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Patterns of roost site selection and use by Southern Ground-Hornbills in north-eastern South Africa

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Different habitats may be used for the needs of various aspects of an animal's life. Southern Ground-Hornbill *Bucorvus leadbeateri* groups announce their presence within year-round territories by calling at dawn from their overnight roost sites. Knowledge on ground-hornbill roosting habits is limited. Groups roost in large trees, apparently close to where they end up after daily foraging. We investigated patterns of roost site selection and use for four Southern Ground-Hornbill groups in the Associated Private Nature Reserves, north-eastern South Africa, based on data from GPS-satellite transmitters. The number of roost sites used per month averaged 15.4 ± 4.7 across all groups, indicating little evidence of strong preferences for specific sites. This number was least when groups were breeding, decreasing throughout the early wet season (October–December) and was lowest during the late wet season (January–March) when actively breeding groups frequently roosted close to the nest (54–83% of roosts <1 000 m of the nest). As might be expected, the mean monthly number of nights per roost peaked during the breeding season (December–January). Riparian habitats were preferred for roosting during the breeding season, whereas disturbed areas, as well as *Combretum*- and mopane-dominated habitats were preferred during the dry non-breeding season. Adequate large trees not only for nesting, but also for roosting, particularly in riparian habitats, may therefore be an important and potentially limiting factor for the successful reproduction of Southern Ground-Hornbills.

Keywords: *Bucorvus leadbeateri,* habitat use, large trees, riparian habitats, roost sites, Southern Ground-Hornbill

Introduction

Understanding a species' pattern of habitat use in relation to the needs of various aspects of its life is important for its effective conservation and management. Specific activity-based habitat use information is limited for the Southern Ground-Hornbill *Bucorvus leadbeateri* (Jordan 2011), which is considered Endangered in South Africa (Taylor et al. 2015) and Vulnerable globally (BirdLife International 2014). Southern Ground-Hornbills remain in groups year-round, with home ranges of 50–100 km^2, determined primarily by the availability of suitable nest sites and secondarily by food availability during the dry season (Kemp 2005; Wilson and Hockey 2013). Throughout their range, ground-hornbills occur in grassland and savanna habitats, favouring open areas where prey is easily detected (Kemp 2005). They display a degree of seasonal habitat selectivity by favouring different habitat types during the wet and dry seasons (Theron et al. 2013; Zoghby et al. 2015). Southern Ground-Hornbill groups announce their presence within year-round territories by calling at dawn from their overnight roost sites.

A roost site is a location where birds rest (Beauchamp 1999). Roosts are often specific in form and are selected for their ability to provide protection against predation and from the elements, as well as for how conveniently they are placed to nearby foraging areas or the nest. Birds roost singly or communally, with communal roosts potentially providing added benefits, including a reduction in thermoregulatory demands, a decrease in individual predation risk and increased foraging efficiency, if the group follows more successful foragers to productive foraging areas (Beauchamp 1999). Many territorial bird species have favoured roost sites within their home-range that are used frequently, returning over long distances at the end of each day, whereas others change roost sites on a daily basis (Khan and Zanneer 2010).

Roosting habits and patterns of roost site selection and use by the Southern Ground-Hornbills have not been described in detail. The species is not known to make use of regular roosts, with groups simply said to roost in large trees where they end up after the day's foraging, possibly because the energetic cost of returning each night to the same roost site is prohibitive (Kemp and Kemp 1980; Kemp 1995). The time at which they ascend to roost varies in relation to the time of sunset, and they may occasionally mock-roost, entering an apparent roost site at dusk and squat as if to sleep, only to fly off before complete darkness to a final roost site several hundred metres away, possibly in an effort to confuse potential predators observing the birds settling down for the night (Kemp 1995).

This study increases our knowledge of the roosting habits of the Southern Ground-Hornbill by investigating (1) the number of roost sites used per season, (2) the frequency of use of roost sites per season, (3) the mean distance

between roost sites and the nest per season, (4) the mean distance between roost sites per season, and (5) roost site location in relation to the habitat type in which they forage. We predict that during the breeding season, when the alpha female is restricted to roosting in the nest, the alpha male and other group members will roost nearby because they are responsible for provisioning the female and chick(s).

Methods

Study area

The study site was the Associated Private Nature Reserves (APNR), which is a complex of privately owned nature reserves in the Limpopo and Mpumalanga provinces of South Africa (24°02′–24°33′ S, 31°02′–31°29′ E), collectively representing 180 000 ha dedicated to wildlife conservation (van Rooyen et al. 2005). The APNR is adjacent to the western boundary of the Kruger National Park and forms part of the Greater Kruger National Park Biosphere Reserve (Greyling et al. 2004). The climate is subtropical with hot, humid summers and moderate, dry winters (Venter et al. 2003). Temperatures range from a mean minimum of 9.4 °C in June, the coldest month, to a mean maximum of 33.6 °C in January, the hottest month (Venter et al. 2003). Mean annual rainfall ranges from 450 mm in the north-east of the study area to 600 mm in the south-west. Rain mainly falls during the austral summer, with approximately 90% falling during October–March. The vegetation varies from open savanna to closed woodland, incorporating a mixture of lowland savanna, open tree savanna, mixed and open woodland, low thicket and shrubveld (Venter and Gertenbach 1986; van Rooyen et al. 2005). Dominant tree species include Umbrella Thorn *Vachellia tortilis* (*Acacia tortilis*), Knob Thorn *Senegalia nigrescens* (*Acacia nigrescens*), Leadwood *Combretum imberbe*, Red Bushwillow *C. apiculatum*, Mopane *Colophospermum mopane*, Marula *Scelerocarya birrea* and *Terminalia* species.

Tracking and analysing bird locations

We used GPS-satellite transmitters to track four Southern Ground-Hornbill groups, named Karan Khaya, Keer Keer, Rhino Road and Senelala, after localities in their home ranges. Birds were captured using a walk-in tunnel trap with a curtain that could be pulled across the entrance once birds entered (Zoghby 2015). A decoy ground-hornbill model was placed inside the trap and recorded calls were played to attract birds to the trap. One bird per group was fitted with a solar-powered Argos/GPS PTT-100 transmitter (Microwave Telemetry, Inc., Columbia, MD, USA). The devices had solar panels to power long-term data collection (two-years maximum) and weighed 70 g, just over 1% of the mass of an adult Southern Ground-Hornbill (Kemp 2005). Devices were attached with a harness of Teflon ribbon (Zoghby 2015) and were programmed to record locations hourly from 04:00 to 24:00.

Because groups forage as a cohesive unit throughout the day and roost communally at night (Kemp and Kemp 1980; Kemp 1995), it is only necessary to track one bird per group. Birds were tracked from October 2010 to September 2011. All four groups attempted to breed during the 2010/11 austral summer breeding season, but the Senelala groups' nestling died early in the season, during November 2011. All four nests were located along drainage lines within the study area (Zoghby et al. 2015).

Because Southern Ground-Hornbills ascend to their overnight roost before dark and only descend at first light (Kemp and Kemp 1980), nightly roost sites were identified as GPS fixes that occurred between dusk and dawn. Typically, GPS fix accuracy is <10 m, therefore roost site fixes were where no movements during the night exceeded this error range. Roost sites were then overlaid onto the georeferenced vegetation map of the APNR (van Rooyen et al. 2005) and analysed using ArcGIS® 9.3 (ESRI, Redlands, CA, USA).

To quantify and better understand the importance of individual roost sites and to assess seasonal patterns of roost site use, the number and frequency of roost sites used per season were determined for four seasons defined according to rainfall: Early Wet (October–December), Late Wet (January–March), Early Dry (April–June) and Late Dry (July–September). The mean number of nights spent at each roost site and the mean number of successive nights at a given roost were calculated per month within each season. One-way ANOVA tests, calculated at the 5% significance level, were used to determine differences between the four groups. Roost information was not available for the Rhino Road group during February and March 2011 because the GPS device fell off the bird, and was only reattached in April 2011. As a result, only January 2011 data were available for the Late Wet season for this group.

The mean distance between roost sites and the nest was calculated per month within each season using ArcGIS® 9.3 to determine seasonal patterns throughout the year. The distance between roost sites and the nest was recorded as one of four distance categories (0–500, 500–1 000, 1 000–2 500 and >2 500 m). The mean distance between roost sites was also calculated to determine seasonal movement patterns in relation to roost sites.

The habitat type for each roost site was identified using the georeferenced vegetation map of the APNR in ArcGIS® 9.3 to determine habitat preference for roost sites selection. We recognised six broad habitat types: Acacia (Umbrella Thorn and Knob Thorn), Combretum, Mopane and Terminalia-dominated vegetation, as well as riparian, and bush-cleared or disturbed habitats. Two analyses were conducted: one for the breeding season (October–March), when groups were more constrained to areas close to the nest, and one for the non-breeding period (April–September), when groups were free to range throughout their territories (Zoghby et al. 2015). Selection for specific habitat types was determined using a modification of Ivlev's Index (E_i; Ivlev 1961):

$$E_i = (r_i - p_i)/(r_i + p_i)$$

where r_i = the percentage of roost sites used within a habitat type and p_i = the percentage of that habitat type within the group's home range. E_i values range from +1 to −1 (Ivlev 1961), and although the index has no statistical properties, values >0.25 were considered to show preference for a habitat type and values < −0.25 were considered to show avoidance of a habitat type.

Results

A total of 4 867 GPS locations were obtained for the four groups between sunset and sunrise. Roosting events were obtained for 1 323 group-nights, with missing data for 137 group-nights (10.4%), of which 59 (4.5% overall) was as a result of the Rhino Road group having lost their transmitter for data fixes during February–March 2011.

Number of roost sites and frequency of use

The mean number of roost sites used per month across all four groups was 15.4 ± 4.7. This decreased progressively through the Early Wet season for the three groups that bred successfully (Karan Khaya, Keer Keer and Rhino Road; Figure 1) and remained low during the Late Wet season. By comparison, the Senelala group increased the number of roost sites used during the Early Wet season after their breeding attempt failed in November, and made use of more roost sites per month in the Late Wet season than the other three groups. The mean number of roost sites used during the dry season increased following the Late Wet season for successful breeding groups, whereas for the Senelala group the mean number of roost sites used remained constant.

The mean monthly nights per roost of all groups (1.9 ± 0.9 nights) were not significantly different throughout the year ($F_{3,42}$ = 0.96, p = 0.42). However, there was a tendency for the number of nights spent at a specific roost each month to be higher for the three successful breeding groups in the wet season than the Senelala group, especially during the peak breeding period (December–January; Table 1). Although no obvious seasonal variations existed, the mean number of successive nights per roost were highest in December for the three groups that bred successfully, consistent with the time of peak breeding (Kemp and Kemp 1991). Mean number of successive nights per roost was not significantly different throughout the year ($F_{3,42}$ = 1.94, p = 0.14), with a mean of 1.4 ± 0.7 nights per roost across all groups (Table 2).

Distance between roost sites and the nest

The mean distance between roost sites was lowest in the Early Wet season, with mean distances ranging from 691 to 1 238 m (Figure 2). In the Late Wet season, the groups that bred successfully maintained a low mean distance between successive roosts (383–1 242 m), whereas the Senelala group increased the distance between successive roost sites (1 809–2 876 m). All four groups increased the mean distance between roost sites throughout the dry season (1 987–3 789 m in the Early Dry season and 3 241–3 998 m during the Late Dry season).

Table 1: Seasonal changes in mean ± SD nights per roost site of four Southern Ground-Hornbill *Bucorvus leadbeateri* groups during October 2010 to September 2011 in north-eastern South Africa. The Senelala group's nestling died during November 2011

Season	Southern Ground-Hornbill group			
	Karan Khaya	Keer Keer	Rhino Road	Senelala
Early Wet	2.7 ± 1.8	2.1 ± 1.0	2.1 ± 0.9	1.9 ± 0.3
Late Wet	3.3 ± 0.5	3.5 ± 1.0	4.1[a]	1.4 ± 0.2
Early Dry	1.5 ± 0.5	1.7 ± 0.5	1.4 ± 0.4	1.5 ± 0.4
Late Dry	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	1.6 ± 0.6

[a] Data available for month of January only

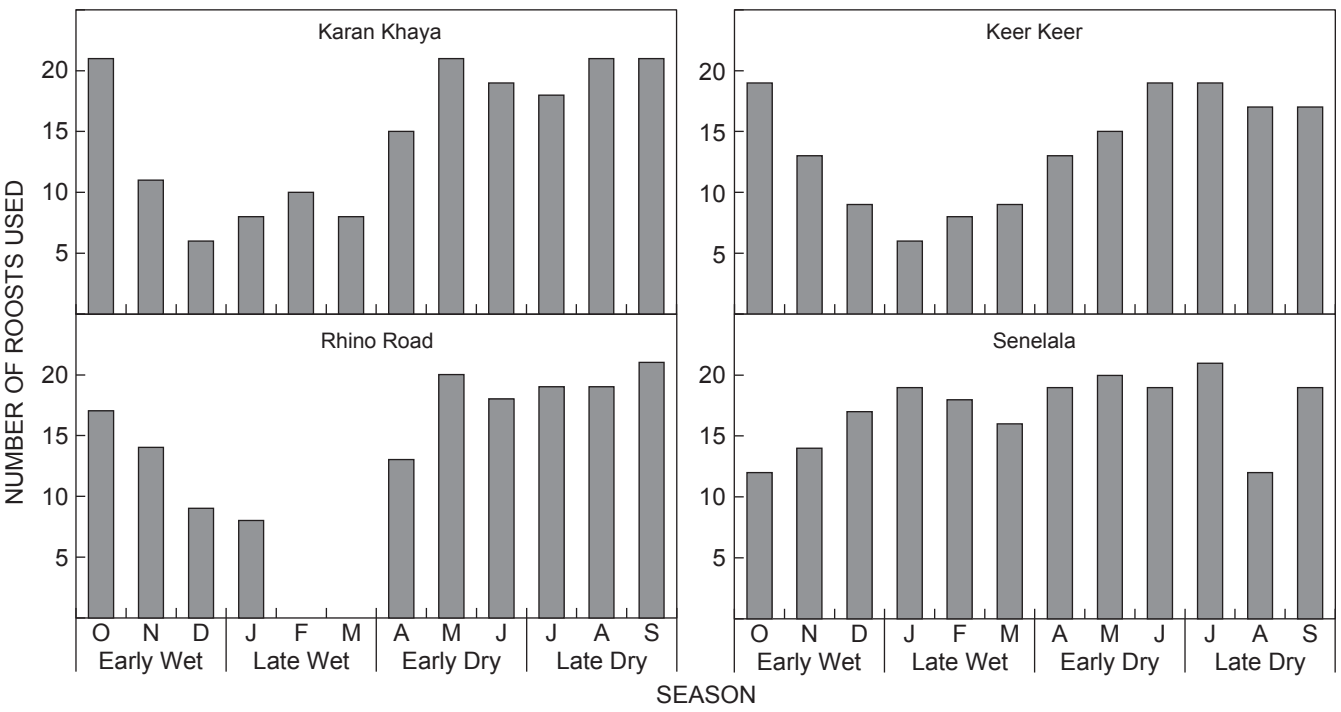

Figure 1: Number of roost sites used each month by four Southern Ground-Hornbill *Bucorvus leadbeateri* groups in north-eastern South Africa during October 2010 to September 2011

Table 2: Seasonal changes in mean ± SD number of successive nights per roost site of four Southern Ground-Hornbill *Bucorvus leadbeateri* groups during October 2010 to September 2011 in north-eastern South Africa. The Senelala group's nestling died during November 2011

Season	Southern Ground-Hornbill group			
	Karan Khaya	Keer Keer	Rhino Road	Senelala
Early Wet	2.5 ± 1.5	2.0 ± 1.1	1.7 ± 0.4	1.6 ± 0.4
Late Wet	2.3 ± 0.9	0.9 ± 0.3	1.7[a]	1.1 ± 0.1
Early Dry	1.2 ± 0.1	1.0 ± 0.2	1.3 ± 0.2	1.1 ± 0.1
Late Dry	1.2 ± 0.1	1.2 ± 0.1	1.2 ± 0.2	1.2 ± 0.2

[a] Data available for month of January only

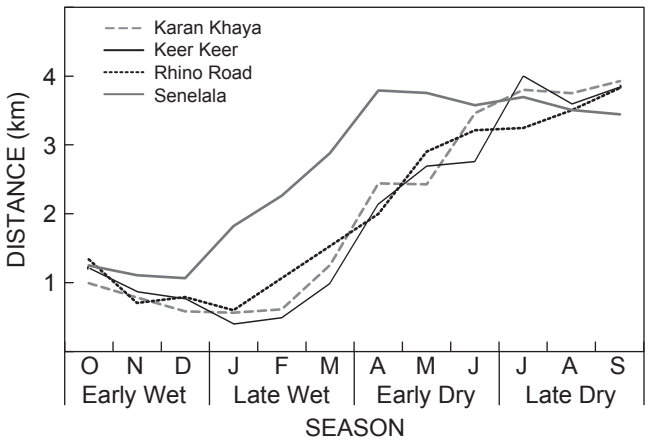

Figure 2: Monthly mean distance between roost sites of four Southern Ground-Hornbill *Bucorvus leadbeateri* groups in north-eastern South Africa during October 2010 to September 2011

All groups frequently roosted close to their nests throughout the Early Wet season, with 54–83% of roosts within 1 000 m of the nest (Figure 3). This proportion increased to 88–100% in the Late Wet season for groups that bred successfully, whereas the Senelala group only roosted near the nest on 12% of nights. All four groups roosted at sites further from the nest throughout the dry season (18–29% in the Early Dry and 18–34% of roosts in the Late Dry season located more than 2 500 m from the nest).

Roost habitat

In the wet season, riparian habitats close to their nests were preferred for roosting by the three groups that bred successfully, whereas the Senelala group did not appear to favour any particular habitat type, and avoided riparian habitats (Table 3). In the dry season, the Karan Khaya group favoured disturbed areas and the Rhino Road favoured Combretum-dominated habitats, whereas Keer Keer and Senelala favoured Mopane-dominated habitats. Tree species commonly used for roosting in this study site were *Combretum imberbe*, *Diospyros mespiliformis*, *Ficus sycomorus* and *Sclerocarya birrea*.

Discussion

Ground-hornbills are not known to make use of regular roost sites (Kemp 1995). We therefore expected to find (1) a large number of individual roost sites and (2) a low frequency of repeated roost site use during the non-breeding season, and during the breeding season for groups that did not attempt to breed or after breeding failure. Once a breeding attempt fails, the group is free to roam more widely. This general pattern was confirmed; during the summer breeding

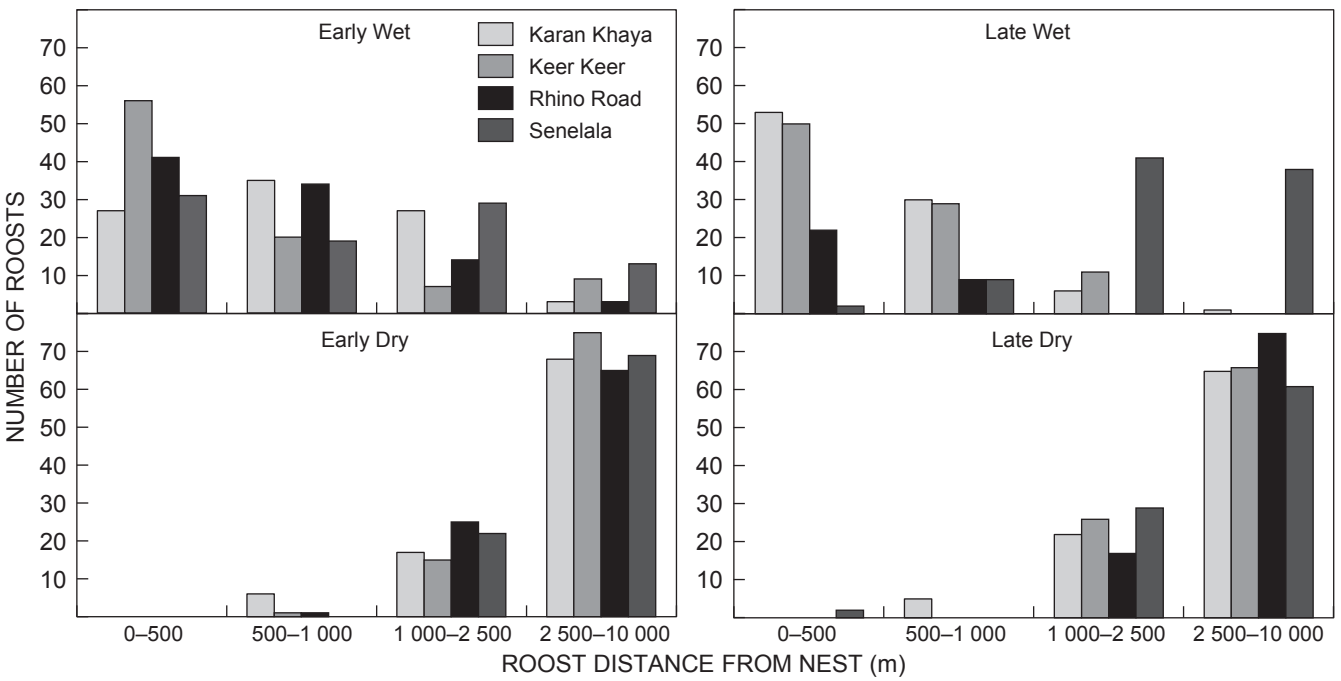

Figure 3: Mean distance between roost sites and the nest of four Southern Ground-Hornbill *Bucorvus leadbeateri* groups per season during October 2010 to September 2011 in north-eastern South Africa

Table 3: Seasonal habitat selection for roosting by four Southern Ground-Hornbill *Bucorvus leadbeateri* groups in north-eastern South Africa during October 2010 to September 2011. Values range from +1 to −1, with values >0.25 (bold) indicating preference, and values < −0.25 (italics) indicating avoidance

Habitat	Karan Khaya		Keer Keer		Rhino Road		Senelala	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Acacia[a]	−0.20	−0.07	0.01	−0.07	*−0.26*	*−0.29*	0.13	−0.04
Combretum	*−0.53*	−0.11	0.06	0.03	−0.07	**0.29**	−0.11	−0.11
Mopane	−0.15	−0.06	−1.00	**0.41**	0.08	0.22	0.13	**0.26**
Riparian	**0.64**	**0.28**	**0.38**	−0.38	**0.60**	0.13	*−0.71*	*−0.85*
Terminalia	–	–	–	–	*−0.73*	−0.21	–	–
Disturbed	**0.38**	**0.68**	*−1.00*	*−1.00*	–	–	*−1.00*	*−1.00*

[a] Umbrella Thorn *Vachellia tortilis* and Knob Thorn *Senegalia nigrescens* dominated habitat

season groups that bred successfully used fewer sites more often, suggesting a degree of seasonal roost site loyalty. This was further confirmed by the proximity of roost sites to the nest as well as between successive roost sites being strongly related to breeding activity. This pattern also occurs in other hornbills (Bucerotidae), where the breeding female is sealed into the nest while the breeding male roosts nearby (Kemp 1995). However, even at the height of the breeding season, ground-hornbill groups still used at least 5–10 roost sites, suggesting that breeding roost sites probably represent a trade-off between the convenience of being close to the nest and the need to avoid being predictable to potential predators (Kemp 1995).

Although Southern Ground-Hornbills occasionally nest in rock and earth bank crevices (Kemp 2005; Witteveen et al. 2013), where available, cavities in large trees are invariably used as nesting sites (Kemp et al. 1989; Kemp and Begg 1996). In drier habitats such as the APNR, ground-hornbills favour trees such as *Ficus sycomorus*, *Diospyros mespiliformis* and *Faidherbia albida*, which generally occur along watercourses (Kemp and Kemp 1980; Kemp and Begg 1996; Msimanga 2004). Unsurprisingly, we found that active breeding groups favoured roosts in riparian habitats. This explains why (1) riparian habitats were favoured during the wet season, when breeding groups roosted close to their nests, (2) the Senelala group did not favour riparian habitats once their chick died, and (3) riparian habitats were not favoured during the dry season, when groups could simply roost where they ended their daily foraging.

Our study confirms the importance of large trees for roosting as well as breeding sites, both along riparian strips during the breeding season and scattered throughout the landscape during the rest of the year. Habitat management should ensure the persistence of such large trees when considering the structural composition of these grasslands and savannas. Management should address the potential threats posed by African Elephants *Loxodonta africana*, inappropriate fire frequencies and bush encroachment to current and future large trees that Southern Ground-Hornbills are known to use for nesting and roosting, especially *Faidherbia albida*, *Ficus sycomorus* and *Diospyros mespiliformis* along water courses and *Adansonia digitata*, *Combretum imberbe* and *Sclerocarya birrea* away from drainage lines in these landscapes. Although Southern Ground-Hornbills are known to use cliffs, plantation trees or artificial structures for roosting in some regions, the availability of suitable large indigenous roost trees should also be considered at sites where artificial nest boxes are placed to augment a population or for reintroduction initiatives.

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