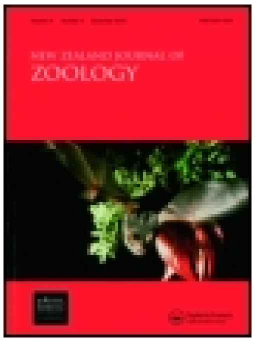

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Sooty shearwater (Puffinus griseus) breeding colonies on mainland South Island, New Zealand: Evidence of decline and predictors of persistence

Chris Jones

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Sooty shearwater (*Puffinus griseus*) breeding colonies on mainland South Island, New Zealand: evidence of decline and predictors of persistence

CHRIS JONES
Department of Zoology
University of Otago
P.O. Box 56
Dunedin, New Zealand
email: chrisj.jones@stonebow.otago.ac.nz

Abstract A survey of 170 km of the mainland Otago coastline was carried out in the 1997/98 breeding season in order to determine the current status of breeding colonies of sooty shearwater (*Puffinus griseus*). The locations of breeding colonies, as defined by the presence of burrows, are described and compared with historical records. Numbers of colonies were found to have declined by at least 54% in the past 50 years. Site characteristics which may predict colony survival were: (1) control of introduced predators and (2) the presence of softer soils. Persistence of burrows was independent of dominant vegetation type. Sooty shearwaters seem to be able to withstand habitat modification, but most of the small colonies recorded in this survey are unlikely to survive without predator control.

Keywords sooty shearwater; *Puffinus griseus*; colony site; distribution; decline; New Zealand; habitat; predation

INTRODUCTION

New Zealand, like many other island ecosystems, has been subject to a progressive defaunation since the first arrival of introduced mammalian predators. This pattern, which is demonstrated in avifauna from all mainland and island communities in New Zealand (Moors & Atkinson 1984; Innes & Hay 1991), can be related to a series of distinct pulses of environmental stresses. The first coincided with the arrival of Polynesian rats, or kiore (*Rattus exulans*), which Holdaway (1996) dates at around 2000 yr B.P. Maori and their dogs, or kuri, (*Canis domesticus*) are thought to have settled at about 800 B.P., followed by Europeans and their introduced mammals from the late 18th Century onwards (King 1990; McGlone & Wilmshurst 1999). Stresses on native species may be direct (predation, competition, habitat loss), or indirect, via secondary effects of habitat manipulation which may convey advantages to predators or competitors. The relative importance of habitat despoilation, competition and predation in causing declines probably varies with prey species, but few quantitative studies of these factors and their interactions have been published. This study investigates such effects on the distribution and persistence of mainland colonies of a native seabird, the sooty shearwater (*Puffinus griseus*).

Seabirds are particularly vulnerable to such pressures because they have few behavioural defences and show well-defined breeding seasons which concerntrate their numbers in space and time (Moors & Atkinson 1984). Ground- and burrow-nesting birds may also be vulnerable to indirect effects of economic development of land, such as trampling by domestic stock and changes in the local plant communities which would otherwise have provided cover.

The sooty shearwater is a burrow-nesting petrel which breeds during the southern hemisphere summer and migrates to the northern Atlantic and northern Pacific during the southern winter. Large breeding colonies of the birds are found on New Zealand's offshore islands, notably those of the Foveaux Strait and around Rakiura (Stewart Island), and mainland colonies have been recorded on headlands and near-shore islets around New Zealand. Mainland breeding colonies of sooty shearwaters are believed to be in decline. Jackson (1957) described a dramatic decrease in the size of a colony over the forty years prior to his writing, and other localised declines and extinctions have been

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described on both main islands (Moors & Atkinson 1984; Wilson 1999). Hamilton et al. (1997) described twelve mainland colonies around the Otago coast in the 1992/93 breeding season, but noted that a further eighteen were believed to have existed within the past fifty years.

This paper describes a systematic survey of the mainland Otago coastline, from Oamaru to Dunedin plus parts of the Catlins coast, which was carried out during the 1997/98 breeding season. My aims were: (i) to describe the locations of breeding colonies of sooty shearwaters, as defined by the presence of burrows; (ii) to compare present distribution with historical records; (iii) to gain an understanding of ongoing threats to extant colonies by investigating associations between habitat characteristics, including predator control, and the likelihood of colony persistence.

METHODS

Information on the past distribution of sooty shearwater colonies on the Otago coast was gathered from published literature and by consulting with local observers. Starting at Oamaru Harbour (45° 6′S, 170° 59′E), the coastline was surveyed as far south as the area above Tunnel Beach, Dunedin (45° 55′S, 170° 28′E), a total distance of 170 km, between October 1997 and March 1998. Any non-urbanised stretch of coastline that was not low-lying sand-dune or marshland habitat was considered a potential colony site. Only areas that could safely be accessed without specialist rock-climbing skills and equipment were surveyed. Sites qualified as colonies if burrows were found during this survey or had been recorded there in the past. A "burrow" was defined as a tunnel >20 cm in length (Lyver et al. 2000). Supplementary data on five sites in the Catlins region with a past history of sooty shearwater breeding colonies were collated from Hamilton et al. (1997) and from my own unpublished work: these were included in the analysis of site characteristics only. They were not used in the calculation of rates of decline, as they were outside the original survey area.

Two or more sub-colonies located in the same area were regarded as different colonies if separated by > 100 m, or if they were surrounded by different dominant vegetation types or land uses. Whilst burrow numbers were recorded, time and logistic constraints prevented any attempt to estimate the proportion that were active. If not maintained, burrows rapidly fall into disrepair, collapse and become overgrown and very difficult to find. Therefore, I assumed that the presence of burrows indicated activity at a colony, either during the current breeding season or in the very recent past.

Colony sites were classified according to a number of factors: (i) soil textural class was tested by hand according to the methods outlined in Brady (1990) and scored according to hardness where 1 = soft; 12 = hard (see appendix for details); (ii) dominant vegetation characteristics (coastal forest, F; rank grass, G; scrub, S; and developed pasture, P); (iii) land use, i.e., whether subject to some form of ongoing economic development or not; and, (iv) whether a predator control programme was in place. For the purposes of this survey predator control refers to a programme of trapping aimed at feral cats (*Felis catus*), ferrets (*Mustela furo*), stoats (*M. erminea*) and/or rats (*Rattus* sp.) which have all been identified as predators of sooty shearwater adults, chicks or eggs (Robertson 1976; Moors & Atkinson 1984; Hamilton 1998). If a site was less than 100 m from an area where predators were controlled it was still classified as being subject to control, since predators have large home ranges (133, 163 and 216 ha for male stoats, ferrets and cats respectively in similar habitat: Moller & Alterio, 1999). Chi-squared tests for association were used to look for any relationships between site characteristics and the presence of sooty shearwater burrows.

RESULTS

Twenty-seven past and present colony sites lie within the area surveyed (Table 1). Four have not been recorded previously, although at least two of these could be considered as outliers of the original colony at Bushy Beach. Of the 23 previously recorded colonies, I found burrows at eight out of 22 where access was permitted. This represents a loss of 64% of colonies (95% C.I.s: 41–83%) over about 50 years. If the newly-described colonies are included, the total number of breeding colonies has declined by 54% (27–67%) within the surveyed area.

The number of burrows found at a colony varied markedly, from over 2000 at Taiaroa Head (private) to only 11 at Shag Point. Sixteen of the seventeen colonies for which data were available (Catlins included) were either reserves or were not subject to any economic development.

There were significant associations between the persistence of burrows and both predator control and softer soil texture (Table 2). Persistence of colonies

Table 1 Details of sites of sooty shearwater breeding colonies included in the survey.

Site (lat./long.)	Soil texture	Vegetation	Land use	Predator control?	No. burrows	Previous survey	Notes
Oamaru Yacht Club 45° 06.40' S 170° 58.40' E	3	S	none	no	15*	N/R	a
Boatman's Harbour 45° 06.50' S 170° 85.70' E	5	S	none	yes	28*	N/R	a
Bushy Beach (I) 45° 07.42' S 170° 59.08' E	3	S	reserve	yes	45	N/R	b
Bushy Beach (II) 47° 07.55' S 170° 58.79' E	5	F	reserve	yes	70	Hamilton et al. 1997	b
Bushy Beach (III) 45° 07.30' S 170° 54.00' E	5	G	none	yes	28	N/R	b
Kakanui 45° 11.75' S 170° 54.00' E	3	G	none	no	18	Lyver et al. 2000	
Katiki (Moeraki) 45° 24.74' S 170° 49.79' E	5	G	none	no	17	N/R	
Shag Point 45° 28.50' S 170° 49.50' E	5	S	reserve	yes	11	Hamilton et al. 1997	b
Cliffs S. of Stony Creek Estuary 45° 31.20' S 170° 46.90' E	5	G	none	no	nil	D.O.C. 1982	
Bobby's Head 45° 31.75' S 170° 46.00' E	5	G	none	yes	12	N/R	
Grassy Point 45° 50.79' S 170° 35.57' E	5	P	grazing	no	nil	1940s/50s	
Taiaroa Head (Reserve) 45° 49.06' S 170° 43.15' E	1–2	G	reserve	yes	70	Lyver et al. 2000	c
Taiaroa Head (Private) 45° 49.80' S 170° 43.20' E	1	G	light grazing	no	2100	Lyver et al. 2000	
Penguin Beach 45° 47.55' S 170° 44.10' E	1–2	G	reserve (pvte.)	yes	nil	1940s/50s	d
Pipikaretu 45° 48.40' S 170° 44.75' E	5	P	grazing	no	nil	N/R	
Victory Beach (N. end) 45° 49.00' S 170° 43.90' E	5	F	reserve	yes	nil	N/R	b
Mount Charles 45° 51.80' S 170° 42.00' E	–	P	grazing	–	–	1940s/50s	no access
Titikoraki 45° 50.87' S 170° 44.96' E	10	P	grazing	no	nil	1940s/50s	
Ohinepuha 45° 51.47' S 170° 44.99' E	10	P	grazing	no	nil	1940s/50s	

(continued overleaf)

Table 1 (*continued*)

Site (lat./long.)	Soil texture	Vegetation	Land use	Predator control?	No. burrows	Previous survey	Notes
Cape Saunders 45° 53.00' S 170° 44.00' E	5	S	grazing	no	nil	1940s/50s	
The Chasm 45° 53.72' S 170° 41.01' E	10	S	none	no	nil	Johnson 1982	
Sandymount (Sandfly Bay) 45° 54.25' S 170° 39.00' E	1	S	reserve	yes	62	Hamilton et al. 1997	b
Double Bay 45° 54.20' S 170° 37.40' E	2	G	none	no	nil	1940s/50s	
Highcliff 45° 54.50' S 170° 35.50' E	10	G	grazed/none	no	nil	1940s/50s	
Maori Head 45° 54.90' S 170° 34.00' E	5	G	none	no	nil	1940s/50s	
Lawyers Head 45° 55.00' S 170° 32.00' E	3	S	recreation	no	nil	1940s/50s	
Tunnel Beach Area 45° 55.40 S 170° 27.65' E	10	G	grazing/ housing/golf	no	nil	N/R	
Nuggets I** 46° 27.00' S 169° 48.30' E	4	G	reserve	yes	127	Lyver et al. 2000	b
Nuggets II** 46° 27.70' S 169° 48.60' E	4	F	reserve	yes	40	Lyver et al. 2000	b
Nuggets III/IV** 46° 26.80' S 169° 48.50' E	3	G	reserve	yes	84	Lyver et al. 2000	
Nuggets V** 46° 26.70' S 169° 48.30' E	3	F	reserve	yes	65	Lyver et al. 2000	
Long Point**	3	G	none	no	30	Lyver et al. 2000	b

Note: 1940s/50s surveys carried out by L. E. Richdale & S. Sharpe; quoted in Hamilton et al. (1997).

Key to symbols

N/R = exact date of previous survey(s) not recorded; * Counts approximate due to possible use of some burrows by blue penguins; ** Catlins sites; a = little blue penguins present; b = yellow-eyed penguin breeding colony present; c = albatross colony; d = information supplied by landowner due to access restrictions.

Vegetation: F = low broadleaf coastal forest; G = rank exotic grassland; P = improved pasture; S = coastal scrub.

Table 2 χ^2 tests of association between burrow presence and site characteristics.

Characteristic	n	χ^2	d.f.	p
Predator control (Y/N)	31	9.83	1	<0.05
Soil texture (Soft: 1–4, med: 5–8, hard: 9–12)	31	9.37	2	<0.05
Dominant vegetation (F, G, S, P)	31	5.87	3	0.12
Vegetation (pasture excl.)	27	0.36	2	0.86

was independent of dominant vegetation type. None of the sites that had been developed as pasture still contained burrows. To exclude the possibility that predator control (more likely at less developed/ reserve sites) influenced this result, the test was repeated with developed pasture sites removed. Again, no association was found.

I eliminated the possibility of an association between soil texture and predator control influencing the results for either category by carrying out Fisher's exact tests within each group (Table 3). The strong association between predator control and colony persistence remained. Results for soil texture with predator control fixed were less clear: for those sites with predator control, none included soils in the harder categories, so further analysis was impossible. At those sites without predator control, there was no association between soil texture and colony persistence. The small sample sizes for these within-group analyses should be noted.

DISCUSSION

Population trends

The presence and number of sooty shearwater breeding burrows at any particular site should not be taken as a direct estimate of the size of the local population of birds. This can be determined only from a knowledge of the burrow occupancy rate (Dyer & Hill 1992; Hamilton 1998). Occupancy rates for this species were estimated at 25–62% by Hamilton (ibid.) and 4–73% by Lyver et al. (2000) for mainland colonies. Birds have also been observed to use more than one burrow in a season (Richdale 1963). Burrow counts at sites shared with little blue penguins (*Eudyptula minor*) should be considered as approximate, as it is often difficult to distinguish between burrows used by the two species.

The data showing a decrease of at least 54% in the number of breeding sites over the past fifty years confirm the results of a more limited survey carried out in 1992–93 (Hamilton et al. 1997). Even though these historical records are not reliable enough to allow any quantitative estimates of wider scale population changes, the decline in number of breeding sites is cause for concern. Extinction is ongoing; at least two of the colonies recorded as active in the 1992–93 survey have subsequently been found to be inactive (C. Jones unpubl. data).

Site characteristics

The association between control of introduced predators and the persistence of colonies is of particular importance. Stoats in particular have been shown to be a significant threat to mainland populations (Lyver 2000; Lyver et al. 2000). None of the predator control programmes in place at sites included in this survey were designed specifically to protect sooty shearwaters; most are for the benefit of yellow-eyed (*Megadyptes antipodes*) and little blue penguins, and one protects a breeding colony of northern royal albatross (*Diomedia epomorphora sanfordi*). Population models for sooty shearwaters (Hamilton & Moller 1995) indicate the susceptibility of the population to predation on breeding adults. Predator trapping to protect breeding yellow-eyed penguins is generally done in the spring, just before the maximum risk period for adult shearwaters. The shearwaters benefit by association in such cases.

The very large colony at Taiaroa Head (private) has no dedicated predator protection, but may persist because (1) it is close to other local control schemes, (2) populations of primary prey (rabbit, *Oryctolagus cuniculus*) are locally high, and (3) the very large size of this colony may "swamp" any predation effects (Lyver et al. 2000). Breeding colonies at unprotected sites are rare.

The relationship between soil hardness and colony persistence is less clear cut. A significant negative association was found when all surveyed sites were considered together, but when sites with

Table 3 Fisher's exact test results for within-class associations between burrow presence and site characteristics.

Fixed class	Characteristic tested	n	p
Sites with predator control	Soil texture (1–6; 7–12)	14	*
Sites without predator control	Soil texture (1–6; 7–12)	17	0.24
Soil textural classes 1–6 *	Predator control (Y/N)	26	0.04

* No sites of harder soil classes 7–12 within this category.

and without predator control were tested separately the analyses were too much affected by the smaller data sets. Of those sites with predator control, none included soils of the harder categories. This infers a preference for softer, more easily dug soils, but the distribution of data makes statistical analysis impossible. This inference is further strengthened by a potential bias towards inactive burrows persisting for longer in harder, more stable soils than in softer soils where collapse is more likely. For sites without predator control, the lack of association between soil hardness and burrow presence could reflect either a real lack of preference, or could again be an artifact of sample size.

Ease of digging, soil drainage and degree of erosion are thought to be important factors in site choice by burrowing petrels (Furness 1991). Manx shearwaters (*Puffinus puffinus*) show a preference for longer burrows (Storey & Lien 1985) which suggests that ease of burrowing may be important in colony establishment and persistence. Short-tailed shearwaters (*Puffinus tenuirostris*) in Tasmania burrowed into soft sandy or silt soils rather than harder soils with high stone content (Oka et al. 1996). Richdale (1963) pointed out that depth of soil is also important. The best choice may require a compromise between softer, more granular soils which are better drained (Warham & Wilson 1982) and easier to dig, and more stable soils with a higher clay content. Similar conclusions were drawn by Stokes & Boersma (1991) in a study of the effects of substrate on distribution of Magellanic penguin (*Spheniscus magellanicus*) burrows.

In spite of the absence of burrows from sites with developed pasture, dominant vegetation type does not seem to be a strong predictor of colony persistence. The relatively small number of sites investigated does not allow for analysis of potential associations between colonies and vegetation type. Of the thirty-one sites examined, fifteen were dominated by rank exotic grasses which may be preferred because the roots of grasses offer less obstruction to burrowing than those of woody plants (Warham & Wilson 1982). Jackson (1957) found no burrows in secondary growth of gorse (*Ulex europaeus*), blackberry (*Rubus fruticosus*) and bracken (*Pteridium esculentum*) after the clearance of native vegetation. This may be due to the density of vegetation above ground, which may restrict movement, or of root systems below ground, rather than a preference for any particular species. Burrows on the Snares Islands tended to fall into disuse as thicket density increased (Warham & Wilson 1982).

Interactions between factors

The evidence presented here suggests that habitat change *per se* may have little effect on colony persistence. Ratz & Murphy (1999) showed similar trends in breeding site selection by yellow-eyed penguins, and suggested that habitat change may not in itself be a significant threat. The effects of habitat alteration on the distribution and population biology of predators could increase the risk to breeding birds by, for example, increasing predator numbers, allowing easier access to nest sites, or increasing the probability of chance predation events. Sooty shearwaters on Macquarie Island, Australia were subject to the interaction of vegetation and predators. Colonies were found in long tussock (*Poa foliosa*) where the birds suffered predation from rats and wekas (*Gallirallus australis*). Where grazing by introduced rabbits had denuded areas of tussock cover, the increased predation risk from cats and skuas (*Stercorarius skua lonnbergi*) led to the loss of colonies (Brothers 1984).

Human activities may also increase disturbance to birds and facilitate access to a colony. Changes in land use may increase grazing by introduced farm stock, which can cause burrow collapse (Strange 1980) or reduce vegetation cover.

CONCLUSIONS

Sooty shearwater populations in the surveyed region are declining rapidly. This confirms the general pattern of decline in mainland petrel breeding sites since the first arrival in New Zealand of kiore, which could have been up to 2000 yr B.P. (Holdaway 1999 a,b). Except for the Taiaroa Head (private) colony, all colonies recorded in this survey comprised fewer than 150 burrows, and the majority were much smaller. Population viability analysis of mainland colonies by Hamilton & Moller (1995) suggested that threshold population sizes of at least 550 individuals in the presence of 80% effective predator control are necessary to ensure persistence. The birds seem able to survive some habitat changes. The degree of change that they can withstand cannot be estimated, although even small changes combined with predation may be too much. In the absence of predator control, the small colonies recorded in this survey are unlikely to persist in even the short term.

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Appendix Soil textural classes.

Lower numbers: coarser particle size, looser structure.
Higher numbers: finer particle size, firmer when moist, harder when dry.

1) sand
2) loamy sand
3) sandy loam
4) loam
5) silt loam
6) sandy clay loam
7) silty clay loam
8) clay loam
9) sandy clay
10) silty clay
11) silt
12) clay