Notornis, 2003, Vol. 50: 123-127
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Burrow occupancy in Westland petrels (*Procellaria westlandica*)

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Abstract The Westland petrel (*Procellaria westlandica*) is endemic to New Zealand, and nests within a restricted area of the West Coast of the South Is. Surveys of burrow occupancy rate in 2 colonies in 2001 using burrow-scopes showed an average of 21% of burrows contained a chick or egg. The rate was *c.* 50% of that recorded for other burrowing seabirds and surveyed using burrow-scopes. These findings may suggest that the breeding population may have declined in recent years, or that a large group of non-breeding birds maintain territories on the colonies. Further work is planned to test the 2 opposing hypotheses.

Waugh, S.M.; Cabrera, H.; Wood, G.C.; Davis, L.S. 2003. Burrow occupancy in Westland petrels (*Procellaria westlandica*). *Notornis 50(3)*: 123-127.

Keywords Westland petrel; Procellaria westlandica; burrow occupancy; burrow-scope

INTRODUCTION

Estimating the population sizes of burrow-nesting seabirds has presented problems, because of the variable reliability of traditional inspection techniques, such as a barricade of twigs (Richdale 1963), insertion of a stick to elicit pecking response from nest occupants (Hamilton 1998b), observation of digging activity (Dyer & Hill 1992), and the use of olfactory cues (Hamilton 1998a,b). Acoustic response to play-back recordings was found to be a reliable method of testing occupancy of white-chinned petrels (*Procellaria aequinoctialis*) (Berrow 2000), but not sooty shearwaters (*Puffinus griseus*) (Hamilton 1998b). Further, biases may arise because nests at the end of long and convoluted burrows are difficult to detect and their numbers may therefore be underestimated (Serventy & Curry 1984). Inspection of nest contents using 'burrow-scopes' was a major advance in estimating population sizes or studying breeding activity in burrow-nesting seabirds, allowing low-impact and repeated viewing of breeding birds and their young (Dyer & Hill 1991, Dyer & Aldworth 1998). The technique has now been used to survey populations of petrels at many sites, mainly reported from Australia and New Zealand (Table 1). Although some questions have been raised about the accuracy of this technique for estimating burrow occupancy in some species, particularly where burrow structures are complex (Hamilton in press), it was found to be the most reliable in a study using several techniques to assess occupancy at the same set of nests (Hamilton 1998b).

The Westland petrel (*Procellaria westlandica*) is a burrow-nesting seabird, which is endemic to New Zealand, and which breeds within a restricted area on the west coast of the South Is. Jackson (1958) suggested that there were 3,000-6,000 adults at the colonies he visited. Best & Owen (1976) surveyed burrows in the known nesting area and estimated that it contained 900 nests, although Baker & Coleman (1977) questioned whether their sample was representative. Bartle (1974) estimated that there were 6,000-10,000

Received 3 July 2002; accepted 1 May 2003

Table 1 Occupancy rate of burrows by breeding pairs of wedge-tailed shearwaters (*Puffinus pacificus*), and sooty shearwaters (*Puffinus griseus*) estimated using burrow-scope inspections. Literature values included if $n > 10$. *, validated by excavation.

Species	Site	% occupied burrows	Reference
Wedge-tailed shearwater	Heron Is, Australia	43%	Dyer & Hill (1992)
	Erskine Is, Australia	56%	Dyer & Hill (1992)
	Rocky Islet, Australia	33%	Carter *et al.* (1996)
	Raine Is, Australia	52%	Dyer (1999)
Sooty shearwater	Snares Is, New Zealand	60-95%	
		91%*	Hamilton (in press)
	Snares Is, New Zealand	71%	Hamilton (in press)
	Whenua Hou, New Zealand	40%	Hamilton (in press)
	Nuggets, New Zealand	24%	Hamilton (1998b)
	Tuhawaiki I., New Zealand	48%	Hamilton (1998b)
	Taiaroa Head, New Zealand	39%	Hamilton (1998b)

Table 2 Burrow occupancy rate and burrow density for Westland petrels (*Procellaria westlandica*) in 2 study plots, at the "Island" and Scotchman's Creek sub-colonies during 18 Jun – 9 Aug 2001.

Colony	Holes	Adults only	Breeding	'Not a Burrow'	Unoccupied	Unknown	Quadrat size (m^2)	Burrows m^{-2}
Scotchman's Creek	287	34	58	13	165	16	1250	0.21
"Island"	157	35	28	5	83	7	560	0.26
Mean ± SD		0.17 ± 0.07	0.19 ± 0.02	0.03 ± 0.01	0.55 ± 0.03	0.05 ± 0.01		0.24 ± 0.03

Westland petrels in 1972, and has suggested (Bartle 1993 in Adams 1998) that the total population in 1982, including non-breeding birds, was 20,000 ± 5,000 individuals, with c. 2,000 breeding pairs in any year. A suggested increase in the Westland petrel population between 1972 and 1982 has been attributed to the effects of increased food supply for breeding birds, scavenging from a developing fishery within their foraging range (Bartle 1985). During 1993-1996, 58-68% of the chick diet was fisheries waste during the hoki (*Macruronus novaezelandiae*) fishing season (Freeman 1998), but that author has since questioned the role of fisheries waste in the population increase (Freeman & Wilson 2002).

The population at the 8 known sub-colonies has never been surveyed systematically, despite the species' "vulnerable" conservation status (IUCN 1994). We aimed to estimate burrow occupancy by breeding birds at 2 Westland petrel colonies by establishing quadrats, and using burrow-scopes. The results will be used, along with a planned census of burrows at all colonies, and repeat burrow-scope surveys, to estimate the size of the breeding population. Here we report our preliminary findings, and compare them with results of other burrow-scope studies of nesting petrels.

MATERIALS AND METHODS

Two quadrats of 1250 m^2 and 560 m^2 were set out at separate colonies, 'Scotchman's Creek' and the "Island", respectively. The colonies occupy opposing ridges in coastal forest, *c.* 50 m asl. The Island is on a small knoll and contains *c.* 300 burrows, whereas the Scotchman's Creek colony contains >1,000 burrows, distributed over a large ridge with systems of side gullies.

Each 'burrow-like structure' within the quadrats was identified in thorough searches and marked with a numbered tag. The marked burrows were then mapped (x,y coordinates) using tape measures from fixed stakes at the quadrat corners. A 'burrow' was defined as a tunnel >20 cm long, with an entrance size >14 × 8 cm. Holes that superficially resembled burrows but were not of an appropriate size nor in a suitable environment for nesting birds, for example exposed to light, or containing debris or tree roots, were included in the survey, but designated as 'not-a-burrow'. To allow for conversion of transect or burrow-density surveys to estimates of breeding numbers, we defined the "burrow" loosely, to include those entrances that could easily be mistaken for a burrow during a cursory visual inspection. Although burrows <20 cm long are probably too short for petrels to nest in, 1 chick was found in a burrow only 20 cm long. That instance probably resulted from the collapse of the entrance tunnel, but, it emphasizes the difficulty in defining an active burrow by an arbitrary length.

Burrows were sampled from the middle of the incubation period until early in the chick-rearing stage, between 18 Jun and 9 Aug 2001. All burrows

were examined, first by hand, then with a burrow-scope, which consisted of a miniature camera and infra-red lights mounted on a 3-m length of hose, connected to a video-display at the surface. The camera head was manipulated using cables inside the plastic hose.

The length, number of tunnels, and occupants in each burrow were noted. Burrow length was estimated by means of tapes at 20 cm intervals on the burrow-scope hose. For occupied burrows, the length was taken to be from the occupant to the entrance, whereas unoccupied burrows were measured to the furthest extent of the burrow. Average occupancy rates were compared with literature values. Only those studies where n >10 burrows were used in the analysis. Results were analysed using the SAS statistical package (SAS Institute 2001), setting the level of statistical significance at $P < 0.05$. Means are given ± SD unless stated otherwise, and *t*-values were calculated assuming unequal variances.

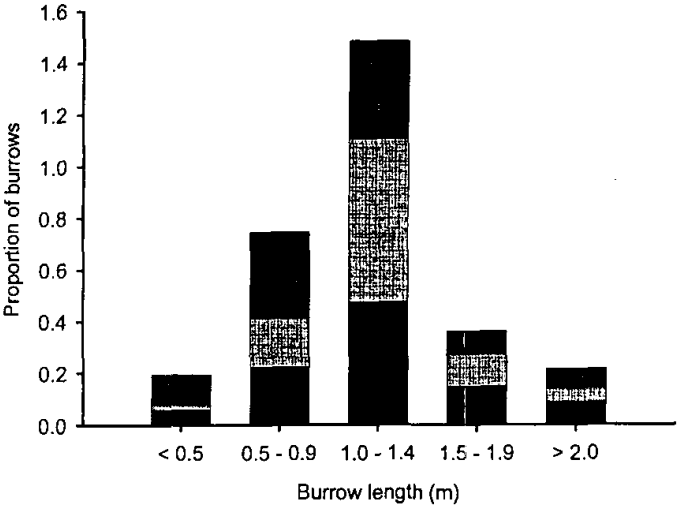

Fig. 1 Proportions of each category of Westland petrel (*Procellaria westlandica*) burrows in 2001, relative to burrow length: filled bar, "Breeding" (egg or chick identified; $n = 67$); light shading, "Adults only" (1 or more adults seen, but no eggs or young; $n = 59$); dark shading, "Unused" (no occupants; $n = 205$). Note: burrows with occupants were measured to breast of bird; unused burrows measured to end of burrow.

RESULTS

We found no differences in parameters between the 2 colonies sampled, so all results were pooled. The occupancy rates and density of burrows at the 2 study sites are shown in Table 2. For 3% of burrows at each site, we were unable to confirm the presence or absence of a nest. Five percent of 'holes' surveyed were designated 'not a burrow'.

We found only 1 nest for each burrow entrance, and only 10% of entrances led to 2 or more tunnels. Because the burrows were dispersed, their short length, and the systematic survey, we are confident that we did not mistake 2 entrances to the same burrow to be 2 separate burrows. Mean burrow length was 1.2 ± 0.5 m ($n = 357$; range, 0.2-2.8 m). Mean entrance size of breeding burrows ($n = 46$) was 24 ± 4.6 cm × 13 ± 2.2 cm (ranges 14-35 cm, 8-19 cm, respectively).

Most burrows were 1.0-1.4 m long (Fig. 1). The 3 categories of "Breeding" (an egg or chick present), "Adults only" (no chick or egg seen), and "Unused" (no occupants seen) all contained both very short (<0.5 m) and very long (> 2.0 m) burrows. Differences in measurement technique between unused and occupied burrows meant that lengths of burrows in these categories could not be compared statistically. Very few non-breeding adults were found in the shortest burrows. Although breeding birds apparently did not shun the shortest burrows, they clearly preferred burrows >0.5 m long.

Westland petrels had significantly lower burrow occupancy rates (21 ± 2.8 %) than wedge-tailed shearwaters (*Puffinus pacificus*) (46 ± 10.3%, $t_{3.46} = -4.78$, $P = 0.01$) or sooty shearwaters (44 ± 17.3%; $t_{4.3} = -3.0$, $P = 0.03$) (Table 1).

DISCUSSION

Since the invention of the burrow-scope in the late 1980s, it has been used in an increasing number of studies of burrow occupancy rates. Here we report on the use of burrow-scopes to assess the burrow occupancy rate for the vulnerable Westland petrel. In other studies using burrow-scopes, occupancy rates in wedge-tailed and sooty shearwaters were commonly >40%, significantly higher than for Westland petrels.

The lower rate for Westland petrels could result from several factors, but not high nest losses at the sites during 2001, nor high levels of deferred breeding in the year of our study. Of 60-61 study burrows followed annually during 1995-2001 at Scotchman's Creek, an average of 0.51 ± 0.07 (range 0.41 - 0.59) contained eggs. In 2001, 54% contained an egg or chick (Department of Conservation, unpubl. data). Fewer breeding birds may have been present than before, and the many vacant burrows could have resulted from a population decrease within the "life span" of an unused burrow. Alternatively, the large proportion of empty burrows at the colonies could represent a population that includes a high proportion of non-breeding birds that maintain territories. The non-breeders could either be non-breeding adults that have bred previously or pre-breeders, such as could be expected if 1 or several large cohorts of birds were establishing territories before beginning to breed.

Jackson (1958) found many unoccupied burrows found during 1954-56 study of Westland petrels and interpreted them as indicating a recent population decline. J.A. Bartle (pers. comm.), suggested that the occupancy rate found in our study was within the range of several over 30 years from the late 1960s. This anecdotal evidence suggests that low rates of burrow occupancy may have been normal for the species over several decades.

The limited demographic information available for Westland petrels suggests a high level of breeding deferral (Department of Conservation, unpubl. data). For 60 study burrows fitted with inspection hatches and examined regularly in 1995-2000, 14% were not used for nesting but were occupied at some time during the breeding season. Several authors have noted many non-breeding Westland petrels at the colony, many of which were actively excavating burrows (Baker & Coleman 1977; Bartle 1985; SW pers. obs.). The non-breeding birds could be responsible for the apparently high proportion of unused burrows maintained in good condition. We have no additional information to suggest that the population has decreased recently, nor that there is high recruitment at present. A detailed analysis of the demography of the population is clearly needed to establish population trends, survival, and recruitment rates.

Burrow length

Our results suggest that Westland petrels prefer to nest in burrows > 0.5 m long, with most burrows used by breeding non-breeders birds 1.0-1.4 m long. Birds not already breeding may avoid very short burrows (< 0.5 m). Further research on burrow preferences of nesting and non-breeding Westland petrels is needed.

Accuracy of the burrow-scope method

Recent studies of sooty shearwaters (Hamilton, in press) concluded that the accuracy of nest inspection by burrow-scope needed rigorous examination, particularly for species that excavate complex burrows or that burrow in substrates which encourage a tendency for tunnel systems to be complex and to contain several nests reached from a single entrance. It is unlikely that our study was affected by a high rate of error, because the burrow structures were relatively simple in comparison to those of sooty shearwaters. Only 10% of Westland petrel burrow entrances led to multiple passages. We never encountered more than 1 nest tunnel^{-1}, and no nest had more than 1 entrance. Further, Westland petrel burrows are shorter than those of sooty shearwaters (H. Moller, pers. comm.). Burrow-length was an important factor in the inaccuracy of occupancy estimates obtained using burrow-scopes (Lyver et. al. 1998). In future, we aim to test the accuracy of the results by repeated surveys of the same areas, and by using burrows with inspection hatches to validate the results.

It is important that the size of the Westland petrel population be estimated immediately, followed by periodic surveys to establish population trends. Studies of the breeding biology and population dynamics could reveal why burrows are occupied only 50% of the rate of some other petrels, and whether the results from these sites and the year studied are typical for the species.

ACKNOWLEDGEMENTS

We thank Henrik Moller and the titi team at the University of Otago for the generous loan of the burrow-scopes used in the study. Melanie Massaro gave helpful suggestions to improve our burrow-scoping technique. We thank Makaira Jenkins and Megan Waugh for assisting with the survey, and Pascaline Legaour for help with the literature search. We are grateful to staff of the Westland Conservancy, Department of Conservation, who collaborated with the project, and wish to thank the Kati Wei Wei Runanga who gave their consent to study Westland petrels. The work was funded by the Foundation for Research Science, and Technology, under contract UOOX0024.

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