

## Hatching Success of the Australian Brush-turkey *Alectura lathami* in South-east Queensland

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Megapodes are unique among birds in incubating their eggs entirely through the exploitation of external sources of heat (Frith 1962). Once eggs are laid into the incubation mound or egg burrow, they receive no attention from the adults, and the chicks hatch and emerge without parental assistance (Baltin 1969). The absence of direct parental care, beyond some defence of the incubation site (Dow 1980), leaves eggs and chicks vulnerable to predation and environmental calamities. For example, Malleefowl *Leipoa ocellata* may suffer egg losses of up to 40% to European Foxes *Vulpes vulpes* (Frith 1959) or more than 10% due to the saturation of mounds (Brickhill 1986).

The mounds of the Australian Brush-turkey *Alectura lathami* are also subject to predation (Kaveny 1958) and climatic disturbance (Jones 1988), but the impacts of these on breeding success have not been assessed. Here, I report the hatching outcome and fate of eggs of a population of Australian Brush-turkeys from Mt. Tamborine (27°55'S, 153°11'E), south-east Queensland. These data were obtained during a larger study of reproductive ecology (Jones 1988, a,b) conducted between May 1983 and February 1986.

### Methods

Birds were studied at three sites in subtropical rainforest remnants surrounded by cleared land (see Jones in press a, for complete descriptions). Most data were obtained from a population of 50-60 marked birds from Site 1 (North Tamborine Environmental Park). All mounds were identified and visited weekly throughout the study, to establish the identity of the male tending the mound, and to assess mound temperatures and useage (see Jones 1988). The numbers of eggs laid in mounds were determined by exca-

vating all mounds used. This was made at the end of the breeding season (usually after February) when mounds had been abandoned and all eggs had hatched. To prevent disturbance to both the birds and the temperature regime of the mound, no excavations were made while mounds were still in use.

Mounds were excavated by very carefully removing horizontal layers of a few centimetres at a time until the ground surface was reached. Each item encountered was described and the depth beneath the original mound surface recorded. Successfully hatched and emerged chicks were assumed for empty egg shells that were shattered into large pieces but not scattered and with the membrane still attached (see Baltin 1969).

### Results

#### *Egg laying*

Laying females dug deep conical excavations made into the interior of mounds. Eggs were laid throughout the mound's interior. Most (47.4% of 572) eggs were laid in a band between 30 and 60 cm radius around the centre of the mound, compared to locations in both the centre of the mound (radius  $\leq 30$  cm, 12.5% of eggs), and the outer rim. Eggs were laid over a wide range (25 to 75 cm) of depths beneath the surface of the mound, but most (76.6% of 572) eggs were laid between 45 and 55 cm depth. There was a significant linear relationship between the range of depths and the number of eggs contained in mounds ( $r = 0.60$ ,  $d.f. = 41$ ,  $P < 0.001$ ). This indicates that in mounds containing larger numbers of eggs, females laid more eggs at both shallower and deeper levels of the mound.

During the three breeding seasons covered in this study, female Brush-turkeys laid a total of 499 eggs in mounds in Site 1 (Table 1). Although the number of eggs laid in 1983 was about 65% less than the totals for the other two years, the average number of eggs per mound was remarkably similar for each season (1983:  $15.5 \pm 10.1$  s.d.; 1984:  $14.5 \pm 7.8$ ; 1985:  $14.2 \pm 13.7$ ). These figures do not, however, represent clutch sizes as individual females may lay in several mounds during a breeding season (Jones in press b). Moreover, male Brush-turkeys may tend either one or two mounds during a breeding season (Jones in press b). Individual successful mounds contained between 58 and three eggs (mean  $14.68 \pm 11.02$  s.d. eggs per mound,  $n = 34$ ). The total (for all mounds tended by a male) numbers of eggs incubated by males in one season

TABLE 1 Summary of hatching success and fate of eggs of Australian Brush-turkeys at Mt. Tamborine for three breeding seasons 1983-1986.

Breeding season	No. of mounds	No. of males	No. of eggs laid	Eggs hatched (%)	Eggs added (%)	Died in egg (%)	Died in egg after hatching (%)
1983/84	9	6	124	79.7	11.1	9.7	0.7
1984/85	13	7	189	87.7	9.4	2.1	0
1985/86	13	9	186	86.6	9.6	3.6	0.4
Total	35	22	499	86.6	9.6	3.6	0.4

ranged from 3-61 (mean:  $22.67 \pm 15.97$  s.d. eggs per male,  $n = 22$ ).

#### Fate of eggs

Of the 499 eggs laid in mounds in Site 1 during the study, 86.6% apparently hatched successfully (Table 1). There was no significant difference in the rates of successful hatchings between the three seasons (Table 1). The mean ( $\pm$  standard error) hatching success for individual males was similar (1983:  $72.6 \pm 23.6\%$ ; 1984:  $87.6 \pm 4.8\%$ ; 1985:  $81.8 \pm 25.5\%$ ). The relatively small standard error for 1984 arises from the high rate of hatching success for all males during that year: no male had less than 80% of eggs hatch and leave the mound. During 1983 and 1985 about half (seven of 15) of males had hatching successes of less than 80%. Only three males successfully hatched all of the eggs in their mounds; these were all in mounds with less than ten eggs. Nonetheless, there was no simple relationship between the number of eggs tended and the proportion surviving. In fact, as most males (72.6% of 22) lost between one and five eggs each year, males with small clutches had a greater hatching failure rate. For example, the mean number of eggs failing to hatch for males with more than 30 eggs was 9.4% ( $n = 5$ ) per male, while for males with less than 20 eggs the figure was 24.5% ( $n = 12$ ).

The most frequent type of egg loss was addling, which effected 9.6% of all eggs laid. These eggs were found to be rotten but with the shell complete and unbroken. It was not possible to determine the cause of failure but the most likely implication was inadequate or incomplete incubation. Infertile eggs, developed eggs subject to dramatic changes in incubation temperatures, and eggs laid too late in the season became addled by the time of excavation.

While the proportions of addled eggs were similar during each of the three seasons (Table 1), the proportion of dead chicks found hatched and unhatched within the mound was higher during 1983 (10.4%) than the other years (1984: 2.1%; 1985: 1.6%). For some individual males these losses represented most of the eggs males were tending. These chicks had passed through a complete incubation period yet most had not been able to escape the egg: only two chicks were found to have died within the mound after leaving the egg. The most likely cause of these deaths was a prolonged drop in mound temperatures. The relatively high death rate in 1983 may be related to the severe rainfall experienced during November of that year, which saturated all mounds and led to most mounds cooling by 8-12°C for up to two weeks (see Jones 1988).

There was no evidence of predation of eggs within the mounds. Large monitors *Varanus* spp., which are common egg predators of many megapodes (e.g. Bergmann 1963; Lincoln 1974), were rare in the study sites. Land mullets

*Egernia major*, were frequently found in the top of mounds but appeared not to burrow deeper than about 15 cm (Jones 1987).

#### Post-emergence mortality

The figures for successful hatchings per year given above for Site 1 represent 99, 166 and 167 live chicks for each year covered, or between 16.5 and 23.6 chicks per male per year. For Malleefowl, Brickhill (1986) obtained a figure of seven chicks per male in southern New South Wales.

The proportion of chicks that survived to become sub-adults can be determined through the numbers of sub-adults detected during the post-hatching period (October to March) of each year (see Jones 1988, unpubl. data). This very rough estimate gives post-emergence mortalities of 90% (89 of 99) for the 1983 breeding season and 97% (161 of 166) for 1984. This reduces the average ratio of successful males to surviving offspring to 1.7 (1983) and 0.8 (1984).

It is probable that at least a high proportion of this mortality was due to predation. Cats were common in the site and were observed eating chicks on numerous occasions; they were probably the main predators of young birds. Other potential predators of chicks seen in the study site were Dingos *Canis familiaris dingo*, Dogs *C. f. familiaris*, Carpet Snakes *Morelia spilotes*, and three raptors: Brown Goshawk *Accipiter fasciatus* and Collared Sparrowhawk *A. cirrhocephalus* (see also Korn [1986] who reported this raptor attacking Malleefowl), while J. Aagard (pers. comm.) has observed Grey Goshawks *A. novaehollandiae* taking sub-adult Brush-turkeys at Mt. Tamborine.

Mortality of adults was apparently very low. Only two adults were known to have died during the study and both were killed by Dingos or Dogs.

#### Discussion

The overall hatching success of the Site 1 population was about 87% of the total eggs laid (Table 1), an emergence rate considerably higher than most reported values for other megapodes. Malleefowl often suffer egg losses of about 50%, resulting mainly from predation of eggs (Frith 1959) or instability of mound temperatures (Chisholm 1934; Brickhill 1986). Booth (1987), however, found a hatching success of 79% in Malleefowl in South Australia and attributed this to a lack of Fox predation. Egg failure due to saturation of mounds in Malleefowl has been estimated to contribute to between 12% and 14% of clutches (Lewis 1940; Brickhill 1986). It is likely that the relatively high (10%, 12 of 124) proportion of dead Brush-turkey chicks found after the 1983 breeding season was also due to saturation of mounds. The rainfalls associated

with these failures were the heaviest and most sustained received during the study (see Jones 1988).

Megapode eggs are large (~180 g, Vleck *et al.* 1984) and a single mound may contain up to 16 eggs, or about three kilograms of eggs mass at any one time (Seymour & Ackerman 1980), a valuable and apparently highly accessible source of food for predators capable of digging. Skutch (1976) and Morse (1980) have attributed the evolution and continued existence of the use of external sources of heat for incubation to an apparent lack of such predators within the range of most megapodes. Yet egg predation has been found to be one of the most serious sources of mortality among many megapode species (Lincoln 1974; MacKinnon 1981). Elsewhere in their range Australian Brush-turkey eggs have been preyed on by Dingos (Gould 1865), Pigs *Sus scrofa* and snakes (North 1912). Monitors (Varanidae) are by far the most important (see Kaveny 1958; Dow 1980) although no estimates of egg losses are available. In other megapodes, monitors account for losses of 10-20% in *Macrocephalon* (MacKinnon 1981) while the mounds of both *Megapodius* and *Talegalla* are frequently excavated by these reptiles (Ripley 1964; Lincoln 1974). In Malleefowl, Frith (1959) found that Foxes accounted for 37% of egg losses, although Booth (1987) and Brickhill (1986) found that Foxes were of marginal importance. However, though such losses to individual mounds may be heavy, they rarely represent the loss of the entire clutch. As pointed out by Vleck *et al.* (1984), the utilisation of external heat sources for incubation greatly extends the breeding seasons, which minimises the predation risk by spreading the clutch over a period of several months.

The absence of predation of Australian Brush-turkeys eggs in this study, and of Malleefowl eggs in Booth's (1987) study, led to high hatching successes in both species. This was probably related to a lack of egg predators within the sites in which both of these studies were undertaken. At Mt. Tamborine the common monitor *Varanus varius* is virtually absent from closed forest and Dingos, though present, are very rare. In dryer habitats nearby, Dow (1980) frequently noted mound defence by Brush-turkeys against monitors and suggested that this was a normal reaction by the species to potential mound predators. Mound defence was not detected in my study population, and this may imply that interspecific interactions with nest predators have been rare events in the study site for some time.

By far the greatest mortality is suffered by chicks following emergence. Australian Brush-turkey neonates arrive at the surface of the mound after 20-30 h (Baltin 1969) or 2.7 days (Vleck *et al.* 1984) of digging through the mound material. They emerge in a visibly exhausted state and must immediately seek shelter and food. They receive no assistance from adults (pers. obs.; Skutch 1976) and are undoubtedly highly vulnerable to predation. Unfortunately, there are no other estimates of post-emergence

mortality rates for megapodes with which to compare the rates of 90-97% determined here.

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## Notes on the Food and Feeding Habits of Cormorants on a Tropical Floodplain

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Ecological aspects of feeding in the Little Pied Cormorant *Phalacrocorax melanoleucos* and the Little Black Cormorant *P. sulcirostris* have been well documented for populations inhabiting temperate Australia. Studies by McNally (1957) in Victoria and McKeown (1944), Vestjens (1977) and Miller (1979) in inland New South Wales reveal the environmental separation of the two species as a result of differences in feeding habits, foraging behaviour and habitat preference between the species. In summary, individual *P. melanoleucos* hunt solitarily in the shallow margins of waterbodies and feed predominantly on decapod crustacea and aquatic insects. *P. sulcirostris*, in contrast, usually feeds co-operatively in open water, and ingests mainly fish. However, the feeding habits of these cormorants in tropical Australia have not been reported.

This note presents results of stomach analyses of small samples of *P. melanoleucos* and *P. sulcirostris* collected on a tropical wetland in the Alligator Rivers Region of the Northern Territory, 250 km east of Darwin. The samples were collected from the Magela floodplain, a freshwater basin that is filled during the wet season by the Magela Creek. Conditions on this floodplain differ from those of most others of the Region in that large areas remain inundated throughout much of the dry season. Both species of cormorant tend to be more abundant there during the dry season, probably as a result of movement of birds from other floodplains of the Region as these dry out. Systematic ground-counts from 1981 to 1984 provided estimates of mean densities for the Little Pied Cormorant of 0.7 km<sup>-2</sup> (wet season) and 2.9 km<sup>-2</sup> (dry season), and for the

Little Black Cormorant of 1.0 km<sup>-2</sup> (wet season) and 2.4 km<sup>-2</sup> (dry season) (S.R. Morton, K.G. Brennan & M.D. Armstrong, unpubl. data). Despite similarities in the mean densities, Little Black Cormorants occurred more sporadically but in larger aggregations than did Little Pied Cormorants.

### Methods

Ten *P. melanoleucos* and 11 *P. sulcirostris* were collected by shooting on the Magela floodplain approximately 15 km north of Jabiru, N.T. The birds were collected by use of an airboat during the early dry season. Two specimens of *P. melanoleucos* were collected on 16-22 June 1982, seven on 6-29 July 1983, and one on 5 August 1983. All specimens of *P. sulcirostris* were collected between 4-29 July 1983.

On return to the laboratory, each bird was weighed, the culmen, gape, wing, tail and tarsus were measured and the stomach contents removed and stored in 70% ethanol. Stomach contents were later sorted and identified in a Petri dish and using a Wild M3 binocular microscope. If necessary, fish specimens were identified from scale morphology using known reference material. The length of each organism was measured to the nearest 0.1 mm using calipers. Fish length was taken as being length from the anterior-most part of the skull to the caudal fork. Where fish were partially digested, length was estimated using regression equations developed by the authors based on width of caudal base, or length of pectoral spine (plotosids). Lengths of fragmented invertebrate types were calculated from body dimensions (e.g. head width, carapace length) using appropriate regression equations. Dry weights were calculated using log transformed length-weight regression equations (Dostine unpubl.) Fish taxonomic classification follows that used by Bishop *et al.* (1986).