HABITAT USE AND BURROW DENSITIES OF BURROW-NESTING SEABIRDS ON SOUTH EAST ISLAND, CHATHAM ISLANDS, NEW ZEALAND

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ABSTRACT

Forest of several types covered 45.14% of South East Island, Chatham Islands (218 ha). All petrel burrows in 200 10 m^2-quadrats in modified and unmodified forest were counted during breeding seasons in 1989 and 1990. From the total of 2675 burrows (1.338 burrows m^{-2} of forest), we estimated a breeding seabird population of more than 1.3 million pairs. The main species were White-faced Storm Petrels (*Pelagodroma marina*) (840,000 pairs), Broad-billed Prions (*Pachyptila vittata*) (330,000 pairs), and Southern Diving Petrels (*Pelecanoides urinatrix*) (127,000 pairs). Smaller numbers of Sooty Shearwaters (*Puffinus griseus*), Grey-backed Storm Petrels (*Oceanites nereis*) and Chatham Petrels (*Pterodroma axillaris*) also bred in the forests. Comparisons are made with population estimates for other New Zealand islands, parts of the Galpágos Islands, Baccalieu Island (Newfoundland), and the Juan Fernandez group. Conservation issues for South East Island are discussed.

INTRODUCTION

South East Island (44°20′ S, 176°10′ W) is, at 218 ha, the third largest island in the Chatham Island group, after Chatham and Pitt. It slopes gently from northern lowlands up to the highest point (224 m) above steep southern cliffs. It has a double rocky summit of largely bare rock with scrubby *Olearia chathamica* in the areas where soil is present. It is composed of volcanic breccias which form the crags and softer basaltic lapilli tuffs at the coast. The island is the southernmost volcanic centre in the Chatham Islands. At about 4-5 million years old, it is, with Mangere, among the youngest of the Chatham Island volcanoes (Adams *et al.* 1988).

Before the island became a reserve in 1954, it was farmed and held sheep, goats, and cattle (Richie 1970). The last sheep were shot between 1956 and 1961 (Veitch & Bell 1990). Much of the island was then in pasture but a large tract of forest in the central and higher parts of the island was relatively unmodified by browsing. In this forest, the undergrowth was grazed but the mature trees were probably little damaged. In contrast, the "Woolshed Bush" forest had been damaged severely by fire, overgrazing, and sowing of grass and had extensive gaps in the canopy. The forest consists mostly of species endemic to the Chatham group.

Since the stock were removed, the forest has encroached rapidly into the grassland, most of which has now been converted to stands of rank grass and bracken (*Pteridium esculentum*) and *Muehlenbeckia australis*. These plants form large impenetrable thickets, and the remaining grassland is gradually

being overtaken. There is very little regeneration or ground cover under the forest canopy, and the ground is riddled with thousands of seabird burrows which make the soil extremely fragile.

In this paper, we report the results of surveys of the density of seabird burrows on South East Island, in relation to forest types, soil type, aspect, and degree of modification of the vegetation. The results are then used to estimate population sizes for the burrow-nesting petrels in the forest on the island. Factors affecting the conservation of some species are also discussed.

METHODS

We sampled burrow densities in different areas in different forest types between January 12 and February 2, 1989 and from January 7 to 25, 1990. Because of the extreme fragility of the forest floor, we kept to established tracks whenever possible and used plywood boards to distribute our weight when positioning and sampling quadrats. Lines were chosen through different forest types. The "Link" and "Clears" tracks (Figure 1) pass through the central relatively unmodified forest so in 1989, 100 quadrats were placed along 1 km of this track. There is a network of tracks in the modified "Woolshed Bush" so in 1990, we sampled 50 quadrats along 1 km of forest track in there. Other existing tracks were used as the line for 30 quadrats in regenerating forest on a high west-facing terrace and 20 in remnant forest patches behind Thinornis Bay and some steeper forest below Rangatira Trig (Figure 1).

Quadrat location

We used four-digit random numbers to locate quadrats. The first two numbers gave the distance in 10 m units along the previously determined line. The second pair, divided by 4, gave the offset at right angles to the track, left (if odd) or right (if even). A 10 m^2 quadrat (side 3.162 m) was then set out starting at the calculated point, running away from the track, then parallel to it away from the origin, then towards it, and finally parallel to the track to the point. For example, quadrat 7574 was 750 m from the line origin and 19 m (74/4, rounded up) to the left of the track.

Burrows

All burrows within each quadrat were assigned to a species and counted. Many burrows were empty during the period of the counts as almost all Broad-billed Prions (*Pachyptila vittata*), and many Common Diving Petrels (*Pelecanoides urinatrix*) had finished rearing their chicks. Burrows were assigned to species on size, shape and state of the entrance and status of the nest chamber, if it could be reached. As many burrows were empty in late January there is a margin of error which could be eliminated if a similar study were repeated earlier in the breeding season when all burrows contain chicks or incubating adults. Entrances with no chamber were ignored. Height and width of entrances of 20 burrows of each species, and all known Chatham Petrel (*Pterodroma axillaris*) were measured.

We recorded the aspect (compass direction of slope), slope and soil state (each in four categories) of each quadrat. The angle of slope was not measured

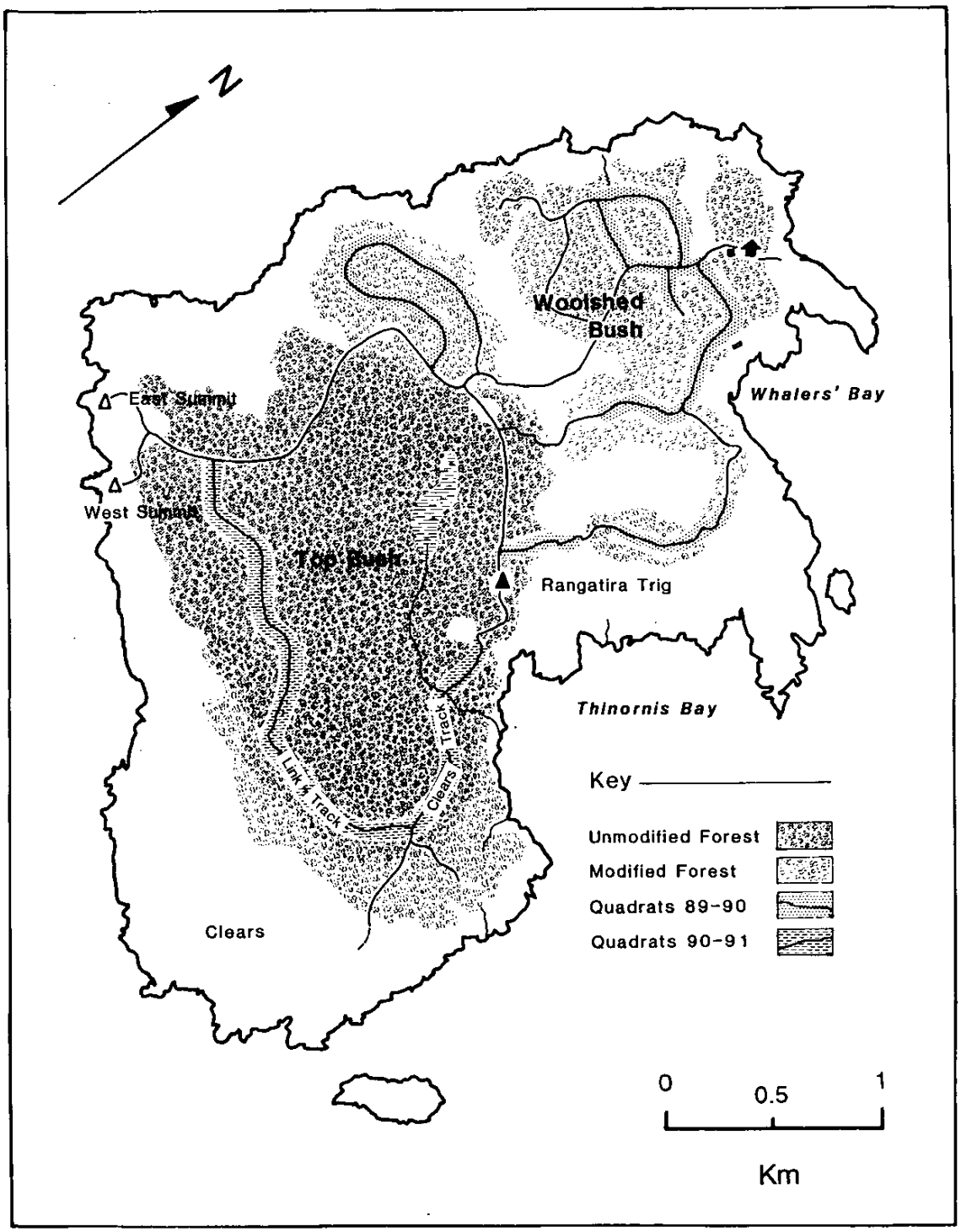

FIGURE 1 – Map of South East Island (Rangatira), with quadrat lines, tracks, and place names used in text.

but estimated: level, slight slope $\leq 10°$, medium 10°- 40°, steep ≥ 40. The four soil types were as follows: firm soil could be walked on without any danger of collapsing; rocky sites had little soil and were usually steep; friable soil was very unstable, even with our plywood boards; and compact soils were quite secure with the use of boards.

Vegetation

The canopy plants on or over each quadrat were recorded to give some quantitative information on the occurrence of the various plant species making up the forest mosaic. We used an aerial photograph and on-the-ground work to compose a map of the forest patterns. This was later used to calculate the areas of the various vegetation types.

TABLE 1 – Breeding cycle dates for South East Island seabirds (Source: Nilsson & West unpublished data).

	Time of activity				
SPECIES	Arrival	Laying	Hatching	Fledging	Departure
Sooty Shearwater	late Sep	late Nov	Jan	late Apr-early May	end May
Broad-billed Prion	early Feb	late Aug - Sep	mid Oct - Nov	mid Dec - late Jan	end Jan
Black-winged Petrel	mid Nov	Jan	early May	late May	mid Jun
Chatham Petrel	mid Nov - early Dec	late Dec - mid Jan	Mar	late May	mid Jun
Grey-backed Storm Petrel	May	late Sep - Dec	Nov - Jan	Jan - Mar	Apr
White-faced Storm Petrel	late Sep	Nov	mid Dec - Jan	mid Feb - early Apr	end Apr
Common Diving Petrel	Apr - May	Sep - Oct	Nov - Dec	Jan - Feb	Mar

RESULTS

Burrowing seabirds

Seven species of petrel (Procellariiformes) are known to breed on South East Island. The dates for each phase of the breeding cycle for each species are summarised in Table 1. There is no time when seabirds are totally absent from South East Island. Broad-billed Prions are there all year, except when they moult at sea in January and February. Grey-backed Storm Petrels (*Oceanites nereis*) are also there for much of the year. All other species are present for a limited time for breeding and are oceanic for the rest of the year. Some species migrate long distances from the Chatham Islands.

Five species of Procellariiformes breed in burrows in the forest on South East Island. Little Blue Penguins (*Eudyptula minor*) also nest in burrows in the forest. Two other procellariiforms nest elsewhere on the island: Black-winged Petrels (*Pterodroma nigripennis*) are found under low scrub around the summit rocks; and Grey-backed Storm Petrels nest in tufted vegetation such as *Carex chathamica, Muehlenbeckia australis,* and *Poa* spp. in clearings and around the coast.

Recently two further species of petrel have been recorded from the island. Juan Fernandez Petrels (*Pterodroma externa*) have been seen flying around

the double summits in January and February of 1984, 1986, 1989, and 1990 (Imber *et al.* 1991). In January 1990 an unknown shearwater was found by the authors among Sooty Shearwaters (*Puffinus griseus*) in the forest. With a bare brood patch and dirt on its feathers, it was certainly in breeding condition. The bird subsequently died and is being studied at the Museum of New Zealand (Millener and Bartle in prep.). It appears to be an undescribed species.

TABLE 2 – Number of quadrats out of 200 over which each canopy plant species was present

	Study season - quadrats covered		
	1989	1990	
Species	Least-modified forest	Modified forest	Total
Melicytus chathamicus	81	75	156
Plagianthus betulinus var chathamicus	72	55	127
Myrsine chathamica	69	46	115
Macropiper excelsum	54	36	90
Coprosma chathamica	44	8	52
Muehlenbeckia australis	14	30	44
Olearia traversii	24	12	36
Carex chathamica	*10*	*20*	*30*
Pseudopanax chathamicum	12	17	29
Ripogonum scandens	4	6	10
Asplenium chathamense	4	4	8
Urtica australis	6	1	7
Myoporum laetum	0	4	4
Dicksonia squarrosa	3	0	3
Phormium tenax	0	2	2
Pteridium esculentum	0	2	2
Hebe dieffenbachii	0	1	1
Corynocarpus laevigatus	0	1	1
Blackberry sp.	0	1	1

Vegetation

Four species of plant contributing to the canopy over the quadrats were ranked in the same order regardless of the degree of forest modification (Table 2). In 1990, both *Carex chathamica* and *Muehlenbeckia australis* occurred in more quadrats than they did in unmodified forest (1989 series). Both species were encroaching around the edges of the bush, and formed dense thickets which were largely unsuitable for burrowing birds. Although *Olearia traversii* was perhaps the largest – and probably the longest-lived – tree, it was present in only 25% of the less-modified (1989 series) quadrats and was rare in the modified forest sampled in 1990 (Table 2). Unmodified forest is made up of three forest types, "Top Bush", *Olearia* forest, and *Dracophyllum* forest (Nilsson *et al.* 1994, and Figure 1). These forests covered 53.83 ha (24.69%) of the island area. The modified forest included six forest types (Nilsson *et al.* 1994) and comprised 44.58 ha (20.45%) of the island. Therefore, 45.14% of the island had forest occupied by burrow-nesting seabirds.

TABLE 3 – Quadrats (%) in burrow frequency groups. Maximum was 28 (1 quadrat) in modified forest, but 34 (3 quadrats) in least-modified forest.

Burrows/ quadrat	Forest condition		Total %
	Least-modified	Modified	
0	2	9	5.5
1-5	8	27	17.5
6-10	14	17	15.5
11-15	23	18	20.5
16-20	15	23	19.0
21-25	27	2	14.5
26-30	4	4	4.0
31-35	7	0	3.5

Burrow density and distribution

Burrows were distributed unevenly within the remaining forest. Of the total of 2675 burrows counted (mean density 1.338 m^{-2} over all forest types), 1663 were examined in 1989 and 1012 in 1990. Few quadrats lacked burrows, but most had fewer than 25 (Table 3). The maximum number in one quadrat was 34 (in 3) in 1989, and 28 (in 1) in 1990.

Quadrats sampled in 1989 (in little-modified forest) sloped in all compass directions, but 68% sloped between NE and S; 14% were flat. Most (62%) quadrats in the modified forest areas had a northerly or easterly aspect; the rest had none (flat). These values reflected the general topography of the island which had forest on gentle slopes on the northwestern to southeastern half and steep southwesterly faces below the summits.

The number of burrows was related to the degree of disturbance of the forest. The highest density of burrows of all species occurred in compact or friable soil in both forest types and on gentle slopes in the least modified forest (Table 4).

White-faced Storm Petrels (*Pelagodroma marina*) were the most abundant burrowing petrels in forests on South East Island (Table 5). Over all areas sampled (all forest types combined), their burrows were more than twice as abundant as those of the next commonest species, the Broad-billed Prion (*Pachyptila vittata*). These were, in turn, twice as abundant as the third most numerous species, the Common Diving Petrel (*Pelecanoides urinatrix*) (Table 5). Densities of burrows of prions and diving petrels are very similar in the two areas. However White-faced Storm Petrels were 2.5 times as dense in the least modified forest. Sooty Shearwaters (*Puffinus griseus*) breed in localized areas around the edges of the island which were not thoroughly sampled and the data reflect this. No attempt was made to sample penguins so the data on this species are not discussed. Although Chatham Petrels (*Pterodroma axillaris*) are present in low numbers in the forest (West, 1994), none was found in any quadrat. An area of burrows of this species was found in 1991 in the least modified forest not far from the 1989 line of quadrats.

TABLE 4 – Number of quadrats and burrows per quadrat in relation to slope and soil type in two habitat types.

	Level of forest modification					
	Least-modified			Modified		
Habitat feature	No. of quadrats	% of quadrats	Burrows/ quadrat	No. of quadrats	% of quadrats	Burrows/ quadrat
Flat	14	10.0	11.9	38	39.0	10.4
Gentle	53	62.1	19.9	42	45.1	10.9
Medium	29	26.4	14.6	15	13.3	9.0
Steep	4	1.5	6.2	5	2.6	5.2
Firm	0	0	0	49	30.0	6.2
Rocky	2	0.5	4.5	5	1.2	2.4
Compact	87	89.5	17.1	37	56.2	15.4
Friable	11	10.0	15.1	9	12.6	14.1

TABLE 5 – Percentage of total burrows and number per quadrat belonging to each species counted in 200 quadrats in two habitat types.

	Level of forest modification				
	Least-modified		Modified		Total
Species	%	Burrows m^{-2}	%	Burrows m^{-2}	%
White-faced Storm Petrel	71.38	1.18	46.05	0.47	63.18
Broad-billed Prion	18.4	0.31	37.15	0.38	24.4
Diving Petrel	9.5	0.15	14.52	0.15	11.12
Sooty Shearwater	0.72	0.01	2.08	0.02	1.3
Little Blue Penguin	0.0	-	0.2	-	-

Estimates of breeding populations

The measured burrow densities were used to estimate the number of breeding pairs of seabirds in the 98.41 ha of forests on South East Island. At the mean density of 1.338 burrows m^{-2}, there may be more than 1,300,000 burrows, about 900,000 in 53.83 ha of unmodified forest, and about 450,000 in 44.58 ha of modified.

Estimates for breeding pairs of individual species were: White-faced Storm Petrel 840,000 (63% of all burrows – 71% = 640,000 in unmodified forest, 46% = 197,000 in modified forest) mean density 0.87 m^{-2}; Broad-billed Prion c. 330,000 plus others under bracken and vine thickets (24% of total burrows – 160,000-170,000 in unmodified forest, same in modified forest) mean density 0.34 m^{-2}; Southern Diving Petrel 164,000 (85,000 in unmodified, 62,000 in modified forest) mean density 0.15 m^{-2}; Sooty Shearwater unknown, but at least 17,000 pairs (1.3% of forest sample).

These are estimates of breeding pairs of all species in the forest only, and are not estimates of total populations. Many pre-breeders of all species were present at certain times in the breeding season and a proportion of all species populations – young birds up to 3-5 years old – do not return to the breeding colony. In addition, many burrows in the *Muehlenbeckia* and grassy areas were not sampled. The numbers also do not include the few pairs of Black-winged Petrels (*Pterodroma nigripennis*) that were continuing to try to nest under the summit vegetation, nor the Grey-backed Storm Petrels (*Oceanites nereis*).

TABLE 6 – Dimensions (mm, mean ± SD) of typical burrow entrances for five species of seabirds in forest on South East Island.

Species	*n*	Dimension	
		Height	Width
White-faced Storm Petrel	20	46.2 ± 7.4	74.0 ± 14.9
Common Diving Petrel	20	75.0 ± 7.7	89.0 ± 6.4
Broad-billed Prion	20	68.5 ± 11.2	126.5 ± 7.8
Sooty Shearwater	20	153.5 ± 27.1	226.0 ± 29.9
Chatham Petrel	7	62.8 ± 4.5	95.7 ± 8.6

Burrow dimensions

Mean dimensions of 20 burrows of each species are shown in Table 6. The seven Chatham Petrel burrows were the only ones known at the time of the survey so it is a small sample. More burrows of this species were located during further survey work during the 1990/1991 breeding season and measurements of burrow entrances taken then had a greater range than those given above (G. Taylor pers. comm.).

DISCUSSION

Few published estimates of seabird populations on forested islands are directly comparable to the South East Island survey. Most estimates are for islands outside New Zealand and are of different species in different habitats from those on South East Island.

In New Zealand, some of the earliest work on petrel populations was by Fleming and Turbott on South East Island where Fleming (1939) found burrows of the White-faced Storm Petrel "in every soil-cover square yard" of grass, scrub and forest but noted that the density was much greater in the forest. The earliest counts were made by Richdale who estimated the number of breeding pairs of several species on Whero Island in Foveaux Strait (Richdale 1942, 1944a). From his map, about 60% of the 3035 m^2 island held soil suitable for burrowing seabirds. White-faced Storm Petrels bred in sedge and *Muehlenbeckia*. Burrow density for 900 pairs was 0.49 m^{-2}.

Other storm petrel populations have been estimated at the Galápagos Is, Bird Island (South Georgia), and on Baccalieu Island (off Newfoundland). Harris (1969) calculated that there were 200,000 pairs of Galápagos Storm Petrel (*Oceanodroma tethys*) on Tower Is (mean 8 pairs m^{-2}, maximum 15.6 burrows m^{-2}). On Plaza Island, also in the Galápagos, Harris (1969) found about 600 occupied burrows of the Madeiran Storm Petrel (*O. castro*) in the hot season and about 300 in the cold season but he did not calculate burrow densities. This species appears to have two distinct breeding seasons and some burrows are used twice per season.

On Bird Island (South Georgia), Copestake *et al.* (1988) estimated a breeding population of 62,400 pairs of Wilson's Storm Petrels (*Oceanites oceanicus*) across scree slopes (0.24 m^{-2}). Leach's Storm Petrels (*Oceanodroma leucorhoa*) breed on many islands around Newfoundland, but the largest known colony is on Baccalieu Island. Burrow densities varied from 0.046 to 4.166 m^{-2} in different habitats, with an estimated overall breeding population of 3.36 million pairs (Sklepkovych & Montevecchi 1989). The density in the forest was 0.94 burrows m^{-2}, which is similar to the density of storm petrels on South East Island. However, they were able to estimate an occupancy of breeders in the burrows which gave 0.604 breeding pairs m^{-2}, or 1.73 million pairs on 286.2 ha.

Swales (1965) recorded the Broad-billed Prion to be the commonest bird on Gough Island but stated that it was impossible to estimate its numbers. On Whero Island, Richdale (1944b) estimated that 100 pairs bred amongst roots and logs (0.05 m^{-2}). This was far lower than the 0.34 m^{-2} in the very large population on South East Island.

Richdale also counted about 200 pairs (c. 0.11 m^{-2}) of Southern Diving Petrels breeding amongst *Poa* sp. where the soil was quite shallow (Richdale 1943, 1965). Hunter *et al.* (1982) arrived at a figure of 4900 pairs of diving petrels in quadrats on Bird Island (South Georgia). The mean density (0.25 m^{-2}) was nearly twice that on South East Island (0.15 m^{-2}). Johnson (1976) sampled only two 2 x 2 m quadrats on Little Solander Island, in western Foveaux Strait, but was satisfied that they were representative of the whole 8 ha island, for which he suggested a total population of 250,000-300,000 pairs (6 m^{-2}). South East Island had far fewer than that in the forest but there was an unknown – but probably small – number in the thickets. Warham (1990) expected the populations around New Zealand to "run into the millions", but gave no basis for the conjecture.

Richdale (1944c) estimated there to be 225 pairs of Sooty Shearwaters on Whero Island (0.12 m^{-2}). Warham & Wilson (1982) estimated a breeding population of 2,750,000 pairs of Sooty Shearwaters on the Snares Islands from quadrat counts, using a 75% occupancy rate (0.84 m^{-2}, assuming all 328 ha was suitable habitat). Our survey of South East Island did not include peripheral areas of the island where there are local colonies of Sooty Shearwaters, but we did record small numbers where the least modified forest gave way to modified steeper areas.

Estimates of other populations of other petrel taxa provide interesting comparisons with the South East Island data. Imber (1976) found

30,000-40,000 pairs of Grey-faced Petrels (*Pterodroma macroptera gouldi*) on Whale Island, Bay of Plenty, New Zealand, where the burrow distribution was patchy but covered in all about 110 ha of the 140 ha island. Burrow numbers varied from 1 to 200 per 20 m x 20 m quadrat (Imber, pers. comm.). Overall, this would give a density of 0.04 m^{-2}.

A mixed breeding colony of two species of *Pterodroma* on Isla Alejandro Selkirk west of Chile covered 219.8 ha (233.9 ha corrected for slope). It contained 1,131,000 pairs – 1,000,0000 *Pt. externa* and 131,000 *Pt. longirostris* – at about 0.484 m^{-2} in the 1985-86 season (Brooke 1987).

The relative numbers of White-faced Storm Petrels and Broad-billed Prions in the least modified forest probably more truly reflect the original balance on South East Island. The species composition over the whole island could change in the future as a result of increasing pressure from prions. Prions are present almost all year and in late April seem to be using all available burrows with paired birds sitting around on the surface (M. Imber, pers. comm.). Plant (1989) found that prions and penguins trampled large areas of bare ground adjacent to their burrows on Houruakopara Island, making it unsuitable for storm petrels burrows. We have observed prions fighting with Chatham Petrels and causing desertion of petrel eggs.

Discussions of conservation priorities usually revolve around protection from predators, or prevention of habitat destruction. However, there are no alien species as yet on South East Island and any habitat changes will result from regeneration after earlier grazing and burning of the forest. The spread of dense thickets of *Muehlenbeckia* and bracken may pose problems for some species in the future.

The greatest threat to the smaller or more docile species of petrel will come from the Broad-billed Prions if they increase in numbers. It may be difficult for storm petrels to recolonize areas where the soil is compacted, having been trampled by grazing animals and then by prions. A further and ever-present threat is that rats or mice might be introduced to the island accidentally. All necessary precautions must be taken to prevent such a catastrophe.

Comparisons of the total species list and our population estimates of burrowing petrels for South East Island with those from other islands show that this small island is one of the most important in the New Zealand region for breeding seabirds. Other islands, such as Little Barrier Island, Codfish Island, the Snares and the New Zealand subantarctic islands are also of major significance, but with the exception of Snares no quantitative work has been published. On none of the others is the total breeding population likely to be as large as 1.3 million pairs. This makes South East Island extremely important in terms of conservation of seabirds as well as its international importance for several other endemic and endangered species.

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