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WEDGE-TAILED SHEARWATER FLEDGLINGS AT ROCKY ISLET, GREAT BARRIER REEF: BURROW DENSITIES AND BREEDING CYCLE

J. L. CARTER,[1] D. A. MILTON,[2] P. K. DYER[3] and S. B. HARDING[4]

[1]Faculty of Science, Northern Territory University, Darwin, Northern Territory 0909
[2]CSIRO, Division of Fisheries, P.O. Box 120, Cleveland, Queensland 4163
[3]Sunshine Coast University College, Sippy Downs, Queensland 4556
[4]SEQ Planning Division, Department of Housing, Local Government and Planning, Box 690 GPO, Brisbane, Queensland 4001

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Wedge-tailed Shearwater burrows were surveyed at Rocky Islet, northern Great Barrier Reef, opportunistically during 1994, and systematically in 1995. The burrow estimate for the island was 5 785 ± 840 for the first year and 4 646 ± 302 during the second survey. The size of the breeding population is estimated to be 2 950 and 2 369 for 1994 and 1995 respectively. Burrow occupancy status was established during 1995 using a burrowscope, and a fledgling occupancy rate of 0.33 found. Chick development was quite advanced compared with birds from southern populations at the same time.

INTRODUCTION

Wedge-tailed Shearwaters *Puffinus pacificus*, are pelagic seabirds which return to breed on Pacific and Indian Ocean islands during summer. Although the species has a widespread distribution, detailed studies into burrow densities, breeding success and regional variations in the breeding cycle are limited. On the east coast of Australia, these studies have occurred on several of the islands of the Capricorn Group, southern Great Barrier Reef (Ogden 1979; Hill *et al.* 1989; Dyer *et al.* 1992; Ogden 1994; Hill *et al.* 1995) and at Mutton Bird Island, off the coast of Coffs Harbour, northern New South Wales (Swanson *et al.* 1974; Roberts *et al.* 1975; Floyd *et al.* 1983). They have been recorded at Rocky Islet in the northern Great Barrier Reef (Domm 1977; Smith *et al.* 1989), but their breeding activities in the region have been little described until now.

This paper describes the outcome of a short opportunistic study performed during February 1994, while researchers were engaged in determining diets of seabirds in the area. A follow-up study in February 1995 builds on the information collected during the previous survey and gives more precise estimates for burrow counts and densities. The paper also establishes the occupancy rate of fledglings during 1994/95 using a burrowscope (Dyer *et al.* 1991) to view burrow contents, and certifies that fledging of chicks has commenced earlier in the calendar year than has previously been found for the species.

STUDY AREA AND METHODS

Rocky Islet (149°29'E, 14°52'S) is the largest island of Rocky Islets National Park, which is situated about 20 kilometres south of Lizard Island (Fig. 1). The islet comprises approximately 3.9 ha of vegetated area and fringing cliffs, which can be categorized into three habitats: the western vegetated sector of predominately *Pisonia grandis* and rainforest elements (1.5 ha); coastal scrub in the east (1.1 ha); and, in the southern sector, rocky cliffs (1.3 ha).

During the 1993/94 season, time constraints did not allow the scrub habitat to be investigated. This area appeared to be devoid of burrows. However, the 1994/95 study allowed an opportunity to traverse the scrub habitat, showing that most of this area contained a mixture of both rock and scrub vegetation, with areas beneath rocks providing suitable sites. For the 1994/95 survey only the rocky and scrub habitats were grouped as a single rocky habitat (2.4 ha).

During February 1994, an opportunistic survey was conducted, comprising seven quadrats of 30 × 4 m (2.2% sample of the island) placed from the edge of the vegetation or rocky cliffs at approximately 100 m intervals. A burrow count was made in each quadrat and the contents of 15 (10 in rocky and five in *Pisonia* habitats) burrows noted. To avoid an overestimate in the rocky areas, only crevices which had obviously been excavated, or which contained a bird were considered as a nest. Mean burrow density was calculated for the *Pisonia* and rocky cliff habitats, and population parameters estimated for individual habitats and for the island. A zero count was used for the scrub area in this sampling season.

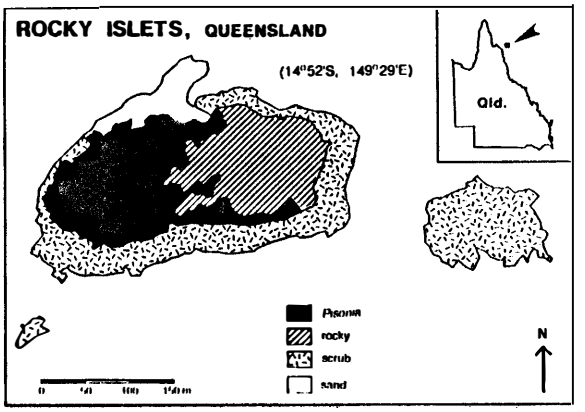

Figure 1. *Sketch map showing habitats and locality of Rocky Islets National Park.*

During February 1995, four transects each 4 m wide, were used to survey the island in a north–south or south–north direction. Each transect was subdivided into quadrats of 10 m in length. In all, 62 quadrats were surveyed, with 42 falling into the rocky habitat and 20 in the *Pisonia* area. Within each quadrat a burrow count was conducted. Burrow densities for habitats and for the island were calculated, and a burrow count estimated for the island.

Due to small sample sizes and non-normal distribution of the burrow count data, a log (Y + 1) transformation was applied to the raw data obtained from the 1994/95 survey. A student's *t*-test for unequal population variances was then conducted to detect differences in burrow density between habitats during the 1994/95 season. Student's *t*-tests for equal population variances were used to test population differences between the 1993/94 and 1994/95 seasons for the whole island and between corresponding habitats. Because quadrats were frequently adjacent (therefore possible lack of independence), the tests were used only to indicate whether there were major differences worth further investigation.

As part of the 1994/95 survey, in 23 randomly selected quadrats the occupancy status of each burrow was established using a burrowscope, which is an infra-red light source attached to a camera lens and video monitor (Dyer *et al.* 1991). Thirty-seven burrows (in six quadrats) were inspected in the *Pisonia* habitat and 84 (in 17 quadrats) in the rocky habitat. Inclement weather conditions prevented more detailed data collection of occupancy status.

From the data obtained using the burrowscope, the proportion of burrows occupied by fledglings was calculated and compared with the proportion of burrows occupied by fledglings at Heron Island using the Cochran-corrected chi-square test. This test was also used to determine differences in fledgling occupancy rates between habitats during the 1994/95 season, and to compare the fledgling occupancy rate of the similar *Pisonia* habitat at each locality. Using the mean occupancy rate within quadrats, the number of fledglings for each habitat, and for the islet, was also estimated.

At Heron Island in the Capricorn Group of islands (approx. 23°27'S, 151°55'E) it was found that 51 per cent of all burrows were used for laying during the same breeding season (Carter 1994). Based on the incubation rate at Heron Island, an estimate of the breeding population for Rocky Islet was calculated for both the 1993/94 and 1994/95 seasons, and for the various habitats.

RESULTS

Burrow density, burrow counts, occupancy rates and breeding pairs

Table 1 summarizes the results of the burrow densities, estimated burrow counts and occupancy rates of both seasons' surveys. The burrow estimate for Rocky Islet during 1993/94 was 5 785 ± 840, or between 3 625 and 7 945 within a 95 per cent confidence interval. This figure was an aggregate of 3 625 ± 600 burrows representing the *Pisonia* habitat, and 2 160 ± 650 in the rocky habitat. The mean burrow density for the island was 0.20 ± 0.03 burrows/m^2, with mean burrow density for the *Pisonia* habitat calculated at 0.24 ± 0.04 burrows/m^2, and 0.17 ± 0.05 burrows/m^2 for the rocky sector. No tests were applied to evaluate differences between habitats in that year due to small sample sizes. At Heron Island (1 175 km to the south) approximately 51 per cent of all burrows are used for laying (Carter 1994). Based on these data the number of breeding pairs for Rocky Islet during the 1993/94 season is estimated at *c.* 2 950. These estimates should provide a more precise figure than the information to date, which estimates approximately 1 000 burrows for the island (Domm 1977), or 990 burrows for the *Pisonia* area alone (Smith *et al.* 1989).

During 1994/95 burrow densities for the island were 0.12 ± 0.01 burrows/m^2, with no significant differences in burrow density found between the *Pisonia* habitat (0.13 ± 0.01 burrows/m^2) and the rocky habitat (0.11 ± 0.01 burrows/m^2) during the 1994/95 season (t = 1.88, df = 54, $p > 0.05$). Based on the most recent estimate of incubation rate at Heron Island (51% of burrows used for laying), approximately 2 369 breeding pairs of Wedge-tailed Shearwaters utilized Rocky Islet during the 1994/95 season.

Comparison between years showed no significant difference in burrow density of the rocky habitat (t = 0.995, df = 52, $p > 0.05$). However, burrow density in the *Pisonia* habitat varied significantly between years (t = 3.11, df = 27, $p < 0.05$), as did the overall burrow density for the island (t = 2.426, df = 82, $p < 0.05$).

Summary of results of burrow density, estimated burrow count, estimated breeding pair population, fledgling occupancy and estimated fledgling count.

	Burrow Density Burrows/m²	Estimated Burrow Count	Estimated Breeding Pair Population	Fledgling Occupancy Fledglings/ Burrow	Estimated Fledgling Count
Rocky Habitat					
1994/95	0.11 ± 0.01	2 640 ± 218	1 346	0.37 ± 0.05	990 ± 67
1993/94	0.17 ± 0.05	2 160 ± 650	1 102		
Pisonia Habitat					
1994/95	0.13 ± 0.01	2 006 ± 198	1 023	0.19 ± 0.05	499 ± 86
1993/94	0.24 ± 0.04	3 625 ± 600	1 849		
Rocky Islet Total					
1994/95	0.12 ± 0.01	4 646 ± 302	2 369	0.33 ± 0.04	1 489 ± 180
1993/94	0.20 ± 0.03	5 785 ± 840	2 950		

Carter (1994) found a fledgling occupancy rate of 0.31 at Heron Island during 1993/94. Using the Cochran-corrected chi-square test, there was no significant difference between the 0.33 ± 0.04 fledgling occupancy rate at Rocky Islet compared with Heron Island ($\chi^2 = 1.26$, df = 1, P = ns).

At Heron Island in the same year, the *Pisonia* habitat had a fledgling occupancy rate of 0.33. The difference between fledgling occupancy in the *Pisonia* habitat at Rocky Islet was not significantly different to the corresponding habitat at Heron Island ($\chi^2 = 1.43$, df = 1, P = ns) but on Rocky Islet, the fledgling occupancy rate of the *Pisonia* habitat was significantly lower than that in the rocky habitat ($\chi^2 = 74.51$, $P < 0.001$).

Timing of breeding

At Mutton Bird Island (33°18'S, 153°09'E) off the coast of Coffs Harbour, New South Wales, Swanson *et al.* (1974) recorded hatching from mid to late January. However, according to research at Heron Island during 1993/94 and previous seasons, chicks hatch in late January and early February (Dyer and Hill, pers. comm.). One week prior to the sampling period during 1994 the authors were involved with a survey of the species on Heron Island in which only eggs and very early stage hatchlings (aged no more than one week) were present. The nestlings found at Rocky Islet were expected to be no older than two weeks. Figures 2 and 3 clearly demonstrate the advanced maturation and stages of development of chicks. On Rocky Islet, all chicks were developing flight feathers in February during both 1993/94 and 1994/95 seasons, therefore the Rocky Islet fledging stage appears to be very advanced in comparison with the studies elsewhere.

Based on nestling ages and chick development at Heron Island, the ages of these Rocky Islet nestlings were estimated. The chick phase lasts around 52–54 days (Roberts *et al.* 1975) suggesting that the nestling period at Rocky Islet during the 1993/94 season commenced earlier than at Heron Island, and probably earlier than at Mutton Bird Island. Table 2 summarizes the trends during the breeding season for the various localities mentioned, and for North Stradbroke Island (27°30'S, 153°30'E) following the work of Dyer (1992). Approximate dates of laying and hatching at Rocky Islet have been estimated based on the duration of the incubation, chick and fledging phases at the other localities (Roberts *et al.* 1975; Swanson *et al.* 1975).

DISCUSSION

Overall burrow density estimates at Rocky Islet were comparable with studies of the species on islands of the Capricorn Group. In these studies, North West Island (90 ha) has shown burrow densities of approximately 0.39 burrows/m² (Dyer 1992) while burrow densities on Heron Island (13.0 ha) have been calculated at 0.15 burrows/m² (Carter 1994), and on the smaller Erskine Island (1.5 ha) burrow density was approximately

TABLE 2

Trends in the breeding cycle for colonies studied along the east coast of Australia.

	Mutton Bird Island	North Stradbroke Island	Heron Island	Rocky Islet
Arrival	early August	late August	late September/ early October	estimated: year round presence
Laying Period	late November/ early December	early December	mid December	estimated: early/mid November
Hatching Period	mid/late January	mid/late January	late January early February	estimated: early/mid January
Fledging Period	March/April	estimated: April	April/May	February

0.07 burrows/m^2 (Dyer 1992). In the Capricorn Group, burrow densities show significant differences between habitats, with the *Pisonia* forest or *Pisonia* with a ground layer of debris, described as the main nesting habitat (Gillham 1963; Ogden 1979; Hill *et al.* 1989). However, in the 1990/91 season at Heron Island, the northern wooded fringe on Heron Island was shown to have the highest occupancy rate of any habitat (Hill *et al.* 1995), which suggested that habitats favouring burrow siting may not maximize breeding success. No significant differences in burrow densities between habitats were found at Rocky Islet.

The burrow density estimates for the island and for the *Pisonia* habitat during the 1994/95 season are significantly less than the previous year. Further investigation is needed to determine whether the decline in nesting density is due to food availability, climatic or other factors.

Although there was no significant difference in the fledgling occupancy rate of the *Pisonia* habitat at the two islands, at Rocky Islet the rocky habitat showed a significantly higher fledgling occupancy rate compared to the *Pisonia* habitat. This suggests that birds either laid in a greater proportion of burrows located in the rocky habitat, or that the survival of offspring was enhanced in the rocky habitat. These trends show that there may be considerable ecological costs and benefits associated with choice of nesting habitat.

Substrate moisture can increase the cohesive properties of sandy soils offering a more stable burrow, however, excessive moisture increases the weight of material which may collapse burrows (Carter 1994). Burrows can vary in their susceptibility to collapse under certain rainfall intensities. The rocky habitat at this locality may offer advantages of reduced burrow collapse.

Carter (1994) estimated a breeding success rate of 0.61 for Heron Island, where breeding success is defined as the number of fledglings produced per egg laid (Nettleship 1972). If 2 369 breeding pairs were laying during 1994/95 at Rocky Islet and 1 489 fledglings were produced, then the breeding success of this population is estimated at around 0.63, which is similar to that at Heron Island.

The breeding population estimate at Rocky Islet for 1994/95 (2 369 breeding pairs) is slightly lower than that for 1993/94 which was 2 950 breeding pairs. However, given the differences in sampling between years, and the inherent population variability with seabirds generally, there do not appear to be large fluctuations in breeding numbers between years.

During February 1994, all nestlings found had commenced fledging, which is earlier in the calendar year than has previously been found for the species. The survey conducted during February 1995 showed a similar stage of nestling development. These observations suggest that the Rocky Islet population has a breeding cycle which is earlier than other populations.

Breeding activities would be expected to vary with environmental conditions (Swanson *et al.* 1974). Previous researchers have suggested a later breeding cycle with decreasing latitude (Dyer 1992), however, an earlier breeding cycle appears

to be occurring in this low latitudinal population. The timing of this population is contrary to the trend, and complicates interpretation.

The Rocky Islet breeding population is somewhat isolated, with the nearest breeding populations located at Raine Island approximately 375 km north and in the Capricorn Bunker Group of islands, approximately 1 175 km south (Blakers *et al.* 1984). The extent of population interchange between these areas is unknown, and changes at one locality may also be reflected elsewhere.

An earlier breeding cycle, in comparison with the Capricorn Group, may also occur in the Raine Island population. Presence of adults in burrows during July at Raine Island was recorded by MacGillivray (1914). Banding records during 1982 also show that the species was present in July during 1982 (Australian Bird and Bat Banding Scheme), although eggs were noted in late November (King 1986). This information suggests early or year-round presence of the shearwaters at Raine Island.

Since Domm (1977) also suggests year-round presence of the species at Rocky Islet, the Rocky Islet population appears to be similar, but not identical, to the Raine Island population. Egg-laying at Raine Island coincides with that at Mutton Bird Island, which would imply that populations either side of the Capricorn Group may vary in a complex manner. Further investigation into the entire breeding cycle and breeding success of this population and others is recommended to establish reasons for the observed differences in development of nestlings, and for monitoring long-term population trends.

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