Corella, 2022, 46: 1-6

Foraging and reproductive behaviour of the Dusky Megapode in Halmahera, North Maluku, Indonesia

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Received: 14 April 2021
Accepted: 20 December 2021

Dusky Megapodes, *Megapodius freycinet* occur in Southeast Asia, but their foraging and reproductive behaviours are very poorly known. The aim of this research was therefore to document some aspects of these traits in the wild. The study was conducted in Halmahera, Indonesia at Simau from July-August 2014 and Tabadamai from January-May 2015. Qualitative observations and focal sampling were performed from 06.30-16.00 daily to document the behaviour repertoire and construct time-activity budgets. Vocalisations were also recorded and data on the nest mound environment, egg morphometrics and the characteristics of vocalizations were collected. Megapodes foraged on the forest floor by raking the leaf litter for insects and fruit with their feet. In Simau village foraging was the dominant diurnal behaviour, whereas in Tabadamai village, where observations were made during the breeding season, nest-hole digging for egg laying was more prominent. Nest mounds, composed of soil, leaf-litter and bark collected from the immediate neighbourhood, were found in lowland forest and were ~0.5 m tall and 5-6 m in diameter. In active mounds, sub-surface soil temperatures were 26-40ºC and relative humidity was highly variable (10-80%). Light intensity at the surface of active mounds ranged from 242-1,787 lux. Egg length and maximum width were 8-10 cm and 3-4 cm, respectively, and egg mass was 75-110 g. Five distinct vocalizations were identified, including contact, alarm and stress-induced calls. This basic information should assist in the conservation of the species, which is subject to hunting and habitat reduction pressures.

Keywords: Dusky Megapode; time-activity budget; vocalizations; nest mound characteristics; egg size.

INTRODUCTION

The Dusky Megapode, *Megapodius freycinet* (Gaimard, 1823) (Fig. 1) has a restricted distribution, being found only on some islands in the northern Moluccas to the west of West Papua, including Halmahera (Jones *et al*. 1995). In the IUCN Red List, this species is placed in the Least Concern category, but due to its limited distribution its status could potentially decline rapidly (BirdLife International, 2016). The Moluccan Scrubfowl, *Eulipoa wallacei*, which is endemic to the Moluccas, also occurs on Halmahera (Irham 2012) and is considered a vulnerable species (Whitten *et al*. 2005). Sofyan (2001) found that the Dusky Megapode population in forest on Masiman Island, Papua, comprised only 0.48 individuals/ha (i.e. 144 individuals in 298.8 ha of forest), with a nest density of 0.06/ha. The main factor limiting its population size in that location was human hunting for its meat and eggs. Our study was carried out in Simau and Tabadamai villages in North Maluku Province, Indonesia and its aim was to document aspects of the species' little-known foraging and reproductive behaviour, vocal repertoire and nest mound characteristics, with the hope that this basic information could contribute to conservation of the species.

Figure 1. *A young Dusky Megapode foraging by scratching with its feet.*

METHODS

Behaviour sampling

The research was conducted for 3 weeks and 11 weeks, respectively, near the villages of Simau (1.8461ºN, 127.8353ºE) and Tabadamai (0.7734ºN, 127.6865ºE), Halmahera (Fig. 2). Every day during the study, observations of behaviour were conducted during a 9.5 h period from 06.30 to 16.00 Eastern Indonesian Time (UTC + 9). They were carried out close to the birds, but from concealment behind a pile of coconut palm fronds or the leaves of other large-leaved plants because the megapodes were very sensitive to human presence. Two kinds of observation were conducted: (a) the general behaviour patterns of all megapodes visible were qualitatively recorded on an *ad libitum* basis and an ethogram constructed to summarise the observed repertoire, and (b) focal animal sampling (Altman

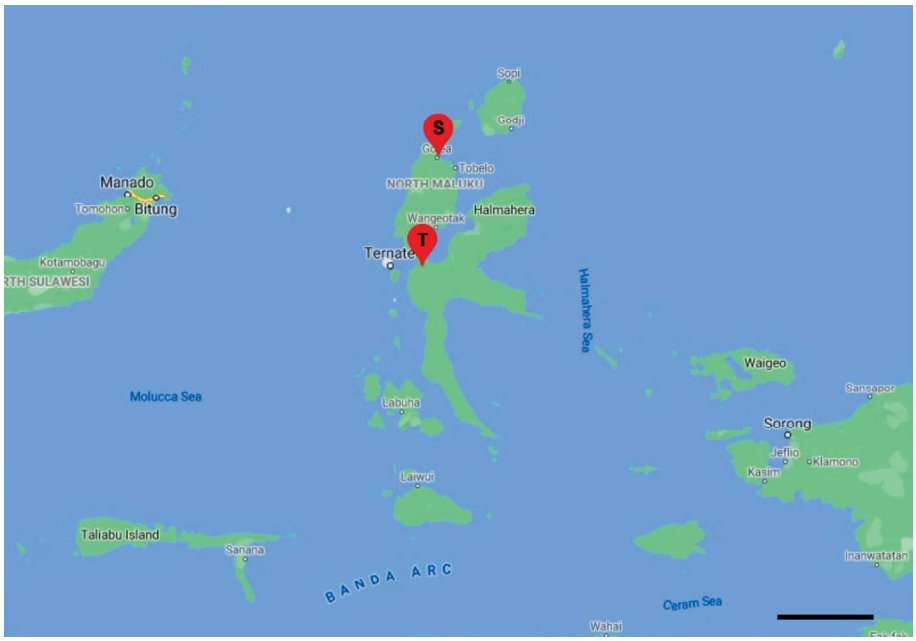

Figure 2. *Map of Halmahera island in North Maluku, with labels indicating locations of Simau (S) and Tabadamai (T) villages. Map generated using Google Maps. Scale bar = 100 km.*

1974) was conducted on certain individuals or pairs that we could keep track of visually to quantitatively describe the daily time-activity budget. In the latter observations, the frequency and duration of all behaviours were measured during continuous recording (Lehner, 1996). Based on preliminary observations, the behaviour of the megapodes was grouped into three main categories: foraging, nesting and other behaviours (walking, vocalizing, observing or vigilance, autopreening, chasing and foot-pecking). Foraging behaviour involved scratching at the substrate and pecking at any food encountered. Nesting behaviour involved the birds digging holes in the mound and laying eggs in them.

Physical characteristics of nest mounds and eggs

The physical properties of the constituent soil (temperature, pH and relative humidity) of all nest mounds found in the forest were measured. Nest mound temperature (± 1°C) was measured with a soil thermometer, relative humidity with a hygrometer (± 1%) and pH using a soil testing kit. These measurements were made approximately 10 cm below the soil surface at three locations in each nest mound, namely the peak and the left and right sides of the mound. Light intensity (± 1 lux) was measured on the surface of the mound with a light meter, but not at the same time of day at each mound. We also documented the most dominant vegetation around the nest mound using the Important Value Index (Parmadi *et al*. 2016). This index was essentially derived by comparing the relative densities and relative frequencies of occurrence of each of the various vegetation components present within 10 m of the mound. Nest mound dimensions (± 0.1 m) were also measured, namely the diameters of the mouth and of the entire mound, and mound height (Fig. 3). Eggs were approximately 50 cm from the nest mouth surface and were vertically orientated (i.e. length perpendicular to the ground surface). Egg length and maximum width (± 0.1 cm) were measured with calipers and egg mass (± 1 g) with a digital table scale.

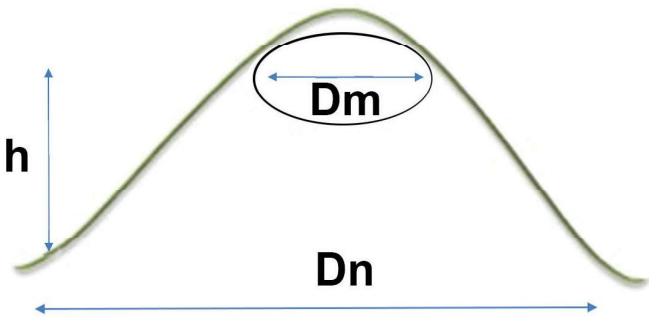

Figure 3. *Nest dimension measurements: Dm – Mouth diameter, Dn – Mound diameter, and h – height.*

Vocalizations

Megapode vocal behaviour during forest floor activity and on upon capture in a bird trap and temporary placement in a cage were recorded using a digital video camera (Sony Cybershot DSC-W530 with 14.1 MP resolution) and a tablet sound recorder (Samsung Tab 3 8 inch). The vocalizations were then analysed using Avisoft-SASlab Lite sound analysis software, which enables sound syllable types to be identified and syllable and inter-syllable durations to be examined.

Data analysis

Kruskal-Wallis non-parametric one-way analyses of variance were used to examine variation in the frequency and duration of the various behaviours comprising the time-activity budget at each study site.

RESULTS AND DISCUSSION

Behaviour repertoire and time-activity budgets

We spent 199.5 hours in the field at Simau village, but Dusky Megapodes were only present for a very small fraction of this

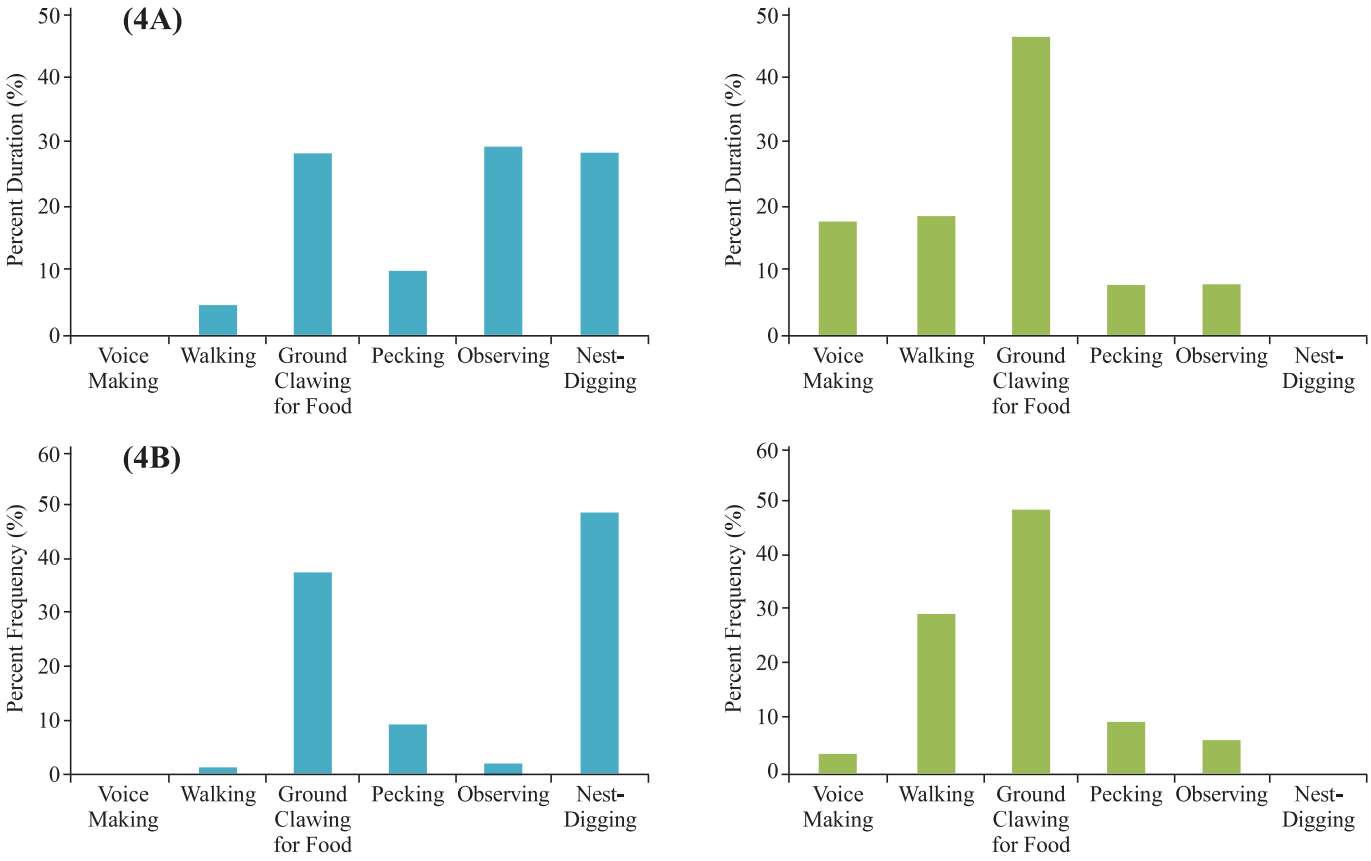

Figure 4. *Time-activity budgets of megapodes at Tabadamai (blue) and Simau (green) villages expressed in terms of mean percentage of: (A) observation time occupied and (B) total number of behaviours observed.* Observing = vigilance and Voice-making = vocalizing.

time; similarly, at Tabadamai village we spent 608 hours in the field, but Dusky Megapodes were only present for 1.46 hours. During the study period at Simau village from July to August 2014 the number of megapodes encountered ranged from an estimated two to five per day; from January to May 2015 at Tabadamai village the estimated daily range was from two to ten individuals. These low encounter rates suggest that Dusky Megapode densities were very low, possibly partly because the locations used for this study were in community plantation areas which have high human disturbance levels.

Not surprisingly, Dusky Megapodes at both locations engaged in some activities significantly more than others (Simau: behaviour duration H = 9.51, behaviour frequency H = 12.144; Tabadamai: behaviour duration H= 12.76; behaviour frequency H= 10.40; P in all cases <0.05) (Fig 4 a, b). Simau birds appeared to spend more time searching for food, and possibly walking, than on any other activity, whilst Tabadamai megapodes appeared to spend more time on nest digging, searching for food, and possibly vigilance (observing) than on any other behaviour. The main difference in time investment between the two locations (more food searching at Simau and more nest-digging at Tabadamai) obviously stemmed from the fact that observations at Simau were made during the non-breeding period when there were no active nests and focused solely on foraging areas, whereas the Tabadamai observations were made during the egg-laying period when there were 19 active nests at this site and the observations were conducted in both nesting and purely foraging areas.

Dusky Megapodes foraged by raking the leaf-litter on the ground with their claws, searching for invertebrates (e.g. worms, ants and termites) and fruit. When feeding on ants and termites, the birds typically only pecked a few times at the target item and then immediately ingested it, whereas when consuming worms they pecked the worm several times and bashed it on the ground until it was paralyzed, before ingesting it. Simau birds mainly foraged on the forest floor, but Tabadamai birds also foraged in the local plantation area and around their nest mounds. These observations are consistent with the findings of Ahmad (2013), who mentioned that the feeding areas of these megapodes are in both their nesting areas and lowland tropical forest. Although Dusky Megapodes foraged throughout the day, time-activity budgeting indicated that this behaviour was more prominent in the morning (from the beginning of sampling at 06:30 to approximately 10:00), which is not surprising given that these diurnal birds must fast overnight. The male and female of a breeding pair mostly foraged about 1-3 m apart.

At both study sites, the activity regime of megapodes included bouts of vigilance behaviour ('observing') which involved visual monitoring of their surroundings. This activity comprised an apparently much greater proportion of the time-activity budget at Tabadamai (29.2 ± 7.2%) than at Simau (8.1 ± 0.9%), probably because birds at the former site were particularly sensitive to disturbance by villagers visiting community plantations close to their nest mounds. We observed that in their nesting areas the Tabadamai birds temporarily ceased vocalizing and nest-hole digging and became vigilant

Figure 5. *A Dusky Megapode nesting mound in the study area. The nest mouth is clearly evident.*

even at the sound of moving vegetation. On average, Tabadamai megapodes also apparently allocated less time to locomotion (walking) (4.7 ± 1.3%) than Simau birds (19.0 ± 2%), probably because the adults spent considerable time digging at the nest and many of the birds were young and tended to forage near the nest site rather than at more distant feeding areas. Dusky megapodes at Tabadamai spent, on average, 45-50% of daytime in nest-digging activity, typically working as a pair back-to-back or side-by-side only 0.5–2m apart.

Nest and egg characteristics

Most nests were under a large tree or on a hill and were mounds of soil and litter with an exposed top, which is a typical of megapodes (Dekker *et al*. 2000) (Fig. 5). They resembled those of another megapode, the Maleo, *Macrocephalon maleo* (Pattiselano *et al*. 1999). Nests were found in lowland forests at altitudes of 33-231 m above sea level and nest-building material was mainly the vegetation litter in the immediate area. Four main species of plants occurred in significant volumes around nests (Table 1); the only differences in the surrounding vegetation between active and inactive nests were the presence of Rattan, *Calamus mannan* near active mounds and Banana, *Musa paradisiaca* near inactive ones, but this may have been coincidental.

Nests of several Dusky Megapode pairs were often built close together e.g. at the base of a large tree trunk on the river bank, in proximity to tree buttress roots, and on a collapsed tree. Most nest mounds were under vegetation with a moderately dense canopy, which was probably important in controlling the degree of incoming sunlight so that an appropriate soil moisture content was maintained for egg incubation. Typically, forest floor vegetation was absent around a nest due to the digging activity of the breeding birds. Nest mounds were ~ 0.5 m tall and ~ 5-6 m in diameter, the nest mouth being ~ 2+ m wide (Table 2). The mean height, diameter and nest mouth diameter of active and inactive mounds were similar, but inactive mounds tended to be on more sloping terrain.

Mounds constructed on sloping ground tended to be taller, but smaller in diameter, than those on flat ground. We suspect that Dusky Megapodes have difficulty constructing mounds on sloping ground. The size and number of nest holes in a mound probably change frequently as the nesting birds open and close nest holes. Mounds were composed of litter, soil, and bark. Leaf-litter from the surrounding area was collected and piled up, which facilitated the process of decomposition while maintaining temperature stability in the nest. According to Jones *et al*. (1995), the heat source for megapode incubation is generated by microbial respiration during the decomposition of organic materials, combined with solar radiation. However, each mound has distinctive temperature characteristics, which depend on the vegetation surrounding the nest, the building material used and the 'texture' of the nest.

The sub-surface soil temperature ranges recorded for active and inactive mounds of Dusky Megapodes were 26-40ºC and 26-35ºC, respectively. These ranges were a bit broader than those reported for this species by Sofyan (2001) in Papua (28-30ºC), but closely resembled those reported for other megapode species (28-35ºC; del Hoyo *et al*. 1994). The relative humidity of the soil in active and inactive nests (n= 23 measurements at 19 nests) varied widely, from 10-80%. Soil pH ranged from 6.0 to 7.0, which is in the neutral range (Purwowidodo 1998). Light intensity at inactive and active nests ranged from 170-1,969 lux and 242-1,787 lux, respectively. The greater maximum light intensity at inactive mounds probably stemmed from the fact that they were in coastal areas where canopy vegetation around nests was less dense. The difference between the physical characteristics of active and inactive mounds was presumably partly due to the inactive ones having been abandoned and not maintained. Hence, not surprisingly, inactive mounds were not quite as tall as active ones and their maximum sub-surface soil temperatures were lower; their maximum surface light intensities were also lower, probably because the surrounding vegetation had grown and shaded the nest.

Table 1

Plant species immediately adjacent to nest mounds.

Nest status		Plant species	Important value index (%)
Active	Bahim	*Hornstedtia scottiana*	26.1
	Rattan	*Calakmu manan*	15.3
	Woka	*Chivistora altissima*	12.1
Inactive	Woka		21.5
	Banana	Musa paradisiaca	19.3
	Bahim		18.6

Table 2

Dimensions of megapode nest mounds. All measurements in metres. In each cell, upper row indicates the range and lower row the mean.

Nest status	Number of nests	Height	Nest mouth diameter	Mound diameter	Slope
Active	11	0.4-2	1.1-4.3	3.3-7.8	2-4.6
		0.5	2.6	5.3	3.4
Inactive	8	0.5-1.7	1.1-3.4	3.8-9.4	1.6-5.3
		0.4	2.3	6.1	7.3

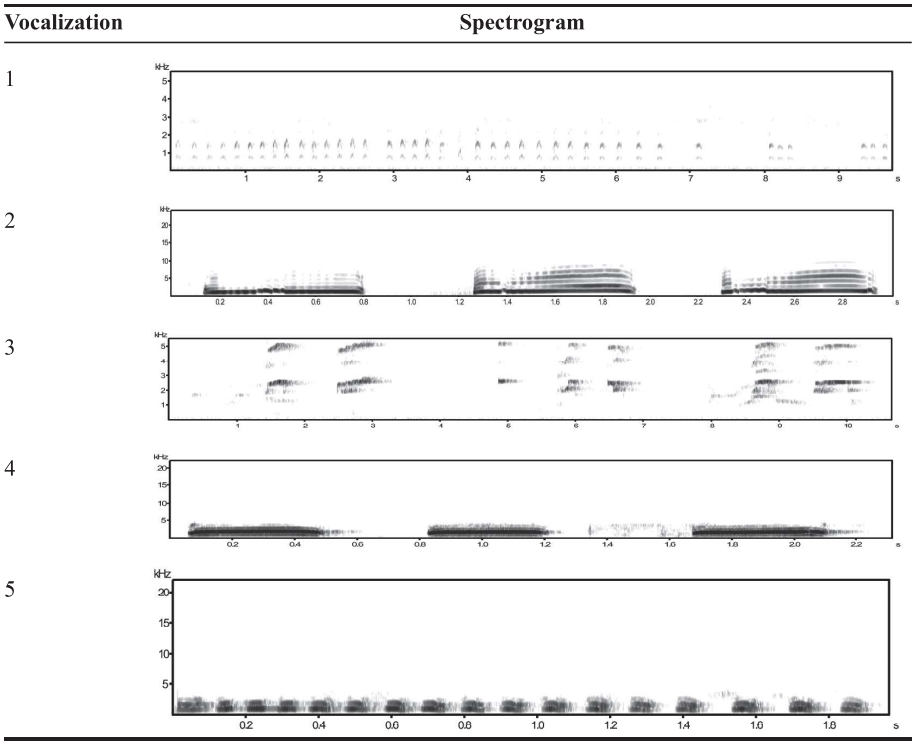

Figure 6. *Sound spectrograms of Dusky Megapode vocalizations. Y axis in Kilohertz and X axis in seconds.*

We could measure only four Dusky Megapode eggs. The ranges in size for three eggs in good condition were: length 8-10 cm, maximum width 3-4 cm and mass 75-110 g. A single addled egg weighed 260 g, but this overweight is due to the excessive moisture in the unmaintained nest, resulting in water infiltration of the egg (Dekker 1988).

Vocalization patterns

Vocalizations occurred when the members of a megapode pair were either together or apart. When apart, the two birds answered each other's calls. One parent typically made a distinctive sound like a person gargling water that sounded like "kee-ourrrr" repeated, whilst the other parent replied with a loud vocalization that sounded like "ki-ouw-kouw ". Another sound emitted by the supposed female bird when the pair were close together sounded like "kek-kek-kek" or "kuk-kuk-kuk". Wallace (1869, cited by Dekker *et al*. 1995) also described megapode vocalisations sounding like " kuk-kuk-kuk " and "ki-ouw-kuow", which he ascribed to either the Dusky Megapode or Forsten's scrubfowl, *Megapodius forstenii*; the latter bird is probably *M. freycinet*, the species in the present study, as the taxonomical name is disputed. Figure 6 presents sound spectrograms of the vocalizations recorded in the present investigation.

The contexts in which the various vocalizations illustrated in Fig. 6 were given were as follows:

Vocalization 1: Recorded in Simau village for ~156 secs. This vocalization was given by a megapode in the morning when it was actively foraging. The sounds were emitted when the bird saw the concealment spot that we used for observation at the feeding location. It is assumed that this was an alarm signal that alerted other individuals within about 2 m. The sounds were produced while looking around the concealment spot, and then the bird ran away from the foraging location. However, the next day the presumed same individual returned to the same location to forage.

Vocalization 2: Recorded for only ~ 25 secs and given by a bird caught in a trap set by Simau villagers. It is not known whether the bird was male or female.

Vocalization 3: Recorded for ~ 300 secs. This vocalization was given when the members of a pair were moving in different directions. It is suspected that the two birds were going to forage in different locations during the morning and the vocalisations may have enabled them to remain in contact when not together (i.e. it was a contact call). However, the sound produced by the two individuals was different; one made a very loud, repetitive sound, whilst the other responded with a different tone but with the same syllabic pattern. Momanto (2009) states that in the Maleo a similar vocalization informs the members of a pair where their mate is or is an alarm call. Seibt and Wickler (1977; cited by Goth *et al*. 1999) reported a synchronized pair duet in the Polynesian Megapode, *Megapodius pritchardii* which we did not record in the present study.

Vocalizations 4 and 5: Recorded in Tabadamai village when a megapode was caught in a trap. This bird made a very loud and repetitive call, which we think was probably the result of being stressed. Conceivably it functions to communicate alarm to other birds in the area or deter the captor if it is a natural predator. The bird was clearly stressed, to the point where it refused to eat the food available in the trap.

Conservation perspective

In the study area, the Tabadamai villagers used to hunt the Dusky Megapode for its meat and eggs and consequently it may be difficult to persuade the villagers of the need to conserve this species. The expansion of their plantations has also led to destruction of habitat used by the megapodes. Conceivably a captive breeding program could restore populations of this species, but it may be difficult to gain support for it and it would be costly. However, it is hoped that the basic information on the bird's behaviour and breeding biology presented here may prove useful in any attempts to conserve this species.

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