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Altered flower/fruit clusters of the kitul palm used as roosts by the short-nosed fruit bat, *Cynopterus sphinx* (Chiroptera: Pteropodidae)

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The short-nosed fruit bat (*Cynopterus sphinx*) creates bell-shaped cavities in flower/fruit clusters of the kitul palm (*Caryota urens*) by chewing and severing flower and fruit strings. These cavities (stem tents) in which the bats roost are usually about one metre deep and 30 cm in diameter. We observed groups of bats roosting in fully-formed stem tents during the daytime, and the construction and subsequent occupancy of newly formed tent cavities. Stem tents are similar in principle to leaf tents except, instead of being formed when bats chew veins and the surrounding tissues of leaves, stem tents are formed in *C. urens* when bats completely cut several of the central flower/fruit strings. Flower/fruit strings are mostly severed when they are in an immature stage, at times when they are thin and widely spaced. Once these strings thicken and become heavily-laden with mature fruits, bats cannot penetrate the cluster to sever them. Our observations suggest that a single male enters an immature flower or fruit cluster either from below or the sides and severs the central strings along the peduncle. In early phases of stem-tent construction, *C. sphinx* severs flower/fruit strings at a rate of about one or two per day, and cluster alteration may continue upwards to two months. Only one immature flower/fruit cluster on a *C. urens* tree is available for alteration by bats at any given time. That this bat does not roost in the fruit/flower cluster during the day, when a tent is under construction, and the accumulation of chewed flower and fruit strings beneath such a cluster in the morning, suggests that tent construction by *C. sphinx* is a night-time activity.

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Introduction

Direct evidence for tent-making behaviour in the Old World Megachiroptera appears to be restricted to the genus *Cynopterus* (Kunz *et al.*, 1994). Phillips (1924) reported that *Cynopterus brachyotis ceylonensis* (referred to as *C. sphinx ceylonensis* by Phillips, 1980), altered large hanging 'seed clusters' of the kitul palm (*Caryota urens*) by biting off the central strings, and thereby creating cavities in which bats could roost. Lekagul & McNeely (1977) reported that

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C. brachyotis altered palm leaves in Thailand, but gave no details of either the tents or the behaviour of this bat. The strongest evidence for tent construction in the Megachiroptera is based on observations in Timor by Goodwin (1979), who noted that *C. sphinx* roosts in modified leaves of the palmate palm *Corypha* sp., and those of Balasingh, Isaac & Subbaraj (1993) and of Bhat (1994), in India, who reported that this bat roosts among altered stems of *Vernonia scandens* and *Polyalthia longifolia*, and in leaf tents of at least two species of palms (*Borassus flabellifer* and *Areca catechu*). When *C. sphinx* constructs tents in palm trees, it usually does so by chewing the veins and plications, creating a characteristic 'flask' or 'funnel-shaped' pattern in the leaf (Goodwin, 1979). This, and similar types of leaf tents attributed to *Cynopterus*, have been observed in Java and North Sulawesi, Indonesia (Kunz *et al.*, 1994). *Cynopterus sphinx* (50–70 g) and *C. brachyotis* (30–40 g) both feed on fruit, flowers and leaves (Marshall, 1985; Bhat, 1994) and are among the most common members of the Megachiroptera.

In his review of roosting ecology of bats, Kunz (1982) considered the type of shelter constructed by *Cynopterus brachyotis* (= *sphinx*) from Sri Lanka as being similar in concept to leaf tents, and has referred to this type of shelter as a 'stem tent' (Kunz *et al.*, 1994). Reports of such shelters formed in *Polyalthia longifolia* in western India (Bhat, 1994), and in *Vernonia scandens* and *P. longifolia* in southern India (Balasingh *et al.*, 1993) suggest that the construction of stem tents may be rather common. The construction of stem tents differs in one important way from leaf tents. Instead of being formed by the alteration of living leaves (reviewed in Kunz, 1982; Timm, 1987; Kunz *et al.*, 1994), they are made when bats sever stems of vines, tree branches, or palm flower/fruit strings. Although both singles and small groups of *C. sphinx* have been observed in roost situations (Goodwin, 1979; Sandhu, 1984; Balasingh *et al.*, 1993; Bhat, 1994), it remains to be determined whether tent construction by this species is an exclusive male behaviour, as has been postulated for some of the tent-making members of New World Phyllostomidae (Kunz & McCracken, 1995).

In the present study, we report on tent-roosting and tent-making behaviour by *C. sphinx* from western India, in which stem tents are formed when one or more bats sever the central flower/fruit strings from immature flower/fruit clusters of the kitul palm (*Caryota urens*).

Study area and methods

Our observations were made near the city of Pune (18°32′N, 73°51′E) in peninsular India. Pune is located in the rain shadow of the western Ghats at an elevation of 660 m. The vegetation of the surrounding area is dry deciduous, but the city and its suburbs have many tropical tree and shrub species, including both native and exotic forms.

In January 1993, while conducting studies on the roosting and feeding ecology of *Cynopterus sphinx* one of us (HRB) observed a small group of about 10 individuals roosting in a cylindrical cavity that was formed in the middle of a compact fruit cluster of the kitul palm, *Caryota urens* (Plate Ia and b). The tree was an isolated specimen situated close to the garden wall of a government building in the city of Pune. The mature, compact cluster of fruits was about 1·5 m long and 60 cm in diameter. The bottom of the fruit cluster was approximately 7 m above the ground. Bats in this cluster, designated as 'group A', were observed each day from late-January until mid-June 1993, except on weekends and holidays.

On 20 February 1993, another group of 14 *C. sphinx* was discovered about 5 km from group A, roosting in a similar cavity inside the flower cluster of a kitul palm. This tree was one in a row of 5 kitul palms, and the bats roosting in this cluster were designated as 'group B'. This tent, located about 8 m above the ground, was observed periodically until mid-June 1993. On 26 April 1993, an unoccupied fruit cluster, presumably altered by *C. sphinx* on another kitul palm, was discovered 200 m from group A. From the onset of our

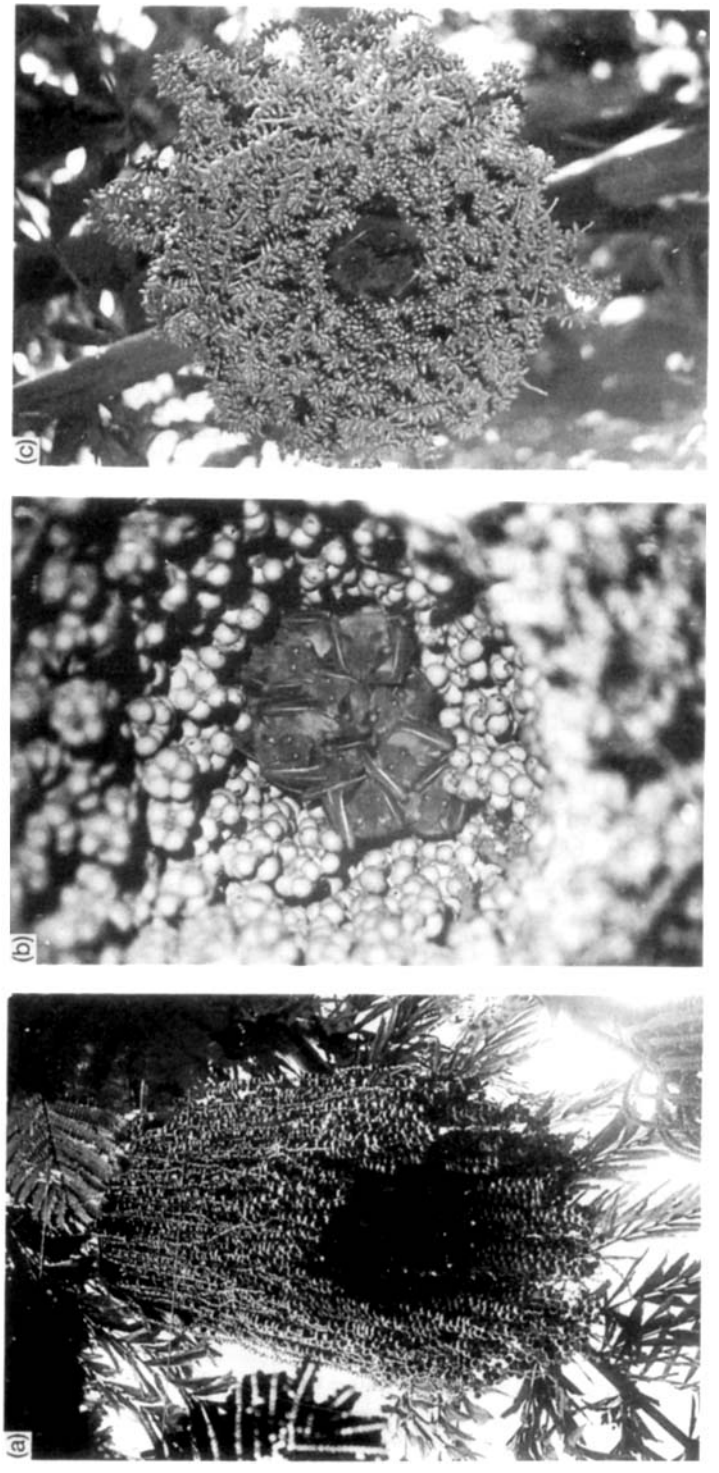


PLATE I. (a) Bell-shaped stem tent, in a fruit cluster of the kitul palm, *Caryota urens*, constructed by *Cynopterus sphinx*. (b) Group of *C. sphinx* roosting in the altered crown of a mature fruit cluster *C. urens*. (c) Roosting group of *C. sphinx* roosting in a newly formed stem tent in a flower cluster of *C. urens*.

observations of group A in late January 1993, the fruits were either ripe or near the ripening stage. Four other flower/fruit clusters were present on the same tree, and each was in a different stage of development, 3 with flower buds and 1 with small, underdeveloped, and tender fruits (Plate II).

Our censuses of tent-roosting bats were made as they emerged at dusk. A complete census of the bats roosting in group A was difficult because they roosted in a compact, overlapping cluster in the tent cavity. Group B bats were not visible during the daytime, because the tree was located within a small grove of trees and a dense overhanging canopy of foliage shaded the tent. Other activities of the bats were observed at dusk and at night, aided by moonlight and available illumination from street lights. Occasionally, a flashlight was used to observe roosting bats.

Observations

In mid-January 1993, we observed about 10 *Cynopterus sphinx* (group A) roosting among the fruit strings in the mature fruit cluster of a kitul palm (*Caryota urens*). About 30 to 40 fruit strings had been previously severed from the peduncle to create a cavity that was about 30 cm in diameter (Plate Ia). The outer dimensions of this compact, bell-shaped fruit cluster was approximately 1·5 m long and 60 cm in diameter. Despite the presence of bats (Plate 1b) and the obvious alteration of the fruit cluster, no fruit strings were found beneath the roost at the time of our initial observations. That we found no strings beneath this cluster probably reflects the fact that ground litter was periodically removed by personnel based at a nearby government building. Subsequent observations indicated that flower/fruit strings from other clusters were completely severed and were dropped to the ground below; none of the strings was transported by bats away from the altered flower/fruit cluster.

On January 25, we noted that several fruit strings had been severed from one of the four clusters that was next in stage of maturity to the one that was occupied by group A. Thereafter, each flower/fruit cluster was regularly monitored for evidence of alteration by bats. Following the first appearance of severed strings beneath this new cluster, we noted that one or two additional fruit strings were chewed off each night. Although no food remains were observed beneath this new tent that appeared to be under construction, some items were deposited beneath the older, occupied tent in the same tree.

Observations at night revealed that only one bat (male?) regularly occupied and altered the new tent. However, from 5 March onwards, this new tent was occupied during the day by 2–3 individuals. Thereafter, food refuse and severed fruit strings began to accumulate under this tent, while most of the other bats from group A continued to roost in the old nearby tent. Observations at dusk on 18 March, revealed that nine bats emerged from the old tent and two from the new one. After a few minutes, one bat, followed by four others, entered the new tent and began chewing on fruit strings in the small cylindrical cavity. We were unable to determine how many of these bats actually chewed the fruit strings, but chewing continued until observations were discontinued at about 22:00 h. Bats from group A continued to use the old tent as the major roost until 31 March, at which time most group members began to roost in the new tent. Thirteen bats

PLATE II. Kitul palm (*Caryota urens*) showing different stages of flower/fruit cluster maturity used by *Cynopterus sphinx* in the construction of stem tents. (a) Reproductively mature kitul palm showing flower and fruit clusters at different stages of maturity. (b) Early developmental stage of flower cluster of a kitul palm when it becomes modified into a tent. (c) Mature fruit (left) and flower cluster (right) of *C. urens*. (d) Cut flower and fruit stems collected from beneath a stem tent that was modified from a flower/fruit cluster of *C. urens*.

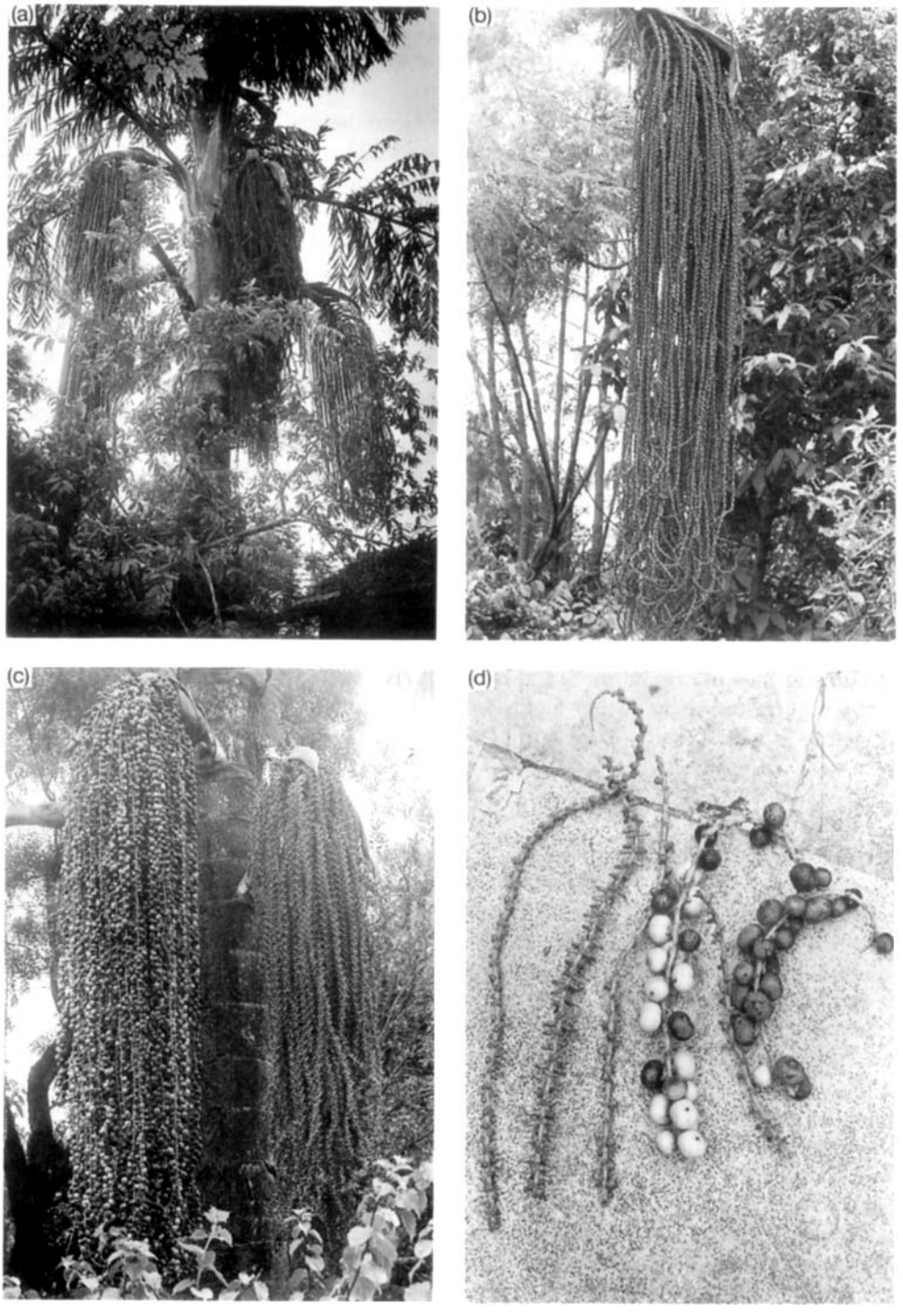


PLATE II

were counted as they emerged from this new tent at dusk on 7 April, and 17 individuals were counted emerging from this same tent on 19 May. One bat continued to roost in the old, withering tent until 20 May; this individual was occasionally accompanied by another, but eventually they both moved to the new tent.

By the time that all bats from group A had moved into the new tent cavity, the fruit cluster was well formed and it was approximately 1·5 m long and 60 cm in diameter. The inner diameter of the new cavity was about 30 cm, and the cluster was comprised mostly of mature fruits. This cavity continued to be enlarged by bats for upwards to two months after it was first occupied. Chewed fragments of fruit strings were found along with food refuse on the ground beneath this tent until mid-June 1993.

Group B bats were first observed roosting in a kitul flower cluster on 20 February 1993. This tent was located in a large flower cluster that was about 3 m long and 60 cm wide. Forty to 50 strings had been previously chewed from the centre close to the peduncle, creating a typical, bell-shaped cavity. Additionally, about 30 strings, nearly half the distance from the top of the cluster had been severed, forming a 30 cm wide and 1·5 m high exit/entry arch in the side of the cluster. When this cluster was first discovered, several flower strings were observed on the ground beneath the tent. Four of the strings were green, suggesting that they had been severed recently. Because the tent was enclosed by a dense layer of canopy foliage it was not possible to observe the bats directly in the tent. However, the number of bats present was determined by counting them as they emerged at dusk. On 20 February, the first bat emerged at 18:50 h. Beginning 30 seconds later, and for the next five minutes, 13 bats emerged. Subsequent observations on 8 March, 3 April, 10 April, 17 April, and 2 May, revealed that 10, 23, 23, 21, 8, and 20 bats, respectively, were counted as they emerged from this tent at dusk. On the same tree we observed a few dry strings clinging to a mature cluster, and a few strings lying on the ground below. From this observation we assumed that a bat had attempted to construct a tent in this cluster but later abandoned its efforts.

Discussion

Mature flower or fruit clusters of the kitul palm (*Caryota urens*) are compact and heavily-laden with flowers or fruits (Plates I and II). Our observations suggest that *C. sphinx* cannot penetrate these mature clusters to chew the strings. Instead, this bat constructs stem tents by chewing the strings when they are immature, thin and widely spaced (Plate IIb and c-right inflorescence). These immature conditions of clusters arise at two stages in the life history of *C. urens*, once in the period between the formation of flower strings from the spathe and the maturation of flower buds, and again between the withering of the male flowers and early stages of fruit growth. During these two periods the strings are thin and widely spaced, and bats are able to crawl easily to the top-centre of the cluster, either from below or the sides.

During these stages of flower and fruit development, the clusters are unsuitable for roosting because they do not provide adequate protection and cover for the bats. However, as the flowers and fruits mature the strings supporting them thicken, become heavier, and sag to form a large, compact, bell-shaped cluster (Plates Ia and IIa). Bats continue to occupy these cavities (Plate Ib) until such time that the fruits wither and drop. They do not begin to roost in newly altered fruit/flower clusters during the day until such time as a sufficient number of strings have been severed and the fruits are mature. Our observations suggest that the entire group will move to a newly constructed tent cavity only after the flowers or fruits are sufficiently mature to provide adequate

shelter from the sides and above. Judging from our observations that stem tents under construction are not occupied during the day, and that severed strings are found beneath clusters in the mornings, this strongly suggests that tent construction in *C. sphinx* occurs at night.

That *C. sphinx* begins to construct tents when the influorescence is still in its flowering stage, suggests that individuals are able to distinguish and anticipate appropriate stages of flower and fruit maturity before they begin tent construction. Whether single males or several members of a roosting group cooperate in tent construction remains to be determined. Based on circumstantial evidence, Kunz & McCracken (1995) postulated that leaf-tent construction by two species of New World bats (*Artibeus jamaicensis* and *Uroderma bilobatum*) is an exclusive male behaviour. If a harem male of *C. sphinx* is solely, or primarily, responsible for constructing a stem tent, it will be important to establish how long it takes to construct such a tent, how much energy is invested in its construction and maintenance, and whether a male constructs and maintains more than a single tent. If cooperation is involved in tent construction, it would be interesting to establish the degrees of relatedness among those which may cooperate. Construction of a stem tent before the flowers/fruits of *C. urens* ripen or wither has an obvious selective advantage because less energy should be required to sever tender seed strings as compared to mature ones. Access to alternate roost sites would be advantageous, especially in anticipation of loss in tent quality as fruits drop seasonally, or as a hedge against unpredictable climatic events (e.g. tropical storms).

Other observations of tent-making behaviour in *C. sphinx* suggest that roosting groups are faithful to specific roosting sites, and that dominant males construct and actively defend these sites against intrusions by other males (J. Balasingh, J. Koilraj & T. H. Kunz, unpubl.). Near Pune, the highest degree of roost fidelity by both male and female *C. sphinx* appears to occur in the period from November and December through late August and early September (H. R. Bhat, unpubl.). Once pups are born in February and March, females undergo a post-partum oestrus, followed by a second annual birth period in June and July (see Krishna & Dominic, 1983; Sandhu, 1984). By late August and early September, pups from the second litter have been weaned and both young and adults show lessened loyalty to a particular site. High roost fidelity by males would have an obvious selective advantage during the two oestrous periods as assurance of paternity.

The kitul palm (*Caryota urens*), as well as many other members of the Palmae, grow vegetatively for two to four decades and, during this time, store enormous quantities of nutrients in their trunks, mostly in the form of starch. Each *C. urens* tree produces from 10 to 15 axillary buds which remain dormant during this period of vegetative growth. Once vegetative growth ceases, the apical meristem is transformed into an inflorescence which blooms, heralding the end of the vegetative growth and the onset of reproduction. Thereafter, the axillary buds become activated one after another in basipetal succession, each maturing into individual flower/fruit clusters. At any one time, a healthy kitul palm may support from 4–6 inflorescences and, over its reproductive life-time, a single tree may produce up to 16 inflorescences before death.

Given the life-time reproductive effort in *C. urens*, and the expected longevity of each flower/fruit cluster, the duration of an altered flower/fruit cluster for up to one year would make it possible for groups of *C. sphinx* to use a series of tents spanning several years, modifying each of several flower/fruit clusters into tents in succession as the tree completes its reproductive life cycle. To understand the life-history and tent-making behaviour of *C. sphinx* further, it will be important to explore the relationship between tent longevity and roost fidelity, and the fidelity of a particular harem group to a specific tree. Direct observations of individual *C. sphinx* in the act of tent-making will further contribute to an overall understanding of the roosting ecology and behaviour of this and other tent-making bats.

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