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Nesting Material and Nest Building Technique in Two Species of Broadbill (*Cymbirhynchus macrorhynchos* and *Corydon sumatranus*, Passeriformes, Eurylaimidae) from Southern Vietnam

E. N. Zubkova
Faculty of Biology, Moscow State University, Moscow, 119991 Russia
e-mail: katz.viet@gmail.com
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Abstract—Despite the relatively small number of species, the biology of most representatives of Suboscines of the Old World, particularly that of broadbills, (Eurylaimidae) remains poorly studied. The nest-building behavior of two species from the monospecific genera of broadbills *Corydon sumatranus* (Dusky Broadbill) and *Cymbirhynchus macrorhynchos* (Black-and-red Broadbill) has been described. A detailed study of nest structures has allowed us to determine the materials used in the construction, as well as to study in detail the techniques of its application at different stages of construction. Some unique techniques of nest-building were described. The connection between the properties of the building materials, design features, and construction techniques was characterized. The study of nests in the described species provides a key to understanding the construction of nests in other species of broadbills and in bird species building similar domed pendent nests.

Keywords: Suboscines, Eurylaimidae, *Cymbirhynchus*, *Corydon*, nest building, nest material, Vietnam
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INTRODUCTION

For the families of the New World suboscine passerine birds characterized by an abundance of species, construction of nests of different types is typical. The different variants of nesting structures are especially fully presented in the family Furnariidae (Zyskowski and Prum, 1999; Remsen, 2003). For the relatively few suboscine passerines of the Old World, only two types of nests have been distinguished, differing in the mounting variant (Lambert and Woodcock, 1996; Bruce, 2003; Erritzoe, 2003; Hawkins, 2003). For all members of this group, the construction of large, complex, closed nests woven from a variety of plant material is characteristic. Such nests are considered to be some of the most complex structures of birds; their construction requires significant time and energy costs (Hansell, 2000).

Despite the extensive collections of bird nests in various museums around the world and the many works devoted to observations at the nests, to date, we still know very little about how birds build nests, what techniques they use, how they choose the building material. The features of nest organization and nest biology of tropical birds are still extremely poorly understood. The main purpose of large-scale expeditions of the 19th and mid 20th century in the tropical regions consisted in faunistic observations. Descriptions of the nests of suboscines, if found in reports on the results of expeditions, contain fragmentary information about their appearance, location, and size. A brief list of building material is sometimes given (Hume, 1890; Hopwood, 1919; Baker, 1926, 1934). We were not able to find descriptions of the structural features and construction methods.

Thanks to the work at the Russian–Vietnamese Tropical Research Center, we were able to study some of the features of nesting biology of two representatives of one of the three families of the Old World suboscines, Eurylaimidae: the Black-and-red Broadbill (*Cymbirhynchus macrorhynchos*) and the Dusky Broadbill (*Corydon sumatranus*) inhabiting southern Vietnam.

The data on the biology of the broadbills was carried out in the Cat Tien National Park (Vườn quốc gia Cát Tiên, 11°25′ N, 107°25′ E) in the south of Vietnam (Dong Nai province) in 2010 (May–July), 2011 (March–November), 2012 (April–May), and 2015 (March–May). The search for the nests of broadbills was carried out both in the areas of closed forest and on forest edges in thickets along roads, rivers, and numerous temporary forest streams and lakes. In addition to a total survey of the territory, we also focused on the vocal signals issued by birds. Depending on the height and density of the surrounding vegetation, the distance available for inspection varied from 10 to 100 m. When a cluster of plant material resembling a nest was found far from the route, we attempted to approach it, which was not always possible due to the thickening or flooding of the forest. The locations of all nests detected were mapped using the Garmin 60 CSx GPS-navigator. The nests were photographed and described. When describing the nests, attention was paid to the biotope features, as well as the location, arrangement, and degree of preservation of the nest.

Near two nests of each species of broadbills, the birds were captured using mist nets produced by Ecoton (Poland) in order to register the standard physiological parameters (weight, measurements, etc.), take the blood (for determining the sex), and mark with color rings.

In total, over the 4 field seasons, 283 nests of Black-and-red Broadbill and 17 nests of Dusky Broadbill were registered (our colleagues observed seven more nests of the Dusky Broadbill in 2003–2009 and 2013). At 17 nests of the Black-and-red Broadbill and one nest of the Dusky Broadbill, lengthy (15–300 min) observations of the construction process (more than 100 and 25 hours, respectively) were carried out. The construction techniques were described based both on direct observation of the nests under construction and on video recordings made with a camera with the possibility of video recording (46 minutes of video recording for the Black-and-red Broadbill and 35 min for Dusky Broadbill). For a detailed study of the design of the nests, nesting material, and construction peculiarities, two nests of the Dusky Broadbill (one of them last year's and damaged) and nine nests of Black-and-red Broadbill (six of them partially damaged as a result of ravaging by predators) were collected. The assembled nests were described in detail and measured as a whole, after which a sequential analysis of their constituent elements up to individual plant fibers was carried out. Details of the design features, mounting options, sequence, and methods of using building materials were described in detail. The nest material was determined, classified according to its properties and application, weighed, and photographed. In addition, some nests in nature were examined and measured, as were nests from the collections of the Zoological Museum of Moscow State University, Russia (*C. macrorhynchos* no. Q-5155, etc.) and the Natural History Museum, Great Britain (*C. macrorhynchos* no. NHMUK N/84.1, *C. sumatranus* no. NHMUK N/129.1, *Smithornis capensis* no. NHMUK N/202.2 and no. NHMUK N/115.1, *Smithornis rufolateralis* no. NHMUK N/180.2).

THE MAIN CHARACTERISTICS OF NESTS

The broadbills build hanging nests in relatively open areas of the forest, fixing them on normally thin, flexible, spiked branches or liana shoots (E.N. Zubkova, personal observations; Lambert and Woodcock, 1996; Bruce, 2003). The nests of the species studied differed noticeably both in appearance and in size. The nests of the Dusky Broadbill are cumbersome sloppy structures, similar to loose bundles of epiphytic plants, which can often be found in the rainforest. The mass of the intact nest (the sum of all the material weighed in the dry state) was 726.2 g, whereas the Dusky Broadbills caught in Cat Tien weighed 113–122 g ($n = 4$); i.e., the weight of the nest was much greater that of the bird. The height of their nests reached 90–120 cm in the main part of the nest (taking into account the long "tails" hanging down from the nest made of the plant material, the height measured up to 165 cm) and the width was up to 36 cm (the measurements of the nests studied are given in Table 1). In terms of shape, the nests of the Dusky Broadbill were spindle-shaped or racemose, elongated along the vertical axis, with many long hanging "tails" (Fig. 1a). The only exception was one of the 24 nests found in Cat Tien, which had a different shape: its width was approximately equal to the height. This form might have appeared due to the fact, at the construction stage, the rattan shoots on which it was fastened parted under the influence of wind and stretched the nest in width. The entrance to the nests of the Dusky Broadbill was located approximately in the middle on the side wall and was sometimes almost invisible, as the birds masked it with nesting material and did not make any canopy over the entrance.

According to our observations, for the construction of the nests, the Dusky Broadbills chose almost exclusively the unbranched shoots of the rattan palm (*Calamus* sp.) hanging vertically down: thin tendrils, covered with upwardly bent spikes. The nests were hung at a height of 2 to 15 m. They spent about 13 days on the building of the nest, and at least four birds participated in the construction process, which was noted for several nests in different years (A.V. Bushuev, A.V. Zinoviev, E.N. Zubkova, P.V. Kvartalnov, and A.B. Kerimov—personal observations).

The nests of the Black-and-red Broadbill were, as a rule, more compact and dense, of a much smaller size (up to 65 cm in height, taking into account the hanging "tails"). The weight of the nest was, on average, 106.4 g (from 59.7 to 181.9 g, $n = 6$), whereas the mass of birds was 51–65 g ($n = 30$). The dimensions of the nests varied considerably, and the height of the main part of the nests ranged from 25 to 46 cm (Table 1). The shapes of the nests were also different.

Of all the nests of the Black-and-red Broadbill, in only 62% could the shape of the nest be identified, the remaining nests were either already destroyed (34%) or not completed (4%). Of the 174 nests with a relatively distinct shape, we counted 94 compact, dense structures, 61 of them more or less oval and 33 small, almost spherical (Fig. 1c). Such nests were located close to the branch, which were usually comparatively elastic horizontal branches of trees or shrubs at least 1 cm thick, or cross-shaped forks of bamboo shoots, lianas, and other hanging plants. If the base was tilted

Table 1. Measurements of nests (in cm) of the Black-and-red (*C. macrorhynchos*) and Dusky (*C. sumatranus*) broadbills

Parameter	*C. macrorhynchos*			*C. sumatranus*		
	mean	min–max	number of nests	mean	min–max	number of nests
Height of the nest, * taking into account the "tail" of plant fibers	33.2, 44.3*	25–46, up to 65*	14, 15*	107.5, 127.5*	90–125, up to 165*	2, 1*
Width of the nest	20.6	14.7–31	15	31.6	23.8–36	3
Diameter of the entrance	5.5	3.8–6.5	10	6.46	4.9–7.5	3
Distance from the top of the nest to the upper edge of the entrance	14	6.7–23	8	48.65	35.3–62	2
Height of the nest chamber	11.3	9.5–13	7	21		1
Diameter of the nest chamber	7.6	6–9	7	12	9–15	2
Depth of the nesting hollow	5.75	4–7	6	7		1
Diameter of the branch-base	0.8	0.4–1.2	15	0.3		2

downwards and/or flexible and thin, the branch bent under the weight of the nest and, as the construction progressed, the nest partially slid downward along it. Its upper part stretched along the base, whereby the nest eventually took the form of a drop or spindle. We recorded 43 teardrop-shaped nests (Fig. 1d) and 37 spindle-shaped nests (Fig. 1b). The latter type, in addition to the elongated apex, also had a stretched bottom, passing into a long "tail" of tangled plant fibers hanging along the side walls of the nest and out of the entrance. Many nests represented intermediate variants between these types, so this graduation is conditional. The entrance to the nests of the Black-and-red Broadbill was located in the middle of the side wall. Regardless of the shape, the nests had a well-defined hood over the entrance (Figs. 1b–1d). Due to the canopy, the entrance was usually directed more downward than forward.

The Black-and-red Broadbills placed their nests on the shoots of the forest edge species of plants: *Acacia pennata*, *Bambusa* sp., various trees, lianas, etc., usually branched and/or covered with spines, at a height of 1.5 to 20 m (usually 2.5–6 m). Construction of the nest took an average of 11 days (7–14, $n = 11$). Not only the main pair, but also 1–2 assistants participated in the construction of three out of 17 monitored nests of the Black-and-red Broadbill.

CONSTRUCTION FEATURES AND BUILDING MATERIAL

The Composition of the Building Material and Its Location in the Nest

An analysis of the nests for their constituent elements revealed a significant number of various building materials, the composition of which was somewhat different in the studied species of broadbills (Table 2). For each type of building material, its condition at the time of use by birds (fresh or dry) is noted, and the average dimensions and weight (in dry condition) are given. We also indicated in which part of the nest it was found. Of the nine nests of the Black-and-red Broadbill taken for detailed study, five nests were ravaged and damaged, and one nest was old, preserved from the previous breeding season. Two more nests remained unfinished. One of them was disrupted by people during the clearing of the road; the other was an unsuccessful attempt to reconstruct a previous year's nest by birds of the same species. During observations of one of the nests, at least three cases of repairing by birds were noted. This nest was also subsequently taken to study the nest material. As a result, we were able to determine the weight of each of the components for only six nests, and the set of materials used during construction could be incomplete, which depended on the preservation of the nest.

Our study showed that both types of broadbills preferred to use a very tenacious and durable material with a lot of rootlets, outgrowths, thorns, etc., which, clinging to each other, firmly held the desired form. It was possible to distinguish clearly several layers in the nests of these birds. Each of them had different sets of building materials and different functions. A number of materials were used by birds only at a certain time of construction. Observations on the building and use of nesting material have shown that the creation of a nest can be divided into several stages, depending on the layer that is being worked on.

In total, we identified three layers and, respectively, three stages of construction. At the first stage, which usually lasted 2–3 days, the primary accumulation of material took place, which constituted the outer, thick, and relatively loose layer, which nevertheless carried the main load (I in Fig. 2). With it, the nest was

Fig. 1. Shape of the nests: (a) racemose nest of the Dusky Broadbill (*Corydon sumatranus*); (b–d) nests of the Black-and-red Broadbill (*Cymbirhynchus macrorhynchos*) ((b) spindlelike; (c) compact oval; (d) teardrop-shaped). Photos by the author.

attached to the base and the nest chamber was retained. It also gave the structure its shape and appearance (i.e., according to Hansell (2000), it perform the functions simultaneously of several "zones": attachment, frame, and decor). The basic building material of this layer in the Black-and-red Broadbill consisted of the shoots of the epiphytic fern *Pyrrosia* spp. (as a rule, weakly branched and leafless), bunches of bast fibers and "garlands" of very thin hairlike rhizomorphs of *Marasmius* spp. with pieces of petioles, twigs and bark attached to them, half-decayed leaves, and other plant debris (Table 2). In addition, the broadbills used other plant materials with similar qualities (i.e., long, thin, and often tenacious plants), in particular, the stems of grassy lianas (*Dischidia* sp., etc.) and various air roots.

For stronger adhesion of all materials, apart from the network of tangled rhizomorphs, the birds also used cobwebs, they wove it round the nest at different stages of construction. The comparatively often found pieces of sprigs with spines and without, as well as pieces of mosses (*Selaginella* sp.), short narrow-leaved grass, and loose bundles of also short tangled plant fibers (bast and grassy) resembling tow, were, as a rule, used as decoration. It appears that cocoons of spiders and caterpillars and dry and partially decayed leaves of trees were used for the same purposes.

Table 2. Material used by broadbills when building the nest

Construction material	Condition of the construction material	Average sizes (in cm): width × length; in parentheses is the maximum length	Application of the construction material	Share of each material	
				C. macrorhynchos, the number of nests is in parentheses	*C. sumatranus* (1 nest)
Various leaves					
Green leaves and pieces of leaves (*Ficus* spp., etc.)	Fresh	2 × 5 (up to 7)	"Bed" and "blanket" for eggs	2.16 (2)	0
Rattan leaves (*Calamus* spp.)	Dry	0.8 × 15 (up to 38)	The basket of the nest chamber (3rd layer)	3.48 (4)	3.33
Bamboo leaves (*Bambusa* spp.)	Dry	2 × 18 (up to 25)		4.11 (4)	0
Skeletons of decayed fern leaves (*Drynaria* sp., etc.) and various trees	Dry	4 × 7 (up to 23)	Walls, floor and ceiling of the nest chamber cavity (2nd layer)	1.31 (5)	0.21
Large leaves and pieces of tree leaves (*Cinnamomum* sp., *Diosphyrus* sp., *Garcinia* sp., *Lagerstroemia* sp., Rubiaceae etc.)	Dry	3 × 10 (up to 18)	Exterior decoration (1st layer)	1.88 (5)	0.37
Bundles of bast fibers ("tow")	Dry	1.8 × 20 (up to 60)	Bottom of the nest chamber cavity (2nd layer), exterior decoration (1st layer), canopy	11.79 (6)	0
Threads of bast fibers (conductive bundles)	Dry	0.2 × 20; 0.2 × 60 (up to 110)	The basket of the nesting chamber (3rd layer), the braid of the entrance, the main part of the nest (1st layer)	2.82 (3)	0
Bines of the epiphytic fern (*Pyrrosia* spp.)				28.72 (6); 32.94 (5)*	47.75
Branched, with a lot of rootlets, usually without leaves	Dry	0.5 × 15 (up to 30)	The floor of the nest chamber cavity (2nd layer), the entrance braid, the main part of the nest (1st layer)	8.33 (3)	0
	Dry	0.5 × 50 (up to 70)	The main part of the nest (1st layer)	8.96 (1)	0

Table 2. (Contd.)

Construction material	Condition of the construction material	Average sizes (in cm): width × length; in parentheses is the maximum length	Application of the construction material	Share of each material	
				C. macrorhynchos, the number of nests is in parentheses	*C. sumatranus* (1 nest)
Bare, unbranched, usually without leaves	Dry	0.5 × 15 (up to 35)	The nest chamber cavity (2nd layer), the entrance braid, the main part of the nest	10.73 (4)	3.51
	Dry	0.5 × 50 (up to 90)	The main part of the nest (1st layer)	8.82 (3)	0
Branched, with roots and soil	Fresh	0.5 × 15 (up to 40)	The floor of the nest chamber cavity (2nd layer)	0	4.10
Short, bare with leaves	Fresh	0.5 × 15 (up to 25)	The nest chamber cavity (2nd layer), the entrance braid, the main part of the nest (1st layer)	0	1.64
Medium, branched with leaves	Fresh	0.5 × 20 (up to 40)	The nest chamber cavity (2nd layer), the entrance braid, the main part of the nest (1st layer)	0	8.25
Long, branched with leaves	Fresh	0.5 × 50 (up to 115)	The main part of the nest and exterior decoration (1st layer)	0	28.22
Very long, branched with leaves	Fresh	0.5 × 150 (up to 200)	The main part of the nest and exterior decoration (1st layer)	0	1.74
Other materials					
Garlands of black hairlike rhizomorphs (*Marasmius* spp.) with attached dry leaves and branches	Fresh, dry	0.01 × 20–40–70 (up to 106)	The main part of the nest and exterior decoration (1st layer)	14.21 (6)	8.25
Unbranched sticks and twigs, bare or with spines (shoots of *Acacia* spp., tendrils of *Calamus* spp., etc.); shoots and tendrils of lianas (Caesalpinioideae, Cocurbitaceae, Vitacea, etc.)	Dry	0.5 × 15 (up to 25)	The main part of the nest and exterior decoration (1st layer)	9.02 (6)	18.16

Table 2. (Contd.)

Construction material	Condition of the construction material	Average sizes (in cm): width × length; in parentheses is the maximum length	Application of the construction material	Share of each material	
				C. macrorhynchos, the number of nests is in parentheses	*C. sumatranus* (1 nest)
Petioles of leaves (Mimosoideae, Caesalpinioideae, etc.), panicles of cereals (*Saccharum* sp.), pinnate leaves (Caesalpinioideae, etc.)	Dry	0.1 × 15 (up to 40)	The nest chamber basket (3rd layer), the nest chamber cavity (2nd layer), the entrance braid, the canopy	4.69 (5)	0.55
Branched herbaceous stems (*Dischidia* sp., etc.), air roots (*Pothos* sp., etc.)	Fresh, dry	0.07 × 20; 0.07 × 50 (up to 95)	The main part of the nest and exterior decoration (1st layer)	1.90 (3)	0.03
Unbranched air roots and wire-like red rhizomorphs (*Marasmius* sp.), herbaceous stems	Fresh, dry	0.1 × 20 (up to 50)	The nest chamber basket (3rd layer), the nest chamber cavity (2nd layer), the entrance braid	3.03 (6)	1.72
Branched inflorescences of Compositae (*Eupatorium* sp.)	Dry	5 × 7 (width up to 11)	Canopy, entrance braid	1.60 (3)	0
Bunches of short branching roots, woody green moss, club-mosses (*Selaginella* sp.), soft dry grass (small sedge, typical of lowlands)	Fresh, dry	5 × 15 (up to 25)	Bottom of the nest chamber cavity (2nd layer), canopy, exterior decoration (1st layer)	3.61 (5)	3.24**
Bunches of small orchids (*Dendrobium* sp., etc.)	Fresh, dry	10 × 15 (up to 70)	The nest chamber cavity (2nd layer), the entrance braid, exterior decoration (1st layer)	0.72 (2)	3.91
Cocoons of spiders and caterpillars, cobwebs		1 × 1.5	The main part of the nest and exterior decoration (1st layer)	0.23 (6)	0

* The weight of the material without taking into account the nest, which needed regular repairing.
** Weighed with the attached pieces of branches.

The composition of the nesting material of the first layer of the Dusky Broadbill's nest is in many respects similar, but not so extensive. The main material is also represented by shoots of epiphytic fern (*Pyrrosia* spp.) and long garlands of hairlike rhizomorphs of the genus *Marasmius*. However, unlike Black-and-red Broadbill, birds of this species use almost exclusively live, with a lot of green leaves, long, often branchy *Pyrrosia* bines. Another elongated plant material—the air roots of orchids and other plants and thin herbaceous stems, most often *Dischidia* sp.—is found in relatively small quantities. At the same time, the amount of various sticks, pieces of branches, and lignified lianas, sometimes quite large, up to 60 cm long (mostly about 15–25 cm) and 10–12 mm thick, often fused with rhizomorphs or various epiphytic plants (i.e., part of the so-called "garlands"), was significantly more than in the nests of the Black-and-red Broadbill (Table 2). Generally, these branches, along with bundles of mosses and orchids, which were also used by the Dusky Broadbill, played the role of decor.

During the second, and longest, construction phase, the nest acquired its final appearance. At this stage, the birds continued to bring building material for the walls of the nest (the first layer) and the work on the appearance of the nest was completed. But most importantly, at this stage, the broadbills formed a cavity for the nest chamber and strengthened the nest from the inside, i.e., created a middle layer (II in Fig. 2). This layer was thinner than the outer, but much denser and stronger. We could not find a reference to a similar layer in bird nests in the book by Hansell (Hansell, 2000).

The composition of the building material of the second layer differed from the one given above. In it, in addition to the shoots of *Pyrrosia*, the largest part consisted of unbranched grassy stems, air roots, red wirelike rhizomorphs of other species of *Marasmius,* and thin bast fibers – conducting bundles (almost absent in the Dusky Broadbill's nest) and other similar material performing the function of strong and long strands was found. To strengthen the walls of the nest from the inside, a variety of materials were collected, which the broadbills hardly used at other stages of construction, namely: rigid skeletonized leaves of various trees and ferns (*Drynaria* sp., etc.), elastic petioles and dry pinnate leaves, most often those of legumes, and panicles of cereals (Table 2). Loose bunches of tow, mosses, thin branched rootlets, etc., were used to line the bottom of the cavity for the nest chamber.

The final stage, also relatively short, was mainly devoted to the creation of the thinnest but no less durable inner layer: lining the nest chamber inside the cavity formed earlier (III in Fig. 2). The main materials at this stage were the long, narrow, but relatively firm and rigid, often with many small thorns, dry leaves of monocotyledonous plants—bamboo and rattan (*Bambusa* spp., *Calamus* spp.). It should be noted that the Dusky Broadbill used exclusively rattan leaves for this purpose. In addition to the material mentioned, long flexible air roots, red wirelike rhizomorphs (*Marasmius* sp.), and thin bast fibers (conducting bundles) were also brought along by the broadbills. At the same time, the birds completed the formation of the entrance braid, and the Black-and-red Broadbill, apart from this, created a canopy above the entrance using dry inflorescences of composites, complex pinnate leaves, panicles of cereals, and loose bunches of thin short branching roots and bast fibers. For the entrance braid, both species collected dry pinnate leaves and plant petioles often with sharp curled spines, short red wire-shaped rhizomorphs, and air roots, and also wove the ends of the building material of the main part of the nest and nest cavity into the edges of the entrance.

When completing the construction, before laying the eggs, the birds of both species tore off small pieces of fresh leaves of evergreens, probably *Ficus* spp. These leaves were spread in a thick layer on the nesting hollow and occasionally renewed during the incubation of eggs. Evidently, these leaves serve to mask the eggs and chicks.

Differences in the Composition of the Building Material of Individual Nests

A comparative analysis of the proportion of each type of building material in different nests of the Black-and-red Broadbill has not revealed any significant differences, except for the nest that required frequent repairs. This nest, from the time of building, suffered significantly from unfavorable weather conditions: strong wind and rain. The main damage was made to the canopy above the entrance, which at some point shifted, almost completely covering the entrance, and the walls of the nest: the structure seemed to "blur" over time, losing its original clear form. Comparison of the weight proportions of the main building materials of this nest and the nests that did not require repair showed that, in the first nest, the amount of *Pyrrosia* shoots (i.e., strong and tenacious material) was significantly smaller, approximately 7%, compared to 25–40% in the "good" nests, whereas the volume of various debris and dust formed during the disassembly of the nest from scattered decaying plant materials (leaves, sticks, etc.), on the contrary, markedly prevailed (27% in the repaired nest and 9–14% in "good" ones). Also, the share of dry leaves of trees in this nest was significantly larger, compared with the rest of the nests (4 versus 1–1.7%, respectively).

A survey of other nests in nature in the south of Vietnam, as well as nests from the collection of the Museum of Natural History (Tring), brought from Malaya, revealed no fundamental differences in the composition of nesting material either. In all the registered nests of this species, the same shoots of *Pyrrosia* sp., black hairlike rhizomorphs of *Marasmius* sp.,

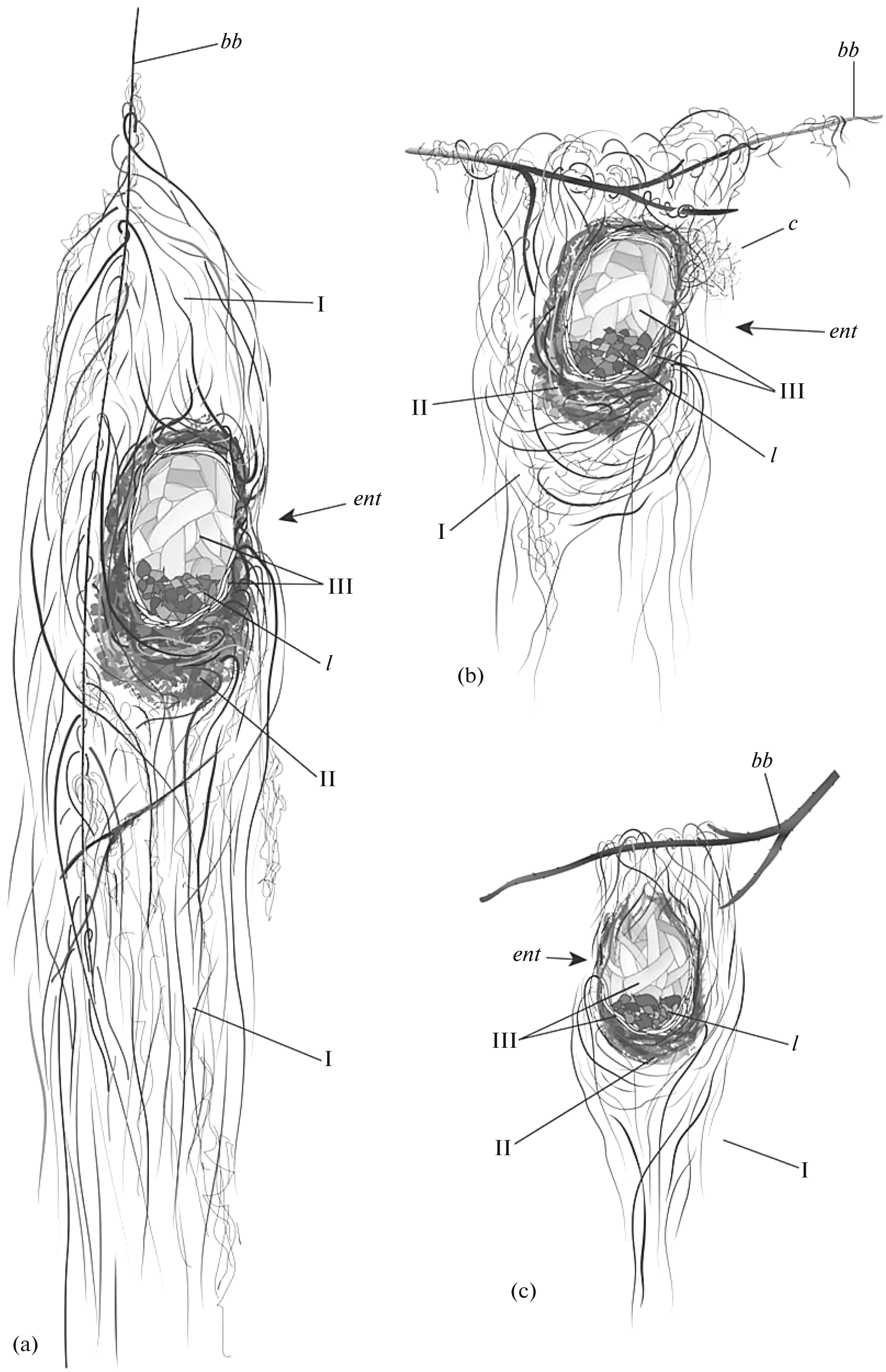

Fig. 2. Arrangement of the layers in the nests of broadbills (conditional cut through the nest chamber): (a) Dusky Broadbill (*C. sumatranus*); (b) Black-and-red Broadbill (*C. macrorhynchos*); (c) African broadbills (*Smithornis* sp.); (I) outer layer; (II) middle layer; (III) third, inner layer; (*bb*) base branch; (*ent*) entrance to the nest; (*c*) canopy; (*l*) a layer of green leaves lining the nesting hollow.

pieces of grassy lianas, and bast fibers served as the main building material. The nests of the Dusky Broadbill discovered by us in the south of Vietnam also differed little in the composition of the main building material from the nest from the collection of the Museum of Natural History (Tring) collected in Pahang (Malaysia). All noticeable differences in the composition of the nesting material in both species concerned mainly "decorative" elements, providing nests with disguises against the background of the surrounding vegetation. We will discuss this issue in more detail below.

The absence of a detailed description of nest material and attempts to classify it accurately in the literature (Hume, 1890; Hopwood, 1919; Baker, 1926, 1934) does not allow for an exhaustive comparative analysis of the building material used by the broadbills in various parts of the range. For example, for the nest of a Dusky Broadbill, one of the descriptions of the nesting material is "grass, branches, leaves, moss, roots, plant stalks, and various plant remains" (Baker, 1926). There are also references to the inner lining of the nesting chamber of dry leaves and a layer of green leaves covering the eggs, which are typical of these birds.

Despite the obvious lack of information on the arrangement of nests of these birds in other regions, knowledge of the composition of the building material of each layer of the nests that we analyzed, as well as descriptions by other authors, will allow a researcher who encounters a broadbill with construction material to determine the stage of nest construction with sufficient accuracy.

Peculiarities of the Nest Material: Disguising the Nests

The long bine of epiphytic plants, garlands of hairy rhizomorphs with attached pieces of branches, leaves, etc., used in the construction of nests and located on the nest in such a way that they hang down from the branch-base—all this gives the nests of broadbills more or less "natural" appearance; i.e., it makes them look like the tangled bundles of air roots and epiphytes hanging on the branches of trees, with various vegetative debris stuck in them, such as fallen leaves, twigs, etc. (Kuznetsov and Kuznetsova, 2011), which are encountered at every step in the rainforest.

Above we noted that the main building material for both species is the bine of the epiphytic fern *Pyrrosia* spp., but the state, sizes of the fragments, and the total amount of this material vary considerably. The Dusky Broadbill use exclusively fresh, densely leafy shoots of the mentioned fern of considerable length (up to 2 m) when building nests, collecting them in the upper, well-lit parts of the crowns. Other plant material used in the south of Vietnam by representatives of this species, as a rule, also carries many fresh leaves. This gives the nest of the Dusky Broadbills the appearance of a large green bundle of epiphytes, which probably disguises it against the background of a dense wall of greenery, among similar clusters of epiphytic plants and lianas.

The Black-and-red Broadbills mainly select the parts of *Pyrrosia* that are almost devoid of leaves, often collecting them in shaded layer of the forest. This material, as well as most of the other building materials they use, has a dark brown or brownish sandy tinge. Due to this, the main color of the nest of the Black-and-red Broadbills is also brownish with chaotically scattered small spots of other colors (green, beige, and gray leaves and bunches of mosses; white, yellow, and pink cocoons of spiders and caterpillars; black bundles of rhizomorphs; beige strands of bast fibers etc.). The presence of different color spots, sometimes quite bright, is probably intended to visually break the monotony and prevent a potential predator from observing the nest against the background of the mosaic of the rainforest.

Evidently, the disguise "works" only under certain conditions. The construction of such a large nest as the broadbill's nest in a different, nonstandard environment makes it quite visible, which certainly increases the risk of nest predation. A similar conclusion was drawn by Sato with colleagues (Sato et al., 2010). In studying the influence of the shape, coloring, and location of the nests of Australian passerine birds from the genus *Gerygone* (the nests of these birds are very similar to the nests of the broadbills in terms of arrangement and location) at the level of predation, they found that the color and material of the nest are adaptive to the background of the natural environment. Thus, it should be expected that changes in the habitats of broadbills that cause them to change their natural environment will inevitably lead to a sharp decrease in the already extremely low nest success, and, consequently, threaten the existence of the population as a whole.

Note that birds can "adjust" to some extent to the surrounding conditions when choosing building material. Comparing the different nests of the Black-and-red Broadbill, we found that the composition and, accordingly, the color of the decorative elements can vary considerably. We assumed that this may be due to the location of the nest. For example, in the decor of one of the nests placed in a thicket of dry rattan leaves, dry strips of bast fibers, leaves, and other materials similar to it prevailed. The degree of illumination can also have an impact: in bright sunlight, the nest can have more light decorative elements, whereas in shady areas, dark-colored materials predominate. However, this hypothesis requires verification, for which special studies are needed.

Collection of Material for Construction

The broadbills collect their nesting material in the same place where they live, in the crowns of the upper (Dusky Broadbills) or medium (both species) sublayers. In search of material, the Black-and-red Broadbill also investigated the lower sublayer, but have never been observed on the ground. The shoots of the epiphytic fern and other similar material necessary for the creation of the main part of the nest, birds of both species collected over a wide area, while the bamboo and rattan leaves for building the nest chamber were found in relative proximity to the nest. Several times, when sitting near the nest, we were able to observe the collection of the nesting material. Plant fibers, fern bines and rhizomorphs, dry and fresh leaves—all these were torn off or collected from branches by the birds. When ripping off the material, they frequently used the weight of their bodies: they flew to the shoots or leaves that they needed, grabbed them with their beaks and hung on them until they broke away. Often broadbills flew to the nest with a whole bunch of various thin shoots, tow, and other building material.

The greatest building activity was noted in both species in the mornings, from 7 a.m. to 9 a.m. In the afternoon and especially during the hottest hours (on average, from 11 a.m. to 2 p.m., when the temperature in the shade rose up to 35–39°C (Deshcherevskaya et al., 2013)), the broadbills either did not show up at the nests at all or appeared very seldom and barely engaged in construction.

CONSTRUCTION TECHNIQUE

Accumulation of the Nesting Material

Let us consider in detail the actions of broadbills when building the nest. We have identified several basic techniques characteristic of these species. Some of them were used only at certain stages of construction (for example, when creating a cavity for the nest chamber), other methods were used by birds at all stages of construction. Using the latter, the broadbills accumulated the nesting mass. In order to do this, they attached the material directly to the basis or wove it into the existing structure. We observed several techniques used by broadbills to fix the nesting material on the branch-base. One of them, relatively specific, was called "winding." It consisted in the fact that birds, holding the nesting material (usually long shoots, roots, or rhizomorphs) around the middle flew to the construction site in such a way that the "tail" of the building material was placed on the base or the nest structure, if it already existed. After that, the broadbill, holding onto the branch-base with its feet and helping itself with wings, made one or several turns (up to five, more often two) around it (Fig. 3a). The tip that remained in the bird's beak was stuck into the structure near the base. The ends of the long bines hanging down, over the material brought earlier, tangled with it.

When creating a nest, the Dusky Broadbill used almost exclusively the method described, threading the building material tightly on the thin base thread, due to which a vertically hanging garland was formed. The use of this technique by the Dusky Broadbills was registered during the entire period of the construction of the nest, whereas the Black-and-red Broadbills used it mainly at the first stage and much less often at the second stage.

In addition to "winding" the Black-and-red Broadbill often just threw the nesting material above across the branch-base. Since many nests of this species were built on relatively horizontal, spiked branches and/or at a forking of the main and lateral branches, this way of fixing the material was also reliable. The Dusky Broadbill used "throwing" extremely rarely, as a rule, only at the very end of the building, when the roof of the nest had become wide enough. Up to this point, the construction material that was put on top but not fixed in a special way simply fell from the nesting structure.

From time to time, the Black-and-red Broadbill applied the material brought to the wall, pressing it with their beaks (in the Dusky Broadbill, the application of this method was noted only in some cases). Due to the head movements from side to side, the material was "reseating" while the spikes, roots, or twigs usually found on the building material and nesting structure clung to each other, firmly holding everything together. In this way the birds fastened the loose bundles of bast fibers, rootlets, grass, moss, and other similar plant material. Less clingy, relatively smooth, unbranched, and elastic vegetable fibers or shoots were stuck into the accumulated mass, often "sewing" the structure through. In the same way, the broadbills tucked in the ends of branches and air roots protruding from the construction in all directions.

According to our observations, each of the above techniques took 1–15 s (usually about 2–5 s). During one flight to the nest, the bird could perform one action or several actions in a variety of sequences, intermingling them with a thorough examination of the entire structure.

Formation of a Cavity for the Nest Chamber

When the volume of the accumulated material became sufficient, the birds made a small depression in the nesting mass with their beak, pushing the material hanging from the outside into the depth of the mass (holding onto the base with their legs and hanging upside down) (Fig. 3b). We consider this moment the beginning of the second stage of construction. Simultaneously with the formation of the cavity, the birds continued to increase the volume of the nesting material in the manner described above, creating walls around the recess. Gradually, the small notch that the broadbills constantly increased first by the "pushing"

Fig. 3. Construction techniques: (a) "winding" the plant bine around the vertical base thread; (b) "pushing," i.e., the beginning of the formation of the cavity for the nest chamber.

with the beak described above, and later using their bodies and legs, it became deeper and turned into a cavity closed on all sides.

At this stage, the ends of long shoots attached to the base, hanging along the frontal part of the nesting structure, were dragged into the cavity and lay there, tangling with the material of the walls. From time to time, the new building material was immediately dragged into the cavity and fixed in the bottom, while the long ends of the shoots remained hanging out freely or were woven by the birds into the edges of the deepening to form the entrance. At this stage, the broadbills often stayed inside the nest for a long time: the Dusky Broadbill stayed for up to 182 s (38.5 s on average, $n = 86$), and the Black-and-red Broadbill, for up to 230 s (51.2 s, on average, $n = 52$). They either trampled and widened the cavity or adjusted the previously brought construction material. The protruding ends of plant fibers were dragged into the interior of the nest and fixed there, creating the braid of the entrance.

Thus, most of the long ends of the building material, freely hanging from the top of the nesting structure and from the inner cavity of the nest, were interwoven or woven into the walls of the nest (both outside and inside) and into the edges of the entrance. Part of the shoots, fibers and rhizomorphs with leaves, sprigs, and webs of spiders attached to them remained free to hang, forming the "decorative tails" described above, which hid the shape of the nest, evidently serving to mask the nest against the background of a wall of vegetation.

In order to increase the strength of the entire construction, at this stage of construction, both layers (outer and middle) were often "sewn" together, using a thin, unbranched, wirelike material (Tables 2, 3) that could easily pass through the thick walls of the nest. This contributed to consolidation of the accumulated nest material. For the Black-and-red Broadbill, a technique was also observed when the birds flew to the nest without the building material, caught the long ends of fern shoots or rhizomorphs hanging from the nest, and flew to the upper part of the nest and fastened the shoots, winding them around the branch. Using this method, the birds "wrapped" the accumulated plant mass with the building material, forming a rounded bottom of the nesting structure, i.e., creating a kind of "hammock," supporting the nest chamber. It should be noted that the Dusky Broadbill do not make the hammock described above, fixing the building material with only one end to the base, which gives the nest a racemose shape. In this case, the nesting chamber is actually suspended on plant strands, which are attached to the branch-base at one end and woven into the bulk of the main part of the nest with the other (Figs. 2a, 2b).

Starting with the moment when the notch in the mass of the nesting material turned into a fully closed cavity on all sides, the birds began to strengthen the ceiling vault and the walls and form the floor. For this, the broadbills lined the cavity from within with rigid skeletonized leaves, as well as elastic petioles, often with spines, panicles of cereals, and other similar material (Table 2), reinforcing the walls. This material was interspersed with relatively short (about 10–20 cm), usually densely covered with spines, pieces of *Pyrrosia* shoots. The Dusky Broadbills especially brought in many such shoots, which, unlike those used by the Black-and-red Broadbills were live, leafy, and branched, often with a layer of soil on numerous rootlets. They were stacked thickly on the floor and walls inside the cavity of the nesting chamber so that the ends of the twigs rested against the walls of the nest. Periodically, the birds further compacted these layers with their legs and body. Longer shoots of the fern (both brought separately and dangling from the branch-bases), as well as smooth elastic plant lines, were alternately placed in rings and spirals by fixing the ends in the thickness of the material (sewing the layers) or around the entrance by both species (Table 3). The alternation of the techniques described and the use of the appropriate materials ensure the creation of a reliable design capable of withstanding a significant load. Completing the formation of the middle layer of the nest, the birds placed loose bundles of various plant fibers on the floor of the cavity between the described spirals (see the description of the material above and in Table 2).

Finishing of the Nest Chamber

When the cavity for the nest chamber was ready, the broadbills began to line the inner walls of the nest chamber with bamboo and/or rattan leaves (Table 2); i.e., they started the third and final stage of construction. Laying the leaves (sometimes folded in half) in different directions, the birds tightly wove them like a mat (Table 3). Compacting the layers of leaves with the body and legs, they caused numerous short spikes on the leaves to cling to each other and other material. Owing to this and the actions described above, a neat, relatively strong basket was created inside the nest, resembling a shoe placed on the toe, i.e., with a rounded bottom and a vaulted ceiling. Bamboo leaves were interspersed with long elastic plant strings, the ends of which, together with dry pinnate leaves and petioles, were woven into the edges of the entrance, forming a strong braid. As mentioned above, at the same time, the Black-and-red Broadbill created a canopy above the entrance, sticking bunches of dry inflorescences and rootlets into the upper part of the entrance and the wall above the entrance (Table 2). The fibers and petioles mentioned above, stretched through the inflorescence, "sewn" it to the wall of the nest. We noted that the broadbills periodically additionally compacted the edges of the entrance using their slightly open beaks and, probably, tongues, moistening with saliva and thereby gluing plant fibers. With the exception of the canopy, the actions of the Dusky Broadbill at this stage did not differ from those described above.

COMPARISON OF THE NESTS OF THE BROADBILLS STUDIED WITH THE NESTS OF OTHER BIRDS

Nests of Some Other Species of Broadbills

We found that the basic principles of nest arrangement, building techniques, and nesting material in the Black-and-red and Dusky Broadbills are similar in many ways. By studying the principles of nest-creation by these species, we can understand certain features of the arrangement of nests of other species of broadbills, without making a detailed analysis of the structure. Thus, the nest of the Banded Broadbill (*Eurylaimus javanicus*) discovered by us on the territory of the National Park of Cat Tien was apparently built in a manner similar to the nests of the Dusky Broadbill, differing mainly in size. The vertical axis of the Banded Broadbill's nest was noticeably shorter, which made it almost spherical. The canopy was absent, and the entrance was masked by the building material of the outer walls. As the main building material for the nests, representatives of this species used, apparently,

Table 3. Construction techniques and variants of using nesting material in both broadbill species

Techniques	Construction material	Functions	Commentary on each species of broadbill	
			C. macrorhynchos	*C. sumatranus*
Winding the construction material around the base	Epiphytic fern (*Pyrrosia* spp.), long grassy stems, air roots, bast fibers, black hairlike rhizomorphs	Primary fixing of the plant material to the base	Generally at the beginning of construction; then more rarely; around the vertical or horizontal base	Fixation of most of the material for nest construction; around the vertical base
Throwing construction material from above onto the base	Epiphytic fern (*Pyrrosia* spp.), long grassy stems, air roots, bast fibers, black hairlike rhizomorphs, bundles of various plant fibers	Fixing construction material on the base, accumulation of the nesting mass	Used for the greater part of material of the first layer	Practically not used
Weaving construction material under the base	Epiphytic fern (*Pyrrosia* spp.), long grassy stems, air roots, black hairlike rhizomorphs	Fixing material on the base	At all stages	At all stages
Wrapping construction material around the nest structure	Epiphytic fern (*Pyrrosia* spp.), long grassy stems, air roots, black hairlike rhizomorphs	Giving a round shape to the entire structure, making the bottom of the nest	Frequently; the ends of fibers are fastened into the side walls or to the base	Not used
Entangling the freely hanging long ends of the building material into a pigtail	Epiphytic fern (*Pyrrosia* spp.), long grassy stems, air roots, bundles of various plant fibers, black hairlike rhizomorphs	Reinforcing the lower part of the nest	From time to time	For the majority of material
Pressing the material hanging outside into the depth of the nesting mass using the beak	Epiphytic fern (*Pyrrosia* spp.), long grassy stems	Initial stage of formation of the nest chamber cavity	Beginning of the 2nd stage	Beginning of the 2nd stage
Expanding the cavity for the nest chamber from the inside using the body and legs	–	Making the nest chamber cavity	2nd stage	2nd stage
Fixing the material hanging from the base (the top of the nest) inside the cavity for the nest chamber	Epiphytic fern (*Pyrrosia* spp.), long grassy stems, air roots	Making and strengthening of the walls, floor, and ceiling of the nest chamber cavity	2nd stage	2nd stage
Fixing the new material inside the cavity for the nest chamber, so that the long ends hang outside	Epiphytic fern (*Pyrrosia* spp.), long grassy stems, air roots	Reinforcing the floor and cavity walls, accumulating material, exterior decoration	2nd stage	2nd stage

Table 3. (Contd.)

Techniques	Construction material	Functions	Commentary on each species of broadbill	
			C. macrorhynchos	*C. sumatranus*
Lining the inner surface of the cavity for the nest chamber	Skeletons of decayed fern leaves (*Drynaria* sp., etc.) and various trees, short branchy pieces of shoots of epiphytic fern (*Pyrrosia* spp.)	Armoring the floor, walls, and ceiling of the nesting chamber cavity	End of the 2nd stage	End of the 2nd stage; shoots of *Pyrrosia* sp. frequently with a layer of soil
Laying the building material was in loops and spirals inside the cavity for the nest chamber	Unbranched air roots and red wirelike rhizomorphs, thin bast fibers (conduction bundles), shoots of epiphytic fern (*Pyrrosia* spp.)	Making the vault and floor of the nesting chamber cavity	End of the 2nd stage	End of the 2nd stage
Sewing the nest walls through	Thin unbranched air roots, red wirelike rhizomorphs and bast fibers (conductive bundles)	Fastening the nest layers	2nd stage	2nd stage
Laying out and intertwining dry leaves in the nest chamber cavity, interlacing them occasionally with thin, durable plant strands	Narrow long dry leaves of rattan palms (*Calamus* spp.) and bamboo (*Bambusa* spp.), thin unbranched air roots and wirelike red rhizomorphs, bast fibers (conduction bundles)	Making a strong woven basket in the nest chamber	3rd stage; applied in equal amounts with bamboo and rattan leaves	3rd stage; used solely for rattan leaves; very rarely for plant strands
Interweaving the plant material along the edge of the entrance, tucking the ends into the walls of the nest	Thin long elastic petioles of compound leaves, short wirelike red rhizomorphs, and air roots	Making the entrance braid	2nd and 3rd stages	2nd and 3rd stages
Reseating and tramping the bundles of building material above the entrance, alternating with the interlacing of filament strands	Dry umbrellas of inflorescences (*Eupatorium* sp.), panicles of cereals (*Saccharum* sp.), dry leaves of leguminous plants (Caesalpinioideae), red wirelike rhizomorphs	Making the canopy; sewing the canopy to the nest using thin wirelike material	3rd stage	Not used
Compacting the entrance braid using a slightly open beak	–	Reinforcing the entrance	3rd stage	Not observed
Lining the nesting hollow with a thick layer of green leaves	Small fresh evergreen leaves and pieces of leaves (*Ficus* spp., etc.)	Making the “bed” and “blanket” for eggs	Completion of construction	Completion of construction

the same plant that the studied species of broadbills choose for their nests, namely, the bines of the epiphytic fern *Pyrrosia* sp. At the same time, the Banded Broadbill, like the Dusky ones, prefer mainly the parts that are densely covered with leaves. The Banded Broadbills prefer to build their nests higher than the species studied. Two nests of this species found by us, as well as a nest discovered by Myers (1999), were built at a height of more than 10 m. Since this species lives and nests in the upper parts of the crowns in a high-stand forest, the detection and conduction of long observations of them is extremely difficult.

Another species of broadbills inhabiting the south of Vietnam (but not in Cat Tien National Park), namely, the Silver-breasted Broadbill *Serilophus lunatus*, builds nests very similar to the nests of the Black-and-red Broadbill. They are also compact, oval in shape, with a pronounced canopy above the entrance. Only the sizes differ: the nests of the Silver-breasted Broadbill are slightly smaller, comparable with the smaller size of the birds themselves. The main building material is, apparently, dry bast fibers, leaves of monocotyledonous plants, and grassy vines.

Comparison of the appearance of the nests of these two species with those described above suggests that the main structural features of the nests and building techniques (such as fixation of the material on the base, organization of the nesting chamber, the formation of the entrance, etc.) are the same as for the studied broadbill.

Constructional Features of the Nests of African Broadbills

As for the other species of broadbills, the most interesting features are the design of the nests of the African and Asian fruit-eating broadbills (from the subfamilies Smithornithinae and Calyptomeninae, respectively). Recently, various researchers have proposed distinguishing these birds into individual families, including on the basis of differences in the organization of nests (Prum, 1993; Moyle et al., 2006). On the basis of our data on the structure of broadbill's nests, we can distinguish several main distinctive characteristics in the design of the nests of the above-mentioned subfamilies.

We had the opportunity to examine the nests of African broadbills from the collection of the Museum of Natural History (Tring, Great Britain). The nests of these birds are neat, relatively small (10.4 × 21.3 cm, $n = 3$) teardrop designs tapering upward, where they are attached to a horizontal branch (Fig. 4). From the enlarged lower part of the nest, a bundle of plant fibers braided in a "pigtail" hangs (similar to the "tail" made by the Black-and-red Broadbill on spindle-shaped nests). The nests of these broadbills lack a canopy above the entrance. Moreover, the entrance, which has, like the nest, the shape of a drop, is neatly braided with plant fibers only in the lower horizontal part where the bird perches. The lateral wall above the entrance is actually missing. Obviously, the main method of fixing the building material to the base is by "throwing," i.e., laying the long plant fibers across the branch-base.

For the construction of nests, these birds mainly use long bundles of bast fibers, grassy stems and leaves of monocotyledonous plants, and air roots, i.e., predominantly the same material used by the Silver-breasted Broadbill. Apparently, this is due to the small size of both birds (the mass of the African broadbills is 10–40 g, that of the Silver-breasted Broadbill is 25–35 g (Lambert and Woodcock, 1996; Bruce, 2003)) and their nests.

The creation of a cavity for the nest chamber in African broadbills is apparently similar to that in other species. The ends of the mass of the nesting material hanging neatly on either side of the branch-base are intertwined to form a hammock. It is possible that the African broadbills also "wrap" the building material around the entire structure, like the Black-and-red Broadbill.

Inside the cavity, these species create a nest chamber of dry leaves typical of broadbills, possibly using cereals or other monocotyledonous plants. However, the nest chamber of these species has, like the nest, the shape of a drop. It actually lacks a ceiling: its role is played by the walls of the chamber converging to the top, while in the cases studied, the nest chamber, as mentioned above, was oval, with a rounded vaulted ceiling. Thus, the main difference between the nests of the broadbills from the subfamilies Smithornithinae and the nests of the studied species (and, obviously, the entire subfamily Eurylaiminae) consists not in the different distance between the entrance to the nest and its apex, according to Moyle (Moyle et al., 2006), but in the approach to creating the nest and the nest chamber. The same can be said for the fruit-eating broadbills (Calyptomeninae), the nesting of which is, apparently, very similar to the African species from the subfamily Smithornithinae.

Surprisingly, the construction of nests of birds from the family Philepittidae inhabiting Madagascar, judging from published descriptions and images (Lambert and Woodcock, 1996; Hawkins, 2003), is much closer to the nests of Asian insectivorous broadbills, namely, the Black-and-red Broadbill, than to the construction of nests of the African and fruit-eating broadbills (Smithornithinae and Calyptomeninae, respectively).

Construction of Suspended Woven Nests by Other Birds

A detailed study of the nesting material and methods of fixing it in these two species of broadbills provided a key to understanding certain principles of nest building not only in other species of broadbills and related asities (Philepittidae) but also some other passerine birds. For example, the principal difference between the nests of weavers (also building relatively large woven hanging nests) from the nests of broadbills is that the former build nests by weaving relatively thin single-layered walls in series, row by row. In this case, the erected walls are also the boundary of the cavity of the nest chamber; i.e., the nest chamber is created simultaneously with the construction of the external walls of the nest. The nests of broadbills are formed sequentially, stage by stage, layer by layer: first, the nesting mass is accumulated, then, a cavity is arranged in it, and only at the very end is the nest chamber created.

FACTORS AFFECTING THE STRENGTH OF THE NEST AND SUCCESS OF THE NESTING

Due to the described features of the construction and building material, the nests of broadbills tend to be strong enough to withstand the unfavorable weather conditions of the wet season and the weight of birds, eggs, and nestlings. However, the reliability of the construction may, in our opinion, depend very much on the experience of birds. We observed a pair of apparently young and inexperienced Black-and-red Broadbills who made at least three attempts in a row to build a nest. At least two of their nests fell before they were completed (S.S. Gogoleva, E.N. Zubkova, personal observations). The experience of assisting (perhaps, for many years) in the building of nests in the Dusky Broadbill evidently increases the strength and safety of the nest structure and the further success of reproduction.

The selected building material also significantly influences the quality of the nest structure. The breeding season in the broadbills in the south of Vietnam begins with the beginning of the wet season. At this time of year, the air is filled with moisture and the fungi threads that are used in the building in large quantities begin to germinate and additionally “sew” the nest material together, which we often observed when analyzing the nests. However, the use of only thin rhizomorphs and adhesive web as the main building material forming a bulky nest cannot provide its walls with the proper strength. An example of this is a nest of the Black-and-red Broadbill, which was constantly in need of repairs and which was eventually abandoned by the birds. The use of a large amount of various fragile, dry, and semidecayed vegetative litter (see above) in this nest instead of the sturdy, tenacious bines of the epiphytic fern made the construction weak, increasing the risk of its premature destruction.

The thick walls of the nests of broadbills formed of several layers, differing both in the composition of the building material and the density, should probably serve as a reliable protection from both the rain and the scorching sun. Owing to this, conditions are created to maintain a constant microclimate inside the nest, which is important for the growth and development of nestlings.

Fig. 4. Nest of the Rufous-sided Broadbill (*Smithornis rufolateralis*) no. NHMUK N/180.2. Photo by the author.

In addition, such walls protect the brood from visual detection by predators, and sometimes mechanically resist nest predation. This assumption is confirmed by traces of attempts to penetrate into the nest found on some nests by destroying its walls. These nests were damaged in the outer and middle layers (sometimes in several places), but the strong basket of the nesting chamber was not destroyed.

However, even a very well-made nest cannot guarantee the success of breeding. This is due to the extremely high press of nest predation along with the unfavorable weather conditions of the wet season with frequent thunderstorms, strong winds, and floods. The issue of the success of nesting in broadbills in Cat Tien National Park is discussed in our other work.

CONCLUSIONS

Our study showed that the stage-by-stage creation of large complex closed nests with thick, relatively dense multilayer walls is characteristic of the studied species of broadbills, as well as, obviously, of all species in the family. In this case, the innermost layer is actually a nest chamber, in the form of a tightly woven basket, neatly built into the nest cavity at the final stage of construction.

The composition of the nest material, slightly differing depending on the stage of construction, is largely similar in both studied species of broadbills, as well as in some other members of the family. Despite the fact that the main building material in the broadbills is the same—*Pyrrosia* spp.—the number, condition, and size of the shoots brought to the nest are different.

During the construction of the nest, different species of broadbills use similar unique techniques: fastening the material to the base, forming parts of the nest, and others. To each technique, a certain set of building materials and functions correspond. A number of structural features have been discovered that make the nests of the Black-and-red and Dusky Broadbills unlike each other.

Studying the peculiarities of creating a nest in the two species of broadbills helped us understand some details of the organization of nests of other species of the family and related asities, as well as some oscine passerines that build complex closed nests.

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