ESTABLISHMENT AND GROWTH OF THE WHITE TERN *GYGIS ALBA* POPULATION ON LORD HOWE ISLAND, AUSTRALIA

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SUMMARY

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The White Tern *Gygis alba* is self-introduced to Lord Howe Island, Australia. It was first recorded there in 1943, but breeding was not confirmed until 1968. Breeding is confined to the central lowlands, with most breeding sites (White Terns do not make nests) located close to shore within the area of human settlement. All sites are in trees, predominantly large mature Norfolk Island Pine *Araucaria heterophylla*. In 2005/06, the White Tern population on Lord Howe Island was estimated to be ~500 breeding pairs, having increased at a mean rate of 12% per annum since 1971. In 2013/14, the population was ~600 pairs, having increased 2.7% per annum between 2006 and 2013. When breeding was monitored in 2005, many pairs re-laid if the first or second breeding attempt failed, with a clutch mean (± SD) of 1.5 ± 0.6 attempts per pair. Hatching success was 37%, fledging success 47% and breeding success 17%. Reproductive output (mean number of fledglings produced per breeding pair) was 0.25, lower than that recorded for most other populations for which data are available. The endemic Lord Howe Pied Currawong *Strepera graculina crissalis* was a major predator of White Tern eggs and chicks, and the introduced Masked Owl *Tyto novaehollandiae* a predator of adults.

Key words: breeding success, hatching success, breeding behaviour, predation

INTRODUCTION

The White Tern *Gygis alba* is a widely distributed seabird that breeds on islands throughout the tropical and subtropical regions of the Pacific, Indian and South Atlantic oceans, with a global population of 150 000 to 1 100 000 pairs (BirdLife International 2010). Breeding populations occur at three sites within Australian territory: the Cocos (Keeling) Islands in the Indian Ocean, and Norfolk and Lord Howe islands in the Pacific Ocean (Higgins & Davies 1996).

The White Tern is self-introduced to Lord Howe Island (LHI), the most southerly breeding location for the species. It was first recorded there in 1943 (Hindwood & Cunningham 1950), but breeding was not confirmed until 1968 (Disney & Smithers 1972), although some pairs may have bred unnoticed much earlier (Hutton 1991). In 1971 the breeding population did not exceed 10 pairs (Fullagar *et al.* 1974), but by 1990 had increased to 60–100 pairs (Hutton 1991). Nowadays, the species is locally abundant, but no systematic census has been conducted on the island, and the current population size and trajectory are unknown. The endemic Lord Howe Pied Currawong *Strepera graculina crissalis* is purported by local residents to be a major predator of White Tern eggs and chicks, but confirmatory studies are lacking.

White Terns do not construct a nest, but lay a single egg in a shallow depression on an exposed site, usually a horizontal tree limb (Hull 1910). Both sexes incubate the egg, which, if lost, is usually replaced at the same site, a pattern that can be repeated several times each season (Dorward 1963). Mean incubation length is 35–36 d (Dorward 1963, Howell 1978, Pettit *et al.* 1981, Hermes *et al.* 1986, Niethammer *et al.* 1992), and the fledging period averages 49 d (Gibson-Hill 1950, Niethammer & Patrick 1998) but is highly variable (Dorward 1963, Miles 1985). Fledglings remain near the breeding site to be fed by their parents for another 3–4 weeks (Dorward 1963, Miles 1985). Typically, young first go to sea when about 10 weeks old, but continue to be fed for another 3 weeks (Miles 1985). In total, the period of parental care (including incubation and post-fledgling feeding) can exceed 126 d (Miles 1985). Chicks are fed by both parents, mainly with small fish but also squid (Ashmole & Ashmole 1967, Harrison *et al.* 1983, Niethammer & Patrick 1998). Sexes are alike, but juveniles are distinctive, having a fine ginger wash to the tips of many feathers. At most colonies around the world, successful breeders produce a single fledgling only, and go to sea after their young fledge. They return the following year with the same partner, and typically use the same site. White Terns are long-lived (longevity >30 years) and appear tolerant of disturbance, often rearing their young near human activity (Niethammer & Patrick 1998, Vanderwerf 2003). Their behaviour at sea has been investigated only in the central Pacific, where they feed by dipping, contact dipping and surface plunging, almost always in flocks associated with fish predators (e.g. tuna). They have relatively high diet diversity compared with other central Pacific seabirds (Spear *et al*. 2007).

On LHI, White Terns breed only within the settled lowlands, and colonies are highly visible. The preferred habitat is large, mature Norfolk Island Pines *Araucaria heterophylla* that line the road along the western shoreline of the lagoon. These trees were planted during the 1900s and have historical significance. Younger stands of Norfolk Island Pine have since established within areas of native vegetation. Concerned about the invasive nature of this species, the controlling authority on LHI (the LHI Board) has declared Norfolk

Island Pine an exotic weed (Lord Howe Island Board 2006), and self-seeded stands that do not have historical value are being systematically removed.

This study investigated the distribution, abundance and breeding success of the White Tern on LHI. The aims were to (1) gather baseline data for future monitoring of the White Tern population on LHI, (2) estimate the rate of increase of the population since its arrival last century, and (3) identify the key factors affecting population growth.

METHODS

Study area

LHI (31°30′S, 159°05′E) is located 780 km northeast of Sydney, New South Wales, Australia, in the South Pacific Ocean. It is a crescent-shaped island of 1455 ha, about 12 km long and 1–2 km wide (Fig. 1). The western side of the island is bordered by a coral reef 6 km in length, which encloses a lagoon. Much of the shoreline of the lagoon is lined by Norfolk Island Pines. Mount Gower (875 m), Mount Lidgbird (777 m) and Intermediate Hill (250 m) form the southern two-thirds of the island, which is extremely rugged. The central lowland has been partially cleared for agriculture or settlement and is crisscrossed by a network of narrow roads. Patches of forest adjoin grazing leases and urban settlement. More than half the island is covered in closed forest, of which 54% is rainforest, 19% is megaphyllous (large-leaved) broad sclerophyll forest (mainly palms), and 2% is gnarled mossy forest on the mountain summits (Pickard 1983). The remaining natural vegetation is scrub, herbfields, grasslands and vegetation on exposed cliffs and littoral terrains (Pickard 1983).

Distribution and abundance of breeding sites

All known and suspected breeding sites for White Terns on LHI, along with all stands of Norfolk Island Pine, were surveyed during the 2005/06 breeding season and again in 2013/14. Surveys were undertaken in December–January, during peak breeding activity (see Results), and in the middle of the day (10h00–14h00 local), when many non-breeding birds were absent from the colony. Breeding sites were located by observers systematically traversing potential habitat on foot. Observers refrained from entering private gardens, but binoculars were used to scan for birds breeding in trees on private property. The sites included either a pair of adults sitting together, a single adult bird incubating an egg or brooding a hatchling, or an unaccompanied chick. The location of each tree containing a breeding site was recorded, along with the position and height of each site within each tree. As some trees could not be identified reliably from afar, tree species was not always recorded.

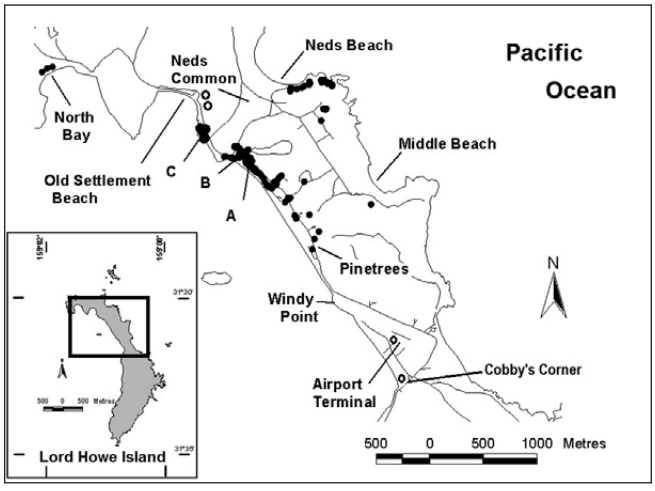

Fig. 1. Locations of White Tern breeding sites on Lord Howe Island (inset) in 2005/06 and 2013/14. Solid circles, sites used in both 2005/06 and 2013/14; open circles used in 2013/14 only. Sampling sites of intensive study in 2005/06 indicated by A, B and C. Internal lines show roads and tracks.

White Terns are capable of laying up to three times in the season if the first or second eggs are unsuccessful (see Results), using the same site each time (Dorward 1963). During the periods between re-laying, breeding sites are unoccupied. To estimate the proportion of the breeding population at the time of the survey, a sample of readily observable breeding sites (n = 177) were monitored throughout the season. These sites were within three dense sub-colonies that bordered the lagoon (A, B and C; Fig. 1). A sub-colony was defined here by stands of suitable trees separated from other breeding sites by unsuitable habitat, mostly palm forest or open ground. Up to 12 observable pairs of terns bred in a single tree. Activity at each sub-colony was sampled monthly (except March) throughout the 2005/06 breeding season (Table 1). At each visit, every known breeding site was inspected to determine whether it was occupied, and any new (previously unrecorded) breeding sites were added.

Counts of flying birds

White Terns are particularly active at dawn, when many birds take flight, circling over the colony. We investigated whether counts of the number of birds in flight at this time of day was a useful indicator of population trends. From a single vantage point above Neds Common (Fig. 1), a slow, measured sweep of the entire panorama was conducted using binoculars, and the number of flying birds was counted. Counts were made during fine weather at dawn on a single day of each month (except March) from November 2005 to May 2006. Counting commenced 15 min before sunrise and was repeated every 5 min for 1 h, giving a total of 12 replicate counts.

TABLE 1
Number of White Tern breeding sites (n = 177) occupied during each sampling period in 2005/06

Date	Sites occupied, number (%)
26 October–05 November 2005	97 (55)
19–27 November 2005	91 (51)
14–23 December 2005	119 (67)
18–27 January 2006	127 (72)
24 February–01 March 2006	86 (49)
20–23 April 2006	16 (9)
26–30 May 2006	0

Breeding activity

Breeding success was assessed for each breeding site within the three colonies monitored intensively for activity (A, B and C; Fig. 1). Surveys were conducted monthly (except March) from October 2005 to May 2006 (Table 1). On each visit, each breeding site (known and new) was inspected, and the presence of an adult, egg, chick or free-flying young was recorded. Free-flying young typically remain close to the breeding site for 3–4 weeks (Ashmole 1968, Howell 1978) and are distinguishable by plumage, bill colour and a narrower eye ring (Niethammer & Patrick 1998). It was not always possible to determine whether adult birds were sitting on an egg or a recently hatched chick, but sites where the contents were uncertain were revisited the following day until a reliable sighting was obtained. These monthly inspections were supplemented with more frequent, but sporadic, observations by local residents.

The following reproductive parameters were calculated: hatching success (proportion of eggs that produced chicks); fledging success (proportion of chicks that survived to fledging); breeding success (proportion of eggs that produced fledglings); and reproductive output (the mean number of fledglings produced per breeding pair). The number of eggs (i.e. clutches) produced per breeding pair was also calculated, and hatching and fledging dates were recorded when data permitted. All means are presented ± standard deviation.

Young chicks (< 5 weeks of age) that were absent at the subsequent monthly inspection were deemed to have died, as they would have not been old enough to have fledged. Advanced chicks (> 5 weeks of age) that were absent the subsequent month were deemed to have fledged. As some advanced chicks may have failed to fledge, estimates of fledging success, breeding success and reproductive output are considered maximum values. Counts of flying birds were transformed logarithmically to normalise variance and compared among months using a single factor analysis of variance (ANOVA) and Student-Newman-Keuls tests.

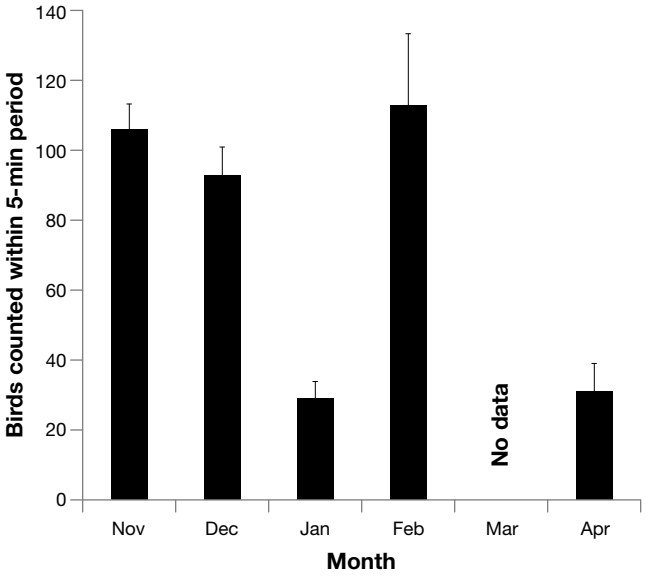

Fig. 2. Number of White Terns flying over Lord Howe Island at dawn between November 2005 and April 2006. Bars indicate means and vertical lines indicate standard errors.

RESULTS

Breeding phenology

In the 2005/06 breeding season, White Terns arrived on LHI in mid-August and departed by the end of May. Eggs were laid between late September and mid-March. If the attempt failed, some birds re-laid, with at least 31% of pairs laying two eggs and 8% laying three eggs. These proportions are conservative, as some eggs may have been lost before they were recorded. The time between the loss of the first egg or chick and laying of the second egg was 13–15 d (mean = 13.7, n = 8), and between the loss of the second egg or chick and laying of the third egg was 23–36 d (mean = 29.5, n = 2). Incubation length was 33–37 d (mean = 35.3, n = 4). Hatching occurred from mid-November to mid-April, but late-hatched birds invariably failed to fledge. Fledglings left the nest site from January until late April, and the last terns present were seen flying over the lagoon during the last week of May.

Distribution of breeding sites

Breeding sites in 2005/06 were widely distributed within the lowlands, mostly along road verges within the settlement and close to the shoreline (Fig. 1). On the western side of the island, sites occurred at North Bay and from south of Old Settlement Beach to Pinetrees Lodge. On the eastern side of the island, sites were concentrated immediately south of Neds Beach, with scattered colonies inland as far south as Middle Beach. Birds were observed near Windy Point and in a large Norfolk Island Pine west of the airport terminal, but no breeding was evident. The distribution of breeding sites in 2013/14 was similar, but with some minor southward and northward expansion. Three pairs had colonised the aforementioned pine, and three pairs were breeding at Cobby's Corner, south of the airport. Birds had also colonised trees along the road north of colony C (Fig. 1, open circles). Notably, the number of breeding sites within the Norfolk Island Pines immediately west of sub-colony B had increased significantly, from 22 to 85 pairs.

All breeding sites were in trees. Some were isolated, but most were aggregated in colonies within preferred habitats. Mature Norfolk Island Pines were particularly favoured, but sites also occurred in a range of other tree species including sallywood *Lagunaria patersonia*, blackbutt *Cryptocarya triplinervis*, maulwood *Olea paniculata*, cottonwood *Celtis conferta*, greybark *Drypetes deplanchei,* banyan *Ficus macrophylla* and pandanus *Pandanus forsteri*. Trees used for breeding were up to 26 m tall, but the sites were generally on the larger branches below 15 m.

Breeding site abundance

The survey in December 2005 to January 2006 recorded a total of 343 active sites. Monitoring of 177 throughout the breeding season revealed that 67% were occupied in December and 72% in January (Table 1). Thus, at the time of the survey, ~69% of sites would have been occupied, and the inverse (1.44) can be used as a correction factor to estimate the total number of breeding pairs. Thus, the breeding population of White Tern on LHI during the 2005/06 breeding season was estimated to be 494 pairs.

The survey in December 2013 recorded a total of 438 active sites. Monitoring of 21 sites throughout the breeding season (October

2013 to April 2014), as part of a separate study, revealed that 71% were occupied at the time of the survey, giving a correction factor of 1.40, similar to that in 2005/06. Thus, the breeding population of White Tern on LHI during 2013/14 was estimated to be 612 pairs.

Counts of flying birds

The number of terns flying at dawn was highly variable among months (Fig. 2). The maximum single count was 201 birds, <20% of the maximum number of birds present on the island (based on a population estimate of 988 breeding adults and 125 flying young). Counts differed between months (single-factor ANOVA, $F_{4,59} = 13.371$, $P < 0.001$), with those in January and April being lower than those in November, December and February. No birds were present during the final survey in late May. The low count in January coincided with the period shortly after non-breeding birds departed the island. The high count in February occurred when flying young were present. The subsequent decline in April and absence in May are consistent with birds returning to sea with their progeny.

Reproductive output

The three colonies monitored in 2005/06 contained a total of 177 active sites (Table 2). A total of 260 eggs were recorded, with a mean of 1.5 ± 0.6 eggs produced per pair. A total of 96 eggs hatched at 88 sites, and overall 45 chicks fledged. Hatching success was 37%, fledging success 47% and breeding success 17%. Reproductive output was 0.25 fledglings per breeding pair.

Causes of mortality

Only one predation event was observed. An adult White Tern brooding a chick approximately 2 d old was attacked by a Pied Currawong. The currawong lunged at the adult three times, forcing it to move off its chick. The currawong then grasped the chick around the neck and flew to a branch approximately 2 m away. There the chick was killed with three sharp blows against the branch before the currawong flew off with it. The entire event lasted <15 s but was accompanied by a loud chorus of distress calls from the attending parent and other terns circling above the tree canopy, as well as general commotion within the colony. Residents with White Terns breeding near their homes have reported witnessing similar events, invariably involving currawongs. From a sample of 13 unsuccessful breeding attempts that were monitored closely, nine failed in the egg stage and four in the early chick stage. Eggs were lost when 3–30 d old (mean = 13.8 d, n = 9) and chicks when 1–6 d old (mean = 3.0 d, n = 4). Alerted by commotion within the colony, observers confirmed that at least three of the four chick losses were due to predation by a currawong.

The remains of 10 adult White Terns were found during the study; all were attributed to predation by the introduced Masked Owl *Tyto novaehollandiae*. Owls tend to detach the head and wings of avian prey, whereas currawongs leave the wings attached to the body but remove much of the ribcage. A Pied Currawong was observed and photographed preying on a pair of adult White Terns (Ian Hutton, pers. comm.). With no studies having been conducted, detailed information on the predatory habits of owls and currawongs on LHI is lacking.

DISCUSSION

This study provides techniques and baseline data for future monitoring of the White Tern population on LHI. Repeated counts of breeding sites and flying birds, together with monitoring of breeding success throughout the season, provide a useful means of tracking population change. Counts should be conducted at least monthly, preferably fortnightly (every two weeks). The survey techniques require no specialised equipment (apart from binoculars) and little ornithological expertise, enabling surveys to be undertaken by interested members of the local community. Counts of birds flying over the colonies at dawn have a high level of variance, but the data are relatively easy to collect. These counts should continue in the short term, and their usefulness should be evaluated by comparing the resulting index of population size with the other, more rigorous, estimates.

White Terns have been reported to breed in trees, on artificial structures, cliff ledges or near the ground (Howell 1978, Miles 1986, Niethammer & Patrick 1998). Those breeding on LHI do so almost exclusively on exposed horizontal branches in trees. Sites are most commonly associated with mature Norfolk Island Pines, so any change in the distribution and abundance of Norfolk Island Pines on LHI may affect the local distribution of White Terns. These terns, however, utilise a variety of other tree species on LHI, many of which are common. This versatility, together with the plan to retain the large historical pines containing the majority of current breeding sites, suggests that the ongoing removal of self-seeded stands of Norfolk Island Pine is unlikely to be a significant driver of population change for White Terns on LHI.

The size of the breeding population of White Tern on LHI in 2005/06 was an estimated ~500 pairs, increasing to ~600 pairs in 2013/14. These population estimates do not include birds that breed in private gardens, which could not be seen from adjacent areas of

TABLE 2
Reproductive parameters for three sub-colonies of White Tern on Lord Howe Island during 2005/06

Sub-colony	Breeding pairs	Eggs laid	Eggs hatched	Fledglings	Reproductive output[a]
A	116	179	76	39	0.34
B	36	52	15	3	0.83
C	25	29	5	3	0.12
Total	177	260	96	45	0.25

[a] Reproductive output is the mean number of fledglings produced per pair.

public access. However, based on those areas where visibility was unimpaired, the number of birds missed is likely to be small.

The population of White Terns on LHI increased at an average 12% per annum between 1971, when no more than 10 pairs were found breeding (Fullagar *et al.* 1974), and 2005/06. If this initial rate of increase was uniform across years, the population in 1990 would have been 86 pairs, which is consistent with Hutton's (1991) estimate of 60–100 pairs. A similar high growth rate has been reported for a newly established population of White Terns on the island of O'ahu, Hawai'i. This population grew at 14% per annum, increasing from just one pair in 1961 to 250 pairs in 2002 (Vanderwerf 2003). Such a high rate of increase was possible because the birds were able to breed almost year-round, producing up to three young per year. On LHI, breeding is seasonal, and successful pairs produce only a single fledgling each year. Although direct evidence is lacking, the initial high rate of population increase on LHI may have been partly due to immigration from other colonies. The closest breeding site to LHI is Norfolk Island, 900 km to the east. There has been no recent census of the population on Norfolk Island, but during the 1980s it exceeded 2000 breeding pairs (van Tets & Fullagar 1984).

Between 2005/06 and 2013/14 the White Tern population on LHI increased less rapidly than previously, with a growth rate of 2.7% per annum. This slower growth rate may be due to a reduction in the relative importance of immigration or a decrease in local breeding success.

Hatching, fledging and breeding success of White Terns varies considerably among populations (Table 3). Low breeding success in the Seychelles is thought to be due to heavy rainfall, limited food availability and interspecific competition (Catry *et al.* 2009). On the other hand, the high level of reproductive success on O'ahu is due to an abundance of prey locally. As a result, about one-third of breeding pairs remain within the breeding area year-round; breeding occurs at less than annual intervals; and pairs rear two to three offspring a year (Miles 1985). Pairs on LHI produce no more than a single fledgling annually, although they may re-lay if the first or second egg fails. Breeding success on LHI was greater than the minimum recorded in the Seychelles, but lower than on O'ahu, Tern and Ascension islands (Table 3). The difference between LHI and these latter three populations was the lower level of fledging success, i.e. the higher rate of chick mortality.

Observations by residents on LHI suggest that predation by Pied Currawongs may be the most significant cause of both egg and chick loss. Predation of chicks by currawongs is reputedly particularly heavy when the chicks are just a few days old (Cam Wilson, pers. comm.). This study tends to support these claims. However, the impact of currawongs could be overstated because currawongs cause audible commotion within the colony, alerting residents to their actions. Other potential causes of mortality are less obvious. Heavy rain and dislodgement of eggs during high winds may also contribute to the high rate of breeding failure. On Tern Island in the French Frigate Shoals, at least 63% of egg failures were caused by wind and rain (Niethammer & Patrick 1998). Ship rats *Rattus rattus* prey on White Tern eggs and chicks on Midway Atoll (Grant *et al.* 1981, Niethammer & Patrick 1998), and this rodent is abundant on LHI. Although confirmatory evidence is lacking, rats on LHI likely prey on White Tern chicks left unattended by their parents. Owl predation of White Terns has been recorded elsewhere (Schulmeister 1980, Niethammer & Patrick 1998). While we believe it occurs on LHI, its extent is unknown because it is detectable only if the remains are dropped where they can be noticed. It is possible that Masked Owls have a greater impact on population growth than currawongs or rats, because they tend to take adults rather than chicks or eggs.

CONCLUSION

The White Tern has successfully colonised LHI. The current breeding population is ~600 pairs, having increased by an average of 12% per annum over the initial three or four decades since breeding commenced. Subsequently, the rate of increase has slowed, with the population increasing at approximately 2.7% per annum between 2006 and 2013. Compared with other breeding populations, the survival of White Tern chicks on LHI currently is particularly low, and chick mortality seems to be the major factor limiting breeding success and further rapid population growth. Predation by the endemic subspecies of Pied Currawong appears to be the main cause of chick loss, but further confirmatory studies are required. Despite these apparent losses, the prolonged and sustained increase in the White Tern population on LHI suggests that direct

TABLE 3
Comparison of breeding parameters among various populations of White Tern

Location	Hatching success[a] % (n)	Fledging success[b] % (n)	Breeding success[c] % (n)	Reproductive output[d] mean (n)	Source
O'ahu, Hawai'i	88.3 (120)	85.6 (106)	75.8 (120)	No data	Miles (1986)
Tern Island, French Frigate Shoals	37.6 (434)	79.8 (163)	30.0 (434)	0.59 (219)	Niethammer & Patrick (1998)
Ascension Island	41.6 (178)	70.3 (74)	29.2 (178)	0.38[e] (47)	Dorward (1963)
Lord Howe Island	36.9 (260)	46.9 (96)	17.3 (260)	0.25 (177)	This study
Aride Island, Seychelles	44.4 (63)–66.7 (27)	17.4 (23)–47.4 (19)	0.09 (23)–0.33 (27)	No data	Catry *et al.* (2009)

[a] Eggs that produced chicks.
[b] Chicks that survived to fledging.
[c] Eggs that produced fledglings.
[d] Mean number of fledglings produced per breeding pair per annum.
[e] Based on 1957/58 data only.

conservation action to mitigate the threat posed by currawongs is unwarranted at this time.

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