Notornis, 2013, Vol. 60: 269-278
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Notes on the distribution, behaviour and status of grey petrel (*Procellaria cinerea*) on Antipodes Island, New Zealand

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Abstract Aspects of the breeding biology of the grey petrel (*Procellaria cinerea*) were studied on Antipodes Island between April and June 2001. The island was surveyed to determine grey petrel distribution and four 2500 m^2 census grids were established. The survey suggested that the distribution of grey petrels was restricted to steep, well-draining areas dominated by *Poa litorosa* tussock (approximately 510 ha of the 2025 ha island). Occupied burrow density within the 4 census grids ranged from 31 to 44 burrows (0.01 burrows per square metre). Extrapolating from the census grid density to the total grey petrel habitat resulted in a population estimate of 114,730 birds: 53,000 breeding pairs (range = 32,000-73,000) and 8,670 non-breeding-birds (range = 4,000-16,320) were present on Antipodes Island. Aspects of the behaviour of the species were recorded. Comparisons are made with other members of the genus *Procellaria*.

Bell, E.A.; Bell, B.D.; Sim, J.L.; Imber, M.J. 2013. Notes on the distribution, behaviour and status of grey petrel (*Procellaria cinerea*) on Antipodes Island, New Zealand. *Notornis 60 (4)*: 269-278.

Keywords grey petrel; *Procellaria cinerea*; distribution; Antipodes Island; population estimate; behaviour

INTRODUCTION

Grey petrels (*Procellaria cinerea*) are a large (1200 g), grey and white seabird with a circumpolar distribution (Warham & Imber 1985; Warham 1990; Heather & Robertson 1996). They have been recorded breeding on Antipodes, Campbell, Marion, Tristan da Cunha, Gough and Prince Edward Is, Iles Crozet, and the Kerguelen Group (Imber 1983; Warham & Imber 1985; Table 1). With the exception of Gough I, Antipodes I is believed to hold the largest population of grey petrels.

Received 14 Sep 2012; accepted 6 Aug 2013
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**Deceased

Grey petrels are winter breeders, being recorded on Antipodes I from mid-Feb to Nov (Warham & Bell 1979). As the least studied southern ocean petrel (Warham & Imber 1985), very little is known about their general behaviour and breeding biology on the Antipodes, although basic breeding information collected during this study was reported in Imber *et al.* (2005) and more detailed ecological and breeding information is available from studies completed on Tristan da Cunha, Crozet and Kerguelen Is (Jouventin *et al.* 1985; Richardson 1989; Weimerskirch *et al.* 1989; Inchausti *et al.* 2003; Chastel 1995; Barbraud *et al.* 2009). Grey petrels have an extended breeding season; adults return to the colony in mid-Feb, lay

Table 1. Estimated numbers of grey petrels (*Procellaria cinerea*) on breeding locations around the world. Data from: Bailey & Sorenson (1962); Jones (1980); Imber (1983); Jouventin *et al.* (1984); Robertson & Bell (1984); Rounsevell & Brothers (1984); Williams (1984); Richardson (1989); Weimerskirch *et al.* (1989); O'Brien (1990); Jouventin (1994); Bester *et al.* (2002); Brooke (2004); Schulz & Robinson (2005); Barbraud *et al.* (2009).

Island(s)	Estimate (breeding pairs)	Notes
Prince Edward	'Thousands'	-
Marion	Thousands	Decline due to cat predation (cats eradicated 1993); mice present
Crozet	2000-9000	Decline due to cat and rat predation
Kerguelen	1900-5600	Decline due to cat and rat predation
Amsterdam	'Hundreds'	Decline due to cat and rat predation
Macquarie	59-80	Eradicated by rats and cats; recovering following cat eradication in 2000
Campbell	100	Zero productivity due to rats (eradication in 2001)
Antipodes	10000 - 50000	Preliminary estimate only, mice (*Mus musculus*) present
Tristan da Cunha	50 – 100	Decline due to cat and rat predation
Gough	10,000-25,000	Mice present

1 egg between Mar and May, the eggs hatch after 55-65 days (May to Jul), and after being reared for 110-120 days, the chicks fledge from Sep to Nov (Imber 1983; Newton & Fugler 1989; Richardson 1989; Weimerskirch *et al.* 1989; Zotier 1990, Imber *et al.* 2005).

In the New Zealand region, grey petrels have been recorded at sea as far north as East Cape/Bay of Plenty (Hellyer *et al.* 1973; Jenkins & Greenwood 1984). At sea, grey petrels have only been observed singly or in small groups (Jenkins & Greenwood 1984). Beach-wrecked fledgling grey petrels have been recovered on the east coast of the North I and west Auckland region of New Zealand (Powlesland 1989). Grey petrels feed mainly on squid, but are known to scavenge around fishing vessels (Warham & Imber 1985; Bartle 2000a, b; Robertson 2000; Robertson & Bell 2002a, b; Conservation Services Programme 2008) and have been associated with whales (Harper 1987). In the New Zealand Exclusive Economic Zone (EEZ), autopsy data from bycatch birds between 1989 and 2009 show over 600 grey petrels being caught on commercial long-line fisheries at East Cape, along the East Cape Ridge, Campbell Plateau and on the Chatham Rise (Murray *et al.* 1983; Bartle 2000a, b; Robertson 2000; Robertson & Bell 2002a, b; Conservation Services Programme 2008; Thompson 2009; 2010a, b; Table 2).

Several scientific parties (Warham & Bell 1979; Imber 1983) have made observations on the grey petrel population on Antipodes I. The only population estimate was 10-50,000 breeding pairs; an educated guess following thorough ground surveys by experienced ornithologists during the 1969 and 1978 expeditions to the Antipodes (Warham & Bell 1979; Robertson & Bell 1984; C.J.R. Robertson, *pers. comm.*). The present study was part of a feasibility project for a long-term study on grey petrel on the Antipodes Is (Bell 2002). This paper covers information gathered during this study on the habitat, distribution, population size and ecology of grey petrels on Antipodes I.

METHODS

The Antipodes I group (49°41'S, 178°48'E) comprises the main island, Antipodes I (2025 ha), Bollons I (57 ha), smaller islets (Leeward, Windward and Orde Lees), and several rock stacks. Antipodes I rises to 366 m above sea level (Mount Galloway). The vegetation is dominated by *Poa litorosa* and *P. foliosa* tussock and *Polystichum vestitum* fern, with several endemic plants including *Anisotome antipoda*, *Senecio antipodus, Gentiana antipoda* and *Coprosma rugosa* var. *antipoda*.

Antipodes I was visited from 23 Apr to 10 Jun 2001. The distribution of breeding grey petrels was determined using transects. Transect lines varied in length from 250 m to 1 km depending on the terrain, and were run along a randomly generated compass bearing starting from a random point (Fig. 1). A 1-m strip along each transect was searched for burrows and any burrow entrance (or partial burrow entrance) within this strip was counted. Records were made of vegetation type, presence of burrows, species occupying the burrows, aspect, and direction.

To produce a population estimate for breeding grey petrels on Antipodes I, census grids (50 x 50 m) were set up in 4 areas on the northern end of the island; the western slopes of Mount Galloway, Perpendicular Head, Crater Bay and Stella Bay (Fig. 1). Each grid was systematically searched for

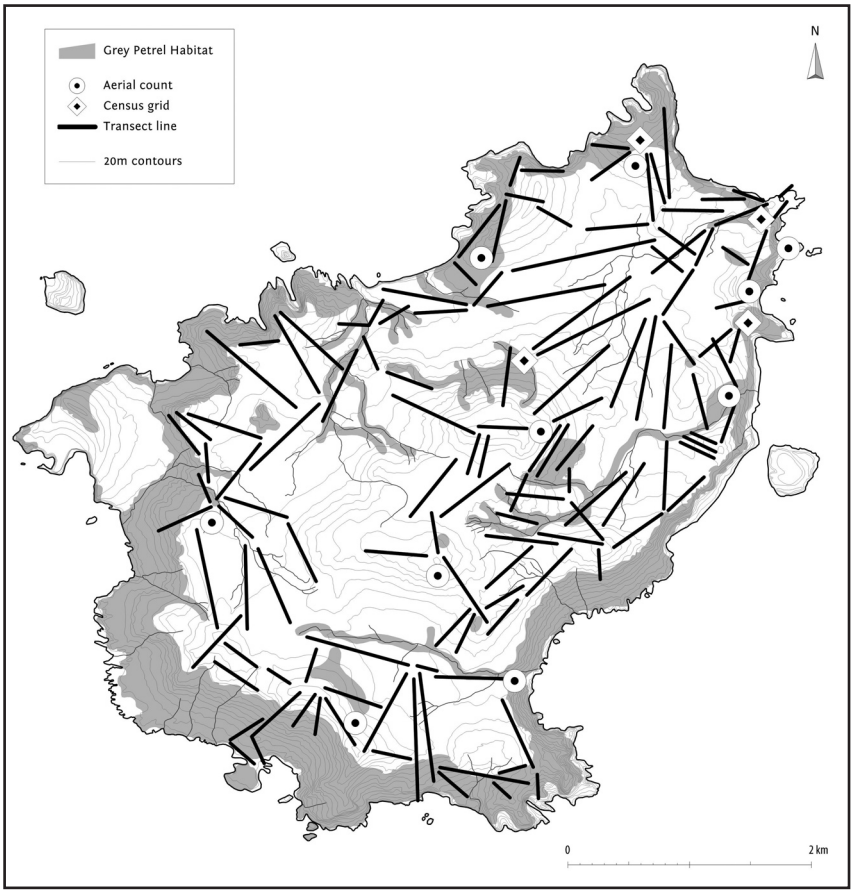

Fig. 1. Location of grey petrel (*Procellaria cinerea*) habitat, transect lines, arrival and departure count sites and census grids on Antipodes I, Apr-Jun 2001.

burrows. The contents of each burrow were noted by either viewing the resident bird through the entrance with a torch, removing the bird from the burrow, gaining a response by the bird attacking a probe stick, returning calls to a previously recorded taped grey petrel call, or using a 'burrowscope' (camera mounted at the end of a long flexible pipe). Where possible, grey petrels were removed from the burrow via the entrance (*i.e.,* observer reached into the chamber, grabbed the bill or head and pulled the bird gently to the entrance), banded, measured using Vernier callipers (skull width; head/bill length; culmen length, width and least depth; tarsus length and mid toe/claw length) and weighed (using 1.5 kg Pesola™ scales). They were then assessed for breeding condition and returned to the burrow. Grey petrel eggs were also measured (length and width only). Burrow position, occupants, nest contents, altitude, aspect, gradient and vegetation details were recorded for each grid.

Grey petrels were observed flying around the island during the day and were counted from high points around the island (Fig. 1). Birds were observed landing at burrow sites during these counts.

RESULTS

Behaviour

Grey petrels were seen returning to the island throughout the day (during the duller periods) and never during any spotlighting exercises at night. Peak departure activity was between 0730 and 0900 hours and peak arrival was between 1400 and 1630 hours. Grey petrels were heard and seen calling nearby, or from their burrow entrances at night, but that was the only nocturnal activity observed. Grey petrels were also heard calling in the early evening and very early morning. Aerial calling was observed on several occasions, once accompanied by aerial display flights. The level of calling had decreased by Jun 2001.

Grey petrels were generally docile and this made banding easy; the birds walked calmly to the entrance as they were being held by the bill or head. A total of 77 adults were banded during this expedition; of these, 29 were from burrows within the census grids. There have been only 16 grey petrels banded before 2001 (14 on Antipodes I and 2 on Campbell I; M. Nesaratham, DOC, *pers. comm*.) and none of these previously banded grey petrels

Table 2. Number and sex of grey petrels (*Procellaria cinerea*) caught by the commercial fishing industry in New Zealand waters on observed vessels and returned for autopsy. Data from: Murray *et al.* (1993), Bartle (2000a, b), Robertson (2000), Manly *et al.* (2002), Robertson & Bell (2002a, b), Robertson *et al.* (2003), Conservation Services Programme (2008), Thompson (2009, 2010a, b). Where M = male, F = female and U = unknown.

Dates	Type of fishing vessel		
	Long-liner	Trawler	Total
1 Jan 89 to 1 Sep 96	51 (2M, 47F, 2U)	0	51 (2M, 47F, 2U)
1 Oct 96 to 31 Dec 97	66 (17M, 48F, 1U)	0	66 (17M, 48F, 1U)
1 Jan 98 to 30 Sep 98	81 (10M, 70F, 1U)	1 (1M)	82 (11M, 70F, 1U)
1 Oct 98 to 30 Sep 99	70 (34M, 9F, 27U)	0	70 (37M, 9F, 24U)
1 Oct 99 to 30 Sep 00	57 (36M, 3F, 18U)	3 (2M, 1F)	60 (38M, 4F, 18U)
1 Oct 00 to 30 Sep 01	187 (42M, 2F, 143U)	3 (1M, 2F)	190 (43M, 4F, 143U)
1 Oct 01 to 30 Sep 02	5 (5M)	0	5 (5M)
1 Oct 02 to 30 Sep 03	61 (29M, 8F, 24U)	0	61 (29M, 8F, 24U)
1 Oct 03 to 30 Sep 04	3 (3F)	0	3 (3F)
1 Oct 04 to 30 Sep 05	3 (1M, 2F)	2 (2M)	5 (3M, 2F)
1 Oct 05 to 30 Sep 06	7 (2M, 5F)	1 (1M)	8 (3M, 5F)
1 Oct 06 to 30 Sep 07	25 (3M, 6F, 1U)	3 (1M, 2F)	28 (4M, 23F, 1U)
1 Oct 07 to 30 Sep 08	5 (3M, 1F, 1U)	1 (1F)	6 (3M, 2F, 1U)
1 Oct 08 to 30 Sep 09	10 (3M, 6F, 1U)	0	10 (3M, 6F, 1U)
Total	631 (187M, 225F, 219U)	14 (8M, 6F)	645 (195M, 231F, 219U)

were recaptured. Measurements were collected from adults; the mean culmen length was 47.3 (± 0.4) mm (n = 13), mean tarsus length was 61.6 (± 0.5) mm (n = 3) and the mean weight was 1,237 (± 50) g (n = 12, Table 3).

Distribution of grey petrels on Antipodes I

The survey of the island showed that grey petrels were restricted to coastal cliffs, steep stream banks or high "knobs" along ridges, *i.e.*, well-draining, steep terrain (Fig. 1). These areas corresponded to 25% of the entire island area (~510 ha; estimated from aerial photographs and topographic maps). Preferred habitat appeared to be tall (1-2 m) "knobbly" *Poa litorosa* tussock, or areas of *Polystichum vestitum* fern interspersed with *Poa litorosa* tussock (and in some instances *Coprosma rugosa* var. *antipoda* shrubs). Generally *Poa litorosa* tussock was found in well-draining areas such as cliffs and steeper slopes and stream banks. These vegetation types were drier and had deeper soil bases than other areas. Steep banks appeared easier for the petrels to excavate burrows.

Census grids

Burrow density was determined by establishing four 50 x 50 m census grids on Antipodes I (Fig. 1). A total of 121 occupied burrows were found in the grids (range = 19-44, mean (± SEM) = 30 (± 5) occupied burrows per grid, 0.012 burrows/m^2, Table 4). The mean number of breeding burrows in the grids was 26 ± 4 (range = 16-36) and non-breeding burrows was 4 ±1 (range = 2-8, Table 4). There were a large number of vacant burrows located in each grid (range = 11-55, mean (± SEM) =25 (± 10), 0.010 burrows/m^2), many of which had fleas present. These vacant burrows were of the same size and physical characteristics as grey petrel burrows. They were regarded as probable grey petrel burrows since they had been used before (*i.e.*, had fresh digging, old and new droppings, old and new grey petrel feathers or old nest material inside), but were not being used for breeding when checked. There could be for a number of reasons for these vacant burrows including a failed breeding attempt, use by a pre-breeder, skipping a breeding season, or possible death. As these vacant burrows may not be used by a grey petrel in the future, they were not included in the breeding population estimate.

Burrow description

Grey petrel burrows were generally large, long and dry. Burrow entrances were usually under *Poa litorosa* tussocks (often hidden by "curtain" of tussock), sloping only slightly downwards with tunnels ranging from 1 to over 3 m in length. The entrances were usually large and "squarish". Usually the entrance and tunnels were kept clear, with

Table 3. Mean measurements from grey petrels (*Procellaria cinerea*) banded between Apr to Jun 2001 and early research (Warham & Bell 1979) on Antipodes I, Crozet (Jouventin *et al.* 1985), Marion I (Newton & Fugler 1989), and Kerguelen Is (Zotier 1990). Number of birds in parentheses; banding locations can be found in Bell (2002).

Date	Head/bill length (mm)	Skull width (mm)	Culmen length (mm)	Culmen width (mm)	Culmen depth (mm)	Culmen least depth (mm)	Tarsus (mm)	Mid toe claw (mm)	Weight (g)
Antipodes 2001	111.1 ± 1.7 (3)	34.4 ± 0.7 (3)	47.3 ± 0.4 (13)	18.8 ± 0.6 (3)	20.0 ± 0.2 (3)	14.3 ± 0.2 (3)	61.6 ± 0.5 (3)	76.9 ± 0.8 (13)	1237 ± 50 (12)
Antipodes 1979	-	-	46.6 ± 1.0 (5)	-	-	-	60.0 ± 1.9 (5)	82.0 ± 2.6 (5)	1106 ± 50 (12)
Marion 1989	-	-	46.4 ± 1.3 (18)	-	-	-	60.7 ± 1.5 (18)	-	1070 (3)
Kerguelen 1990	-	-	49.6 ± 1.4 (37)	-	-	-	-	-	1131 ± 133 (37)
Crozet 1985	-	-	46.3 ± 1.9 (5)	-	-	-	64.0 ± 3.4 (5)	-	1073 ± 137 (3)

vegetation only being found in the nest chambers. Nest chambers were large and dry, with tussock, fern and other vegetation making up the nest, which was on a slightly raised mound. The chamber was slightly rounded and larger than the tunnel. Nearly all burrows were infested with fleas.

In comparison with burrows used by the other petrel species on the island, each was distinctive from grey petrel burrows. White-chinned petrels (*Procellaria aequinoctialis steadi*) burrows, although used by a similar-sized bird, were usually found on flat areas and lower slopes, particularly in damp areas. There was only a slight habitat overlap with grey petrels, and this occurred along the cliff top edges. At times a pool of water filled the entrance to white-chinned petrel burrows. These burrows had open (*i.e.*, not restricted or hidden by vegetation) and large, irregular-shaped entrances, and the tunnels generally sloped downwards. Burrows used by white-headed petrels (*Pterodroma lessonii*) were smaller, with open entrances that were much rounder and sloped down steeply towards the chamber. A grey petrel would not be able to fit into most white-headed petrel burrows. The storm petrel burrows (*Fregetta* sp. and *Oceanites* sp.) were much smaller and impossible for a grey petrel to use.

Burrow monitoring

Despite most burrows being straight and the resident grey petrel easily visible, only 24% of the burrows in the study grids (range = 16-30%) had nesting chambers that were accessible (i.e., birds within "arms reach") through the entrance. Tape recordings of grey petrel calls and/or the burrowscope were used to determine whether grey petrels were using the burrow in cases where the resident bird was not visible through the entrance.

Two burrows had dead sooty shearwater (*Puffinus griseus*) fledglings inside; due to the head wounds and crushed skull it was possible that the grey petrel had killed the sooty shearwater chick. Nesting habitat of grey petrels was shared with the smaller storm petrels and white-headed petrels, but our observations suggest that white-chinned petrels rarely nested in the same areas as grey petrels.

Estimating population size

It became clear during the study that arrival and departure counts, counts at specific points, call counts, raft counts and transect lines only gave a relative estimate of the range of habitat occupied by grey petrels, and not specific numbers of birds or accurate population estimates. Unlike other petrel species on the island, grey petrels arrived and departed at any time during daylight, and generally took a long time to land and enter their burrows.

Arrival counts were not a useful tool for estimating numbers as most birds took between 15 minutes and 3 hours to land. Numbers varied around the island and the highest count was 50 birds circling the Ringdove cliffs and the least was 1 or 2 individuals along Anchorage Bay cliffs. Although a number of grey petrels were visible in the air at any one time, the erratic flight paths and behaviour of the birds made it difficult to determine whether it was the same bird on each return "fly-by". No common launch sites were used as grey petrels departed by launching off taller tussocks or steeper areas on cliffs near their burrows.

Although call counts were not useful for estimating population size during this time of the breeding season, it was useful for determining presence and absence in the island survey as petrels called when the team walked near to or on top of burrows. The amount of calling by grey petrels was very low; there was limited calling at night, but the levels decreased throughout the study. Vocalisation on the wing during arrival and during paired display flights was seen and heard on 7 occasions. Grey petrels were not seen rafting offshore at any stage.

Table 4. Grey petrel (*Procellaria cinerea*) burrow density within the 4 census grids (each 2500 m^2) on Antipodes I, Apr-Jun 2001.

	Breeding	Non-breeding	Total occupied burrows	Total vacant burrows	Total burrows
Stella Bay	27	4	31	55	86
Perpendicular Head	25	2	27	13	40
Mt Galloway	16	3	19	11	30
Crater Bay	36	8	44	21	65
Total	104	17	121	100	221
Mean (± SEM)	26 (± 4)	4 (± 1)	30 (± 5)	25 (± 10)	55 (± 13)

Table 5. Population estimate of grey petrels (*Procellaria cinerea*) on Antipodes I, Apr-Jun 2001. Total area searched was 510 ha.

Grid	Burrow density (number/ha)		Population estimate	
	Breeding pairs	Burrows occupied by non-breeding birds	Breeding pairs	Burrows occupied by non-breeding birds
Perpendicular Head	100	8	51,000	4,080
Mount Galloway	64	12	32,640	6,120
Stella Bay	108	16	55,050	8,160
Crater Bay	144	32	73,440	16,320
Mean (± SEM)	104 ± 16	17± 5	53,033 ± 8,369	8,670± 2,683

As for arrival and departure counts, the random transect lines showed the preferred habitat and general distribution of the grey petrels over the island, but were not useful in estimating the population size. The vegetation and terrain made transects difficult in some areas, and in many cases, transects proved to be out of grey petrel habitat. Transects showed a distinct pattern between location of grey petrel burrows and the slope, drainage and vegetation of the area.

From experience during earlier visits (Bell & Warham 1979; Imber 1983), mark-recapture work was attempted by catching adults as they called on tussocks during the night. Unfortunately, it appeared that it was too late in the season for this behaviour, with most birds incubating eggs. Most calling was from the burrow entrance or further inside burrows, with few birds visible on the surface.

Extrapolating from the census grid density data to the total area of identified grey petrel habitat on Antipodes I (*i.e.*, 510 ha of suitable habitat out of the total 2025 ha island; Fig. 1) the grey petrel population is estimated at 114,730 birds; between 32,000 and 73,000 breeding pairs (mean = 53,000 ± 8,369 breeding pairs) and between 4,000 and 16,320 non-breeding birds (mean = 8,670 ± 2,683 birds; Table 5). The total population estimate was 114,736 individuals (Table 5).

DISCUSSION

The survey of Antipodes I in Apr to Jun 2001 suggested that grey petrels appeared to favour steep, well-draining areas dominated by *Poa litorosa* tussocks for burrow locations across an area of ~510 ha. Measured densities of 0.01 occupied burrow/ha was extrapolated to give a population estimate of 53,000 breeding pairs of grey petrels on Antipodes I. The low occupancy rate and the fact that only 24% of grey petrel burrows were accessible through the entrance means alternative methods would be required for any long-term population monitoring study.

Grey petrel burrows were easily identified; large, long and dry under *Poa litorosa* tussocks with slightly sloping tunnels up to 4 m in length. The large square entrances were clear, but nest chambers had vegetation for the raised nest. The other petrel species on Antipodes I also had distinctive burrows; open, large and deep on flat areas or the lower slopes for white-chinned petrels and small, open entrances and steep tunnels for white-headed petrels and much smaller entrances for storm petrels, both found over most of the island.

During this study, no burrows on Antipodes I were shared between grey petrels and white-chinned petrels. The habitat separation for these 2 species appeared to be pronounced and likely to prevent both species using the same burrow despite

the breeding cycles of both species overlapping significantly. Grey petrels lay from early March while white-chinned petrel chicks do not fledge until late Apr (Imber 1983; Weimerskirch *et al.* 1989). However, on Possession I, Despin (1976) noted a white-chinned petrel in a burrow with a grey petrel chick and it has been recorded on Mayes I that grey petrel chicks have been pushed out of their burrows by returning adult white-headed petrels (Zotier 1990), so some level of burrow competition may occur and could be noted in a long-term study.

Grey petrels were found to occasionally share burrows with sooty shearwaters on Antipodes I and this behaviour has also been recorded on Campbell I (Bailey & Sorensen 1962). As the sooty shearwater population on Antipodes I is thought to be very small (Warham & Bell 1979), there is probably only limited burrow competition. However, the overlap of breeding seasons (sooty shearwaters fledge mid Apr to late May, and grey petrels return to the colony in mid Feb) may restrict the chance of sooty shearwaters establishing on Antipodes I in greater numbers.

There were a total of 121 occupied burrows in the census grids and due to the length of the tunnels it was possible to only reach between 16 and 36% of the occupants through the entrance. Excavation hatches, observation windows and false roofs were used successfully in grey petrel studies on Mayes I in the Kerguelen Group (Zotier 1990), and Marion I by using removable earth plugs (Newton & Fugler 1989) and in a black petrel (*Procellaria parkinsoni*) study on Great Barrier I (Bell *et al.* 2011). Any long-term research on Antipodes I could use these or similar techniques to increase the level of accessibility to the resident birds and to enable breeding status and success, population trends, burrow density and occupancy rates to be determined.

There were a large number of unoccupied grey petrel burrows found during the census grids (46%) and line transect surveys (52%). This is comparable to Westland petrel (*Procellaria westlandica*), another other winter breeder, where 62% of burrows monitored were unoccupied (Waugh *et al.* 2003), but much higher than summer breeding black petrel where only 11% of monitored burrows are unoccupied annually (Bell *et al.* 2011). These unoccupied burrows were interesting as they could be used by intermittent or possibly biennial breeding birds, vacant burrows due to mortality of birds or adolescent pre-breeding or non-breeding birds that do not stay in the burrows during the day. Nearly all burrows had evidence of visits during the study. Research on Mayes I in the Crozet Group suggests that grey petrels there were annual breeders, with 83% returning the following year to breed (Chastel 1995); only a long-term project will show the relevance of these unoccupied burrows on Antipodes and whether the grey petrels returned to breed in similar numbers each year.

Adult grey petrels were docile and easy to handle while banding. No previously banded birds were captured during this study; the only recovery off a grey petrel banded anywhere in New Zealand was one that was recovered dead at the mouth of the Karori Stream, Wellington in 1977; this bird had been banded by Brian Bell during the 1969 Antipodes I expedition (Warham & Bell 1979). Measurements taken while handling the birds were similar to those previously recorded on Antipodes, Crozet, Marion and Kerguelen Is (Warham & Bell 1979; Jouventin *et al.* 1985; Newton & Fugler 1989; Zotier 1990).

The amount of calling by grey petrels was very low; most occurred at night although calling was sometimes recorded during the day throughout the study. Calling levels decreased throughout the study and is probably due to the number of non-breeders and pre-breeders decreasing as the breeding season continued. In most petrel species non-breeders and pre-breeders leave the colony much earlier than breeding birds (Warham 1990; Bell *et al.* 2011). Vocalisations by grey petrels on the wing during arrival and during paired display flights were both seen and heard on several occasions. Vocalisation on the wing had not been recorded previously (Warham & Johns 1975; Warham 1988). Grey petrels were not seen rafting offshore at any stage during the visit; this may be due to the timing of the expedition as rafting has been noted in the Kerguelen Group during mid-Feb (Zotier 1990).

The population estimate of grey petrels on Antipodes I was 53,000 breeding pairs (range = 32,000-73,000). This was obtained by extrapolating from only 4 census grids. The estimate may not be detailed or accurate across the entire island, but it does give a more quantitative estimate compared to earlier guesses. All other survey methods trialled were unsuitable due to grey petrel behaviour (*i.e.,* diurnal, lack of calling, range and spread of burrow locations, etc.) and terrain. A more accurate estimate could be obtained if a greater number of census grids were established over the entire island. Occupancy of the burrows would need to confirm grey petrels were present. Grey petrel presence and absence along line transects was used to determine preferred habitat on Antipodes I during this study and distance sampling or detailed line-transect surveys could also be used to determine a more statistically sound population estimate in a long-term study. A 2-year population and tracking study commenced in 2009 may provide a more accurate population estimate for grey petrels on Antipodes I (D. Thompson, NIWA, *pers. comm*.).

Grey petrels have been caught in high numbers as commercial fisheries by-catch in New Zealand waters; between 1989 and 2009 over 600 birds have been caught and autopsy data shows that most of these birds were adults in breeding condition (Murray *et al.* 1993, Bartle 2000a, b; Robertson 2000, Manly *et al.* 2002, Robertson & Bell 2002a, b, Robertson *et al.* 2003, 2004, 2005a, b, 2006, Conservation Services Programme 2008, Thompson 2009. 2010a, b). This means that these birds can only come from the New Zealand breeding populations on Antipodes or Campbell Is, as the other grey petrel populations are too distant and are unlikely to forage that far from their breeding location. Unfortunately, as there are less than 100 grey petrels banded from Antipodes I, band recoveries have been limited. If banding levels increased it is expected that a higher number of recoveries would result, including as by-catch returns. In the long-term it is important to establish where by-catch specimens originate and a long-term mark/recapture study on Antipodes I would enable greater numbers of adult and fledgling grey petrels to be banded.

Any adult grey petrels caught and killed in commercial long-line fisheries between April and Oct could be incubating an egg or foraging for chicks and this would result in the death of the egg or starvation of the chick as one parent is unable to successfully incubate and egg or raise a chick (Warham 1996). Like other procellariiforms, grey petrels have delayed maturity, low reproduction rates and high adult survivorship, and any change in adult survivorship will affect the population greatly by reducing recruitment and productivity (Warham 1990; Murray *et al.* 1993). The capture of breeding adults means reduced breeding success, cause a decline in the number of pairs breeding in following years and impose a greater impact on the overall population. The death of a partner means that at least one year's breeding is lost, with a possible reduction in success even after a new pair bond is fashioned (Warham 1996). If large numbers of breeding adults continue to get caught on commercial long-lines, this species could be drastically affected. Mortality of significant numbers of any petrel species is ultimately unsustainable. It is vital to monitor the grey petrel population on Antipodes I especially in relation to adult survivorship, mortality, productivity and breeding success as these factors could help to determine the overall effects of by-catch in the commercial long-line fishing industry. A programme to collect yearly demographic data for the Antipodes I grey petrel population is urgently required and has been suggested for many years (Murray *et al.* 1993; Robertson *et al.* 2003; Imber *et al.* 2005).

It has been noted from by-catch data that grey petrels appear to have segregated feeding locations with males feeding around the Pukaki Rise and females foraging much farther north near East Cape (Bartle 1990, 2000a, b; Robertson 2000; Robertson & Bell 2002a, b, Conservation Services Programme 2008; Thompson 2009, 2010a, b). It is important to evaluate the foraging behaviour of grey petrels, including both location and timing of foraging events for both sexes, to cover the possibility of segregated feeding. The 2-year population and tracking study begun in 2009 may provide details on these aspects (D. Thompson, NIWA, *pers. comm*.).

The lack of knowledge regarding population dynamics and trends and the high occurrence of fisheries by-catch means that long-term monitoring of grey petrels is vital. Research on population dynamics (*i.e.*, adult and juvenile survivorship, recruitment, fidelity, etc.) and at-sea distribution would increase the general knowledge about this species and ensure that impacts on, and changes to, the population are known and can be managed if required. A long-term monitoring and mark/recapture project on the grey petrel population (using study burrows) should commence on Antipodes I to collect data to determine an accurate population estimate, population dynamics and trends, breeding ecology, survival, recruitment and fidelity. These data could be used to determine the population status of grey petrels and assess the risk of commercial fishing interaction with these birds.

ACKNOWLEDGEMENTS

This study was funded by the fishing industry through the Conservation Services Levy via the Marine Species and Threats Unit of the Department of Conservation (DOC). Permits to undertake the research and expedition were provided by Southland Conservancy and banding and handling permits and banding data on grey petrels were provided by Mala Nesaratnam at the DOC Banding Office. Thanks to Matthew Brown, Anthony Henry and Saskia Wood for their assistance on Antipodes I. Transport to and from the Antipodes was by MV *Ranui.* Ian West (National Office, DOC), Kerri-Anne Edge and Pete McClelland (Southland Conservancy) provided logistical support. Dr. Christopher Robertson (Wild Press) provided information from the 1978 Antipodes expedition and supplied technical equipment. Daily radio schedules were kept with DOC Stewart I, DOC Te Anau or Meri Leask (Bluff Fisherman's Radio). Kelvin Floyd produced Figure 1. Paul Sagar kindly commented on early drafts of this paper.

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