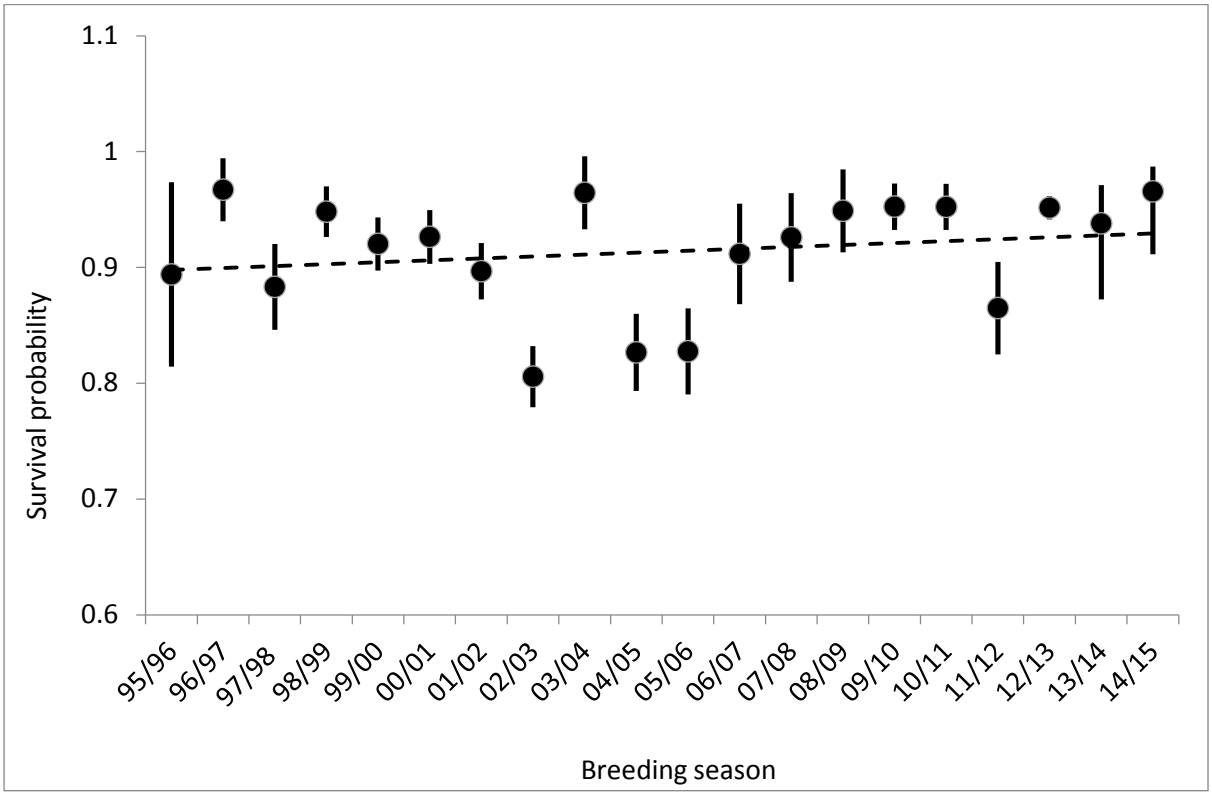
4.4 Survival estimates and recapture probabilities using Program MARK

A Burnham Live/Dead analysis (adult survival and probability of recapture varying over time and with age) model was run; S(age) P(age) r(*) F(*) where S = apparent survival, P = probability of recapture, r = reportability and F = fidelity) of all adults recaptured on GBI between 1964 and 2015. This generated an adult apparent survival of 96.6% ± 1.7% for the 2014/15 season (Table 7). Table 7 lists the apparent adult survival since the 1995/96 season. Figure 9 shows that adult survival fluctuates from year to year and that overall adult survival has increased since 1995.

Table 7 Adult survival estimates for black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island) between 1995/96 and 2014/15. Estimates obtained by Burnham Live/Dead model [S(age) P(age) r(*) F(*)] analysis (using Program MARK) with standard errors.

SEASON	SURVIVAL ESTIMATE	SE
1995/96	0.8939	0.08
1996/97	0.9671	0.03
1997/98	0.8832	0.04
1998/99	0.9481	0.02
1999/00	0.9203	0.02
2000/01	0.9264	0.02
2001/02	0.8967	0.02
2002/03	0.8057	0.03
2003/04	0.9644	0.03
2004/05	0.8266	0.03
2005/06	0.8275	0.04
2006/07	0.9117	0.04
2007/08	0.9259	0.04
2008/09	0.9489	0.04
2009/10	0.9525	0.02
2010/11	0.9523	0.02
2011/12	0.8649	0.04
2012/13	0.9516	0.01
2013/14	0.9380	0.02
2014/15	0.9656	0.02

Figure 8 Adult survival estimates for black petrels (Procellaria parkinsoni) on Great Barrier Island (Aotea Island) between 1995/96 and 2014/15. Estimates obtained by Burnham Live/Dead model analysis [S(age) P(age) r(*) F(*)] using Program MARK.



The mean probability of fidelity to the nest site (burrow) was 87.8% (± 1.6%); this is expected as adult black petrels generally maintain ownership of their breeding burrows for life and consistent with the analysis completed last season (Bell et al. 2014). Movement between burrows is low and generally related to poor breeding success for a number of years or death of a partner bird.

A Burnham analysis of survival of chicks banded in the 35-ha study site on GBI between 1995 and 2015 was also completed. Only 194 of over 2900 chicks banded on GBI have been recaptured. As earliest age of return was 2 years, it was not possible to calculate apparent survival before a chick's third year; however, a model incorporating chick recapture and survival parameters gave an apparent juvenile survival estimate of 88.3% (± 1.8%). Juvenile survival continues to have the strongest effect on population trajectory with the models suggesting population growth ranging from -2.3% per year (if Juvenile survival = 0.85) to +2.5% per year (if juvenile survival = 0.97) (Bell *et al*. 2015). Giving that juvenile survival is estimated at 0.88 for this season, the overall population trend is likely to still be in slow decline.

4.5 Population estimate

Random transects were surveyed within the study area in 2004/05, 2009/10 and 2012/13 breeding seasons (Bell et al. 2007, Bell et al. 2011b, Bell et al. 2013b). These transects ranging in length from 130 m to 400 m, with between 0 and 40 burrows located along each (Bell et al. 2013b). The following habitat grades were identified: high-grade petrel habitat (4.669 ha), medium-grade (15.3013 ha); low-grade (13.5607 ha) and non-petrel habitat (1.7509 ha) (Bell et al. 2013b) and each transect was stratified into these habitat grades along the transect length and the burrows along the length were assigned to the relevant habitat grade. The mean number of burrows for each habitat grade was calculated from the three random transect surveys: between 13.3 (± 7.7) to 39.7 (± 1.2) non-

breeding burrows, 21.7 (± 14.0) to 55.7 (± 12.8) breeding burrows and 24.7 (± 17.7) to 53.0 (± 26.6) empty burrows were identified (Bell et al. 2014).

The population estimate for the 35-ha study area was determined by extrapolating from mean burrow data from the previous random transects and this season's census grid data after stratification of the 35-ha study area into four habitat grades. This population estimate for the 2014/15 burrow-occupying black petrel population was between 2296 and 2606 adults (2451 ± 155 birds, Table 8), consisting of 716 ± 71 non-breeding adults and 1918 ± 239 breeding adults (i.e. 959 breeding pairs).

Table 8 2014/15 population estimate of black petrels (*Procellaria parkinsoni*) in the 35-ha study area around Mount Hobson, Great Barrier Island (Aotea Island) after stratifying and grading all transects and census grids. Area of each burrow density grade is 4.669 ha of high grade petrel habitat, 15.3013 ha of medium petrel habitat, 13.5607 ha of poor petrel habitat and 1.7509 ha of non-petrel habitat.

RANK	Transect or Census Grid	Area (ha)	DENSITY (Number/ha)		TOTAL AREA	POPULATION ESTIMATE (35 ha)	
			Breeding adults	Non-breeding adults		Breeding adults	Non-breeding adults
LOW	Transects	1.03	43	16	13.5607	579	214
	KDG2	0.008	0	0		0	0
	KDG3	0.008	0	0		0	0
MEAN (± SEM)			14 ± 14	5 ± 5		193 ± 193	71 ± 71
MEDIUM	Transects	1.52	74	33	15.3013	1128	503
	KDG1	0.008	0	0		0	0
	KDG2	0.032	188	0		2869	0
	KDG3	0.106	19	0		289	0
	SFG1	0.032	188	0		2869	0
	SFG3	0.11	55	45		835	696
	PTG2	0.04	0	31		0	478
	PTG3	0.06	33	21		510	319
	MEAN (± SEM)		69 ± 27	16 ± 7		1032 ± 417	250 ± 101
HIGH	Transects	0.78	141	58	4.669	658	269
	KDG1	0.152	197	74		922	346
	KDG2	0.12	233	63		1089	292
	KDG3	0.046	87	82		406	381
	SFG1	0.128	203	29		948	137
	SFG2	0.16	100	23		467	109
	SFG3	0.05	40	0		187	0
	PTG1	0.16	263	39		1226	182
	PTG2	0.12	100	73		467	340
	PTG3	0.1	120	13		560	58
MEAN (± SEM)			148 ± 23	45 ± 9		693 ± 106	212 ± 42
TOTAL POPULATION ESTIMATE (± SE)						1918 ± 239	716 ± 71
						2451 ± 155	
POPULATION ESTIMATE RANGE						**2296 to 2606 adults**	

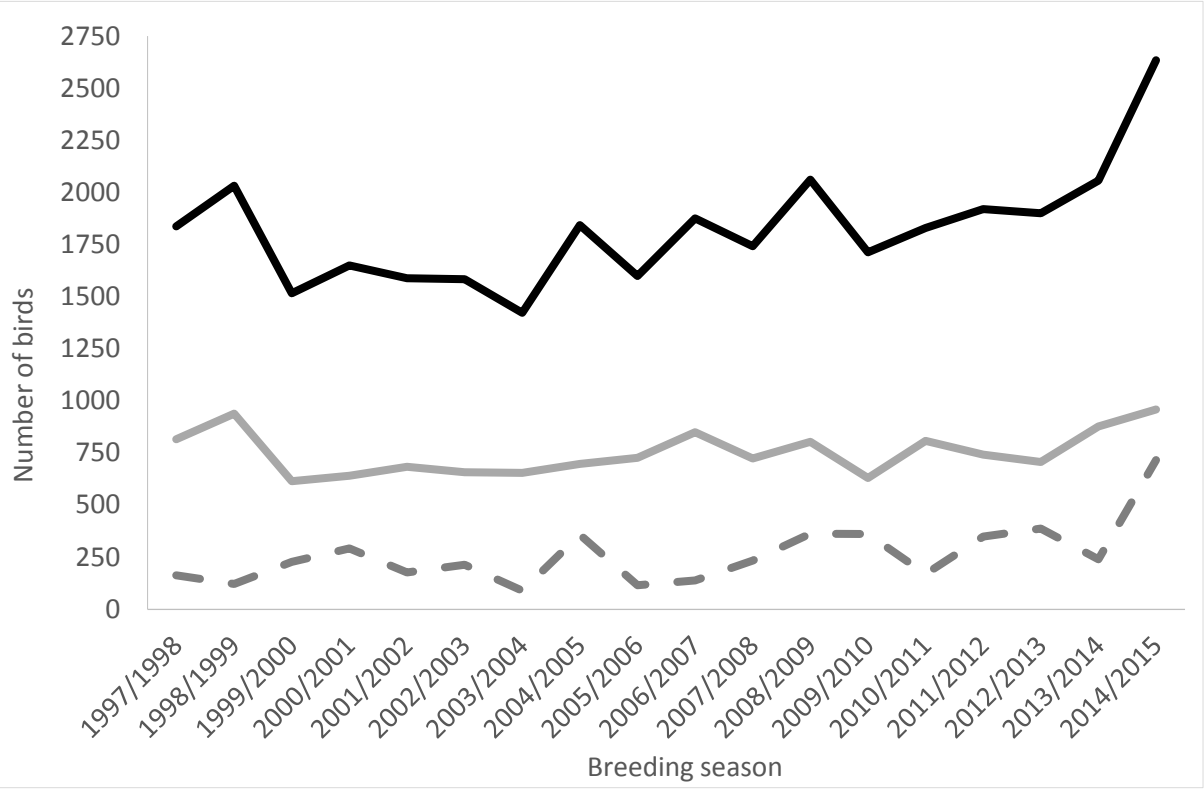
Although it is suspected that any population estimate determined by extrapolating from the nine census grids only may overestimate the population size (as these grids were originally established in known areas of high petrel density and that the study site does not have a uniform distribution of burrows), comparing annual populations estimates using this data may suggest the trend of the black petrel population on Great Barrier Island. Table 9 gives the annual population estimates since

1995 and Figure 9 shows the trend in the overall population estimate and number of breeding pairs and non-breeding birds.

Table 9 Annual population estimates calculated by extrapolating from the nine census grids with habitat stratification and compared to estimates from the nine census grids without habitat stratification since 1995/96 season for black petrel (*Procellaria parkinsoni*) using the 35-ha study site on Mount Hobson, Great Barrier Island (Aotea Island).

YEAR	NON—STRATIFIED ESTIMATE			STRATIFIED ESTIMATE		
	Breeding pairs	Non-breeding birds	Total population estimate (number of individual birds)	Breeding pairs	Non-breeding birds	Total population estimate (number of individual birds)
1995/96	1677	1094	4448	242	201	684
1996/97	2552	948	6052	827	167	1821
1997/98	2479	1167	6125	816	205	1838
1998/99	2406	802	5615	940	153	2032
1999/00	1993	705	4691	616	285	1517
2000/01	1847	899	4594	642	366	1650
2001/02	1920	753	4594	684	222	1590
2002/03	1847	875	4569	658	268	1584
2003/04	1872	462	4205	355	113	1422
2004/05	2042	729	4813	698	448	1844
2005/06	2236	340	4813	727	146	1599
2006/07	2333	583	5250	851	174	1876
2007/08	2236	753	5226	724	293	1742
2008/09	2358	705	5420	804	454	2062
2009/10	2090	899	5080	631	452	1714
2010/11	2358	559	5274	809	212	1830
2011/12	2115	1142	5372	742	437	1921
2012/13	2163	1021	5347	708	485	1900
2013/14	2260	851	5372	878	301	2057
2014/15	2259	978	5496	959	716	2451
MEAN (± SEM)	2152 (± 53)	813 (± 49)	5118 (± 116)	716 (± 39)	305 (± 34)	1757 (± 77)

Figure 9 Trends in annual population estimates from the nine census grids (after habitat stratification) for black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island) between 1996/97 and 2014/15. Solid black line = population estimate, solid grey line = breeding pairs and dashed grey line = non-breeding birds.



4.6 Preliminary surveys across GBI

The locations of the ground-based searches using seabird detector dogs at various locations on Great Barrier Island/ Aotea are given in Figure 2. Active black petrel burrows were located in all areas; 61 breeding burrows, 33 non-breeding burrows and 20 empty (Table 10). Burrow density varied from 0.8 to 14.9 burrows per ha (Table 10).

Table 10 Black petrel (*Procellaria parkinsoni*) burrows located on Great Barrier Island (Aotea Island) during random surveys, 2014/15.

Location	Size of area surveyed (in ha)	Burrows				
		Breeding	Non-Breeding	Non-occupied	Total	Burrows/ha
Mount Heale	2.6234	21	9	8	**38**	14.9
Maungapiko	3.1465	1	5	2	**8**	2.5
Kaiaraara Track Ridge	12.8801	18	12	5	**35**	2.7
Windy Canyon	4.2189	7	1	1	**9**	2.1
Whangaparapara Hill	7.7952	3	2	1	**6**	0.8
Te Ahumata	1.2211	2	0	0	**2**	1.6
Cooper's Castle	10.1667	6	1	2	**9**	0.9
Ruahine	7.2645	3	3	1	**7**	1.0
TOTAL	**49.3164**	**61**	**33**	**20**	**114**	**2.3**

Within these burrows, five already banded birds were caught and four adults were also banded this season. Of the banded birds, two were returned 'chicks' (one aged 9 years and the other aged 10

years) and both being caught for the first time at the colony) and 3 were banded as adults (banded in 2004, 2007 and 2010).

5. DISCUSSION

The black petrel population on Great Barrier Island has been monitored since the 1995/96 breeding season (Bell & Sim 1998a, Bell & Sim 1998b, Bell & Sim 2000a, Bell & Sim 2000b, Bell & Sim 2000c, Bell & Sim 2002, Bell & Sim 2003a, Bell & Sim 2003b, Bell & Sim 2005; Bell et al. 2007, Bell et al. 2009; Bell et al. 2011a; Bell et al. 2011b, Bell et al. 2013, Bell et al. 2014).

5.1 Breeding success

In the 2014/14 breeding season, there were 199 breeding successes and 84 breeding failures, equating to an overall breeding success rate of 70% (Table 2). This breeding success is identical to last season but lower than most previous breeding seasons, except 2001/02, 2002/03, 2005/06 and 2010/11, and is lower than the mean (74.05% ± 1.3%) of the overall study (Tables 1 and 2). This rate of breeding success remains higher than reported in the earlier studies; 1977 (50%) and 1978 (60%, Imber 1987) and 1988/89 (62%, Scofield 1989). The level of abandoned eggs, infertile eggs, disappeared eggs (i.e. present in December, but missing in January/February) and rat predated eggs was the lower than last season, but the number of crushed eggs and dead embryos were much higher this season than last year (Table 2).

These crushed eggs may be due to competition over burrows as adults continue to fight over very good burrows in some locations of the colony (EAB pers. obs.). This may also relate to the loss of habitat following the June 2014 storm on Great Barrier Island/Aotea where at least 15 ha of black petrel habitat around the summit was destroyed by slips. Birds in these areas would have returned to the colony and had to find a new burrow; this could have resulted in fighting over established burrows within the study area.

The level of egg abandonment was high (n = 6); this was lower than last season and brings the total number of abandoned eggs since 1995 to 90 (Table 2). Although the odd incident may be related to handler disturbance, the remainder may be related to the age of the birds as younger birds seem to be less experienced in successfully incubating eggs to hatching or body condition as lighter adults appeared to have less commitment to the egg (EAB, pers. obs.).

There were 18 dead chicks; of which 17 were healthy chicks during one check, but dead at the next check or when the final check was completed in April 2015; it was not possible to determine all the causes of mortality for these chicks; although one died from avian pox and it was suspected that at least four died from starvation. This may be due to the loss of a parent as it is not possible for one parent alone to successfully raise a chick (Warham 1996), but this will have to be confirmed next season if the burrow is inactive or only one partner returns. With 199 chicks fledging this season, the breeding success is over 70% (Table 2). This breeding success rate is high compared to many other seabird species (such as Westland petrel, *Procellaria westlandica*, 39-50%; Freeman & Wilson 2002, Warham 1996), but the apparent juvenile survival estimate (0.88 ± 0.02) suggests that over 10% of these fledged chicks will not survive to return to the colony. Given the low level of recaptures of returned chicks at the colony (i.e. only approximately 8% of all banded chicks have been recaptured), juvenile survival is possibly even lower than the models predict.

Only one egg was predated by rats this season (0.4% of all breeding attempts) within the study burrows and 15 eggs (5.3% of all breeding attempts) disappeared (but may have been predated by rats or crushed by parents, Table 2). There were no feral cat predation events recorded within the study burrows this season. All juvenile petrels since 1995/96 breeding season that have been predated by feral cats were out of burrows (stretching wings, attempting to fledge at a launch site, etc.) since carcasses were found in the open and in some cases well away from burrows (EAB, pers.

obs.). Juvenile petrels are particularly vulnerable to feral cat predation at fledging time (Warham 1996). There have been 15 chicks predated by feral cats since 1995 (Table 2). It is, therefore, important to continue cat trapping at the summit, in the wider Palmer's Track/Windy Canyon area and in the Okiwi Basin before, during and after the black petrel breeding season.

The number of burrows used for breeding has increased from last season but continues to show an overall decline since the beginning of the study (Tables 1 and 2, Figure 2). Breeding success has remained high and appears to be stable (Tables 1 and 2, Figure 2). This may be related to the fact that site fidelity is high (88%) given that once a pair begins to breed within the study area (particularly in a study burrow) they are more likely to remain in that burrow. Breeding pairs are more likely to attempt to breed rather than skip breeding (i.e. become non-breeders) and most successful breeders in one year return to breed the following year (Bell et al. 2014). Skipping breeding and subsequent improvement of breeding chances following a gap year may also relate to migration as it is not known if birds choose to remain in South America if they do not obtain adequate body condition to return to New Zealand to breed.

The percentage of non-occupied and non-breeding burrows has fluctuated from year to year (Tables 1 and 2, Figure 2) which means that the number of non-breeding or pre-breeding birds in the study area varies each season. It is also possible that as many as half the non-breeding and pre-breeding birds become breeding birds the following year and that they replace previous breeders that may have died, divorced or skipped a year. This may relate to the increase in breeding birds this season (Table 1) These changes in proportions of non-breeding birds may relate to whether the non-breeding and pre-breeding birds were successful in creating and maintaining a pair bond that season (and then will attempt to breed the next season). It is also possible that as the number of monitoring visits to the colony has been increased to three trips during the incubation and chick rearing stages there has been more accurate determination of whether a burrow is being used by breeding or non-breeding birds (rather than remaining non-occupied).

The decreased number of non-occupied burrows this season could be related to the known number of consistently empty burrows as well as the condition of certain study burrows deteriorating over time. This season previously empty study burrows become active with birds excavating the burrows to make them suitable for breeding. Given the number of displaced birds following the June 2014 storm, a small number of previously empty burrows were active this season by both breeding and non-breeding birds. Reasons whether a burrow is used for breeding may relate to the characteristics of that burrow (exposure, depth, entrance, moisture) and any changes to those characteristics (flooding, collapse etc.) may cause birds to move from or avoid these burrows and as a result affect breeding success and burrow activity (Warham 1996).

Using data since 1998/99, the proportion of non-occupied study burrows has been increasing, although it has stabilised in recent years (Table 1, Figure 2). This may be directly related to burrow deterioration, handler disturbance, observation hatches being dug or adult mortality. Analysis of adult survival and site fidelity suggested that black petrels have a relatively low mean apparent adult survival (89-96%) compared to other seabird species such as Antipodean albatross (*Diomedea antipodensis*) at 96% (Walker & Elliott 2004), but high (88-98%) site fidelity. Although birds do not appear to abandon the burrow during the breeding season, they may choose to move to a new burrow the following year if their partner dies or burrow deteriorates. Further surveys within the study area could determine whether known birds have moved to nearby non-study burrows to avoid disturbance. As stated earlier the reduction in burrows used for breeding may also relate to changes in the their characteristics, as several burrows have flooded in particularly wet years and collapsed over time, making then unusable for a year or more. This may account for the declining occupancy of burrows, but given there has been an immigration event from Hauturu/Little Barrier Island, site fidelity and the possibility of emigration from Great Barrier Island needs further investigation. Work needs to be done separating the components of apparent survival to determine whether the low apparent survival is due to mortality or emigration. This would require a thorough search for

recovery data from banding records and continued (and wider) recapture effort at the study. It should be noted that the fidelity model only used a small number of recoveries and that more work needs to be done to determine whether this is true and whether emigration or mortality have a larger effect.

It should also be noted that many of the study burrows have been monitored for ten seasons or more and many of the resident birds have continued to use these burrows for the entire study period. This suggests that handler disturbance does not have a large impact, although the response between individual birds may vary (as some birds are more vulnerable to disturbance).

5.2 Recruitment

A total of 919 banded birds were identified this season; 704 were adults and 215 were chicks (Table 4). There were 537 recaptures of previously banded birds, including 89 that were 'returned chicks' (Tables 4 and 5). A total of 194 chicks banded between 1995 and 2015 have been recaptured in the study area (7.3%, Table 6). Although the adult banded as a chick on Hauturu/Little Barrier Island was not recaptured on Great Barrier Island again this season, this bird still represents the first recorded immigration event for black petrels. Nearly 250 chicks were transferred from Great Barrier Island (Aotea Island) to Hauturu/Little Barrier Island between 1988 and 1990 and 6.2% have been recaptured (between 1990 and 2000) (Imber *et al*. 2003); of these 12 (4.8%) have returned to their natal area on Great Barrier Island. It is likely that birds from Little Barrier Island are being attracted to Great Barrier Island due to the number of birds' resident there (and resulting noise early in the breeding season). Immigration has implications for population modelling work (as most models assume no immigration), and further surveys and mark-recapture work is needed to maximise the chances of recapturing known birds and returned fledglings. This also has implications for the recovery of the Little Barrier Island population as pre-breeders are more likely to be attracted to Great Barrier Island than Little Barrier Island, slowing the population growth there. It is possible that the Little Barrier Island population may not recover until Great Barrier Island reaches carrying capacity; however as the population on Little Barrier Island is not being monitored for adult survival and recruitment, this is difficult to assess. It is important that the black petrel population on Little Barrier Island is monitored to determine population dynamics, status and trends.

Of the 89 returned chicks, 14 were recaptured in their natal burrows, 64 in their natal area (less than 50 metres from their natal burrow) and the other 11 were caught more than 100 m away from their natal areas. There is a probable capture bias towards the returning males due to their behaviour, i.e. calling outside burrows. Despite being attracted to calling males, females are likely to be more difficult to detect as they will attend males in all parts of the colony, both inside and outside the study area. Much of the 35-ha study area is difficult to reach and cannot be searched. This will need to be taken into account for further survival and recruitment analyses.

Since the first chick was recaptured in the 1999/00 season, 194 'chicks' banded between 1995 and 2015 have been recaptured at the Great Barrier Island colony (Table 6, Figure 5). There have been 118 records of 'returned chicks' attempting to breed during this period and the age of first recorded breeding attempt is between 4 and 17 years. Of these breeding attempts, 94 have been successful and the age at first successful breeding are also between 4 and 17 years (Figure 6, Appendix 2). It is important to check for more 'returned chicks' and maintain intensive burrow monitoring in areas where returned 'chicks' are present. Many of the returned 'chicks' were recaptured at night during the December visit, so it is important to maintain a high level of night searching at this time of year. Additional searches using a DOC trained seabird dog also resulted in 'returned' chicks being found on the surface and new burrows (including one new burrow in a census grid). Further, these data allow for mark/recapture analyses, which could greatly assist in understanding black petrel demographics.

5.3 Survival estimates

The mean apparent adult survival estimate for black petrels in the study area in the 2014/15 season from the Program MARK model was 96.6%, higher than the mean value over all years of 91.4%. Previous adult survival estimates using other models ranged from 88% (SEABIRD) to 89.7% (Bayesian) with a range of around 3% between the estimates from the different models due to the different assumptions of each model (Bell *et al.* 2014). The apparent adult survival estimates for this season from Program MARK is much higher than these and previous estimates of 88% by Hunter et al. (2001) and 85% by Fletcher et al. (2008). All models suffer from being unable to distinguish mortality from emigration. It is important to undertake thorough surveys within the 35-ha study area to get better recapture rates of banded adults, juveniles and immigrating adults (including recoveries of dead adults) to increase the accuracy of the survival, immigration and fidelity estimates.

Chick recapture data (for chicks banded on Great Barrier Island since 1995) determined that apparent annual juvenile survival (for the first three years) was 88% which is higher to other juvenile seabirds of this size (Hunter *et al.* 2001, Barbraud *et al*. 2008, Fletcher *et al*. 2008) and the previous estimate from the Bayesian model (70%) but lower than the previous estimate from the SEABIRD model (92%) (Bell *et al.* 2015). Again this may be related to the different assumptions in the calculation of juvenile survival used by each model. All models indicate that the population is stable or increasing only if mean annual juvenile survival is over 92% and as it is unlikely that juvenile survival is higher than adult survival, this suggests a population decline over the length of the study.

The increased amount and improvement of recapture data enables a more accurate calculation of mean apparent adult and juvenile survival and it is important that future analysis and population modelling reflects this. It is important to continue monitoring the black petrel population within the 35-ha study area to obtain a clearer picture of the trend of the Great Barrier Island (Aotea Island) black petrel population.

5.4 Population estimate and trend

The population estimate for the 35-ha study area was calculated using the three random transect surveys and this season's census grid data following stratification since surveys and local knowledge of Great Barrier Island (Aotea Island) showed that petrel burrow densities varied through the 35-ha study area (EAB, pers. obs.). From the both this season's and earlier transect data it was found that the highest densities of black petrel burrows were located on ridges or spurs with established canopy.

The breeding population was estimated at approximately 959 breeding pairs (1918 breeding birds) using the census grids and mean of all three random transect surveys (Table 8). This estimate only covers the 35-ha study area around the summit of Mount Hobson, although this is the main population location and contains the highest density of the population. We consider that delimiting the lower boundaries of the entire black petrel colony within the Mount Hobson Scenic Reserve is the highest priority for further work, so that a complete estimate of the black petrel population in this area can be achieved.

Although this population estimate is higher than previous estimates for the 35-ha study site (Table 9), it is lower than the previous estimates from the 2012/13 transect/census grids survey (2954 breeding birds) and Program SEABIRD (3248 breeding birds) (Bell *et al.* 2015). This suggests that overall less adults returned to the colony this season compared to previous seasons which is also supported by the higher resighting probability (i.e. more birds were counted) in 2012/13 in the Bayesian model.

Although the census grid data alone suggests that the black petrel population in the 35-ha study area is stable or slightly increasing, the SEABIRD model analysis completed last season suggests that

the population is slightly decreasing, but that the rate of decline is affected by juvenile survival (Bell *et al.* 2015). As it is unlikely that juveniles have a higher survival rate than adults, the conclusion is that the black petrel population on Great Barrier Island (Aotea Island) within the 35-ha study area is slowly declining.

Repeats of the random transect surveys throughout the 35-ha study area would improve overall study area population estimates and overall trend of the black petrel population within the 35-ha study area. It could be important to examine the difference between two- and three-dimensional estimates of density and population size in this steep and difficult terrain.

Surveys in eight other areas on Great Barrier Island (Aotea Island) were competed this season with a total of 114 burrows found within nearly 50 ha of search area (Table 10). Over half of these burrows were breeding (*n* = 61, 53.5%), although many had been unsuccessful due to cat and rat predation. The mean burrow density per hectare within these sites was 2.3 (range: 0.8-14.9) which is much lower than the mean burrow density per hectare of the census grids on Mount Hobson (Hirakimata) (*n*=18, range: 38-194). This confirms that the majority of the Great Barrier Island (Aotea Island) black petrel population is found on Mount Hobson (Hirakimata) with small clusters of burrows in certain locations across the rest of the island. Given the limited predator control over the rest of Great Barrier Island (Aotea Island) and amount of feral cat sign in the survey locations, the majority of birds using these burrows are unlikely to successfully fledge chicks. This was shown by the number of rat predated eggs detected (*n* = 7, 11%) and evidence of cat predation events (*n* = 6) at the burrow locations during these surveys. Given that these surveys were completed in February 2015, there are two months remaining in the breeding season and the chicks at these sites would be vulnerable to later predation events.

To gain a better population estimate of the black petrel population on the whole of Great Barrier Island (Aotea Island), further detailed surveys need to be undertaken in other areas on the island (i.e. on or near the Hog's Back, Mount Heale and Mount Matawhero). In addition to the summit area of Mount Hobson, black petrels are known to nest on other high points around the summit area, in northern areas of the island, in small pockets of private land and towards the southern end of the island. Randomly selected census grids, transects or further intensive surveys using seabird-detector dogs in these areas would give a better idea of burrow density and range around the island. It is interesting to note that black petrel breeding burrows have been found well below 300 m a.s.l. (EAB pers. obs.), which raises the possibility that other birds may also be breeding at lower elevations. This possibility should be investigated further.

The number of burrows within the nine census grids continued to increase this season (n = 159) with two burrow being located. However, despite this increase in burrow numbers, currently there is a downward trend in the percentage of study burrows used for breeding. It continues to be important to assess population growth in relation to survival (adult, pre-breeder and juvenile) as this increase is due to the increased search effort rather than an actual increase in bird numbers, breeding population or creation of new burrows.

New burrows do not necessarily mean that more black petrels are present in the colony, as over 300 birds have moved between numbered burrows within the 35-ha study area between 1995/96 and 2014/15 breeding seasons. Loss of a partner (particularly for females), predation events and competition between adults and pre-breeders can all cause movement between burrows (EAB, pers. obs., Warham 1996). Pre-breeding males appear to be attracted back to their natal area and can excavate new burrows in those areas (Warham 1996); in the 35-ha study area more than 60 pre-breeding (or non-breeding) birds have returned to their natal area (and in 14 cases to their natal burrows) and have been recorded either fighting with the resident pair (which can be their parents) for their natal burrow or have started to excavate new burrows nearby, hence increasing burrow numbers in certain areas (including census grids).

Black petrels have a high site fidelity and the majority of pairs survive annually given previous analysis suggesting only 10% of pairs divorce (Bell *et al.* 2014). It is difficult to determine the reason for divorce, and the reasons why birds chose to skip a year may relate to breeding outcome, partner selection, burrow condition, handler disturbance or a combination of these (or other) factors. The trend in behaviour and outcome prior to the divorce event needs to be investigated. For example, if one bird skips a year (i.e. remaining in South America), does the other bird attempt to breed with a new partner when it returns to the colony? Does the original pair return to breed at a later date? Bell et al. (2011a) suggested that original pairings return in about 1% of cases of divorce, but increasing recapture effort to determine whether birds have really divorced or skipped is vital. Further analysis of the present breeding and recapture data may give a clearer pattern to the levels and causes of skipping and divorce.

5.5 At-sea behaviour

Information on the foraging range and at-sea distribution of the black petrel has been gathered from band recoveries, bird watching expeditions, fishermen, fisheries observers and other vessels and more recently from the use of tracking devices such as geolocator light loggers and high-resolution GP devices (Freeman et al. 2010, Bell et al. 2011a Bell et al. 2011c, Bell et al. 2013b). Many of the earlier records provide only general locations, and may be related to black petrels' habits of following boats to scavenge (rather than the routes they would follow in the absence of fishing boats).

The tracking devices showed that black petrels demonstrate large variability in habitat use patterns and foraging ranges which appeared to allow individuals to locate habitats with increased resource availability as environmental conditions change within the breeding season (Freeman et al. 2010, Bell et al. 2011c, Bell et al. 2013b). These studies showed that foraging during the breeding season was centred on the outer Hauraki Gulf, northern New Zealand towards the Kermadec Islands, East Cape and towards Fiji (Freeman et al. 2010, Bell et al. 2011c, Bell et al. 2013b, Bell et al. 2014). Both males and females foraged into the same areas; northern New Zealand, Tasman Sea and East Cape and used habitat ranging from < 1000 m to > 5000 m deep (Freeman et al. 2010, Bell et al. 2011c, Bell et al. 2013b, Bell et al. 2014). Nearly 123 hours of the total 861 hours of deployment time in the 2013/14 season was spent within the Hauraki Gulf Marine Park boundaries, suggesting that black petrels foraging outside the Hauraki Gulf towards seamounts (and the accompanying upwelling of nutrients and prey species) and continental shelf edges rather than inshore areas. Overall, males and females foraged in similar areas, but females headed further north while males tended to forage towards East Cape. This suggests a slightly different foraging pattern and habitat between the sexes, but this needs further investigation and additional deployment of GPS devices to confirm these patterns.

LOTEK LAT 1900-8 Time-Depth Recording (TDR) devices were deployed on breeding black petrels in the 2012/13 ad 2013/14 breeding season (Bell et al. 2013, Bell et al. 2014). The majority of dives over 1 m were during the day (93-94%) for both males and females (Bell et al. 2014). The majority of the dives were shallow (<5 m, 81%) (Bell et al. 2014). This suggests that that the black petrels are predominately surface or shallow water feeders and the risk from fishing gear is close to the surface (generally less than 10 m). Most dives were short (<10 sec) (Bell et al. 2014). This foraging activity suggests that there may be two feeding strategies for black petrels; the majority during the day as deeper dives (greater than 1 m) when targeting fish or other prey species that the birds observe from the air or surface or scavenging scraps or dead prey on or just below the surface (or possibly following fishing vessels) and the other at night when feeding on squid on and just below the surface (0-1 m). It is likely that black petrels also forage on the surface during the day including during their association with dolphins and whales targeting surface scraps for these feeding events (Pitman and Balance 1992). Despite Imber (1976) reporting that stomach contents indicated nocturnal feeding

due to the level of bioluminescent cephalopods in their diet, it appears that black petrels forage more during the day than previously thought.

Although vital new data on black petrel diving behaviour, these results are limited and as such it is important to gather further dive depth, timing and behaviour information from black petrels to clarify the timing of foraging and detailed diving behaviour characteristics. Additional TDR devices should be deployed on breeding black petrels during the incubation and chick rearing stages of the breeding season to determine if there are differences in dive patterns and timing.

Current mitigation measures for commercial fisheries in New Zealand waters include weighted lines, night-setting (unless lines are weighted), restrictions on offal discharge while setting or hauling bottom longlines and the use of streamer lines (or bird baffler or warp deflectors) during setting and hauling (MPI 2013). It is currently thought that if lines sink to a depth of 5 m when protected by streamer lines this will prevent most seabirds from reaching the bait. However, given that this study showed that both male and female black petrels were capable of diving to depths exceeding 25 metres, this target depth needs to be reassessed. Black petrels rarely dived over 10 metres and this should be the minimum depth for unprotected hooks. Pierre et al. (2013) showed that some inshore bottom longline vessels only achieved the 10 m depth at over 200 m from the back of the vessel which was well outside the range of the streamer lines and on bottom longline vessels targeting snapper, the lines were rarely at a depth greater than 5 m at the end of the streamer lines (Pierre et al. 2013). Additional line weighting has also been shown to increase the sink rate and prevent bait access to seabirds (Smith 2001, Robertson et al. 2006, Pierre et al. 2013). On-going research into developing new or updating current mitigation tools to reduce seabird interaction with fishing vessels needs to take into account new information on dive depth and foraging behaviour of black petrels.

Bell et al. (2013) showed that black petrel distribution had the highest overlap throughout the breeding season (October to May) with snapper bottom longline, big-eye tuna surface longline and inshore trawl which was consistent over the three-year tracking study (2007-2010). This suggests similar overlaps are likely to occur during the current breeding season. Over the same three-year analysis period there were 64 black-petrel captures on observed fishing vessels; 51 between January and April, 6 in May, and 9 captures between October and December (Abraham & Thompson 2012, Bell 2012). Since 2010 there have been 8 captures of black petrels on observed fishing; 7 between January and April and 1 between October and December (EAB, pers. obs.). All these observed captures were consistent with the highest fisheries overlap periods over the incubation and chick-rearing stages. It is important to note that observer coverage in these fisheries has been very low (generally less than 1%) and improving observer coverage in inshore trawl fisheries and in bluenose bottom longline fisheries, within the region of overlap, would help to better define the extent of the impact of fishing on black petrel populations.

There have been 79 observed black petrels captures on commercial fishing vessels in the New Zealand fisheries between 2003 and 2011 have been caught on both trawl and long-line vessels between October and May, either east of North Cape, near the Kermadec Islands or around Great Barrier Island (Abraham & Thompson 2012). The timing of these captures suggests that most birds may have been breeding adults. This means that their deaths would have reduced overall productivity and recruitment (as one bird cannot incubate an egg or raise a chick) and pair stability. The level of bycatch for black petrels outside New Zealand waters is unknown, and may impact on the population dynamics of the species. If breeding adults continue to be caught by commercial fishing operations in New Zealand and overseas, this species could be adversely affected even by a small change in adult survival, especially as black petrels have delayed maturity, low reproduction rates and high adult survival (Murray et al. 1993). Continued bycatch of breeding adults in New Zealand and overseas fisheries has the potential to seriously affect the species.

Although black petrels are recognised as the seabird species that is at the greatest risk from commercial fishing activity within New Zealand fisheries waters (Richard & Abraham 2013), there is a high level of uncertainty around total bycatch estimates within New Zealand fisheries. Recent estimation work suggests the number black petrel captures in New Zealand commercial trawl and long-line fisheries may be several hundred per annum (Richard & Abraham 2013), suggesting that bycatch is potentially far exceeding the biological limit and could have serious impacts on the black petrel population. It is important that increased observer coverage is implemented in overlap zones used by black petrels and fishing vessels to determine risk and bycatch levels.

Further detailed information to better describe the at-sea distribution and foraging behaviour of the Great Barrier Island (Aotea Island) black petrel population is needed. Long-term population data can be used to develop an accurate population model to determine adult and juvenile survivorship, recruitment, site fidelity, mortality and productivity. Combined with further use of high-resolution GPS and geo-locator data-loggers, using improved technology, will allow assessment of factors affecting the black petrel population on land and at-sea, particularly changes in habitat, foraging zones and prey species and identifying risks (such as fisheries interaction, predators and climate change).

6. RECOMMENDATIONS

The authors recommend that:

- Monitoring of the black petrel population (using the study burrows) is continued at Great Barrier Island up to, and including, the 2024/25 breeding season. This will ensure that 25 years of comparative data are collected to determine the population dynamics of black petrels, allowing us to develop a multi-generational population model to determine survivorship, mortality and the effects of predation, fisheries interaction and other environmental factors.
- There are three visits to the Great Barrier Island colony; (i) November/December to allow a large number of birds to be banded or recaptured easily, as the birds are often outside the burrows during this period. A high rate of banding and recapture will enable the continuation of the mark-recapture programme; (ii) January/February to continue with the mark/recapture programme and to confirm breeding status of the adults (and study burrows), and (iii) April/May to allow surviving chicks to be banded before they fledge.
- The study burrows should be checked for breeding status during every visit to the study area, to give a more accurate estimate of breeding success and determine sex of adults. This would also provide an opportunity to recapture returning birds banded as chicks.
- A sample of 30 black petrels should carry high-resolution GPS data-loggers over three consecutive breeding seasons to accurately investigate foraging behaviour including distances, locations and flight patterns throughout the breeding period (in particular the apparent high risk period of chick rearing; end January to May). This information should be assessed in relation to fisheries overlap.
- A sample of 30 black petrels should carry time-depth recorders over three consecutive breeding seasons to accurately investigate foraging behaviour including depth, number of dives and location (if deployed in conjunction with GPS loggers) throughout the breeding season (in particular the apparent high risk period of chick rearing; end January to May). This information should be assessed in relation to fisheries risk (in particular fishery type and gear).
- A sample of 30 black petrels should carry light-geolocator data-loggers over two consecutive breeding seasons and the intervening non-breeding period (including migration to and from South America) to accurately investigate foraging distances and locations, water temperature

and flight patterns throughout the breeding and non-breeding seasons. This information should be assessed in relation to fisheries overlap.

- Further random transects are undertaken every five years throughout the 35-ha study area around Mount Hobson to increase the likelihood of adult and juvenile recaptures (to improve survival and immigration estimates) and to compare with earlier transect surveys to determine population trends.
- The exact limits of the entire Mount Hobson (Hirakimata) colony should be established and the area calculated by a ground truth survey. Random transects should be established on other high points around the Mount Hobson area (e.g. Mount Heale, Mount Matawhero and The Hogs Back). These sites should be monitored as long as the study continues.
- Cat trapping should be implemented before and during the black petrel breeding season, November to June, especially during pre-laying (October/November) and the fledging period (May to June).
- Future analysis of the resighting data should consider the association of birds and burrows, to allow estimate of movement of birds between burrows. This may increase the estimate of the apparent adult survival.

7. ACKNOWLEDGMENTS

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9. APPENDICES

9.1 Results from the black petrel (*Procellaria parkinsoni*) study burrows (*n* = 432) near Mount Hobson/Hirakimata, Great Barrier Island (Aotea Island) during the 2014/15 breeding year.

Table 11 Results from the study of black petrel burrows (n = 432) near Mount Hobson, Great Barrier Island (Aotea Island) during the 2014/15 breeding year.

Study burrows within census grids have their location noted (in brackets) in the burrow column: Palmers Track grid one, two, three (= P1, 2, 3); South Fork Grid one, two, three (= S1, 2, 3); or Kauri Dam Grid one, two and three (= K1, 2, 3). Occupants of burrows are represented by band number or, if not caught, by a question mark (?). Where known, sex of bird is indicated in parentheses in the Band column: male (M); female (F). An asterix represents a dead adult. Grey-shaded box represents a non-study burrow.

BURROW	BAND				Outcome
1	?	?			Non-breeding
2	34610	34957 (?F)	38627 (?M)		Non-breeding
3	29927 (M)	35298 (F)			Dead embryo
4	28378 (?M)	394005 (?F)			Chick (39637)
5	27967 (M)	31971 (F)			Chick (39678)
6	33540 (M)	34394 (F)			Chick (39641)
7	?	?			Abandoned egg
8	35518 (M)	39601 (F)			Chick (41379)
9					Empty
10	36396 (?M)	34401 (?F)			Crushed egg
11		?			Empty
12	36361 (?M)	37595 (?F)			Disappeared egg
13	?	?			Non-breeding
14	34449 (M)	34421 (F)			Chick (39575)
15	35361 (M)	33329 (F)			Chick (39658)
16	35302	?			Chick (39727)
17	31108 (M)	38624 (F)			Dead chick
18	35209 (M)	29815 (F)			Chick (39593)
19	28376	?			Chick (39652)
20	34264 (M)	33683 (F)			Disappeared chick
21	33466 (M)	?			Abandoned egg
22	36393	36901			Chick (41312)
23	?	29847 (F)			Chick (41311)
24	34338 (?M)	36319 (?F)			Chick (41356)
25	?	?			Non-breeding
26	23014 (M)	28357 (F)			Chick (39690)
27	35198 (M)	35549 (F)			Chick (39715)
28					Empty
29					Empty
30	36151 (?M)	27976 (?F)			Chick (39718)
31	33052 (M)	33003 (F)			Disappeared chick
32 (P1)	31112 (M)	?			Non-breeding
33	28076 (?M)	31244 (?F)			Chick (39585)
34	31121 (M)	31248 (F)			Chick (39750)
35	34836 (M)	36320 (F)			Chick (41357)
36	33460 (M)	34359 (F)			Chick (41330)
37	36204 (M)	31107 (F)			Dead embryo

38					Empty
39	25426 (M)	35251 (F)			Chick (39587)
40	36166 (?M)	34384 (?F)			Chick (39568)
41	31112 (M)	39605 (?M)			Non-breeding
42	39510	39642			Non-breeding
43	36427	?			Non-breeding
44	31494 (M)	36364 (?F)			Chick (41317)
45	39441 (?M)	38861 (?F)			Dead embryo
46	34360 (M)	28813 (F)			Chick (41325)
47	?	33786 (F)			Crushed egg
48	36190 (M)	?			Non-breeding
49	34380 (?M)	?			Chick (39720)
50	31282 (M)	33747 (F)			Chick (39719)
51	37588 (?M)	36383 (?F)			Crushed egg
52	38863 (?M)	39609 (?F)			Non-breeding
53	31257 (M)	37587 (F)			Chick (39653)
54	39413	?			Non-breeding
55 (P1)	23635 (M)	33638 (F)			Chick (39659)
56 (P1)	36327 (M)	29684 (F)			Chick (39699)
57 (P1)	31153 (M)	33725 (F)			Non-breeding
58 (P1)	28029 (?M)	31205 (?F)			Disappeared chick
59 (P1)	31125 (M)	34392 (F)			Chick (39697)
60 (P1)	?	?			Non-breeding
61 (P1)	28354 (?M)	?			Chick (39692)
62 (P1)					Empty
63 (P1)	35256	38637			Chick (39691)
64 (P1)	31366 (M)	33323 (F)			Disappeared egg
65	39494 (M)	?			Chick (39722)
66	30874 (M)	39795 (F)	39495 (?M)		Non-breeding
67 (K1)	36118 (M)	33311 (F)			Dead chick
68 (K1)	32005 (F)	?	25673 (M) (interloper)	39423 (F) (interloper)	Chick (41398)
69	37569	?			Non-breeding
70	27604 (M)	31240 (F)			Chick (39716)
71 (K1)	34351 (M)	?			Chick (39713)
72 (K1)	34901 (?M)	?			Chick (41375)
73 (K1)	39602 (M)	37524 (F)			Chick (41376)
74 (K1)	?	29693 (F)			Non-breeding
75 (K1)	28572 (M)	?			Chick (41401)
76 (K1)	?	?			Non-breeding
77 (K1)	36354 (?M)	28390 (?F)			Abandoned egg
78 (K1)	30867 (M)	?			Dead chick
79 (K1)	38563 (?M)	38649 (?F)			Chick (41402)
80 (K1)	34843	?			Chick (41403)
81 (K1)	28046 (M)	28370 (F)			Chick (39721)
82	35448 (M)	?			Chick (39709)
83	34781 (M)	?			Chick (39708)
84	39519	37513			Non-breeding
85 (S1)	39407	?			Dead chick
86 (S1)	25661 (M)	34365 (F)			Chick (41353)
87 (S1)	39752 (M)	?			Dead embryo
88 (S1)					Empty
89 (S1)	31495 (M)	?			Chick (41306)
90 (S1)	33097 (M)	?			Chick (41305)

91 (S1)	39614	?			Infertile egg
92 (S1)	32928 (M)	36334 (F)			Chick (41355)
93					Empty
94	35200 (?M)	34886 (?F)			Chick (41374)
95	33089 (M)	36374 (F)			Chick (39739)
96 (P1)	35235	29820			Chick (39672)
97	34385 (M)	36194 (F)			Chick (39600)
98	39774 (?M)	?			Dead embryo
99	31262 (M)	36378 (F)			Chick (39573)
100	38560	?			Chick (39679)
101 (K1)	35186 (M)	?			Dead chick
102 (K1)	33389 (?M)	35239 (?F)			Dead embryo
103 (K1)	25673 (M)	?			Non-breeding
104 (K1)	?	?			Non-breeding
105	?	?			Crushed egg
106	36277 (M)	38625 (?F)			Non-breeding
107	33764 (M)	33799 (F)			Chick (39731)
108	27952 (?M)	38802 (?F)			Chick (41372)
109	?	37593 (F)			Chick (39707)
110 (S1)	33654 (?M)	37535 (?F)			Chick (41304)
111 (S1)					Empty
112 (S1)	28037 (M)	34796 (F)			Chick (41351)
113 (S1)	35193 (?M)	39513 (?F)			Chick (41354)
114 (S1)	35101 (?M)	34953 (?F)			Abandoned egg
115	39626	?			Non-breeding
116 (P1)	25435 (?M)	?			Chick (39592)
117	37600 (?M)	39613 (?F)			Non-breeding
118	39442 (?M)	39612 (?F)			Chick (41309)
119	34389	33530			Chick (39584)
120 (P1)	?	?			Non-breeding
121 (P1)	33035 (M)	29817 (F)			Chick (39698)
122 (P1)	27961	36328			Chick (39696)
123 (P1)	29818 (?M)	38858 (?F)			Chick (39655)
124 (P1)	25442 (M)	35255 (F)			Dead chick
125 (P1)					Empty
126 (P1)	33477 (?M)	37586 (?F)			Chick (39695)
127	33301 (M)	35538 (F)			Chick (41316)
128	31054 (M)	39511 (F)			Crushed egg
129					Collapsed
130	39404	38900			Dead chick
131	35406	38583			Chick (41377)
132 (K2)	36290 (?M)	38585 (?F)			Chick (41386)
133 (K2)	25525 (M)	?			Chick (41388)
134 (K2)	37503 (?M)	37574 (?F)			Chick (41385)
135 (K2)	25447 (M)	34377 (F)			Chick (41389)
136 (K2)	29699 (M)	38558 (F)			Dead chick
137 (K2)	25494 (M)	31572 (F)			Dead chick
138 (K2)	34553	37573	35439 (?M) (interloper)		Chick (41382)
139	33248 (M)	38554 (F)	39754 (M) (interloper)		Disappeared egg
140	29809 (M)	36179 (F)			Chick (41396)
141 (S2)	36233 (?M)	?			Dead chick
142 (S2)	?	?			Non-breeding
143 (K2)	38623 (M)	39798 (F)			Non-breeding

144 (K2)	34417	?			Chick (41383)
145 (K2)	34527 (M)	38701 (F)			Infertile egg
146 (K2)	37536 (M)	34550 (?M)	39449 (?M) (interloper)		Non-breeding
147 (K2)	34903 (M)	36368 (F)			Chick (41397)
148 (K2)	36355 (?M)	38871 (?F)	39794 (?F)		Non-breeding
149 (K2)	29825 (M)	?			Crushed egg
150 (K2)	33575 (M)	38621 (F)			Chick (41394)
151	39755 (M)	29047 (F)			Crushed egg (adopted chick 41324)
152 (S2)	37519 (M)	?			Non-breeding
153 (S2)	29978 (M)	?			Disappeared egg
154 (P1)	34320	36382			Disappeared egg
155 (P2)	?	?			Non-breeding
156 (P2)	39526	39606			Non-breeding
157 (P2)	33473 (M)	39525 (F)			Chick (39673)
158 (P2)	35574 (?M)	39528 (?F)	39625 (?F)		Non-breeding
159 (P2)	37584 (M)	25441 (F)			Chick (39682)
160	36384 (M)	38553 (F)			Chick (41371)
161 (P2)	31542 (M)	?			Chick (39657)
162 (P2)	35544 (?M)	36329 (?F)			Chick (39683)
163 (P2)	35490	?			Non-breeding
164 (P2)	33737 (?M)	37585 (?F)			Chick (39656)
165 (K2)	29700 (M)	37575 (F)			Chick (41384)
166	25437 (M)	34386 (F)			Chick (39651)
167	35543	36326			Chick (39694)
168 (P1)					Empty
169					Empty
170	36380	39604			Non-breeding
171	35529 (M)	36346 (F)			Chick (39574)
172	31048 (M)	?			Dead embryo
173	31586 (?M)	?			Non-breeding
174	28071 (?M)	28050 (?F)			Chick (39747)
175	25503 (M)	28001 (F)			Chick (39687)
176 (K1)	?	?			Non-breeding
177	39619	?			Non-breeding
178	36186 (M)	36312 (F)			Chick (41345)
179	37516 (?M)	33481 (?F)			Chick (41339)
180	25694 (M)	29832 (F)			Chick (41338)
181	39508 (M)	35204 (F)			Crushed egg
182	29085 (?M)	?			Dead embryo
183 (S1)	37534 (?M)	38893 (?F)			Chick (41308)
184	39617	?			Non-breeding
185 (K1)					Empty
186	?	?			Dead chick
187	31047 (?M)	31452 (?F)			Chick (39588)
188	34972	?			Disappeared egg
189	36139 (M)	38851 (F)			Disappeared egg
190	34738 (M)	?			Chick (41344)
191 (P2)	34800 (M)	34762 (F)			Chick (39674)
192 (S1)	35187 (M)	39615 (F)			Chick (41352)
193 (K2)	?	?			Non-breeding
194 (K2)	34720 (?M)	39637 (?F)			Non-breeding
195	35160 (?M)	39797 (?F)			Chick (41395)
196	39753 (?M)	?			Disappeared egg

197	34660 (M)	39620 (F)			Chick (41343)
198	39420 (M)	39509 (?F)			Non-breeding
199	38859 (?M)	38716 (M) (interloper)			Disappeared egg
200	28073 (M)	34265 (F)			Chick (39599)
201	36373 (?M)	38705 (?F)			Dead embryo
202 (P2)	33375	39786	39607		Non-breeding
203	30930 (M)	?			Infertile egg
204 (K1)	35000 (M)	32957 (F)			Chick (41400)
205	25697 (M)	29664 (F)			Chick (39730)
206	34936 (M)	34382 (F)			Chick (39733)
207 (P1)					Empty
208 (P1)	35360	38878			Chick (39654)
209 (K3)	34374 (M)	?			Disappeared egg
210 (K3)	37568 (?M)	39636 (?F)			Abandoned egg
211 (K3)	35197	39448			Non-breeding
212 (K3)	?	?			Non-breeding
213 (K2)	36369 (M)	36343 (F)			Chick (41392)
214 (K2)	?	?			Non-breeding
215 (S3)	?	?			Non-breeding
216 (S3)	39757 (?M)	?			Non-breeding
217 (K3)	31991 (M)	38571 (F)			Chick (41399)
218	38635	?			Chick (39595)
219 (P3)					Empty
220 (P3)					Empty
221 (P3)	39430	?			Dead embryo
222	39791	3886			Non-breeding
223 (S3)	33673 (M)	37531 (F)			Chick (41328)
224 (P3)	37958 (M)	27992 (F)			Chick (39577)
225 (S3)	13634 (?M)	34404 (?F)			Dead chick
226 (P3)	28385	?			Chick (39579)
227 (K1)	25509 (M)	25407 (F)			Chick (41380)
228	33633 (M)	33308 (F)			Chick (39725)
229 (P3)	38868	35531			Chick (39598)
230 (P3)					Empty
231 (P3)	39624	?			Non-breeding
232					Empty
233	34820 (?M)	?			Chick (41333)
234	29835 (?M)	35245 (?F)			Chick (41331)
235	34387	?			Abandoned egg
236					Empty
237	39618	?			Non-breeding
238 (S1)	?	?			Non-breeding
239	39523 (M)	39496 (F)			Chick (39736)
240	?	?			Non-breeding
241	38551 (?M)	39640 (?F)			Dead embryo
242	39512 (?M)	35263 (?F)			Chick (41318)
243	39792 (?M)	27988 (F)	36367 (F)	39551 (?M)	Crushed egg
244	37567 (?M)	?			Chick (39723)
245 (K1)	?	?			Non-breeding
246 (P3)	37507	37579			Chick (39580)
247	?	?			Non-breeding
248	35297 (?M)	35278 (?F			Chick (41347)
249	37515	37563	39780 (interloper)		Chick (41346)

250					Empty
251 (K3)	?	?			Cooks
252	34794 (M)	34852 (F)			Chick (39703)
253 (K3)	39514	39515			Non-breeding
254 (P1)					Empty
255 (K2)	34431 (M)	29089 (F)			Disappeared chick
256	?	?			Non-breeding
257	34758 (M)	38915 (?F)			Non-breeding
258 (P3)					Empty
259	33508 (?M)	37592 (?F)			Chick (39734)
260 (S3)	25651 (M)	14009 (F)			Dead embryo
261	32021 (?M)	?			Disappeared egg
262	34739 (M)	32902 (F)			Chick (41335)
263	29073 (M)	36339 (F)	39799 (M) (interloper)	39782 (F) (interloper)	Chick (41342)
264					Empty
265 (K2)	35300 (M)	?			Chick (41393)
266	31975 (M)	25444 (F)			Chick (39724)
267	29823 (M)	?			Non-breeding
268					Empty
269	38555 (?M)	38862 (?F)			Chick (39732)
270	35188 (?M)	37510 (F)			Dead embryo
271 (K1)	38559 (?M)	37571 (?F)			Non-breeding
272	?	?			Breeding
273	?	?			Non-breeding
274	37521 (M)	39611 (F)			Chick (41358)
275	27981 (M)	39500 (F)	39649 (F)		Dead embryo
276					Empty
277	33620 (?M)	?			Chick (39704)
278	34751 (?M)	25695 (F)			Chick (39701)
279					Empty
280	36184 (?M)	?			Chick (41302)
281	32995 (M)	34733 (F)			Chick (41301)
282	33652 (?M)	33643 (?F)			Chick (41337)
283	39521	?			Non-breeding
284	32099 (?M)	37581 (?F)			Chick (39581)
285	35218	38566			Chick (39726)
286	?	?			Non-breeding
287	33699 (M)	36187 (F)			Chick (41327)
288	33671 (?M)	39758 (?F)	36441 (?F)		Non-breeding
289	39754 (M)	35536 (?F)			Non-breeding
290	35212 (M)	35534 (F)			Chick (39743)
291	39633	?			Non-breeding
292	39498 (?M)	39643 (?F)			Non-breeding
293	38638 (M)	38852 (F)			Chick (39706)
294	36185 (M)	27984 (F)			Chick (41303)
295	33630 (M)	39812 (F)			Dead embryo
296	32980 (M)	37589 (F)			Chick (39749)
297	28034 (M)	33755 (F)			Chick (39742)
298	33646 (?M)	34429 (F)			Chick (41326)
299	38857	?			Chick (39738)
300	35232 (?M)	39541 (?M)			Non-breeding
301	33768 (M)	?			Disappeared egg
302					Empty

303	38885 (M)	39499 (F)			Dead embryo
304	34370 (?M)	39641 (?F)			Chick (41348)
305	35244 (M)	33645 (F)			Chick (41336)
306					Empty
307	34876 (?M)	33796 (?F)			Dead embryo
308	?	?			Non-breeding
309	33476 (M)	30858 (F)			Dead chick
310 (S2)	33276	?			Chick (41321)
311 (S2)	?	?			Cooks
312 (S2)	38807	38867			Dead chick
313 (S2)	34865 (?M)	?			Chick (41322)
314 (S2)					Empty
315	33714 (M)	33318 (F)			Chick (39702)
316	33715 (M)	38746 (F)			Chick (39688)
317 (P2)					Empty
318	25555 (M)	39301 (F)			Chick (39596)
319					Empty
320	34941 (M)	36202 (F) (DEAD)	39524 (interloper)		Dead embryo
321	38747 (M)	37591 (F)			Chick (39744)
322 (P3)	38634 (?M)	38818 (?F)			Chick (39594)
323	27526 (M)	39610 (F)			Chick (41370)
324	?	34403 (F)			Chick (41310)
325	38641 (?M)	28000 (?F)			Dead embryo
326	35199 (?M)	38811 (?F)			Chick (39740)
327 (K2)	34898 (M)	34257 (F)			Chick (41381)
328	?	?			Non-breeding
329 (P3)	33528 (?M)	29665 (?F)			Chick (39597)
330	33090 (M)	?			Chick (39676)
331	32025 (M)	32924 (F)			Chick (39712)
332	39629	?			Non-breeding
333	32927 (M)	29082 (F)			Chick (39745)
334					Empty
335	28358 (?M)	34379 (?F)			Dead embryo
336 (P2)	35489	?			Non-breeding
337 (S1)	?	?			Non-breeding
338	36356	37570			Chick (41391)
339	?	33493 (F)			Chick (41390)
340	35540 (?M)	34357 (?F)			Chick (41340)
341	?	?			Collapsed
342 (S2)	39760 (?M)	28399 (?F)			Chick (41320)
343(S2)	?	?			Non-breeding
344 (S2)	34687	39439			Chick (41323)
345	34861 (M)	34362 (F)			Rat predation (egg)
346	?	?			Non-breeding
347	39498 (?M)	37513 (F)			Non-breeding
348 (P3)	39501 (M)	39623 (F)			Non-breeding
349 (P3)					Empty
350 (P2)	39787	?			Non-breeding
351 (P1)	34266 (M)	34390 (F)			Chick (39675)
352	39796	39789			Non-breeding
353	35545	?			Chick (39681)
354	33480 (?M)	?	39788 (interloper)	39790 (interloper)	Chick (39680)
355	33467 (M)	36191 (F)			Chick (39735)

356	34580 (M)	36375 (F)			Chick (39748)
357	39638	?			Non-breeding
358	33474 (M)	33494 (F)			Chick (39729)
359	32985 (M)	38556 (F)			Chick (39686)
360	33482 (M)	35237 (F)	35292 (?M) (interloper)		Crushed egg
361	14018 (M)	39793 (F)			Dead embryo
362 (K1)	?	?			Non-breeding
363	33581 (M)	36336 (F)			Disappeared egg
364	34854 (?M)	?			Chick (39717)
365 (K2)					Empty
366 (K1)					Empty
367	38716 (?M)	39751 (?F)	38628		Non-breeding
368	38853	?			Non-breeding
369 (S1)	?	?			Non-breeding
370	39438	?			Chick (39705)
371	34717 (M)	?			Chick (41341)
372	?	?			Non-breeding
373	?	36153 (F)			Chick (41344)
374	36193	?			Non-breeding
375 (P1)	39785	?			Chick (39583)
376	37520 (M)	36363 (F)			Chick (41319)
377					Empty
378 (K3)					Empty
379 (K2)	?	?			Joined to 209
380	29960 (M)	27972 (F)			Chick (41378)
381					Empty
382	28362 (M)	29834 (F)			Chick (41332)
383 (S1)					Empty
384	39429 (?M)	37548 (?F)			Dead chick
385	?	?			Non-breeding
386	28352	35530	39773 (?M) (interloper)		Chick (39591)
387 (S3)	39757 (?M)	?			Non-breeding
388	33762 (M)	31324 (F)			Disappeared egg
389	?	?			Non-breeding
390					Empty
391	33244 (M)	28377 (F)			Chick (39677)
392 (K1)	?	?			Cooks
393	36124 (M)	37525 (F)			Dead chick
394	34878 (M)	36305 (F)			Dead chick
395	35392 (M)	39644 (F)	38814 (?M) (interloper)		Non-breeding
396	35213 (M)	?			Chick (41350)
397	?	?			Non-breeding
398	35299	39788			Non-breeding
399 (P1)	?	?			Non-breeding
400	?	?			Non-breeding
401	34304 (?M)	36347 (?F)			Disappeared egg
402	31981 (?M)	?			Chick (41315)
403	36400	37508			Chick (39693)
404	36357 (M)	39651 (F)			Chick (41359)
405	34273	38809	39756 (?M) (interloper)		Crushed egg
406 (S2)					Empty

407	33607 (M)	35284 (F)			Chick (39589)
408	39621	?			Non-breeding
409	36377 (?M)	36399 (?F)			Chick (39578)
410	38645	?			Non-breeding
411	?	?			Non-breeding
412	37580	?			Chick (39582)
413 (P1)	34505	37582			Chick (39685)
414 (P1)	37583	?			Chick (39684)
415	33246 (M)	36163 (F)			Chick (39671)
416 (S1)	38552 (?M)	36308 (?F)			Dead chick
417	25536 (M)	36321 (F)			Chick (39710)
418	39776 (?M)	?			Dead embryo
419	38561 (?M)	31204 (?M)	39777 (?F)		Crushed egg
420	39777 (?M)	?			Non-breeding
421	26955 (?M)	39428 (?F)			Chick (39576)
422 (P1)	33369	39431			Chick (39700)
423					Empty
424 (P2)	33584	39608			Non-breeding
425 (S1)	36318 (?M)	?			Infertile egg
426	29848 (M)	39639 (F)			Chick (41373)
427	39764 (?M)	39647 (?F)			Dead embryo
428	28017 (?M)	?			Dead embryo
429 (K1)	39635 (M)	36115 (?F)			Non-breeding
430 (S1)	?	34869 (F)			Chick (41307)
431 (S2)	?	?			Non-breeding
432 (S2)	39554	?			Chick (41329)

9.2 Number of recaptures, age at first recapture, age at first breeding and age at first successful breeding for black petrels (*Procellaria parkinsoni*) banded as chicks and recaptured in the study site on Great Barrier Island (Aotea Island) between 1995/96 and 2014/15, with a note about an immigrant banded as a chick on Hauturu/Little Barrier Island.

Table 12 Number of recaptures, age at first recapture, age at first breeding and age at first successful breeding for black petrels (Procellaria parkinsoni) banded as chicks and recaptured in the study site on Great Barrier Island (Aotea Island) between 1995/96 and 2014/15, with a note about an immigrant banded as a chick on Hauturu/Little Barrier Island.

BAND	SEX	SEASON BANDED	SEASON WHEN LAST RECAPTURED	NUMBER OF RECAPTURES	AGE AT FIRST RECAPTURE (years)	AGE AT FIRST BREEDING (years)	AGE AT FIRST SUCCESSFUL BREEDING (years)
25525	Male	1998/99	2014/15	8	7	8	10
25536	Male	1998/99	2014/15	6	6	14	14
25546	Male	1998/99	2013/14	9	5	7	7
25630	Male	1999/00	2005/06	2	5		
25631	? Male	1999/00	2003/04	1	4		
25635	Male	1999/00	2008/09	5	5	6	6
25637	Male	1999/00	2004/05	1	5		
25648	Male	1999/00	2008/09	4	5	8	
25651	Male	1999/00	2014/15	10	5	6	6
25658	Male	1999/00	2004/05	1	5	5	5
25659	Female	1999/00	2012/13	2	6	6	6
25661	? Male	1999/00	2014/15	7	9	9	10
25663	Male	1999/00	2008/09	6	4	7	8
25664	? Female	1999/00	2013/14	9	3	6	10
25669	Male	1999/00	2005/06	2	5	5	5
25673	Male	1999/00	2014/15	10	5	7	7
25677		1999/00	2006/07	1	7	7	7
28085	Male	1998/99	2005/06	1	5		
29027		2008/09	2013/14	1	5		
29047	Female	2008/09	2014/15	1	6	6	
29098		2008/09	2012/13	1	4		
29912	? Male	2000/01	2012/13	5	5	5	6
29927	Male	2000/01	2014/15	11	9	12	12
29960	Male	1999/00	2014/15	6	9	9	9
29978	Male	1999/00	2014/15	4	9	14	14
30161 [11]		2007/08	2009/10	1	2		
30167		2007/08	2012/13	1	5		
30175		2007/08	2013/14	1	5		
30177		2007/08	2011/12	1	3		
30908	? Male	1995/96	2002/03	1	7		
30924	Male	1995/96	2010/11	9	6	6	6
30930	Male	1995/96	2014/15	15	4	5	5
30934		1995/96	2013/14	1	18		

[11] This bird was caught at sea off San Jose, Peru (entangled in a drift net) and released alive. It has not been recaptured at the colony to date.

31076		1997/98	2002/03	1	5		
31080		1997/98	2001/02	1	4		
31081	? Male	1997/98	2002/03	2	4		
31082	Male	1997/98	2001/02	1	4		
31089	Female	1997/98	2013/14	9	5	6	9
31194	Male	1996/97	2001/02	1	5	5	
31322[12]		2005/06	2009/10	1	3		
31324	Female	2005/06	2014/15	3	7	7	7
31340		2005/06	2014/15	1	9	9	9
31345	? Male	2005/06	2011/12	1	6		
31366	Male	1997/98	2014/15	13	5	6	6
31370	? Male	1997/98	2012/13	5	5	8	
31377	? Male	1997/98	2001/02	1	4		
31382	Female	1997/98	2008/09	5	4	5	5
31383	Male	1997/98	2003/04	1	6		
31389		1997/98	2014/15	1	17	17	17
31405		1996/97	2004/05	2	6	7	7
31406	? Female	1996/97	2001/02	1	5		
31413	Female	1996/97	2004/05	1	8	8	8
31415	? Male	1996/97	2003/04	1	7		
31422		1996/97	2012/13	1	16	16	
31424	? Male	1996/97	2008/09	5	6	8	8
31474	? Male	1998/99	2002/03	1	4		
31476	Male	1998/99	2004/05	2	4	6	
31478	Male	1998/99	2012/13	2	10	10	10
31490	? Male	1998/99	2002/03	1	4		
31491	Male	1998/99	2005/06	1	7		
31494	Male	1998/99	2014/15	8	6	9	10
31495	Male	1998/99	2014/15	11	4	5	5
31498	? Female	1998/99	2008/09	4	6	6	8
31527	? Male	1998/99	2002/03	1	4		
31537	? Male	1998/99	2013/14	6	8	8	8
31542	Male	1998/99	2014/15	13	4	6	7
31546	Male	1998/99	2007/08	1	9		
31956	Male	2000/01	2008/09	2	7		
32063		2000/01	2005/06	1	5		
32073[13]		2000/01	2007/08	1	7		
32091		2000/01	2007/08	1	7		
32099	? Male	2000/01	2014/15	8	5	8	8
32100		2000/01	2012/13	1	12	12	
32915		2001/02	2009/10	3	6	6	6
32921		2001/02	2012/13	1	11	11	11
32927	? Male	2001/02	2014/15	7	6	6	6
32957	Female	2001/02	2014/15	9	5	6	7
32979		2001/02	2006/07	1	5		
32980	Male	2001/02	2014/15	4	4	11	11
32985	? Male	2001/02	2014/15	3	11	11	11
32995	Male	2001/02	2014/15	3	11	11	13
33003	Female	2001/02	2014/15	4	7	7	7

[12] The bird was recovered dead on Te Rere Beach (near Goat Island Marine Reserve) on 14 January 2010 and had not been recaptured at the colony.

[13] This bird was caught at sea in Ecuador and released alive. It has not been recaptured at the colony to date.

33015	Male	2001/02	2009/10	3	6		
33035	Male	2001/02	2014/15	7	6	7	7
33052	Male	2001/02	2014/15	8	6	6	6
33055		2001/02	2009/10	1	8	8	8
33067		2001/02	2009/10	1	8		
33068		2001/02	2009/10	2	7	8	
33071	Male	2001/02	2012/13	1	11		
33088[14]		2001/02	2004/05	1	2		
33208[15]	Male	2002/03	2010/11	4	5	7	
33218	? Female	2002/03	2008/09	2	5	6	
33225		2002/03	2006/07	1	4		
33226	Male	2002/03	2014/15	1	12	12	
33244	Male	2002/03	2014/15	4	6	10	10
33246	Male	2002/03	2014/15	3	10	10	10
33248	Male	2002/03	2014/15	7	6	8	8
33276		2003/04	2014/15	4	7	7	7
33335	Male	2003/04	2010/11	2	5	7	
33369		2003/04	2014/15	3	9	8	8
33375		2003/04	2014/15	6	5	5	5
33376		2003/04	2012/13	2	8	8	
33380		2003/04	2007/08	1	4		
33389	? Male	2003/04	2014/15	6	6	6	7
33397	Male	2003/04	2008/09	1	5	5	5
33453		2005/06	2010/11	1	5		
33508	? Male	2005/06	2014/15	3	7	7	7
33518		2005/06	2009/10	1	4		
33528		2005/06	2014/15	3	7	7	7
33530		2005/06	2014/15	5	5	6	6
33540	Male	2005/06	2014/15	4	4	7	7
33546	Male	2005/06	2012/13	1	7	7	
33550		2005/06	2012/13	3	4	5	5
33575	Male	2005/06	2014/15	5	5	5	5
33581	Male	2005/06	2014/15	4	5	6	
33584		2005/06	2014/15	1	9		
33589		2005/06	2013/14	4	5	5	5
33591		2005/06	2010/11	1	5		
33596		2005/06	2010/11	1	5	6	
33737	? Male	2002/03	2014/15	5	7	7	7
34273		2004/05	2014/15	4	7	7	7
34276	Male	2004/05	2013/14	4	5	8	8
34278	? Male	2004/05	2014/15	1	12	12	12
34299		2004/05	2012/13	2	7	7	7
34304	? Male	2004/05	2014/15	3	8	8	8
34308		2004/05	2014/15	1	10	10	10
34317		2004/05	2013/14	2	8	8	8
34320		2004/05	2014/15	5	5	8	8
34338		2004/05	2014/15	4	5	6	6
34349	Male	2004/05	2013/14	3	7		
34435		2006/07	2013/14	7	7	7	7

[14] This bird was caught at sea in Ecuador and released alive. It has not been recaptured at the colony to date.
[15] This bird was recovered dead on 29/1/11 in KDG2.

34505		2006/07	2014/15	3	6	6	6
34520	Male	2006/07	2011/12	1	5		
34527	Male	2006/07	2014/15	3	6	6	
34550		2006/07	2014/15	1	8		
34553		2006/07	2014/15	2	7	8	8
34574		2006/07	2010/11	1	4		
34580	Male	2006/07	2014/15	3	5	6	6
34599		2006/07	2012/13	1	6		
34600	Male	2006/07	2013/14	3	5		
34610		2006/07	2014/15	1	7		
34615	Male	2006/07	2014/15	2	7		
34621		2006/07	2010/11	1	4		
34624		2006/07	2012/13	1	6		
34660	Male	2006/07	2014/15	4	4	5	5
34687		2006/07	2014/15	2	7	8	8
34698		2006/07	2013/14	2	7		
34804		2004/05	2009/10	2	4	5	5
34808	Male	2004/05	2012/13	1	8		
34820	? Male	2004/05	2014/15	4	6	6	10
34828		2004/05	2009/10	1	5		
34836	Male	2004/05	2014/15	3	6	7	10
34837		2004/05	2013/14	1	9		
34843		2004/05	2014/15	5	5	6	6
34867		2004/05	2011/12	1	7	7	7
34886		2004/05	2014/15	4	7	7	8
34901	? Male	2004/05	2014/15	6	5	7	7
34903	? Male	2004/05	2014/15	5	5	7	7
34916		2004/05	2013/14	1	9		
35101	? Male	2008/09	2014/15	1	6	6	
35131	Male	2008/09	2014/15	2	5		
35160	? Male	2008/09	2014/15	2	5	6	6
35186	Male	2008/09	2014/15	2	4	6	
35187	Male	2008/09	2014/15	2	5	6	6
35188	Male	2008/09	2014/15	1	6	6	
35189	Male	2008/09	2012/13	1	4		
35193	? Male	2008/09	2014/15	2	5	6	6
35360		2008/09	2014/15	2	5	6	6
35361	Male	2008/09	2014/15	2	5	6	6
35380		2008/09	2013/14	1	5		
35392	Male	2008/09	2014/15	1	6		
35397		2008/09	2012/13	1	4	4	4
35439	? Male	2010/11	2014/15	1	4		
35489		2010/11	2014/15	1	4		
35490		2010/11	2014/15	1	4		
35518	Male	2008/09	2014/15	2	4	6	6
35571		2009/10	2012/13	1	3		
35574		2009/10	2014/15	1	5		
35583		2009/10	2013/14	1	4	4	4
36112	Male	2007/08	2012/13	1	5		
36115		2007/08	2014/15	1	7		
36118	Male	2007/08	2014/15	4	5	7	
36139	Male	2007/08	2014/15	2	6	7	
36140		2007/08	2012/13	1	5		
36147		2007/08	2012/13	1	5		

36216		2007/08	2011/12	1	4		
36233	? Male	2007/08	2014/15	2	6	7	
36241		2007/08	2012/13	1	5		
36271		2007/08	2014/15	1	7		
36277	Male	2007/08	2014/15	1	7		
36290	? Male	2007/08	2014/15	3	5	6	7
36294		2007/08	2013/14	1	6	6	
36427		2010/11	2014/15	1	4		
36441		2010/11	2014/15	1	4		
36474		2009/10	2013/14	1	4		
36476		2009/10	2014/15	1	5		
MEAN (± SEM)				2.9 ± 0.2	6.0 ± 0.2	7.3 ± 0.2	7.6 ± 0.2
30807[16]	Female	1996/97	2009/10	5	9	9	9

[16] Immigrant originally banded on Hauturu/Little Barrier Island, but now breeding successfully on Great Barrier Island (Aotea Island).