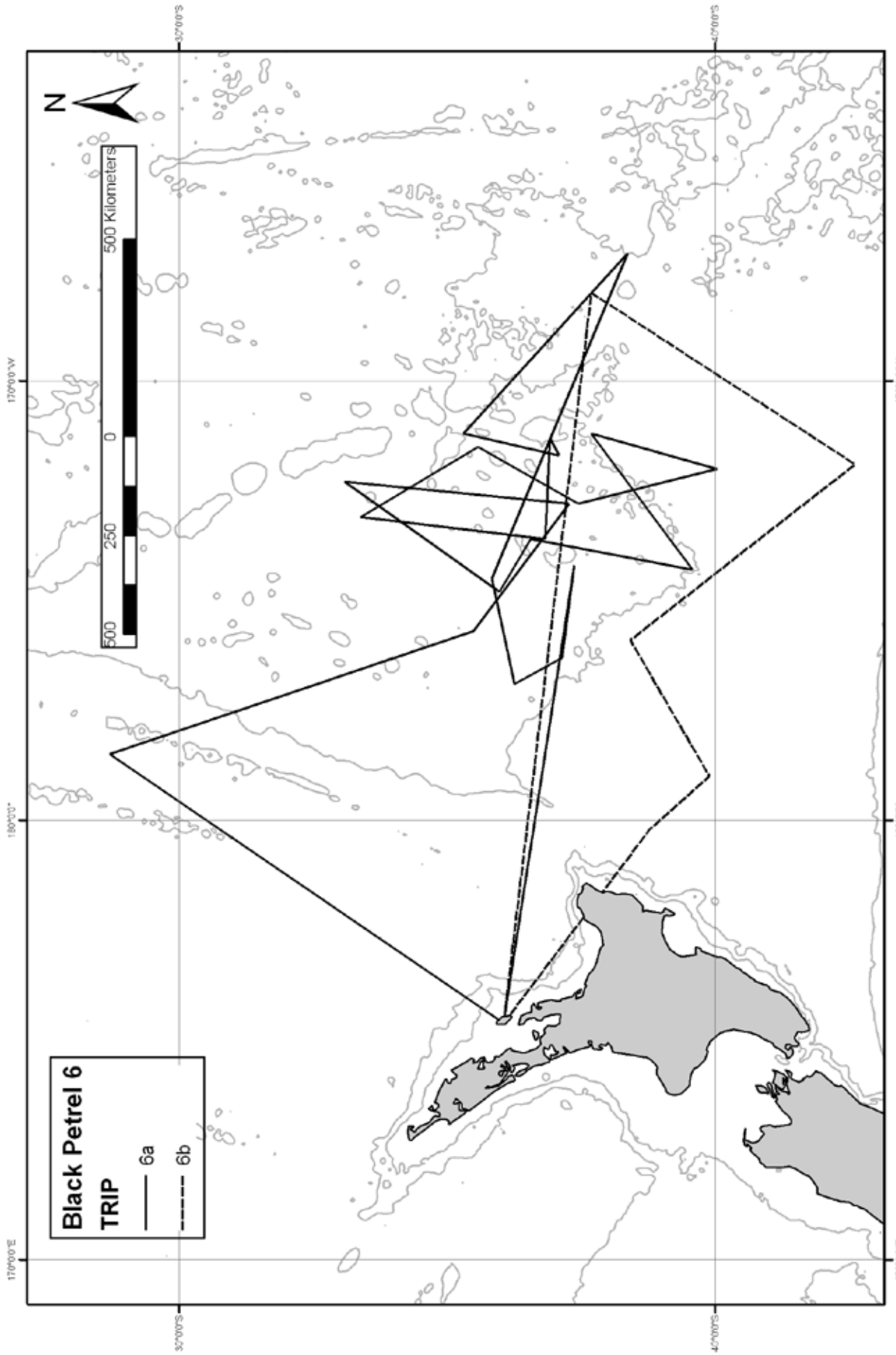

Figure 11. Geo-locator data-logger tracks from two trips made by black petrel (*Procellaria parkinsoni*) Bird 6 (H31023 (female)). Trip 6a (solid line) = 23 days, Trip 6b (dashed line) = 7 days.

A Burnham analysis of survival of chicks banded in the 35-ha study site between 1995 and 2005 was also completed. Only 50 of the more than 1100 chicks banded on Great Barrier Island have been recaptured. However, a model incorporating two chick survival parameters (one in which there was a single age-specific survival between 0–3 years and one for individuals > 3 years) gave an apparent survival estimate of 0.443 (± 0.02) during the first 3 years of life. This survival estimate increased to 0.979 (± 0.19) for birds > 3 years old.

4.7 GEO-LOCATOR DATA-LOGGERS

Of the 11 geo-locator data-loggers placed on known breeding birds during the incubation period, all were retrieved with reliable tracks from each logger. The loggers were worn for between 42 and 57 days, and the birds showed no apparent adverse affects (Appendix 2). The 11 birds came from nine burrows (both parents from burrow 71 and 102 had loggers attached (Appendix 2). Six chicks successfully fledged from these nine burrows and the remaining eggs failed due to the embryos dying inside the eggs (Appendices 1 and 2).

A total of 17 foraging trips were recorded (Appendix 2, Fig. 7). Six birds made two foraging trips and the remaining five birds made only one long foraging trip (Appendix 2; Figs 7–11). With the exception of one bird that made two very short trips, most trips (n = 11; 65%) of the trips were longer than 15 days and the maximum duration was 39 days (Appendix 2). Both males and females had variable foraging areas (Figs 7–11).

The birds mainly travelled to the west and east of northern New Zealand (Fig. 7), with the specific locations and lengths of foraging trips highly variable for both sexes. One bird (H27604, male) travelled much further south than the other birds (around Puyseger Point, Fiordland; Fig. 7) and another (H27534, male) travelled well north of New Zealand (to Fiji; Fig. 8). Four birds approached the Chatham Rise (Fig. 6) and four birds travelled towards Australia, with one bird (H25511, female) making two trips to similar areas on the Australian coast (Fig. 9). The presence of black petrels off the Australia coast had been previously confirmed through banding records—a pre-breeding adult (banded by the authors in the 2001/02 season) was captured off Australia in December 2004 and released alive (C.J.R. Robertson, Wild Press, pers. comm. 2005).

Although five birds foraged in the Bay of Plenty and East Cape area, two birds showed distantly different foraging patterns; one (H30866, male) made a trip through the Bay of Plenty to the East Cape area and towards the Chatham Rise (Fig. 10) and the other (H31023, female) made two trips to the same area of seamounts approximately 1100 km east of East Cape (Fig. 11).

5. Discussion

5.1 STUDY BURROWS

In the 2005/06 breeding season there were 172 breeding successes and 85 breeding failures, equating to an overall breeding success rate of 67%. This breeding success is the lowest since the study began (Table 1), but is still higher than rates reported in the earlier studies in 1977 (50%) and in 1978 (60%; Imber 1987) and in 1988/89 (62%; Scofield 1989). The level of rat predation was much higher in the 2005/06 season than previously recorded and this appears to have had an impact on overall breeding success. It was also assumed that 8 chicks fledged safely before the May 2006 banding visit (Table 1, note 9). Chicks were assumed to have fledged successfully if traces of down, quill sheaths, pin feathers and/or recent activity in the burrow could still be identified during the April 2006 visit. If any of these chicks had died or been predated earlier in the season, this would reduce the breeding success to 64%. The 67% breeding success rate is high compared with those for many other seabird species (such as Westland petrel (*Procellaria westlandica*) 39%–50%; Freeman & Wilson 2002; Warham 1996), but the apparent juvenile survival estimate (Section 4.6) suggests that as many as 50% of the chicks that fledge will not survive their first three years.

As previously mentioned, there was a much higher level of predation by both rats and cats in the 2005/06 season than in previous seasons (Table 1). Fifteen eggs were either predated or scavenged by rats (6% of all breeding attempts) within the study burrows and 19 eggs (7% of all breeding attempts) disappeared (but may have been predated by rats). Two juvenile petrels were predated by feral cats (1% of all breeding attempts), as were two adults from the study burrows. These were the first adults recorded as having been predated by feral cats in the study burrows. Three other juvenile petrels inside the study area, but not in study burrows, and two chicks outside the study area, were also predated by feral cats. All of the juvenile petrels appeared to have been predated after leaving their burrows to practise flying (stretching wings, attempting to fledge at a launch site, etc.), as their bodies were found in the open (EAB pers. obs.). Juvenile petrels are particularly vulnerable to feral cat predation just prior to fledging (Warham 1996). Adult petrels are also potentially vulnerable when they first return to the colony and sit on the ground outside burrow entrances calling to their mates. This appears to have been the case in both adult predation events, as the bodies were found very close to the burrow entrances in December 2005. Fourteen chicks are known to have been predated by cats between the 1997/98 and 2005/06 seasons (Table 1). It is important that cat trapping continues in the black petrel breeding area before, during and after the breeding season.

There were 172 chicks still present in the study burrows in May 2006 (Table 1). Compared with previous seasons, most chicks were in very good condition and many were about to fledge. The chick-banding trip was well-timed, as only eight chicks had already fledged and most chicks, although ready to fledge, were still present in their burrows. Chicks were noted trying to fledge on most nights, using trees and rocks in the area.

Although the number of burrows used for breeding has decreased since the 1999/00 season (Fig. 5), breeding success has remained relatively constant within a range of 67% to 84% (Table 1). Our analysis of all adult recaptures which found an 8% rate of birds skipping from successful breeding to non-breeding status, an 8% rate of skipping from unsuccessful breeding to non-breeding status (Table 9) and a reduction in the number of non-breeding birds (Fig. 5), could partially explain the decline in the number of burrows used for breeding. 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.; Warham 1996) may cause birds to move from or avoid the burrow and thus affect breeding success.

The decrease in the number of burrows used for breeding since 1999/00 and the increase in non-occupied burrows may be related to handler disturbance and observation hatches dug into burrows. Although birds do not appear to abandon the burrow at any time during the breeding season, they may choose to move to a new burrow the following year. Further surveys within the study area could determine whether birds have moved to nearby, but non-study, burrows to avoid disturbance. As stated earlier, the reduction in burrows used for breeding may also relate to changes in their characteristics, as several burrows have flooded in particularly wet years and collapsed over time, making then unusable for a year or more.

The percentage of burrows used by non-breeding birds has fluctuated since the 1997/98 season (but with a constant downward trend, Fig. 5). This means that the number of non-breeding or pre-breeding birds in the study area varies each season. This could be explained by transition rates, as 80% of non-breeding birds become breeding birds the following year (successful 49% or failed 31%, Table 9) and 20% remain non-breeding. This may relate to whether the birds were successful in creating and maintaining a pair bond that season (and then will attempt to breed the next season). It 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.

Data from the past nine breeding seasons (1997/98 to 2005/06) shows that the number of non-occupied study burrows has been increasing and in 2005/06 the percentage of non-occupied burrows was also higher than in most of the previous seasons (18%; Fig. 5). It was suggested that this may be directly related to handler disturbance or adult mortality (M. Williams, Victoria University of Wellington, pers. comm. 2005). Our analysis of adult survival and site fidelity suggested that black petrels have low apparent adult survival (79%) compared with other seabird species (e.g. Antipodean albatross (*Diomedea antipodensis*) 96%; Walker & Elliott 2004; Warham 1996; Table 8). However, approximately 10% of birds may be permanently emigrating from the study area (Bell et al. 2007). This may account for the declining occupancy of burrows, but as there has been an immigration event from Little Barrier Island, site fidelity and the possibility of emigration 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 work would require a thorough search for recovery data from banding records and continued (and wider) recapture effort at the study area. It should be noted that the fidelity model only used a small number of recoveries and that more work is needed to determine whether present survival estimates are true and to determine whether emigration or mortality have a larger effect.

5.2 CENSUS GRIDS

Nine grids were intensively monitored over three periods during the 2005/06 breeding season and only one new burrow was located in the grids (SFG1). This burrow was being dug out by a non-breeding bird (Appendix 1). As the black petrel study has progressed, the number of burrows found within the grids has increased from 118 in 1999/2000 to 148 in 2005/06. However, this increase this may be due to the increased search effort over the past two seasons (where complete searches of the census grids to find new burrows was undertaken).

New burrows do not necessarily mean that more birds are present in the colony, as 158 birds have moved between numbered burrows in the 35-ha study site and original burrows are no longer in use (due to collapse). Loss of a partner can result in a bird (particularly females) moving burrows (Warham 1996). Predation events and competition between adults and pre-breeders can also cause movement between burrows (Warham 1996). Males appear to be attracted back to their natal area and may excavate new burrows in those areas (Warham 1996). This has occurred on Great Barrier Island as several pre-breeding (or non-breeding) birds have returned to their natal area (and in ten 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 starting to excavate new burrows nearby, hence increasing burrow numbers in certain areas (and census grids).

5.3 BANDING DATA

A female (H30807) banded on Hauturu/Little Barrier Island is now breeding on Great Barrier Island. This is the first immigration event recorded for black petrels. Immigration has implications for population modelling work (as many models assume no immigration), and further surveys and mark-recapture work is needed to maximise the chances of recapturing known birds and returned fledglings.

There is probably a capture bias towards the returning adult males because certain aspects of their behaviour—i.e. calling outside burrows—make them easier to detect. Despite being attracted to calling males, adult 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 site. Much of the area within the study site is difficult to reach and cannot be searched. Aspects such as these will need to be taken into account in future survival and recruitment analyses.

Using the recapture data for chicks banded on Great Barrier Island, our Burnham analysis found that chick survival after the first 3 years increased to 97%, which is higher than the apparent adult survival (79%). This suggests that population decline in the monitored population is not associated with juvenile survival, as these survival figures are similar to those of other juvenile seabirds of this size (see literature review in Hunter et al. 2001). Again, these estimates may be biased by the low recapture rate of returned chicks. Further search effort throughout the year may increase the recapture rate; however, this effort may be limited by the difficulty in covering the entire study area imposed by the terrain. It is also possible that there is a bias towards the capture of male chicks, as their calling from outside the burrow makes them easier to detect. It is important that as many returned chicks as possible are captured so that more accurate survival estimates can be obtained.

5.4 POPULATION ESTIMATE

Three estimates for the population within the 35-ha study area were calculated by various means (Section 3.5, Tables 5–7). Surveys and local knowledge of Great Barrier Island showed that petrel burrow densities were not identical throughout the 35-ha summit study area, so there was concern that extrapolating from the census grids (i.e. known high burrow density areas) or from random transects to the entire 35-ha study area was likely to overestimate the black petrel population. These estimates are likely to incorrectly estimate the population by not adequately taking into account the range of habitat types and burrow densities identified with the study site. The estimates from the census grids (4977 ± 969 birds) and transects (4346 ± 470) birds) proved to be higher than the estimate produced by stratifying the 35-ha study site into four petrel burrow density grades (incorporating habitat characteristics) (3604 ± 450 birds). The stratification method probably gave the most accurate population estimate.

Further transects throughout the study area could improve this population estimate as well as allowing the four burrow density ranges within the area to be more accurately defined (and, possibly, more areas to be identified). It will also be important to examine the difference between two- and three-dimensional estimates of density and population size in this steep and difficult terrain.

The black petrel breeding population was estimated at approximately 1300 breeding pairs. 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.

To gain a better population estimate of the whole black petrel population on Great Barrier Island, further surveys would need to be undertaken in other areas on the island. In addition to the summit area, black petrels are also 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 in these areas would give a better idea of burrow density and range around the island. These surveys could be undertaken on or near Mount Heale, The Hogs Back, and Mount Matawhero in the Mt Hobson area. It is interesting to note that several pairs of black petrels 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.

5.5 ADULT SURVIVAL AND POPULATION TRENDS

The apparent adult survival estimates for black petrels in the study area (79%; Table 8) were unusually low for a seabird of its size, but comparable with other adult black petrel survival estimates made by Hunter et al. (85%; 2001). The data also suggested that adult survival has increased between 1995/96 and 2005/06 (Table 8). This may relate to the regular increase in the number of study burrows monitored over the study period and increased night capture effort (i.e. surveys carried out every night for seven nights during the December trip).

5.6 DATA-LOGGERS

Very little is known about the foraging range and at-sea distribution of black petrels beyond anecdotal records from bird-watching expeditions, fishermen, Ministry of Fisheries observers on fishing boats, and other vessels. However, these records only give general locations and may reflect the black petrel's habit of following boats to scavenge discarded fish waste.

The geo-locator data-loggers indicated that black petrels use a range of foraging areas (Figs 7–11). Although based on a small sample size (n = 11), the results of the trip recording indicate that black petrels prefer to forage on the continental shelf or seamounts, as most of the tracked birds seemed to make direct flights to specific water depths (as indicated by bathymetric contours) and/or underwater features such as seamounts, ridges or trenches (Figs 7–11). This pattern of behaviour occurred during both incubation and chick rearing, but the foraging trips during incubation were longer. In addition, the foraging locations of males and females appear to overlap.

The trips recorded by the geo-locator data-loggers during incubation (December to January) commonly alternated between a short trip (2–6 days) and a longer trip (15–22 days). The birds appeared to make more direct flights to feeding locations on shorter-duration trips (e.g. Fig. 10) compared with longer-duration trips, but further logger work is needed to confirm these preliminary results. Determining foraging behaviour throughout all stages of the breeding season (honeymoon, egg laying, incubation and chick rearing) may show increased variations in foraging locations and length of trips, as these may depend on the stage of breeding; for example, during incubation the adult only has to feed itself (and maintain condition for breeding and sitting for long periods on the egg) compared with chick rearing, when it also has to find extra food for the chick.

It is very important that further data-logger work be carried out to confirm and build on these preliminary results. To ensure a statistically viable data set, loggers should be deployed on at least 30 adult black petrels continuously for two breeding seasons (December 2007 (2007/08 season) to March 2009 (2008/09 season)). This would enable tracking during incubation, chick rearing, migration to South America, the non-breeding season in South America and migration back to the New Zealand breeding location; and further tracking during incubation and chick-rearing trips through the second breeding season.

5.7 CONSERVATION

A recent estimate indicates that about 6640 people visit Mount Hobson each year (Peter Cann, DOC, pers. comm.), but this use appears to have little or no impact on the breeding success of the black petrels in the area. Information about the black petrels at the track start/end points and on the summit has increased awareness of the birds and the unique environment they inhabit. However, littering and public fouling (defecation), which continues to be a problem in the summit area, is of concern because it may introduce disease or lead to an increase in rat numbers.

As stated in earlier reports (Bell & Sim 2000a, b, c, 2002, 2003a, b, 2005; Bell et al. 2007), the construction of raised walkways around the summit has decreased damage to the environment and, especially, to the black petrel burrows. As serious erosion continues to occur along the summit ends of the South Fork and Palmers Tracks (EAB, pers. obs.), the boardwalk system should be extended.

A total of 11 black petrels (including one banded by the authors) were recorded as bycatch on domestic longline vessels in the New Zealand fisheries between 01 October 1996 and 30 September 2005 (Robertson et al. 2004; Conservation Services Programme 2008). All of these birds were caught between November and April, either east of North Cape, near the Kermadec Islands or north of Great Barrier Island (Robertson et al. 2003, 2004; Conservation Services Programme 2008). The timing of their captures suggests that most may have been breeding adults. This means that their deaths would have reduced overall productivity and recruitment. 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. Data-loggers could also be used to identify areas of overlap with fisheries outside New Zealand waters.

Black petrels have delayed maturity, low reproduction rates and high adult survivorship. As a result, any change in adult survivorship, however small, will affect the population greatly (Murray et al. 1993). If breeding adults continue to be caught on long-lines in New Zealand and overseas waters, the species could be drastically affected. It is therefore important that monitoring of the Great Barrier Island black petrel population continues. An accurate population model is needed to determine adult survivorship, recruitment, mortality and productivity. Long-term population data, improved technology and further use of data-loggers can be used to develop this model, which could also be used to assess factors affecting the black petrel population, identify likely overlap areas with fisheries and estimate the effects of fisheries bycatch.

6. Recommendations

Based on the findings of this study (and previous years' reports), 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 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, mortality and the effects of predation, fisheries bycatch and other environmental factors (e.g. El Nino).
- The November/December visit to the study area should be continued. Visiting at this time allows 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 recaptures will enable the continuation of the mark-recapture programme.

- The study burrows could be checked for breeding status during every visit to the study site, to give a more accurate estimate of breeding success and to determine the sex of adults occupying the burrows. This would also provide chance to recapture returning birds banded as chicks.
- The April/May visit should continue, as this allows time for chicks to be banded before they fledge.
- A sample of 30 black petrels should carry GPS data-loggers and/or geo-locator data-loggers for 16 months (December 2007 to March 2009) to provide data on foraging distances and locations, water temperature and flight patterns throughout the breeding and non-breeding seasons.
- The exact limits of the entire Mount Hobson black petrel colony should be established and the area of the colony calculated by a ground truth survey. Random transects should be established on other high points around the Mount Hobson area (e.g. Mount Heale, Mount Matawhero and The Hogs Back). These sites should be monitored as long as the study continues.
- Cat trapping should be implemented before and during the black petrel breeding season (November to June) especially during pre-laying (October/ November) and the fledging period (May to June).
- The walkway systems down Palmers (Windy Canyon) and South Fork Tracks should be extended. Construction should be completed between July and mid-October, when the chicks have fledged and before the adults return. This work will require full consultation with the appropriate experts to prevent the accidental destruction of known burrows and important plant species around the summit area.

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Appendix 1

Results from the study of black petrel burrows (n = 369) near Mount Hobson, Great Barrier Island during the 2005/06 breeding year

Study burrows within census grids have their location noted (in brackets) in the burrow column: Palmers Track grid one, two, three (= PTG1, 2, 3); South Fork Grid one, two, three (= SFG1, 2, 3); or Kauri Dam Grid one, two, three (= KDG1, 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 asterisk represents a dead adult. Grey-shaded box represents a non-study burrow.

BURROW	BAND	OUTCOME
1	H31370 ?	Rat predation
2	H34770 (M) H34939 (F)	Disappeared egg
3	H31109 (M) ?	Chick H33547
4	H23017 (M) H28100 (F)	Disappeared egg
5	H31161 H33324	Non-breeder
6	H14014 (M) ?	Chick H33540
7	H31272 H30854	Chick H33588
8	H31103 (M) H31273 (F)	Chick H33589
9	?	Non-breeder
10	? ?	Crushed egg
11	H31458 H31585	Non-breeder
12	H33612 (M) H34870 (F)	Chick H31321
13	H34760 (F) H33089 (M)	Disappeared egg
14	H31284	Non-breeder
15	H25488 ?	Chick H31337
16	H34949 H34976	Disappeared egg
17	H31108 (M) ?	Chick H34994
18	H31204 H33326	Chick H33519
19		Empty
20	H34264 H25476 (M) H33457	Non-breeder
21	H33466 (M) H34956 (F)	Disappeared egg
22	H33320 (M) ?	Crushed egg
23	H33461 (F) ?	Disappeared egg
24	H25663 H33465 H34986	Non-breeder
25	? H31217 (M)	Chick H33538
26	H34963	Non-breeder
27	?	Non-breeder
28		Empty
29	H28004 (M)	Chick H33552
	?	
30	?	Non-breeder

Continued on next page

Appendix 1 continued

BURROW	BAND	OUTCOME
31	H34944 (F) H34874 (M)	Dead chick
32 (PTG1)	H34783 ?	Chick H33531
33	H31244 ?	Dead chick
34	H31248 (F) H31121 (M)	Chick H33543
35	H33654 ?	Chick H31333
36	H33460 ?	Crushed egg
37	H28036 (F) H31107 (M)	Crushed egg
38		Empty
39	H25426 (M) H31578 (F)	Chick H33515
40		Empty
41	H31112 H31029	Chick H33529
42	H33948 ?	Chick H31320
43	H25546 (M) H31586 (F)	Chick (unbanded)
44	H31130 H25424	Chick (fledged before banding)
45		Empty
46	? ?	Crushed egg
47	? H31018 (M)	Chick H31322
48	H31003 H31003	Dead chick
49	H31243 H31010	Chick H33503
50	H33747 (F) H31282 (M)	Chick H33504
51	? H22169 (M)	Chick H33535
52	H31289 H34965	Non-breeder
53	H34964 ?	Chick H33534
54		Empty
55 (PTG1)	? H33638	Chick H31334
56 (PTG1)		Empty
57 (PTG1)	H31153 (M) ?	Dead chick
58 (PTG1)	H28029 H31205	Dead embryo
59 (PTG1)	H31125 ?	Chick H31336
60 (PTG1)	H33659 (M)	Non-breeder
61 (PTG1)	H25505 (F) H30878 (M)	Chick H31346
62 (PTG1)	H31257 (M) ?	Cat predation
63 (PTG1)	H31424 H33267	Chick (H33533)
64 (PTG1)	H33713 H31366	Chick (fledged before banding
65	H31460 (F) ?	Dead embryo
66	H30874 H34853	Non-breeder
67 (KDG1)	H31270 (F) H31271 (M)	Chick H33563
68 (KDG1)	H32005 (F) H31172 (M)	Chick H33567
69	H27604 (M) H31240 (F)	Dead chick
70	H27665 (M) H31992 (F) H25536 (M)	Chick H33569
71 (KDG1)	H31023 (F) H31242 (M)	Chick H33568
72 (KDG1)		Empty
73 (KDG1)	H28572 (M) H30876 (F)	Chick H33590
74 (KDG1)	H31974 H29693	Chick H33591

Continued on next page

Appendix 1 continued

BURROW	BAND	OUTCOME
75 (KDG1)	H25421 H33314	Chick H33592
76 (KDG1)	H33758 ?	Chick H33593
77 (KDG1)	? H30870 (M)	Chick H33594
78 (KDG1)	H34875 H30867	Crushed egg
79 (KDG1)	? ?	Rat predation
80 (KDG1)	H29682 (F) H25404 (M)	Rat predation
81 (KDG1)	H31155 (F) ?	Chick H33561
82	H25635 (M) H33453 (F) H34736 (M)	Disappeared egg
83	H34781 (M)	Non-breeder
84	H 29677 (M) H33463 (F)	Disappeared egg
85 (SFG1)	? H31118 (M)	Chick H31326
86 (SFG1)		Empty
87 (SFG1)	H25664 H34954	Crushed egg
88 (SFG1)		Empty
89 (SFG1)	H30910 H31495	Chick H31327
90 (SFG1)	? H33097 (M)	Chick H31328
91 (SFG1)	? ?	Chick H31329
92 (SFG1)	H33660 (F) H32928 (M)	Chick H31331
93	H33655 (F) ?	Dead chick
94	H23018 H31028	Chick (unbanded)
95	H34262 H34938	Crushed egg
96 (PTG1)		Empty
97	H30872(M) ?	Chick H33517
98	?	Non-breeder
99	? H31201	Chick (fledged before banding
100	H29660 (M) H32924 (F)	Dead embryo
101 (KDG1)	? H25588	Chick H33596
102 (KDG1)	H22511 (F) H30866 (M)	Dead embryo
103 (KDG1)	H29690 H25673 H32905 H35000	Non-breeder
104 (KDG1)	?	Non-breeder
105	?	Non-breeder
106	H31038 H25458	Non-breeder
107	H33799 (F) H33764 (M)	Chick H33507
108	? H25452 (M)	Disappeared egg
109	H31052 ?	Chick H33596
110 (SFG1)	H31008 (M) H31007 (F)	Chick H31330
111 (SFG1)	? H31986	Crushed egg
112 (SFG1)	H28037 (M) H34796 (F)	Crushed egg
113 (SFG1)	H33322 (M) H25409 (F)	Disappeared egg
114 (SFG1)	H25453 H31142	Chick H31325
115	H31031 ?	Chick H33539
116 (PTG1)	H25411 ?	Disappeared egg
117 (SFG1)	H33693 H25664	Non-breeder
118	H31985 ?	Chick H31324

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Appendix 1 continued

BURROW	BAND	OUTCOME
119	? H31055	Chick H33530
120 (PTG1)	H32099	Non-breeder
121 (PTG1)	H25455 ?	Crushed egg
122 (PTG1)	H34988	Non-breeder
123 (PTG1)	H31053 ?	Chick H31345
124 (PTG1)	H28032 H33478	Non-breeder
125 (PTG1)	?	Breeder
126 (PTG1)	H33477 ?	Chick H33532
127	H34747 ?	Crushed egg
128	H31054 ?	Chick (unbanded)
129		Empty
130		Empty
131	H34948 H34970	Crushed egg
132 (KDG2)		Empty
133 (KDG2)	H25525 (M) H32027 (F)	Non-breeder
134 (KDG2)	H33313 (F) ?	Chick H33583
135 (KDG2)	? H25447	Rat predation
136 (KDG2)	H29691 H29699	Crushed egg
137 (KDG2)	H25494 (F) H31572 (M)	Chick H33582
138 (KDG2)	H33306 (M) H31565 (F)	Chick (fledged before banding)
139	H14012 (F) H23035 (M) H32980 (M)	Chick (fledged before banding)
140 (KDG2)	H25507 (F) H33484 (M)	Chick H33573
141 (SFG2)	?	Breeder
142 (SFG2)	H28026 H28027	Chick (unbanded)
143 (KDG2)		Empty
144 (KDG2)	H25459 H34969	Chick H33586
145 (KDG2)	H34947 H28074	Non-breeder
146 (KDG2)	H25460 ?	Chick H33564
147 (KDG2)	H34720 H34945	Non-breeder
148 (KDG2)	H27534 (M) H25483 (F)	Chick H33574
149 (KDG2)	H31569 (M) H25401 (F)	Chick H33581
150 (KDG2)	? H25493	Chick H33576
151	H25593 (M) H29674 (F)	Non-breeder
152 (SFG2)	H31983 (M) ?	Chick (unbanded)
153 (SFG2)	? ?	Chick (unbanded)
154 (PTG1)		Empty
155 (PTG2)	H33792 H33473 H34989	Non-breeder
156 (PTG2)	H33472 (F) H31559 (M)	Chick H31339
157 (PTG2)		Empty
158 (PTG2)	H25440 (F) H31451 (M)	Crushed egg
159 (PTG2)	H25441 (F) H31557 (M)	Chick H31342
160	H25690 (M) H29671 (F)	Chick (unbanded)
161 (PTG2)	H31542 (M) ?	Chick H31336
162 (PTG2)	H29658 (F) ?	Crushed egg
163 (PTG2)	H33658 H34961	Dead chick

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Appendix 1 continued

BURROW	BAND	OUTCOME
164 (PTG2)	H33606 (M) H34962 (F)	Chick H31343
165 (KDG2)	H29700 ?	Chick H33485
166	H25437 (M) ?	Chick H31335
167	H28012 (M) H33657 (F)	Rat predation
168 (PTG1)		Empty
169		Empty
170	H33770 (F) ?	Dead embryo
171	H28006 ?	Chick H33516
172	H31048 (M) H34727 (F)	Dead chick
173	H31143 H28018	Chick (unbanded)
174	H28071 (F) ?	Dead embryo
175	H25503 (M) H28001 (F)	Chick H34996
176 (KDG1)	H27702 ?	Crushed egg
177	H31462 H31459	Rat predation
178	H33302 (M) H34715 (F)	Rat predation
179	H25694 (M)	Non-breeder
180	H31560 ?	Chick (unbanded)
181	H31463 (M) H31561 (F)	Chick (fledged before banding)
182	H25514 H34864	Chick (unbanded)
183 (SFG1)	H32063 H34985	Non-breeder
184	H34781 (M)	Non-breeder
185 (KDG1)		Empty
186	H31577 ?	Chick H33513
187	H31047 H31452	Chick H33514
188	*H26956 (F) H34971 H34872	Non-breeder
189	H34758 (M) H34868 (F)	Rat predation
190	H34738 ?	Disappeared egg
191 (PTG2)	H34800 ?	Chick H31340
192 (SFG1)		Empty
193 (KDG2)		Empty
194 (KDG2)		Empty
195	H33311 H33327	Chick H33575
196	? ?	Chick (unbanded)
197	? H29685	Disappeared egg
198	H25699 (M) H31593 (F)	Disappeared egg
199	? ?	Rat predation
200	H34265 H28073	Chick H33518
201	H31581 (M) H28002 (F)	Chick H33502
202 (PTG2)	H33329 (F) H28031 (M)	Chick H31341
203	H29668 (F) H30930 (M)	Chick H33553
204 (KDG1)	H34726 H34999	Chick H33562
205	? H29664	Chick H33506
206		Empty
207 (PTG1)		Empty
208 (PTG1)	H29912 ?	Dead embryo
209 (KDG3)		Empty

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Appendix 1 continued

BURROW	BAND	OUTCOME
210 (KDG3)	H25691 (M) ?	Chick H33565
211 (KDG3)	H33310 (F) H25669 (M)	Chick H33566
212 (KDG3)	H28040 (F) H30869 (M)	Chick H33564
213 (KDG2)		Empty
214 (KDG2)	H25687	Non-breeder
215 (SFG3)		Empty
216 (SFG3)	H28051 (M) H29673 (F) H25651 H33470	Rat predation
217 (KDG3)	H31991 H32903	Dead embryo
218	H34731 H32010	Chick H33527
219 (PTG3)		Empty
220 (PTG3)		Empty
221 (PTG3)	H33704 ?	Chick H33523
222	H29657 (F) H28049 (M)	Chick H33541
223 (SFG3)	H33673 ?	Chick (unbanded)
224 (PTG3)	? H25564	Chick H33521
225 (SFG3)	H31600 H13634	Chick (fledged before banding)
226 (PTG3)	H27058 ?	Chick H33522
227 (KDG3)	? H33702	Chick H33587
228	? H33308 (F)	Chick H34990
229 (PTG3)	H28042 ?	Chick H33525
230 (PTG3)		Empty
231		Empty
232		Empty
233	H29698 H25558	Cat predation
234	H25571 (M) ?	Dead embryo
235	H25566 (F) H28044 (M)	Chick H33526
236	? ?	Crushed egg
237		Empty
238 (SFG1)		Empty
239	H25700 (F) H32013 (M)	Chick H33554
240	*H31973 (M) H33777 (F)	Chick H33545
241	H34769 H34975	Non-breeder
242	H28099 ?	Chick (unbanded)
243	H33264 (M) H30807 (F)	Chick H33556
244	H33757 (F) H33800 (M)	Chick H33557
245 (KDG1)	H34753 ?	Chick H33595
246 (PTG3)	H25586 (M) ?	Chick H33520
247	H33499 H34951	Non-breeder
248	H33307 (F) H28067 (M)	Chick (unbanded)
249	H33760 ?	Disappeared egg
250	H31168 (F) H30924 (M)	Rat predation
251	?	Non-breeder
252	H34852 (F) ?	Chick H31312
253		Empty
254		Empty
255		Empty

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Appendix 1 continued

BURROW	BAND	OUTCOME
256		Empty
257	H30877 H33759	Chick H33599
258 (PTG3)		Empty
259	H32025 (M) H33495 (F)	Chick H33506
260 (SFG3)	H33266 (M) H14009 (F)	Chick (unbanded)
261	H32021 H34983	Dead chick
262	H32902 (F) H34739 (M)	Crushed egg
263	H28085	Non-breeder
264		Empty
265 (KDG2)	H33312 H33492	Chick H33577
266	H31975 (M) H25444 (F)	Chick H33555
267		Empty
268		Empty
269	H34958 H34959	Non-breeder
270	H33669 (M) H33791 (F)	Chick H33510
271 (KDG1)	? H32920 (M)	Crushed egg
272	?	Breeder
273	H33708 (M)	Non-breeder
274	H23034 H33706	Chick (unbanded)
275	H34978	Non-breeder
276		Empty
277	? H33620	Chick H311311
278	H34751 (F) H34757 (M)	Chick H31316
279		Empty
280	? H33319 (F)	Crushed egg
281	H33602 ?	Chick H31317
282	H33652 H33643	Crushed egg
283		Empty
284		Empty
285		Empty
286		Empty
287	H33670 (F)	Chick
	H33699 (M)	(unbanded)
288	H33705 ?	Rat predation
289	H33621 (M) H34955 (F)	Chick (fledged before banding)
290	? H33617 (M)	Disappeared egg
291	H33618 (M) ?	Chick H33505
292	H31966 ?	Dead chick
293	? H33317	Chick H31310
294	H32931 (M) H34869 (F)	Chick H31319
295	? H33630 (M)	Rat predation
296	H28054 (F) H33682 (M)	Chick H33544
297	H33755 H28034	Chick H33511
298	H33646 H25579	Crushed egg
299	H34937 (M) H34980	Non-breeder
300	H33716 (M) H33497 (F)	Chick H31313
301	H33768 (M) H28060 (F)	Chick H33597
302	H33686 (M) H33787 (F)	Chick H31318

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Appendix 1 continued

BURROW	BAND	OUTCOME
303	H33797 (F) H34977 H32004 (M) H33464	Crushed egg
304		Empty
305	H33645 H33788	Chick (unbanded)
306		Empty
307	H33796 H34876	Chick H34991
308		Empty
309	H28020 H33476	Chick H33512
310 (SFG2)		Empty
311 (SFG2)		Empty
312 (SFG2)		Empty
313 (SFG2)	H34865 H34900	Chick (unbanded)
314 (SFG2)		Empty
315	H33714 H33318	Chick H31315
316	H33715 H33325	Chick H34992
317 (PTG2)		Empty
318 (PTG3)		Empty
319	H33722 ?	Dead chick
320	H34941 (M) H33475 (F)	Chick H34995
321	H34968 H33771 H33617 (M)	Chick H33549
322 (PTG3)	H25555 (M) H34300 (F)	Chick H33543
323	H27504 (F) H27526 (M)	Chick (unbanded)
324	H13638 H34952	Abandoned egg
325	? ?	Chick H31332
326	H34742 (F) H25688 (M)	Chick H33546
327 (KDG2)	H34257 (F) H33498 (M)	Rat predation
328	H33093 (F) H33491 (M)	Chick H33571
329 (PTG3)	H33637 (M) ?	Chick H33528
330	H33090 (M) ?	Chick H33542
331	H34967	Rat predation
332	H34730 ?	Chick H33550
334	? ?	Crushed egg
335		Empty
336 (PTG3)		Empty
337		Empty
338	H34766 H34946	Chick H33578
339	H34722 H33493	Chick H33579
340	H33458 ?	Dead chick
341	H34858 H33459	Chick (unbanded)
342	H25648 (M)	Non-breeder
343 (SFG2)		Empty
344 (SFG2)	H33471 (F) H34984 (M)	Chick (unbanded)
345 (SFG2)	H34861 ?	Chick (unbanded)
346	H34795 (M)	Non-breeder
347	H33496 ?	Chick (H33600)
348 (PTG3)		Empty
349 (PTG3)		Empty
350 (PTG3)		Empty
351 (PTG1)	H34266 ?	Chick (unbanded)

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Appendix 1 continued

BURROW	BAND	OUTCOME
352	H33481 H34966	Disappeared egg
353	H33479 ?	Chick H33536
354	H33480 ?	Chick H33537
355	H33467 (M) ?	Disappeared egg
356	H28804 ?	Chick H33509
357	H34982 ?	Crushed egg
358	H33494 N33474	Chick H34993
359	H34771 (M) H34940 (F)	Chick H33501
360	H33482 ?	Chick H33558
361	H33483 (F) ?	Chick H33559
362 (KDG1)	H33490 H34987	Chick H33560
363	H31238 (F) ?	Chick H33570
364	H34854 ?	Chick H33572
365 (KDG2)		Non-breeder
366 (KDG1)		Empty
367	H31175 H34957	Chick H33548
368	H33451 (M) H34942 (F)	Crushed egg
369 (SFG1)		Non-breeder

Appendix 2

DETAILS OF GEO-LOCATOR DATA-LOGGER DEPLOYMENT ON INDIVIDUAL BLACK PETRELS (*Procellaria parkinsoni*)

Where more than one trip was recorded, separate trips are denoted by different lettered suffixes

BAND	SEX	BURROW NO.	DEPLOYED	RETURNED	NO. OF DAYS LOGGER WORN	NO. OF TRIPS	TRIP LENGTHS(S) (DAYS)	BREEDING RESULT
27604	Male	69	3 Dec 2005	19 Jan 2006	48	2	Trip a = 26 days Trip b = 6 days	Chick
31460	Female	65	10 Dec 2005	14 Jan 2006	35	1	19 days	Dead embryo
25493	? Female	150	4 Dec 2005	15 Jan 2006	43	1	22 days	Chick
25511[a]	Female	102	3 Dec 2005	29 Jan 2006	58	2	Trip a = 22 days Trip b = 20 days	Dead embryo
30866	Male	102	4 Dec 2005	14 Jan 2006	42	2	Trip a = 6 days Trip b = 4 days	
31023[b]	Female	71	3 Dec 2005	29 Jan 2006	58	2	Trip a = 23 days Trip b = 7 days	Chick
31242	Male	71	4 Dec 2005	14 Jan 2006	42	1	21 days	
31271	Male	67	3 Dec 2005	14 Jan 2006	43	1	15 days	Chick
27534[c]	Male	148	3 Dec 2005	15 Jan 2006	44	2	Trip a = 4 days Trip b = 17 days	Chick
25460	? Male	146	4 Dec 2005	14 Jan 2006	42	2	Trip a = 29 days Trip b = 3 days	Chick
30869[d]	Male	212	4 Dec 2005	15 Jan 2006	43	1	39 days	Chick

[a] = Bird 4 in Fig. 9.
[b] = Bird 6 in Fig. 11.
[c] = Bird 9 in Fig. 8.
[d] = Bird 11 in Fig. 10.