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Population parameters of the black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island), 2015/16.

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Frontispiece: View along Windy Canyon Track to Mt Hobson/Hirakimata.

ABSTRACT

This report is part of the ongoing study of the black petrel, *Procellaria parkinsoni,* on Great Barrier Island/Aotea that was begun in the 1995/96 breeding season. During the 2015/16 breeding season, 433 numbered burrows within the 35-ha study area near Mount Hobson/Hirakimata were checked and intensively monitored. Of these 419 are used as study burrows and 286 were used by breeding pairs, 75 by non-breeding adults and the remaining 59 burrows were non-occupied. By 10 May 2016, 191 chicks were still present in the study burrows, corresponding to a breeding success of 66.8%. Nine census grids were monitored within the study area and accounted for 164 of the inspected burrows and 154 of the study burrows, with 103 burrows being used for breeding. There were 108 chicks from earlier breeding seasons were recaptured within the Mount Hobson/Hirakimata colony area this season (a total of 254 'returned chicks' have been caught since the 1999/2000 season). Over 1550 hours of recordings were collected by automated acoustic recording units showing black petrels began calling between 2100 and 2252 hours and that activity was highest near the summit (Mt Hobson/Hirakimata). Mean clacking rate varied between 1.1 to 12.7 clacks per minute. Analysis of the stratified census grid and mean transect data estimated that there were 1947 to 2197 birds present in the 35-ha area around Mount Hobson/Hirakimata.

Keywords: black petrel, *Procellaria parkinsoni*, monitoring, population estimate, acoustic recording unit, breeding success, fishing effort, bycatch, Great Barrier Island/Aotea, 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 (36°187'S 175°4125'E) (GBI), New Zealand (Heather and Robertson 2015).

The National Plan of Action for Seabirds called for an accurate estimate of the total population size of black petrels (MPI 2013). In order to complete this, the uncertainty around the population size outside the main colony on GBI must be corrected. Another key aspect of the research is to refine the key demographic parameters, primarily juvenile survival which is critical to determining the population trajectory.

The main breeding area on GBI is around the summit of Mount Hobson (Hirakimata) (hereafter Mount Hobson). Monitoring work carried out during the 2015/16 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, Bell *et al.* 2015), 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 Department of Conservation (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 (2015/16) 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, Bell *et al.* 2015). 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:

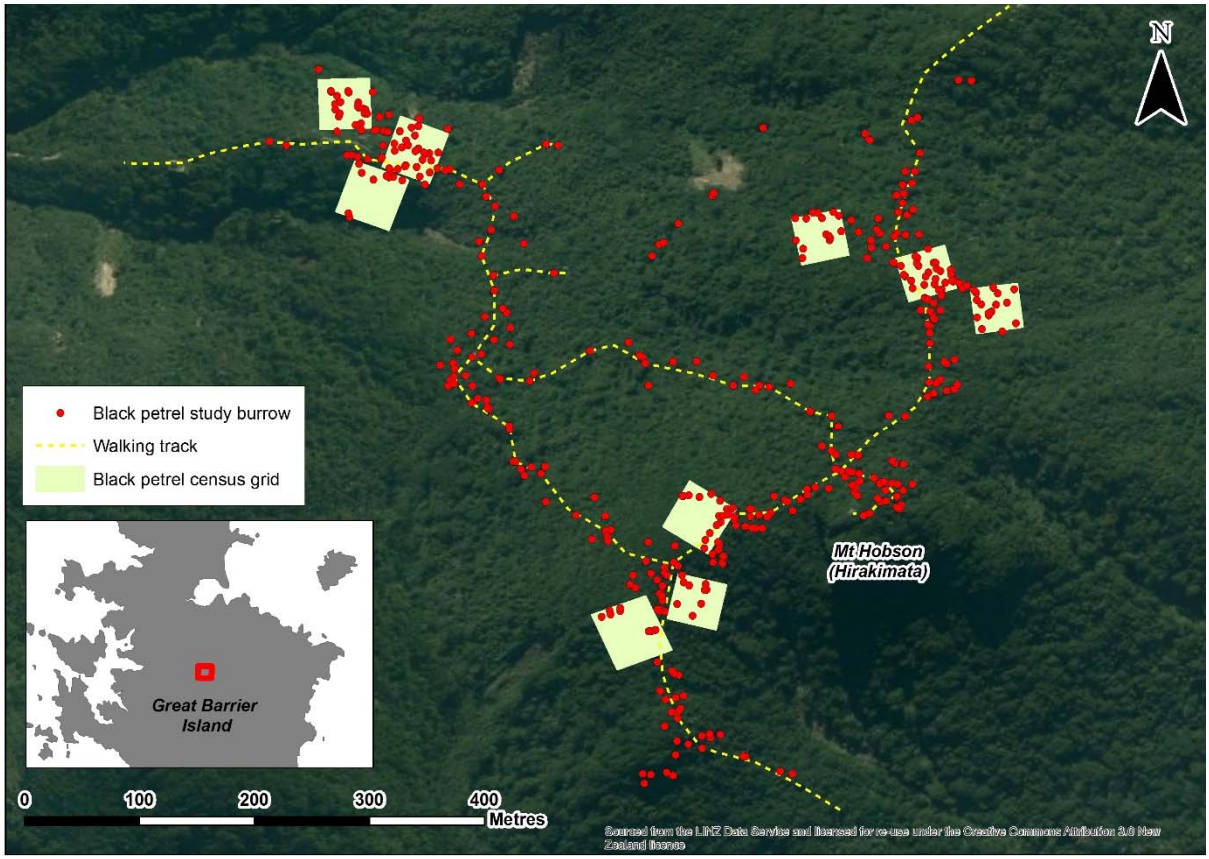
- Collect data that will allow estimation of the black petrel population size and describe the population trend by comparing the estimate to relevant existing data. Key tasks conducted under this objective were:
    - Monitor a sample of burrows within the main breeding area and band all adults present in the burrows during December and January/February and band all remaining fledglings during April/May.
    - 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 breeding area.
- Use high-resolution GPS data-loggers to determine at-sea distribution of black petrels during their breeding season (incubation and chick rearing) suitable to inform fisheries risk assessment.
- Use time-depth recorders to determine diving ability and behaviour of black petrels during their breeding season.
- Identify the range of the black petrel population on GBI using automated acoustic recorders across the island.
- Determine a population estimate for areas outside the main colony on GBI using information from the acoustic recordings and seabird-detector dog surveys

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; 2-14 December 2015. 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, Bell *et al.* 2015). 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.

Figure 1 Location of the black petrel (Procellaria parkinsoni) study burrows and census grids within the study area on Great Barrier Island/Aotea. Altitude (621 m a.s.l.) is shown. Approximate North is shown (N).



On a second visit to the colony (25 January-5 February 2016) 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 (5-10 May 2016). 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™ or ArcView™).

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) in December 2015 by authors (EAB and JS) using Rua (DOC-certified seabird detection dog 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

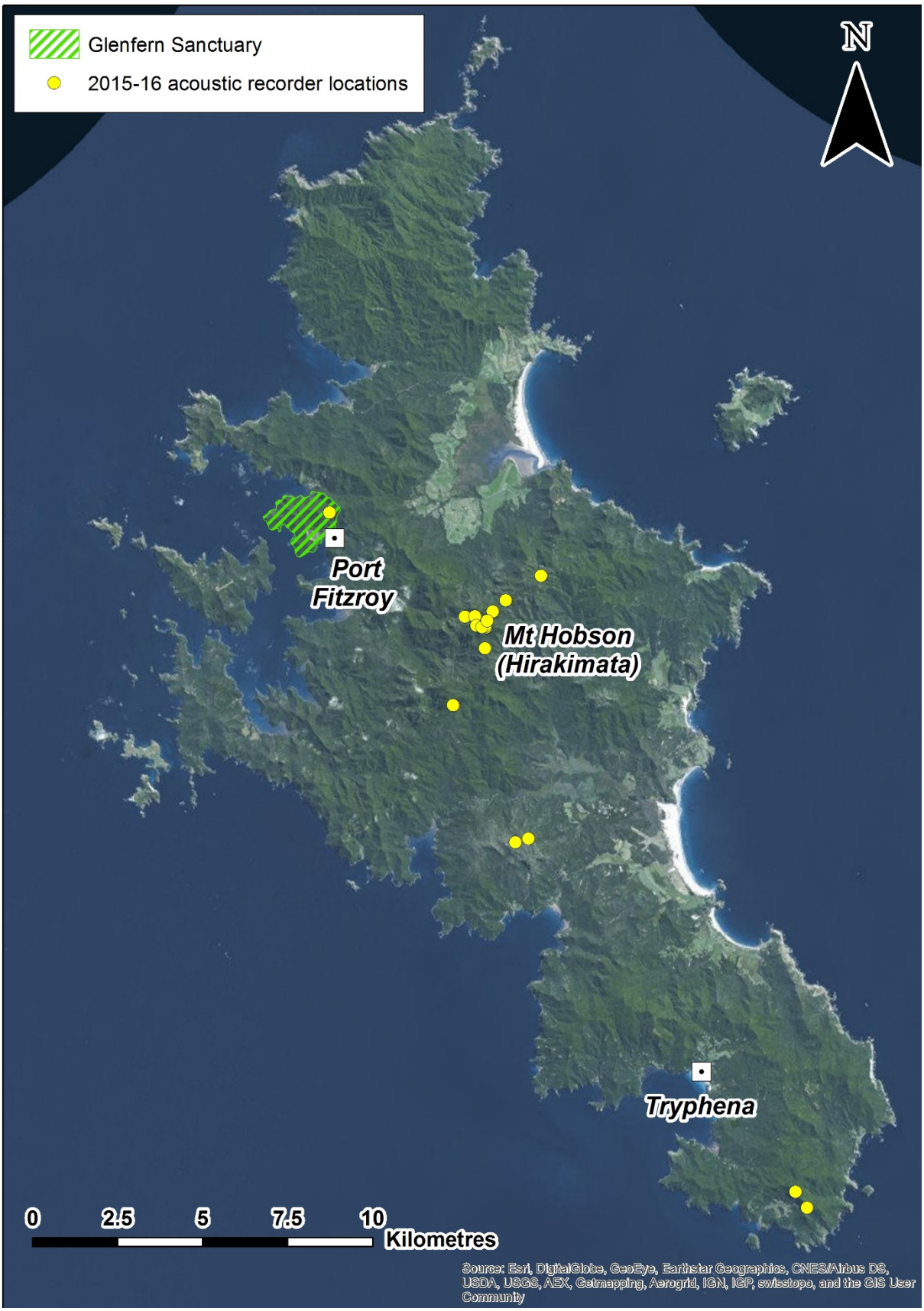
Night work was undertaken during the December 2015 visits to the study area. This involved searching the study area by walking the track system and capturing any adult petrel on the surface. Several nights were also spent at known petrel launch sites, where birds were captured at take-off or landing.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

3.4 Deployment of GPS data-logger devices

Twenty-five MicroTrack GPS data-logger devices (Microsystems Research, New Zealand) were deployed on known breeding adult black petrels on GBI between 4 and 14 December 2015. The birds were chosen from study burrows within the 35-ha study area if they had been successful breeders for at least one season and had been in the same pair for two seasons. These GPS devices were 16 g units that measured 44 mm x 28 mm x 10 mm including the plastic shrink-wrap. The total instrument load (percentage of bird's weight) is 2.3% (for a 700 g breeding bird). Each bird was weighed (using Pesola™ scales) before and after deployment to obtain information on body condition and impact of carrying the devices. These GPS devices were attached to feathers in the central dorsal area using Tesa™ tape. When the birds were recaptured, the unit was removed by snipping the tape with scissors. Application of each GPS device took no longer than 22 minutes (mean ± SEM = 14.6 ± 0.6 minutes; range 8.4-21.7 minutes) and removal of each GPS devices took no longer than 12 minutes (mean ± SEM = 3.5 ± 0.5 minutes; range 0.6-11.8 minutes). These devices give accurate position location (to within 1 m, depending on satellite reception). The loggers' recorded position data every 15 minutes).

Animal ethics approval for the use of the GPS data-loggers was given by DOC Animal Ethics Committee (8/12/2014, AEC279).

Figure 2 Location of the automated acoustic devices deployed on Great Barrier Island/Aotea during the 2015/16 black petrel (*Procellaria parkinsoni*) breeding season.



3.5 Automated acoustic recorder units

Seventeen automated acoustic recorder units (ARU) were placed out within the study area, within the known black petrel habitat and across GBI from 3 December 2015 to 31 January 2016 (Figures 2 and 3). The devices were temporarily attached to a tree using soft cable ties or electrical tape (Figure 2). These devices were set up to record all sounds from half an hour after dark (2100 hr NZST) and recorded for two hours.

Figure 3 Example of the automated acoustic recording unit deployed on Great Barrier Island/Aotea, 2015/16.

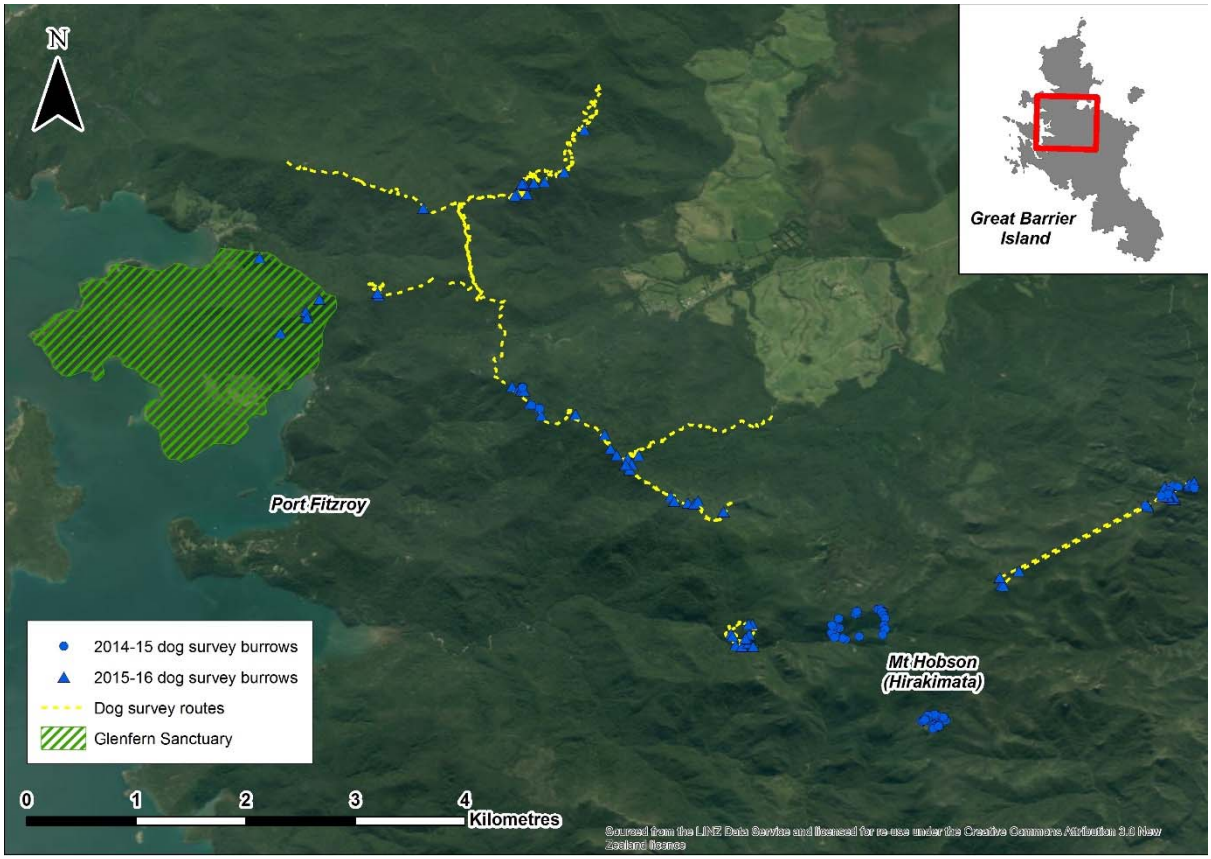
3.6 Seabird-detector dog surveys around the island

Ground-based searches using seabird detector dogs and two searchers were conducted between 11 and 23 February 2016 and focused on the areas around at Kaiaarara, Tramline, Okiwi Ridges, Glenfern, Mt Heale, Windy Canyon, Cooper's Castle and Ruahine. 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 dog-team followed the main tracks or ridgelines, but the search area was defined by the scenting of burrows with the dog leaving the track or ridge to indicate at occupied burrows (i.e. breeding burrows containing chicks or adults with chicks) or recently active burrows (i.e. where a non-breeding adult had been prospecting or calling to attract a mate or a failed breeder had been present).

The dog could scent burrows up to 10 metres on either side of the track on calm days, with greater distances on the windward side of the track (up to 30 metres).

Figure 4 Location of black petrel (*Procellaria parkinsoni*) burrows within seabird detector dog survey areas on Great Barrier Island/Aotea, February 2016.



Any burrows located within the search area was recorded (and its position was marked by GPS) and searched for the presence of an adult, egg or chick, The same procedure as outlined in Section 3.1 was followed for any bird caught in the transect burrow. Petrel sign (i.e. droppings) or burrows outside the width of each transect were noted. Details of vegetation (species and density), slope, aspect and general information on burrows were recorded.

3.7 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).

3.8 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 419 study burrows (those burrows that could be accessed to determine occupancy out of the 433 numbered burrows in the 2015/16 season), 286 contained breeding birds, 75 contained non-breeding birds and 59 were non-occupied (Appendix 1, Tables 1 and 2).

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.

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	76.8
1999/00	94	6	16:1	72	22	3.3:1	73.6
2000/01	95	5	19:1	66	29	2.3:1	76.2
2001/02	92	8	12:1	68	24	2.8:1	70.3
2002/03	88	12	7:1	63	25	2.5:1	68.8
2003/04	82	18	5:1	64	18	3.6:1	76.0
2004/05	86	14	6:1	63	23	2.7:1	79.6
2005/06	82	18	5:1	70	12	5.8:1	66.9
2006/07	91	9	10:1	70	21	3.3:1	82.5
2007/08	85	15	6:1	68	17	4.0:1	77.3
2008/09	89	11	8:1	69	21	3.3:1	75.6
2009/10	87	13	7:1	62	25	2.5:1	73.8
2010/11	85	15	6:1	66	19	3.5:1	60.7
2011/12	92	8	12:1	63	29	2.2:1	76.6
2012/13	91	9	10:1	66	25	2.6:1	80.8
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
2015/16	86.2	14.1	6:1	68.3	17.7	3.9:1	66.8
MEAN (± SEM)	88.8 (± 0.9)	11.2 (± 0.9)	9.25:1 (± 0.9)	66.7 (± 0.7)	22.2 (± 1.0)	3.2:1 (± 0.2)	73.5 (± 1.3)

Data from the past 18 breeding seasons shows the ratio of breeding to non-breeding burrows has averaged 3.2:1 (± 0.2) with a range of 2.2 to 5.8 over this period, and the number of the burrows used for breeding has increased slightly over the period (Table 1, Figure 5).

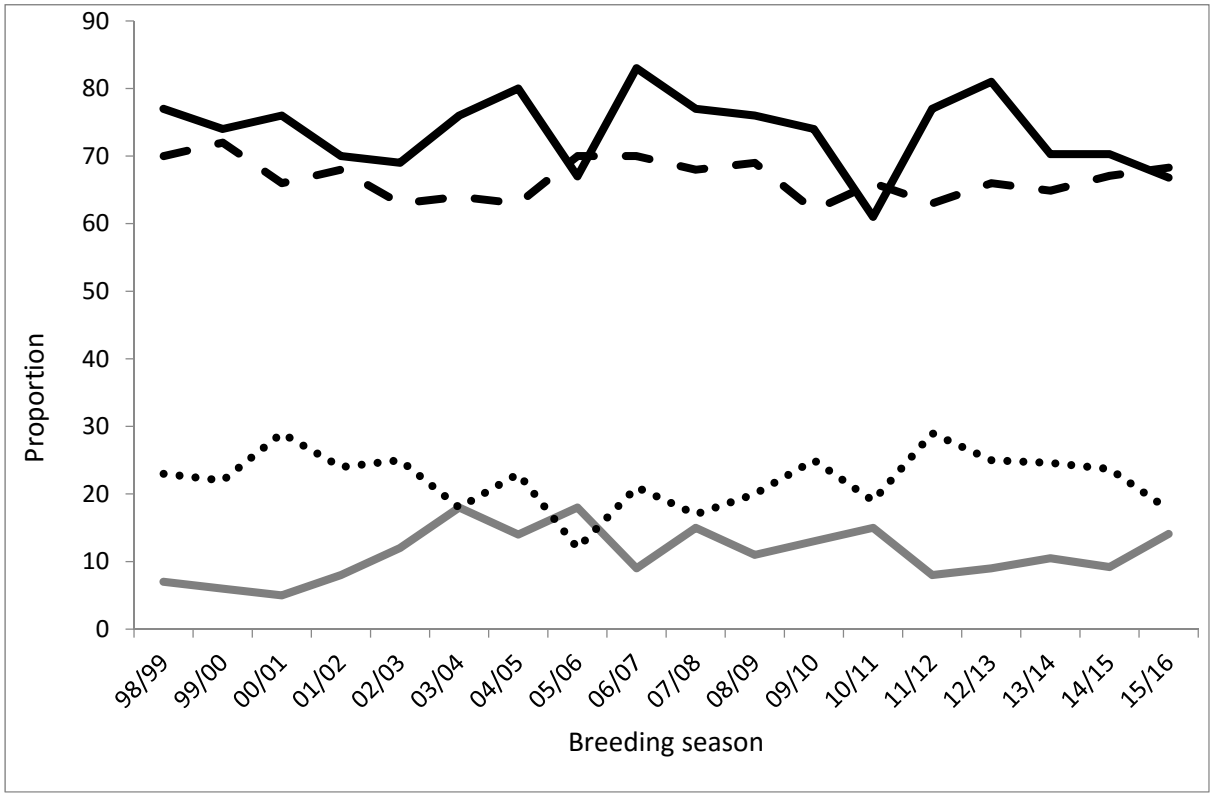
Over this same 18-year period, the ratio of occupied to non-occupied burrows has ranged from 5:1 to 19:1; the number of non-occupied burrows has also increased over this time including this season (Table 1, Figure 5).

There has been a drop in the number of occupied burrows and a subsequent increase in the number of non-occupied burrows this season (Table 1). The number of burrows used by breeding birds has declined overall despite the increase in breeding occupancy from last season (Figure 5). Similarly the number of burrows being used by non-breeding birds have slightly declined over the past 18 years with a consistent declining trend since 2011 (Figure 5).

The number of burrows used for breeding this season was only very slightly higher than last season and the overall mean for the entire study (66.8% compared to 66.7 ± 0.7%, Table 1).

Figure 5 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 slightly declining over the 18-year period (with regular fluctuations between years) and the number of burrows being used for breeding has also reduced over the same time (Figure 5). The number of non-occupied burrows has also increased over the length of the study (Figure 5).

Figure 5 Occupancy and breeding success of study burrows (1998/99 to 2015/16 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.



There were 95 failures (e.g. loss of eggs, infertility, predation, etc. and this corresponds to a breeding success of 66.8% (Table 2, Figure 3). The annual breeding success this season was much lower than the mean annual breeding success (73.5% ± 1.3) for the past 18 years of the

study (Tables 1 and 2). Table 2 shows the failures and overall breeding success rate within the study burrows since the 1995/96 breeding season.

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

Year	Number of study burrows	Eggs									Chick						**BREEDING SUCCESS (%)**
		Laid	Predation (rat)	Crushed[1]	Abandoned	Infertile	Dead embryo	Disappeared egg[2]	Unknown[3]	Hatched	Predation (rat)	Predation (cat)	Died (know causes)[4]	Died (unknown causes)	Disappeared chick[5]	Fledged[6]	
95/96	80	57	1	0	0	0	0	2	0	54	0	0	0	0	0	54	**94.7[7]**
96/97	118	92	6	5	2	6	0	0	0	73	0	0	1	0	0	72	**78.3**
97/98	137	95	1	0	1	4	8	0	0	81	0	0	1	0	0	80	**84.2**
98/99	197	142	2	1	5	12	6	0	0	116	2	2	0	3	0	109	**76.8**
99/00	248	178	9	10	1	6	13	0	0	139	0	2	0	6	0	131	**73.6**
00/01	255	168	6	6	3	8	9	0	0	136	0	1	0	7	0	128	**76.2**
01/02	283	192	5	5	9	3	14	11	0	145	0	2	0	8	0	135	**70.3**
02/03	318	199	1	14	7	2	19	3	5	148	0	3	0	8	0	137[8]	**68.8**
03/04	324	208	2	13	0	7	16	0	0	170	0	2	0	10	0	158[7]	**76.0**
04/05	362	226	3	7	3	4	12	5	0	192	0	0	0	7	5	181[7]	**79.6**
05/06	366	257	15	27	1	0	9	19	0	186	0	2	0	12	0	172[7]	**66.9**
06/07	370	257	0	7	2	1	6	19	0	222	0	0	0	10	0	212[7]	**82.5**
07/08	379	256	5	9	11	4	0	19	0	208	0	0	0	9	1	198[7]	**77.3**
08/09	388	266	5	11	6	3	18	7	0	216	0	0	0	15	0	201[7]	**75.6**
09/10	393	244	8	2	3	3	20	20	0	188	0	0	0	8	0	180[7]	**73.8**
10/11	396	262	8	15	13	3	15	33	0	175	0	1	0	13	2	159[7]	**60.7**
11/12	363[9]	214	6	12	1	0	4	23	0	168	0	0	0	0	4	164[7]	**76.6**
12/13	409	276	2	11	8	4	12	8	0	231	0	0	0	5	3	223[7]	**80.8**
13/14	410	266	6	3	8	8	3	35	0	203	0	0	4	0	12	187[7]	**70.3**
14/15	422	283	1	12	6	4	24	15	0	221	0	0	1	17	4	199	**70.3**
15/16	419	286	3	24	7	1	11	36	0	204	0	0	0	2	11	191[7]	**66.8**

[1] Only shell fragments were recovered from the burrow; may have been predated by rats, infertile or contained an embryo which died.

[2] Present in December, but were gone when checked in January; most burrows had been cleaned out and the adults were not caught again.

[3] Five burrows were not located in May 2003 and as a result it is not known if the eggs hatched successfully. To determine overall breeding success it has been assumed that these eggs failed.

[4] These chicks died of either disease (i.e. avian pox) or starvation.

[5] Present in February, but were gone in April or May; these chicks were too young to have fledged and some may have been predated by rats or cats, or died due to various reasons.

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

[7] The 1995/96 breeding success rate is biased as most of these 80 study burrows were located in late February when large chicks were already present (and these chicks were likely to survive to fledging).

[8] 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, 2 in 2013/14 and 6 in 2015/16). The remaining chicks were banded.

[9] Although there were actually 401 study burrows, but only 363 were monitored over the complete 2011/12 breeding season; 38 burrows could not be located by the field team in April 2012.

4.1.1 Cat predation within the study burrows

The Department of Conservation (DOC) on GBI have maintained annual feral cat control at Okiwi Station since 2002 for the protection of brown teal/pateke (*Anas chlorotis*), banded rail (*Gallirallus philippensis*) and chevron skink (*Oligosoma homalonotum*). They have removed over 1370 feral cats from the area (Table 3). This has had flow-on effects for the black petrels and other species on Mt Hobson by reducing the number of feral cats moving onto the mountain and predating chicks and adults between March and June. DOC have also maintained feral cat trapping on Mt Hobson in 1996 and 1997 and between 2011 and 2015 removing 6 feral cats (Table 3). Lack of funding meant the trapping on Mt Hobson was not completed in the 2015/16 season (L. Mack, DOC GBI, pers. comm.).

Table 3 Number of feral cats trapped in Okiwi Basin and on Mt Hobson/Hirakimata and cat predation events recorded in the black petrel (*Procellaria parkinsoni*) study burrows on Great Barrier Island/Aotea Island since the 1995/96 breeding season.

Year	Cat trapped in Okiwi Basin	Cats trapped on Mt Hobson/Hirakimata	Cat predation in study burrows
95/96	-	1	0
96/97	-	0	0
97/98	-	-	0
98/99	-	-	2
99/00	-	-	2
00/01	-	-	1
01/02	-	-	2
02/03	88	-	3
03/04	92	-	2
04/05	147	-	0
05/06	128	-	2
06/07	84	-	0
07/08	84	-	0
08/09	103	-	0
09/10	99	-	0
10/11	126	-	1
11/12	95	4	0
12/13	91	0	0
13/14	69	1	0
14/15	79	0	0
15/16	93	-	0
Total	**1378**	**6**	**15**
MEAN (± SEM)	98.4 ± 5.7	1.0 ± 0.6	0.7 ± 0.2

4.2 Number of burrows in the census grids

A total of 164 numbered and 155 study burrows were found in the nine census grids (Appendix 1, Table 4) in the 2015/16 breeding season.

Of these 155 study burrows, 103 burrows were used by breeding pairs, 25 were used by non-breeding adults and 27 burrows were non-occupied (Table 4).

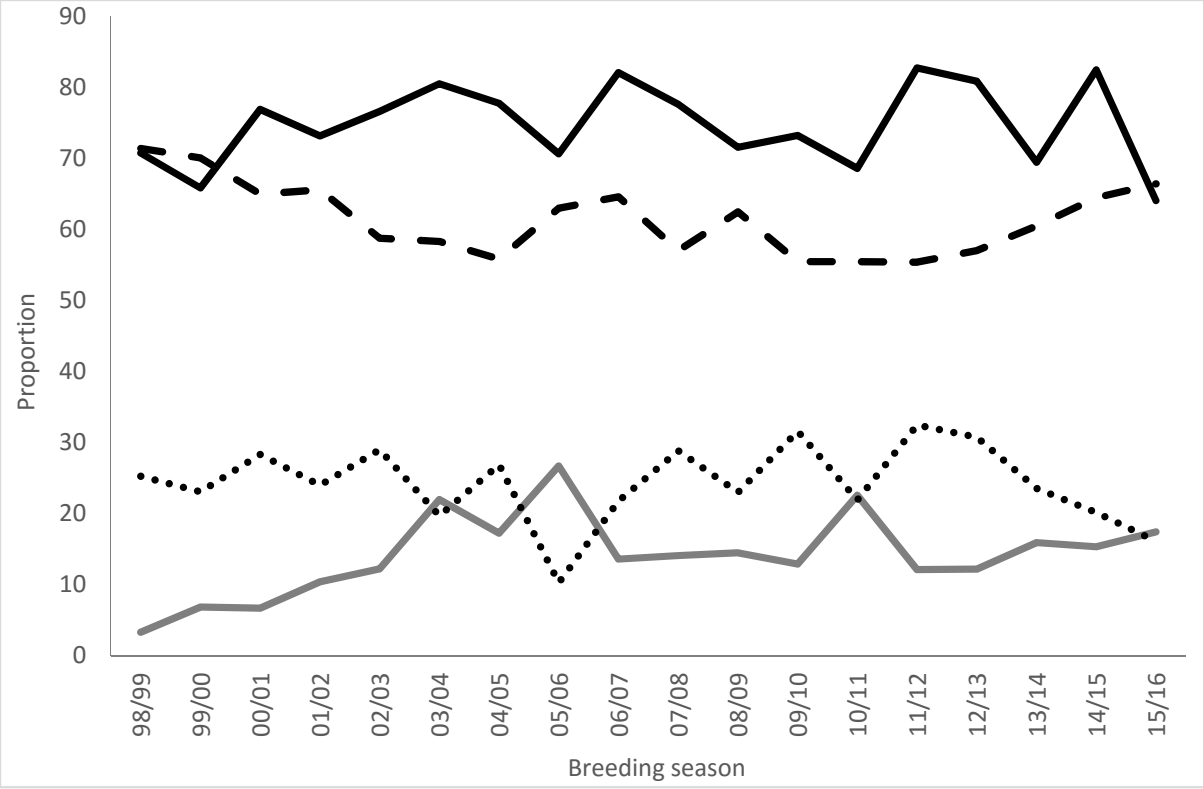
Table 4 Type and number of study burrows within the black petrel (*Procellaria parkinsoni*) census grids (Kauri Dam, Palmers Track and South Forks) in the study area on Great Barrier Island/Aotea since the 1995/96 breeding season.

	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**
	2015/16	**5**	**16**	**4**	**25**	**4**	**23**	**3**	**30**	**5**	**10**	**8**	**23**	**78**
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**
	2015/16	**4**	**19**	**2**	**25**	**2**	**11**	**1**	**14**	**1**	**10**	**2**	**13**	**52**
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**
	2015/16	**1**	**2**	**3**	**6**	**4**	**9**	**0**	**13**	**2**	**3**	**1**	**6**	**25**

Figure 6 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 an increase over the past four seasons. Breeding success appears to be relatively stable despite fluctuating from year to year since the beginning of the study. The number of non-breeding burrows within the census grids decreased again this season and the overall trend for non-breeding burrows is a slight decline. There was a slight increase in the number of non-occupied burrows this season and the overall trend for non-occupied burrows shows an increase since 1998 (Figure 6).

Figure 6 Occupancy of census grid burrows since the 1998/99 breeding seasons by black petrels (*Procellaria parkinsoni*) on Great Barrier Island/Aotea. Dashed black line = burrows used by breeding birds; dotted line = burrows used by non-breeding birds; solid grey line = unoccupied burrows.



There were also several 'potential' or inaccessible 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.

4.3 Banding data

During the 2015/16 season, 771 adults were identified. Of these, 600 were already banded and 171 were banded this season (Appendix 1, Table 5). Three dead banded adults were recovered; all three had been hung up in vegetation (Table 5). There were 184 chicks still present in the study burrows during the April visit and all were banded (Appendix 1, Table 5). An additional chick was banded in a random burrow within the study area.

Table 5 Banding, recapture and recovery data from all black petrels (*Procellaria parkinsoni*) caught within the study area on Great Barrier Island/Aotea since the 1995/96 breeding season.

	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	**15/16**
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	**9**
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	**3**
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	**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	**5**
Recaptures of birds banded in 1998/99	-	-	-	-	95	82	71	64	49	36	39	33	32	37	39	24	17	29	19	17	**18**
Recaptures of birds banded in 1999/00	-	-	-	-	-	86	75	66	47	51	52	37	31	39	34	33	20	22	17	15	**20**
Recaptures of birds banded in 2000/01	-	-	-	-	-	-	51	52	41	22	36	28	29	40	30	21	12	22	18	15	**15**
Recaptures of birds banded in 2001/02	-	-	-	-	-	-	-	68	88	26	25	22	21	26	36	20	18	24	22	17	**19**
Recaptures of birds banded in 2002/03	-	-	-	-	-	-	-	-	61	55	57	54	39	56	52	38	26	36	34	31	**27**
Recaptures of birds banded in 2003/04	-	-	-	-	-	-	-	-	-	22	28	23	21	26	27	24	16	23	19	15	**18**
Recaptures of birds banded in 2004/05	-	-	-	-	-	-	-	-	-	-	48	31	33	48	59	42	28	47	43	38	**35**
Recaptures of birds banded in 2005/06	-	-	-	-	-	-	-	-	-	-	-	46	34	49	50	35	23	35	28	27	**25**
Recaptures of birds banded in 2006/07	-	-	-	-	-	-	-	-	-	-	-	-	27	46	42	35	22	43	45	38	**40**
Recaptures of birds banded in 2007/08	-	-	-	-	-	-	-	-	-	-	-	-	-	29	20	19	18	32	23	24	**20**
Recaptures of birds banded in 2008/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	71	55	46	66	54	53	**51**
Recaptures of birds banded in 2009/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	29	39	40	33	**41**
Recaptures of birds banded in 2010/11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	39	32	35	**38**
Recaptures of birds banded in 2011/12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	26	24	**31**
Recaptures of birds banded in 2012/13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	70	71	**66**
Recaptures of birds banded in 2013/14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	**51**
Recaptures of birds banded in 2014/15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**53**
TOTAL RECAPTURES	**19**	**45**	**151**	**155**	**256**	**312**	**326**	**370**	**380**	**306**	**377**	**347**	**334**	**469**	**529**	**412**	**341**	**517**	**531**	**537**	**600**
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	**171**
TOTAL ADULTS	**60**	**224**	**211**	**284**	**401**	**409**	**440**	**549**	**447**	**441**	**485**	**432**	**387**	**652**	**636**	**494**	**390**	**761**	**665**	**704**	**771**
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	**185**
TOTAL NUMBER OF BIRDS	**119**	**293**	**296**	**400**	**538**	**546**	**600**	**611**	**557**	**625**	**627**	**647**	**578**	**855**	**807**	**638**	**553**	**980**	**864**	**919**	**956**
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	**108**
BAND RECOVERIES FROM DEAD BIRDS	0	1	1	0	2	1	2	2	0	0	2	1	1	2	3	2	0	3	0	1	**3**

[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).

Table 6 Number of black petrel (*Procellaria parkinsoni*) 'returned chicks' that have been recaptured within the study site on Great Barrier Island/Aotea since the 1995/96 breeding season.

	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	**15/16**
Recaptures of chicks banded pre-1995/96	9	12	11	9	12	9	9	8	8	6	9	7	7	8	5	5	3	7	5	5	**5**
Recaptures of chicks banded in 1995/96	-	-	-	-	1	1	2	3	2	2	2	1	2	2	2	2	1	1	2	1	**1**
Recaptures of chicks banded in 1996/97	-	-	-	-	-	-	2	2	3	4	1	0	0	1	0	0	0	1	0	0	**0**
Recaptures of chicks banded in 1997/98	-	-	-	-	-	-	5	6	4	1	2	3	1	4	6	7	3	3	2	2	**1**
Recaptures of chicks banded in 1998/99	-	-	-	-	-	-	-	6	3	7	6	6	6	8	5	5	3	8	7	5	**4**
Recaptures of chicks banded in 1999/00	-	-	-	-	-	-	-	1	2	10	9	5	5	8	2	1	4	7	6	5	**6**
Recaptures of chicks banded in 2000/01	-	-	-	-	-	-	-	-	-	0	4	1	5	2	8	3	1	4	2	2	**2**
Recaptures of chicks banded in 2001/02	-	-	-	-	-	-	-	-	-	1	1	2	6	8	1	2	5	10	8	8	**9**
Recaptures of chicks banded in 2002/03	-	-	-	-	-	-	-	-	-	-	-	2	2	3	2	4	1	4	3	5	**3**
Recaptures of chicks banded in 2003/04	-	-	-	-	-	-	-	-	-	-	-	-	1	3	8	7	2	5	4	4	**5**
Recaptures of chicks banded in 2004/05	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	8	9	14	14	12	**11**
Recaptures of chicks banded in 2005/06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	3	5	9	8	9	**8**
Recaptures of chicks banded in 2006/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	4	7	11	9	**13**
Recaptures of chicks banded in 2007/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	7	7	8	**7**
Recaptures of chicks banded in 2008/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	8	11	**12**
Recaptures of chicks banded in 2009/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	3	**10**
Recaptures of chicks banded in 2010/11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	**7**
Recaptures of chicks banded in 2011/12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**3**
Recaptures of chicks banded in 2012/13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**
Recaptures of chicks banded in 2013/14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Recaptures of chicks banded in 2014/15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
TOTAL RECAPTURE OF 'RETURNED CHICKS'	**9**	**12**	**11**	**9**	**13**	**10**	**18**	**26**	**22**	**31**	**34**	**27**	**35**	**48**	**44**	**47**	**43**	**92**	**90**	**94**	**108**
TOTAL RECAPTURE OF POST-1995 'RETURNED CHICKS'	0	0	0	0	1	1	9	18	14	25	25	20	28	40	39	42	40	85	85	89	**103**

There have been 3362 chicks banded within the study area between 1995 and 2016 (Tables 5, 6 and 7) and these birds have begun to return to the colony as pre-breeders, non-breeders and breeders (*n* (2015/16 season) = 103; *n* (total) = 249, Table 7, Appendix 2).

The proportion of 'returned chicks' from each season varies from 0 to 12.9% (mean ± SEM = 8.0 ± 1.0); the greatest number of chicks that have been recaptured is from the 2004/05 and 2006/07 breeding seasons (*n* = 22), but the highest proportion of chicks recaptured were banded in both the 1997/98 and 1998/99 season (12.9%, Table 7). Figure 7 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 7 shows the number of returned chicks that have been recaptured each season; since the first chicks were banded in 1995/96, the total number of recaptures of 'returned chicks' has increased to 249 in 2015/16.

There were 108 'returned chicks' recaptured at the colony this season (Table 6); of these, 72 attempted to breed, with 45 successfully raising chicks of their own. The remaining 36 did not breed, although several males were recaptured while calling to attract a mate. Figure 8 shows the total number of 'returned chicks' and number that was caught breeding and non-breeding each season between 1995 and 2016.

Table 7 Total number of black petrel (*Procellaria parkinsoni*) chicks banded each season and the proportion of those chicks that have been recaptured within the study site on Great Barrier Island/Aotea since the 1995/96 breeding season.

	Total number of banded chicks	Total number of returned chicks	Proportion (%) of returned chicks
Pre-1995	209	26	12.4
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	18	11.3
2002/03	62	7	11.3
2003/04	110	9	8.2
2004/05	184	22	12.0
2005/06	143	18	12.6
2006/07	215	22	10.2
2007/08	191	18	9.4
2008/09	203	18	8.9
2009/10	171	15	8.8
2010/11	144	10	6.9
2011/12	163	3	1.8
2012/13	219	1	0.5
2013/14	199	0	0
2014/15	215	0	0
2015/16	171	0	0
TOTAL	**3362**	**249**	**7.4**
MEAN (± SEM)	152.8 ± 11.0	11.3 ± 1.7	8.0 ± 1.0

Figure 7 The number of black petrel (*Procellaria parkinsoni*) chicks banded each season and the percentage of those chicks that have been recaptured in the study site on Great Barrier Island/Aotea. Grey column = the number of chicks banded per season and solid black line = percentage of those chicks that have been recaptured.

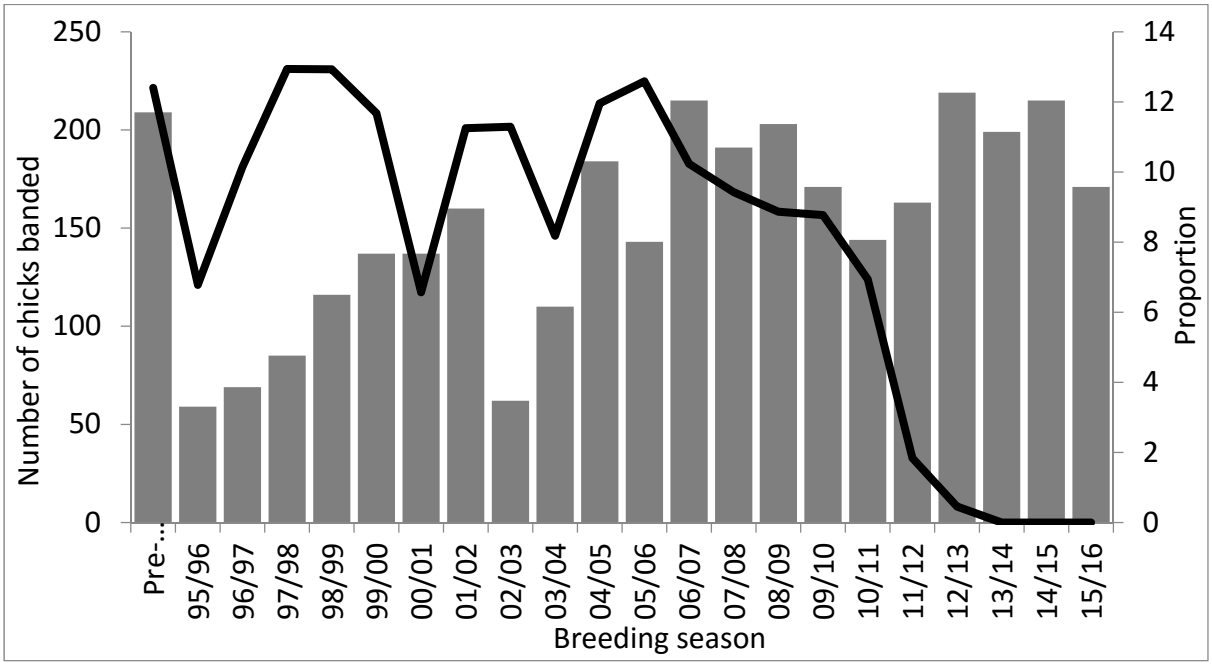


Figure 8 The number of breeding and non-breeding black petrel (*Procellaria parkinsoni*) 'returned chicks' recaptured each season since the 1995/96 breeding season in the study site on Great Barrier Island/Aotea. Dotted black line = total number of recaptured 'returned chicks', grey column = the number of non-breeding 'returned chicks' and black column = the number of breeding 'returned chicks'.

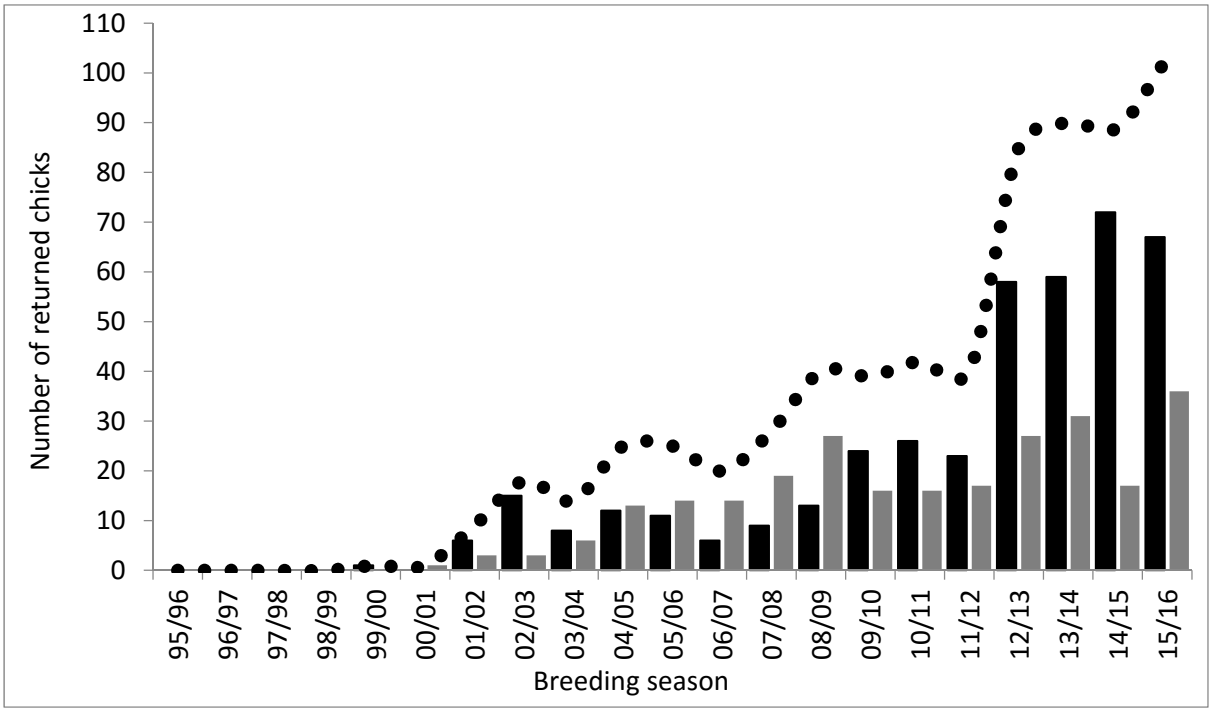
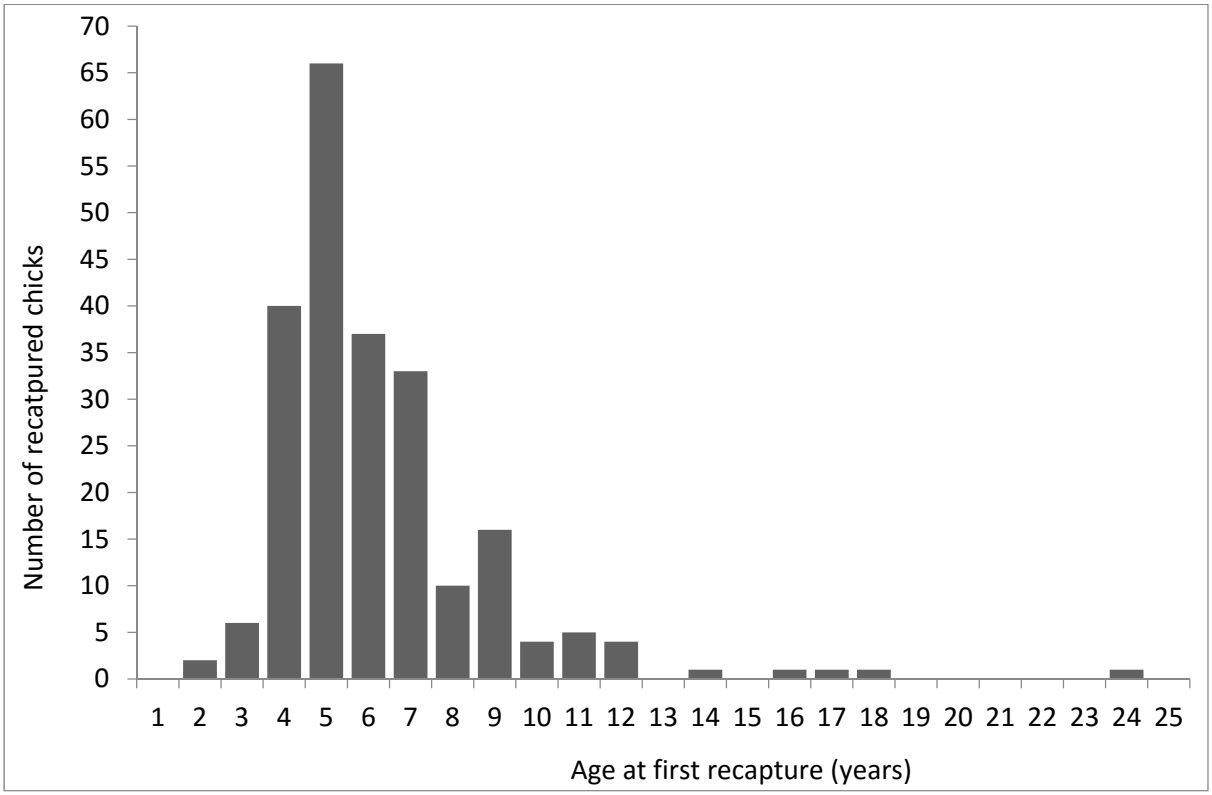


Figure 9 Observed frequency of age of first recapture of returned black petrel (*Procellaria parkinsoni*) 'chicks' to the 35-ha study area on Great Barrier Island/Aotea since the 1995/96 breeding season.



Since the first returned chick (banded on GBI in the 1995/96 season) was recaptured as a pre-breeder in the 1999/00 season, 249 'chicks' have been recaptured as pre-breeders, non-breeders or breeding adults (Table 7); 248 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 21 times (mean ± SEM = 3.3 ± 0.2; Appendix 2). The frequency of first recapture of each age class is given in Figure 9. Although the youngest age at first recapture at the colony is 2 years, the mean age ± SEM at first return is 6.2 ± 0.2 (range 2 to 24 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 GBI colony, 141 of these 'returned chicks' have attempted to breed, with 107 breeding successfully over this period (75.9%; Appendix 2). This means the age at first breeding attempt ranges from 4 to 24 years (mean ± SEM = 7.5 ± 0.2) and the age at first successful breeding also ranges from 4 to 24 years (mean ± SEM = 7.9 ± 0.3) (Appendix 2).

4.4 GPS data-logger devices

There were 27 deployments of MicroTrack high-resolution GPS data-logger devices between 3 December 2015 and February 2015. Of these 27 deployment, two were removed from the birds as they got too light to carry the devices before leaving the burrow. Of the remaining 25 deployments, one device was lost at sea and two devices were still on the birds in May 2016; these will fall off the birds during the moult and migration to South America.

Of the GPS devices deployed, 16 were placed on males and 11 were placed on females. The birds came from 27 different burrows and overall breeding success was lower in these

burrows (51.9%) than in the study burrows as a whole (66.8%), with only 14 pairs successfully fledging chicks.

Devices were worn for between 6 and 61 days and the birds showed few, if any, adverse effects from carrying them. Mean weight loss of the GPS device birds over the entire deployment period was 25.6 g (± 16.0 g) although this ranged from -130 to 180 g. Over the entire deployment period, males carrying devices lost more weight than females carrying devices, but this was not significant ($t_{23} = 0.31$, $P = 0.38$).

Of the 25 GPS devices deployed, all devices failed to record any position data. It was suspected that the devices had not been programmed with sufficient time to detect satellites once the birds had left the burrow for the first time (i.e. the Time to First Fix was underestimated). The sampling interval of 5 seconds every 15 minutes to allow the unit to maintain power for up to 4 weeks was too short for ephemeris recovery after up to 3 weeks in the burrow.

4.5 Acoustic monitoring

Seventeen ARU were deployed between 3 December 2015 and 31 January 2016. This equates to a total of 1020 recording nights and 2040 recording hours (2 hour each night per device). Out of the total recording nights, only 1551.5 hours of data were collected as several nights had to be discarded due to wind, rain, stream noise or digital saturation of black petrel calls at certain locations (i.e. Mt Heale and upper Palmer's Track); 552 from the Mt Hobson recorders and 999.5 hours from all other areas combined (Table 8). Efficacy of the recorders varied from 35.8% to 90.8% with most failures due to wind (Table 8). Black petrel calls were recorded at most locations with only Ruahine failing to detect any calls (Table 8).

Table 8 Summary of results of black petrel (*Procellaria parkinsoni*) calls recorded on automated acoustic recording units on Great Barrier Island/Aotea, 2015/16.

Site	Number of ARUs	Readable hours	Efficacy	Total number of clack calls	Mean number of clacks per minute (± SEM)
Mt Hobson/Hirakimata	6	552	65.7%	20959	5.5 ± 0.5
Palmers Track (upper)	1	78	66.1%	22816	12.7 ± 0.8
Palmers Track (mid)	1	97.5	81.9%	4931	2.1 ± 0.4
Windy Canyon (lower)	1	109	90.8%	7268	2.7 ± 0.6
Mt Heale	1	43	35.8%	4521	5.2 ± 1.6
Kaiaarara Track (lower)	1	104	86.7%	9013	3.6 ± 0.4
Hog's Back	1	100	82.0%	2690	3.6 ± 0.5
Ahumata (east)	1	52	43.3%	777	1.3 ± 0.5
Ahumata (west)	1	176.5	69.6%	1217	1.5 ± 0.4
Ruahine (lower)	1	73	61.4%	0	
Ruahine (upper)	1	60.5	50.4%	0	
Glenfern	1	106	88.3%	2330	1.1 ± 0.3
Total	**17**	**1551.5**	**67.7%**	**76522**	**3.3 ± 0.2**

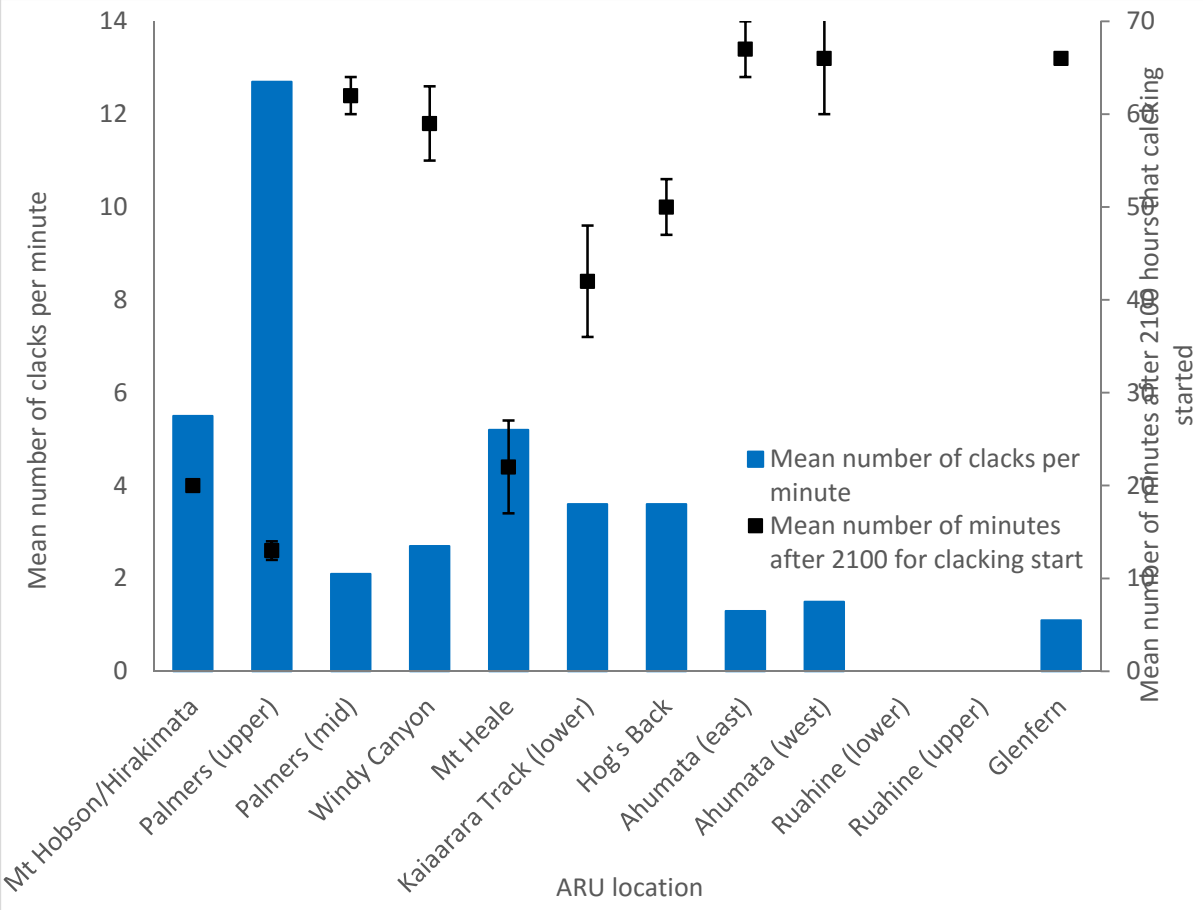
Male black petrels call ('clack') from the ground outside their burrows to attract females and females rarely call from the air while approaching the colony (EAB, pers. obs.). The ARUs showed that black petrels began calling at different times at each location with birds closest to the main colony generally starting the earliest; between 2100 hours at the earliest and 2252 at the latest (Table 9, Figure 10). The upper areas of Palmers Track had the highest

clacking rate and earliest start time while the areas further away from the colony had low clacking rates and late start times (Figure 10).

Table 9 Earliest and latest clack start times for black petrel (*Procellaria parkinsoni*) calls recorded on automated acoustic recording units on Great Barrier Island/Aotea, 2015/16.

Site	Earliest clack start time	Latest clack start time	Mean clack start time (± SEM)
Mt Hobson/Hirakimata	2100	2225	2120 ± 1
Palmers Track (upper)	2100	2132	2113 ± 2
Palmers Track (mid)	2118	2252	2202 ± 4
Windy Canyon (lower)	2104	2246	2159 ± 5
Mt Heale	2104	2122	2122 ± 6
Kaiaarara Track (lower)	2105	2220	2142 ± 3
Hog's Back	2100	2242	2150 ± 3
Ahumata (east)	2145	2239	2207 ± 6
Ahumata (west)	2125	2252	2206 ± 6
Ruahine (lower)	-	-	-
Ruahine (upper)	-	-	-
Glenfern	2141	2251	2206 ± 6
Total	**2100**	**2252**	**2150 ± 2**

Figure 10 Mean number of black petrel (*Procellaria parkinsoni*) clacks per minute and mean number of minutes after 2100 hours that clacking started at each automated acoustic recording unit on Great Barrier Island/, 2015/16.



4.6 Seabird-detector dog surveys

The seabird-detector dog surveys found a total of 80 burrows (Table 10, Figure 11). Where possible these adults were banded. The seabird-detector dog surveys only found occupied burrows or burrows that had very recently been used by breeding or non-breeding birds as the dog does not indicate for non-occupied or disused burrows. Most of the burrows were breeding burrows with adults incubating eggs or guarding chicks present (Table 10).

Figure 11 Location of black petrel (*Procellaria parkinsoni*) burrows within seabird detector dog survey areas on Great Barrier Island/Aotea, February 2016.

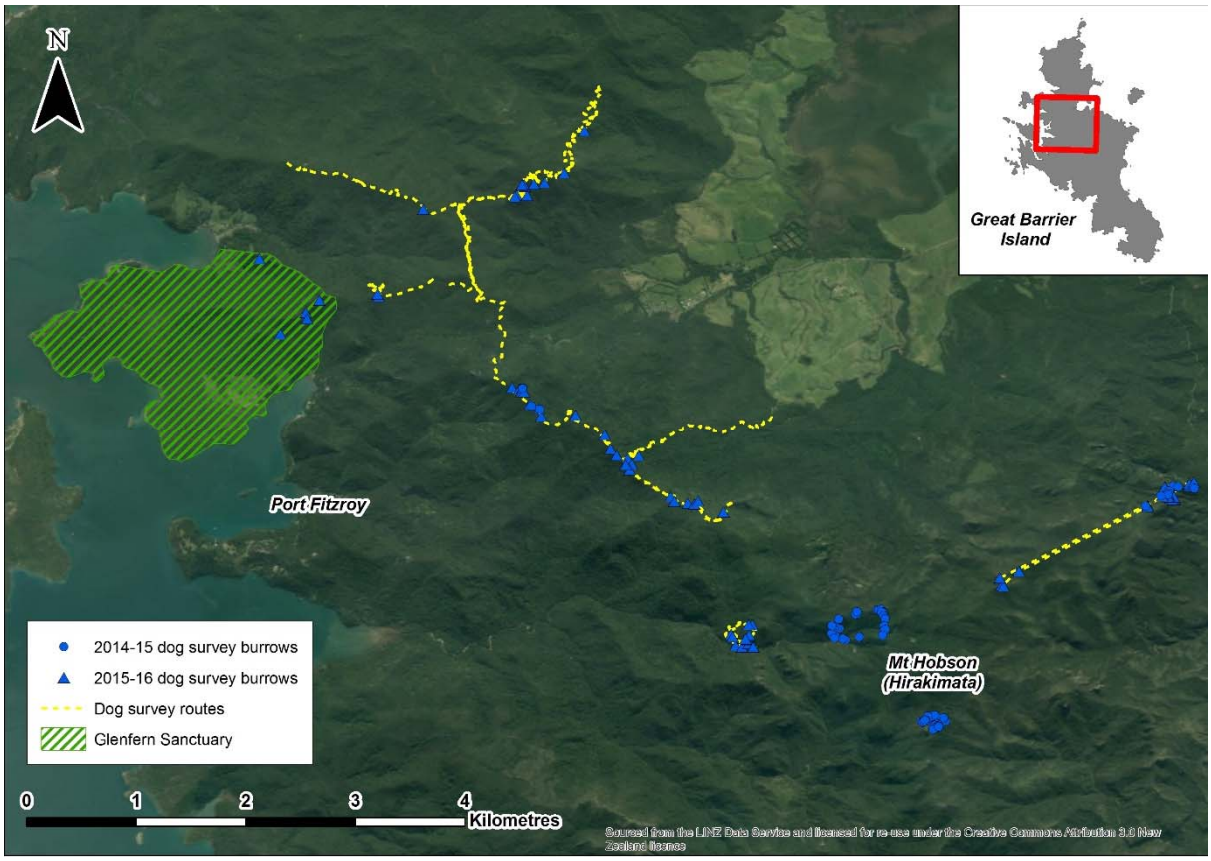


Table 10 Number and altitude of black petrel (*Procellaria parkinsoni*) burrows recorded on seabird-detector dog surveys on Great Barrier Island/Aotea, 2015/16.

Area	Burrows				Altitude (m a.s.l.)
	Non-occupied	Breeding	Non-breeding	Total	
Kawa Bay – Okiwi Ridge	0	10	1	**11**	224-309
Kaiaarara Valley	0	9	3	**12**	235-304
Cooper's Castle	0	7	15	**22**	309-426
Glenfern Sanctuary	1	2	2	**5**	98-180
Mount Heruheru	0	1	0	**1**	353
Orama telephone line	0	1	1	**2**	208
Windy Canyon	2	20	5	**27**	349-425
Total	**3**	**50**	**27**	**80**	**98-426**

The total area covered by the seabird-detector dog surveys was 49.9 ha. This relates to an occupied burrow density of 1.5 burrows per ha. Most burrows were located above 200 metres.

4.7 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 2016. This generated an adult apparent survival of 97.6% ± 2.0% for the 2015/16 season (Table 11). Table 11 lists the apparent adult survival since the 1995/96 breeding season. Figure 12 shows that adult survival fluctuates from year to year and that overall adult survival has increased since 1995.

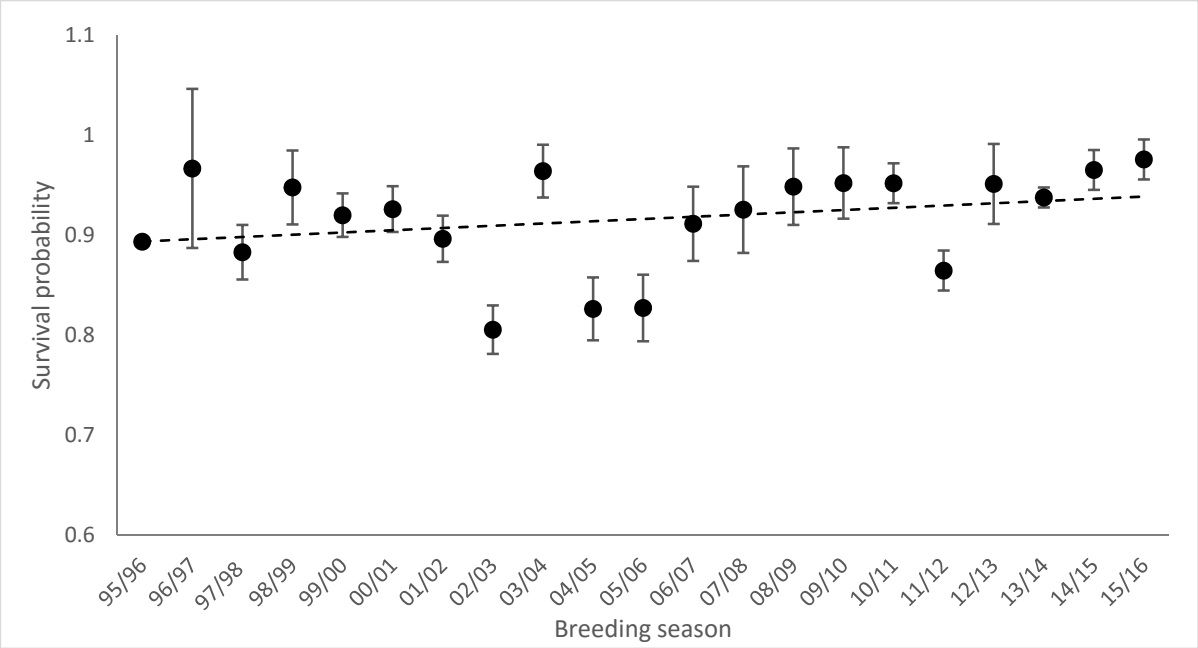
Table 11 Adult survival estimates for black petrels (*Procellaria parkinsoni*) on Great Barrier Island/Aotea since the 1995/96 breeding season. Estimates obtained by Burnham Live/Dead model [S(age) P(age) r(*) F(*)] analysis (using Program MARK) with standard errors.

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
2015/16	0.9762	0.02

The mean probability of fidelity to the nest site (burrow) was 86.9% (± 1.8%); this is expected as adult black petrels generally maintain ownership of their breeding burrows for life and although lower than last season, is consistent with the analysis completed in previous years (Bell *et al*. 2015). Movement between burrows is low and generally related to poor breeding success for a number of years, death of a partner bird, fighting between birds or collapse of the original burrow.

Owing to the high site fidelity, the probability of recapturing an adult within the study area is 61.8% (± 0.8%), but the reportability of a dead bird (i.e. band recovery) was only 1.1% (± 0.4%).

Figure 12 Adult survival estimates for black petrels (*Procellaria parkinsoni*) on Great Barrier Island/Aotea since the 1995/96 breeding season. Estimates obtained by Burnham Live/Dead model analysis [S(age) P(age) r(*) F(*)] using Program MARK.



A Burnham analysis of survival of chicks banded in the 35-ha study site on GBI between 1995 and 2016 was also completed. Only 223 of over 3300 chicks banded on GBI have been recaptured and the probability of recapture from the model was only 8.5% (± 0.6%). 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 89.1% (± 2.2%). 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 0.89 for this season, the overall population trend is likely to still be in slow decline.

4.8 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).

In June 2014 there was a severe storm event on Great Barrier Island/Aotea which caused significant damage to the black petrel study area. No study burrows were affected, but major slips within the boundaries of the study site meant loss of suitable breeding habitat. This has

reduced the area available for black petrels. Using Arcview™ the habitat grades were corrected to: high-grade petrel habitat (4.669 ha), medium-grade (14.8636 ha); low-grade (12.6853 ha) and non-petrel habitat (3.0641 ha).

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.

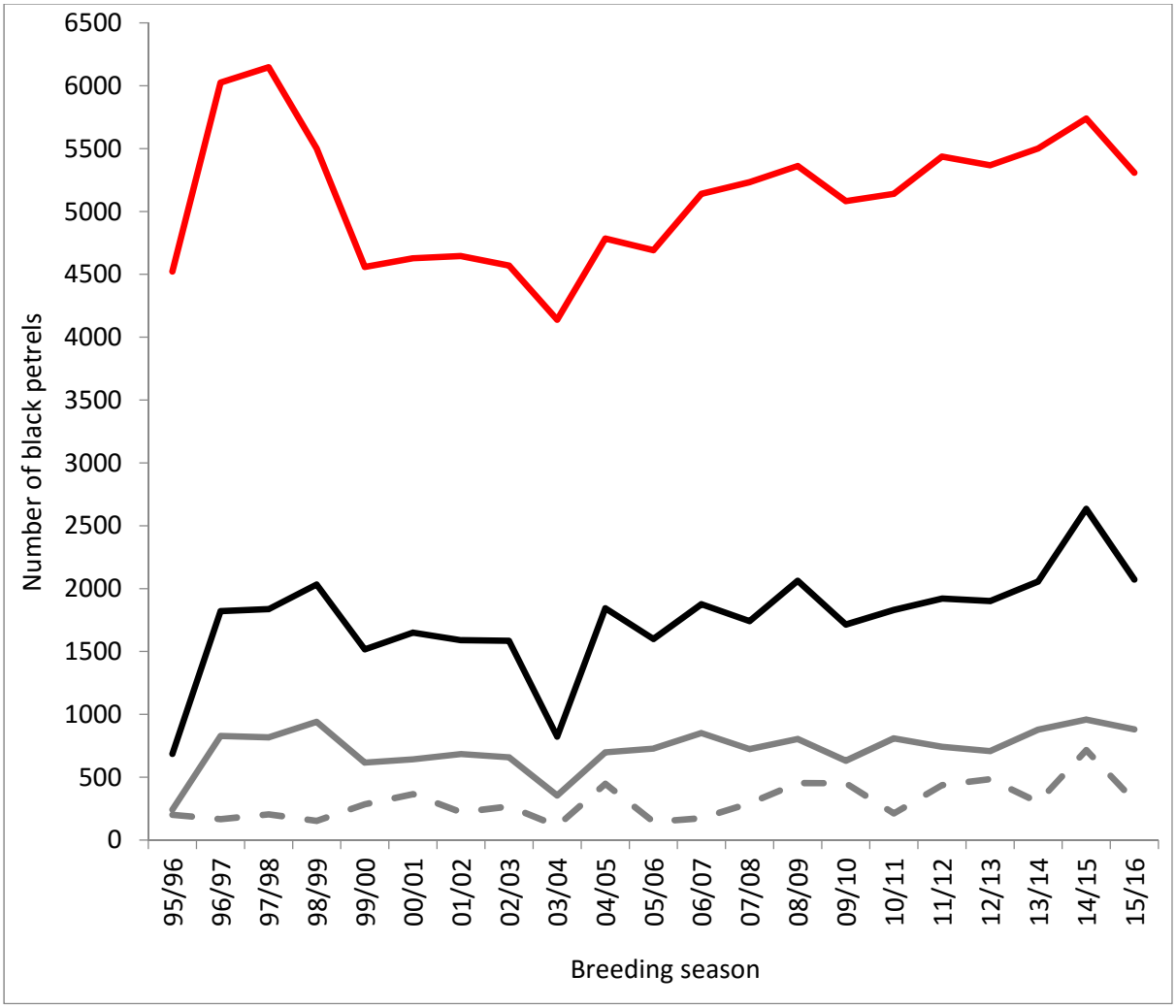
This population estimate for the 2015/16 burrow-occupying black petrel population was between 1947 and 2197 adults (2072 ± 125 birds, Table 12), consisting of 312 ± 57 non-breeding adults and 1760 ± 193 breeding adults (i.e. 880 breeding pairs).

Table 12 2015/16 population estimate of black petrels (*Procellaria parkinsoni*) in the 35-ha study area around Mount Hobson, Great Barrier Island/Aotea after stratifying and grading all transects and census grids. Area of each burrow density grade is 4.669 ha of high grade petrel habitat, 14.8636 ha of medium petrel habitat, 12.6853 ha of low petrel habitat and 3.0641 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	42	16	12.6853	542	200
	KDG2	0.008	0	0		0	0
	KDG3	0.008	0	0		0	0
MEAN (± SEM)			14 ± 14	5 ± 5		180 ± 180	67 ± 67
MEDIUM	Transects	1.52	74	33	14.8636	1128	503
	KDG1	0.008	0	0		0	0
	KDG2	0.032	125	0		1858	0
	KDG3	0.106	19	12		280	175
	SFG1	0.032	125	0		1858	0
	SFG3	0.11	55	11		811	169
	PTG2	0.04	0	0		0	0
	PTG3	0.06	67	0		991	0
MEAN (± SEM)			58 ± 18	7 ± 4		862 ± 263	104 ± 65
HIGH	Transects	0.78	141	58	4.669	658	269
	KDG1	0.152	211	41		983	192
	KDG2	0.12	283	21		1323	97
	KDG3	0.046	43	54		203	254
	SFG1	0.128	125	78		584	365
	SFG2	0.16	125	16		584	73
	SFG3	0.05	0	0		187	0
	PTG1	0.16	288	23		1342	109
	PTG2	0.12	183	10		856	49
	PTG3	0.1	140	0		654	0
MEAN (± SEM)			153 ± 29	30 ± 8		718 ± 136	141 ± 39
TOTAL POPULATION ESTIMATE (± SE)						1760 ± 193	312 ± 57
						2072 ± 125	
POPULATION ESTIMATE RANGE						**1947 to 2197 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 13 gives the annual population estimates since 1995 and Figure 13 shows the trend in the overall population estimate and number of breeding pairs and non-breeding birds.

Figure 13 Trends in annual population estimates from the nine census grids (before and after habitat stratification) for black petrels (*Procellaria parkinsoni*) on Great Barrier Island/Aotea since the 1995/95 breeding season. Solid red line = non-stratified population estimate, solid black line = stratified population estimate, solid grey line = stratified breeding pairs and dashed grey line = stratified non-breeding birds.



It appears from Figure 13 that despite the large drop in numbers of birds this breeding season, the black petrel population within the 35-ha study area is increasing. This is in contrast to the population trend predicted by population model developed by Francis & Bell (2010) updated using the current juvenile survival estimate which suggests the population is in low decline.

Table 13 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/Hirakimata, Great Barrier Island/Aotea.

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
2015/16	2304	559	5308	880	312	2072
MEAN (± SEM)	2079 (± 51)	771 (± 47)	5120 (± 115)	723 (± 38)	305 (± 33)	1752 (± 90)

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, Bell *et al.* 2015).

5.1 Breeding success

In the 2015/16 breeding season, there were 191 breeding successes and 95 breeding failures, equating to an overall breeding success rate of 66.8%. This breeding success is lower than all previous breeding seasons, except 2010/11, and is much lower than the mean (73.6% ± 1.3%) of the overall study. 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), but is much lower than on LBI which had a breeding success of over 85% in the study burrows in both the 2014/15 and 2015/16 breeding seasons (Bell *et al.* 2015a, Bell *et al.* 2016). The level of abandoned eggs, disappeared eggs (i.e. present in December, but missing in January/February), rat-predated eggs and crushed eggs was higher than last season, but the number of infertile eggs and dead embryos were lower this season than last year.

These crushed or disappeared 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 high level of crushed eggs may also be directly related to the loss of habitat following the June 2014 storm on GBI where at least 5 ha of black petrel habitat around the summit was destroyed by slips. Birds in these areas may have returned to the colony this season and had to find a new burrow; this could have resulted in fighting over established burrows within the study area. At least 15 burrows had one or more interlopers (an extra bird in addition to the established resident pair) captured during this breeding season (Appendix 1).

The level of egg abandonment was high (n = 7); this was higher than last season and brings the total number of abandoned eggs since 1995 to 97. 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 13 dead chicks; of which 2 were healthy chicks during one check, but dead at the next check or when the final check was completed in May; it was not possible to determine all the causes of mortality for these chicks. 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 191 chicks fledging this season, the breeding success is over 66%. 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 (90%) suggests that 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.

Three eggs were predated by rats this season (1.0% of all breeding attempts) within the study burrows and 36 eggs (12.6% of all breeding attempts) disappeared (but may have been predated by rats or crushed by parents). There were no feral cat predation events recorded within the study burrows this season; however there have been 15 chicks found predated by cats since 1995. The remains of two chicks from non-study burrows, but within the study area, were found predated by feral cats in May 2016. Two adults in a non-study burrow near the start of the Windy Canyon Track were found in November 2015 that had both been predated by a feral cat. All juvenile petrels since the 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). The highest numbers of black petrel chicks in the study burrows predated by feral cats occurred in the five years prior to and two years overlapping with the start of DOC trapping regime in Okiwi Basin suggesting that prior to this Okiwi trapping programme, feral cats from this area were moving up onto Mt Hobson/Hirakimata to target fledging chicks. Feral cats can have home ranges between 50-1000 ha depending on prey availability, terrain, density of feral cats and other factors and have been known to roam up to 10 km in a night when targeting specific seasonal prey (Harper 2004); as such it would be well within the range of a feral cat based in Okiwi Basin to reach Mt Hobson/Hirakimata in a night. The removal of over 1370 feral cats from Mt Hobson/Hirakimata and the Okiwi Basin by DOC has helped reduce the number of predation events in recent years. However, given there are still chicks and adults predated by feral cats within the colony each year it is important to continue to fund and complete feral 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. Breeding success has remained high and appears to be stable. This may be related to the fact that site fidelity is high (83%) 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 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. 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 apparently non-occupied).

The increased 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 or the fact that non-breeders did not return to the island this season. This season one previously empty study burrow become active with birds excavating the burrow to make it 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. 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 2005), but high (82-98%) 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 immigration events from LBI to GBI and from GBI to LBI, site fidelity and the possibility of emigration from GBI 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 956 banded birds were identified this season; 771 were adults and 185 were chicks. There were 600 recaptures of previously banded birds, including 108 that were 'returned chicks'. A total of 249 chicks banded between 1978 and 2016 have been recaptured in the study area (8.0%). Although the adult banded as a chick on LBI was not recaptured on Great Barrier Island again this season, this bird still represents the first recorded immigration event for black petrels. Another adult banded on GBI was recaptured on LBI this season making it the first confirmed immigration event (excluding the transferred chicks between 1988 and 2000) of a GBI bird leaving the colony to establish a breeding pair on LBI (Imber *et al.* 2003,

Bell *et al.* 2016). Nearly 250 chicks were transferred from GBI to LBI 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 and 8 (3.2%) have still been caught since 1995. It is likely that birds from LBI are being attracted to GBI due to the number of birds' resident there (and resulting noise early in the breeding season). Immigration and emigration has implications for population modelling work (as most models assume no immigration/emigration), 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 LBI population as pre-breeders are more likely to be attracted to GBI than LBI, slowing the population growth there. It is possible that the LBI population may not recover until GBI reaches carrying capacity; however as the population on LBI is not being monitored for adult survival and recruitment, this is difficult to assess. It is important that the black petrel population on LBI is monitored to determine population dynamics, status and trends. Given the recent monitoring of the historic Mike Imber study burrows and establishment of 149 study burrows on LBI in 2014/15 and 2015/16 (Bell *et al.* 2015, Bell *et al.* 2016) it is important to compare adult and juvenile survival of black petrels at each island colony separately to assess whether there are differences between each site as well as combined a whole to determine population dynamics for the species.

'Parkinson's die-off event in early June this year with several dead/weak individuals on the beach near Santa Rosa including one NZ banded bird. Also, many fishermen have also reported seeing dead/sick birds at sea

A number of dead, sick and weak black petrels have been sighted on beaches and at sea by fishers and two were rescued in inshore waters off Salinas, Ecuador (G. Suarez-Espin, American Bird Conservancy, pers. comm.). One of the rescued birds was banded (H33487) as an adult in 2006 and recaptured at the GBI colony in 2013 as a breeding adult. All of these rescued birds are reported as in poor condition; skinny, dehydrated with no waterproofing. It is possible that these break wrecks could be associated with lower sea surface temperature correlated with La Niña events and could indicate oceanic changes predicting strong wind or storm events commonly associated with La Niña. It will be interesting to see whether this wreck event will affect recruitment at the colony in 2016/17 or into the future and overall survival of black petrels. It will be important to continue the mark-recapture aspect of the black petrel project on GBI to determine if this die-off event affects the number of black petrels at the colony.

Of the 249 returned chicks, 29 were recaptured in their natal burrows (11.6%), 153 in their natal area (less than 50 metres from their natal burrow; 61.5%) and the remaining 67 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, 26 'chicks' banded prior to 1996 and 223 'chicks' banded between 1995 and 2016 have been recaptured at the GBI colony. There have been 141 records of 'returned chicks' attempting to breed during this period and the age of first recorded breeding attempt is between 4 and 24 years; on average 7.5 years old. Of these breeding attempts, 107 have been successful and the age at first successful

breeding are also between 4 and 24 years; on average 7.9 years old. 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 2015/16 season from the Program MARK model was 97% which is higher than many other previous seasons. This may relate to the number of birds that got displaced by the June 2014 slip and have moved into other study burrows or outside the study area rather than actual fatalities. It will be important to survey the study burrows and areas within the 35-ha study area to detect these and other banded birds. 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 89% 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 GBI 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 GBI 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 and the seabird-detector dog surveys 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 880 breeding pairs (1760 breeding birds) using the census grids and mean of all three random transect surveys. 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. The seabird-detector dog surveys this season found burrows in every location searched, but that the densities were much lower than at the main colony site (1.5 burrows/ha compared to approximately 18 burrows/ha at Mount Hobson/Hirakimata) which suggests that although black petrels may be found at lower altitudes their numbers and density are very low.

This population estimate from the 35-has study area is lower than last season's estimate for the 35-ha study site as well as 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 or even possibility that some of the birds may have moved out of the study area.

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 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 using seabird-detector dogs in other areas on GBI were competed this season with a total of 80 burrows found within nearly 50 ha of search area. Most of these burrows were breeding, although many had been unsuccessful due to cat and rat predation. The mean burrow density per hectare within these sites was 1.5 which is much lower than the mean burrow density per hectare of the census grids on Mount Hobson (18). This confirms that the majority of the GBI black petrel population is found on Mount Hobson with small clusters of burrows in certain locations (i.e. suitable habitat) across the rest of the island. Given the limited predator control over the rest of GBI 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 and evidence of cat predation events (n = 6) at these burrows during these surveys. Given that these surveys were completed in February 2016, there were two months remaining in the breeding season and the chicks at these sites would be vulnerable to later predation events.

Black petrels were recorded by the ARUs at all, but one location on GBI, but the clacking rate was much lower and started later than those recorded on Mount Hobson. This calling rate suggests that the population level of black petrels on other areas around GBI are much lower

than that found at the main colony. However, it does not mean that black petrels were not present in these areas as burrows containing adults were seen in December 2015 at Ruahine and in December 2014 at Ahumata and Whangaparapara. It may be that the petrels call much later in these areas than those on Mount Hobson (whose activity starts at approximately 2115 hours at high density areas within the main) and as a result were outside the recording time (2145-2245 hours) that was set on the ARUs or there were very few non-breeding birds within the range of the ARUs.

To gain a better population estimate of the black petrel population on the whole of GBI, 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 = 165) with one new burrows being located; 1 in P1 which was newly dug out this season. 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 2015/16 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 180 pre-breeding (or non-breeding) birds have returned to their natal area (and in 29 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 GLS and GPS tracking 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).

Black petrels demonstrate large variability in habitat use 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). Foraging during the breeding season was centred on the outer Hauraki Gulf, northern New Zealand towards the Kermadec Islands and northern New Zealand, East Cape and towards Fiji with both males and females in the same areas 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). Only 14% of deployment time in the 2013/14 season was spent within the Hauraki Gulf Marine Park boundaries, suggesting that black petrels forage outside the Hauraki Gulf towards seamounts (and the accompanying upwelling of nutrients and prey species) and continental shelf edges rather than inshore areas (Bell e*t al.* 2014). 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.

Time-Depth Recording (TDR) devices have also been deployed on breeding black petrels (Bell *et al.* 2013, Bell *et a*l. 2014, Bell 2016). The majority of dives over 1 m by both males and females were during the day (94%), the majority of the dives (86%) were shallow; <5 m and were short; < 10 seconds (Bell *et al.* 2014, Bell 2016). 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). This 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 the TDR results 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. Since 2002 there have been 96 captures of black petrels on observed fishing vessels; 11 on trawl vessels, 25 on surface longline and 60 on bottom longline vessels (Abraham & Thompson 2015). These captures occurred between September and May; 1 in September, 2 in October, 7 in November and December, 24 in January, 20 in February, 3 in March, 21 in April and 11 in May (Abraham & Thompson 2015). 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.

The 96 observed black petrels captures on commercial fishing vessels in the New Zealand fisheries between 2002 and 2014 have been caught either east of North Cape, near the Kermadec Islands, off East Cape or around Great Barrier Island (Abraham & Thompson 2015). The timing of these captures (between September and May) 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. If breeding adults continue to be caught by commercial fishing operations in New Zealand and birds of all ages are getting captured 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 GBI 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.
- Acoustic recorder units should be deployed in 2016/17 at a range of other locations across the island to obtain information on the range and density of black petrels on Great Barrier Island/Aotea.
- Acoustic recorder units should be deployed in 2016/17 at known-density sites within the main colony on Great Barrier Island/Aotea to obtain information on the call rate and activity to compare with other sites on the island and with call rates obtained from Hauturu-o-Toi/Little Barrier Island.
- 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).
- Feral cat trapping should be maintained in the Okiwi Basin by DOC and implemented along the main track network though the main black petrel colony around Mt Hobson/Hirakimata (Windy Canyon, Palmers, Kaiaarara and South Forks Tracks) 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.

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9. APPENDICES

9.1 Results from the black petrel (*Procellaria parkinsoni*) study burrows (*n* = 433) near Mount Hobson/Hirakimata, Great Barrier Island/Aotea during the 2015/16 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	41592	?				Non-breeding
2	38716	41488				Abandoned egg
3	29927 (M)	35298 (F)				Chick (fledged)
4	28378 (M)	39405 (F)				Chick (fledged)
5	27967 (M)	31971 (F)				Chick (fledged)
6	33773 (M)	36352	33540	34394		Egg (crushed)
7	39425	29693				Non-breeding
8	39601	41465				Egg (crushed)
9						Empty
10	34401	36396				Egg (disappeared)
11						Empty
12	36361 (?M)	37595 (F)				Chick (fledged)
13	37550 (M)	41558 (F)				Egg (crushed)
14	34449 (M)	34421 (F)				Chick (fledged)
15	33329	35361				Chick (dead)
16	35302	?				Chick (fledged)
17	31108 (M)	38624 (F)				Egg (abandoned)
18	35209 (M)	29815 (F)				Chick (fledged)
19	28376	33324				Chick (fledged)
20	34264 (M)	33683 (F)	41526 (Interloper)			Chick (fledged)
21	34615 (M)	35265 (F)				Egg (disappeared)
22	36393	36901				Chick (fledged)
23	36470 (M)	29847 (F)	38855 (interloper)			Chick (fledged)
24	34338					Chick (fledged)
25	39445	41585				Chick (fledged)
26	28357					Chick (fledged)
27	35198 (M)	35549 (F)				Chick (disappeared)
28						Empty
29						Empty
30	27976	36151				Egg (crushed)
31	33052 (M)	41562 (F)	41460 (interloper)			Non-breeding
32 (P1)	31112 (M)	41588 (F)				Chick (disappeared)
33	31244 (M)	28076 (F)				Chick (fledged)
34	31121	31248				Chick (fledged)
35	34836 (M)	36320 (F)				Chick (fledged)

BURROW	BAND					Outcome
36	33460 (M)	34359 (F)				Chick (fledged)
37	31107 (M)	36204 (F)				Chick (fledged)
38						Empty
39	25426 (M)	36378 (F)				Egg (disappeared)
40	36166 (M)	34384 (F)				Chick (fledged)
41	41565	39605				Egg (dead embryo)
42	27981 (M)	41516 (F)	35229 (interloper)	41472 (interloper)		Non-breeding
43						Empty
44	31494 (M)	?				Chick (fledged)
45	39441 (M)	38861 (F)				Egg (disappeared)
46	28813 (M)	34360 (F)				Chick (fledged)
47	31018 (M)	33786 (F)				Chick (fledged)
48	41527 (M)	41457 (F)				Egg (disappeared)
49	36322 (M)	34380 (F)				Chick (fledged)
50	31282	33747				Chick (fledged)
51	36383 (M)	?				Chick (fledged)
52	39609 (M)	38863 (F)				Chick (fledged)
53	31257 (M)	37587 (F)				Chick (fledged)
54	39413 (M)	41587 (F)				Chick (disappeared)
55 (P1)	23635	33638				Egg (disappeared)
56 (P1)	36327 (M)	29684 (F)				Chick (fledged)
57 (P1)	31153 (M)	33725 (F)				Chick (fledged)
58 (P1)	28029 (M)	31205 (F)				Chick (fledged)
59 (P1)	31125 (M)	34392 (F)				Chick (fledged)
60 (P1)	38819 (M)	41590 (F)				Egg (crushed)
61 (P1)	?	?				Non-breeding
62 (P1)						Empty
63 (P1)	35256	38637				Egg (rat predation)
64 (P1)	31366 (M)	?				Chick (fledged)
65	39494 (M)	?				Non-breeding
66	30874 (M)	39797 (F)	33003 (Interloper)	35313 (M) (Interloper)	39495 (Interloper)	Non-breeding
67 (K1)	42020	42021				Non-breeding
68 (K1)	35315 (M)	?				Non-breeding
69	37569 (M)	36344 (F)				Egg (disappeared)
70	27604 (M)	31240 (F)				Egg (disappeared)
71 (K1)	34351 (M)	34352 (F)				Egg (disappeared)
72 (K1)	34901 (M)	?				Chick (fledged)
73 (K1)	37524	39602				Chick (fledged)
74 (K1)	35311 (M)	41468 (F)				Chick (fledged)
75 (K1)	28572	38599				Chick (fledged)
76 (K1)	35521	41480				Egg (crushed)
77 (K1)	28390	36354				Egg (disappeared)
78 (K1)	37572	?				Egg (disappeared)
79 (K1)	38563	38649				Chick (fledged)
80 (K1)	41454	?				Egg (crushed)
81 (K1)	28046 (M)	28370 (F)				Chick (fledged)
82	35448 (M)	39784 (F)	42015 (interloper)			Non-breeding
83	34781 (M)	34781 (F)				Chick (fledged)
84						Non-breeding
85 (S1)	35193	41477				Non-breeding
86 (S1)	25661 (M)	41564 (F)				Non-breeding

BURROW	BAND					Outcome
87 (S1)	31495 (M)					Non-breeding
88 (S1)						Empty
89 (S1)	31495 (M)	?				Non-breeding
90 (S1)	33097 (M)	32935 (F)				Chick (fledged)
91 (S1)	?	?				Non-breeding
92 (S1)	32928 (M)	36334 (F)				Egg (disappeared)
93	35536	41579				Egg (disappeared)
94	34886	?				Chick (fledged)
95	33089 (M)	41483 (F)				Egg (disappeared)
96 (P1)	29820	35235				Chick (fledged)
97	34385	36194				Chick (fledged)
98	39774	41583				Non-breeding
99	31262 (M)	36378 (F)				Chick (fledged)
100	38560 (M)	38741 (F)				Chick (fledged)
101 (K1)	38646	42026				Non-breeding
102 (K1)	33389 (M)	36397 (F)				Non-breeding
103 (K1)	25673 (M)	39423 (F)				Chick (fledged)
104 (K1)						Empty
105						Empty
106	41534	41526				Non-breeding
107	33764 (M)	33799 (F)				Egg (disappeared)
108	27952 (M)	38802 (F)				Chick (fledged)
109	34734 (M)	?				Chick (fledged)
110 (S1)	33654 (M)	?				Non-breeding
111 (S1)						Empty
112 (S1)	34796 (M)	28037 (F)				Chick (fledged)
113 (S1)	35193 (M)	39513 (F)				Egg (crushed)
114 (S1)	35101 (M)	34953 (F)				Chick (fledged)
115	41550	41531				Non-breeding
116 (P1)	25435 (M)	25411 (F)				Chick (fledged)
117	39408 (M)	?				Chick (fledged)
118	39442 (M)	38708 (F)				Egg (crushed)
119	33530 (M)	28354 (F)	42013 (interloper)			Non-breeding
120 (P1)	35481	?				Non-breeding
121 (P1)	29817	33035				Chick (fledged)
122 (P1)	27961	36328				Chick (fledged)
123 (P1)	38858	41486				Non-breeding
124 (P1)	25442 (M)	35255 (F)				Chick (disappeared)
125 (P1)						Non-breeding
126 (P1)	33477	37586				Chick (fledged)
127	33301 (M)	41597 (F)				Egg (disappeared)
128	31054	39511				Chick (fledged)
129						Collapsed
130	39404 (M)	38900 (F)				Chick (fledged)
131	35406	38583				Chick (fledged)
132 (K2)	36290 (M)	41462 (F)	41500 (interloper)			Non-breeding
133 (K2)	25525 (M)	35241 (F)				Chick (fledged)
134 (K2)	37503 (M)	37574 (F)				Chick (fledged)
135 (K2)	25477	34377				Chick (fledged)
136 (K2)						Empty
137 (K2)	25494 (M)	31572 (F)				Chick (fledged)

BURROW	BAND					Outcome
138 (K2)						Empty
139	33248 (M)	?				Chick (fledged)
140	29809 (M)	36179 (F)				Chick (fledged)
141 (S2)	?	?				Non-breeding
142 (S2)	33667 (M)	41475 (F)				Egg (rat predation)
143 (K2)	38623 (M)	41464 (F)				Non-breeding
144 (K2)	34417	36175				Chick (fledged)
145 (K2)	34527 (M)	38701 (F)				Egg (disappeared)
146 (K2)	37536 (M)	41502 (F)				Chick (fledged)
147 (K2)	34903 (M)	41560 (interloper)				Chick (fledged)
148 (K2)	38871	36355				Egg (dead embryo)
149 (K2)	29825 (M)	41467 (F)				Chick (disappeared)
150 (K2)	33575 (M)	38621 (F)				Chick (fledged)
151	29047	?				Non-breeding
152 (S2)	37519 (M)	41594 (F)				Chick (fledged)
153 (S2)	29978	33471				Chick (disappeared)
154 (P1)	34320 (M)	36382 (F)				Chick (fledged)
155 (P2)	34513 (M)	?				Egg (crushed)
156 (P2)	39606 (M)	39526 (F)				Chick (fledged)
157 (P2)	33473	39525				Chick (fledged)
158 (P2)	35574 (M)	41556 (F)				Egg (rat predation)
159 (P2)	25441	37584				Chick (fledged)
160	36384 (M)	38553 (F)				Chick (fledged)
161 (P2)	41591	?				Chick (fledged)
162 (P2)	35544	36329				Egg (disappeared)
163 (P2)	35490 (M)	38854 (F)				Egg (crushed)
164 (P2)	33737	37585				Egg (crushed)
165 (K2)	29700	37575				Chick (fledged)
166	25437 (M)	34386 (F)				Chick (fledged)
167	35543	36326				Chick (fledged)
168 (P1)						Empty
169						Empty
170	36380 (M)	39604 (F)				Non-breeding
171	35529 (M)	36346 (F)				Chick (fledged)
172	31048 (M)	36379 (F)				Chick (fledged)
173	36389 (M)	31586 (F)				Egg (disappeared)
174	28021 (M)	28050 (F)				Chick (fledged)
175	25503 (M)	28001 (F)				Chick (fledged)
176 (K1)						Empty
177	41579 (M)	39619 (F)				Chick (fledged)
178	36186 (M)	36312 (F)				Chick (fledged)
179	37516 (M)	33481 (F)				Egg (crushed)
180	41542 (M)	29832 (F)	42025 (interloper)			Non-breeding
181	39508 (M)	?				Egg (crushed)
182	29085	34864				Non-breeding
183 (S1)	37534 (M)	38893 (F)				Egg (crushed)
184						Empty
185 (K1)						Empty
186	42006	?				Non-breeding
187	31047	31452				Chick (fledged)
188	34972 (M)	27965 (F)				Chick (fledged)

BURROW	BAND					Outcome
189	36139 (M)	38851 (F)				Egg (dead embryo)
190	34738 (M)	41474 (F)				Non-breeding
191 (P2)	34762	34800				Chick (fledged)
192 (S1)	35187	?				Chick (fledged)
193 (K2)						Empty
194 (K2)	34720 (M)	39637 (F)				Chick (fledged)
195	35160 (M)	39797 (F)				Egg (dead embryo)
196	39753 (M)	?				Chick (disappeared)
197	32960	34660	39620 (interloper)			Chick (fledged)
198						Empty
199	36248 (M)	38859 (F)				Non-breeding
200	28073	34265				Chick (fledged)
201	38705 (M)	36373 (F)				Chick (fledged)
202 (P2)	33375 (M)	?				Chick (fledged)
203	30930 (M)	35233 (F)				Chick (disappeared)
204 (K1)	32957	35000	41561 (interloper)			Egg (crushed)
205	25697 (M)	29664 (F)				Egg (disappeared)
206	34382	34936				Egg (disappeared)
207 (P1)						Empty
208 (P1)	35360	?				Chick (fledged)
209 (K3)	?	?				Empty
210 (K3)	35151 (M)	41452 (F)				Egg (crushed)
211 (K3)	41453	41471				Non-breeding
212 (K3)	35316	?				Non-breeding
213 (K2)	36346	36369				Chick (fledged)
214 (K2)	35180 (M)	41461 (F)				Chick (fledged)
215 (S3)	?	?				Empty
216 (S3)	41506 (M)	41544 (F)				Chick (fledged)
217 (K3)	31991	38571				Chick (fledged)
218	38635 (M)	42012				Non-breeding
219 (P3)						Empty
220 (P3)						Empty
221 (P3)	29695 (M)	39430 (F)				Egg (disappeared)
222	39791 (M)	38866 (F)				Chick (fledged)
223 (S3)	41545	33673				Non-breeding
224 (P3)	27958 (M)	27992 (F)				Chick (fledged)
225 (S3)	41507 (M)	34404 (F)				Chick (fledged)
226 (P3)	28385	35252				Chick (fledged)
227 (K1)	25509 (M)	25407 (F)				Egg (disappeared)
228	41532 (M)	33308 (F)				Chick (fledged)
229 (P3)	35531 (M)	38868 (F)				Chick (fledged)
230 (P3)						Empty
231 (P3)	41568 (M)	41555 (F)				Chick (fledged)
232						Empty
233	34820 (M)	35247 (F)				Chick (fledged)
234	29835 (M)	35245 (F)				Chick (fledged)
235	36495	42011				Egg (abandoned)
236	?	?				Non-breeding
237	39416	41569				Non-breeding
238 (S1)						Empty
239	39523 (M)	39496 (F)				Chick (fledged)

BURROW	BAND					Outcome
240	38864 (M)	41487 (F)				Chick (fledged)
241	38551 (M)	39640 (F)				Chick (fledged)
242	35263	?				Chick (fledged)
243	33264 (M)	36367 (F)				Chick (fledged)
244	37567 (M)	29841 (F)				Egg (disappeared)
245 (K1)	31992 (M)	33589 (F)				Chick (disappeared)
246 (P3)	37579 (M)	37507 (F)				Chick (fledged)
247	41599	?				Egg (disappeared)
248	35297 (M)	35278 (F)				Chick (fledged)
249	37515	37563				Chick (fledged)
250						Empty
251 (K3)						Cook's petrel burrow
252	34794 (M)	?				Non-breeding
253 (K3)	41451	?				Non-breeding
254 (P1)						Empty
255 (K2)	34431 (M)	29089 (F)				Egg (crushed)
256	36147	41473				Non-breeding
257	34758 (M)	38915 (F)				Chick (fledged)
258 (P3)						Empty
259	33508	37592				Chick (fledged)
260 (S3)	14009 (M)	25651 (F)				Egg (disappeared)
261	32021 (M)	41543 (F)				Chick (fledged)
262	34739 (M)	32902 (F)				Chick (fledged)
263	29073 (M)	39832 (F)				Non-breeding
264						Empty
265 (K2)	35300 (M)	29682 (F)				Chick (fledged)
266	31975 (M)	25444 (F)				Chick (fledged)
267	29823 (M)	41559 (F)				Chick (dead)
268						Empty
269	38555 (M)	38862 (F)				Chick (fledged)
270	31588 (M)	37510 (F)				Chick (fledged)
271 (K1)	38559 (M)	37571 (F)				Chick (disappeared)
272	41593					Chick (out of reach)
273	29651	?				Non-breeding
274	37521 (M)	39611 (F)				Chick (fledged)
275	35229 (M)	41584 (F)				Egg (crushed)
276						Empty
277	33620 (M)	33619 (F)				Chick (fledged)
278	34751 (M)	25695 (F)				Chick (fledged)
279						Empty
280	35232 (?M)	41504 (?F)	41470 (interloper)			Non-breeding
281	32995 (M)	34733 (F)				Egg (dead embryo)
282	33652 (M)	?				Chick (fledged)
283	36147 (M)	?				Non-breeding
284	32099	?				Egg (disappeared)
285	35218	?				Chick (fledged)
286	41458	41466	41484	41499		Non-breeding
287	33699 (M)	36911 (M)	31324 (F)	36187		Non-breeding
288	33671 (M)	39758 (M)	36147			Non-breeding
289	41535 (M)	41578 (F)				Non-breeding
290	35212 (M)	35534 (F)				Chick (fledged)
291						Empty

BURROW	BAND					Outcome
292	39498 (M)	?				Egg (disappeared)
293	38638 (M)	38852 (F)				Egg (disappeared)
294	36185 (M)	27984 (F)				Chick (fledged)
295						Empty
296	32980	37589				Chick (fledged)
297	28034 (M)	33755 (F)	41600 (M) (interloper)			Chick (fledged)
298	33646 (M)	34429 (F)				Chick (fledged)
299	34937 (M)	38857 (F)	34610 (interloper)			Chick (fledged)
300	34655 (M)	39541 (F)				Egg (infertile)
301	41549	41540				Non-breeding
302						Empty
303	38885 (M)	42016 (F)				Non-breeding
304	34370 (M)	39641 (F)				Chick (fledged)
305	35244 (M)	33645 (F)				Egg (crushed)
306						Empty
307	33796 (M)	34876 (F)				Chick (fledged)
308						Empty
309	33476 (M)	30858 (F)				Egg (crushed)
310 (S2)	33276	36392				Chick (fledged)
311 (S2)						Cook's petrel burrow
312 (S2)	38807 (M)	38867 (F)				Egg (dead embryo)
313 (S2)	41509 (M)	36331 (F)				Non-breeding
314 (S2)						Empty
315	33714 (M)	33318 (F)				Chick (fledged)
316	33715 (M)	38746 (F)				Egg (crushed)
317 (P2)						Empty
318	25555 (M)	39521 (F)				Non-breeding
319						Empty
320						Empty
321	38747 (M)	37591 (F)				Chick (fledged)
322 (P3)	38643	38818				Chick (fledged)
323	27526 (M)	41574 (F)				Chick (fledged)
324	34299	41476				Non-breeding
325	28000 (M)	38641 (F)				Chick (fledged)
326	35199	38811				Chick (fledged)
327 (K2)	34898 (M)	34257 (F)				Chick (fledged)
328	34535 (M)	41459 (F)				Chick (fledged)
329 (P3)	33528 (M)	?				Chick (fledged)
330	33090 (M)	33099 (F)				Egg (crushed)
331	32025	32924				Chick (fledged)
332						Empty
333	32927 (M)	29082 (F)				Chick (fledged)
334						Empty
335	28358 (M)	34379 (F)				Chick (fledged)
336 (P2)	35489	42008				Empty
337 (S1)	41563 (M)	?				Non-breeding
338	41533 (M)	41533 (F)				Chick (fledged)
339	34722 (M)	33493 (F)				Egg (disappeared)
340	35540 (M)	34357 (F)	41505 (M) (interloper)	41580 (interloper)	41541 (interloper)	Egg (dead embryo)
341	42001	?				Collapsed
342 (S2)	28399					Egg (dead embryo)

BURROW	BAND					Outcome
343(S2)	41510 (M)	41547 (F)				Egg (dead embryo)
344 (S2)	34687					Chick (fledged)
345	415008 (M)	34416 (F)				Chick (disappeared)
346	29098	39436				Chick (fledged)
347	41469	42003				Non-breeding
348 (P3)	39501 (M)	39623 (F)				Egg (disappeared)
349 (P3)						Empty
350 (P2)						Empty
351 (P1)	34266 (M)	34390 (F)				Chick (fledged)
352	39796 (M)	39796 (F)				Egg (disappeared)
353	36994 (M)	41566 (?F)	28044 (M) (interloper)	41482 (interloper)		Non-breeding
354	33480	36337				Chick (fledged)
355	33467 (M)	36191 (F)				Chick (fledged)
356	34580 (M)	36375 (F)				Chick (fledged)
357	39638 (M)	38650 (F)				Chick (fledged)
358	33474 (M)	33494 (F)				Chick (fledged)
359	32985 (M)	38556 (F)				Chick (fledged)
360	33482 (M)	35237 (F)				Chick (fledged)
361	14018 (M)	35459 (F)				Non-breeding
362 (K1)	39635 (M)	36115 (F)				Chick (fledged)
363						Empty
364	34854 (M)	38598 (F)				Chick (fledged)
365 (K2)						Empty
366 (K1)						Empty
367	38628	?				Non-breeding
368	38853 (M)	33451 (F)				Non-breeding
369 (S1)						Empty
370	39519 (M)	39438 (F)				Egg (abandoned)
371	34717 (M)	42002 (F)				Non-breeding
372	41578 (M)	41456	41523			Non-breeding
373	29834	36153				Egg (dead embryo)
374	41605 (M)	36193 (F)	41601 (Interloper)			Chick (fledged)
375 (P1)	41589	?				Chick (fledged)
376	?	36363 (F)				Chick (fledged)
377						Empty
378 (K3)						Empty
379 (K2)						Joined to 209
380	29960 (M)	27972 (F)				Chick (fledged)
381						Empty
382						Empty
383 (S1)						Empty
384	37548 (M)	41530 (F)				Non-breeding
385	41503	41455				Egg (disappeared)
386	28352	35530				Chick (fledged)
387 (S3)						Empty
388						Empty
389	28045 (M)	35493 (F)				Chick (fledged)
390						Empty
391	28377	?				Chick (fledged)
392 (K1)						Cook's petrel burrow
393	36124 (M)	37525 (F)				Chick (fledged)

BURROW	BAND					Outcome
394	34878 (M)	36305 (F)				Chick (fledged)
395	35392 (M)	?				Egg (crushed)
396	35213 (M)	35243 (F)				Chick (fledged)
397	41573	?				Non-breeding
398	33646 (M)	35299 (F)	39788 (interloper)			Chick (fledged)
399 (P1)	35286 (M)	28354 (F)				Egg (dead embryo)
400						Empty
401	34304 (M)	36347 (F)				Chick (fledged)
402	36365 (M)	?				Chick (fledged)
403	36400					Chick (fledged)
404	36357 (M)	29654 (F)				Egg (abandoned)
405	34273 (M)	38809 (F)				Chick (fledged)
406 (S2)	41572	41546	41595			Non-breeding
407	33607 (M)	35284 (F)				Non-breeding
408	39800	?				Egg (abandoned)
409	36377 (M)	36399 (F)				Chick (fledged)
410	36377 (M)	41485 (F)				Egg (disappeared)
411	37539	42010				Chick (fledged)
412	28056	37580				Chick (fledged)
413 (P1)	34505	37582				Chick (fledged)
414 (P1)	34317	37583				Chick (fledged)
415	33246 (M)	36163 (F)				Chick (fledged)
416 (S1)	36308 (M)	38552 (F)				Chick (fledged)
417	25536 (M)	36321 (F)				Chick (fledged)
418						Empty
419	31204 (M)	39777 (F)				Egg (crushed)
420	31204 (M) (Interloper)	?				Non-breeding
421	26955 (?M)	39428 (?F)				Chick (fledged)
422 (P1)	33369 (M)	39431 (F)				Egg (disappeared)
423						Empty
424 (P2)	41481	?				Non-breeding
425 (S1)	41528 (M)	36318 (F)				Chick (fledged)
426	29848 (M)	39639 (F)	42024 (interloper)			Egg (disappeared)
427	39764 (M)	39647 (F)	41554 (Interloper)			Chick (fledged)
428	28017 (M)	25519 (F)				Egg (disappeared)
429 (K1)	34626	?				Non-breeding
430 (S1)	?	34869 (F)				Egg (abandoned)
431 (S2)	?	?				Non-breeding
432 (S2)	41598	?				Chick (fledged)
433 (S1)	36455 (M)	29651 (F)				Non-breeding

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) since the 1995/96 breeding season, 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)
23635	Male	1987/88	2015/16	16	9	10	14
25525	Male	1998/99	2015/16	9	7	8	10
25536	Male	1998/99	2015/16	7	6	12	12
25546	Male	1998/99	2015/16	10	5	5	11
25630	Male	1999/00	2005/06	2	5		
25631	? Male	1999/00	2003/04	1	4		
25635	Male	1999/00	2015/16	5	5	6	
25637	Male	1999/00	2004/05	1	5		
25648	Male	1999/00	2008/09	4	5	8	
25651	Male	1999/00	2015/16	11	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	2015/16	8	9	9	13
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	2015/16	11	5	7	7
25677		1999/00	2006/07	1	7	7	7
26955	? Male	1987/88	2015/16	3	24	24	24
27604	Male	1988/89	2015/16	21	6	6	8
28085	Male	1998/99	2005/06	1	5		
28572	Male	1991/92	2015/16	21	3	6	6
29027		2008/09	2013/14	1	5		
29047	Female	2008/09	2015/16	2	6	6	
29098		2008/09	2015/16	2	4	7	7
29912	? Male	2000/01	2012/13	5	5	5	6
29927	Male	2000/01	2015/16	12	9	12	12
29960	Male	1999/00	2015/16	8	9	9	9
29978	Male	1999/00	2015/16	5	9	14	14
30161[1]		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	2015/16	16	4	5	5
30934		1995/96	2013/14	1	18		
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		

[1] 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.

31089	Female	1997/98	2013/14	9	5	6	9
31194	Male	1996/97	2001/02	1	5	5	
31322[2]		2005/06	2009/10	1	3		
31324	Female	2005/06	2015/16	4	7	7	7
31340		2005/06	2014/15	1	9	9	9
31345	? Male	2005/06	2011/12	1	6		
31366	Male	1997/98	2015/16	14	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	2015/16	9	6	9	10
31495	Male	1998/99	2015/16	12	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[3]		2000/01	2007/08	1	7		
32091		2000/01	2007/08	1	7		
32099	? Male	2000/01	2015/16	9	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	2015/16	8	6	6	6
32957	Female	2001/02	2015/16	10	5	6	7
32960		2001/02	2015/16	1	14	14	14
32979		2001/02	2006/07	1	5		
32980	Male	2001/02	2015/16	5	4	11	11
32985	? Male	2001/02	2015/16	4	11	11	11
32995	Male	2001/02	2015/16	4	11	11	13
33003	Female	2001/02	2015/16	5	7	7	7
33015	Male	2001/02	2009/10	3	6		
33035	Male	2001/02	2015/16	8	6	7	7
33052	Male	2001/02	2015/16	9	6	6	6
33055		2001/02	2009/10	1	8	8	8

[2] 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.

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

33067		2001/02	2009/10	1	8		
33068		2001/02	2009/10	2	7	8	
33071	Male	2001/02	2012/13	1	11		
33088[4]		2001/02	2004/05	1	2		
33208[5]	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	2015/16	4	10	10	10
33248	Male	2002/03	2015/16	8	6	8	8
33276		2003/04	2015/16	5	7	7	7
33335	Male	2003/04	2010/11	2	5	7	
33369		2003/04	2015/16	4	9	8	8
33375		2003/04	2015/16	7	5	5	5
33376		2003/04	2012/13	2	8	8	
33380		2003/04	2007/08	1	4		
33389	? Male	2003/04	2015/16	7	6	6	7
33397	Male	2003/04	2008/09	1	5	5	5
33453		2005/06	2010/11	1	5		
33508	? Male	2005/06	2015/16	4	7	7	7
33518		2005/06	2009/10	1	4		
33528		2005/06	2015/16	4	7	7	7
33530		2005/06	2015/16	6	5	6	6
33540	Male	2005/06	2015/16	5	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	2015/16	6	5	5	5
33581	Male	2005/06	2014/15	4	5	6	
33584		2005/06	2014/15	1	9		
33589		2005/06	2015/16	5	5	5	5
33591		2005/06	2010/11	1	5		
33596		2005/06	2010/11	1	5	6	
33737	? Male	2002/03	2015/16	6	7	7	7
34273		2004/05	2015/16	5	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	2015/16	3	7	7	7
34304	? Male	2004/05	2015/16	4	8	8	8
34308		2004/05	2014/15	1	10	10	10
34317		2004/05	2015/16	3	8	8	8
34320		2004/05	2015/16	6	5	8	8
34338		2004/05	2015/16	5	5	6	6
34349	Male	2004/05	2013/14	3	7		
34435		2006/07	2013/14	7	7	7	7
34505		2006/07	2015/16	4	6	6	6
34513	Male	2006/07	2015/16	1	9	9	
34520	Male	2006/07	2011/12	1	5		
34527	Male	2006/07	2015/16	4	6	6	
34535	Male	2006/07	2015/16	1	9	9	9
34550		2006/07	2014/15	1	8		

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

34553		2006/07	2014/15	2	7	8	8
34574		2006/07	2015/16	2	4		
34580	Male	2006/07	2015/16	4	5	6	6
34599		2006/07	2012/13	1	6		
34600	Male	2006/07	2013/14	3	5		
34610		2006/07	2015/16	2	7		
34612		2006/07	2015/16	1	9		
34615	Male	2006/07	2015/16	2	7	9	
34621		2006/07	2010/11	1	4		
34624		2006/07	2012/13	1	6		
34626		2006/07	2015/16	1	9		
34655	Male	2006/07	2015/16	1	9	9	
34660	Male	2006/07	2015/16	5	4	5	5
34687		2006/07	2015/16	3	7	8	8
34698		2006/07	2013/14	2	7		
34712		2003/04	2015/16	1	12		
34804		2004/05	2009/10	2	4	5	5
34808	Male	2004/05	2012/13	1	8		
34820	? Male	2004/05	2015/16	5	6	6	10
34828		2004/05	2009/10	1	5		
34836	Male	2004/05	2015/16	4	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	2015/16	5	7	7	8
34901	? Male	2004/05	2015/16	7	5	7	7
34903	? Male	2004/05	2015/16	6	5	7	7
34916		2004/05	2013/14	1	9		
34994		2005/06	2015/16	1	10	10	
35101	? Male	2008/09	2015/16	2	6	6	7
35131	Male	2008/09	2015/16	3	5		
35151	Male	2008/09	2015/16	1	7	7	
35160	? Male	2008/09	2015/16	3	5	6	6
35180	Male	2008/09	2015/16	1	7	7	7
35186	Male	2008/09	2014/15	2	4	6	
35187	Male	2008/09	2015/16	3	5	6	6
35188	Male	2008/09	2014/15	1	6	6	
35189	Male	2008/09	2012/13	1	4		
35193	? Male	2008/09	2015/16	3	5	6	6
35311	Male	2009/10	2015/16	1	6	6	6
35313	Male	2009/10	2015/16	1	6	6	
35316		2009/10	2015/16	1	6		
35360		2008/09	2015/16	3	5	6	6
35361	Male	2008/09	2015/16	3	5	6	6
35380		2008/09	2013/14	1	5		
35392	Male	2008/09	2015/16	2	6	7	
35397		2008/09	2012/13	1	4	4	4
35419		2010/11	2015/16	1	5		
35439	? Male	2010/11	2014/15	1	4		
35459		2010/11	2015/16	1	5		
35466		2010/11	2015/16	1	5		
35481		2010/11	2015/16	1	5		
35489		2010/11	2015/16	2	4		
35490	Male	2010/11	2015/16	2	4	5	

35493		2010/11	2015/16	1	5	5	5
35518	Male	2008/09	2014/15	2	4	6	6
35521		2009/10	2015/16	1	6	6	
35571		2009/10	2012/13	1	3		
35574	Male	2009/10	2015/16	2	5	6	
35583		2009/10	2013/14	1	4	4	4
35584		2009/10	2015/16	1	6		
36112	Male	2007/08	2012/13	1	5		
36115		2007/08	2015/16	2	7	8	8
36118	Male	2007/08	2014/15	4	5	7	
36124	Male	2007/08	2015/16	1	8	8	8
36139	Male	2007/08	2015/16	3	6	7	
36140		2007/08	2012/13	1	5		
36147		2007/08	2015/16	2	5		
36216		2007/08	2011/12	1	4		
36233	? Male	2007/08	2014/15	2	6	7	
36241		2007/08	2012/13	1	5		
36248	Male	2007/08	2015/16	1	7		
36271		2007/08	2014/15	1	7		
36277	Male	2007/08	2015/16	2	7		
36290	? Male	2007/08	2015/16	4	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		
36455	Male	2009/10	2015/16	1	6		
36474		2009/10	2013/14	1	4		
36476		2009/10	2014/15	1	5		
36911	Male	2011/12	2015/16	1	4		
36994	Male	2011/12	2015/16	1	4		
37638	Female	2011/12	2015/16	1	4		
38655		2012/13	2015/16	1	3		
41507	Male	1987/88	2015/16	17	11	12	12
MEAN (± SEM)				**3.3 ± 0.2**	**6.2 ± 0.2**	**7.5 ± 0.2**	**7.9 ± 0.3**
30807[6]	Female	1996/97	2009/10	5	9	9	9

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