Grey petrels (*Procellaria cinerea*) on Antipodes Island, New Zealand: research feasibility, April to June 2001

DOC SCIENCE INTERNAL SERIES 60

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Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

DOC Science Internal Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff, or external contractors funded by DOC. It comprises progress reports and short communications that are generally peer-reviewed within DOC, but not always externally refereed. Fully refereed contract reports funded from the Conservation Services Levy (CSL) are also included.

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ISSN 1175-6519

ISBN 0-478-22287-4

This report originated from work carried out under Department of Conservation investigation no. 3095. It was prepared for publication by DOC Science Publishing, Science & Research Unit; editing by Helen O'Leary and layout by Ruth Munro. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

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A B S T R A C T

The grey petrel (*Procellaria cinerea*) is an indigenous seabird, which breeds on Antipodes Island, New Zealand and has a circumpolar distribution. During April to June 2001 Antipodes Island was visited to determine the feasibility of a long-term monitoring study. The island was surveyed to determine the grey petrel distribution and four 50 m × 50 m census grids were set up. The survey of the island showed 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 four census grids ranged from 19 to 44 burrows (with a mean density of 0.01 burrows/m^2). Extrapolating from the census grid density to the total grey petrel habitat resulted in a preliminary population estimate of 53 000 breeding pairs. Aspects of the behaviour and breeding biology of the species were recorded. A long-term population study is feasible, however several difficulties such as cost, weather and access into burrows, will need to be overcome.

Keywords: Grey petrel, *Procellaria cinerea*, Antipodes Island, by-catch, feasibility, population estimate, monitoring, distribution.

Bell, E.A. 2002: Grey petrels (*Procellaria cinerea*) on Antipodes Island, New Zealand: research feasibility, April to June 2001. *DOC Science Internal Series 60*. Department of Conservation, Wellington. 31 p.

1. Introduction

The Antipodes Islands (49°41′S, 178°48′E) have the main population of grey petrels (*Procellaria cinerea*) in New Zealand. The group comprises the main island, Antipodes (2025 ha), a smaller island, Bollons (57 ha), smaller islets (Leeward, Windward and Orde Lees) and several rock stacks. Antipodes Island rises to 366 m above sea level (Mount Galloway). The vegetation is dominated by *Poa litorosa* and *Poa foliosa* tussock and *Polystichum vestitum* fern, with other endemic plants including *Anisotome antipoda*, *Senecio antipodus, Gentiana antipoda* and *Coprosma rugosa* var. *antipoda* (O'Connor 1999).

Grey petrels are large (1000 g), grey and white, indigenous New Zealand seabirds (Warham & Imber 1985; Warham 1990; Heather & Robertson 1996). Grey petrels have a circumpolar distribution and breed in varying numbers on Antipodes (including Bollons Island), Campbell, Gough, Marion and Prince Edward Islands, Iles Crozet and the Kerguelen and Tristan da Cunha Groups (Imber 1983; Warham & Imber 1985; Table 1). With the exception of Gough Island, Antipodes Island holds the largest population of grey petrels. It is definitely their largest New Zealand population.

Common at sea, grey petrels have been recorded as far north as East Cape/Bay of Plenty (Hellyer et al. 1973; Jenkins & Greenwood 1984). When seen at sea, grey petrels have been observed in groups of 1–3 birds (Jenkins & Greenwood 1984; Harper 1987) as well as in larger flocks of 10–50 birds (Harper 1987; Smith 2001). A count of approximately 150 grey petrels has been observed during one fishing voyage (Smith 2001). Beach-wrecked fledgling grey petrels have been recovered on the east coast of the North Island and west Auckland region of New Zealand (Powlesland 1989). Autopsy data show grey petrels

TABLE 1. LOCATIONS AND ESTIMATED NUMBERS OF GREY PETRELS.

ISLAND(S)	ESTIMATE (BREEDING PAIRS)	NOTES	REFERENCES
Prince Edward	Thousands		Imber 1983; Williams 1984; O'Brien 1990
Marion	Thousands	Population in decline due to cat predation (cats eradicated). Mice present.	Williams 1984; O'Brien 1990
Crozet	Thousands	Population in decline due to cat and rat predation.	Jouventin et al. 1984; O'Brien 1990
Kerguelen	5000–10 000	Population in decline due to cat and rat predation.	Jouventin et al. 1984; Weimerskirch et al. 1989; O'Brien 1990
Amsterdam	Hundreds	Population in decline due to cat and rat predation.	Jouventin et al. 1984; O'Brien 1990
Macquarie	10	Population eradicated by rats and cats (cats eradicated 2000). Grey petrels recorded prospecting during the 2000/2001 breeding season (J. Hamill, pers. comm.).	Jones 1980; Rounsevell & Brothers 1984; O'Brien 1990
Campbell	100	Zero productivity due to rats (eradication programme begun in June 2001).	Bailey & Sorensen 1962; Robertson & Bell 1984; O'Brien 1990
Antipodes	10 000–50 000	Preliminary estimate; mice (*Mus musculus*) present.	Robertson & Bell 1984; O'Brien 1990
Tristan da Cunha	50–100	Population in decline due to cat and rat predation.	Imber 1983; Richardson 1984; Williams 1984; O'Brien 1990
Gough	100 000	Mice present.	Imber 1983; Williams 1984; O'Brien 1990

being caught on long-line fisheries at East Cape, along the East Cape Ridge (approximately 36°S) and towards the Chatham Islands (Bartle 2000a, 2000b; Robertson 2000; Robertson & Bell 2002a, 2002b).

Grey petrels are winter breeders, being recorded on Antipodes Island from mid-February to November (Warham & Bell 1979). As the least studied southern ocean petrel (Warham & Imber 1985), very little is known about the general behaviour and breeding biology of this species. Grey petrels have been studied by several seabird biologists on Tristan da Cunha, Crozet and Kerguelen Islands (Richardson 1984; Jouventin et al. 1985; Weimerskirch et al. 1989) and some basic information is available.

Grey petrels have an extended breeding season. Adults return to the colony in mid February and lay one egg between March and May; the eggs hatch after 55–65 days (May to July) and after 110–120 days, the chicks fledge in September to November (Imber 1983; Richardson 1984; Newton & Fugler 1989; Weimerskirch et al. 1989; Zotier 1990).

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) and have been associated with whales (Harper 1987). Grey petrels have been recorded as incidental catches on long-line fisheries in New Zealand waters since 1989. Between 1989 and 1992, 47 grey petrels were caught as by-catch on the Japanese tuna long-line fishery around the East Cape (Murray et al. 1993). Between the 1996/97 and 1999/2000 fishing years 269 grey petrels were caught by fishing vessels and returned by observers (Table 2; Bartle 2000a, b; Robertson 2000; Robertson & Bell 2002a, b). Approximately 189 grey petrels were returned during the 2000/2001 fishing year (C.J.R. Robertson, pers. comm.).

Several investigators (Warham & Bell 1979; Imber 1983) have made observations on the grey petrel population on Antipodes Island, but only information on basic biology and behaviour was gathered. The only population estimate is of 10 000–50 000 breeding pairs (Robertson & Bell 1984). This lack of knowledge about the species and their high occurrence as a fisheries by-catch means that long-term study of grey petrels is vital.

Research on population dynamics, including aspects such as adult and juvenile survivorship, age of first return, age of first breeding and foraging information

TABLE 2. NUMBER OF GREY PETRELS CAUGHT BY THE FISHING INDUSTRY IN NEW ZEALAND WATERS ON OBSERVED VESSELS AND RETURNED FOR AUTOPSY. (DATA FROM MURRAY ET AL. 1993; BARTLE 2000a, b; ROBERTSON & BELL 2002a, b.)

FISHERY	YEAR					
	1989–1992	1 JAN 96–30 SEPT 96	1 OCT 96–31 DEC 97	1 JAN 98–30 SEPT 98	1 OCT 98–30 SEPT 99	1 OCT 99–30 SEPT 00
Bottom long-liner	?	–	4	–	62	56
Joint venture tuna long-liner	?	4	62	72	8	1
Trawler	?	–	–	1	–	3
TOTAL	47	4	66	73	70	60

(such as range, times and locations) would increase the general knowledge about this species and ensure that impacts on, and changes to, the population are known.

2. Objectives

The objectives of this study were to investigate the practicality of carrying out a long-term breeding success and population biology study of the grey petrel on Antipodes Island.

In summary, these were:

- Evaluate the practicality, resource requirements and relative merits of different population size estimation techniques (e.g. burrow mapping, monitoring and counts, call counts, arrival counts, mark-recapture etc.).
- Provide an initial, defensible estimate of the Antipodes Island breeding population size.
- Assess the feasibility of 'burrow monitoring' for breeding biology and population dynamic studies.
- Assess the practicality of banding.
- Assess the feasibility of grey petrels carrying satellite transmitters.

3. Methods

Antipodes Island was visited from April 22 to June 10, 2001. The team arrived at Antipodes Island on Sunday April 22; however, due to weather conditions the landing was delayed until Tuesday April 24. Landing went well and all personnel and gear were landed without incident. Solar panels, a generator and other equipment were set up over the first three days. The radio was set up immediately, but due to some minor problems, direct communication with DOC Stewart Island was not possible for five days. DOC Te Anau and Meri Leask (Bluff Fisherman's Radio) were contacted and they contacted DOC Stewart Island. Once most of the radio problems were sorted out, daily communication with both DOC Te Anau and DOC Stewart Island was maintained. The track marked by the albatross team to the northern plains was opened up to aid access and reduce habitat disturbance for soft-plumaged petrels (*Pterodroma mollis*) and other species.

The weather was settled during the first two weeks (mild, calm, misty drizzle), but deteriorated over the last three or four weeks (cold, windy, rain at times). Snow fell several times and on one occasion remained on the ground for seven days.

Several survey techniques were used to determine the distribution and density of grey petrels on Antipodes Island. These included transect lines, census grids, arrival and departure counts, and call monitoring. Each is described below. To facilitate coverage of the whole island, two campsites were established; one at the southern end (Ringdove Stream) and the other on the western side (Orde Lees Stream).

Research and access permits (from DOC Southland Conservancy) for this expedition were only received the day before the team departed to Christchurch (four days prior to sailing). This meant little discussion was possible about conditions and restrictions placed on some aspects of the feasibility study by those permits.

3.1 TRANSECT LINES

Two techniques were used. The first was using randomly chosen starting points, which were plotted by Global Positioning Satellite (GPS, using a GARMIN™ GPS 12) and walking along a random compass bearing. The transects were measured in a straight line for 300 m unless the terrain became too steep (for example, one transect finished at a cliff at 257 m). A 30 m tape measure was used to measure each transect line and 1 m either side of the tape measure was searched for burrows.

The second technique was random walking transects. This technique was used as the party walked between study sites and while surveying the entire island. These transect lines varied in length from 250 m to 1 km, depending on the terrain. Only a 1 m strip was searched along the walking transect. The start and finish points of each transect were plotted on maps while in the field. These transects were not necessarily in a straight line.

For all transects, records were made of vegetation type (Types A–D, defined in Appendix 1), presence of burrows, species occupying the burrows, aspect, slope and direction of travel. The location of transect lines are shown in Fig. 1.

The contents of each burrow along the transect lines where checked either by 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, or returning calls to a previously recorded taped grey petrel call, or using the burrowscope. The size and other characteristics (presence of feathers, droppings etc.) of the burrows were also noted.

3.2 CENSUS GRIDS

After preliminary surveys over most of the island had been completed, four sites were selected for the census grids. The northern end of the island was chosen for the grid sites because of its ease of access to grey petrel habitat and proximity to the hut. Although grey petrels appeared to be present in large numbers at the southern end of the island, they were only seen landing on, or taking off from, very steep slopes (between 35–75°) that would have been dangerous to work on, or in areas that took 2 h to reach from the southern

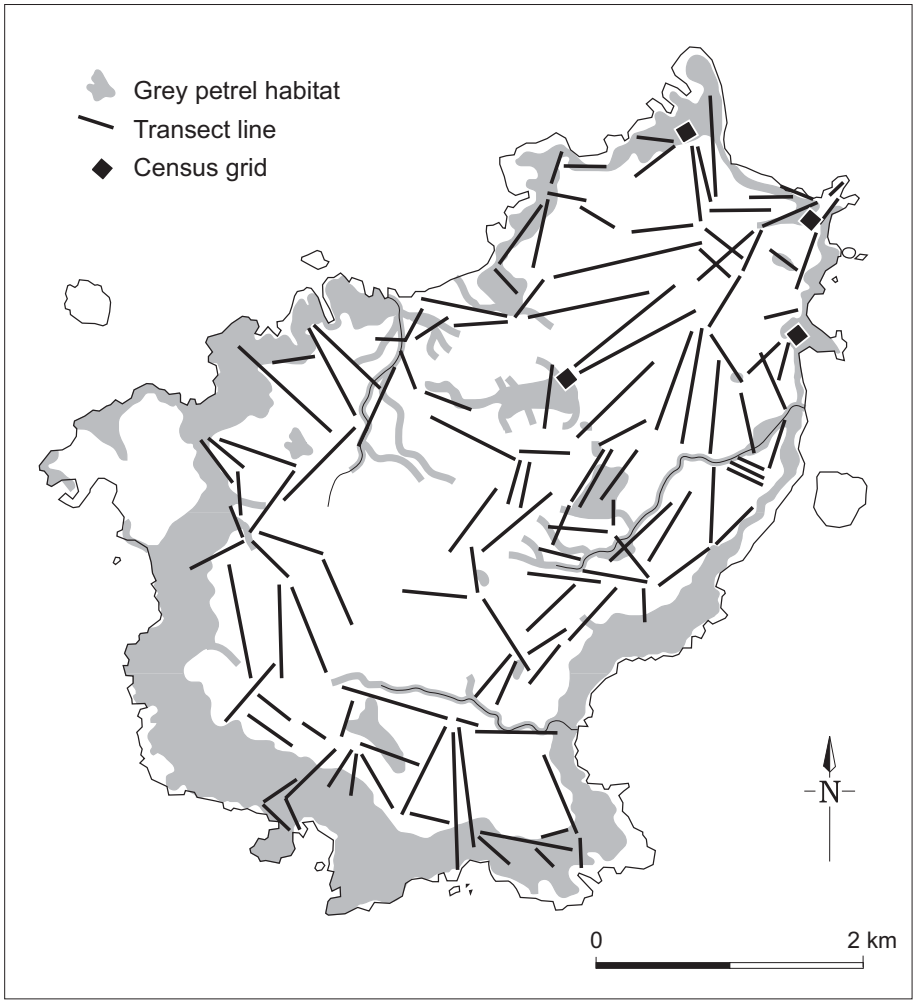


Figure 1. Location of grey petrel habitat, transect lines and census grids.

camp site (down steep scree slopes into South or Stack Bays). In addition to this, it took 3–4 h to travel to the campsite at the southern end of the island. After setting up the first grid, it was found that each would take one day to set up and at least two days to search thoroughly. This, and the time required to get to other sites once at the southern end, made it impractical to work there.

Each site was randomly selected in four general areas with different aspect, preferred habitat and known presence of grey petrels (i.e. seen landing in the area and/or found or heard calling from burrows during the transect surveys, Fig. 1). The census grids were set up on Perpendicular Head (May 9–11), Crater Bay (May 12–14), the western slopes of Mount Galloway (May 15–18) and Stella Bay (May 15–May 21). Each grid was 50 m × 50 m. Altitude, aspect, slope and vegetation details were recorded for each grid. GPS points were recorded for one corner of each grid (noted as the primary pole or PP). A random compass bearing from the primary pole was used to select the direction of one grid side. Intermediate markers were placed every 10 m along the edge of the grid. A marking pole was also placed in the centre of the grid. These markers aided the mapping of the position of each grey petrel burrow.

The grids were systematically searched for burrows. All grey petrel burrows located within the grids were marked with dazzle spray paint. The occupancy of each burrow was noted either by 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, or returning calls to a previously recorded taped grey petrel call, or using the burrowscope. The presence of other burrows being used by different species was also noted.

Where possible, grey petrels were removed from the burrow via the entrance (i.e. an observer reached into the chamber, grabbed the bill or head and pulled the bird gently to the entrance), banded, checked for breeding status and returned to the burrow. Burrows with grey petrels present were mapped. Empty burrows (those suspected to be vacant grey petrel burrows from their size and characteristics) were noted, but were not used for estimating the population size.

Where possible, adult grey petrels were measured (n = 13). The following measurements were recorded: skull width, culmen (i.e. bill) width at base, culmen depth at base, least depth of culmen, culmen length, head/culmen length, tarsus length, mid-toe/claw length and weight. Where possible, grey petrel eggs were also measured (length and width only, n = 10). We used 1.5 kg (± 0.15 g) Pesola™ scales to measure weight and vernier callipers (± 0.1 mm) for all other measurements.

3.3 ARRIVAL AND DEPARTURE COUNTS

Grey petrels were observed flying around the island during the day and were counted from several high points around the island. This method was useful to determine grey petrel presence when the terrain was too steep or dangerous to access (such as at Ringdove and Stack Bays). Many of the birds could be observed landing and taking off from burrow sites during these counts. Binoculars were used occasionally.

3.4 SATELLITE TRANSMITTERS

A dummy transmitter model and construction equipment (wire, lead, bees' wax and epoxy adhesive) to build others was taken to the island. The dummy transmitter weighed 22 g, had a streamlined front and measured 20 mm × 66 mm × 13 mm with a 'battery' (16 mm × 25 mm × 7 mm) protruding from the lower right side and 200 mm length of wire to represent the antenna, similar to that pictured in Söhle et al. (2000). However, our permits had only approved the tape method of attachment, which was not recommended by all other transmitter users we spoke to before the expedition.

4. Results

4.1 BEHAVIOUR

Grey petrels were diurnal, with the birds being seen throughout the day, but never during any of the spotlighting exercises at night. The only nocturnal activity observed was calling nearby, or from their burrow entrances. Grey petrels were also heard calling in the early evening and very early morning. Peak departure activity was between 0730 and 0900 hours and peak arrival was between 1400 and 1630 hours. The hours of daylight were from 0700–1700 hours at the beginning of the expedition, decreasing to 0745–1615 hours by the end.

When trying to determine burrow occupancy (when the resident bird was out of sight and/or reach) taped calls were played. Some grey petrels responded to these tapes. Several also responded to imitation calls. This was a useful tool in many cases. Aerial calling was observed on several occasions, once accompanied by aerial display flights.

4.2 DISTRIBUTION OF GREY PETRELS ON ANTIPODES ISLAND

A 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 (approximately 510 ha) corresponded to 25% of the entire island area (Fig. 1).

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. Areas with these vegetation types were drier and had deeper soil bases than other areas. Steep banks appeared easier for the petrels to excavate. Burrow density was determined from four census grids.

4.3 CENSUS GRIDS

Four 50-m × 50-m census grids were set up on Antipodes Island (Section 3.2 and Figs 2, 3, 4 and 5), each with a different aspect and all with some preferred habitat and known presence of grey petrels. A total of 121 occupied burrows were found in the grids (i.e. a mean of 30 burrows/grid, equating to 0.012 burrows/m^2, Table 3). The number of occupied grey petrel burrows in each grid ranged from 19 to 44.

There were a large number of vacant burrows located in each grid (ranging from 11 to 55 burrows/grid, or a mean density of 0.01 burrows/m^2), many of which had fleas present. These burrows were of the same size and physical

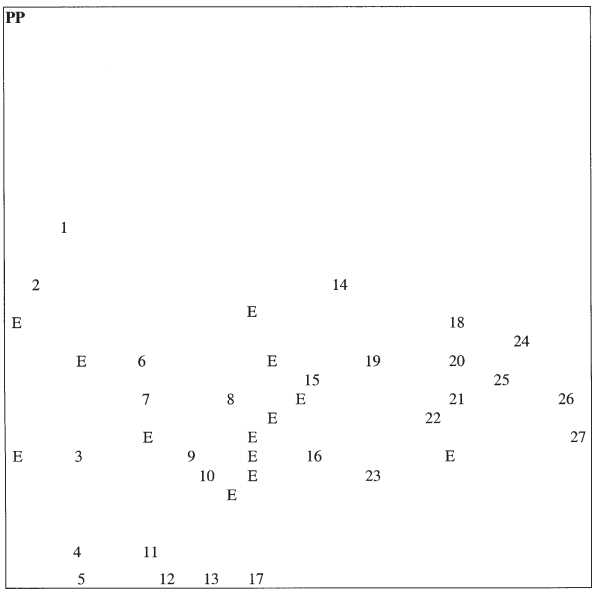


Figure 2. Location of burrows found in the Perpendicular Head census grid (50 × 50 m). 1–27 = active burrows with grey petrels (both breeding and non-breeding birds) present; E = empty grey petrel burrow (may have fleas, digging, droppings or feathers present inside or at entrance); primary pole (**PP**): 49°39′ 54.0″S, 178°47′ 44.5″E; bearings of grid sides (from primary pole): 310°, 220°; aspect: west facing; gradient: 35° at the top, 45° at the bottom.

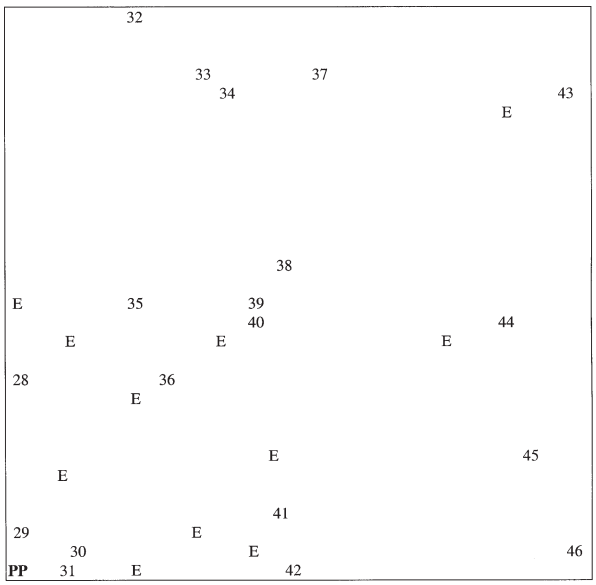


Figure 3. Location of burrows found in the Mt Galloway Head grid (50 × 50 m). 28–46 = active burrows with grey petrels (both breeding and non-breeding birds) present; E = empty grey petrel burrow (may have fleas, digging, droppings or feathers present inside or at entrance); primary pole (**PP**): 49°40′ 48.4″S, 178°46′ 52.2″E; bearings of grid sides (from primary pole): 90°, 180°; aspect: west facing; gradient: 10°; altitude: 167 m.

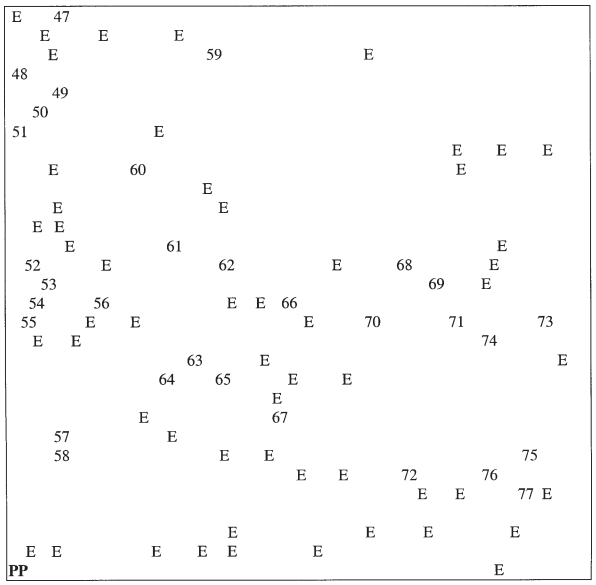


Figure 4. Location of burrows found in the Stella Bay grid (50 × 50 m). 47–77 = active burrows with grey petrels (both breeding and non-breeding birds) present; E = empty grey petrel burrow (may have fleas, digging, droppings or feathers present inside or at entrance); primary pole (**PP**): 49°40′ 8.8″S, 178°48′ 32.6″E; bearings of grid sides (from primary pole): 170°, 260°; aspect: north facing; gradient: 25°; altitude: 47 m.

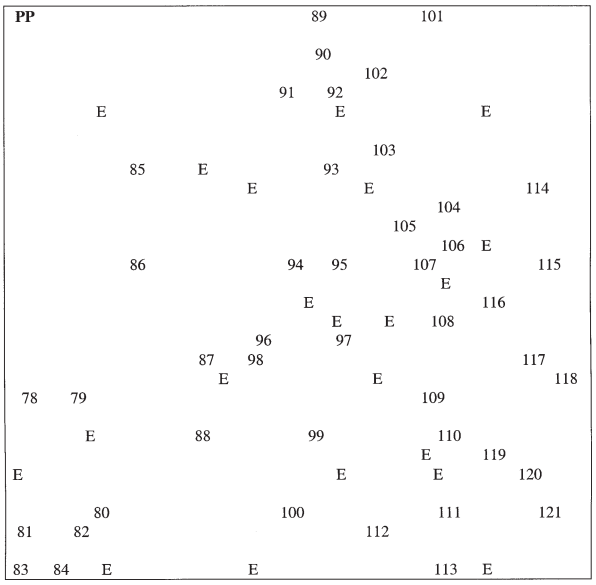


Figure 5. Location of burrows found in the Crater Bay grid (50 × 50 m). 78–121 = active burrows with grey petrels (both breeding and non-breeding birds) present; E = empty grey petrel burrow (may have fleas, digging, droppings or feathers present inside or at entrance); primary pole (**PP**): 49°40′ 41.8″S, 178°48′ 17.8″E; bearings of grid sides (from primary pole): 210°, 300°; aspect: south facing; gradient: 30°; altitude: 134 m.

TABLE 3. BURROW DENSITY WITHIN THE FOUR CENSUS GRIDS (EACH 2500 m^2).

GRID	BURROWS			
	BREEDING	OCCUPIED NON-BREEDING	TOTAL	VACANT
Mt Galloway	16	3	19	11
Perpendicular Head	25	2	27	13
Stella Bay	27	4	31	55
Crater Bay	36	8	44	21
TOTAL	104	17	121	100

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 feathers or old nest material inside) but were not being used for breeding when checked. There could be a number of reasons for these vacant burrows, including a failed breeding attempt, use by a pre-breeder, use by a breeding-age bird that had not managed to find a partner, skipping a breeding season or possible death. As these vacant burrows might not be used by grey petrels in the future, they were not used in the breeding population estimate.

4.4 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 slightly downwards with tunnels ranging from 1 m to over 3 m in length. The entrances were usually large and 'squarish'. Usually the entrance and tunnels were kept very clear, with vegetation only being found in the nest chambers. Nest chambers were usually large and very dry, with tussock, fern and other vegetation making up the nest, which was on a slightly raised mound. The chamber was generally slightly rounded and larger than the tunnel. Nearly all burrows were infested with fleas.

Grey petrel burrows were distinct in character from burrows used by other petrel species on the island.

White-chinned petrel (*Procellaria aequinoctialis steadi*) burrows, although used by a similar-sized bird, were usually found on all 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. Burrow entrances were open (i.e. not restricted or hidden by vegetation), very large and irregularly shaped, and the tunnels generally sloped downwards. At times, a pool of water filled the entrance.

The burrows used by white-headed petrels (*Pterodroma lessonii*) were smaller than grey petrel burrows, generally with rounded, open entrances. These burrows usually sloped down steeply towards the chamber. A grey petrel would not be able to fit into most white-headed petrel burrows.

The diving petrel (*Pelecanoides urinatrix*) burrows were very much smaller and impossible for a grey petrel to use.

In addition to grey petrel burrows, only white-headed petrel and diving petrel burrows were located within the census grids.

4.5 BURROW MONITORING

Despite most burrows being straight and the resident grey petrel easily visible, only 24% of the burrows in the study grids (ranging from 16 to 30%) had nesting chambers that were accessible through the entrance (i.e. birds within an arm's reach). 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 cases of burrows shared with dead sooty shearwater (*Puffinus griseus*) fledglings were noted. In both cases it was inferred that the grey petrel had killed the sooty shearwater chick (on the basis of head wounds and crushed skull). Nesting habitat was shared with the smaller diving petrels and white-headed petrels, but white-chinned petrels rarely nested in the same areas as grey petrels.

4.6 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 gave some idea of the range of grey petrel habitat, but not specific numbers of birds, and, as a result, would not give accurate population estimates. The factors contributing to this conclusion are discussed below.

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 frustrating, as most birds took between 15 min and 3 h to land. Numbers varied around the island and the highest count was 50 birds circling the Ringdove Bay cliffs and the lowest was one or two 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 the observer was viewing the same bird on each return 'fly-by'. Departure counts were not possible as there were no common departure sites. Grey petrels departed by launching off taller tussocks or steeper areas on cliffs near their burrows.

Although call counts were not particularly useful for estimating population size during this stage of the breeding season (late in the incubation period), they were extremely useful for determining presence and absence in an area during the survey of the island, as the petrels called when the team walked near to or on top of burrows. Call counts were also useful for determining which species was present in burrows.

During this expedition, calling by grey petrels was very infrequent. Some calling occurred at night, but this decreased significantly throughout the expedition. This was 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 & Sim 1998a, b, 2000a, b, c). It is interesting that vocalisation, both on the wing during arrival, and during paired display flights, was recorded on several occasions. Vocalisation on the wing had not been recorded previously (Warham 1988).

Transect lines, as with arrival and departure counts, showed the preferred habitat and general distribution of grey petrels over the island, but were not useful in estimating the population size. The vegetation and terrain made transects very difficult in some areas and, in many cases, transects proved to be well out of grey petrel habitat. However, the transects indicated a distinct pattern between location of grey petrel burrows and the slope, drainage and vegetation in that area. Preferred grey petrel habitat was easily identifiable towards the end of the expedition.

Raft counts were not possible, as grey petrels were not seen rafting offshore at any stage during the visit. This may have been due to the timing of the expedition, as rafting has been noted in the Kerguelen Group during mid-February (Zotier 1990). Future visits, earlier in the year, should check for this aspect of behaviour.

From experience during earlier visits (Warham & Bell 1979; Imber 1983), we had hoped that a mark-recapture estimate would be possible by catching a large number of adults as they called on tussocks during the night. Unfortunately, it appeared that our expedition was too late in the season for this behaviour, with most birds incubating eggs. Most of the calling was from the burrow entrance or further inside burrows, with few birds visible on the surface. The mark–recapture technique may be useful for expeditions that occur earlier in the breeding season (mid-February to late April).

The most accurate population estimate was obtained by extrapolation from the densities determined from the census grids to the total area of identified grey petrel habitat (Fig. 1) on the island (i.e. 510 ha of suitable habitat out of the

TABLE 4. POPULATION ESTIMATE OF GREY PETRELS ON ANTIPODES ISLAND.

GRIDS	DENSITY (number/ha)			POPULATION ESTIMATE	
	BREEDING PAIRS	BURROWS OCCUPIED BY NON-BREEDING BIRDS	TOTAL AREA SIZE (ha)	BREEDING PAIRS	BURROWS OCCUPIED BY NON-BREEDING BIRDS
Mount Galloway	64	12		32 640	6120
Perpendicular Head	100	8		51 000	4080
Stella Bay	108	16	510	55 050	8160
Crater Bay	144	32		73 440	16 320
MEAN (grids combined)	104	17		53 040	8670

2025 ha island). The grey petrel population is estimated at between 32 000 and 73 000 breeding pairs (or a mean of 53 000 breeding pairs, Table 4).

4.7 ADULTS

Grey petrels were generally very docile and this made banding very easy. The only difficulty was access to the birds. There were 77 adults banded during this expedition (Appendix 2). Of these, 29 were from burrows within the census grids. No previously banded grey petrels were recovered during this expedition. The only band recovery for a grey petrel (recovered dead at the mouth of the Karori Stream, Wellington in 1977) was banded by Brian Bell during the 1969 Antipodes Island expedition (R. Cossee, pers. comm.; Warham & Bell 1979).

On two occasions, while we were attempting to get them out of the burrow, the adults became agitated when a long time was taken to extract them (i.e. they ran around the burrow trying to avoid capture) and later they abandoned their eggs. Generally, the adults walked calmly to the entrance as they were being held by the bill or head. Few adults attempted to bite or struggle in the hand and usually walked back to the chamber and settled on the egg quickly. On most occasions, removal from the burrow, banding and return to the burrow took less than 5 mins. Measurements were collected from some adults (Appendix 3) and this increased the handling time by only a further 5 mins.

4.8 BREEDING BIOLOGY

When grey petrel burrows were investigated early in the expedition, most adults were incubating eggs. Measurements were collected from 10 eggs (Appendix 4). The first chick was located on May 9, having hatched approximately 3 days earlier. This means that the laying date was approximately the first week in March, assuming the incubation period is similar to Kerguelen Islands, i.e. 55–65 days or Gough Island, approximately 58 days (Imber 1983; Zotier 1990). This was an early chick, as peak hatching appeared to be from May 25 to June 1 and some eggs were still being incubated when we departed. This corresponds to an extended breeding cycle similar to that of the grey petrels located on Tristan da Cunha (Imber 1983; Richardson 1984) and Kerguelen (Newton & Fugler 1989; Zotier 1990).

4.9 SATELLITE TRANSMITTERS

Satellite transmitters were not trialed due to permit restrictions on the attachment methods. Only taping on the transmitter to the back of the bird was approved and this method has proven to be ineffective and unsuccessful in other studies (H. Moller, pers. comm., C.J.R. Robertson, pers. comm., Söhle pers. comm.; Söhle et al. 2000). We also assessed there to be a high probability of abandonment of eggs or small chicks, due to the handling time (at least half an hour per transmitter) required for transmitter attachment.

5. Discussion

The five main study objectives were covered during this feasibility study. Each is discussed below. In addition, there are general comments on biology, behaviour and conservation relating to grey petrels.

5.1 EVALUATION OF POPULATION SIZE ESTIMATION TECHNIQUES

Several population estimate techniques were trialed to determine which, if any, would be the most suitable to use in the long term. Most methods were found to be completely unsuitable at this stage of the breeding season (late incubation). Grey petrel behaviour (diurnal habits, lack of calling, range and spread of burrow locations, etc.) and the terrain made it difficult to use estimation methods such as call counts, arrival and departure counts.

The best population estimate was obtained by extrapolating from densities determined from the four census grids to the total area of identified grey petrel habitat from the island survey. Although this may not be the most accurate method, it does give a reasonable estimate. This method was very labour intensive, as it took approximately a full day to construct each grid and at least two days to search depending on the weather.

5.2 FEASIBILITY OF BURROW MONITORING

Burrow monitoring was relatively simple on Antipodes Island. Grey petrel burrows were easily identified, and determining occupancy and breeding status was possible and quick on most occasions. It would be feasible to study the grey petrel using long-term study burrows and/or census grids. It is a labour-intensive method, but it is the only practical way to ensure accurate monitoring of adults and breeding success.

To undertake a long-term population study it is vital that adults are identified (i.e. banded); but owing to grey petrel behaviour (minimal time spent on the surface during this part of the breeding season), this is only possible with access into the burrows.

This preliminary study has shown that it is possible to identify areas of optimum grey petrel habitat and to reach a certain number of birds through the entrance of the burrows. It was possible to reach birds in 24% of the surveyed burrows. Given the substrate on the island (volcanic peat), it should be easy to excavate into the other burrows and replace the opening with an artificial cover and substrate. It was not possible to trial such excavation techniques during this expedition due to the conditions of the permit. Excavation hatches, observation windows and false roofs were used successfully in a three-year grey petrel study on Mayes Island in the Kerguelen Group (Zotier 1990); a similar project on Marion Island used removable earth plugs (Newton & Fugler 1989).

A study similar to the black petrel monitoring programme on Great Barrier Island would be possible (Bell & Sim 1998a, b, 2000a, b, c). Census grids could be set up in areas of optimum grey petrel habitat and accessibility (e.g. Crater Bay, Orde Lees Stream and Perpendicular Head) using the hut as a base. Each grid could be searched, each burrow identified and labelled and intensively monitored. This would enable breeding status, breeding success, burrow density and occupancy rates to be determined each year.

5.2.1 Unoccupied, 'vacant' burrows

Results from the preliminary burrow monitoring found a large number of unoccupied grey petrel burrows. These unoccupied burrows are very interesting, as they could be used by intermittent or possibly biennial breeding birds, vacant due to mortality of birds, or occupied by adolescent pre-breeding or non-breeding birds which do not stay in the burrows during the day. Only a long-term project will reveal the precise nature of these burrows. Research on Mayes Island suggests that its grey petrels are annual breeders, with 83% returning the following year to breed (Chastel 1995).

5.2.2 Burrow sharing

On Antipodes Island, grey petrels did not share burrows with white-chinned petrels, whereas on Possession Island, Despin (1976) noted a white-chinned petrel in a burrow with a grey petrel chick. Grey petrel adults return in February and lay from early March, while white-chinned petrel chicks do not fledge until late April (Imber 1983; Weimerskirch et al. 1989). Despite the breeding cycles of both species overlapping significantly, the pronounced habitat separation on Antipodes Island may prevent both species using the same burrow. However, on Mayes Island, 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 found in a long-term study.

We found that grey petrels share some burrows with sooty shearwaters on Antipodes Island. Grey petrels and sooty shearwaters have been known to share burrows on Campbell Island (Bailey & Sorensen 1962). As the sooty shearwater population on Antipodes Island is thought to be very small, there is probably only limited burrow competition. However, the overlap of breeding seasons (sooty shearwaters fledge mid-April to late May, and grey petrels return to the colony in mid-February) may restrict the chance of sooty shearwaters establishing themselves on Antipodes Island in greater numbers.

5.3 PRACTICALITY OF BANDING

Adults were very docile and easy to handle while banding, despite two cases of egg abandonment during this expedition. Although abandonment is likely to occur in only a few cases where the birds are younger and more easily disturbed, the choice was made to reduce the banding effort during the hatching period (mid-May to early June). However, banding of greater numbers should be practical earlier in the season (late February) when the birds return to claim their burrows and spend more time on the surface.

5.4 FEASIBILITY OF GREY PETRELS CARRYING SATELLITE TRANSMITTERS

No dummy transmitters were trialed during this expedition as only tape attachment was permitted. All advice obtained from other transmitter users (H. Moller, pers. comm.; C.J.R. Robertson, pers. comm., I. Söhle, pers. comm.) before the expedition, stated that tape was the least successful method and was probably not worth trialing. One model dummy transmitter and construction equipment (to build others) were taken to the island and, once there, the decision to proceed with this aspect of the project was discussed. Since two birds had become agitated during banding and it was approaching peak hatching time, it was decided that the required time frame for placement of transmitters would disturb the birds too much and this section of the feasibility study was not undertaken.

The presently available satellite transmitters are easily within the size range of grey petrels. With the advances in tape and glue attachment, it is probably not necessary to use harnesses. Harnesses have caused abrasion to Cory's shearwater (*Calonectris diomedea*) and required longer time in the hand (Dr. F. Zino, pers. comm.). Sooty shearwaters fitted with trial harnesses failed to return to their colony (I. Söhle, pers. comm.). However, if designed correctly and applied properly, there can be few problems with harnesses (C.J.R. Robertson, pers. comm.). Robertson (pers. comm.) has applied harnessed transmitters to northern royal albatross (*Diomedea sanfordi*) in less than 5 mins and these transmitters have been carried for two years without abrasion.

There are several new methods of taping and gluing and these should be trialed in any future study. Advice from colleagues has suggested that glue, or a combination of glue, tape and wire, is a more successful option for attachment, particularly when trying to locate foraging locations during incubation (H. Moller, pers. comm.; C.J.R. Robertson, pers. comm.; I. Söhle, pers. comm.; Dr. F. Zino, pers. comm.). Satellite transmitters on Cory's shearwaters in Madeira have successfully tracked both male and females during incubation cross-over and the researchers have managed to reclaim the transmitters on all occasions (Dr. F. Zino, pers. comm.). Trials on black petrel (*Procellaria parkinsoni*) wearing satellite transmitters and modes of attachment are being planned for the 2001/02 season and this may answer some of the issues for grey petrel.

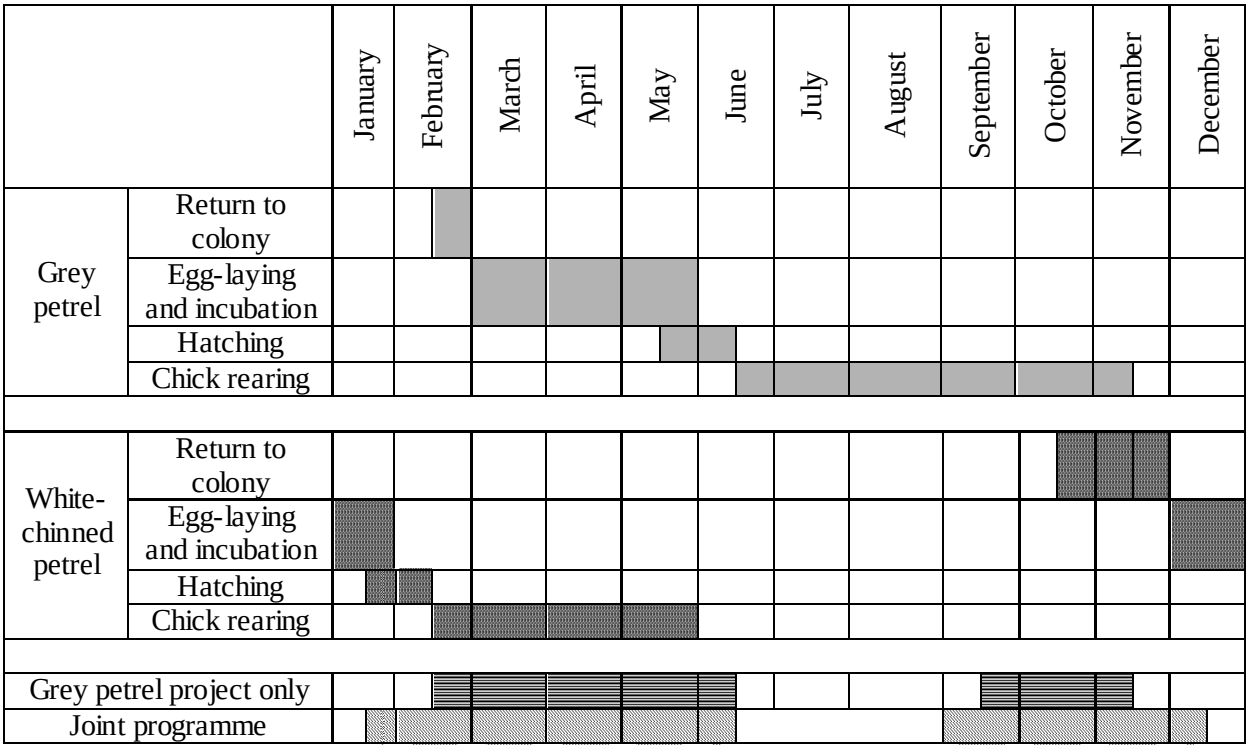
Future trials will be important, as recent studies on sooty shearwaters have indicated that current satellite transmitters remain attached for different lengths of time, result in different recapture rates and reduce colony attendance (I. Söhle, pers. comm.; Söhle *et al.* 2000). It is important to determine the impact of these factors before the expensive, real transmitters are applied.

5.5 FEASIBILITY OF A LONG-TERM STUDY

A long-term study of grey petrels is feasible on Antipodes Island. Grey petrels were easily handled, at least 24% of the burrows are accessible in most areas, and there are well established expedition facilities on the island. There are several areas where census grids and study burrows can be set up safely and easily monitored. There will be several difficulties.

1. Any long-term study will be very expensive. Preliminary estimates, depending on the structure of the project, put the costs at up to NZ$500 000 per year (with satellite transmitter costs additional to this). Costs will depend on the objectives of the long-term study, as it may require up to two visits to the island during a year: one in early autumn (late February to May) to set up the monitoring areas or census grids and study burrows, identify and monitor adults and breeding status; and another in spring (September to November) to band the chicks and assess breeding success. The first year will require a large team (ideally 8 people or the maximum for the hut) to enable all the monitoring areas or census grids and study burrows to be established.
2. A more cost-effective option may be to run a joint project, studying both the grey petrel and white-chinned petrel concurrently. The white-chinned petrel is also caught in large numbers in the New Zealand fisheries (332 between 1996 and 2001, C.J.R. Robertson, pers. comm.). As one species is a winter breeder (grey petrel) and the other a summer breeder (white-chinned petrel), adding an extra month to each visit on the original timetable would ensure both projects could be run concurrently (Table 5).
3. Antipodes Island is a difficult island to travel over in autumn and winter due to dense vegetation, steep terrain and harsh weather. Any long-term study will have to cope with these conditions.
4. The autumn and winter weather, particularly the cold, will be one aspect of the project any team will have to cope with. There should be a minimum of four monitoring areas or census grids in areas with different altitudes, aspects and slope to ensure that some work can be undertaken in most weather conditions. All team members will have to be aware of others' temperature

TABLE 5. BREEDING CYCLE OF THE GREY AND WHITE-CHINNED PETRELS AND POSSIBLE TIMING OF VISITS TO STUDY EACH SPECIES.



and safety when working in this environment. The monitoring areas or census grids should be within range of the hut as this would reduce overall impact on the island, limit disturbance to smaller numbers of grey petrels, enable the study sites to be accessed easily and ensure the team has comfortable living quarters.

5. The main problem will be the requirement for a large number of study burrows to be monitored within established monitoring areas or census grids; and at least 75% of these burrows will have to be fitted with access lids, depending on the location of the grid. If the population is to be studied accurately to monitor trends, then at least 1–2% of the population may need to be studied (i.e. 500–1000 burrows). This means a large number of artificial covers for the burrows will have be provided and placed in census grids. As the island has minimum impact requirements, this could be an issue for obtaining research and access permits. However, if this population is to be studied effectively and the study is to give the desired results and information, access to adults in the burrows is vital. Adult birds do not remain on the surface long enough for this to be an effective method of identifying resident birds. If the study burrows are placed in specific areas (I recommend the use of the census grids), then the effects on the environment can be limited to the northern end of the island.

5.6 BY-CATCH

Grey petrels have been caught in high numbers as fisheries by-catch in New Zealand waters. Between 1989 and 2001, over 300 birds were been caught and the autopsy data show that most of these birds were adults in breeding condition (Table 6, Bartle 1990; Murray et al. 1993; Bartle 2000a, b; Robertson 2000; Robertson & Bell 2002a, b). This means that these birds can only come from the New Zealand breeding populations, as the other grey petrel populations are too distant.

As there are less than 100 grey petrels banded from Antipodes Island, band recoveries have been limited. If banding levels increased it is expected that a

TABLE 6. NUMBER AND SEX OF GREY PETRELS CAUGHT BY THE FISHING INDUSTRY IN NEW ZEALAND WATERS ON OBSERVED VESSELS AND RETURNED FOR AUTOPSY BETWEEN 1989 AND 2001. (DATA FROM C.J.R. ROBERTSON, PERS. COMM.; MURRAY ET AL. 1993; BARTLE 2000a, b; ROBERTSON 2000; ROBERTSON & BELL 2002a, b.)

SEX	YEAR						
	1989–92	1 JAN–30 SEPT 96	1 OCT 96–31 DEC 97	1 JAN 98–30 SEPT 98	1 OCT 98–30 SEPT 99	1 OCT 99–30 SEPT 00	UP TO JUNE 01
Male	2	–	17	3	37	38	43
Female	43	4	48	70	9	4	3
Unknown*	2	–	1	–	24	18	143
TOTAL	47	4	66	73	70	60	189

* Unknown sex is due to damage to birds by sea-lice before recovery.

higher number of recoveries would result, particularly from the by-catch returns. In the long term it is important to establish where the by-catch specimens originate. A mark-recapture and long-term study on Antipodes Island would enable large numbers of adult and fledgling grey petrels to be banded.

It has also been noted from the by-catch data that grey petrels appear to have segregated feeding locations, with males feeding around the Pukaki Rise and females foraging much further north near East Cape. (C.J.R. Robertson, pers. comm.; Bartle 1990, 2000a, b; Robertson 2000; Robertson & Bell 2002a, b). It is important to evaluate the foraging behaviour of grey petrels, including both location and timing of foraging events. It will be equally important to determine this for both sexes, to cover the possibility of segregated feeding.

As the main long-line fishing periods overlap with the breeding season of grey petrels, most birds caught are likely to be breeding adults. The capture of breeding adults means reduced breeding success, causes a decline in the number of pairs breeding in following years and imposes 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 formed (Warham 1996).

Mortality of significant numbers of any petrel is ultimately unsustainable. Monitoring breeding populations, and determining their survival and productivity levels is vital. Because of low reproductive rates, high survival and delayed maturity, procellariiformes are particularly susceptible to small changes in adult mortality (Warham 1990). A programme to collect yearly demographic data for the Antipodes Island grey petrel population is urgently required and has been suggested for many years (Murray et al. 1993).

6. Recommendations

- Monitoring of the grey petrel population (using census grids, monitoring areas and/or long-term study burrows) should commence on Antipodes Island and continue for at least five breeding seasons.
- Antipodes Island should be visited during February to June to monitor grey petrel pair bonding, pre-breeding behaviour and egg laying timing. This would allow a large number of adults to be easily banded (and hence identifiable) as the birds are generally outside their burrows at this time. This could be established as a mark-recapture programme to provide a better or alternative population estimate.
- Antipodes Island should be visited in September/October to band grey petrel chicks and to determine breeding success. In the long term this will enable age of first return and age of first breeding to be determined as the chick cohorts return to Antipodes Island.
- Census grids (or monitoring areas) and long-term study burrows should be set up in significant congregations of grey petrel burrows.

- To ensure the team can be based at the hut and to reduce impact on the island, the monitoring areas or census grids should be established at the northern end of the island in the following locations: Perpendicular Head, Stella Bay, Crater Bay, Orde Lees Stream (waterfall) and the Western slopes of Mt Galloway. This may also reduce the impact of weather on the project, as each grid can be worked in different wind conditions. These areas have high numbers of grey petrels and there is good access to the birds through the burrow entrances.
- Data needs to be collected for determining the population dynamics of grey petrels, to determine survivorship, mortality and the effects of predation, fishing and other environmental factors.
- A joint project studying both white-chinned and grey petrels should be considered as a possible option. White-chinned petrels are also caught in high numbers by the fishing industry. Extending the grey petrel study to incorporate monitoring of this species would not dramatically increase the timing or costs of the project, as there is an overlap in the breeding cycles of the two petrel species. Early trips in late spring (September to early December) could monitor adult white-chinned petrels, determine breeding status and band departing grey petrel fledglings and a return trip in late summer to autumn (mid-January to June) could band returning grey petrel adults, determine breeding status and band fledgling white-chinned petrels.

7. Acknowledgements

This project was funded by the fishing industry through the Conservation Services Levy (CSL) via the Science and Research Unit (SRU) of the Department of Conservation. Permits to undertake the research and expedition were provided by Southland Conservancy. Thanks to Brian Bell, Matthew Brown, Anthony Henry and Joanna Sim for their assistance on Antipodes Island, advice on both fieldwork and analysis and comments on this paper. Dr. Mike Imber (DOC representative) and Saskia Wood (DOC technician) assisted on Antipodes Island and commented on early drafts of this paper. Special thanks to Richard Allen and crew of the MV Ranui for transport to and from Antipodes Island. Ian West (CSL, SRU), Kerri-Anne Edge and Pete McClelland (Southland Conservancy) assisted with technical aspects, some technical equipment and departmental requirements of the expedition. DOC Stewart Island and DOC Te Anau assisted with daily radio schedules and messages. Special thanks to Meri Leask (Bluff Fisherman's Radio) for maintaining early radio schedules. Christopher Robertson assisted with technical equipment, information on by-catch and satellite transmitters, unpublished autopsy results and commented on this paper. Henrik Moller, Ilka Söhle and Dr Frank Zino provided information on satellite transmitters and Jason Hammil provided grey petrel observations from Macquarie Island. Rod Cossee (DOC) supplied banding permits and information on grey petrel band recoveries. Chris Edkins (DOC) gave advice on early drafts of the figures and produced Fig. 1.

8. References

Bailey, A.M.; Sorensen, J.H. 1962. Subantarctic Campbell Island. *Proceedings of Denver Museum Natural History 10*. 305 p.

Bartle, J.A. 1990. Sexual segregation of foraging zones in procellariiform birds: implications of accidental capture on commercial fishery long-lines of grey petrels (*Procellaria cinerea*). *Notornis 37*: 146–150.

Bartle, J.A. 2000a. Autopsy report for seabirds killed and returned from New Zealand fisheries, 1 January 1996 to 30 September 1996. *Conservation Advisory Science Notes 292*. Department of Conservation, Wellington.

Bartle, J.A. 2000b. Autopsy report for seabirds killed and returned from New Zealand fisheries, 1 October 1996 to 31 December 1997. *Conservation Advisory Science Notes 293*. Department of Conservation, Wellington.

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, New Zealand.

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, New Zealand.

Bell, E.A.; Sim, J.L. 2000a. Surveying 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, New Zealand.

Bell, E.A.; Sim, J.L. 2000b. Surveying 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, New Zealand.

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, New Zealand.

Brothers, N.P. 1984. Breeding, distribution and status of burrow-nesting petrels at Macquarie Island. *Australia Wildlife Research 11*: 113–131.

Chastel, O. 1995. Influence of reproductive success on breeding frequency in four southern petrels. *Ibis 137*: 360–363.

Despin, B. 1976. Observations sur le Petrel Gris (*Procellaria cinerea*). *L'oiseau et la R.F.O. 46*: 432–433.

Harper, P.C. 1987. Feeding behaviour and other notes on 20 species of procellariiformes at sea. *Notornis 34 (3)*: 169–192.

Heather, B.D.; Robertson, H.A. 1996. The field guide to the birds of New Zealand. Viking (Penguin Books NZ Limited), Auckland, New Zealand.

Hellyer. N.R.; Kinsky, F.C.; Imber, M.J. 1973. A soft-plumaged petrel from the Bay of Plenty. *Notornis 20*: 71–72.

Imber, M.J. 1983. The lesser petrels of Antipodes Islands, with notes from Prince Edward and Gough Islands. *Notornis 30*: 283–298.

Jenkins, J.A.F.; Greenwood, E. 1984. Southern seabirds in New Zealand coastal waters, July 1984. *Notornis 31*: 325–330.

Jones, E. 1980. A survey of burrow-nesting petrels at Macquarie Island based upon remains left by predators. *Notornis 27 (1)*: 11–20.

Jouventin, P.; Stahl, J-C.; Weimerskirch, H.; Mougin, J.L. 1984. The seabirds of the French subantarctic islands and Adelie Land, their status and conservation. Pp. 609–626 in Croxall, J.P.; Evans, P.G.H.; Schreiber, R.W. (Eds): Status and conservation of the world's seabirds. *ICBP Technical Publication 2*.

Jouventin, P.; Mougin, J-L.; Stahl, J-C.; Weimerskirch, H. 1985. Comparative biology of the burrowing petrels of the Crozet Islands. *Notornis 32 (3)*: 157–220.

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

Newton, I.P.; Fugler, S.R. 1989. Notes on the winter-breeding great-winged petrel *Pterodroma macroptera* and grey petrel *Procellaria cinerea* at Marion Island. *Cormorant 17*: 27–34.

O'Brien, R.M. 1990. *Procellaria cinerea*, Grey Petrel. Pp. 579–586 in Marchant, S.; Higgins, P.J. (Eds): Handbook of Australian, New Zealand and Antarctic birds. Volume 1: Ratites to Ducks. Part A: Ratites to Petrels. Oxford University Press, Melbourne.

O'Connor, T. (Ed.). 1999. New Zealand's subantarctic islands. Reed Publishing (NZ) Ltd., Auckland.

Powlesland, R.G. 1989. Seabirds found dead on New Zealand beaches in 1987, and a review of *Procellaria* species recoveries since 1960. *Notornis 36*: 299–310.

Richardson, M.E. 1984. Aspects of the ornithology of the Tristan da Cunha Group and Gough Island, 1972–1974. *Cormorant 17 (1/2)*: 123–201.

Robertson, C.J.R. 2000. Autopsy report for seabirds killed and returned from New Zealand fisheries, 1 January 1998 to 30 September 1998. *Conservation Advisory Science Notes 294*. Department of Conservation, Wellington.

Robertson, C.J.R.; Bell, B.D. 1984. Seabird status and conservation in the New Zealand region. Pp. 573–586 in Croxall, J.P.; Evans, P.G.H.; Schreiber, R.W. (Eds.): Status and conservation of the world's seabirds. *ICBP Technical Publication 2.*

Robertson, C.J.R.; Bell, E.A. 2002a. Autopsy report for seabirds killed and returned from New Zealand fisheries, 1 October 1998 to 30 September 1999: birds returned by Ministry of Fisheries observers to the Department of Conservation. *DOC Science Internal Series 28*. Department of Conservation, Wellington. 41 p.

Robertson, C.J.R.; Bell, E.A. 2002b. Autopsy report for seabirds killed and returned from New Zealand fisheries, 1 October 1999 to 30 September 2000: Birds returned by Ministry of Fisheries observers to the Department of Conservation. *DOC Science Internal Series 29*. Department of Conservation, Wellington. 41 p.

Rounsevell, D.E.; Brothers, N.P. 1984. The status and conservation of seabirds at Macquarie Island. Pp. 587–592 in Croxall, J.P.; Evans, P.G.H.; Schreiber, R.W. (Eds): Status and conservation of the world's seabirds. *ICBP Technical Publication 2.*

Smith, N.W.McL. 2001. Longline sink rates of an autoline vessel, and notes on seabird interactions. *Science for Conservation 183*. 32 p.

Söhle, I.S.; Moller, H.; Fletcher, D.; Robertson, C.J.R. 2000. Telemetry reduces colony attendance by sooty shearwaters (*Puffinus griseus*). *New Zealand Journal of Zoology 27*: 357–365.

Warham, J. 1988. Vocalisations of *Procellaria* petrels. *Notornis 35 (3)*: 169–183.

Warham, J. 1990. The petrels: their ecology and breeding systems. Academic Press Limited, London, United Kingdom.

Warham, J. 1996. The behaviour, population biology and physiology of the petrels. Academic Press Limited, London, United Kingdom.

Warham, J.; Bell, B.D. 1979. The birds of Antipodes Islands, New Zealand. *Notornis 26*: 121–169.

Warham, J.; Imber, I.J. 1985. Grey Petrel. P. 89 in: Reader's Digest complete book of New Zealand birds. Reader's Digest, Sydney, Australia.

Weimerskirch, H.; Zotier, R.; Jouventin, P. 1989. The avifauna of the Kerguelen Islands. *Emu 89*: 15–29.

Williams, A.J. 1984. The status and conservation of seabirds on some islands in the African sector of the southern ocean. Pp. 627–635 in Croxall, J.P.; Evans, P.G.H.; Schreiber, R.W. (Eds): Status and conservation of the world's seabirds. *ICBP Technical Publication 2.*

Zotier, R. 1990. Breeding ecology of a subantarctic winter breeder: the grey petrel *Procellaria cinerea* on Kerguelen Islands. *Emu 90 (3)*: 180–184.

Appendix 1

VEGETATION TYPES

There were four composite vegetation types identified on Antipodes Island for analysing the habitat in each of the transects. Grey petrels were predominantly found in Type C vegetation. Each is described and pictured below.

TYPE A. Short to medium vegetation, comprising fern (*Blechnum* sp. and/or *Polystichum vestitum*), small tussocks (both *Poa litorosa* and *P. foliosa*); may have some interspersed *Asplenium* fern, *Carex* sp., Antipodes carrot (*Anisotome antipoda*), small shrubs (*Coprosma rugosa* var. *antipoda* and *C. perpusilla*) and bidi-bid (*Acaena minor*). Low ground cover, easy to walk through, 'albatross country' (i.e. where albatross nest, gather in gams etc.).

TYPE B. *Carex* sp. dominant, with interspersed Antipodes carrot (*Anisotome antipoda*), generally swampy or marshy.

TYPE C. *Poa litorosa* tussock dominant, some *Polysticum vestitum* fern (can be in 'fingers', i.e. tongues of fern interspersed into tussock slopes). Few *Coprosma* shrubs (*C. rugosa* var. *antipoda* and *C. perpusilla*) may be present. Medium to tall vegetation.

TYPE D. *Polystichum vestitum* dominant. Varying heights, can have isolated tussock (*Poa litorosa*) interspersed.

Appendix 2

GREY PETREL BANDING DATA FROM ANTIPODES ISLAND

BAND NUMBER	DATE BANDED	LOCATION	NOTES
Z-54101	30 April 01	Western slopes, Mount Galloway	Adult, incubating egg
Z-54102	30 April 01	Western slopes, Mount Galloway	Adult, incubating egg
Z-54103	30 April 01	Western slopes, Mount Galloway	Adult, incubating egg
Z-54104	30 April 01	Western slopes, Mount Galloway	Adult, incubating egg
Z-54105	1 May 01	NW cliffs	Adult, incubating egg
Z-54106	1 May 01	NW cliffs	Adult, incubating egg
Z-54107	1 May 01	NW cliffs	Adult, incubating egg
Z-54108	6 May 01	Reliance Ridge	Adult, incubating egg
Z-54109	7 May 01	Southern slope, Mount Waterhouse	Adult, with Z-54110, non-breeder
Z-54110	7 May 01	Southern slope, Mount Waterhouse	Adult, with Z-54109, non-breeder
Z-54111	9 May 01	Perpendicular Head (census grid)	Burrow 9, adult, incubating egg, measurements taken (Appendix 3)
Z-54112	9 May 01	Perpendicular Head (census grid)	Burrow 8, adult, guarding chick, measurements taken (Appendix 3)
Z-54113	9 May 01	Perpendicular Head (census grid)	Burrow 15, adult, incubating egg, measurements taken (Appendix 3)
Z-54114	9 May 01	Perpendicular Head (census grid)	Burrow 19, adult, incubating egg
Z-54115	9 May 01	Perpendicular Head (census grid)	Burrow 21, adult, incubating egg
Z-54116	9 May 01	Perpendicular Head (census grid)	Burrow 20, adult, incubating egg
Z-54117	9 May 01	Perpendicular Head (census grid)	Burrow 18, adult, incubating egg
Z-54118	9 May 01	Perpendicular Head (census grid)	Burrow 27, adult, incubating egg
Z-54119	12 May 01	Crater Bay (census grid)	Burrow 80, adult, non-breeder, alone
Z-54120	12 May 01	Crater Bay (census grid)	Burrow 81, adult, incubating egg
Z-54121	12 May 01	Crater Bay (census grid)	Burrow 78, adult, incubating egg, dead sooty shearwater chick in nest chamber
Z-54122	12 May 01	Crater Bay (census grid)	Burrow 99, adult, incubating egg
Z-54123	12 May 01	Crater Bay (census grid)	Burrow 97, adult, incubating egg
Z-54124	12 May 01	Crater Bay (census grid)	Burrow 95, adult, incubating egg
Z-54125	12 May 01	Crater Bay (census grid)	Burrow 111, adult, incubating egg
Z-54126	12 May 01	Crater Bay (census grid)	Burrow 96, adult, incubating egg
Z-54127	12 May 01	Crater Bay (census grid)	Burrow 92, adult, incubating egg
Z-54128	12 May 01	Crater Bay (census grid)	Burrow 112, adult, incubating egg
Z-54129	12 May 01	Crater Bay (census grid)	Burrow 106, adult, incubating egg
Z-54130	12 May 01	Crater Bay (census grid)	Burrow 119, adult, incubating egg
Z-54131	15 May 01	Mount Galloway (census grid)	Burrow 43, adult, incubating egg
Z-54132	15 May 01	Mount Galloway (census grid)	Burrow 36, adult, non-breeder, alone
Z-54133	15 May 01	Mount Galloway (census grid)	Burrow 35, adult, incubating egg
Z-54134	16 May 01	Crater Bay	Adult, guarding chick
Z-54135	31 May 01	Dougall Stream	Adult, incubating egg
Z-54136	31 May 01	Dougall Stream	Adult, incubating egg
Z-54137	31 May 01	Dougall Stream	Adult, incubating egg
Z-54138	1 June 01	Stella Bay	Adult, alone, non-breeder
Z-54141	31 May 01	Knobs	Adult, with Z-54150, non-breeder
Z-54142	31 May 01	Knobs	Adult, incubating egg
Z-54150	31 May 01	Knobs	Adult, with Z-54141, non-breeder
Z-54201	28 April 01	Reef Point (cave)	Adult, with Z-54250, non-breeder
Z-54202	28 April 01	Reef Point	Adult, incubating egg
Z-54203	29 April 01	Stella Bay	Adult, incubating egg
Z-54204	29 April 01	Stella Bay	Adult, incubating egg

APPENDIX 2 (*continued*)

BAND NUMBER	DATE BANDED	LOCATION	NOTES
Z-54205	29 April 01	Stella Bay	Adult, incubating egg
Z-54206	29 April 01	Stella Bay	Adult, incubating egg
Z-54207	29 April 01	Stella Bay	Adult, incubating egg
Z-54208	29 April 01	Stella Bay	Adult, incubating egg
Z-54209	29 April 01	Stella Bay	Adult, incubating egg
Z-54210	29 April 01	Stella Bay	Adult, incubating egg
Z-54211	29 April 01	Stella Bay	Adult, incubating egg
Z-54212	29 April 01	Triple craters	Adult, incubating egg
Z-54213	29 April 01	Triple craters	Adult, incubating egg
Z-54214	29 April 01	Mount Galloway (western slopes)	Adult, incubating egg
Z-54215	29 April 01	Mount Galloway (western slopes)	Adult, with Z-54233, non-breeder
Z-54216	29 April 01	Mount Galloway (western slopes)	Adult, incubating egg
Z-54217	29 April 01	Mount Galloway (western slopes)	Adult, with Z-54232, non-breeder
Z-54222	1 May 01	Clark's Hill	Adult, incubating egg
Z-54232	29 April 01	Mount Galloway (western slopes)	Adult, with Z-54217, non-breeder
Z-54233	29 April 01	Mount Galloway (western slopes)	Adult, with Z-54215, non-breeder
Z-54234	29 April 01	Reef Point	Adult, incubating egg, measurements taken (Appendix 3)
Z-54235	29 April 01	Reef Point	Adult, guarding chick, measurements taken (Appendix 3)
Z-54236	30 April 01	Reef Point	Adult, incubating egg, measurements taken (Appendix 3)
Z-54237	29 May 01	Stella Bay (census grid)	Burrow 58, adult, incubating egg
Z-54238	1 May 01	Reef Point	Adult, incubating egg, measurements taken (Appendix 3)
Z-54239	29 May 01	Stella Bay (census grid)	Burrow 66, adult, incubating egg, measurements taken (Appendix 3)
Z-54240	29 May 01	Stella Bay (census grid)	Burrow 67, adult, incubating egg, measurements taken (Appendix 3)
Z-54241	29 May 01	Stella Bay (census grid)	Burrow 70, adult, incubating egg, measurements taken (Appendix 3)
Z54242	29 May 01	Stella Bay (census grid)	Burrow 77, adult, incubating egg
Z-54243	29 May 01	Stella Bay (census grid)	Burrow 47, adult, incubating egg, measurements taken (Appendix 3)
Z-54244	29 May 01	Stella Bay	Adult, incubating egg, measurements taken (Appendix 3)
Z-54245	28 May 01	Stella Bay	Adult, with Z-54246, non-breeder, measurements taken (Appendix 3)
Z-54246	28 May 01	Stella Bay	Adult, with Z-54245, non-breeder, measurements taken (Appendix 3)
Z-54247	28 May 01	Stella Bay	Adult, guarding chick, measurements taken (Appendix 3)
Z-54248	28 May 01	Stella Bay	Adult, with Z-54249, non-breeder
Z-54249	28 May 01	Stella Bay	Adult, with Z-54248, non-breeder
Z-54250	28 May 01	Reef Point (cave)	Adult, with Z-54201, non-breeder

Appendix 3

MEASUREMENTS TAKEN FROM ADULT GREY PETRELS ON ANTIPODES ISLAND*

BAND NUMBER	MEASUREMENTS (mm) SKULL WIDTH	CULMEN LENGTH	CULMEN WIDTH	CULMEN DEPTH	CULMEN LEAST DEPTH	HEAD-BILL LENGTH	TARSUS LENGTH	MID-TOE/ CLAW LENGTH	WEIGHT (g)
Z-54111	35.8	47.2	17.8	19.9	14.4	114.4	64	82	-
Z-54112	33.5	47.2	18.6	19.6	14.0	109.8	63.2	81.9	-
Z-54113	33.9	46.5	19.9	20.4	14.5	109.1	59	78	-
Z-54234	-	48.2	-	-	-	-	64	78.8	1185
Z-54235	-		-	-	-	-			1305
Z-54236	-	47.9	-	-	-	-	63.4	79.5	1220
Z-54238	-	49.4	-	-	-	-	62.9	74.5	1063
Z-54239	-	46.4	-	-	-	-	59.3	74.5	1315
Z-54240	-	47.9	-	-	-	-	60.7	75.5	1240
Z-54241	-	47.8	-	-	-	-	61.7	74	1685
Z-54243	-	47.8	-	-	-	-	58.9	76	1270
Z-54244	-	-	-	-	-	-	-	-	1280
Z-54245	-	45.2	-	-	-	-	62.1	75	1100
Z-54246	-	44.7	-	-	-	-	60.3	72.5	995
Z-54247	-	48	-	-	-	-	61.6	77	1180

* Z-54111 to Z54113 measured by E.A. Bell; Z-54234 to Z-54236, and Z-54238 to Z54247 measured by M.J. Imber.

Appendix 4

GREY PETREL EGG MEASUREMENTS FROM ANTIPODES ISLAND*

EGG	LENGTH (mm)	WIDTH (mm)	WEIGHT (g)
1	79.3	56	142
2	82	58	145
3	84.3	53.8	-
4	81.5	54.1	-
5	81.9	52.5	130
6	83.4	56.9	135
7	83.2	53.7	135
8	81.8	56.6	135
9	80.7	55.3	120
10	80.9	57	-
AVERAGE	81.9	55.4	134.6

* Eggs 1–9 measured by M.J. Imber; egg 10 measured by E.A. Bell.