THE SIZE OF THE SOOTY SHEARWATER POPULATION AT THE SNARES ISLANDS, NEW ZEALAND*

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ABSTRACT

The size of the Sooty Shearwater *(Puffinus griseus)* population at the Snares Islands was estimated by counting burrows in the main vegetation types. Some 3 287 000 burrows were calculated for Main Island, the highest densities being 1.9/m^2 in *Poa* meadows, with 1.2/m^2 under the trees of the *Olearia* forest. Most burrows were occupied but data on rates of occupation by breeding birds were not satisfactory. Assuming a 75% occupancy rate, we get a total population of about 2 750 000 burrow-holding pairs on the 328 ha of the two largest islands.

INTRODUCTION

In recent years there has been a marked increase in attempts to estimate seabird populations. Much of this effort has been to establish base-line information in the face of threats or potential threats posed by new developments in the exploitation of marine resources. Such threats exist in the southern hemisphere as in the northern one, and with the prospect of further exploration oil drilling in the ' Great South Basin,' phosphate mining on the Chatham Rise and similar projects in New Zealand seas, there is a clear need for information on the sizes of New Zealand seabird populations. Such information is also needed to evaluate the mortality occurring in the northern hemisphere, to which many southern species migrate after breeding. For example, King *et al.* (1979) estimated that the shearwaters *Puffinus griseus* and *P. tenuirostris* comprised 27% of the annual mortality of 214 000 - 715 000 seabirds killed by the Pacific offshore salmon gill-net fishery. More recent data (Ainley *et al.*, in press) suggest that these mortality estimates should be doubled. Contamination by chlorinated hydrocarbons and PCBs while in northern waters may also be important — summary in Bourne (1976).

Probably the most important of New Zealand seabirds in terms of numbers and biomass is the Sooty Shearwater, or New Zealand Muttonbird *(Puffinus griseus)*. This breeds in small numbers as far north as Three Kings Islands (34°S), more commonly in Cook Strait (41°S), but its centre of abundance is south of the South Island — in Foveaux Strait and on islands around Stewart Island. The Snares Islands at 48°S 166°E have big populations. Further south at Antipodes,

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Campbell, the Auckland Group and Macquarie Islands only quite small colonies occur.

The Sooty Shearwater population at The Snares appears to be in a very healthy state with no evidence of the derelict burrows that are seen at petrel colonies in decline. Many eggs are laid on the surface and abandoned. We found that these averaged narrower than those laid underground and were presumably produced by young birds (Serventy 1967): such surface eggs appear to be typical of shearwater colonies in good fettle.

On the two largest islands in the group, Main Island (280 ha) and Broughton Island (48 ha), the whole of the peaty soil is burrowed, except where the soil is too thin, areas where the bare peat has been eroded by wind and rain, where the ground is occupied by colonies of Snares Crested Penguins *(Eudyptes robustus)* or where the soil becomes waterlogged and burrows flooded after heavy rain.

For the purpose of our census only four vegetation types needed consideration — minor types were poorly burrowed and 38 ha of the Main Island and 13 ha of Broughton Island were bare of soil.

The deep peat supports a central forest of *Olearia lyallii* forming an almost closed canopy at about 6 m. This is surrounded by meadows of *Poa* tussocks which extend outwards to the coastal cliffs. There are small patches of forest dominated by the tree *Senecio stewartiae* and thickets of the coastal bush *Hebe elliptica.* These vegetation types are rather clearly defined and with the help of a series of stereo-aerial photographs and a ground survey, a detailed vegetation map of the Main Island was prepared by C. H. Hay in 1970. This shows the planar areas for each vegetation type. In 1974 a similar map of Broughton Island was made by H. A. Best.

Conditions for burrowing vary with vegetation type. Beneath *Olearia* the ground is clear of understorey and leaf litter as the shearwaters remove all loose vegetation for their nest linings but the soil is interlaced with stout roots which hinder burrowing. Similar conditions apply to the *Senecio* areas, but these trees tend to occur on rather waterlogged soils. The *Poa* tussocks are of two types. *Poa tennantiana* plants are about 0.6 m across and 0.6 m high and form meadows surrounding the central forest. These meadows are themselves surrounded by a zone of *Poa astonii* whose plants tend to form large stools 1-1.5 m high and 0.5 m diameter and extend down steep coastal slopes wherever there is enough soil. This grass does well on quite shallow soils but on steep slopes offers fewer opportunities for burrowing shearwaters, although it is suitable for smaller species of petrels.

METHODS

To lessen damage through breakthrough in the extensively burrowed ground, while permitting ready movement around the island, an access track was cleared and marked at the start of the study (see map in Warham, 1967).

An estimate of the number of burrows was attempted by sampling burrow densities in the four vegetation types and computing the total number of burrows. On level or near-level ground burrow densities in the two *Poa* zones were found to be similar and the figures for these have been aggregated.

In the summers of 1969/70 and 1970/71 a series of 10 m × 10 m quadrats was pegged out and the number of used burrow entrances counted. Quadrats were located at random within the various zones and burrow entrances counted inside the tape and marked with a short stick as counted. Those on the boundaries were included if the nest chambers were clearly within the quadrat. Used burrows were those whose entrances were free from obstructions, cobwebs and the like, but the only instances of disuse were some burrows in dense *Hebe* which were blocked with sticks and whose birds had clearly been excluded by the rapid growth of the bushes since the previous season. The planar areas for each vegetation type were measured from the vegetation map by planimeter.

Most parts of the Main Island were sampled, and in the *Olearia* zone some quadrats were close to forest margins and others towards the centre of the island. In the small area of *Senecio* the few quadrats examined were not chosen randomly but selected to include a high-density area, a poorly drained one, one near the *Olearia-Senecio* boundary and one at random, to show all the extremes in this vegetation type.

No allowance was made for slope in computing burrow densities because, although the ground slopes gently to the east and is dissected by shallow gullies (see Fleming *et al.* 1953), checks on gully sides showed that in planar projection burrow densities were not greater than on more level ground: such slopes tended to be wet and burrow densities low. On gently sloping ground burrow densities were higher than on flat ground — an effect of better drainage perhaps — but variations between quadrats were far greater than could be accounted for by slope alone.

Attempts were made to get information on burrow occupancy from three kinds of data: (a) from the contents of nest chambers accidentally broken into between 3 December 1970 and 24 February 1971, (b) from the disturbance of fences of fine wires set across burrow entrances and checked each morning from 4 to 22 January 1971 while hatching was in progress and (c) from the state of 100 burrows chosen at random under the *Olearia* forest and examined daily during April 1972 by C. J. and D. S. Horning. Examination was by feeling an occupant by hand or with a long wire, by noting fresh digging, by finding nestling down in the tunnel and by seeing birds entering burrows.

RESULTS

The total number of burrows on Main Island was estimated at 3 287 000. See Table 1. The highest burrow densities of nearly 2/m^2 occurred among tussock grass. This is probably because burrowing is

TABLE 1 — Sooty Shearwater burrow densities on Main Island, Snares Islands

Vegetation type	n	Burrows/100 m^2 $\pm$ 1 S.E.	Range	Area covered by vegetation (ha)	Estimated no. of burrows*	95% confidence intervals *†
Olearia forest	22	116.1 $\pm$ 7.10	40 - 155	146.80	1 704 000	1 496 000 - 1 913 000
Poa tussock	15	194.8 $\pm$ 5.83	159 - 240	76.51	1 490 000	1 401 000 - 1 580 000
Senecio forest	4	45.8	20 - 76	3.32	15 000	
Hebe elliptica	10	68.3 $\pm$ 11.48	10 - 129	11.45	78 000	51 900 - 91 300
TOTAL				238.08	3 287 000	2 963 900 - 3 599 300

* Figures rounded to the nearest 1,000 † $\pm$ 2 standard errors

easier there with less obstruction from roots. Variability between quadrats was also least in the tussock, probably because the plants themselves are very evenly distributed and of rather constant size. Densities for the *Senecio* forest were low, partly owing to the damp ground conditions. The great variability in the counts in the *Hebe* quadrats directly reflected their openness, with dense, nearly impenetrable thickets being almost unused.

Figures for Broughton Island are less reliable as no ground sampling was done there, but the shearwater flocks over this island appeared as dense as those over the Main Island. If we assume similar burrow densities in similar vegetation, the 13.5 ha of *Olearia/Senecio* forest would have 131 900 burrows, the 14.3 ha of *Poa* 235 600 burrows and the 2.6 ha of *Hebe* 14 800 burrows, some 382 000 burrows in all for that island.

DISCUSSION

Some previous figures for shearwater burrow densities have been published. Rowan (1952) estimated nest densities of the Greater Shearwater (*Puffinus gravis*) at Nightingale Island, Tristan da Cunha, from 15 sample counts in three vegetation types. She found the highest density of 1.5 nests per square yard (1.8/m^2) in short tussock and sedge, falling to about 1 per square yard (1.2/m^2) in very heavy tussock 2-2.5 m high, and only about 0.6 nests per square yard (0.7/m^2) under groves of *Phylica* trees. She estimated an average burrow density of 1.2/m^2. The same figure was gained for a colony of the Short-tailed Shearwater (*P. tenuirostris*) from 10 sample counts in the two predominant vegetation types at Cat Island, Tasmania (Warham 1960). Recently Skira & Wapstra (1980) estimated much lower burrow densities (0.21-0.81/m^2) at a number of *Puffinus tenuirostris* colonies using a line transect method. For this same Australian species Norman & Harris (1981) reported rather similar densities at Rabbit Island, Victoria, of 0.3-0.6/m^2 but Harris & Bode (1981) estimated lower densities of burrows (0.05-0.47/m^2) at the small and rather disturbed colonies in Phillip Island, Victoria. At his small colony of 295 nests of Sooty Shearwaters spread over 420 m^2 Richdale (1963, p. 94) calculated the burrow density at 0.7/m^2. Wormell (1976) counted occupied burrows of Manx Shearwaters (*P. puffinus*) on Rhum in 36 sample plots, finding a mean density of 150 burrows per square chain (0.37/m^2), but densities there are low, partly because the birds burrow under boulders (Bourne, pers. comm.).

Very recently Floyd & Swanson (in press) have estimated breeding success and population size and density of the Wedge-tailed Shearwater (*P. pacificus*) at Muttonbird Island, New South Wales, and compared their findings with those from other Australian colonies of that species. These authors also found that burrow densities varied with vegetation type, their mean being 0.51/m^2 with 25-34% of nests occupied.

None of these figures approaches the burrow density of nearly 2/m^2 calculated for *Poa* tussock at The Snares. The figures for the total numbers are also smaller. Rowan (1952) estimated 2 million Greater Shearwater burrows on Nightingale's 200 ha, but thought that this was an underestimate. Elliott (1970) examined the same species on Gough Island, computing some 600 000 square yards (501 600 m^2) as being burrowed, found about 1 chick per square yard (1.2/m^2) and hence a breeding population of 600 000 pairs. Warham (1960) calculated that there were 250 000 burrows of *P. tenuirostris* on Cat Island, Bass Strait (49 ha), and pointed out that there were much larger colonies on bigger islands in the area. Wormell's estimate for occupied burrows on Rhum, stated to be the largest colony of the Manx Shearwater in Britain, was 116 100.

The main problem in estimating population sizes by burrow counts lies in the difficulty of relating burrow numbers to the numbers of birds. At the Snares Islands it is quite impossible to establish occupancy by direct inspection for many burrows have long twisting tunnels leading to chambers 0.5-1 m below ground and quite hidden from view. The difficulties are exacerbated by the sensitivity of Sooty Shearwaters to interference. Birds disturbed on eggs frequently desert, and regular handling such as seems possible with Manx Shearwaters is not feasible.

None of our attempts to determine occupancy rates was entirely satisfactory. Of 54 nesting chambers accidentally broken into during other work, 30, or 56%, contained eggs or chicks. Fourteen of the others were empty by day and 10 contained one or two adults without egg or chick. This latter group would have included non-breeders and failed breeders. In all, 74% of nests were occupied by day. All 31 fenced burrows examined over a 20-day period had their fences disturbed. At 23 burrows the fences were displaced on 10-18 days (mean 14.2 days); the rest were displaced much less often (0-9 days), mean 4.4 days. If entry about every other day is taken to mean occupancy, then 74% of the sample were occupied during that period. However, some of the more disturbed burrows could have been visited by prospecting non-breeders while some of the less disturbed ones could have held incubating birds, as these often fast for 9 days during their incubating stints (pers. obs.).

More useful are the data from the 100 burrows examined in April 1972, of which at least 86 had occupants. This figure is significant because by April non-breeding and failed breeders have left the island. Richdale (1963, p. 80), for example, found no 'unemployed' birds ashore by day after 8 March and believed that the regimes of such birds were similar to those found for *P. tenuirostris* (see Serventy 1967). Disturbances in April must therefore have been caused by parents or by chicks. The probable source of error here, of unknown magnitude, is due to chicks that failed to reach the sea and sheltered in another burrow at daybreak. Skira & Wapstra's figures for Short-tailed Shearwater chicks in burrows during mid- to late March are much lower, their highest rates of 51.2 and 64.7% being at colonies not subjected to muttonbird harvesting.

An occupancy rate of 86% towards the end of the breeding season is very high. However, there was indirect evidence for a high level of burrow use at these islands because (a) large numbers of eggs were laid on the surface and abandoned, which seems unlikely to occur if nesting chambers were readily available, (b) disused or cobwebbed burrows were very seldom seen, (c) even unsuitable ground susceptible to flooding still attracted some burrowers and (d) physical competition occurred for burrows with the eviction of intruders and some fighting. Occupants defended an area around the entrance and this may have acted as a spacing-out mechanism. Deterring others from digging too close to existing nests would reduce the risk of burrow collapse.

Nevertheless, we regard none of these figures for burrow occupancy as being sufficiently reliable, the sizes of the samples being much too small. Clearly a simple method for determining the presence of birds underground is needed. Fibre-optics are almost useless in the tortuous and obstructed tunnels and the most promising technique we are now investigating is to detect petrels by their heartbeats or breathing using a sensitive microphone.

The huge size of some of the southern shearwater populations has long been known. During his remarkable circumnavigation of Tasmania in 1798, Matthew Flinders (1801) described an encounter with a flock of *P. tenuirostris* which he calculated as containing 151 500 000 birds and requiring 186 geographic square miles of ground for their burrows — he allowed a square yard for each. Although Flinders' arithmetic was faulty — the correct figure on his data is 132 000 000 birds (Campbell 1900), the total is still impressive.

So is the size of The Snares Island Sooty Shearwater population. Even at a 75% occupancy rate, some 2 750 000 pairs must be based on Main and Broughton Islands together with an unknown number of burrowless non-breeders. At a mean weight of 800 g (SD 74.5 g; n = 154), a 75% occupancy would represent a biomass of 4 400 000 kg.

The density of birds is remarkable too, for the above biomass requires only 328 ha of ground for nesting, while, in addition to the shearwaters, some hundreds of thousands of other petrels and of penguins also breed there. Indeed, this small area supports a bird population similar in size to that of the whole of the seabird population of Britain and Ireland — some 3 million pairs (Cramp *et al.*, 1974) — and although the shearwaters can travel far for food, the surrounding seas must be highly productive to support such a biomass. In turn, the nutrients brought ashore are believed to be important for the plants (Fineran 1969) and doubtless rainwater run-off fertilises the surrounding seas, although we have no data on that.

With populations of such magnitude it is not surprising that the southern shearwaters *P. gravis, tenuirostris* and *griseus* can come to dominate the northern waters into which they migrate during the southern winter. For example, Wiens & Scott (1975), using a simulation model approach, calculated that the Sooty Shearwater is the major seabird consumer during its fall passage off the Oregon coast, taking some 24 000 metric tons of anchovies during its 2 months' stay.

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