

Population parameters and  
distribution of the black petrel  
(*Procellaria parkinsoni*)  
on Great Barrier Island  
(Aotea Island), 2007/08

DOC MARINE CONSERVATION SERVICES SERIES 8



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*Te Papa Atawhai*



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Elizabeth A. Bell, Joanna L. Sim and Paul Scofield

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# Population parameters and distribution of the black petrel (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island), 2007/08

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## ABSTRACT

This report is part of an ongoing long-term study of the black petrel, *Procellaria parkinsoni*, on Great Barrier Island (Aotea Island) that was begun in the 1995/96 breeding season. During the 2007/08 breeding season, 379 study burrows within the 35-ha study site near Mount Hobson (Hirakimata) were checked and intensively monitored. Of these, 256 were used by breeding pairs, 65 by non-breeding adults and the remaining 58 burrows were empty. By 13 April 2008, 190 chicks were still present in the study burrows and eight had already fledged, corresponding to a breeding success of 77%. Nine census grids were monitored within the study area and accounted for 148 of the inspected burrows, with 91 burrows being used for breeding. Twenty-seven chicks from earlier breeding seasons were recaptured within the Mount Hobson colony area this season (a total of 67 'returned chicks' have been caught since the 1999/2000 season). Analysis of the census grid data estimated the black petrel population from the 35-ha area around Mount Hobson to be in the range of 3342–4130 birds. Twenty-eight Lotek™ geo-locator data-loggers were deployed on breeding black petrels. Eight were retrieved for tracking analysis (to determine foraging locations and possible interaction with fisheries) and the remaining loggers were left for retrieval after the birds' migration to South America and return to the colony in the following (2008/09) breeding season.

Keywords: black petrels, *Procellaria parkinsoni*, monitoring, population estimates, breeding success, predation, bycatch, geo-locator, data-logger, foraging, Great Barrier Island (Aotea Island), New Zealand

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# 1. Introduction

The black petrel, *Procellaria parkinsoni*, is a medium-sized endemic seabird which is only known to breed on Hauturu/Little Barrier Island (36°199'S 175°082'E) and Great Barrier Island (Aotea Island) (36°187'S 175°4125'E), New Zealand (Heather & Robertson 1996). The main breeding area on Great Barrier Island (Aotea Island) (hereafter Great Barrier Island) is around the summit of Mount Hobson (Hirakimata) (hereafter Mount Hobson). Monitoring work carried out during the 2007/08 breeding season was a continuation of the survey and monitoring study begun in 1995/96 (Bell & Sim 1998a, b, 2000a, b, c, 2002, 2003a, b, 2005; Bell et al. 2007, 2009), adding to the baseline data on the Great Barrier Island black petrel population. Field work carried out in the 2006/07 season was privately funded and has not been reported as a DOC publication. The annual report for this season can be obtained from the lead author (EAB). Mark/recapture, breeding and population data from the 2006/07 season has been included in this (2007/08) report. This study will assist in identifying effects that long-line fishing, rat and cat predation and habitat disturbance may have on the population. The population estimate has been updated, ensuring that any population changes will be detected in time to implement the appropriate management strategies.

## 2. Objectives

The main objectives of this study were to undertake an annual census of the black petrel population on Great Barrier Island via burrow monitoring and the banding of adults and fledglings to establish levels of adult mortality, breeding success and recruitment, and to investigate at-sea distribution. 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 to:

- Monitor a sample of black petrel burrows within the main breeding area on Great Barrier Island and band all adults present in the burrows during December 2007 and January/February 2008, and all remaining fledglings during April 2008
- Collect data that will allow estimation of population size and trends
- Determine breeding success in the sample of long-term study burrows and record causes of breeding failure, such as predation or disappearance of parents
- 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
- Determine a population estimate by extrapolating from transect lines and census grids to the main Mount Hobson breeding area



- Continue the mark/recapture programme and band as many birds as possible during the breeding season to determine juvenile (pre-breeder) survival, 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. monitor the study burrows at the beginning, middle and end of the breeding season) and, where possible, identify the sex of the resident adult
- Use light geo-locator data-loggers to determine at-sea distribution of black petrels during their breeding season (incubation and chick rearing), and during migration to and residence in South America during their winter non-breeding period

## 3. Methods

### 3.1 STUDY BURROWS

The study area (35 ha at and around the summit of Mount Hobson; Fig. 1) was visited from 11 to 18 December 2007. During this visit the study burrows ( $n = 379$ , Figs 1–4) were checked for the presence of adults and eggs or chicks. The study burrows 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 the 1995/96 season (Bell & Sim 1998a, b, 2000a, b, c, 2002, 2003a, b, 2005; Bell et al. 2007, 2009). 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 into the chamber. This opening was covered by a piece of plywood, which was camouflaged with soil and debris. Any occupying adult was removed from the burrow, banded (or the band number recorded if a recapture), sexed by viewing the cloaca (if swollen, the bird is a female—the cloaca is particularly obvious immediately after egg laying), and returned to the burrow. The presence of any egg was noted.

On a second visit to the colony (planned for 17 January to 5 February 2008), the intention was to monitor the study burrows intensively. Because of very bad weather conditions, this trip was cut short (17–20 January 2008) and a further visit to the colony was made from 16 to 22 February 2008, when 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 (10–13 April 2008). All remaining fledgling chicks were banded. This information was used to determine breeding success.

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

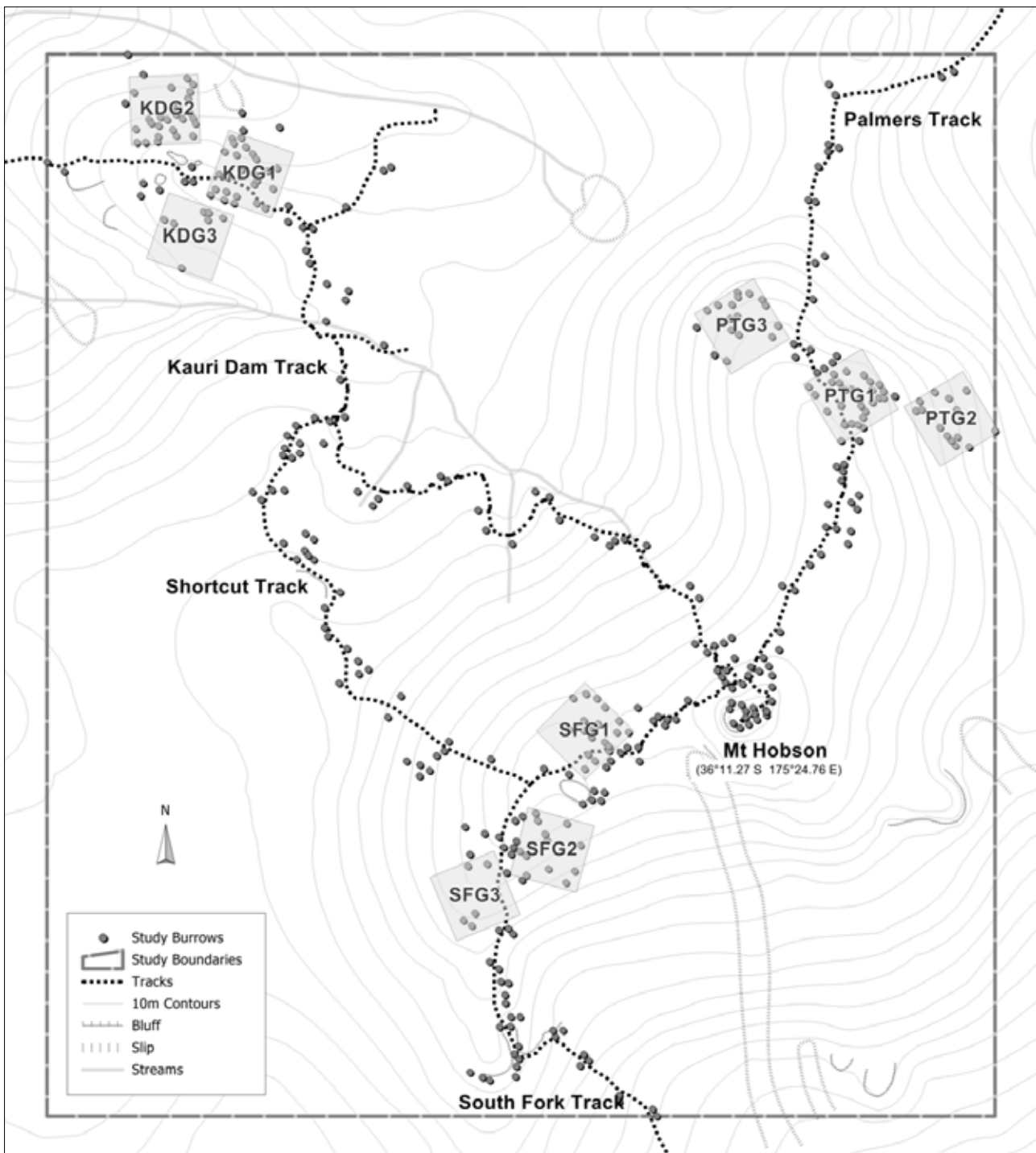


Figure 1. Location of the black petrel (*Procellaria parkinsoni*) study burrows and census grids within the study area on Great Barrier Island (Aotea Island). Altitude (621 m a.s.l.) is shown. Approximate North is shown (N). KDG = Kauri Dam Grid; SFG = South Forks Grid; PTG = Palmers Track Grid.

### 3.2 CENSUS GRIDS

The three original grids (KDG1, PTG1 and SFG1) were established in 1996 (Bell & Sim 1998a). These grids were located in areas that had a known historical presence of black petrels, different strata, vegetation types and topography and were near known petrel launch sites (Bell & Sim 1998a). 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, b).

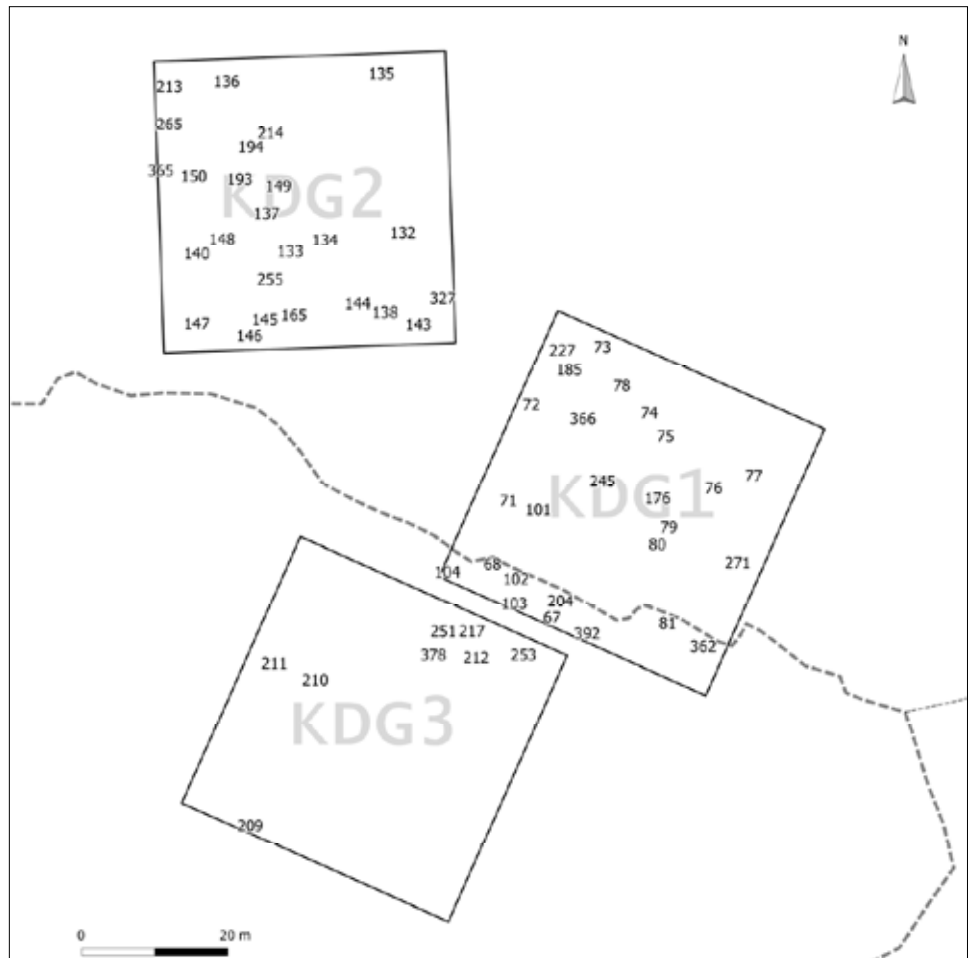
The nine census grids (each 40 × 40 m) set up around Mount Hobson were systematically searched (at 1-m intervals) during the December 2007 visit to locate any new burrows and to determine occupancy rates (Figs 1–4). The same procedure as for study burrows (see section 3.1) was followed for all birds in the burrows in the grids.

### 3.3 TRANSECTS

Twenty-six random transects were completed during the 2004/05 breeding season and seven of these were resurveyed in 2005/06 to determine burrow density throughout the study site (Bell et al. 2007, 2009). A further five were resurveyed during the December 2007 visit (LT8, 12, 17, 20 and 38). Any burrows located within the search area were treated in the same manner as given in the 2004/05 season report (Bell et al. 2007) and the same procedure as outlined in section 3.1 was followed for any bird caught in the transect burrows.

In the present (2007/08) study, four grades of petrel habitat were identified, based on the density of petrel burrows and incorporating habitat characteristics such as terrain (slope and aspect), vegetation (emergent tree species, dense or moderate canopy species and undergrowth species) and coverage (scrub, secondary growth, or primary forest).

Figure 2. Location of black petrel (*Procellaria parkinsoni*) burrows found on the Kauri Dam Grid (each grid is 40 × 40 m), Great Barrier Island (Aotea Island). Approximate North is shown (N).



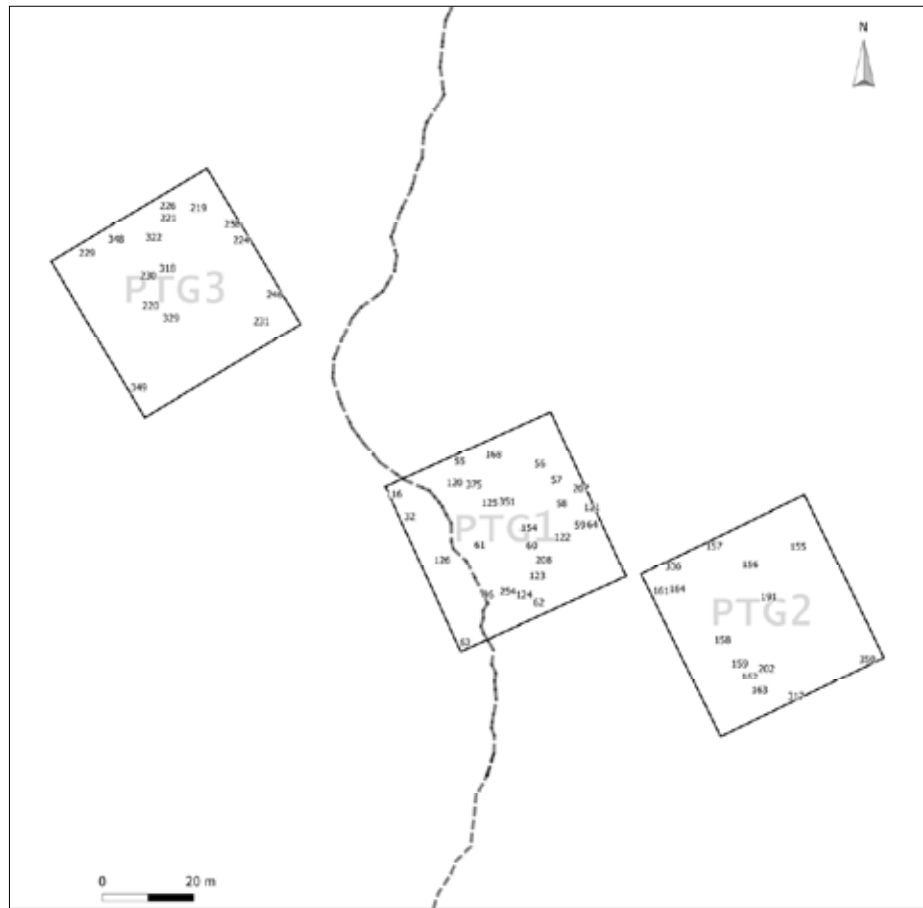
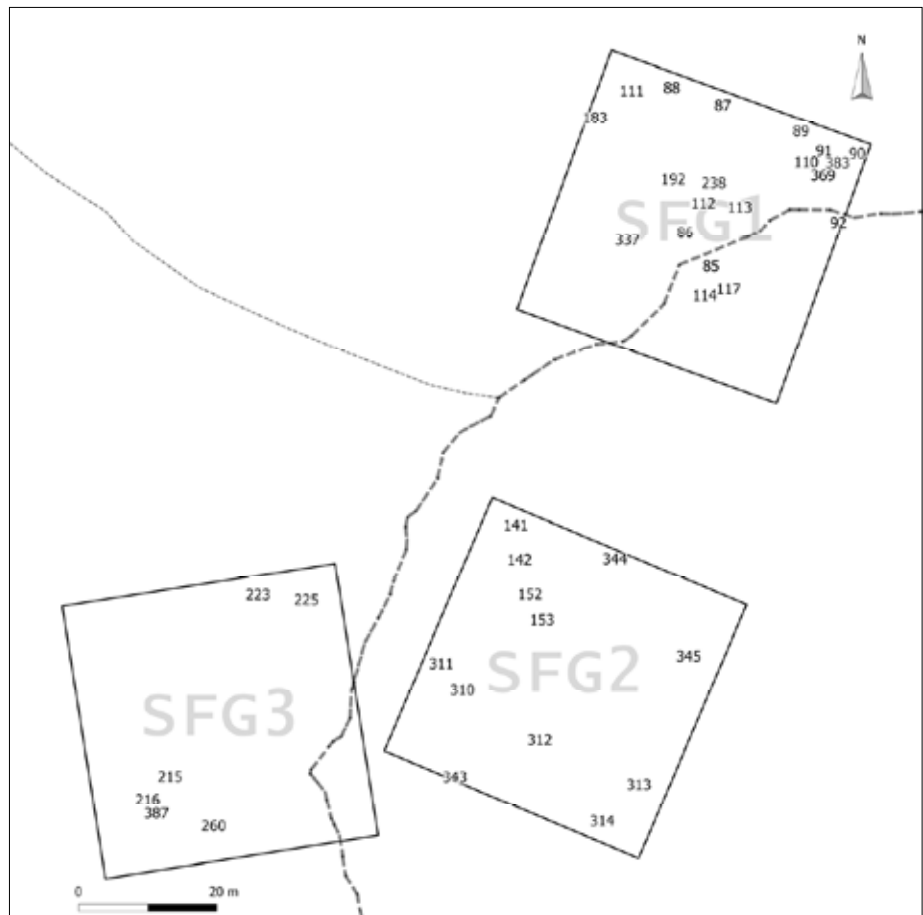


Figure 4. Location of black petrel (*Procellaria parkinsoni*) burrows found on the South Fork Grid (each grid is 40 × 40 m) on Great Barrier Island (Aotea Island). Approximate North is shown (N).



Each transect was then stratified using these four grades of habitat. The coverage area (two-dimensional only) of the four different grades of petrel habitat (non-petrel habitat, low-, medium- and high-grade petrel habitat) within the study site was determined using Manifold™.

### 3.4 NIGHT BANDING

Night work was undertaken during the December 2007 and January and February 2008 visits to the study area. This involved searching the study area by walking the track system and capturing any adult petrel on the surface. Several nights were also spent at known petrel launch sites, where birds were captured at take-off or landing. All birds were banded or had their band numbers recorded. During the December 2007 visit, sex was determined (if possible) by cloacal inspection.

### 3.5 POPULATION ESTIMATE

Bell et al. (2007) noted that previous population estimates determined by direct extrapolation from the nine census grids have overestimated the black petrel population size (Bell & Sim 1998a, b, 2000a, b, c, 2002, 2003a, b, 2005). This is because the original census grids were established in areas of known high petrel density, whereas the distribution of burrows over the whole 35-ha study area is not uniform. Extrapolation from the transect data might give a more accurate estimate, but it still fails to take into account the range of habitat types identified within the study site.

This can be shown by deriving three possible population estimates for the 35-ha study site:

- Extrapolating from the original census grids (multiplying their density values by 35)
- Extrapolating from transects only (multiplying their density values by 35)
- Extrapolating from the 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 the transects and census grids into those habitat types, and then extrapolating from the ranked transects to the habitat areas that make up the 35 ha)

For all estimates, any breeding burrow was treated as having two resident birds present and any non-breeding burrow 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).

Adult survival and the corresponding dispersion coefficient (Chat) value were calculated using the Cormack Jolly Seber model for adult survival over time ( $\Phi(t)$   $P(t)$ , where  $\Phi$  = apparent survival,  $t$  = time,  $P$  = probability of recapture.). Adult sex-linked survival was calculated using the Cormack Jolly Seber model ( $\Phi(\text{sex})$   $P(t)$  and  $\Phi(t) P(\text{sex}*t)$  where  $\Phi$  = apparent survival,  $t$  = time,  $\text{sex}$  = sex of bird,  $P$  = probability of recapture). Juvenile survival and corresponding Chat values were also calculated, using the Burnham Jolly Seber model, Population

trends were measured using multi-state models to determine the probability of changing states from chick to successful or non-successful breeder to non-breeder:  $S(.) P(.) \psi(\text{breeder to non-breeder} \cdot t)$ , where  $S$  = survival rate,  $P$  = probability of recapture,  $\psi$  = transition probability and  $t$  = time using five states (unknown status, successful breeder, unsuccessful breeder, chick, non-breeder). Adult survival was assumed to be constant and the probability of survival of chicks was set at 0.5 for the first 3 years and then 0.92 thereafter. These parameters were calculated by the Burnham Jolly Seber model. All parameters were determined using Program MARK (<http://welcome.warnercnr.colostate.edu/~gwhite/mark/mark.htm>). The goodness of fit of the models (i.e. likelihood value) was measured using Akaike's Modified Information Criterion (AICc). Models with lower AIC are better than those with higher AIC, i.e. it is more likely that the model fits the population and is likely to be an accurate explanation of, or value for, the parameter (such as survival).

### 3.6 GEO-LOCATOR DATA-LOGGERS

Twenty-eight LOTEK™ LAT2500 geo-locator data-loggers (Lotek Wireless, Ontario, Canada) were attached to known breeding adult black petrels during the December 2007 visit. The birds were chosen from the Kauri Dam area (within the study site) if they had been successful breeders for at least five seasons and had been in the same pair for over the same five seasons. These loggers were light (6 g) and small and glued to a specially designed holder, which was then attached to the bird's leg by two cable ties.

Twelve data-loggers were placed on known males, 4 were placed on known females and 12 were placed birds of unknown sex (of which 8 were suspected males and 3 were suspected female) from 25 burrows (both birds from three burrows were used). The data-loggers give data on position, flight time, time spent on the water, surface temperature and dive depth, recording temperature and pressure data every 6 minutes.

Eight loggers were retrieved during the January 2008 visit (three from males, one from a female and four from birds of unknown sex). Detailed plots of each bird's flight, together with spatial analysis in relation to bathymetry, environmental factors and fishing effort will be reported separately. Ethical approval for the use of all geo-locator data-loggers was given by the DOC Animal Ethics Committee (1 Dec 2007, AEC162).

## 4. Results

### 4.1 STUDY BURROWS

Of the 379 study burrows (those burrows that could be accessed to determine occupancy out of the 382 numbered burrows in 2007/08), 256 contained breeding birds, 65 contained non-breeding birds and 58 were empty (Tables 1 and 2). There were 54 failures (e.g. loss of eggs, infertility, predation, etc., Table 2). This corresponds to a breeding success of 77% (Table 2, Fig. 5).

Table 1 shows the percentage of occupied and empty burrows within the study burrows and the percentages of empty, breeding and non-breeding burrows. Data from the past ten breeding seasons show that the ratio of breeding to non-breeding burrows has averaged 3:1, but the ratio of occupied to non-occupied has varied greatly (Bell & Sim 2000a, b, 2000c, 2002, 2003a, b, 2005; Bell et al. 2007). Table 2 shows the failures and overall breeding success rate within the study burrows since 1995/96.

Figure 5 shows the trends in the numbers of empty, breeding and non-breeding burrows since the 1998/99 breeding season. It is apparent from the graphs that breeding success has been slowly increasing despite the number of burrows being used for breeding decreasing over the same time. The mean annual breeding success (1998/99 to 2007/08) within the study burrows is 75% ( $\pm 2$ , Table 1).

### 4.2 NUMBER OF BURROWS IN THE CENSUS GRIDS

A total of 148 burrows were found in the nine census grids (Table 3, Figs 2–4). Of these, 91 were used by breeding pairs, 38 were used by non-breeding adults and 25 burrows were empty (Table 3). Figure 6 shows the trend in the number of non-occupied, breeding and non-breeding burrows in the census grids since 1995/96.

TABLE 1. PROPORTIONS OF OCCUPIED, NON-OCCUPIED, EMPTY, 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.

| SEASON                           | OCCUPIED<br>BURROWS<br>(%)   | NON-<br>OCCUPIED<br>BURROWS<br>(%) | RATIO<br>(OCCUPIED<br>TO NON-<br>OCCUPIED) | EMPTY<br>(%)                 | BREEDING<br>BURROWS<br>(%)     | NON-<br>BREEDING<br>BURROWS<br>(%) | RATIO<br>(BREEDING<br>TO NON-<br>BREEDING) | BREEDING<br>SUCCESS<br>(%)   |
|----------------------------------|------------------------------|------------------------------------|--|------------------------------|--------------------------------|------------------------------------|--|------------------------------|
| 1998/99                          | 93                           | 7                                  | 13:1                                       | 7                            | 71                             | 23                                 | 3:1  | 77                           |
| 1999/00                          | 94                           | 6                                  | 16:1                                       | 6                            | 72                             | 22                                 | 3:1  | 73.5                         |
| 2000/01                          | 95                           | 5                                  | 19:1                                       | 5                            | 66                             | 29                                 | 2:1  | 76                           |
| 2001/02                          | 92                           | 8                                  | 12:1                                       | 8                            | 68                             | 24                                 | 3:1  | 70                           |
| 2002/03                          | 88                           | 12                                 | 7:1  | 12                           | 63                             | 25                                 | 3:1  | 69                           |
| 2003/04                          | 82                           | 18                                 | 5:1  | 18                           | 64                             | 18                                 | 4:1  | 76                           |
| 2004/05                          | 86                           | 14                                 | 6:1  | 14                           | 63                             | 23                                 | 3:1  | 80                           |
| 2005/06                          | 82                           | 18                                 | 5:1  | 18                           | 70                             | 12                                 | 6:1  | 67                           |
| 2006/07                          | 91                           | 9                                  | 10:1                                       | 9                            | 70                             | 21                                 | 3:1  | 82.5                         |
| 2007/08                          | 85                           | 15                                 | 6:1  | 15                           | 68                             | 17                                 | 4:1  | 77                           |
| <b>MEAN <math>\pm</math> SEM</b> | <b>89 <math>\pm</math> 2</b> | <b>11 <math>\pm</math> 2</b>       | <b>10:1 (<math>\pm 2</math>)</b>           | <b>11 <math>\pm</math> 2</b> | <b>67.5 <math>\pm</math> 1</b> | <b>21 <math>\pm</math> 2</b>       | <b>3:1 (<math>\pm 0.3</math>)</b>          | <b>75 <math>\pm</math> 2</b> |

TABLE 2. BREEDING SUCCESS AND CAUSES OF MORTALITY IN THE BLACK PETREL (*Procellaria parkinsoni*) STUDY BURROWS ON GREAT BARRIER ISLAND (AOTEA ISLAND) BETWEEN THE 1995/96 AND 2007/08 BREEDING SEASONS.

| YEAR                                | 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            |
|-------------------------------------|-----------------------|-----------|-----------|-----------|-------------|-----------|-----------|------------------|------------------|------------------|------------------|------------------|------------------|
| Number of study burrows             | 80                    | 118       | 137       | 197       | 248         | 255       | 283       | 318              | 324              | 362              | 366              | 370              | 379              |
| Eggs                                |                       |           |           |           |             |           |           |                  |                  |                  |                  |                  |                  |
| laid                                | 57                    | 92        | 95        | 142       | 178         | 168       | 192       | 199              | 208              | 226              | 257              | 257              | 256              |
| predation (rat)                     | 1                     | 6         | 1         | 2         | 9           | 6         | 5         | 1                | 2                | 3                | 15               | 0                | 5                |
| crushed <sup>1</sup>                | 0                     | 5         | 0         | 1         | 10          | 6         | 5         | 14               | 13               | 7                | 27               | 7                | 9                |
| abandoned                           | 0                     | 2         | 1         | 5         | 1           | 3         | 9         | 7                | 0                | 3                | 1                | 2                | 11               |
| infertile                           | 0                     | 6         | 4         | 12        | 6           | 8         | 3         | 2                | 7                | 4                | 0                | 1                | 4                |
| dead embryo                         | 0                     | 0         | 8         | 6         | 13          | 9         | 14        | 19               | 16               | 12               | 9                | 6                | 0                |
| disappeared egg <sup>2</sup>        | 2                     | 0         | 0         | 0         | 0           | 0         | 11        | 3                | 0                | 5                | 19               | 19               | 19               |
| unknown <sup>3</sup>                | 0                     | 0         | 0         | 0         | 0           | 0         | 0         | 5                | 0                | 0                | 0                | 0                | 0                |
| Chicks                              |                       |           |           |           |             |           |           |                  |                  |                  |                  |                  |                  |
| hatched                             | 54                    | 73        | 81        | 116       | 139         | 136       | 145       | 148              | 170              | 192              | 186              | 222              | 208              |
| predation (rat)                     | 0                     | 0         | 0         | 2         | 0           | 0         | 0         | 0                | 0                | 0                | 0                | 0                | 0                |
| predation (cat)                     | 0                     | 0         | 0         | 2         | 2           | 1         | 2         | 3                | 2                | 0                | 2                | 0                | 0                |
| died (disease)                      | 0                     | 1         | 0         | 0         | 0           | 0         | 0         | 0                | 0                | 0                | 0                | 0                | 0                |
| died (starvation)                   | 0                     | 0         | 1         | 0         | 0           | 0         | 0         | 0                | 0                | 0                | 0                | 0                | 0                |
| died (unknown causes)               | 0                     | 0         | 0         | 3         | 6           | 7         | 8         | 8                | 10               | 7                | 12               | 10               | 9                |
| disappeared chick                   | 0                     | 0         | 0         | 0         | 0           | 0         | 0         | 0                | 0                | 4 <sup>4</sup>   | 0                | 0                | 1                |
| fledged <sup>5</sup>                | 54                    | 72        | 80        | 109       | 131         | 128       | 135       | 137 <sup>6</sup> | 158 <sup>6</sup> | 181 <sup>6</sup> | 172 <sup>6</sup> | 212 <sup>6</sup> | 198 <sup>6</sup> |
| <b>OVERALL BREEDING SUCCESS (%)</b> | <b>94<sup>7</sup></b> | <b>78</b> | <b>84</b> | <b>77</b> | <b>73.5</b> | <b>76</b> | <b>70</b> | <b>69</b>        | <b>76</b>        | <b>80</b>        | <b>67</b>        | <b>82.5</b>      | <b>77</b>        |

- <sup>1</sup> These eggs have been crushed and only shell fragments were recovered from the burrow. Some may have been predated by rats, infertile or contained an embryo that died.
- <sup>2</sup> These eggs were present in December, but were gone when first checked in January. Many of the burrows had been cleaned out and the adults were not caught again.
- <sup>3</sup> There were five burrows not located in May 2003 and as a result it is not known if the eggs hatched successfully. To determine overall breeding success we have been cautious and assumed that they failed.
- <sup>4</sup> These chicks were present in February, but were gone in April. The chicks were too young to have fledged. Some may have been predated by rats or cats, or died due to starvation or disease and removed from the burrow by their parents.
- <sup>5</sup> All chicks still present at the end of the April trip. It is assumed all will fledge safely.
- <sup>6</sup> 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 and 8 in 2007/08). The remaining chicks were banded.
- <sup>7</sup> This breeding success rate is biased as most of these 80 study burrows were located in late February when chicks were already present (and these chicks were likely to survive to fledging).

Figure 5. Occupancy and breeding success of study burrows (1997/98 to 2007/08 breeding years) 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.

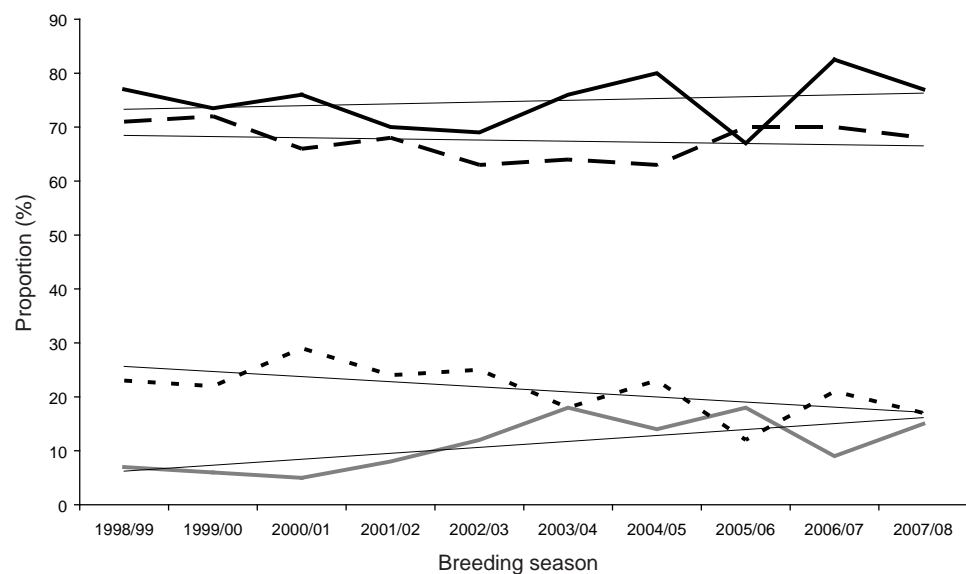
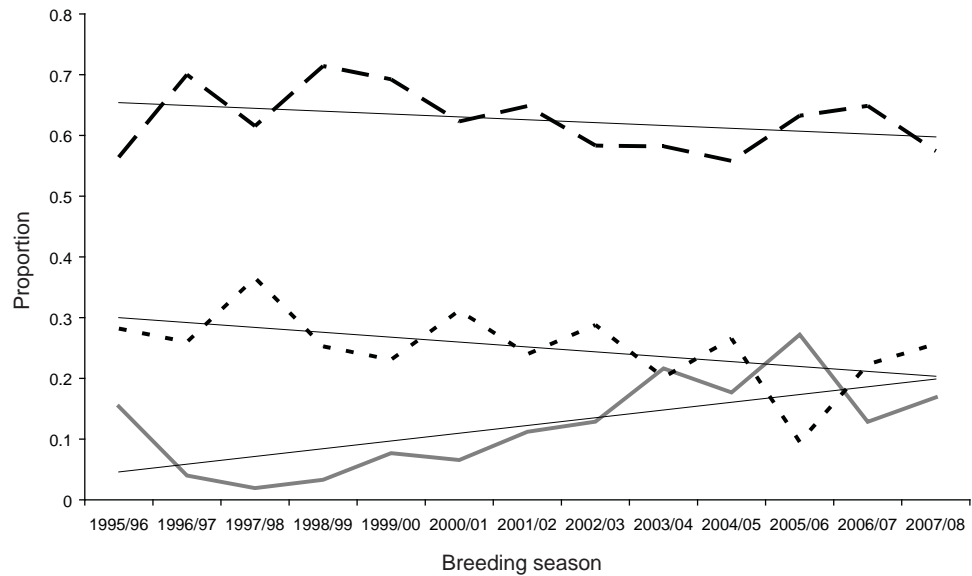




TABLE 3. TYPE AND NUMBER OF BURROWS WITHIN THE BLACK PETREL (*Procellaria parkinsoni*) CENSUS GRIDS (KAURI DAM, PALMERS TRACK AND SOUTH FORKS) IN THE STUDY AREA ON GREAT BARRIER ISLAND (AOTEA ISLAND), BETWEEN THE 1995/96 AND 2007/08 BREEDING SEASONS.

| YEAR       | KAURI DAM |          |              | PALMERS TRACK |          |              | SOUTH FORKS |          |              | TOTAL |       |    |    |
|------------|-----------|----------|--------------|---------------|----------|--------------|-------------|----------|--------------|-------|-------|----|----|
|            | EMPTY     | BREEDING | NON-BREEDING | EMPTY         | BREEDING | NON-BREEDING | EMPTY       | BREEDING | NON-BREEDING |       | TOTAL |    |    |
| 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 |
| GRID ONE   |           |          |              |               |          |              |             |          |              |       |       |    |    |
| 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 |
| GRID TWO   |           |          |              |               |          |              |             |          |              |       |       |    |    |
| 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             | 7        | 7            | 7           | 16       | 1            | 3     | 1     | 5  | 28 |
| 2007/08    | 1         | 4        | 2            | 7             | 9        | 5            | 2           | 16       | 1            | 3     | 1     | 5  | 28 |
| 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            | 7           | 16       | 1            | 4     | 0     | 5  | 28 |
| 2006/07    | 1         | 5        | 1            | 7             | 7        | 7            | 7           | 16       | 1            | 3     | 1     | 5  | 28 |
| 2007/08    | 1         | 4        | 2            | 7             | 9        | 5            | 2           | 16       | 1            | 3     | 1     | 5  | 28 |

Figure 6. Occupancy of census grid burrows (1995/96 to 2007/08) by black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island). Dashed black line = burrows used by breeding birds; dotted line = burrows used by non-breeding birds; solid grey line = unoccupied burrows.



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

### 4.3 TRANSECTS

During the 2004/05 breeding season, 26 transects had been measured and surveyed within the study area (Bell et al. 2007). Five of these transects were resurveyed this season. One new burrow was located along LT38 (and this is now being monitored as part of the study burrows). Vegetation and terrain information was also clarified. Details of the transects surveyed in 2007/08 are provided in Table 4.

Following resurveying work in 2005/06 and this season, four burrow density grades with corresponding habitat types were identified within the study 35-ha study area:

- High-grade petrel habitat on ridges or spurs, usually in established canopy, with high burrow density ( $\geq 100$  burrows/ha)
- Medium-grade petrel habitat on steep slopes, usually in established canopy or tall secondary growth, with medium burrow density (50–99 burrows/ha)
- Low-grade petrel habitat, on low slopes or flat ground, often boggy, with low burrow density (1–49 burrows/ha)
- non petrel habitat, on stream beds, cliffs, slips and swampy areas with scrub or *Garnia*, with no burrows

Using Manifold™, vegetation and terrain survey data and ranking transects, the two-dimensional area for each of the habitat types in the 35-ha study area was found to be 7 ha of high-grade petrel habitat, 17 ha of medium-grade petrel habitat, 10 ha of poor-grade petrel habitat and 1 ha of non petrel habitat (Fig. 7).