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TABLE 4. NUMBER OF EMPTY, BREEDING AND NON-BREEDING BURROWS PER HECTARE ON THE 26 TRANSECTS IN THE BLACK PETREL (*Procellaria Parkinsoni*) STUDY AREA ON GREAT BARRIER ISLAND (AOTEA ISLAND), AND RANKING OF THE TRANSECTS ACCORDING TO GRADE OF PETREL HABITAT THEY REPRESENT.

LINE TRANSECTS SURVEYED IN 2007/08	LENGTH (m)	AREA (ha)	NUMBER OF BURROWS (per ha)				HABITAT GRADE
			EMPTY	BREEDING	NON-BREEDING	TOTAL	
LT1	400	0.1600	6	31	25	63	Medium
LT6	130	0.0520	0	38	58	96	Medium
LT7	200	0.0800	13	0	13	25	Low
LT8	400	0.1600	6	44	13	63	Medium
LT9	320	0.1280	0	31	39	70	Medium
LT10	400	0.1600	0	88	38	125	High
LT11	400	0.1600	0	19	6	25	Low
LT12	380	0.1520	7	20	20	46	Low
LT13A	150	0.0600	17	50	50	117	High
LT14	140	0.0560	0	36	0	36	Low
LT15	120	0.0480	0	42	21	63	Medium
LT16	110	0.0440	23	23	0	45	Low
LT17	400	0.1600	13	44	13	69	Medium
LT18	400	0.1600	0	31	25	56	Medium
LT19	250	0.1000	0	0	0	0	None
LT20	190	0.0760	13	26	13	53	Medium
LT24	180	0.0720	0	42	14	56	Medium
LT25	400	0.1600	13	56	56	125	High
LT26	400	0.1600	6	69	25	100	High
LT31	170	0.0680	0	15	0	15	Low
LT37	150	0.0600	0	100	33	133	High
LT38	400	0.1600	6	38	13	56	Medium
LT40	330	0.1320	8	23	45	76	Medium
LT41	400	0.1600	6	31	25	63	Medium
LT93	330	0.0520	0	38	58	96	Medium
LT97	320	0.0800	13	0	13	25	Low

4.4 BANDING DATA

During the 2007/08 season, 387 adults were identified. Of these, 334 were already banded and 53 were banded this season (Table 5). There were 190 chicks still present in the study burrows and these were banded (Table 5). Eight chicks had already fledged.

There have been 1668 chicks banded within the study area between 1995 and 2008 (Table 5). These birds have begun to return to the colony as pre-breeders, non-breeders and breeders (n = 66, Table 6).

There were 27 returned 'chicks' recaptured at the colony this season (Table 5); of these, 19 attempted to breed, with 14 successfully raising chicks of their own. The remaining eight did not breed, although several males were recaptured while calling to attract a mate.

Since the first returned chick (banded on Great Barrier Island in the 1995/96 season) was recaptured as a pre-breeder in the 1999/00 season, 67 'chicks' have been recaptured as pre-breeders, non-breeders or breeding adults; 66 from chicks banded on Great Barrier Island and one from Hauturu/Little Barrier Island

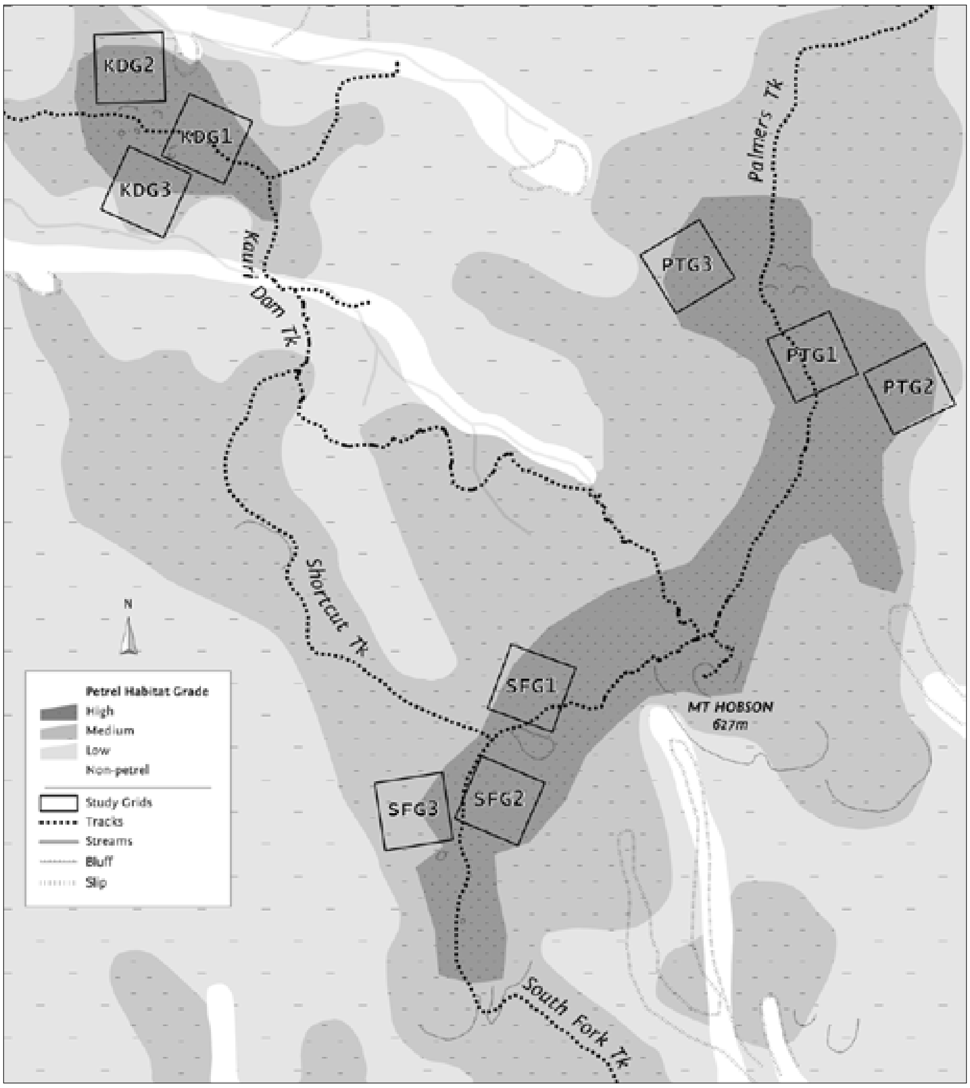

Figure 7. Habitat grades, based on black petrel (*Procellaria parkinsoni*) burrow density (incorporating habitat characteristics), within the 35-ha study site on Great Barrier Island (Aotea Island). Approximate North is shown (N). There are 7 ha of high-grade petrel habitat, 17 ha of medium-grade petrel habitat, 10 ha of poor-grade petrel habitat and 1 ha of non-petrel habitat.

(Table 6). The number of times chicks have been recaptured ranges from 1 to 8 (Mean ± SEM = 1.8 ± 0.2, Table 6). Although the youngest age at first return is 3 years, the mean age ± SEM at first return is 5.1 ± 0.2 (Table 6, range 3–9 years). Thirty-six of these 'returned chicks' have attempted to breed over nine seasons (1999/2000 to 2007/08, Bell & Sim 2002, 2003a, b, 2005; Bell et al. 2007, 2009), with 27 breeding successfully over this period. The age at first breeding attempt ranges from 4 to 9 years (Mean ± SEM = 6.0 ± 0.2, Table 6) and the age at first successful breeding also ranges from 4 to 9 years (Mean ± SEM = 6.3 ± 0.2, Table 6).

4.5 POPULATION ESTIMATE

As stated in the reports for the 2004/05 and 2005/06 surveys (Bell et al. 2007, 2009), the original population estimates determined in earlier reports by extrapolating from the nine census grids are suspected to overestimate the population size (Bell & Sim 1998a, b, 2000a, b, c, 2002, 2003a, b, 2005). This is due to the fact that these grids were originally established in known areas of high petrel density and that the study site does not have a uniform distribution of burrows.

TABLE 5. BANDING, RECAPTURE AND RECOVERY DATA FROM ALL BLACK PETRELS (*Procellaria parkinsoni*) CAUGHT WITHIN THE STUDY AREA ON GREAT BARRIER ISLAND (AOTEA ISLAND) FOR THE BREEDING SEASONS 1995/96 TO 2007/08.

	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
Recaptures of:													
birds banded prior to 1995	19	31	24	23	29	27	27	27	21	22	22	19	19
birds banded in 1995/96	–	14	14	14	16	14	11	12	12	8	12	10	7
birds banded in 1996/97	–	–	113	86	84	73	63	57	43	37	391	31	281
birds banded in 1997/98	–	–	–	32	32	30	28	24	18	27	18	13	13
birds banded in 1998/99	–	–	–	–	95	82	71	64	49	36	39	33	32
birds banded in 1999/00	–	–	–	–	–	86	75	66	47	51	52	37	31
birds banded in 2000/01	–	–	–	–	–	–	51	52	41	22	36	28	29
birds banded in 2001/02	–	–	–	–	–	–	–	68	88	26	25	22	21
birds banded in 2002/03	–	–	–	–	–	–	–	–	61	55	57	54	39
birds banded in 2003/04	–	–	–	–	–	–	–	–	–	22	28	23	21
birds banded in 2004/05	–	–	–	–	–	–	–	–	–	–	48	31	33
birds banded in 2005/06	–	–	–	–	–	–	–	–	–	–	–	46	34
birds banded in 2006/07	–	–	–	–	–	–	–	–	–	–	–	–	27
TOTAL RECAPTURES	**19**	**45**	**151**	**155**	**256**	**312**	**326**	**370**	**380**	**306**	**377**	**347**	**334**
Number of new adults (banded that season)	41	179	60	129	145	97	114	179	67	135	108	85	53
TOTAL ADULTS	**60**	**224**	**211**	**284**	**401**	**409**	**440**	**549**	**447**	**441**	**485**	**432**	**387**
Number of chicks (banded that season)	59	69	85	116	137	137	160	62	110	184	143	215	191
TOTAL NUMBER OF BIRDS	**119**	**293**	**296**	**400**	**538**	**546**	**600**	**611**	**557**	**625**	**627**	**647**	**578**
Number of chicks recaptured alive (returned to colony)	–	–	–	–	1	2	11	18	13	24	26	20	27
BAND RECOVERIES FROM DEAD BIRDS	–	1	1	–	2	1	2	2	–	–	2	1	1

In light of these issues, we have calculated three different population estimates for the 35-ha study area by:

1. Extrapolating from the original census grids only (Table 7)
2. Extrapolating from the transects only (Table 8)
3. Extrapolating from the transects and census grids with stratification of the study site (Table 9)

Any breeding burrow was treated as having 2 resident birds present and any non-breeding burrows was treated as having 1.25 birds present (because, in any non-breeding burrow there is a 25% chance of capturing more than one bird in the burrow as the resident male attracts females to that burrow).

For the first scenario, extrapolating from the census grid data to the 35-ha area around the summit area of Mount Hobson, the 2007/08 burrow-occupying black petrel population is estimated to be between 4257 and 6361 adults (5309 ± 1052 birds, Table 7), comprising 1167 ± 235 non-breeding adults and 4142 ± 817 breeding adults; i.e. approximately 2071 breeding pairs).

For the second scenario, extrapolating from the transects to the 35-ha study site around the summit area of Mount Hobson, the 2007/08 burrow-occupying black petrel population is estimated to be between 3070 and 4038 adults (3554 ± 484 birds, Table 8), comprising 1037 ± 158 non-breeding adults and 2517 ± 326 breeding adults (i.e. approximately 1259 breeding pairs).

TABLE 6. NUMBER OF RECAPTURES, AGE AT FIRST RECAPTURE, AGE AT FIRST BREEDING AND AGE AT FIRST SUCCESSFUL BREEDING FOR BLACK PETRELS (*Procellaria parkinsoni*) BANDED AS CHICKS AND RECAPTURED IN THE STUDY AREA ON GREAT BARRIER ISLAND (AOTEA ISLAND) (n = 66), WITH A NOTE ABOUT AN IMMIGRANT BANDED AS A CHICK ON HAUTURU/LITTLE BARRIER ISLAND.

BAND	SEX	SEASON BANDED	SEASON WHEN LAST RECAPTURED	NUMBER OF RECAPTURES	AGE AT FIRST RECAPTURE (years)	AGE AT FIRST BREEDING (years)	AGE AT FIRST SUCCESSFUL BREEDING (years)
H25525	Male	1998/99	2006/07	1	7	8	–
H25536	Male	1998/99	2005/06	2	6	–	–
H25546	Male	1998/99	2007/08	5	5	7	7
H25630	Male	1999/00	2005/06	2	5	–	–
H25631	?Male	1999/00	2003/04	1	4	–	–
H25635	Male	1999/00	2007/08	4	5	6	–
H25637	Male	1999/00	2004/05	1	5	–	–
H25648	Male	1999/00	2007/08	3	5	8	–
H25651	Male	1999/00	2006/07	3	5	6	–
H25658	Male	1999/00	2004/05	1	5	5	5
H25659	Female	1999/00	2005/06	1	6	6	6
H25663	Male	1999/00	2007/08	5	4	7	8
H25664	?Female	1999/00	2005/06	3	3	6	–
H25669	Male	1999/00	2005/06	2	5	5	5
H25673	Male	1999/00	2007/08	4	5	7	7
H25677		1999/00	2006/07	1	7	7	7
H28085	Male	1998/99	2005/06	1	5	–	–
H29912	?Male	2000/01	2007/08	3	5	5	6
H29978		1999/00	2007/08	1	9	–	–
H30908	?Male	1995/96	2002/03	1	7	–	–
H30924	Male	1995/96	2005/06	5	6	6	6
H30930	Male	1995/96	2007/08	8	4	5	5
H31076		1997/98	2002/03	1	5	–	–
H31080		1997/98	2001/02	1	4	–	–
H31081	?Male	1997/98	2002/03	2	4	–	–
H31082	Male	1997/98	2001/02	1	4	–	–
H31089		1997/98	2006/07	3	5	6	9
H31194	Male	1996/97	2001/02	1	5	5	–
H31366	?Male	1997/98	2007/08	6	5	6	6
H31370	?Male	1997/98	2005/06	2	5	8	–
H31377	?Male	1997/98	2001/02	1	4	–	–
H31382	Female	1997/98	2006/07	4	4	5	5
H31383	Male	1997/98	2003/04	1	6	–	–
H31405		1996/97	2004/05	2	6	7	7
H31406	?Female	1996/97	2001/02	1	5	–	–
H31413	Female	1996/97	2004/05	1	8	8	8
H31415	?Male	1996/97	2003/04	1	7	–	–
H31424	?Male	1996/97	2005/06	4	6	8	8
H31474	?Male	1998/99	2002/03	1	4	–	–
H31476	Male	1998/99	2004/05	2	4	6	–
H31490	?Male	1998/99	2002/03	1	4	–	–
H31491	Male	1998/99	2005/06	1	7	–	–
H31494	Male	1998/99	2007/08	2	6	–	–
H31495	Male	1998/99	2007/08	5	4	5	5
H31498	?Female	1998/99	2007/08	3	6	6	8
H31527	?Male	1998/99	2002/03	1	4	–	–

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BAND	SEX	SEASON BANDED	SEASON WHEN LAST RECAPTURED	NUMBER OF RECAPTURES	AGE AT FIRST RECAPTURE (years)	AGE AT FIRST BREEDING (years)	AGE AT FIRST SUCCESSFUL BREEDING (years)
H31537	?Male	1998/99	2006/07	1	8	8	8
H31542	Male	1998/99	2007/08	6	4	6	7
H31546	Male	1998/99	2007/08	1	9	–	–
H31956	Male	2000/01	2007/08	1	7	7	7
H32063		2000/01	2005/06	1	5	–	–
H32073		2000/01	2007/08	1	7	–	–
H32091		2000/01	2007/08	1	7	–	–
H32099	?Male	2000/01	2007/08	2	5	–	–
H32915		2001/02	2007/08	1	6	6	6
H32927	?Male	2001/02	2007/08	1	6	6	6
H32957	Female	2001/02	2007/08	2	5	6	–
H32979		2001/02	2006/07	1	5	–	–
H32980	?Male	2001/02	2005/06	1	4	–	–
H33015	Male	2001/02	2007/08	1	6	–	–
H33035		2001/02	2007/08	1	6	–	–
H33052	Male	2001/02	2007/08	1	6	6	6
H33218	?Female	2002/03	2007/08	1	5	–	–
H33225		2002/03	2006/07	1	4	–	–
H33248	Male	2002/03	2007/08	2	4	5	5
H33380		2003/04	2007/08	1	4	4	4
MEAN ± SEM				1.8 ± 0.2	5.1 ± 0.2	6.0 ± 0.2	6.3 ± 0.3
H30807[1]	Female	1996/97	2007/08	3	9	9	9

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

TABLE 7. 2007/08 POPULATION ESTIMATE FOR BLACK PETRELS (*Procellaria parkinsoni*) IN THE STUDY AREA AROUND MOUNT HOBSON (HIRAKIMATA), GREAT BARRIER ISLAND (AOTEA ISLAND), EXTRAPOLATING FROM CENSUS GRIDS ONLY.

CENSUS GRID	DENSITY (Number/ha)		POPULATION ESTIMATE (35 ha)	
	BREEDING ADULTS	NON-BREEDING ADULTS	BREEDING ADULTS	NON-BREEDING ADULTS
Grid One (KDG1)	188	55	6580	1925
Grid Two (KDG2)	213	23	7455	805
Grid Three (KDG3)	50	3	1750	105
Grid Four (PTG1)	213	31	7455	1085
Grid Five (PTG2)	100	39	3500	1365
Grid Six (PTG3)	63	31	2205	1085
Grid Seven (SFG1)	125	63	4375	2205
Grid Eight (SFG2)	75	47	2625	1645
Grid Nine (SFG3)	38	8	1330	280
Mean	**118 ± 23**	**33 ± 7**	**4142 ± 817**	**1167 ± 235**
Total population estimate			**5309 ± 1052**	
Population estimate range			**4257 to 6361 adults**	

TABLE 8. 2007/08 POPULATION ESTIMATE FOR BLACK PETRELS (*Procellaria parkinsoni*) IN THE STUDY AREA AROUND MOUNT HOBSON (HIRAKIMATA), GREAT BARRIER ISLAND (AOTEA ISLAND), EXTRAPOLATING FROM TRANSECTS ONLY.

TRANSECTS SURVEYED IN 2007/08	DENSITY (Number/ha)		POPULATION ESTIMATE (35 ha)	
	BREEDING ADULTS	NON-BREEDING ADULTS	BREEDING ADULTS	NON-BREEDING ADULTS
LT1	62	31	2170	1085
LT6	76	73	2660	2555
LT7	0	16	0	560
LT8	88	16	3080	560
LT9	62	49	2170	1715
LT10	176	48	6160	1680
LT11	38	8	1330	280
LT12	40	25	1400	875
LT13A	100	63	3500	2205
LT14	72	0	2520	0
LT15	84	26	2940	910
LT16	46	0	1610	0
LT17	88	16	3080	560
LT18	62	31	2170	1085
LT19	0	0	0	0
LT 20	52	16	1820	560
LT 24	84	18	2940	630
LT 25	112	70	3920	2450
LT 26	138	31	4830	1085
LT 31	30	0	1050	0
LT37	200	41	7000	1435
LT38	76	16	2660	560
LT40	46	56	1610	1960
LT41	62	31	2170	1085
LT93	76	73	2660	2555
LT97	0	16	0	560
Mean (± SE)	**72 ± 9**	**30 ± 5**	**2517 ± 326**	**1037 ± 158**
Total population estimate (± SE)			**3554 ± 484**	
Population estimate range			**3070 to 4038 adults**	

The third estimate, involving extrapolation from transects and census grids with stratification of the 35-ha study area into the four habitat grades, produced an estimate for the 2007/08 burrow-occupying black petrel population of between 3342 and 4130 adults (3736 ± 394 birds, Table 9), comprising 1020 ± 151 non-breeding adults and 2716 ± 243 breeding adults (i.e. approximately 1358 breeding pairs). This is likely to be more accurate than the first two estimations.

4.6 SURVIVAL ESTIMATES, RECAPTURE PROBABILITIES AND TRANSITION RATES

As there were 501 black petrels within the study area in 2007/08 for which sex was known, we carried out a Cormack Jolly Seber (CJS) analysis using a simple survival model to compare survival and the probability of recapture between the two sexes. Using these known-sex birds, it was found that while the Phi(sex*t) *P*(t) model had the lowest AICc, and thus the best fit, the Phi(t) *P*(sex*t) model (adult survival and probability of recapture varying with sex and time) had an AICc of only 0.11 less (Table 10).

TABLE 9. 2007/08 POPULATION ESTIMATE FOR BLACK PETRELS (*Procellaria parkinsoni*) IN THE STUDY AREA AROUND MOUNT HOBSON (HIRAKIMATA), GREAT BARRIER ISLAND (AOTEA ISLAND) AFTER STRATIFYING AND GRADING THE TRANSECTS AND CENSUS GRIDS. [AREA OF EACH PETREL HABITAT TYPE IS 7 ha OF HIGH-GRADE HABITAT, 17 ha OF MEDIUM-GRADE HABITAT, 10 ha OF POOR-GRADE HABITAT AND 1 ha OF NON-PETREL HABITAT].

PETREL	LINE	DENSITY (Number of adults/ha)		AREA	POPULATION ESTIMATE (35 ha)	
		BREEDING ADULTS	NON-BREEDING ADULTS		BREEDING ADULTS	NON-BREEDING ADULTS
LOW	LT7	o	16	10 ha	o	160
(1–49 burrows per ha)	LT11	38	8		380	80
	LT12	40	25		400	250
	LT14	72	0		720	0
	LT16	46	0		460	0
	LT31	30	0		300	0
	LT97	0	16		0	160
	KDG3	50	3		500	30
	SFG3	38	8		380	80
MEAN ±SEM		35 ± 8	8 ± 3		349 ± 77	84 ± 30
MEDIUM	LT1	62	31	17 ha	1054	527
(50–99 burrows per ha)	LT6	76	73		1292	1241
	LT8	88	16		1496	272
	LT9	62	49		1054	833
	LT15	84	26		1428	442
	LT17	88	16		1496	272
	LT18	62	31		1054	527
	LT20	52	16		884	272
	LT24	84	18		1428	306
	LT38	76	16		1292	272
	LT40	46	56		782	952
	LT41	62	31		1054	527
	LT93	76	73		1292	1241
	PTG2	100	39		1700	663
	PTG3	63	31		1071	527
	SFG2	75	47		1275	799
MEAN ±SEM		72 ± 4	36 ± 5		1228 ± 62	605 ± 82
HIGH	LT10	176	48	7 ha	1232	336
(≥ 100 burrows per ha)	LT13A	100	63		700	441
	LT25	112	70		784	490
	LT26	138	31		966	217
	LT37	200	41		1400	287
	KDG1	188	55		1316	385
	KDG2	213	23		1491	161
	PTG1	213	31		1491	217
	SFG1	125	63		875	441
MEAN ±SEM		163 ± 15	47 ± 6		1139 ± 104	331 ± 39
TOTAL POPULATION ESTIMATE (± SE)					**2716 ± 243**	**1020 ± 151**
					3736 ± 394	
POPULATION ESTIMATE RANGE					**3342 to 4130 adults**	

Additionally, the Phi(t) *P*(sex*t) model (using sex as a variable in recapture probability) detected that there was a difference in recapture probability between males and females and that this was likely to be a confounding influence in estimating adult survival using a sex-based model.

TABLE 10. ADULT SEX-SPECIFIC SURVIVAL MODELS AND THEIR AKAIKE'S MODIFIED INFORMATION CRITERION (AICc) SCORES FOR BLACK PETRELS (*Procellaria parkinsoni*) ON GREAT BARRIER ISLAND (AOTEA ISLAND). MODELS WERE FITTED TO DATA USING CORMACK JOLLY SEBER ANALYSIS (USING PROGRAM MARK) WHERE Phi = APPARENT SURVIVAL, sex = SEX OF THE BIRD, t = TIME AND *P* = PROBABILITY OF RECAPTURE.

MODEL	QAICc	ΔQAICc	AICc WEIGHT	MODEL LIKELIHOOD	NUMBER OF MODELS	DEVIANCE PARAMETERS
Phi(sex*t) *P*(t)	3251.51	0.00	0.48	1.00	35	936.22
Phi(t) *P*(sex*t)	3251.62	0.11	0.46	0.95	35	936.33
Phi(sex*t) *P*(sex*t)	3256.27	4.76	0.05	0.09	46	918.02
Phi(t) *P*(t)	3258.19	6.68	0.02	0.04	23	967.64
Phi(sex) *P*(sex*t)	3266.49	14.98	0.0003	0.0006	26	969.79
Phi(sex) *P*(t)	3269.37	17.86	0.00006	0.0001	14	997.18

Using the adult survival model that takes into account the difference in recapture rates for known-sex birds (Phi(t) *P*(sex*t)), the mean adult survival was 0.90 ± 0.03 (Table 11). Figure 8 shows a decline in adult survival over this study, but this may be due to poor survival or poor recapture rates over the 2005/06 and 2006/07 seasons.

A Burnham analysis of survival of chicks banded in the 35-ha study site between 1995 and 2008 was also completed. Only 67 of over 1660 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 0.4600 (± 0.0281) during the first 3 years of life (Table 12). This survival estimate increased to 0.8992 (± 0.0370) for birds > 3 years old (Table 12).

TABLE 11. ADULT SURVIVAL ESTIMATES FOR BLACK PETRELS (*Procellaria parkinsoni*) ON GREAT BARRIER ISLAND (AOTEA ISLAND) BETWEEN 1996/97 AND 2006/07. ESTIMATES OBTAINED BY CORMACK JOLLY SEBER MODEL (Phi(t) *P*(sex*t) ANALYSIS (USING PROGRAM MARK) WITH STANDARD ERRORS AND 95% CONFIDENCE INTERVALS.

SEASON	SURVIVAL ESTIMATE	SE
1996/97	0.8939	0.0796
1997/98	0.9671	0.0273
1998/99	0.8832	0.0370
1999/00	0.9481	0.0218
2000/01	0.9203	0.0229
2001/02	0.9264	0.0232
2002/03	0.8967	0.0243
2003/04	0.8057	0.0264
2004/05	0.9644	0.0315
2005/06	0.8266	0.0333
2006/07	0.8275	0.0371
2007/08	0.9117	0.0433
MEAN ± SEM	**0.90 ± 0.03**	

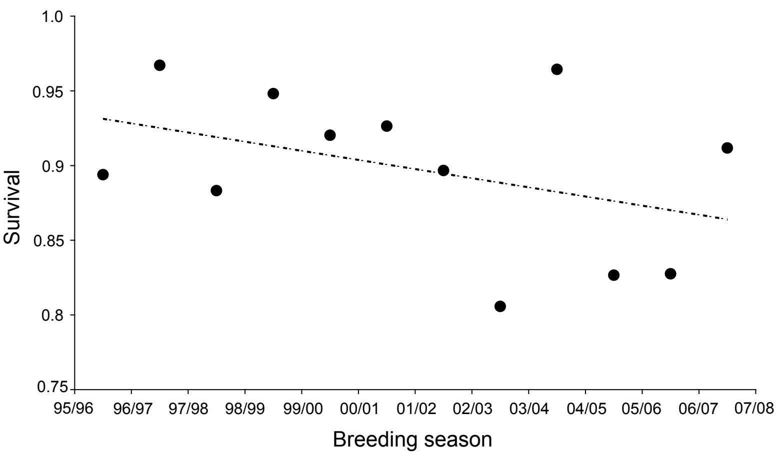


Figure 8. Adult survival estimates for black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island) between 1996/97 and 2006/07. Estimates obtained by Cormack Jolly Seber model analysis (Phi (t) *P* (sex*t)) using Program MARK.

Given that sex was not identified as overly important in survival, and given that few pre-breeding birds had been sexed, a simple CJS model (Phi(g) *P*(g)) was run comparing the survival of adult (and pre-breeding) birds (n = 1452) with that of chicks (n = 1668) within the study burrows between 1996 and 2008 (Table 12). As earliest age of return was 3 years, it was not possible to calculate apparent survival before a chick's third year; unsurprisingly, a model with survival and recapture probability estimated as a single parameter over the first 3 years of life had a much lower AICc than any other model (AICc = 3738.3, delta AICc 4.3). It is interesting to note that (as in 2006/07) survival of chicks following their return to the colony was lower in 2007/08 than overall adult survival (although not significantly; Table 12, Fig. 9).

Of 1668 chicks that have been banded during the study on Great Barrier Island, only 66 have so far been recaptured (Table 6). Figure 10 shows the frequency of first recapture of each age class.

TABLE 12. ADULT AND CHICK SURVIVAL ESTIMATES FOR BLACK PETRELS (*Procellaria parkinsoni*) ON GREAT BARRIER ISLAND (AOTEA ISLAND). ESTIMATES OBTAINED BY CORMACK JOLLY SEBER MODEL (Phi(t) *P*(t)) ANALYSIS USING TWO SURVIVAL AND RECAPTURE PROBABILITIES FOR CHICKS (≤ 3 AND > 3 YEARS).

	SURVIVAL ESTIMATE	SE
Adult survival (after first year)	0.8724	0.0093
Chick survival (over their first 3 years of life)	0.4600	0.0281
Chick survival (following first return to the colony)	0.8992	0.0370

Figure 9. Comparison of adult and chick (following first return to the colony) survival estimates over time (1995/96 to 2006/07 breeding seasons) for black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island). Circles = adults; triangles = returned chicks.

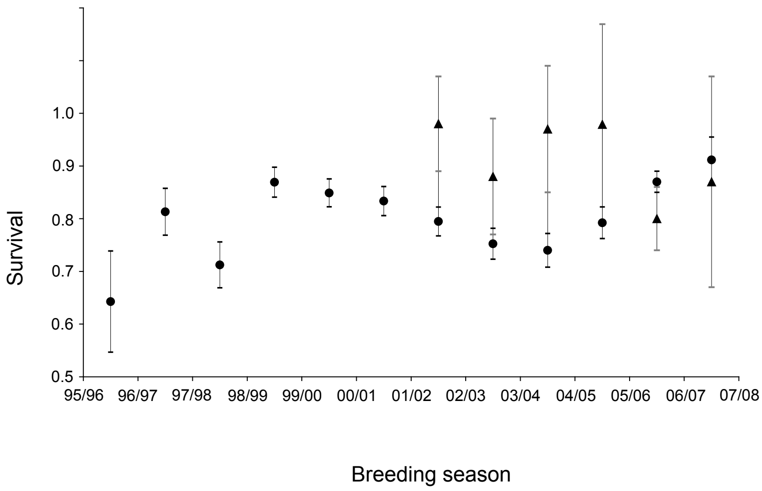
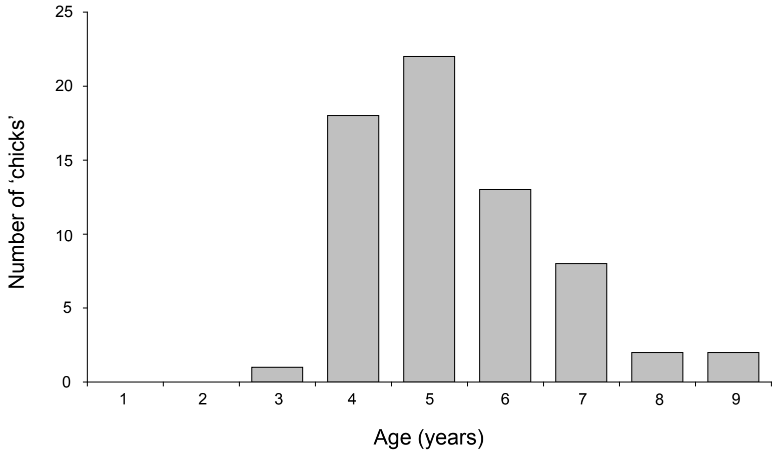


Figure 10. Observed frequency of age at first recapture of returned black petrel (*Procellaria parkinsoni*) 'chicks' to the study area on Great Barrier Island (Aotea Island).



By setting recapture probabilities for the first 3 years to zero in the model, the probability of recapture of each chick cohort using the model Phi(g) *P*(g) with two survival and recapture probabilities for returned 'chicks' (≤ 3 and > 3 years) can be calculated (Table 13, Fig. 11). Figure 11 shows that the probability of recapture increases up until the chick is 8 years old, then starts to decrease; interestingly, this is despite most of the returned chicks being first recaptured at the colony at ages 4 to 6 years (Fig. 10).

Using the outcome of active nests within the the study area, the probability of transition from one breeding state to another was calculated using the multi-state Mark-Recapture model. Three states were identified: successful breeder, failed breeder and non-breeding bird. The probability of a nest going from each breeding state in one year to the same state in the next year is shown in Table 14. The probability of either a successful breeder or an unsuccessful breeder changing to a non-breeder (i.e. skipping a year in breeding), was 0.2806 (i.e. about a 28% chance, Table 14). However, if a bird does skip a year, it is more likely to be a successful breeder in the following year (42% compared with 35%, Table 14).

A multi-state Mark-Recapture model was created using capture histories of 2823 birds caught between 1995 and 2008 and whose partners were known. Capture history was restricted to four states where A = same partner, B, C and D = new partners. The best model fitting the data was S(.) *P*(.) Psi A-B(.) Psi B-C(.) Psi C-D(.) where S = survival rate, *P* = probability of recapture, Psi = transition probability using the four states. This model produced an annual divorce rate of 13% (Table 15). However, the model also showed that more than 70% of the pairs survived and that 64% of pairs (new or surviving) nest in any one year (Table 15).

TABLE 13. PROBABILITY ESTIMATES (WITH STANDARD ERRORS) FOR THE AGE OF FIRST RETURN OF BLACK PETREL (*Procellaria parkinsoni*) 'CHICKS' TO THE STUDY AREA ON GREAT BARRIER ISLAND (AOTEA ISLAND).

AGE	PROBABILITY ESTIMATE	SE
3 years	0.1546	0.0056
4 years	0.3732	0.0929
5 years	0.5267	0.1128
6 years	0.5976	0.1290
7 years	0.6939	0.1571
8 years	0.8042	0.2023
9 years	0.6193	0.4042
10 years	0.4194	0.4853
MEAN	**0.5236**	**0.1987**

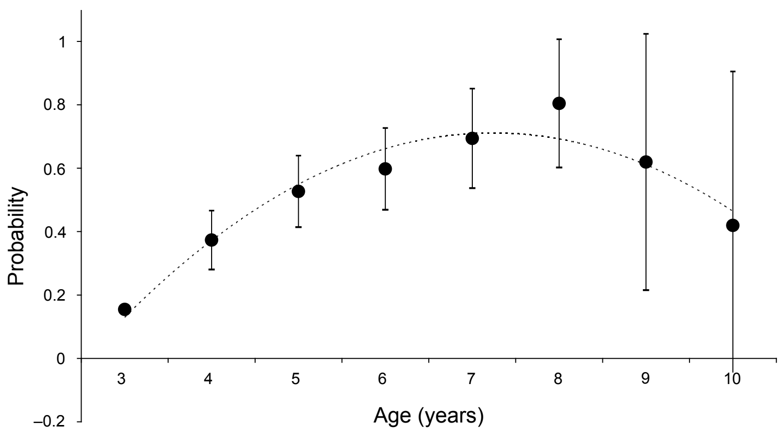


Figure 11. Probability estimates of the age at first recapture of black petrel (*Procellaria parkinsoni*) 'chicks' returning to the 35-ha study area on Great Barrier Island (Aotea Island).

TABLE 14. PROBABILITY ESTIMATES FOR BREEDING STATE IN ONE YEAR CHANGING TO A DIFFERENT STATE IN THE FOLLOWING YEAR FOR ADULT BLACK PETRELS (*Procellaria parkinsoni*) IN THE STUDY AREA ON GREAT BARRIER ISLAND (AOTEA ISLAND).

YEAR ONE STATE	YEAR TWO STATE		
	SUCCESSFUL BREEDER	FAILED BREEDER	NON-BREEDING
Successful breeder	0.6821	0.1904	0.1275
Failed breeder	0.4357	0.4112	0.1531
Non-breeding	0.4166	0.3500	0.2335

TABLE 15. PROBABILITY ESTIMATES FOR BREEDING PAIR SURVIVAL, NESTING AND DIVORCE FOR BLACK PETRELS (*Procellaria parkinsoni*) IN THE STUDY AREA ON GREAT BARRIER ISLAND (AOTEA ISLAND).

PARAMETER	PROBABILITY ESTIMATE	SE
Pair survival	0.7104	0.0062
Nesting in any season	0.6436	0.0090
Divorcing 1st partner	0.0557	0.0039
Divorcing 2nd partner	0.0510	0.0098
Divorcing 3rd partner	0.0202	0.0200
Returning to any partner after ‘a fling’	0.0087	0.0044

4.7 GEO-LOCATOR DATA-LOGGERS

In 2007/08, eight of the 28 Lotek™ geo-locator data-loggers that were placed on known breeding birds were retrieved. The eight birds from which data-loggers were retrieved came from eight different burrows (of the total 25—see section 3.6). The loggers were worn for between 31 and 37 days and the birds showed no apparent adverse effects. Breeding success was higher in the 25 burrows from which birds with data-loggers attached originated than in the study burrows as a whole (80% compared with 77%), with 20 chicks being successfully fledged and five nests failing due to eggs disappearing from two burrows, two non-logger partner birds abandoning the egg in the other burrow and a chick dying.

The eight loggers were downloaded and all appeared to have reliable tracks. The tracking information was sent to Scott Shaffer for analysis and to be collated with the data that was to be collected from the remaining loggers in December 2008. Four of the birds were recaptured in 2007/08 and the loggers checked. There appeared to be no impact on the birds and the adults were actively feeding chicks.

Complete analysis of the tracking information will be completed when all loggers have been retrieved. Preliminary data appears to confirm much of the early tracking work (Bell et al. 2009)—that the birds forage in two main directions—west towards Australia and east towards East Cape.

5. Discussion

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

5.1 STUDY BURROWS

In the 2007/08 breeding season, there were 198 breeding successes and 54 breeding failures, equating to an overall breeding success rate of 77% (Table 2). Although this breeding success is less than last season (2006/07: 82.5%, Table 2), it is still relatively high and higher than the mean for the overall study (75%), and higher than reported in the earlier studies in 1977 (50%) and in 1978 (60%, Imber 1987) and in 1988/89 (62%, Scofield 1989). The level of egg abandonment was much higher this season than previously recorded and this appears to have had an impact on overall breeding success. This level of abandonment may be related to handler disturbance or the age of the breeding birds, as younger, less-experienced birds seem to be less successful in incubating eggs to hatching (EAB pers. obs.). It was also assumed that eight chicks successfully fledged before the April 2008 banding visit (Table 2). Chicks were assumed to have fledged successfully if traces of down, quill sheaths, pin feathers and/or recent activity in burrows could be identified. If any of these chicks had died or been predated earlier in the season, this would reduce the breeding success for the season to 74%. Both breeding success rates (82.5% and 74%) are high compared with many other seabird species (such as Westland petrel *Procellaria westlandica* at 39–50%, Freeman & Wilson 2002; Warham 1996), but the apparent juvenile survival estimate (0.46 ± 0.03 for the first 3 years, Table 12) suggests that as many as 50% of these fledged chicks will not survive their first 3 years.

Five eggs were predated by rats (2% of all breeding attempts) within the study burrows and 19 eggs (7% of all breeding attempts) disappeared (but may have been predated by rats, Table 2). There were no feral cat predation events recorded within the study burrows in the 2007/08 season; however, two other juvenile petrels inside the study area and one chick outside the study area were predated by feral cats. All of these juvenile petrels appeared to have been predated when outside the burrow (stretching wings, attempting to fledge at a launch site, etc.), as their bodies were found in the open and, in some cases, well away from burrows (EAB pers. obs.). Juvenile petrels are particularly vulnerable to feral cat predation at fledging time (Warham 1996). Fourteen chicks are known to have been predated by cats between the 1996/97 and 2007/08 seasons (Table 1). This highlights the importance of continuing cat trapping in the area before, during and after the black petrel breeding season.

Although the number of burrows used for breeding has decreased since the 1999/2000 season (Fig. 5), breeding success has remained high since 1998—within a range of 67% to 84%—and appears to be increasing (Table 1, Fig. 5). Analysis of adult recaptures found a 13% rate of skipping from successful breeding status to non-breeding status as well as a further 15% rate of skipping from unsuccessful breeding status to non-breeding status (Table 14). However, if a bird does skip a year, it is more likely to successfully breed (42%) or fail at breeding (35%) the following year than remain a non-breeder (23%, Table 14). Skipping a year and subsequent improvement of breeding chances may also relate to migration, as it is not known if birds choose to remain in South America if they do not obtain adequate body condition to return to New Zealand to breed.

The reduction in numbers of non-breeding birds (Fig. 5) could partially explain the decline in the number of burrows used for breeding (Fig. 5). Reasons why 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 these burrows and thus affect breeding success.

It also appears that the percentage of burrows used for breeding has remained relatively constant over the past ten breeding seasons (mean 75%, Table 1), whereas the percentage of empty and non-breeding burrows has fluctuated from year to year (Table 1). This may mean that once a pair begins to breed they are more likely to remain as a breeding pair (71%, Table 15) and attempt to breed (64% Table 15) rather than skip breeding (i.e. become non-breeders), and that the number of non-breeding or pre-breeding birds in the study area varies each season. However, nearly 25% of non-breeding birds will remain as non-breeders (Table 14). It is also possible that as non-breeding (or pre-breeding) birds becoming breeders (explained by transition rates of 77% of non-breeding birds becoming breeding birds the following year, Table 14), they replace previous breeders that may have died, divorced or skipped a year. These changes in proportions of non-breeding birds 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 is also possible that as the number of our monitoring visits to the colony has been increased to three trips during the incubation and chick-rearing stages there has been more accurate determination of whether a burrow is being used by breeding or non-breeding birds (rather than remaining empty).

Using data from the past ten breeding seasons (since 1997/98), the proportion of non-occupied (empty) study burrows has been increasing (Table 1, Fig. 5). This may be directly related to handler disturbance, observation hatches being dug or adult mortality (mean apparent adult survival rate of 0.8976 ± 0.03, Table 11). Our analysis of adult survival and site fidelity suggested that black petrels have relatively low apparent adult survival (89%) compared with other seabird species (e.g. Antipodean albatross *Diomedea antipodensis* 96%, Walker & Elliott 2004). However, nearly 10% of birds may be permanently emigrating from the study area (Bell et al. 2007). Although birds do not appear to abandon their burrow at any time during the breeding season, they may choose to move to a new burrow in 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 the number of study 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 them unusable for a year or more. This may account for the declining occupancy of burrows, but as there has been an immigration event from Hauturu/Little Barrier Island to Great Barrier Island, site fidelity and the possibility of emigration from Great Barrier needs further investigation. Work needs to be done to separate the components of 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 this is true and whether emigration or mortality have a larger effect.

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

5.2 CENSUS GRIDS

Nine grids were intensively monitored over four periods during the 2007/08 breeding season. Although no new burrows were found this season, the number of burrows within the grids rose from 118 in 1999/2000 to 148 in 2005/06. This increase in burrow numbers may have been due to the increased search effort in recent seasons, rather than the creation of new burrows.

New burrows do not necessarily mean that more birds are present in the colony, as several birds (n = 163) have moved between numbered burrows within the 35-ha study area and certain original burrows are no longer active (due to collapse). Loss of partners can result in birds (particularly females) moving burrows (Warham 1996). Predation events and competition between adults and pre-breeders can also cause movement between burrows (Warham 1996). Pre-breeding males appear to be attracted back to their natal area and may excavate new burrows in those areas (Warham 1996). This has occurred in the study area on Great Barrier Island when 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 total of 578 banded birds were identified this season; 387 were adults and 191 were fledglings (Table 5). There were 334 recaptures of previously banded birds, including 27 that were 'returned chicks' (Tables 5 and 6). One adult (banded as a chick on Hauturu/Little Barrier Island) and first caught on Great Barrier Island in 2005/06 was recaptured again in 2007/08. This bird represents the first recorded immigration event for black petrels. Immigration has implications for population modelling work (as most models assume no immigration), and further surveys and mark-recapture work is needed to maximise the chances of recapturing known birds and returned fledglings.

Of the 27 returned chicks, 4 were recaptured in their natal burrows, 10 in their natal areas (less than 50 m from their 'hatching' burrow) and the other 13 were caught more than 100 m away from their natal areas. There is a probable capture bias towards returning males because of their behaviour, i.e. calling outside burrows. 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 area. Much of the 35-ha study area is difficult to reach and cannot be searched. This will need to be taken into account in any further survival and recruitment analysis.

Since the first chick was recaptured in the 1999/00 season, 67 chicks have been recaptured. There have been 36 records of returned chicks attempting to breed during this period, which means that the age of first recorded breeding and that of first successful breeding are both between 4 and 9 years (Table 6). It is important to check for more returned chicks and to maintain intensive burrow monitoring where returned chicks are present. Many of the returned chicks were recaptured at night during the December 2007 visit, so it is important to maintain a high level of searching at this time. Further, these data allow for mark/recapture analyses, which could greatly assist in understanding black petrel demographics.

Using the recapture data for chicks banded on Great Barrier Island since 1996, a CJS analysis (incorporating two chick-survival parameters, 0–3 years and > 3 years) suggested that chick survival up to year 3 was 0.46 (± 0.03, Table 12), but after the first 3 years of life it increased to 0.90 (± 0.04), which is higher than the mean apparent adult survival (0.87 ± 0.01, Table 12). 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 reviews in Hunter et al. 2001). However, these figures may change as more returned 'chicks' are recaptured.

5.4 POPULATION ESTIMATE

Three estimates for the population within the 35-ha study area were calculated by various means (see section 3.5; Tables 7–9). 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 or from random transects (i.e. known high burrow density areas) 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 taking into account the range of habitat types and burrow densities identified with the study area. The estimate from the census grids (5309 ± 1052 birds) proved to be higher than that produced by stratifying the 35-ha study site into four petrel burrow density grades (3736 ± 394 birds), but the extrapolation from transects only was less (3554 ± 484 birds). Despite this, it is still believed that the stratification method probably gave the most accurate population estimate. From the transect data it was found that the highest densities of black petrel burrows were located on ridges or spurs with established canopy.

The breeding population was estimated at approximately 1350 breeding pairs (Table 9). 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.

Further transects throughout the study area would also improve the population estimate as well as more accurately defining the range of the four burrow density habitat grades (or possibly identify more). 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 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 of Mount Hobson, black petrels are known to nest on other high points around the summit area, in northern areas of the island, in small pockets of private land and towards the southern end of the island. Randomly selected census grids, transects or further intensive surveys 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. (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 ESTIMATES AND POPULATION TRENDS

The apparent adult survival estimates for black petrels in the study area (87%, Table 12) were unusually low for a seabird of this size, but comparable with adult black petrel survival estimates made by Hunter et al. (85%, 2001). The data also suggested that total adult survival has increased between 1995/96 and 2007/08 (Table 11), despite sex-based survival estimates showing a decrease over the same period (Fig. 8). However, these trends are not significant and may be related to different recapture probabilities for males and females. The increase in overall adult survival 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 10 nights during all December trips).

Although the adult recapture data for the whole study to date suggests that the black petrel population is increasing, comparing the overall data with just that relating to the 'foundation burrows' (i.e. those which have been monitored for 10 years or more), indicates that the population has slightly decreased (Bell et al. 2007). However, as survival in this foundation group was lower than in the entire adult dataset, the population trend may be related to occupancy of the study burrows and the possibility of handler disturbance rather than mortality. Again, it is important to undertake further thorough surveys within the 35-ha study area to get better recapture rates of banded adults, juveniles and immigrating adults (including recoveries of dead adults) to increase the accuracy of the survival, immigration and fidelity estimates.

Analysis of recapture data to determine rates of transition between breeding states showed that there was a probability of 28% of either a successful breeder or an unsuccessful breeder changing to a non-breeder (i.e. skipping a year, Table 14), but that once a bird skipped a year, it was more likely to attempt to breed the following year rather than skip breeding again (77% compared with 23%, Table 14). The option of skipping may relate to a number of factors including breeding outcome, partner selection, burrow condition, handler disturbance and divorce. Further analysis of mark-recapture data suggested an annual divorce rate of 13% (Table 15); however, it also showed that more than 70% of pairs survive annually and 64% of any pairs (new or surviving) nest in any one year (Table 15). It is difficult to determine the reason for divorce, and the reasons why birds choose to skip a year may relate to breeding outcome, burrow condition, handler disturbance or a combination of these (or other) factors. Trends in behaviour and breeding outcomes prior to divorce events need to be investigated. For example, if one bird skips a year (i.e. by remaining in South America), does the other bird attempt to breed with a new partner when it returns to the colony? Does the original pair return to breed at a later date? The analysis suggests that original pairings return in about 1% of cases of divorce (Table 15). Increasing recapture effort to determine whether birds have really divorced or skipped is vital. Further analysis of the present breeding and recapture data may give a clearer pattern to the levels and causes of skipping and divorce.

5.6 DATA-LOGGERS

Very little is known about the foraging range and at-sea distribution of black petrels beyond anecdotal records from band recoveries, bird-watching expeditions, fishermen, Ministry of Fisheries observers and from other vessels. However, many of these records provide only very general locations, and may reflect black petrels' habits of following boats to scavenge (rather than the routes they would follow in the absence of fishing boats).

Preliminary results from the 2005/06 season indicated that black petrels use a range of foraging areas and preferred to forage on the continental shelf or seamounts (Bell et al. 2009). Males and females appeared to overlap in their foraging locations (Bell et al. 2009). As these results were from a small sample size (n = 11 loggers, 17 tracks), further logger work was undertaken, with the aim of obtaining more information on incubation and chick rearing. Twenty-eight loggers were deployed and eight have been retrieved this season. Initial analysis of the tracks appears to confirm the preliminary results from Bell et al. (2009); however, further in-depth analysis has yet to be completed. This was due to be done when the other 20 loggers were retrieved in December 2008. These loggers will have been worn by the birds during one complete breeding season (2007/08), then migration to South America, residence in South America during their non-breeding season, migration back to their New Zealand breeding location, and incubation and chick-rearing trips through the next (2008/09) breeding season. This coverage should give very important information on black petrels' at-sea movements and range, both within New Zealand waters and internationally. Full details of these tracking results will be in the 2008/09 breeding season report.

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 petrel 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 could introduce disease or lead to an increase in rat numbers.

Construction of raised walkways around the summit reduced damage to the overall environment and to the burrows in that area. However, serious erosion continued to occur along certain sections of the South Fork and Palmers Tracks, and DOC (Great Barrier Area Office) began extending the boardwalk system into these areas during 2007/08. The contract construction team (Te Ngahere Limited) consulted with local DOC staff and the authors. A number of burrows were identified within the construction zone and these were avoided by the new boardwalk. The Palmers Track section was completed in the 2007/08 season (EAB, pers. obs.) and the South Forks Track was due to be completed by the end of the following (2008/09) season (Ken Scott, DOC, pers. comm.).

A total of 16 black petrels (including one banded by the authors) were recorded as bycatch on domestic long-line vessels in the New Zealand fisheries between 1 October 1996 and 30 September 2008 (Robertson et al. 2004; Conservation Services Programme 2008; C.J.R. Robertson (WildPress) pers. comm.; David Thompson (NIWA), pers. comm.). Most 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 (Robertson et al. 2003, 2004, Conservation Services Programme 2008). The timing of their capture suggests that most were breeding adults. This means that their deaths would have reduced overall productivity and recruitment. The level of bycatch for black petrels outside New Zealand waters is unknown, and may also impact on the population dynamics of the species.

Black petrels have delayed maturity, low reproduction rates and high adult survival, so any change in adult survival, however small, could affect the population greatly (Murray et al. 1993). Continued bycatch of breeding adults in New Zealand and overseas fisheries has the potential to seriously affect the species. Data-loggers may assist in identifying problem or high-risk areas within New Zealand and overseas fisheries. The preliminary logger work in 2006/06 obtained interesting results on foraging behaviour and at-sea distribution of black petrels during the breeding season (Bell et al. 2009). The deployment of 28 loggers this season will build on these preliminary results, giving detailed tracks during incubation and chick rearing, migration to South America, non-breeding foraging in South America, migration back to New Zealand and further incubation and chick rearing periods. Eight loggers had been retrieved at the time of writing, with the remainder due to be retrieved in December 2008 or January 2009.

It is important to continue to monitor the Great Barrier Island black petrel population. Long-term population data combined with improved technology can be used to develop an accurate population model to determine adult survivorship, recruitment, mortality and productivity as well as assessing factors affecting the black petrel population, particularly likely overlap or risk areas with fisheries, and the overall effects of fisheries bycatch.

6. Recommendations

The authors recommend that:

- Monitoring of the black petrel population (using the study burrows) is continued at Great Barrier Island up to and including the 2009/10 breeding season. This will ensure that 15 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, long-line fishing and other environmental factors.
- 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 should be checked for breeding status during every visit to the study site, to give a more accurate estimate of breeding success and determine sex of adults. This would also provide an opportunity to recapture returning birds banded as chicks.
- The April/May visit should continue, as this allows time for chicks to be banded before they fledge.
- A sample of at least 20 black petrels should carry GPS data-loggers to investigate foraging distances and locations, water temperature and flight patterns throughout the breeding and non-breeding seasons.
- Further random transects should be undertaken throughout the study 35-ha study area around Mount Hobson to increase the likelihood of adult and juvenile recaptures and thus improve the accuracy of survival and immigration estimates.
- 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 are 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 to November) and the fledging period (May to June).

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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.

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.

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.

Bell, E.A.; Sim, J.L.; Scofield, P. 2007: Demographic parameters of the black petrel (*Procellaria parkinsoni*). *DOC Research and Development Series 273.* Department of Conservation, Wellington. 32 p.

Bell, E.A.; Sim, J.L.; Scofield, P. 2009: Population parameters and distribution of the black petrel (*Procellaria parkinsoni*), 2005/06. *DOC Research and Development Series 307.* Department of Conservation, Wellington. 47 p.

Conservation Services Programme 2008: Summary of autopsy reports for seabirds killed and returned from observed New Zealand fisheries: 1 October 1996 to 30 September 2005, with specific reference to 2002/03, 2003/04 and 2004/05. *DOC Research and Development Series 291.* Department of Conservation, Wellington. 110 p.

Freeman, A.N.D.; Wilson, K.-J. 2002: Westland petrel and hoki fishery waste: opportunistic use of a readily available resource? *Notornis 49*: 139–144.

Heather, B.; Robertson, H. 1996: Field guide to the birds of New Zealand. Penguin Books (NZ) Ltd, Auckland. 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. 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 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. *Department of Conservation Internal Series 155*. Department of Conservation, Wellington. 43 p.

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

Walker, K.; Elliott, G. 2005: Population changes and biology of the Antipodean wandering albatross (*Diomedea antipodensis*). *Notornis 52*: 206–214.

Warham, J. 1996: The behaviour, population biology and physiology of the petrels. Academic Press, London. 613 p.

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