Short Communications

Breeding Cycle of Wedge-tailed Shearwaters *Puffinus pacificus* at Heron Island, Great Barrier Reef

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Heron Island (23°27′S, 151°55′E), is a small coral cay of the southern Great Barrier Reef, one of several cays constituting the Capricorn Group of islands which supports a large breeding colony of Wedge-tailed Shearwater *Puffinus pacificus*. These birds excavate burrows for nesting in suitable ground, and nest colonially (Warham 1990). To date, only breeding population estimates, burrow incubation rates, and a preliminary investigation into hatching success have been made at this locality (Gillham 1963; Shipway 1969; Ogden 1979, 1994; Hulsman 1984a; Hill & Barnes 1989; Dyer 1992; Dyer & Hill 1992; Ogden 1994; Hill et al. 1995). This study was based at Heron Island during the 1993–94 breeding season and describes the timing of the breeding cycle, particularly the hatching and fledging phases.

Methodology

Sixty-five quadrats measuring 40 m^2 (10 m x 4 m) were used in a stratified sample of the island. All burrows within quadrats were monitored for occupancy status throughout the season using a burrowscope, that is, an infra-red light source attached to a camera case at one end and video monitor at the other (Dyer & Hill 1991). The initial sample consisted of 264 burrows, or 4.1 ± 0.4 burrows per quadrat. However, some degree of collapse and new burrow excavation occurred through the season altering the total number of burrows monitored at each sampling period.

Presence or absence of an egg, chick or fledgling was recorded in each of the sampling periods between 12–17 December 1993, 8–11 February, 11–28 April and 22–25 May 1994. On the few occasions when an adult was present during initial sampling periods it was counted as a breeding attempt, since further verification of occupancy was not possible at that time. For the purposes of this study, a fledgling is defined as any offspring in which flight feathers have started developing, estimated as 34.9 days for this species in the Hawaiian Islands (Petit et al. 1984). Most fledglings were not observed immediately prior to their departure from the island. It is assumed that fledglings not present during the May sampling period had successfully departed as only one malnourished fledgling was found on the entire island during the last sampling period. During the April sampling period, 74 fledglings of the 117 observed in burrows were able to be reached, removed from their burrows, and banded.

The monitoring times were chosen based on previous literature which indicated the timing of the breeding cycle at Heron Island or at Mutton Bird Island off the north coast of New South Wales (Kikkawa 1970; Swanson & Merritt 1974; Roberts et al. 1975; Ogden 1979; Hulsman 1984b). Using data collected in this study, and from the duration of breeding stages reported previously, more precise estimates for the times of laying, hatching and fledging at Heron Island are calculated.

Results

Results for the three survey periods (excluding the May survey when few individuals remained) are shown in Table I. Of the 192 eggs apparently laid over the entire season, only 112 eggs were laid during the December sampling period (58%). In February, an extra nine eggs and 53 chicks (62 individuals of the total of 192, or 32%) were recorded in burrows where there had been no record of an egg from the December data. During the April sampling period, an additional 18 new fledglings out of the total of 192 (9% of final offspring total) were noted. Eight of these 18 new fledglings in April occurred in newly excavated burrows. The extra individuals noted do not include several burrows in which there was an egg in December, no occupant in February, but a fledgling in April. If these burrows are included the number of new fledglings in April increases to 31.

Table 1 Census results for permanent survey quadrats at Heron Island during the 1993–94 breeding season. [(new) = newly found]

	Eggs	Chicks	Fledglings
December	112	70	54
February	9 (new)	6	6
		53 (new)	39
April		18 (new)	

Since eggs were still present or chicks estimated to be up to seven days old during 8–11 February, the hatching period is estimated to have been between 1–12 February. Roberts et al. (1975) report an incubation phase of 52-54 ± 1 days and an entire nestling period of 98 days in southern populations. From this information, it is assumed that eggs would have been laid between 8–21 December, and that flight feathers on most birds would have begun to emerge between 8–19 March, with the fledging period continuing until approximately 10–21 May; late developers would fledge slightly later. In April, 117 fledglings had survived out of the total of 192 eggs laid (61%). By 22–25 May only 20 of these 117 fledglings remained, 14 of which were able to be banded the previous month.

Discussion

The research reported here indicates that the timing of the breeding cycle at Heron Island occurs later than reported for other localities. Since there is no evidence that adult shearwaters lay replacement eggs (Marchant & Higgins 1990), the large percentage of chicks found after mid-December suggests that the laying period continued beyond mid-December. This contrasts with the laying period found at Mutton Bird Island (33°18′S, 153°09′E) which was estimated to last from approximately 21 November to 5 December (Swanson & Merritt 1974; Roberts et al. 1975), while at North Stradbroke Island (27°30′S, 153°30′E) laying occurred during early December in 1989–90 (Dyer 1992). It has also been estimated that the laying period for Rocky Islet in the northern Great Barrier Reef (14°52′S, 149°29′E) occurs during early to mid-November (Carter et al. 1996a) and at Raine Island (11°36′S, 144°02′E) laying was observed in late November (King 1986). It appears that egg laying in the Capricorn Group may occur later than at any of the other eastern Australian populations.

Although Gross et al. (1963) found egg laying for 1960–61 on Heron Island was at a peak during late December, Dyer (1992) during 1989–90 and 1990–91 found it had been completed by mid-December. It appears, therefore, that the egg laying period at Heron Island may vary between years from a cycle similar to that of the southern populations in some years, to a delayed or extended laying in others. This yearly variation in laying may be due to fluctuations in the food supply; it has been suggested that some seabirds will delay laying or the time of egg formation so that hatching or egg formation coincides with maximum food supply (Perrins 1966, 1970; Hulsman 1984b).

Alternatively, adverse weather conditions may act to desynchronise breeding by selecting against early breeders in a population (Gochfeld 1980), resulting in either delayed or extended breeding. Carter (1994) found that soil moisture was the most significant habitat factor to affect hatching success and attributed these findings to sand cohesiveness under certain rainfall conditions. The sandy, coral cay substrate of Heron Island compared with the metamorphic rock-based substrate of Mutton Bird Island, may render burrows on Heron Island more susceptible to cyclones, storms or drought.

Not only did the laying period extend beyond what was expected, but the appearance of new burrows on each sampling occasion was unexpected. There is only one record of a similar increase towards the end of a season, which occurred at North Stradbroke Island (Dyer & Hill 1995). Although non-breeders were probably responsible for new burrows, on one occasion late in the season a juvenile was observed actively burrow-digging or clearing. The frequency of such behaviour is unknown.

Hatching was also later than at Mutton Bird Island and North Stradbroke Island where it occurs from mid- to late January (Swanson & Merritt 1974; Roberts et al. 1975; Dyer 1992). It is also probably later than at Rocky Islet further to the north, where hatching is estimated to occur during early to mid-January (Carter et al. 1996a), and at Raine Island where, based on King's (1986) egg laying observations, hatching would occur in mid-January.

Fledging at Heron Island was underway during March, April and May, with the last fledglings still present on 25 May. Miles (1964) suggests that fledging at Heron Island is complete by late May, although Kikkawa (1970) reports that some juveniles were still present during June, which further supports inter-annual variability in the timing of the breeding cycle. At Mutton Bird Island, fledgling departure is probably complete by about 10 May (Swanson & Merritt 1974; Roberts et al. 1975) which implies that the fledging period at Heron Island during 1993–94 was later. Fledging is also estimated to occur during March–April at North Stradbroke Island, since hatching times coincide with the Mutton Bird Island population. It appears that the timing of the entire breeding cycle at Heron Island during 1993–94 was later than the southern populations. However, inter-annual variability may not have been detected from the Mutton Bird Island surveys which spanned seven non-consecutive seasons (Swanson & Merritt 1974; Roberts et al. 1975; Floyd & Swanson 1983).

Fledglings of other shearwater species gradually move towards the island periphery before departure (Lockley 1942; Skira 1991) but on Heron Island there was no evidence of this. On the final visit only 14 of 74 banded fledglings were found on the island and these were all still in their natal burrows (Carter et al. 1996b), although it is acknowledged that only 14 recaptures is a very small sample size. Those extra fledglings found in the April sample period may be due to fledglings generally moving around, as has been noted on a few occasions (PKD pers. obs.; Fry et al. 1986), but there was no trend for numbers to increase toward the island periphery.

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The Tolerance of Malleefowl *Leipoa ocellata* to 1080

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The distribution and abundance of Malleefowl *Leipoa ocellata* have both declined considerably throughout Australia since European settlement (Frith 1962; Priddel & Wheeler 1990). Malleefowl were previously distributed over much of the southern mainland of Australia, from the south-west of Western Australia to central New South Wales (Blakers et al. 1984). The main cause of the decline has been attributed to the destruction of habitat through clearing for agriculture and the impact of introduced grazing animals (Frith 1962; Priddel & Wheeler 1990). However, indications of declines have also been noted in areas which were uncleared and ungrazed (Brickhill 1987). The impact of predation on Malleefowl by foxes *Vulpes vulpes* was noted as early as 1916 (North 1917). Subsequent workers have recorded high levels of predation by foxes on eggs (Frith 1962), chicks (Priddel & Wheeler 1994) and adult Malleefowl (Booth 1987). It was stated by Priddel & Wheeler (1994) that 'without effective fox control, further extinction of remaining populations of Malleefowl within the New South Wales wheatbelt appears inevitable.'

The use of 1080 baits to control foxes is increasing greatly in fauna reintroduction and management programs in Australia (Friend 1990; Kinnear et al. 1988; Lundie-Jenkins et al. 1993; Short & Smith 1994). Foxes are very sensitive to 1080 (McIlroy & King 1990), whereas some native fauna in Australia have developed very high tolerances to the toxin (Twigg & King 1991). To determine the suitability of using 1080 baits in fox control operations to enhance the conservation of Malleefowl, the tolerance of Malleefowl to 1080 was determined to assess the potential non-target hazard to these birds.

Materials and methods

Malleefowl from captive breeding programs in New South Wales and South Australia were supplied by the New South Wales National Parks and Wildlife Service and the South Australian National Parks and Wildlife Service. Eggs were collected from nest mounds in Western Australia by the Department of Conservation and Land Management and incubated in our laboratory. Birds were housed in outdoor aviaries and were transferred into indoor cages in an animal house maintained at 23 ± 1°C and 70% humidity 1-2 days before dosing.