4. Results

4.1 NUMBER OF BURROWS IN THE CENSUS GRIDS

A total of 147 burrows were found in the nine census grids (Figs 2–4). Of these, 82 burrows were used by breeding pairs, 39 were used by non-breeding adults and 26 burrows were empty. There were also several 'potential' burrows within the grids, which were not included in any burrow estimate. We defined 'potential' burrows as those that had been investigated and/or preliminarily dug out, but were not being used by breeding or non-breeding petrels. These potential burrows were monitored seasonally to check whether they had become active (i.e. were being used by a black petrel).

Twelve new burrows were located within the census grids: two in Kauri Dam Grid 1 (KDG1), one in Kauri Dam Grid 2 (KDG2), one in Palmers Track Grid 1 (PTG1), two in Palmers Track Grid 2 (PTG2), two in Palmers Track Grid 3 (PTG3), one in South Fork Grid 1 (SFG1) and three in South Fork Grid 2 (SFG2). Of these, eight had previously been identified as potential burrows and the remaining four had been newly dug out this season. Nine were being used by non-breeding birds and three by breeding birds (all successfully fledging chicks).

4.2 STUDY BURROWS

Within the 362 study burrows (those burrows that could be accessed out of the 366 numbered burrows), 226 contained breeding birds, 52 contained non-breeding birds and 84 were empty. There were 45 failures (due to loss of eggs, infertility or predation, etc.; Table 1). This corresponds to a breeding success of 80% (Table 1).

The number of burrows being used for breeding has declined over the duration of the study (Fig. 7), but the ratio of non-breeding burrows to breeding burrows has been very similar between seasons (1:3 or 1:2; Bell & Sim 2000a,b,c, 2002, 2003a,b).

4.3 TRANSECTS

Twenty-six transects were sampled within the study area (Fig. 5 and Table 2). They ranged in length from 110 m to 400 m, and between 0 and 20 burrows were located on each (Table 2).

Using the transect data, three distinct habitat types were identified within the study area: optimum petrel habitat on ridges or spurs, usually with established canopy trees or tall secondary growth, with moderate to high density black

petrel burrows; poor petrel habitat, on low slopes or flat ground, often boggy, usually with moderate secondary growth or scrub vegetation, with low burrow density or no burrows; and non-petrel habitat, in stream beds or on slips, with no burrows (Fig. 6). Based on Arcview results, there was 18.25 ha of optimum petrel habitat, 15.3 ha of poor petrel habitat and 1.73 ha of non-petrel habitat (Fig. 6).

TABLE 1. BREEDING SUCCESS AND CAUSES OF MORTALITY OF BLACK PETRELS (*Procellaria parkinsoni*) IN THE STUDY BURROWS ON GREAT BARRIER ISLAND (AOTEA ISLAND).

	YEAR								
	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05
Number of study burrows	118	137	197	248	255	283	318	324	362
Eggs									
Laid	92	95	142	178	168	192	199	208	226
Predation (rat)	6	1	2	9	6	5	1	2	3
Crushed[a]	5	0	1	10	6	5	14	13	7
Abandoned	2	1	5	1	3	9	7	0	3
Infertile	6	4	12	6	8	3	2	7	4
Dead embryo (at various stages)	0	8	6	13	9	14	19	16	12
Disappeared egg[b]	0	0	0	0	0	11	3	0	5
Unknown[c]	0	0	0	0	0	0	5	0	0
Chicks									
Hatched	73	81	116	139	136	145	148	170	192
Predation (rat)	0	0	2	0	0	0	0	0	0
Predation (cat)	0	0	2	2	1	2	3	2	0
Died (disease)	1	0	0	0	0	0	0	0	0
Died (starvation)	0	1	0	0	0	0	0	0	0
Died (unknown causes)	0	0	3	6	7	8	8	10	7
Disappeared chick	0	0	0	0	0	0	0	0	4[d]
Fledged[e]	72	80	109	131	128	135	137[f]	158[g]	181[h]
Overall breeding success (%)	78	84	77	73.5	76	70	69	76	80

[a] These eggs were crushed by the parents or during fighting with interloping birds and only shell fragments were recovered from the burrow. Some may have been preyed upon by rats, been infertile or contained an embryo that died.

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

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

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

[e] All chicks still present at the end of the April trip. It was assumed that all would fledge safely.

[f] Of these, 78 chicks had already fledged prior to the banding visit; only 59 chicks were banded.

[g] Of these, 50 chicks had already fledged prior to the banding visit; only 108 chicks were banded.

[h] Of these, 6 chicks had already fledged prior to the banding visit; only 108 chicks were banded.

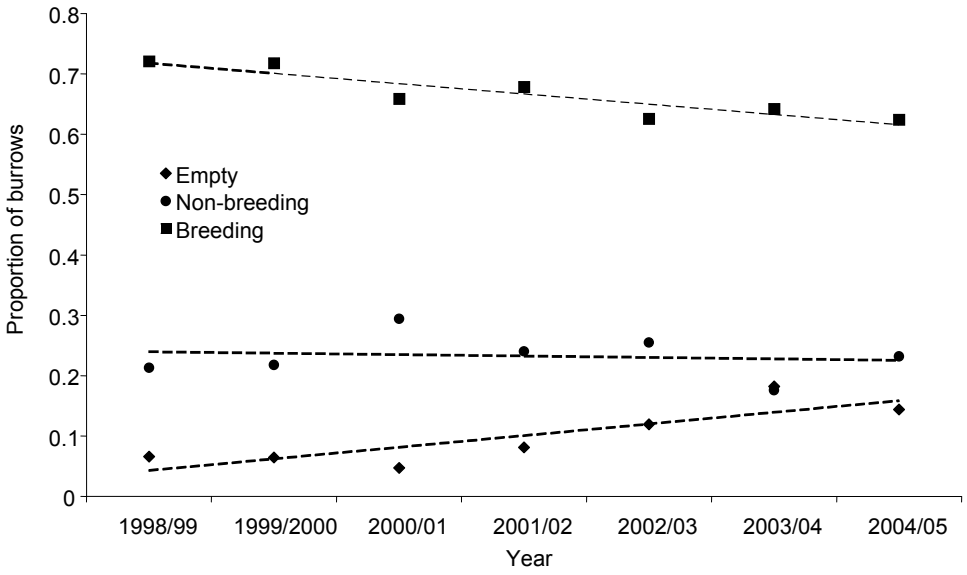

Figure 7. Occupancy of black petrel (*Procellaria parkinsoni*) study burrows on Great Barrier Island (Aotea Island).

TABLE 2. BLACK PETREL (*Procellaria parkinsoni*) BURROWS, BREEDING STATUS AND HABITAT TYPE RANKING ALONG TRANSECTS SURVEYED IN THE 35-ha STUDY AREA, GREAT BARRIER ISLAND (AOTEA ISLAND).

NO.	TRANSECT	LENGTH (m)	BURROW				NUMBER OF BURROWS (per ha)	RANK (habitat type)
			EMPTY	BREEDING	NON-BREEDING	TOTAL		
1	LT1	400	–	6	4	10	63	Optimum
2	LT10	400	–	14	6	20	125	Optimum
3	LT11	400	–	3	1	4	25	Poor
4	LT12	380	–	4	3	7	46	Poor
5	LT13A	150	1	3	3	7	117	Optimum
6	LT14	140	–	2	–	2	36	Poor
7	LT15	120	–	2	1	3	63	Optimum
8	LT16	110	1	1	–	2	45	Poor
9	LT17	400	–	8	3	11	69	Optimum
10	LT18	400	–	5	4	9	56	Optimum
11	LT19	250	–	–	–	0	0	Poor
12	LT20	190	–	2	2	4	53	Optimum
13	LT24	180	–	3	1	4	56	Optimum
14	LT25	400	2	9	9	20	125	Optimum
15	LT26	400	1	11	4	16	100	Optimum
16	LT31	170	–	1	–	1	15	Poor
17	LT37	150	–	6	2	8	133	Optimum
18	LT38	400	1	5	2	8	50	Poor
19	LT40	330	1	3	6	10	76	Optimum
20	LT41	400	–	7	6	13	81	Optimum
21	LT6	130	–	2	3	5	96	Optimum
22	LT7	200	1	–	1	2	25	Poor
23	LT8	400	1	6	3	10	63	Optimum
24	LT9	320	–	4	5	9	70	Optimum
25	LT93	330	–	3	–	3	91	Optimum
26	LT97	320	–	2	1	3	23	Poor
Total		7470	9	112	70	191		
Mean ± SEM		287.3 ± 22.5	1.1 ± 0.1	4.7 ± 0.7	3.3 ± 0.5	7.3 ± 1.1		

4.4 BANDING DATA

There were 441 adults identified during the 2004/05 season (Table 3); 306 of these were already banded and 135 were banded this season. There were 175 chicks still present in the study burrows and nine chicks in extra non-study burrows that were also banded (Table 3). The number of adults recaptured from the study site has been over 300 birds for the past five seasons (Table 3), and generally over 100 adults have been banded each season since 1998/99 (Table 3).

Since the first banded chick was recaptured in the 1999/00 season, 42 'chicks' have been recaptured as pre-breeders, non-breeders or breeding adults (Table 3 and Appendix 1). Sixteen of these have bred over five seasons (2000/01 to 2004/05; Bell & Sim 2002, 2003a,b), with nine breeding successfully over that period. Of the 24 'chicks' that returned this season, 12 attempted to breed, with seven successfully raising chicks of their own, indicating that the age at first breeding ranges from 5 years to at least 8 years (Appendix 1). The remaining chicks had not bred, although several males were recaptured while calling to attract a mate.

TABLE 3. BANDING, RECAPTURE AND RECOVERY DATA FOR BLACK PETRELS (*Procellaria parkinsoni*) FROM GREAT BARRIER ISLAND (AOTEA ISLAND).

	YEAR									
	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05
Recaptures of birds banded prior to 1995	19	31	24	23	29	27	27	27	21	22
Recaptures of birds banded in 1995/96	–	14	14	14	16	14	11	12	12	8
Recaptures of birds banded in 1996/97	–	–	113	86	84	73	63	57	43	37
Recaptures of birds banded in 1997/98	–	–	–	32	32	30	28	24	18	27
Recaptures of birds banded in 1998/99	–	–	–	–	95	82	71	64	49	36
Recaptures of birds banded in 1999/00	–	–	–	–	–	86	75	66	47	51
Recaptures of birds banded in 2000/01	–	–	–	–	–	–	51	52	41	22
Recaptures of birds banded in 2001/02	–	–	–	–	–	–	–	68	88	26
Recaptures of birds banded in 2002/03	–	–	–	–	–	–	–	–	61	55
Recaptures of birds banded in 2003/04	–	–	–	–	–	–	–	–	–	22
Total recaptures	19	45	151	155	256	312	326	370	380	306
Number of new adults (banded that season)	41	179	60	129	145	97	114	179	67	135
Total adults	**60**	**224**	**211**	**284**	**401**	**409**	**440**	**549**	**447**	**441**
Number of chicks (banded that season)	59	69	85	116	137	137	160	62	110	184
Total number of birds	**119**	**293**	**296**	**400**	**538**	**546**	**600**	**611**	**557**	**625**
Number of chicks recaptured alive (returned to colony)	–	–	–	–	1	2	11	18	13	24
Band recoveries from dead birds	–	1	1	–	2	1	2	2	–	–

4.5 POPULATION ESTIMATE

There were three possible methods for obtaining population estimates from the 35-ha study area: extrapolating from the original census grids, extrapolating from the transects and extrapolating from the transects with stratification of the study site (Appendices 2–4).

Extrapolating from the census grid data to the 35-ha area around the summit of Mount Hobson yielded an estimate of the burrow-occupying black petrel population of between 3953 and 5916 adults (4934 ± 982 birds; Table 4 and Appendix 2), consisting of 948 (± 186) non-breeding adults and 3986 (± 794) breeding adults (i.e. 1993 breeding pairs). However, this estimate is likely to overestimate the population, as high-density areas were used to extrapolate to the entire study site.

Extrapolating from the transects to the 35-ha area around the summit area of Mount Hobson yielded an estimate of the burrow-occupying black petrel population of between 2903 and 3782 adults (3343 ± 440 birds; Table 4 and Appendix 3), consisting of 793 (± 124) non-breeding adults and 2551 (± 316) breeding adults (i.e. approximately 1276 breeding pairs). However, this estimate is also likely to incorrectly estimate the population, as it does not take into account the range of habitat types identified within the study site.

Stratification of the study site and extrapolation from the transects to the 35-ha area around the summit of Mount Hobson yielded an estimate of the burrow-occupying black petrel population of between 3551 and 5021 adults (4286 ± 735 birds; Table 4 and Appendix 4), consisting of 935 (± 180) non-breeding adults and 3351 (± 555) breeding adults (i.e. approximately 1676 breeding pairs).

TABLE 4. COMPARISON OF THE BLACK PETREL (*Procellaria parkinsoni*) POPULATION ESTIMATES USING DIFFERENT EXTRAPOLATING TECHNIQUES FOR THE 35-ha AREA AROUND MOUNT HOBSON, GREAT BARRIER ISLAND (AOTEA ISLAND).

TECHNIQUE	BREEDING	NON-BREEDING	TOTAL	RANGE
Census grids	3986 ± 796	948 ± 186	4934 ± 982	3952–5916
Transects	2551 ± 316	793 ± 124	3342 ± 440	2903–3782
Stratification and transects	3351 ± 555	935 ± 180	4286 ± 735	3555–5021

4.6 SURVIVAL

Using Cormack Jolly Seber (CJS) analysis (Model: Phi(t) p(t) (AICc = 2760.3; Chat = 1.76) of all adults recaptured during the 10-year study, the mean adult survival was calculated to be 0.7786 (± 0.02) (where Phi = apparent survival, t = time, p = probability of recapture, AICc = Aikake modified Information Criterion (corrected for small sample size) and Chat = dispersion coefficient or likelihood parameter). The data suggest that there has been a slight increase in adult survival over the 10 years of study (Fig. 8).

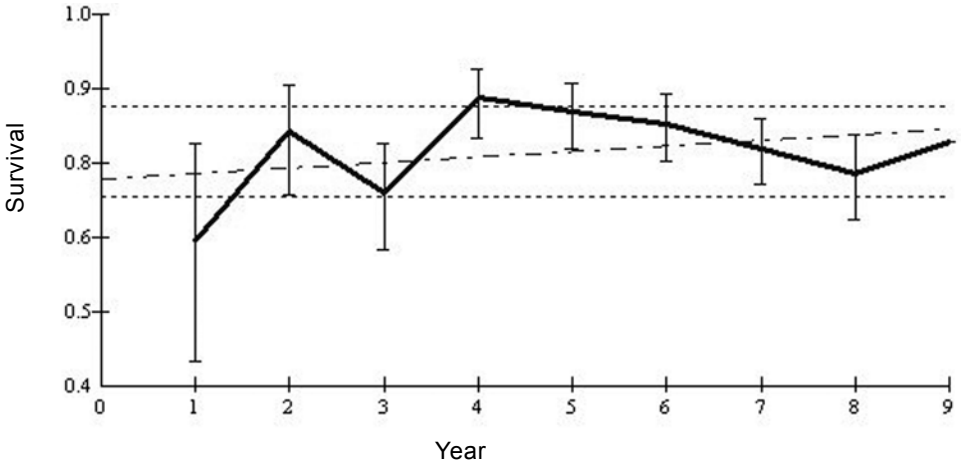

Figure 8. Trends in black petrel (*Procellaria parkinsoni*) adult survival over the 10-year study. Survival estimates were calculated using Cormack Jolly Seber analysis; estimates (± SE) and their 95% confidence intervals are shown.

There has also been an increase in population size at the study site over the 10 years of study (Fig. 9). However, this is likely to be an artefact of the increase in the number of study burrows and night search effort. Therefore, we also analysed the original foundation study burrows. This analysis (using a CJS estimate of population size by multiplying p(t)* number caught for the Phi(t) p(t) model) showed a slight decrease in population size over the 10-year study (Fig. 10) Adult survival estimates based on the foundation burrows (mean = 0.7923 ± 0.02) were comparable to those based on the whole adult dataset (Fig. 11).

A Burnham analysis of the recoveries made during the 10-year study suggested that the low survival estimates may be due to high levels of permanent emigration. Estimates from the best model [S(t) p(g*t) r(.) F(.)] suggested that site fidelity could be as low as 0.905 (± 0.015) (where S = survival, t = time, p = probability of recapture, g = group (i.e. live and dead birds), r = reporting probability (i.e. probability that the band will be recovered given that the bird is dead) and F = fidelity), in which case approximately 10% of birds may be permanently emigrating from the study area.

A preliminary Burnham analysis of survival of chicks banded in the study was also completed. Only 41 of over 1100 chicks banded have been recaptured. However, a model incorporating two chick survival parameters (survival for 0–3 years, and survival for individuals 3 years old and older) gave an apparent survival estimate of 0.491 (± 0.03) in the first 3 years. Remarkably, after the first 3 years of life, the survival estimate increased to 0.923 (± 0.05).

A CJS analysis (Phi(t) p(t) model, AICc = 2.8, compared with Phi(sex) p(t)) of 107 birds of known sex suggested that there is no significant difference between male and female survival.

A multi-state model (s(.) p(.) psi(breeder to non-breeder*t)) using five states (unknown status, successful breeder, unsuccessful breeder, chick and non-breeder) showed that there has been a slight increase in the probability of birds changing from successful breeders to non-breeders over the course of the study (Fig. 12).

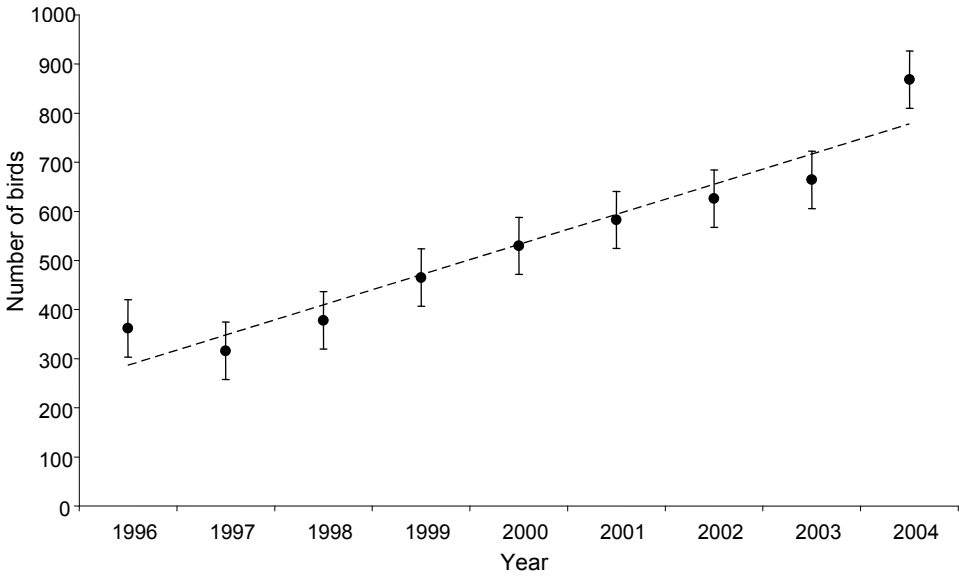

Figure 9. Trends in black petrel (*Procellaria parkinsoni*) population size (± SEM) within the study burrows over the 10-year study (using dataset of all adults).

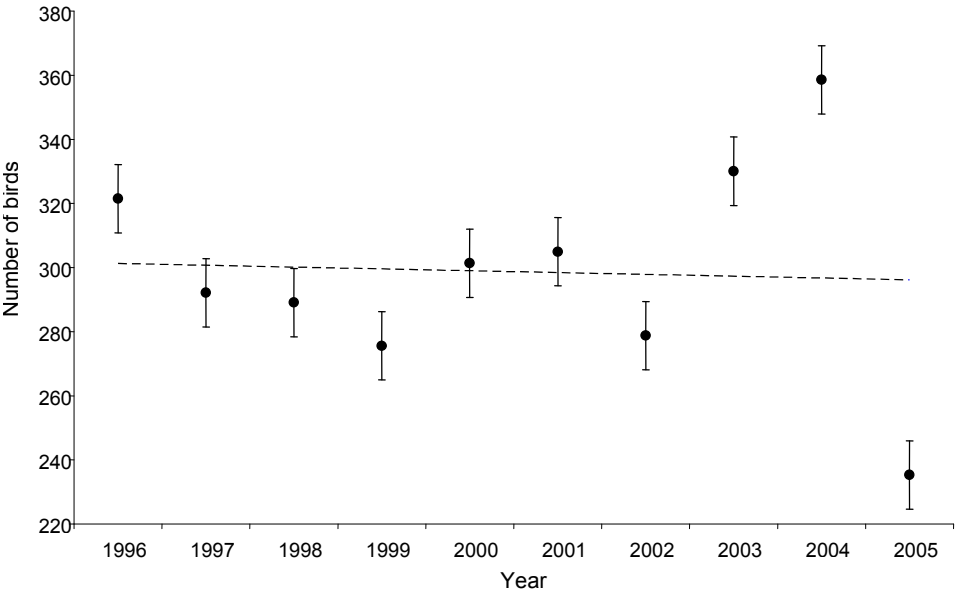

Figure 10. Trends in black petrel (*Procellaria parkinsoni*) population size (± SEM) within the 100 foundation burrows over the 10-year study (using dataset of 100 foundation burrows).

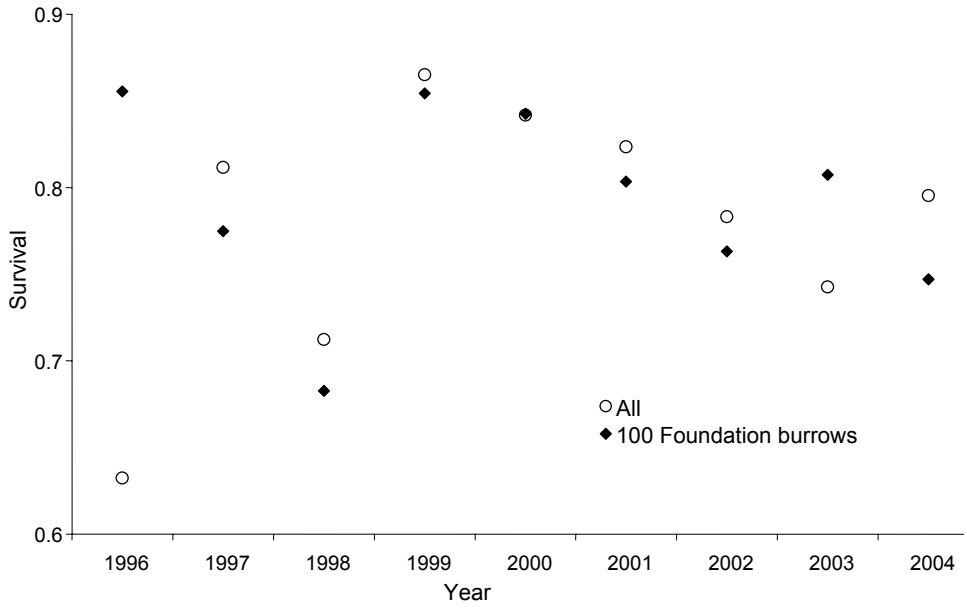

Figure 11. Comparison between black petrel (*Procellaria parkinsoni*) adult survival estimates based on all birds and the 100 foundation burrows.

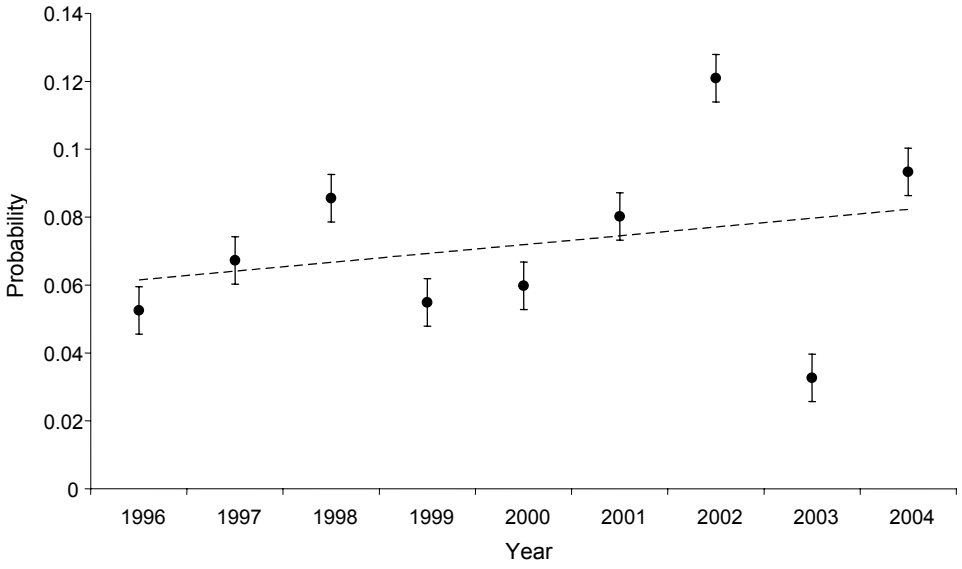

Figure 12. Probability (Psi) of black petrels (*Procellaria parkinsoni*) making a transition from successful breeders to non-breeders over the 10-year study.

5. Discussion

The black petrel population on Great Barrier Island (Aotea Island) has been monitored since the 1995/96 breeding season (Bell & Sim 1998a,b, 2000a,b,c, 2002, 2003a,b).

5.1 CENSUS GRIDS

Nine grids were intensively monitored over three periods during the 2004/05 breeding season and 12 new burrows were located in the grids. Only three of these new burrows were used for breeding this season, all of which successfully fledged chicks. As the study continued, new burrows regularly were found within the census grids; however, this may have been due to the increased search effort and/or pre-breeding birds digging new burrows.

The fact that new burrows were found in the census grids does not necessarily mean that more birds were present in the colony, as many birds ($n = 154$) had moved between burrows at the study site and some original burrows were no longer active. Loss of a partner can result in a bird (particularly a female) changing its burrow. Predation events can also cause movement between burrows.

It appears that pre-breeding and non-breeding birds were returning to their natal area and starting to excavate new burrows. One returned chick (H25648) was digging a new burrow only 50 m from his natal burrow.

In the comparison of data from the past six breeding seasons, the ratio of non-breeding burrows to breeding burrows was very similar between seasons (1:3 or 1:2; Bell & Sim 2000a,b,c, 2002, 2003a,b). This may be explained by a consistent number of resident birds returning to the colony to breed

each season. It is interesting to note that there was the same percentage of empty burrows in the 2004/05 season (18%) as the previous season, which was higher than previously recorded (12% in 2002/03, 8% in 2001/02, 5% in 2000/01, 6% in 1999/2000, and 7% in 1998/99); the percentage of empty burrows had steadily increased. This may relate to handler disturbance, which may be causing the birds to move outside the study areas. Further widespread surveys within the study area may be able detect this movement.

5.2 STUDY BURROWS

During the 2004/05 season, 38 study burrows were added to the 324 that had previously been identified. There were 181 breeding successes and 45 breeding failures this season, equating to an overall breeding success of 80%. This breeding success is higher than in the previous 7 years (Table 1) and is also higher than reported in 1977 (50%) and 1978 (60%) (Imber 1987), and in 1988/89 (62%) (Scofield 1989), although this may be due to differences in the methods used to calculate these percentages (i.e. breeding success for 2004/05 was calculated as chicks fledged from eggs laid). However, it is still less than the most successful season to date (1997/98). It should also be noted that it was assumed that six chicks fledged safely before the banding visit at the end of April. If any of these chicks had actually died or been preyed upon earlier in the season, this would reduce the breeding success. Chicks were assumed to have fledged successfully if traces of down, quill sheaths, pin feathers and/or recent activity in the burrow were identified during the April visit. This breeding success rate is high compared with many other seabird species (Warham 1996), but the apparent juvenile survival estimate suggests that as many as 50% of these fledged chicks may not survive their first 3 years.

It was interesting to note that although the number of burrows used for breeding decreased over the past seven seasons (Fig. 7), breeding success remained relatively constant (Table 1). Analysis of all the adult recaptures showed that there was an increased rate of birds skipping from breeding to non-breeding status, which could help explain the reduction in the number of burrows used for breeding.

A comparison of data from the past seven breeding seasons showed that the number of non-occupied (empty) study burrows increased (Fig. 7). It was suggested that this may be directly related to handler disturbance or adult mortality (M. Imber, pers. comm.). However, an analysis of adult survival and site fidelity suggested that although there is low apparent adult survival, approximately 10% of birds may be permanently emigrating from the study area, which would account for the declining occupancy of burrows. More work is needed to separate the components of apparent survival to work out whether the low apparent survival is due to mortality, emigration or handler disturbance. This requires a thorough search of banding records for recovery data and continued (and wider) recapture effort at the study site.

5.3 PREDATION

During the 2004/05 season, there was evidence of predation or scavenging by rats on three eggs (1% of all breeding attempts) within the study burrows; for five further eggs (2%), the cause of failure was unknown but may have been due to predation. Interestingly, there was no predation by cats nor any detection of feral cat sign in the study site. This contrasts with previous seasons, when juvenile petrels were vulnerable to predation by feral cats as soon as they left the burrows to strengthen their wings and practise flying (Warham 1996). Adult petrels are also potentially vulnerable when they first return to the colony and are sitting on the ground outside burrow entrances calling mates. Over ten chicks have been preyed upon by cats over the past six seasons (Table 1). Therefore, it is important to continue cat trapping in the area before, during and after the black petrel breeding season.

5.4 CHICKS

There were 175 chicks still present in the study burrows in April 2005. Compared with previous seasons (where many chicks were in poor condition), during the 2004/05 season most chicks were in very good condition and many were about to fledge (Bell & Sim 2000a,b,c, 2002, 2003a,b). Only one chick had avian pox and this was only the dry form. Although mild cases of avian pox may not adversely limit fledging chances, overall survival may be reduced.

The chick-banding trip, although earlier in 2004/05 than the previous season, was well timed with regards to fledging as, although most chicks were ready to fledge, they were still present in the burrows. Chicks were noted trying to fledge on most nights, using trees and rocks in the area.

5.5 POPULATION ESTIMATE

Three methods were used to calculate population estimates: extrapolating from the census grids; extrapolating from random transects; and stratifying the study area into habitat types and again extrapolating from transects (Table 4 and Appendices 2–4). Surveys and local knowledge of Great Barrier Island (Aotea Island) showed that petrel burrow densities were not identical throughout the summit area. Therefore, it was obvious that the estimate based on extrapolation from the census grids (i.e. known high burrow density areas) to the entire 35-ha study area (4934 ± 982 birds) was an overestimate of the black petrel population. The estimate calculated from random transects (3343 ± 440 birds) appeared to underestimate the black petrel population, as the study site was still being treated as one habitat (and burrow density) type. The transects identified three habitat types within the study site: areas of high burrow density, areas of low burrow density and areas with no burrows. The highest densities of black petrel burrows were located on ridges or spurs with established canopy. Therefore, stratification of the 35-ha study site into three areas of high and low density of burrows and no

burrows and subsequent extrapolation from the transects is likely to have given the most accurate population estimate (4286 ± 735 birds). The breeding population was estimated at approximately 1650 breeding pairs. It should be noted that this estimate covers only the 35-ha area around the summit of Great Barrier Island (Aotea Island); however, this is the main location of the population where it is at its highest density. We consider that delimiting the lower boundaries of the colony within the Hirakimata Block is the highest priority to achieve a complete estimate of the total population.

Further transects throughout the study site could improve this population estimate as well as more accurately define the range of the three (or possibly identify more) habitat types within the study area. It is also important to examine the difference between two- and three-dimensional estimates of density and population size in this steep and difficult terrain.

To gain a better population estimate for the whole black petrel population on Great Barrier Island (Aotea Island), surveys would need to be undertaken in other areas. Black petrels are known to nest in the Northern Block, in other high points around the summit area, in small pockets of private land and towards the southern end of the island. Randomly selected census grids, transects or further intensive surveys in these areas would give a better idea of burrow density and range around the island. These surveys could be undertaken on or near the Hog's Back, Mount Heale and Mount Matawhero. It is interesting to note that several pairs of black petrels have been found well below 300 m a.s.l., raising the possibility that other birds are also now breeding at lower elevations; this should be investigated further.

5.6 BANDING DATA

A total of 625 birds were identified this season; 441 were adults (of which 306 were recaptures of previously banded birds, including 24 that were returned chicks) and 184 were fledglings (Table 3).

Sixteen chicks were recaptured in their natal area (less than 50 m from their 'hatching' burrow) and two were recaptured in their natal burrows. The other six chicks were caught over 100 m away from their natal areas. There is a likely capture bias towards the returning males owing to their behaviour, i.e. calling outside burrows. In contrast, females are likely to be more difficult to detect, as they are attracted to calling males and as such could be in other parts of the colony both inside and outside the study area. This will need to be taken into account for further survival and recruitment analyses.

Since the first chick was recaptured during the 1999/00 season, 42 'chicks' have been recaptured. Seventeen of these have bred during this period, which means the age of first recorded breeding is between 5 years and 8 years (Appendix 1). It is important to check for more returned 'chicks' and maintain intensive burrow monitoring where there have been returned 'chicks' present. Many of the returned 'chicks' were recaptured at night during the December visit; therefore, it is important to maintain a high level of searching at this time. These data also allow for mark/recapture

analyses, which could greatly assist in understanding the demographics of this species.

Using this 'chick' recapture data (42 out of over 1100 banded chicks), a preliminary Burnham analysis of chick survival (incorporating two chick survival parameters: 0–3 years and over 3 years) suggested that chick survival up to year 3 was 0.491 (± 0.03). Interestingly, chick survival after the first 3 years of life increased to 0.923 (± 0.05). This suggests that juvenile survival is not the reason for any population decline, as both these figures fall into the normal range for seabirds of this size (Hunter et al. 2001).

5.7 ADULT SURVIVAL AND POPULATION TRENDS

The apparent adult survival estimates (mean = 0.7786 ± 0.02) were unusually low for a seabird of this size, but were comparable to estimates made by Hunter et al. (2001). There was also a suggestion that adult survival has increased over the last 10 years of study (Fig. 8). It was also interesting to note that there was no significant difference in adult survival between males and females.

Analysis of all the adult recaptures over the 10-year study shows that the black petrel population appears to be increasing (Fig. 9). This is almost certainly owing to the increase in the number of study burrows and night capture effort. This effect can be examined by comparing population size estimates based on all recaptures with those based on the original randomly selected 'foundation' study burrows (i.e. those that have been monitored for 10 years). A CJS estimate of the population size based on these 'foundation' burrows indicated that there has been a slight decrease in the population size over the past 10 years (Fig. 10). This decrease in population size in the foundation burrows may be related to handler disturbance and needs to be investigated by widespread searches of the study area as survival in this group (mean = 0.7923 ± 0.02) was comparable to that derived from the entire adult dataset.

A Burnham model analysis using only four recoveries made during the study suggests that the apparently low adult survival may be owing to high levels of permanent emigration (i.e. approximately 10% of birds may be permanently emigrating from the study site). However, as stated earlier, more work needs to be done to determine whether this movement from the study site actually occurs and is related to handler disturbance.

5.8 CONSERVATION

As in previous seasons, large numbers of the public continue to visit Mount Hobson and this appears to have little or no obvious impact on the breeding success of the black petrel. Information about the black petrels at the track start points and on the summit has increased awareness of the birds and this unique environment. This is particularly important in relation to littering and public fouling, which continue to be a problem in the summit area.

As stated in earlier reports (Bell & Sim 2000a,b,c, 2002, 2003a,b), the construction of raised walkways around the summit has decreased damage to the overall environment and to the burrows; therefore, as serious erosion continues to occur along the summit ends of the South Fork and Palmers Tracks (pers. obs.), the boardwalk system should be extended. Construction should only be carried out following full consultation with the appropriate experts to prevent the accidental destruction of burrows and important plant species around the summit area.

In total, ten black petrels (including one that had been banded by the authors) have been recorded as being caught as bycatch on domestic long-line vessels in the New Zealand fisheries between 1 October 1996 and 30 September 2004 (Robertson et al. 2004). All of these birds were caught on domestic pelagic long-line vessels between November and April, either east of North Cape, near the Kermadec Islands, or north of Great Barrier Island (Aotea Island) (Robertson et al. 2003, 2004). This means that most of these may have been adults either returning to breed or already incubating an egg or feeding a chick, in which case their deaths would result in a breeding failure, reducing overall productivity and recruitment. It is interesting to note that a pre-breeding adult (banded by the authors in the 2001/02 season) was captured off Australia in December 2004 and was released alive (C.J.R. Robertson, Wild Press, pers. comm.). This pre-breeding bird was only 3 years old and, at the time of writing, has not yet been recorded back at the colony. The level of bycatch for black petrels and other seabirds outside New Zealand waters is unknown and may impact on the population dynamics of the species. Black petrels have delayed maturity, low reproduction rates and high adult survivorship, so that any change in adult survivorship, however small, will affect the population (Murray et al. 1993). If breeding adults continue to be caught on long-lines in New Zealand and overseas, this species could be adversely affected. It is important to continue to monitor the Great Barrier Island (Aotea Island) black petrel population. Long-term population data can be used to develop an accurate population model, allowing us to determine adult survivorship, recruitment, mortality and productivity, as well as assess factors affecting the black petrel population. It will also help with determining the overall effects of bycatch by the long-line fishing industry.

6. Recommendations

The authors recommend that:

- Monitoring of the black petrel population (using the study burrows) be continued at Great Barrier Island (Aotea Island) up to and including the 2008/09 breeding season. This will ensure that 10 years of comparative data are collected to determine the population dynamics of black petrels, allowing us to develop a population model to determine survivorship and mortality, and the effects of predation, long-line fishing and other environmental factors (e.g. El Niño).

- The November/December visit to the study area be continued. This will allow a large number of birds to be banded or recaptured easily as the birds are often outside the burrows at this time. It will also enable the continuation of the mark/recapture programme. At the same time, the study burrows could be checked for breeding status, to give a more accurate estimate of breeding success and to determine the sex of adults. This would also provide a chance to recapture returning birds that were banded as chicks.
- The January/February visit be continued. This will enable intensive monitoring of the study burrows, allow the adults to be identified and help determine breeding status in the burrows. The April/May visit should also continue, allowing time to band the surviving chicks.
- A sample of black petrels carry GPS data loggers as part of an investigation of foraging distances and locations, water temperature and flight patterns.
- The Northern Block (Tataweka) be visited in November to survey the black petrel population and obtain a more accurate estimate of the population there.
- The exact limits of the Hirakimata Block colony be established and the area be calculated by a ground-truth survey, and random transects be established on other high points around the Mount Hobson area (e.g. Mount Heale, Mount Matawhero and Hog's Back). This will ensure that a rigorous total estimate for the black petrel population on Great Barrier Island (Aotea Island) can be made.
- Cat trapping be implemented before and during the black petrel breeding season (November to June), especially during pre-laying (October/ November) and the fledging period (April to June).
- The walkway systems down Palmers (Windy Canyon) and South Fork Tracks be extended. Construction should be completed between July and mid-October, when the chicks have fledged and before the adults return. Known petrel burrows should be identified for the construction team to avoid.

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8. References

Bell, E.A.; Sim, J.L. 1998a: Survey and monitoring of black petrels on Great Barrier Island 1996. *Science for Conservation 77*. Department of Conservation, Wellington. 17 p.

Bell, E.A.; Sim, J.L. 1998b: Survey and monitoring of black petrels on Great Barrier Island 1997. *Science for Conservation 78*. Department of Conservation, Wellington. 18 p.

Bell, E.A.; Sim, J.L. 2000a: Survey and monitoring of black petrels on Great Barrier Island 1997/98. Published client report on contract 3085, funded by Conservation Services Levy. Department of Conservation, Wellington. 24 p.

Bell, E.A.; Sim, J.L. 2000b: Survey and monitoring of black petrels on Great Barrier Island 1998/99. Published client report on contract 3089, funded by Conservation Services Levy. Department of Conservation, Wellington. 23 p.

Bell, E.A.; Sim, J.L. 2000c: Survey and monitoring of black petrels on Great Barrier Island 1999/2000. Published client report on contract 3018, funded by Conservation Services Levy. Department of Conservation, Wellington. 30 p.

Bell, E.A.; Sim, J.L. 2002: Survey and monitoring of black petrels on Great Barrier Island 2000/01. *DOC Science Internal Series 48*. Department of Conservation, Wellington. 24 p.

Bell, E.A.; Sim, J.L. 2003a: Survey and monitoring of black petrels on Great Barrier Island 2001/02. *DOC Science Internal Series 134*. Department of Conservation, Wellington. 24 p.

Bell, E.A.; Sim, J.L. 2003b: Survey and monitoring of black petrels on Great Barrier Island 2002/03. *DOC Science Internal Series 135*. Department of Conservation, Wellington. 28 p.

Bell, E.A.; Sim, J.L. 2005: Survey and monitoring of black petrels on Great Barrier Island 2003/04. *DOC Research and Development Series 213*. Department of Conservation, Wellington. 27 p.

Heather, B.; Robertson, H. 1996: Field guide to the birds of New Zealand. Penguin Books (NZ) Ltd, Auckland, New Zealand. 432 p.

Hunter, C.; Fletcher, D.; Scofield, P. 2001: Preliminary modelling of black petrels (*Procellaria parkinsoni*) to assess population status. *DOC Science Internal Series 2*. Department of Conservation, Wellington, New Zealand. 42 p.

Imber, M.J. 1987: Breeding ecology and conservation of the black petrel (*Procellaria parkinsoni*). *Notornis 34*: 19–39.

Murray, T.E.; Bartle, J.A.; Kalish, S.R.; Taylor, P.R. 1993: Incidental capture of seabirds by Japanese southern bluefin tuna long-line vessels in New Zealand waters, 1988–1992. *Bird Conservation International 3(3)*: 181–210.

Robertson, C.J.R.; Bell, E.A.; Scofield, P. 2003: Autopsy report for seabirds killed and returned from New Zealand fisheries, 1 October 2000 to 30 September 2001: birds returned by Ministry of Fisheries observers to the Department of Conservation. *DOC Science Internal Series 96*. Department of Conservation, Wellington. 36 p.

Robertson, C.J.R.; Bell, E.A.; Scofield, P. 2004: Autopsy report for seabirds killed and returned from New Zealand fisheries, 1 October 2001 to 30 September 2002: birds returned by Ministry of Fisheries observers to the Department of Conservation. *DOC Science Internal Series 155*. Department of Conservation, Wellington. 43 p. + 49 p. data supplement.

Scofield, R.P. 1989: Breeding biology and conservation of the black petrel (*Procellaria parkinsoni*) on Great Barrier Island. Unpublished MSc (Zoology) thesis, University of Auckland, Auckland, New Zealand. 69 p.

Warham, J. 1996: The behaviour, population biology and physiology of the petrels. Academic Press, London. 440 p.

Appendix 1

RECAPTURE DATA FOR 'CHICKS'

Recapture data for black petrel (*Procellaria parkinsoni*) 'chicks' banded on Mount Hobson, Great Barrier Island (Aotea Island).

BAND	SEX	SEASON LAST RECAPTURED	NUMBER OF RECAPTURES	AGE AT FIRST RECAPTURE (YEARS)	AGE AT FIRST BREEDING (YEARS)
H25536		2004/05	1	6	–
H25546		2004/05	2	5	5
H25630	Male	2004/05	1	5	–
H25631		2003/04	1	4	–
H25635	Male	2004/05	1	5	–
H25637	Male	2004/05	1	5	–
H25648		2004/05	1	5	–
H25651		2004/05	1	5	–
H25658	Male	2004/05	1	5	–
H25663		2004/05	2	4	–
H25664		2004/05	2	3	–
H25669		2004/05	1	5	–
H25673	Male	2004/05	1	5	5
H30924	Male	2004/05	3	6	6
H30908	Male	2002/03	1	7	–
H30930	Male	2004/05	6	4	5
H31076		2002/03	1	5	–
H31080		2001/02	1	4	–
H31081		2002/03	2	4	–
H31082	Male	2001/02	1	4	–
H31089		2003/04	2	5	6
H31194	Male	2001/02	1	5	5
H31366		2004/05	3	5	6
H31370		2002/03	1	5	–
H31377		2001/02	1	4	–
H31382	Female	2003/04	3	4	5
H31383	Male	2003/04	1	6	6
H31405		2004/05	3	6	7
H31406		2001/02	1	5	–
H31413		2004/05	1	5	5
H31415		2004/05	1	8	8
H31424		2004/05	3	6	8
H31474		2002/03	1	4	–
H31476	Male	2004/05	2	4	6
H31490		2002/03	1	4	–
H31494	Male	2004/05	1	6	–
H31495		2004/05	3	4	6
H31498		2004/05	1	6	6
H31527		2002/03	1	4	–
H31536		2003/04	1	5	–
H31542	Male	2004/05	3	4	6
H31536		2003/04	1	5	–
Mean (±SEM)			1.6±0.2	4.9±0.2	5.9±0.2

Appendix 2

2004/05 POPULATION ESTIMATE USING CENSUS GRIDS ONLY

2004/05 population estimate of black petrels (*Procellaria parkinsoni*) in the 35-ha summit area around Mount Hobson, Great Barrier Island (Aotea Island), using census grids only.

GRID	DENSITY (number/ha)		POPULATION ESTIMATE (35 ha)	
	BREEDING ADULTS	NON-BREEDING ADULTS	BREEDING ADULTS	NON-BREEDING ADULTS
Grid One (KDG1)	213	44	7455	1540
Grid Two (KDG2)	200	38	7000	1330
Grid Three (KDG3)	50	6	1750	210
Grid Four (PTG1)	175	44	6125	1540
Grid Five (PTG2)	88	25	3080	875
Grid Six (PTG3)	63	31	2205	1085
Grid Seven (SFG1)	138	19	4830	665
Grid Eight (SFG2)	50	38	1750	1330
Grid Nine (SFG3)	50	0	1750	0
Mean	114 ± 23	27 ± 5	3994 ± 794	953 ± 188
Total population estimate			4947 ± 982	
Population estimate range			3965–5929 adults	

Appendix 3

2004/05 POPULATION ESTIMATE USING TRANSECTS ONLY

2004/05 population estimate of black petrels (*Procellaria parkinsoni*) in the 35-ha summit area around Mount Hobson, Great Barrier Island (Aotea Island), using transects only.

TRANSECT	DENSITY (number/ha)		POPULATION ESTIMATE (35 ha)	
	BREEDING ADULTS	NON-BREEDING ADULTS	BREEDING ADULTS	NON-BREEDING ADULTS
LT1	75	25	2625	875
LT10	175	38	6125	1330
LT11	38	6	1330	210
LT12	53	13	1855	455
LT13A	100	50	3500	1750
LT14	73	0	2555	0
LT15	83	21	2905	735
LT16	46	0	1575	0
LT17	100	19	3500	665
LT18	63	25	2205	875
LT19	0	0	0	0
LT20	53	26	1855	910
LT24	83	14	2905	490
LT25	113	56	3955	1960
LT26	138	25	4830	875
LT31	29	0	1015	0
LT37	200	33	7000	1155
LT38	63	13	2205	455
LT40	46	46	1610	1610
LT41	75	44	2625	1540
LT6	77	58	2695	2030
LT7	0	13	0	455
LT8	75	19	2625	665
LT9	63	39	2205	1365
LT93	47	0	1645	0
LT97	31	8	1085	280
Mean	73±9	23±4	2555±316	796±124
Total population estimate			3351±440	
Population estimate range			2911–3790 adults	

Appendix 4

2004/05 POPULATION ESTIMATE USING STRATIFIED TRANSECTS

2004/05 population estimate of black petrels (*Procellaria parkinsoni*) in the 35-ha summit area around Mount Hobson, Great Barrier Island (Aotea Island) using stratified transects. Note transects with greater than 50 burrows/ha were classed as optimum habitat areas and transects with less than or equal to 50 burrows/ha were classed as poor habitat areas.

TRANSECT	DENSITY (number/ha)		POPULATION ESTIMATE	
	BREEDING	NON-BREEDING	BREEDING	NON-BREEDING
High burrow density				
LT1	75	25	1369	456
LT10	194	42	3541	767
LT13A	107	54	1953	986
LT15	111	28	1698	428
LT17	107	20	1953	365
LT18	85	34	1551	621
LT20	56	28	1022	511
LT24	188	31	2876	474
LT25	111	125	1663	2281
LT26	151	27	2756	493
LT37	222	37	4052	675
LT40	75	75	1148	1148
LT41	75	44	1369	803
LT6	77	58	1405	1059
LT8	102	25	1862	456
LT9	91	57	1661	1040
LT93	86	0	1316	0
Mean	113 ± 12	42 ± 7	2052 ± 210	762 ± 123
Low burrow density				
LT11	86	19	1316	291
LT12	100	25	1530	383
LT14	222	0	3397	0
LT16	125	0	1913	0
LT19	0	0	0	0
LT31	77	0	1178	0
LT38	104	21	1591	321
LT7	0	24	0	367
LT97	50	13	765	199
Mean	84 ± 23	11 ± 4	1299 ± 345	173 ± 57
High density area mean			2052 ± 210	762 ± 123
Low density area mean			1299 ± 345	173 ± 57
Total			3351 ± 555	935 ± 180
Total population estimate			4286 ± 735	
Population estimate range			3551–5021 adults	