

Host tree canopy isolation by nesting Sri Lanka Drongo *Dicrurus lophorinus*

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The endemic Sri Lanka Drongo *Dicrurus lophorinus* nests in trees and is known to use the same host tree for several years. Here we describe a previously unknown behaviour of this species, in which it actively eliminates canopy contact between the host tree and adjacent trees, and attempts to reduce the roughness of the main trunk of the host tree to create a barrier to isolate the canopy from below. We believe that this behaviour has evolved to protect nests from non-avian (particularly nocturnal) predators by limiting access to the host tree, as it eliminates pathways for them from adjacent tree canopies and makes it more difficult for them to approach from below. Through extensive canopy pruning activities, the Sri Lanka Drongo maintains the isolation of the canopy of the host tree, significantly altering the microhabitat and enabling it to re-use the tree for several seasons.

INTRODUCTION

Predation pressure has influenced the evolution of diverse nest architecture and nest placement and related life-history traits in birds. Many bird species seek protection by placing their nests in cryptic sites, on sheer cliffs or inside caves, while some nests are protected by being surrounded by water (Gill 2007). A diverse group of birds nest in out-of-reach sites such as the ends of long, thin, high branches which most climbing predators (e.g. snakes and rodents) cannot reach (Winkler 2016). It has been suggested that some tropical birds nest in isolated trees with no vines or canopy contact in order to avoid predation by snakes and monkeys (Snow 1976). Similarly, the reason some accipitrid raptor species use isolated host trees is thought to be as a defence against monkeys and other nest predators (Thiollay 1994).

The endemic Sri Lanka Drongo *Dicrurus lophorinus* inhabits the forests of the south-west wet zone of Sri Lanka (Henry 1998, Rasmussen & Anderton 2012, del Hoyo & Collar 2016). It is similar in body size to the Greater Racket-tailed Drongo *D. paradiseus*, found in the dry zone of the country as well as in India, but differs in lacking a pair of long, bare-shafted rackets in the tail and having a smaller nasal crest (Rasmussen & Anderton 2012, Warakagoda *et al.* 2012). The Sri Lanka Drongo (hereafter the drongo) is considered a nuclear species in mixed-species feeding flocks in the island's rainforests (Henry 1998, Kotagama & Goodale 2004) and is well known for its repertoire of calls and mimicry (Legge 1983, Henry 1998, Goodale & Kotagama 2006a,b, Goodale *et al.* 2014a,b).

Although the species is locally rather common and easily observed in its preferred habitat, data on its breeding habits are limited. Nests were documented and described by Henry (1946, 1998), Wijemanna (1993), Hoffmann (1995) and Hettige (2000). Most recently, Goodale *et al.* (2014b) surveyed and documented 37 nests on 14 nesting trees over two breeding seasons in the Sinharaja World Heritage Reserve, Kudawa (hereafter Sinharaja), and showed that the species nests on generally isolated trees in forest openings and re-uses the same host tree.

During February–March 2015, in the Deraniyagala area, Sabaragamuwa province, we observed the drongo pairs at two nests regularly tearing and stripping off leaves from both the host tree and the adjacent trees (hereafter 'leaf-stripping'), and removing loose bark and epiphytes from the trunks of the host trees (hereafter 'trunk-cleaning'). At another nest site in Sinharaja we noted damage to the host tree and the foliage of surrounding trees which we considered attributable to similar behaviour. In order to determine whether this behaviour was common, and hoping to determine its purpose, we studied the species's nesting behaviour during two breeding seasons, January–May 2016 and 2017.

METHOD

Study area

Deraniyagala lies in the western foothills of the central massif, in Sri Lanka's wet zone (6.936°N 80.338°E). The area consists mostly of villages, tea and rubber plantations, and abandoned land with secondary growth forests. The protected primary rainforests of Makandawa Forest Reserve and Peak Wilderness Sanctuary lie north and east of the area respectively. Three nest sites, D1–D3, were located between 140 and 230 m.

Six nest sites, S1–S6, were studied at Sinharaja (6.443°N 80.420°E), in the northern foothills of Rakwana massif, also in the wet zone. The nest sites here were located between 335 and 527 m. Two more nest sites, R1 and R2, were located in Morapitiya-Runakanda Proposed Forest Reserve (6.457°N 80.324°E) in the contiguous rainforest north-west of Sinharaja, at 128 and 156 m respectively.

The habitats in which the nest trees were located varied: well-wooded home gardens, secondary growth in cultivated and abandoned land, natural and man-made forest clearings, forest edges and streamsides. All three sites in Deraniyagala and two sites in Sinharaja, S3 and S4, were close to human habitation, four of them lying next to roads and the other near a house. The other four sites in Sinharaja were in previously logged forest, two of them (S1 and S2) in a fairly well regenerated area, and the two sites in Morapitiya-Runakanda were along streams in relatively intact rainforest.

Measurements of host trees and habitat

A total of 11 nest sites were observed in this study. Six were monitored in 2016 and followed up in the next season, and another five sites were added during 2017. With use of the host trees in subsequent seasons, 18 breeding attempts were observed, including attempts in the 2015 season (nests D1, D2 & S5). Sometimes a new nest was built in a different location in the same tree if the first one was destroyed; thus 20 nests were measured, but the two replacement nests were both counted as part of a single breeding attempt.

Details of the nesting habitat, including surrounding vegetation and approximate height of undergrowth, were recorded. The full height and girth-at-breast-height (GBH) of trees within 10 m of the host tree were measured. Host trees were identified to species, and their height, GBH, canopy radius (average of three measurements in three different directions) and height of the lowest branch were measured. The position of the nest in the branches, plus its height and distance from the main trunk, were also recorded. A laser range-finder was used to measure heights to the nearest 0.5 m.

A metre tape was used for horizontal distances correlating the positions at ground level, with measurements taken to the nearest 10 cm.

Observations of leaf-stripping and trunk-cleaning

The 20 nests were at one of three stages when discovered: under construction, incubating, or with nestlings. Except at site D1 (see below), they were observed for 1–3 hours per site per season, at a random time of day between dawn and dusk (06h00–18h00). Attempts were made to find and observe nests during the early stages of construction, as it was quickly apparent that the stripping and cleaning behaviour occurred mainly during this period. Observations were made from a distance using binoculars, and close-up images and videos were taken using a DSLR camera with 500 mm lens and 1.4x teleconverter.

At each nest site we identified the part of the canopy of each adjacent tree of more than 20 cm GBH within a 10 m radius circle that was closest to the canopy or emergent trunk of the host tree, and visually assessed the distance between them to the nearest 0.5 m. A total of 151 such measurements were analysed. We noted leaf-stripping in the host tree, adjacent tree(s), or both, at or near these points, either by direct observation or via evidence such as the presence of leafless branches, damaged leaves or fresh leaves on the ground. If leaf-stripping had occurred in several locations in an adjacent tree, only the single location closest to the host tree was considered. Creepers on an adjacent tree were considered part of that tree and not as separate entities. All the above measurements were taken at each site during one breeding season, after nesting activities were concluded.

Changes in the frequency of stripping and cleaning behaviour

Site D1 was extensively observed during 2015 and 2016 and to a lesser extent in 2017 as part of a separate study to document other aspects of the drongo's breeding biology. In 2016 at site D1 we attempted to quantify the time spent by each partner on isolating the canopy and how it differed during the three nesting stages. We undertook day-long watches at all three stages of the nesting process. At each stage we observed for two days, day 1 during the early part of the stage and day 2 during the latter part. We noted all attempts at leaf-stripping and trunk-cleaning, plus their duration and which member of the pair was involved (told apart because the D1 male, observed mating, had an aberrant tail with bare-shafted outer rectrices). The first nest was destroyed during incubation, so the second clutch was used for data on the latter half of incubation and on the nestling stage. Additionally, time spent on nest-building (excluding time spent on collecting nesting material) by both sexes was recorded.

RESULTS

Nest sites, host trees and location of nests

All 11 nest sites were in well-wooded areas but without a thick intact canopy. The number of trees >20 cm and >50 cm GBH within a 10 m radius averaged 13.7 ± 3.5 (range 7–19) and 5.2 ± 2.5 (range 1–9) respectively.

All the host trees were medium to large trees with a narrow form (Figure 1, Table 1). Host tree species were four *Alstonia macrophylla*, two *Pometia pinnata*, one each of *Shorea trapezifolia*, *Vernonia arborea*, *Vateria copallifera* and *Terminalia zeylanica*, plus one unidentified species. The canopies of these host trees did not touch those of adjacent trees and were devoid of creepers and lianas. Six of the host trees were shorter than other trees within the 10 m radius, and two were overshadowed by the canopies of much taller

Figure 1. Schematic diagram of an average host tree depicting undergrowth height and nest location, drawn to scale according to mean values (site R2 host tree not considered for height of first branching and length of bare trunk); a = GBH; b = tree height; c = canopy radius; d = undergrowth height; e = height of first branching; f = length of bare trunk; g = nest height; h = distance from main trunk to nest.

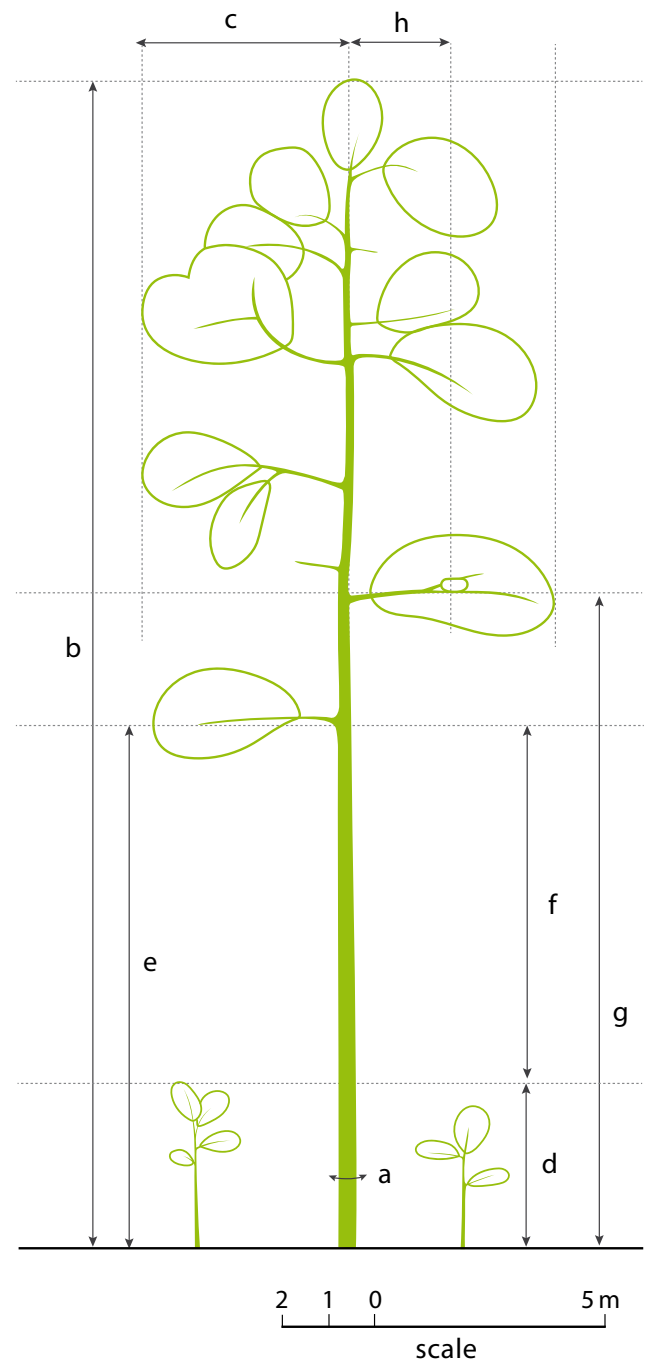


Table 1. Mean and range values of host tree parameters and nest placement. (*Site R2 host tree not included.)

Parameter	Mean	Range	
a	GBH (cm)	117.3 ± 33.6	68–175
b	Tree height (m)	25.2 ± 8.2	15–39
c	Canopy radius (m)	4.4 ± 1.5	2.6–7.5
d	Undergrowth height (m)	3.3 ± 2.9	0.5–10.5
e	Height of first branching* (m)	11.2 ± 5.0	3.5–21
f	Length of bare trunk* (m)	8.6 ± 4.5	3–18
g	Nest height (m)	13.9 ± 5.9	6–23
h	Distance from main trunk to nest (m)	2.3 ± 1.2	0.7–4.5



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Plate 1. *Alstonia macrophylla* host tree at site S6 in logged part of the forest (left) and *Pometia pinnata* tree at site D2 in a home garden (right).

trees. Thus the only contact which the host tree canopies had with the ground or undergrowth vegetation was via the main trunk. All host trees but one had unbranched main trunks emerging from the undergrowth and these trunks rose well clear of the undergrowth before their first branches separated (Plate 1). The site R2 host tree had a single branch at undergrowth level but above that an unbranched trunk emerged, as in the other trees.

The nests were flimsy cups, circular to roughly triangular in shape, hung from two small branches in a fork, located on a tertiary branch or beyond. Vertically, all nests were located in the lower part of the canopy (apart from the R2 tree), and horizontally they varied from being close to the main trunk to near the outer edge of the canopy.

Observations of leaf-stripping

The drongos used their bills to strip off leaves from small branches of the host trees and the adjacent trees. Small leaves were broken from their stems and larger leaves were torn off piece by piece (Video 1). Young buds and shoots were chewed and destroyed. The broken or torn leaves were not carried away but were allowed to fall. This leaf-stripping was observed exclusively on peripheral branches where the canopies of the host tree and an adjacent tree came into contact or near-contact. As a result, the foliage of either or both the host tree and the adjacent tree was damaged. Leaf-stripping was not limited to areas close to the nest but seen all round the host tree. The emerging shoots and branches of undergrowth that grew towards the exposed main trunk or lower branches of the host tree were also damaged in the same way (Plate 2). This behaviour was directly observed at five nesting sites (D1–D3, S1 and S5) and during nine breeding attempts. However, evidence of the behaviour was found at all 11 sites, involving 18 breeding attempts.

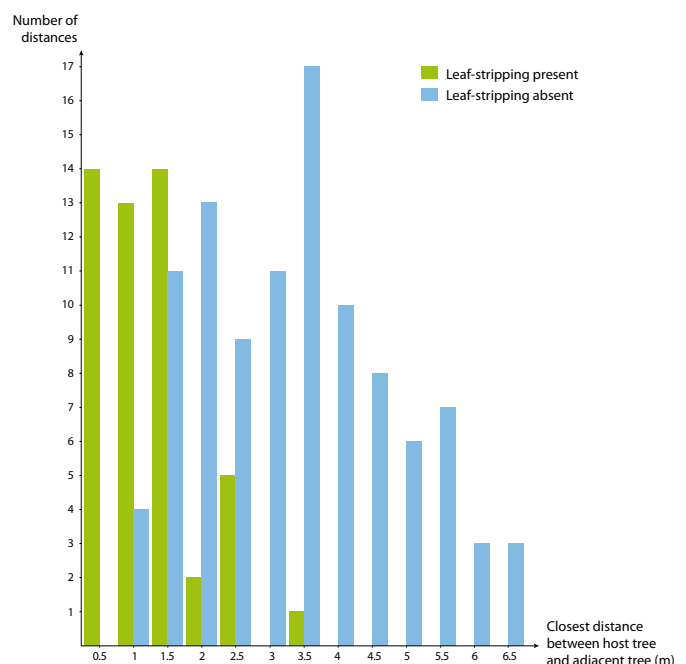
Of the 151 measurements obtained (see above), leaf-stripping was evident at a host tree's closest point, at an adjacent tree's closest point, or both, in 49 cases. These were clustered closely around the host tree, with 84% of them occurring when the distance between a host tree and an adjacent tree was less than 1.5 m. Leaf-stripping was evident in all cases up to 0.5 m, 76.5% of cases when the distance was between 0.5 and 1.0 m, and 56% when the distance was 1.0–1.5 m. Beyond 1.5 m, occurrence of leaf-stripping diminished further and



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Plate 2. Female Sri Lanka Drongo *Dicrurus lophorinus* at site D1 perched on an *Amomum* stem with leaf blades stripped off and one in her bill, Deraniyagala, Sabaragamuwa province, Sri Lanka, 4 February 2015.

Figure 2. Occurrence of leaf-stripping in relation to distance between a host tree and an adjacent tree (measurements under 0.5 m include several undergrowth trees that were touching the host tree trunk from below—thus at a distance of 0 m).



was not evident when the distance between a host tree and its nearest neighbour was more than 3.5 m (Figure 2).

Observations of trunk-cleaning

The drongos used their bills to break off pieces of loose bark and to remove mosses and lichens from the host tree trunks. This activity was carried out on the main trunk of the host tree between the points where it emerged from the undergrowth and where the first branching occurred. At site R2, evidence of this behaviour was seen in the emergent segment of the trunk between the first and second branches. The birds moved around the trunk, pecking and scraping it while hovering for a few seconds (Plate 3, Video 2). Sometimes a bird perched vertically on the trunk like a woodpecker, splaying its tail for support, and cleaned the trunk for up to three minutes at a time (Plate 4, Video 2). Trunk-cleaning was directly observed at five nest sites (D1–D3, S1 and S2) during nine breeding attempts. Evidence was also clearly found on two other host trees (R1 and R2), where the clean smooth trunk contrasted with the rough areas with mosses, lichens and loose bark above and below the emergent part of the main trunk (Plate 5). However, on trees with smooth bark in more open habitat (S3–S6), it was difficult to detect unambiguous evidence of this behaviour.

Occurrence of stripping and cleaning behaviour

During observations at site D1, both leaf-stripping and trunk-cleaning activities were highest during the early nest-building period and seemed to decrease thereafter. However, increased activity was observed in the latter part of the incubation stage in 2016, following the destruction of the initial clutch; stripping and cleaning activities greatly decreased once the eggs hatched. In general, the female drongo was more active than the male, who surpassed her only in trunk-cleaning activities during the latter part of the incubation stage. Stripping and cleaning activities were highest during the morning and evening hours.

The D1 pair spent a significant proportion of time in stripping and cleaning activities in comparison to the time invested in nest-building. During the early part of the nest-building stage the female drongo spent about 58 minutes building the nest while the male's involvement was only 4 minutes. During the same period the female spent about 37 minutes on stripping and cleaning activities while the male spent about 4 minutes. During the latter part of the nest-building stage the female spent 36 minutes on nest building compared with the male's 4 minutes; in contrast the time spent on stripping and cleaning activities by the female and the male were 6 minutes and 3 minutes respectively. However, it should be borne in mind that our observations only covered activity during two days.

DISCUSSION

Although relatively small, drongos are aggressive birds, known to mob and chase even large predators (Rocamora & Yeatman-Berthelot 2009). At site D1, we observed the drongo pair mobbing and chasing off potential predators such as Changeable Hawk Eagle *Nisaetus cirrhatus*, Crested Serpent Eagle *Spilornis cheela*, Oriental Honey Buzzard *Pernis ptilorhynchus*, Shikra *Accipiter badius*, Besra *A. virgatus*, Sri Lanka Grey Hornbill *Ocyrocus gingalensis*, Greater Coucal *Centropus sinensis* and Western Koel *Eudynamis scolopaceus*. Apart from these avian predators, they fended off a troupe of Toque Macaques *Macaca sinica* on several occasions and were observed mobbing a domestic dog *Canis familiaris*, domestic cat *Felis catus* and a rat snake *Ptyas mucosa*. They even mobbed humans approaching the host tree after eggs were laid. They frequently used alarm mimicry of raptors and Toque Macaques during such mobbing.



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Plate 3. Female Sri Lanka Drongo at site D1 removing pieces of bark while hovering, Deraniyagala, 4 February 2015.



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Plate 4. Female Sri Lanka Drongo at site D1 perched on the host tree trunk and cleaning it, Deraniyagala, 31 January 2015.

Plate 5. Middle part of host tree trunk at site S2, where drongos have partially removed mosses (left) in contrast to lower part of trunk at level of undergrowth (right), 12 February 2017.



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Nevertheless, despite their aggressive nature, drongos suffer relatively high rates of nest failure, mainly due to predation of eggs and chicks (Rocamora & Yeatman-Berthelot 2009). In an earlier study of Sri Lanka Drongo, only 16 of 37 nests produced fledglings (Goodale *et al.* 2014b), and we noticed a similar high nest failure rate. However, we were unable to identify the causes of these failures. At site D1 in 2015, our limited observations suggested that, once the chicks were several days old, the female was no longer able to brood them at night in the small nest and both parents roosted on a tree about 20 m from the host tree, leaving the chicks unattended.

Nesting in isolated host trees has been shown to prevent nest predation in studies of Brown Jay *Cyanocorax morio* (Lawton & Lawton 1980) and Black-billed Amazon *Amazona agilis* (Koenig *et al.* 2007). Canopy contact and an abundance of vines are identified as major factors that facilitate predation by snakes (Koenig *et al.* 2007), and presumably such conditions also permit access by nocturnal arboreal mammalian predators such as civets and rodents. Unable to utilise aggressive behaviour at night, it appears that the drongos try to thwart nocturnal nest predators by nesting in trees that can be 'managed' by leaf-stripping and trunk-cleaning to increase their isolation. Our observations suggest that this behaviour is limited to host trees and adjacent trees, but it appears that drongos may start preparing the site several months prior to nest-building. We twice observed similar leaf-stripping and trunk-cleaning behaviour on isolated trees in two other locations during October and November, in the pre-nesting season. We also observed similar behaviour at site D1 on two consecutive days in December 2015, when the birds were still searching for a suitable forked branch on which to build a nest.

Leaf-stripping was not seen to occur in *Artocarpus nobilis*, *A. heterophyllus* and *Mangifera indica* trees adjacent to several host trees, despite the proximity of their branches, nor was it seen in peripheral branches of a *Vateria copallifera* host tree. The thick leathery leaves or the presence of latex in the leaves of these species of tree may have deterred the birds, which, however, intensified leaf-stripping in the adjacent thinner-leaved foliage.

All these changes reduce the pathways for snakes and small mammalian predators along the tree canopies and make it difficult for larger mammalian predators like macaques and civets to jump across to the host tree. At site D1, macaques could not reach the host tree directly owing to the absence of canopy contact, although they moved easily among the adjacent trees. The canopy distances between the host tree and adjacent trees appeared to be just beyond range for them to jump.

The trunk-cleaning behaviour of the drongos creates a smooth-surfaced section of the host tree trunk where it emerges from the undergrowth. Any predator climbing from the ground below will encounter this section as a considerable barrier that will at least slow its ascent. The climbing ability of Black Rat Snake *Pantherophis obsoletus* decreases sharply with the smoothness of tree trunks (Withgott & Amlaner 1996). This clearing was not seen on the main trunk below undergrowth level or above the first branch, and was not seen on any main branches. Also, the behaviour was seen less frequently at site D1, where the host tree bark was naturally smooth and devoid of mosses and lichens. In contrast, more activity was observed at site S2, where the trunk was full of mosses and lichens.

Although we recorded two cases where pairs abandoned trees in which they had previously nested (one apparently owing to rattan *Calamus* invasion and one to a wasp nest), Sri Lanka Drongos show high fidelity to their host trees; given the level of investment in the management of these trees, this is perhaps unsurprising. Our study demonstrated host tree re-use by drongos in each season, similar to the findings of Goodale *et al.* (2014b). Host trees at sites S1, S3 and S4 had been used for nesting since 2008, as they were included in

Goodale *et al.* (2014b), and were probably used every year. Host trees at sites D1 and D2 were used in all three seasons. According to nearby villagers who had endured their mobbing, drongos had used the D1 host tree for the preceding five years. Indeed, the D1 host tree broke in half in a storm prior to the 2015 season, but the birds continued to nest in it. In 2017 almost a third of the area next to this tree was cleared, with large trees felled and the land levelled for a house, yet the drongos started nesting and, although the attempt failed when a large branch fell onto the nest, the pair built another nest in the same tree.

Whether the canopy isolation behaviour of Sri Lanka Drongo is unique to the species remains to be ascertained. It would seem surprising if it has been widely overlooked in the family. However, the closely related Greater Racket-tailed Drongo has been observed stripping leaves off its host tree at Udawalawa, Sri Lanka (Hoffmann 1978). It was suggested (at the time) that this behaviour was an expression of agitation. Neelakanthan (1972) described similar leaf-stripping behaviour in Kerala, India, by the same species. Further observations would clearly be worthwhile at other drongo nests in South Asia and beyond.

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