

Seasonal trends and nightly variation in colony attendance of grey-faced petrels (*Pterodroma macroptera gouldi*)

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Abstract The night-time activity of grey-faced petrels (*Pterodroma macroptera gouldi*) was measured at a colony on Tiritiri Matangi Island between 27 April and 10 December 1998. Considerable seasonal variation was observed (0 to >120 birds/night). A decline in numbers of birds at the colony in early June was likely resulted from the departure of both breeding (pre-laying stage) and non-breeding birds. Another decline at the end of September was most likely a consequence of the departure of non-breeding birds only. In general, as the season progressed there were fewer petrels per night, and they arrived later. The number of birds returning to the colony increased with increasing wind speeds and birds arrived earlier when winds were stronger. High wind speeds facilitate movement between breeding and foraging grounds for this pelagic species. A sampling period of 1 h from the arrival of the 1st bird provides sufficient information to discern definite patterns in numbers throughout the year.

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INTRODUCTION

The temporal use of terrestrial habitat by pelagic seabirds is a largely unstudied aspect of their ecology. Understanding the patterns of colony attendance and the environmental factors that influence activity at a colony is necessary both for conservation and in the design of population estimate studies. Information about seasonal abundance patterns in conjunction with known temporal patterns of breeding activities may help efficacy of pest control programmes and enable potential impacts of ecotourism to be minimised. This is particularly important for pelagic species that can be difficult to observe because of their nocturnal habits and use of underground burrows for breeding.

Seasonal patterns of colony use are likely to be determined primarily by the timing of breeding activities. However, previous studies examining colony attendance have concentrated on diurnal species because of the difficulty of making observations at night. For example, colony attendance patterns and behaviour at the colony have been well documented for northern fulmar (*Fulmarus glacialis*) (Coulson & Horobin 1972; Dott 1975;

Macdonald 1980) and the cape pigeon (*Daption capense*) (Weidinger 1996a, 1996b). Both of these species nest on ledges or beneath overhangs (Serventy *et al.* 1971; Cramp *et al.* 1977) and observations on abundance were readily made from cliffs adjacent to the breeding colonies. Most studies of nocturnal burrowing petrels only record initial return to the colony at the beginning of the breeding season and the departure of the non-breeders, breeders and fledglings. Richdale (1942) documented colony attendance by a nocturnal species, the sooty shearwater (*Puffinus griseus*) on 34 consecutive nights and observed considerable variation between nights but did not relate this to environmental conditions.

Pelagic seabirds must regularly (2-7+ days) fly long distances (up to thousands of kilometres) between breeding and foraging grounds (Haney 1987). Selecting the most suitable environmental conditions for these flights may minimise the energetic costs of these journeys (Spear & Ainley 1997a, 1997b). Studies of northern fulmars (Coulson & Horobin 1972; Macdonald 1980,) and cape petrels (Weidinger 1996a) found that wind speed was negatively correlated with abundance at the colony. When wind speed was greater than Beaufort Force 5, no fulmars were observed in the colony

(Macdonald 1980). Weidinger (1996a) also found that numbers of cape petrels at the colony varied with wind direction. Wind speed and direction can have an effect on the flight behaviour of petrels and other seabirds (Blomqvist & Peterz 1984; Haney 1987; Spear & Ainley 1997a, 1997b). Spear & Ainley (1997b) found that gliders were present in areas at significantly greater wind speeds than species with other flight styles. The abundance of black-capped petrel (*Pterodroma hasitata*) in the pelagic environment increased with wind speed, with a peak at Beaufort Force 5 (Haney 1987).

The grey-faced petrel (*Pterodroma macroptera gouldi*) is a pelagic, nocturnally-active seabird, which breeds in New Zealand. Previous studies of this species have focussed on foraging and breeding behaviour (Imber 1973, 1976; Johnstone & Davis 1990). In our study we examine environmental correlates of activity at a small grey-faced petrel colony at the northern end of Hobbs Beach on Tiritiri Matangi Island, Hauraki Gulf, New Zealand (36° 45' S, 174° 50' E). We profile the change in adult abundance throughout a season and test whether wind force, wind direction, and time of year influenced the nocturnal activity and arrival times of grey-faced petrels.

METHODS

Night counts and arrival times

This study was conducted from September 1997 until January 1999. Night counts of incoming grey-faced petrels were made every 3-4 days from 27 April to 10 December 1998 at the northern end of Hobbs Beach, Tiritiri Matangi Island. The colony was observed from a fixed point above and on the edge of the colony. The observer was at the colony at least 30 min before sunset and remained there until about midnight. Counts were begun after the arrival of the 1st bird and continued for 1 h. Clearly sampling error and repeat landings are likely to increase with increasing activity at the colony. Therefore the number of petrels seen or heard landing in the colony from the time of arrival of the first bird was measured using the following index: 0 (0), 1 (1-5), 2 (6-15), 3 (16-30), 4 (31-60), 5 (61-120), 6 (>120). These estimates gave us a relative measure of activity within the colony rather than an absolute count, based on the assumption that the number of repeat landings was constant. First arrival time (relative to sunset) was recorded and an abundance index was estimated for every bird landing at the colony during the following hour. Arrival times were standardised as the deviation in minutes after sunset. No bird was observed to arrive before sunset. To reduce observer bias, the same observer conducted all counts. On the nights when no petrels were seen or heard the

observer remained at the colony for a minimum of 3 h after sunset. Sampling was not attempted in either extremely high winds (>45 knots) or rain, as petrel landings could not be seen or heard. On all other sampling occasions petrels could be seen silhouetted against the sky, heard on the ground, or observed during intermittent checks using a low intensity red light.

Determining sampling duration

Because of the difficulty of measuring nocturnal activity of petrels we used the number of landings during a 1-h period as an index of petrel activity at the colony. A subsample of the dataset was used to check the suitability of the 1-h sampling period. Activity and arrivals at the colony were observed for up to 3 h on 5 different nights during the peak of activity at the colony in May 1998. Results showed that activity at the colony was at a maximum during the 1st hour after the arrival of the 1st bird for all 5 nights. Therefore a sampling period of 1 h after the arrival of the 1st bird was used for all nightly counts.

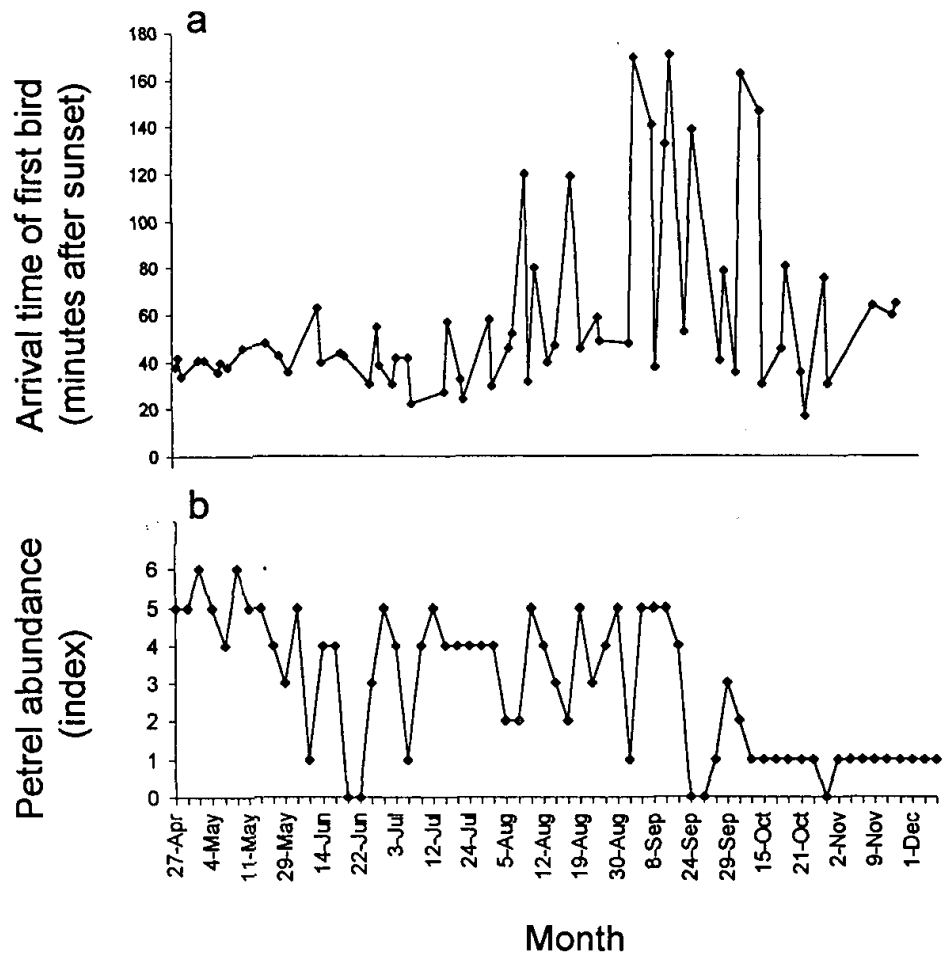
Wind and sunset data

A meteorological station on Tiritiri Matangi Island recorded wind speed (Beaufort scale) and direction at 0900 h daily. Despite the chance of weather conditions changing quite rapidly we assumed that there was a strong correlation between the 0900 h records and wind speed and direction during the sampling period. Measurements of wind force and wind direction were collected on 46 days from 27 April to 29 September 1998. Wind direction was recorded as a category (e.g., north, north-east) and later transformed into an angle for the linear circular regression analysis (Ross 1999). The time of sunset was determined using a proprietary computer package (Ligon 1994).

Statistical analyses

We used generalised linear models (Proc GLM: SAS Institute Inc. 1996) to determine the effects of wind force and direction, and time of year on arrival times. Activity estimates were measured on a categorical scale and the effects of wind force and direction, and time of year were analysed using a maximum-likelihood categorical data analysis (Proc CATMOD: SAS Institute Inc. 1996). A linear-circular regression was performed on the wind direction variable (Fisher 1993). Spearman's rank correlations were used to determine the relationship between wind speed and arrival times and the petrel abundance index. For all parametric statistical tests the residuals were examined for normality and data were transformed if necessary. A significance level of $\alpha = 0.05$ was used for all tests.

Fig. 1 Seasonal variation in **a**, the nightly arrival time of the 1st grey-faced petrel (*Pterodroma macroptera gouldi*) at the Hobbs Beach, Tiritiri Matangi Island, breeding colony, during each sampling period from April to December 1998 (nights when no petrels arrived were excluded), and **b**, petrel abundance index: 0 (0), 1 (1-5), 2 (6-15), 3 (16-30), 4 (31-60), 5 (61-120), 6 (>120) total number of grey-faced petrels arriving.



RESULTS

Variation in arrival time

As the breeding season progressed the birds gradually arrived later and the variation in arrival times increased (Fig. 1a). Both wind force and time of year significantly affected arrival time (ANOVA, $F = 5.85$, $P < 0.0001$; $F = 7.13$, $P < 0.001$, respectively) and that there was no interaction effect ($F = 2.11$, $P = 0.25$). Arrival times were earlier with increasing wind force ($r_s = -0.84$, $P < 0.001$). Arrival times became steadily later during the year and peaked during October (Fig. 1a). Wind direction did not have a significant effect on arrival time (linear-circular regression: $R^2 = 0.14$, ns, Fig. 2a), although the variation between different directions was considerable.

Variation in petrel activity at the colony

Adult grey-faced petrels began arriving at the Hobbs Beach colony on 31 March in 1998. Sampling was conducted on 63 nights between 27 April and 10 December 1998. The activity of grey-faced petrels at the colony during the 1st hour at the breeding colony showed considerable variation between sampling nights (range from 0 to >120, Fig. 1b). Two periods of decreasing numbers were observed, the 1st in early June, the 2nd in mid-September. Very few petrels were observed after 4

October 1998 and the variation between nights was extremely low.

The results from the categorical analysis showed that both time of year (month) and wind force significantly affected activity ($\chi^2 = 83.88$, $P < 0.0001$; $\chi^2 = 19.52$, $P < 0.001$, respectively) and that there was no interaction effect ($F = 1.06$, $P = 0.31$). In general, landings increased significantly with increasing wind force ($r_s = 0.67$, $P < 0.001$) but declined as the year progressed (Fig. 1b). Wind direction did not significantly affect activity (linear-circular regression: $R^2 = 0.13$, ns, Fig. 2b). However, variation in petrel landings was substantial.

DISCUSSION

During our study, petrels returned to the Hobbs Beach colony on 31 March (B. Walters *pers. comm.*), which is 1 month later than dates given in Marchant & Higgins (1990) for other colonies of grey-faced petrels in New Zealand. Petrels arriving at the colony at this time probably included both breeding and non-breeding birds. We found that the time the 1st bird arrived after sunset and the nightly activity of grey-faced petrels at the breeding colony both varied considerably. In general, as the season progressed fewer petrels arrived, and they arrived later in the day. The observed drop in petrel numbers in June

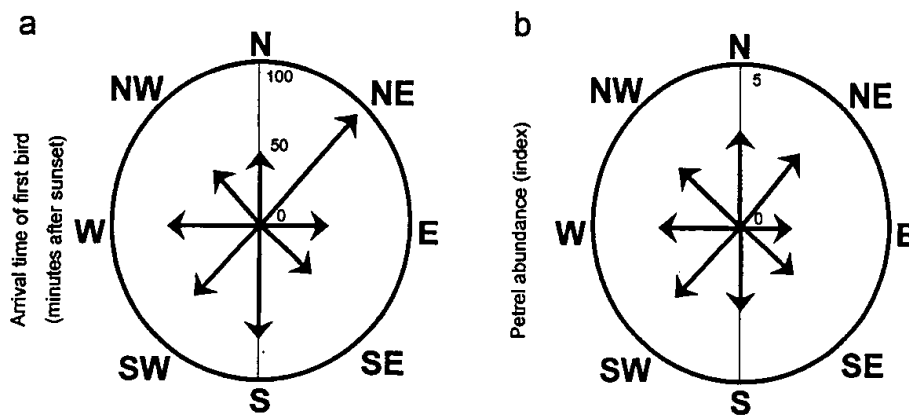


Fig. 2 The relationship between wind direction and a, the mean nightly arrival time of the 1st grey-faced petrel (*Pterodroma macroptera gouldi*) at the Hobbs Beach, Tiritiri Matangi Island, breeding colony (nights when no petrels arrived were excluded), and b, the mean petrel abundance index: 0 (0), 1 (1-5), 2 (6-15), 3 (16-30), 4 (31-60), 5 (61-120), 6 (>120).

corresponds to the pre-laying exodus (Imber 1976). As counts did not recover after this period, it is likely that some non-breeding birds left the colony at this time. A 2nd decrease in numbers was observed in September, corresponding to the last of the non-breeders leaving the colony (Ross 1999). This period is about the end of chick hatching (Imber 1976; Johnstone & Davis 1990). Although by the end of September petrels returned more directly to their burrows (less circling the colony before landing) they still made considerable noise and we do not feel that the birds were less easy to detect.

Astronomical twilight was shortest in winter as the sun sets further north. Hence the length of twilight between 27 April to 22 June is comparable to that between 22 June and 20 August, while twilight steadily lengthens after 20 August. This increasing length of twilight may account for some variation in the timing of petrels' arrival after sunset, particularly the variability in arrival times, which was much greater from September onwards.

Wind speed was the only environmental variable to be significantly related to the arrival times and activity of grey-faced petrels at the colony. Petrels arrived at the colony earlier in higher winds (regardless of time of year) and as wind speed increased so did the number of petrel landings. In contrast, fulmar numbers were lowest when wind speed was greater than Beaufort Force 5, presumably as these are good conditions for foraging (Macdonald 1980). Gliding birds rely on higher wind speeds for flight and foraging (Haney 1987). Foraging efficiency increases with wind speed up to a point after which increased wind may be detrimental to the birds (Dunn 1973). Fulmars and cape petrels leave the colony in higher winds (Coulson & Horobin 1972; Macdonald 1980; Weidinger 1996a). In contrast, grey-faced petrels arrived at the Hobbs Beach colony in larger numbers in higher wind speeds.

Breeding in winter coincides with low food availability (Ashmole 1971), so why do grey-faced petrels return to the breeding colony when the foraging

conditions seem optimal? The large distance between the foraging areas and the colony (Imber 1973) could mean that, in addition to optimising foraging efficiency, they are utilising high wind conditions for movement between the areas. Because grey-faced petrels are nocturnal foragers, this could result in high abundances 1 day after high wind conditions, but this was not observed. Another explanation could be that they do not remain at the colony the entire night and hence are still able to take advantage of good flying conditions. No petrels were observed leaving the colony during the sampling periods but they probably leave later in the night. One of the limitations of our study is that wind speed and direction were measured 8-12 h before sunset and weather conditions in New Zealand can change rapidly. It is likely that we have underestimated the strength of these relationships. Additionally, we were not able to measure arrival times or activity in extremely high wind speeds.

Management implications

An understanding of the temporal pattern of colony use is necessary when developing methods for estimating population size. Fluctuations in abundance suggest that the proportion of breeders and non-breeders using the colony changes over the breeding season. Most population estimation methods involve measuring density of burrows within quadrats, then extrapolating to the known area of burrows, or suitable habitat (Warham & Wilson 1982; West & Nilsson 1994; Gaston & Scofield 1995). Often only occupied burrows are included (Warham & Wilson 1982; Gaston & Scofield 1995). Therefore, the burrow occupancy method will provide different estimates of the population size, and sample from different classes of the population, depending on the time of year. Sampling could be timed to estimate the breeding population, or the maximum number of birds visiting the colony. Knowledge of how the population changes will provide a better understanding of the population being estimated.

The methods developed in this study for measuring abundance are only feasible for small populations (<200 birds) and although this method potentially has some observer bias it is still useful in quantifying relative changes throughout the year. We used a sampling period of 1 h after the arrival of the 1st bird and an index of petrel activity at the colony. This sampling period should provide sufficient information to see definite changes in numbers throughout the season. Future research should include a comparison of daytime burrow occupancy with nocturnal activity to determine the degree of correlation. Standardising population estimating methodologies would enable useful comparisons between different populations.

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LITERATURE CITED

- Ashmole, N.P. 1971. Seabird ecology and the marine environment, pp. 223-286. In: Farner, D.S.; King, J.R.; Parkes, K.C. (ed.), *Avian biology*. Vol. 1. New York, Academic Press.
- Blomqvist, S.; Peterz, M. 1984. Cyclones and pelagic seabird movements. *Marine ecology progress series* 20: 85-92.
- Coulson, J.C.; Horobin, J.M. 1972. The annual re-occupation of breeding sites by the fulmar. *Ibis* 114: 30-42.
- Cramp, S.; Simmons, K.E.L.; Ferguson-Lees, I.J.; Gillmor, R.; Hollom, P.A.D.; Hudson, R.; Nicholson, E.M.; Ogilvie, M.A.; Olney, P.S.S.; Voous, J.H.; Wattel, J. 1977. *Handbook of the birds of Europe and the Middle East and North Africa: The birds of the Western Palearctic*. Vol. 1: *Ostrich to Ducks*. Oxford, Oxford University Press.
- Dott, H.E.M. 1975. Fulmars at colonies: Time of day and weather. *Bird study* 22: 255-259.
- Dunn, E.K. 1973. Changes in fishing ability of terns associated with windspeed and sea surface conditions. *Nature* 244: 520-521.
- Fisher, N.I. 1993. *Statistical analysis of circular data*. Cambridge, Cambridge University Press.
- Gaston, A.J.; Scofield, P. 1995. Birds and tuatara on North Brother Island, Cook Strait, New Zealand. *Notornis* 42: 27-41.
- Haney, J.C. 1987. Aspects of the pelagic ecology and behaviour of the black-capped petrel (*Pterodroma hasitata*). *Wilson bulletin* 99: 153-168.
- Imber, M.J. 1973. The food of grey-faced petrels (*Pterodroma macroptera gouldi* (Hutton)), with special reference to the diurnal vertical migration of their prey. *Journal of animal ecology* 42: 645-662.
- Imber, M.J. 1976. Breeding biology of the grey-faced petrel *Pterodroma macroptera gouldi*. *Ibis* 118: 51-64.
- Johnstone, R.M.; Davis, L.S. 1990. Incubation routines and foraging-trip regulation in the grey-faced petrel *Pterodroma macroptera gouldi*. *Ibis* 132: 14-20.
- Ligon, T.R. 1994. *Dance of the planets*. Loveland, CO, USA, ARC Software.
- Macdonald, M.A. 1980. The winter attendance of fulmars at land in NE Scotland. *Ornis scandinavica* 11: 23-29.
- Marchant, S.; Higgins, P.J. 1990. *Handbook of Australian, New Zealand and Antarctic birds, Vol. 1. Part A. Ratites to Petrels*. Melbourne, Oxford University Press.
- Richdale, L.E. 1942. Whero: Island home of petrels and other birds. *Emu* 42: 85-105.
- Ross, E. 1999. Seasonal trends and nightly variation in colony attendance of grey-faced petrels (*Pterodroma macroptera gouldi*). Unpubl. MSc thesis, University of Auckland, New Zealand.
- SAS Institute Inc. 1996. *The SAS system for Windows*. Cary, NC, USA, SAS Institute Inc.
- Serventy, D.L.; Serventy, V.; Warham, J. 1971. *The handbook of Australian seabirds*. Sydney, A.H. & A.W. Reed.
- Spear, L.B.; Ainley, D.G. 1997a. Flight behaviour of seabirds in relation to wind direction and wing morphology. *Ibis* 139: 221-233.
- Spear, L.B.; Ainley, D.G. 1997b. Flight speed of seabirds in relation to wind and speed and direction. *Ibis* 139: 234-251.
- Warham, J.; Wilson, G.J. 1982. The size of the sooty shearwater population at the Snares Islands New Zealand. *Notornis* 29: 23-30.
- Weidinger, K. 1996a. Effects of weather on the cyclic patterns of colony attendance in the cape petrel *Daption capense*. *Polar biology* 16: 330-344.
- Weidinger, K. 1996b. Patterns of colony attendance in the cape petrel *Daption capense* at Nelson Island, South Shetland Islands, Antarctica. *Ibis* 138: 243-249.
- West, J.A.; Nilsson, R. 1994. Habitat use and burrow densities of burrow nesting seabirds on South East Island, Chatham Islands, New Zealand. *Notornis* 41 (supplement): 27-37.