

A conservation status survey of hornbills (Bucerotidae) in the Western Ghats, India

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Abstract

The Western Ghats biodiversity hotspot in India is threatened by habitat loss and fragmentation, which is likely to impact large-bodied, wide-ranging species with specialised requirements such as hornbills. In this survey along the Western Ghats, we surveyed for four hornbill species that occur here: Malabar Pied Hornbill *Anthracoceros coronatus*, and Indian Grey Hornbill *Ocyrceros birostris* (endemic to South Asia), Malabar Grey Hornbill *Ocyrceros griseus* (endemic to the Western Ghats), and the Great Hornbill *Buceros bicornis*. We visited 45 localities across five states: Maharashtra, Goa, Karnataka, Kerala, and Tamil Nadu. These included 26 wildlife sanctuaries, 5 national parks, 13 reserved forests, and one plantation landscape. Across sites, we walked 80 transect surveys totalling a length of 286.4 km. In all, 631 individual hornbills (412 detections) were recorded across 35 localities. The Malabar Grey Hornbill was most frequently detected, and widely-distributed, followed by the Great, and Malabar Pied hornbills. The Indian Grey Hornbill, more widespread across India, was seen in only two locations in this survey. Hornbill encounter was up to five times higher in moist, and wet forests as compared to dry forest types. Based on hornbill distribution and protected areas, five important hornbill conservation landscapes were identified in the Western Ghats (Amboli–Goa–Dandeli, Anamalai–Parambikulam–Vazhachal, Nilgiris–Wayanad, Someshwara–Sharavati–Mookambika, Neyyar–Peppara–KMTR, and Periyar) along with key reserved forests (Kottiyoor, New Amarambalam, Vazhachal, Nelliampathy, Goodarickal, Kulathupuzha–Palode). Hornbill densities were estimated in two of the above landscapes, and are provided as a baseline. We highlight some key considerations for hornbill research and conservation, and future needs.

Introduction

A large body of research has shown that the threats of habitat loss, and fragmentation severely impact large-bodied, wide-ranging species as well as species that have highly restricted geographic ranges or specialised requirements. Among birds, for instance, this makes wide-ranging species such as hornbills, and restricted-range species (endemics), more significant for conservation attention. The sensitivity of hornbills to hunting and habitat disturbance, and their specialised requirements for diverse old-growth forests for feeding and nesting have been amply demonstrated across Asia (see Poonswad & Kemp 1993; Kinnaird & O'Brien 2007—for recent syntheses), including India (Reddy 1988; Kannan 1994; Kannan & James 1997, 2006; Mudappa & Kannan 1997; Mudappa 2000; Datta 1998, 2001; Datta & Rawat 2003, 2004; Balasubramanian *et al.* 2004). Even in the case of the more widespread Indian Grey Hornbill, a species of drier and more open habitats, sensitivity to habitat alteration leading to local extinctions have been reported in studies at the northern extremity of the Western Ghats—Purna/

Ratanmahal, Gujarat (Trivedi & Soni 2006). In central Indian forests, their sensitivity to habitat disturbance due to logging has also been reported (Mehta 1998).

Of the 54 species of hornbills known from the world (Kemp 1993), nine occur within India, and four occur in the Western Ghats: the Malabar Pied Hornbill *Anthracoceros coronatus*, and Indian Grey Hornbill *Ocyrceros birostris* (endemic to the Indian Subcontinent), Malabar Grey Hornbill *Ocyrceros griseus* (endemic to the Western Ghats), and the endangered Great Hornbill *Buceros bicornis*. Apart from the two smaller *Ocyrceros* spp., all other hornbill spp., are rare and threatened, and have been placed under Schedule I of the Indian Wildlife (Protection) Act, 1972¹. Past research on hornbills in India has addressed many aspects of their biology such as breeding, nest selection, and diet (Reddy 1988; Kannan 1994; Kannan & James 1997, 2006; Mudappa & Kannan 1997; Mudappa 2000, 2005; Datta 2001; Datta & Rawat 2003, 2004; Balasubramanian *et al.* 2004). Less information is available on distribution and abundance patterns of hornbills, particularly in the face of large scale landscape transformations and continuing fragmentation and disturbance (Datta 1998; O'Brien *et al.* 1990; Reddy *et al.* 1990; Raman & Mudappa 2003). A recent survey by Balasubramanian *et al.* (2004, 2007) recorded hornbill distribution in a number of sites in Kerala, Tamil Nadu, Karnataka, and Goa in the Western Ghats, as well as in parts of the Eastern Ghats. This survey found the Malabar Grey

1 All hornbills (Family: Bucerotidae) were earlier placed in Schedule I; however, the two smaller *Ocyrceros* have been removed from the listing. In what is possibly an oversight, the Malabar Pied Hornbill *Anthracoceros coronatus* appears to have been omitted from the listing as currently (15 August 2008) evident on the website of the Ministry of Environment and Forests, Government of India (<http://envfor.nic.in/legis/wildlife/wildlife1.html>).

Hornbill to be the most frequently observed species, and reported vegetation types in which each species occurred in the region.

The Western Ghats mountain chain, along the country's western coast, is recognised as one of the eight 'hottest hot spots' of biological diversity in the world (Myers *et al.* 2000; Mittermeier *et al.* 2004), and an ecologically important region within India. The Western Ghats have historically been heavily altered due to human impacts on natural landscapes through urbanisation, agriculture, plantations, hydro-electric projects, roads, and deforestation (Nair 1991; Menon & Bawa 1997; Williams 2003; Kumar *et al.* 2004). This is not surprising given that this region is one of the hotspots with the highest human population density (Cincotta *et al.* 2000). Jha *et al.* (2000) estimated that one-fourth (25.6%) of the Western Ghats's forest cover had been lost over a period of 22 years from 1973 to 1995, giving an annual deforestation rate of 1.16%.

The present survey targeted tropical forest areas restricted to elevations below 1,500 m along the Western Ghats from northern Maharashtra to Kerala. We aimed to: (1) assess distribution of hornbills using field surveys and secondary information, (2) identify important hornbill conservation units based on our survey, and (3) estimate population density of hornbills in some important conservation units to serve as a baseline. The survey covered 31 protected areas (wildlife sanctuaries and national parks) and 13 reserved forests along the Western Ghats. A larger goal was to identify key areas in the regional landscape, for conservation and management of these flagship species, and their habitats.

Study region

The Western Ghats is a 1,600 km long chain of hills running along

the western coast of the Indian Peninsula, from near Kanyakumari at 8°N at the southern end, to the Tapti River in the north at 21°N (Fig. 1). The Western Ghats, distributed narrowly between 73° and 77°E, is less than 100 km wide over most of its length, being widest in the region of the Anamalai and Nilgiri ranges. Passing through the states of Gujarat, Maharashtra, Goa, Karnataka, Kerala, and Tamil Nadu, a number of hill ranges link up to form the Western Ghats. Going from north to south, these include the Sahyadri of Maharashtra and Goa, the hills of Uttara and Dakshina Kannada, Pushpagiri and Brahmagiri, and tall and imposing ranges of the Nilgiri (a meeting point with the Eastern Ghats), Anamalai, Palni, Cardamom (Elamalai), Varushanad, and Agasthyamalai hills (Nair 1991).

The Western Ghats has a tropical climate that shows pronounced variation along north–south, east–west, and altitudinal gradients. A comprehensive account of climate and vegetation in the Western Ghats is beyond the scope of this report, and is available in other publications (Champion & Seth 1968; Subramanyam & Nayar 1974; Puri *et al.* 1983; Pascal 1988). In general, the vegetation becomes drier as one progresses from west to east (rain shadow) across the hills. Lower elevations on the eastern aspect, receiving less than 1,200 mm annual rainfall, contain tropical dry deciduous and thorn forest, with tropical moist deciduous forests in more well-watered areas (Champion & Seth 1968). With increasing elevation, tropical wet evergreen rainforest appears along the higher slopes and ridges. The western aspect of the hills tends to have mostly tropical moist deciduous and wet evergreen forest types at lower elevations, giving way to the latter type as one climbs higher. The tropical wet evergreen forests of the Western Ghats, which are a main focus of this survey, have been classified by Pascal (1988) into low- (mostly below < 700 m), medium- (700–1,400 m), and high-elevation (>1,400 m) types.



Photo: Kalyani Varna

Malabar Pied Hornbill pair.

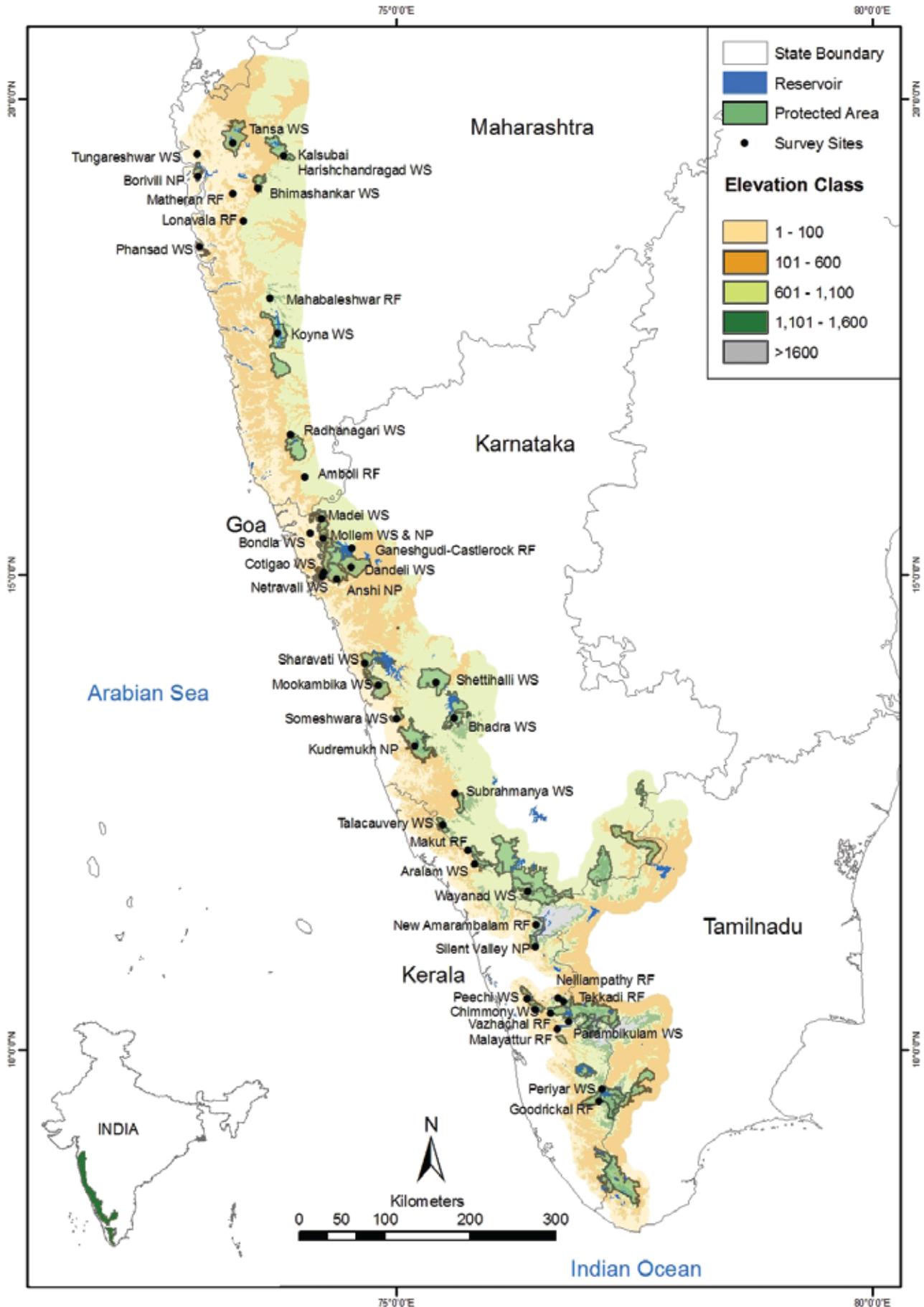


Fig. 1. The Western Ghats of India showing protected areas and reserved forests and surveyed sites.

Map: Arundhati Das and Jagdish Krishnaswamy, ATREE, and R. Raghunath, NCF

Table 1. Localities visited and effort in sites where transect survey was carried out.

State	Site	Transects	Duration (min)	Length (km)	State	Site	Transects	Duration (min)	Length (km)	
Maharashtra	Amboli RF	—			Kerala	Shettihalli WS	1	60	1.34	
	Bhimashankar WS	2	223	4.31		Someshwara WS	1	60	1.59	
	Borivili NP	1	60	2.04		Subrahmanya WS	1	64	2.10	
	Kalsubai–Harishchandragad WS	1	45	1.04		Talacauvery WS	1	60	1.61	
	Koyna WS	4	383	8.65		TOTAL	13	902	24.41	
	Lonavla RF	—				Aralam WS	1	60	1.34	
	Mahabaleswar RF	1	85	1.56		Chimmony WS	1	60	1.34	
	Matheran RF	1	84	2.20		Goodrickal RF	1	65	1.22	
	Phansad WS	1	115	3.01		Malayattur RF	1	61	1.47	
	Radhanagari WS	2	315	24.62		Nadugani RF	—	+	—	
	Tansa WS	1	68	1.41		Nelliampathy RF	2	120	2.35	
	Tungareshwar WS	1	70	1.68		New Amarambalam RF	—	+	—	
	TOTAL	15	1448	50.51		Parambikulam WS	1	61	1.21	
	Goa	Bondla WS	3	204		5.75	Peechi WS	1	59	1.04
		Cotigao WS	3	198		5.56	Periyar WS	2	120	2.68
Madei WS		3	263	5.31	Silent Valley NP	1	60	1.94		
Mollem WS & NP		6	699	18.07	Tekkadi RF	—	+	—		
Netravali WS		1	56	1.12	Vazhachal RF	5	405	8.97		
TOTAL		16	1420	35.81	Wayanad WS	1	60	1.41		
Karnataka	Anshi NP	2	123	4.15	TOTAL	17	1131	24.96		
	Bhadra WS	1	60	1.44	Tamil Nadu	Indira Gandhi WS* survey	4	344	6.93	
	Dandeli WS	3	295	7.96		Indira Gandhi WS* transects	11	c. 6000	117.5	
	Ganeshgudi–Castle Rock RF	—	+	—		Valparai fragments transects	4	c. 1800	33.2	
	Kudremukh NP	1	60	1.34		TOTAL	15	c. 7800	157.63	
	Makut RF	—	+	—		WS—Wildlife Sanctuary, NP—National Park, TR—Tiger Reserve, RF—Reserved Forest, +—visited briefly, *—now known as Anamalai Tiger Reserve.				
	Mookambika WS	1	69	1.41						
	Sharavati WS	1	51	1.47						

Materials and Methods

Survey localities and effort

We visited 45 localities across five states along the Western Ghats: Maharashtra, Goa, Karnataka, Kerala, and Tamil Nadu. These included 26 wildlife sanctuaries, five national parks, 13 reserved forests, and one plantation landscape. Logistics restricted the amount of time spent in each area; although we passed through a number of other sites, it was not possible to gather first-hand information due to various limitations.

We covered 135.69 km in 65 line transect surveys in various sites across Maharashtra, Goa, Karnataka, Kerala, and Tamil Nadu (Table 1; locations in Appendix). In addition, 15 line transects in Tamil Nadu were repeatedly surveyed five times each (for a total distance of 150.7 km). Besides the approximately 211 hours spent on transect surveys, we spent substantially more time (around 80 field-days) in various sites excluding Tamil Nadu.

To examine broad habitat affiliations, we also categorised the transects into four major habitat types: dry forests (dry thorn and deciduous forests), moist forests (moist deciduous and semi-

evergreen forests), wet forests (primarily tropical wet evergreen forest), and Sahyadri or northern wet forests (evergreen forests typical of the northern Sahyadri portion). The survey effort was distributed across major vegetation types as follows: dry forests—12 transects, 24.52 km; moist forests—17 transects, 30.6 km; wet forests—32 transects, 79.4 km; and, hilltop evergreen forests—4 transects, 8.07 km.

Identifying key sites for hornbill conservation

The information on number of hornbill species and their abundance (encounter rates, density) within sites was examined with other landscape and habitat characteristics that are likely to be relevant for the conservation of these large and wide-ranging birds. We shortlisted landscapes with contiguous protected areas of at least 500 km², giving higher priority to larger areas and those adjoining suitable buffer habitats (reserved forests, plantations with shade tree cover). We also examined habitat status ratings based on a number of criteria assessing the type and intensity of threats that were used in a related conservation assessment

across the Western Ghats (CEPF 2007). Using a semi-quantitative approach that combined these rankings, we arrived at a list of potentially important sites for hornbill conservation.

Population density estimation

Besides occurrence, and encounter rates of species, population estimation from line transect surveys is an important aspect in identifying key areas for conservation of hornbills, especially for the larger, threatened species. Among the identified areas, given constraints of survey effort and logistics, we were able to carry out line transect density estimation across two landscapes: Dandeli–Goa, and Anamalai–Parambikulam.

From hornbill detections obtained during the line transect surveys we estimated population densities using distance sampling techniques as implemented in the DISTANCE computer program (version 5.0, Buckland *et al.* 2003; Thomas *et al.* 2005). All hornbills detected by sight, or call, in the field were categorised into the following perpendicular distance (from the transect line) intervals in metres: 0–5, 5–10, 10–20, 20–30, 30–50, 50–75, 75–100, >100, with a maximum detection distance (truncation point) of 150 m. Distances were estimated visually to most sightings or calls, by pace-length in a few cases, or measured with a rangefinder whenever possible. We took each detection (=cluster) to represent an individual, pair, or flock found in relatively close proximity and apparently moving or foraging together, and estimated flock or cluster density. Since flocks could not be counted in many cases for visual detections (and all aural detections), we used estimated average flock (cluster) size and its SE from data within and outside transects where complete counts of individuals were obtained. We multiplied the average flock size (F) by the average cluster density (C) to obtain individual hornbill density (D). Standard error of individual density (seD) was calculated using standard error of cluster density (seC) and standard error of average cluster size (seF) using Goodman's (1960) formula: $(seD)^2 = C^2(seF)^2 + F^2(seC)^2 - (seC)^2(seF)^2$. We evaluated different models of detection probability (half-normal, uniform, and hazard-rate) with cosine adjustment terms and used standard model selection procedures in DISTANCE to select the best model for estimating density.

Results & discussion

In all, 631 individual hornbills (412 detections) were recorded in 35 localities across the entire Western Ghats during this survey. The Malabar Grey Hornbill was the most frequently observed, and widely-distributed species (342 individuals, 33 localities), followed by the Great Hornbill (146 individuals, 13 localities), and the Malabar Pied Hornbill (131 individuals, 10 localities). The Indian Grey Hornbill, more common and widespread across the Indian peninsula, was seen at only 2 locations (12 individuals) along the Western Ghats, in this survey.

State-wise summaries

Maharashtra

All four hornbill species were recorded in Maharashtra (33 detections comprising 45 individuals). Malabar Grey Hornbills (14 detections, 15 individuals) were seen in Amboli, Phansad, and Radhanagari, Great Hornbills (nine detections, 18 individuals) in Amboli, Radhanagari, and Mahabaleshwar (latter seen by Tanya Balcar and Bob Stewart—*verbally*), whereas Malabar Pied Hornbills (four detections, five individuals) were recorded only in Amboli and Phansad during the survey. The Indian Grey Hornbill (six detections, seven individuals) was recorded only from Borivili.

Goa

During the survey across five protected areas in Goa, and nearby areas, we recorded only two hornbill species: Malabar Grey Hornbill (59 detections, 75 individuals), and Malabar Pied Hornbill (18 detections, 25 individuals). The Malabar Grey Hornbill was seen in all five sites, whereas the Malabar Pied Hornbill was recorded in Mollem, Madei, and Cotigao. Local reports indicate that it also, occasionally, occurs in Bondla, and Netravali.

Karnataka

All four hornbill species were recorded during the survey across 13 sites in Karnataka (193 individuals, 103 detections). The Indian Grey Hornbill was detected thrice in Dandeli Wildlife Sanctuary (five individuals). The Malabar Grey Hornbill was most widespread, being detected 77 times (85 individuals) across all sites. The Malabar Pied Hornbill was detected 17 times across four sites: Dandeli, Ganeshgudi–Castlerock, Bhadra, and Mookambika, and we counted 96 individuals including those at roost sites. We had only six detections (seven individuals) of Great Hornbill, three each from Dandeli and Mookambika.

Kerala

Three hornbill spp., Malabar Grey, Malabar Pied, and Great hornbills, were recorded across 14 sites in Kerala (151 detections, 212 individuals). The Malabar Grey Hornbill was detected 118 times (158 individuals) across all sites except Peechi, Silent Valley, and Wayanad (where it almost certainly was overlooked due to short survey period). We obtained only four detections (five individuals) of Malabar Pied Hornbill, all from the Vazhachal–Athirampilly area. Great Hornbills were detected 29 times (49 individuals), from Chimmony, Goodrickal, Nelliampathy, Parambikulam, Periyar, Thekkadi, and Vazhachal. The Indian Grey Hornbill was not recorded, although there were reports of its occurrence near the Trichur and Chalakudi foothills.

Tamil Nadu

In Tamil Nadu, our focus was on estimation of hornbill population density in and around the Anamalai Tiger Reserve (formerly Indira Gandhi Wildlife Sanctuary). During the survey, detections on transects and other supplementary observation resulted in around 500 detections of Malabar Grey Hornbill and over 100 detections of Great Hornbills numbering over 750 and 250 individuals,

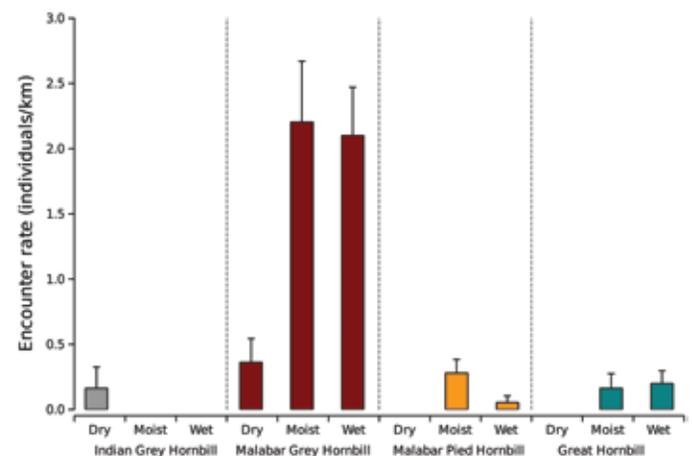


Fig. 2. Encounter rates of hornbill species in three broadly categorised vegetation types in the Western Ghats (vertical bars represent standard errors).

respectively (exact numbers are not provided as many are counts over repeatedly surveyed transects or locations).

Species-wise summaries

Great Hornbill

This species was recorded in 13 of the 45 survey sites, chiefly in or in close proximity to wet evergreen forests at elevations from 50 m to 1500 m asl. The records range from southern Maharashtra (Radhanagari and Amboli) to the southern-most sites in the Western Ghats. Relatively higher numbers were encountered in Radhanagari, Anamalai hills (Anamalai, and Parambikulam Tiger Reserves and, Vazhachal Reserved Forests), and Periyar during the survey.

Malabar Pied Hornbill

Recorded in ten localities of the 45, the Malabar Pied Hornbill was relatively more frequently encountered in moist deciduous and riverine areas on the western aspect of the Ghats. All detections were at elevations <600 m, with most being at elevations between 100 and 450 m. The main stronghold of this species appears to be in the central portion of the Western Ghats (Goa–Dandeli to Sharavati–Mookambika), with scattered populations or more sporadic occurrence further north (Amboli, Phansad) and in the southern Western Ghats (e.g., Athirapilly–Vazhachal).

Malabar Grey Hornbill

This endemic species is clearly the most widely distributed (recorded in 33 of 45 localities) and relatively common hornbill in the Western Ghats, distributed over a range of forest types from moist deciduous, riverine, and semi-evergreen forests to tropical wet evergreen forests. Our records of this species extend from around 50 m elevation to 1500 m elevation, from Phansad in Maharashtra to the southernmost sites in the Western Ghats.

Indian Grey Hornbill

This species, more typical and widely distributed across the plateaux and plains of India, than in the Western Ghats, was noted only in a few peripheral localities, or the foothills, during this survey. This included direct records only from Borivili and Dandeli, besides received reports of its occurrence around Trichur and Chalakudi in Kerala, and an earlier record from Panchgani, Maharashtra (Gole 1998). Despite the few records obtained in this survey, we would like to observe that this species is clearly still relatively common and widely distributed across India, even in urban centres (e.g., New Delhi, Nagpur, and Mysore, to name a few). However, being a species endemic to South Asia and one of the large-bodied species, it merits continuing conservation attention (R. Sankaran, *verbally*). Even during this survey, we obtained reports of hunting, and poaching, of nests of hornbills in the Western Ghats.

Habitat affiliations of hornbills

Hornbill encounter rates were calculated from transect data in vegetation types broadly categorised as dry forests (tropical dry thorn and dry deciduous), moist forests (chiefly tropical moist deciduous and riverine), and wet forests (tropical semi-evergreen and wet evergreen). No hornbills were detected in the four sites in the northern wet evergreen forests of Maharashtra and hence these sites were excluded from analysis. The overall encounter rate of hornbills varied significantly by habitat type (Kruskal-Wallis ANOVA $\chi^2 = 12.4$, $df = 2$, $P = 0.002$). The encounter rate was around five times higher in moist forests (mean = 2.65 hornbills/km, ± 0.51 SE), and wet forests (2.36 ± 0.38), as compared to dry forests (0.52 ± 0.22). The encounter rates of the four hornbill species in these three broad vegetation types indicates their main habitat affinities (Fig. 2). It is clear that the Indian Grey Hornbill is restricted to dry forests, although variation in encounter rates were not statistically significant due to the few locations in which the species was seen on transects (Kruskal-Wallis $\chi^2 = 4.1$, $df = 2$, $P = 0.13$). The Malabar Grey Hornbill is more widely distributed, and showed significant differences in encounter among habitat types ($\chi^2 = 13.2$, $df = 2$, $P = 0.001$), occurring chiefly in moist forest types and some dry deciduous areas adjoining moist forest tracts. The two larger hornbills are restricted to moist/wet forests. The Malabar Pied was more frequent in moist deciduous and riverine areas ($\chi^2 = 10.2$, $df = 2$, $P = 0.006$). The Great Hornbill was a species largely of wet evergreen zone, spilling over into some adjoining moist forest types, but statistical significance could not be established due to its rarity and low detections on transects ($\chi^2 = 2.0$, $df = 2$, $P = 0.37$).

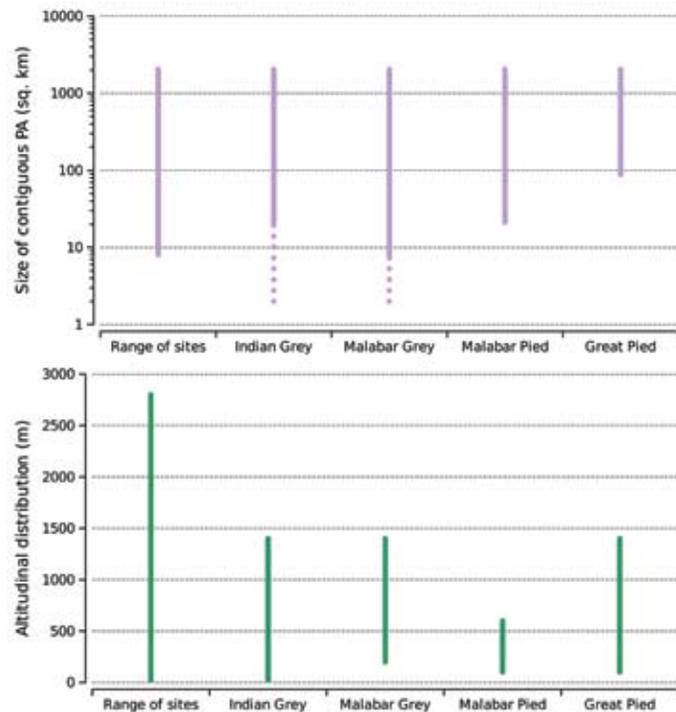


Fig. 3. Distribution of range of sites surveyed and individual hornbill species in relation to size of contiguous protected area and altitude. Broken lines indicate records from outside the survey.

Identifying important hornbill conservation landscapes

Compiling the occurrence data from our survey and the work of Balasubramanian *et al.* (2004, 2007) presents a picture of hornbill occurrence in relation to altitude and area of contiguous habitat within protected areas (PA) where the hornbill species occurred (Fig. 3). As seen from Fig. 3, the two smaller *Ocyrceros* hornbills are seen across a wider range of sites in terms of contiguous PAs and altitudes than the larger species. In particular, the Malabar Pied Hornbill appears to have the narrowest altitudinal distribution in the Western Ghats coupled with an occurrence primarily in PAs at least larger than 20 km². It must be noted, however, that this analysis excludes areas of forest that may adjoin PAs and currently lack the same level of protection (e.g., reserved forests, plantations). The effective area of contiguous forest that determines the occurrence of these hornbill species (especially the larger species) is thus likely to be higher than illustrated here.

Based on the occurrence of the four hornbill species, encounter rates/densities from the sites for which these indices of abundance are available, and the configuration and size of contiguous protected areas along the Western Ghats, a priority list of conservation units are identified. The main sites and some key aspects regarding each are listed below (in rough order of priority):

Amboli-Goa-Dandeli: This is a key region being perhaps the most important region for the conservation of the Malabar Pied Hornbill as evidenced from the preponderance of the records of this species being from this region and the relatively high encounter rates and density. Besides three crucial wildlife sanctuaries (Mollem, Madei, and Dandeli), a significant proportion of the population is found outside designated protected areas in reserved forests such as at Amboli, Ganeshgudi, Dandeli, and around Mollem-Madei. All four species of hornbills are found in the Amboli-Goa-Dandeli region. A detailed survey of the reserved forests and their fragmentation and conservation status is required for Amboli and around Dandeli, for consideration of possible inclusion with protected areas.

Anamalai-Parambikulam-Vazhachal: Again, a region with all four species of hornbills, this area appears significant particularly in terms of conservation of the Great Hornbill. Population densities estimated in and around Anamalai Tiger Reserve provide a baseline for this, and the Malabar Grey Hornbill (see next section). While the large area of forest and abundance of these two species indicate that their populations here are relatively secure, there is concern over the status of the Malabar Pied Hornbill that is threatened by the proposed Athirapilly dam, and lack of protected area status for reserved forests where it occurs (e.g., Vazhachal, Nelliampathy).

Nilgiris-Wayanad: This is one of the important conservation areas of the Western Ghats although fragmented due to dams, roads, agriculture, and timber and monoculture plantations. It gains importance due to the large areas of dry and wet forests, and the occurrence of all four species of hornbills. Quantitative estimates of hornbill encounter/abundance are, however, lacking. The patchy occurrence of Malabar Pied Hornbills on the eastern (Coimbatore forest division) and western/northern (Wayanad-

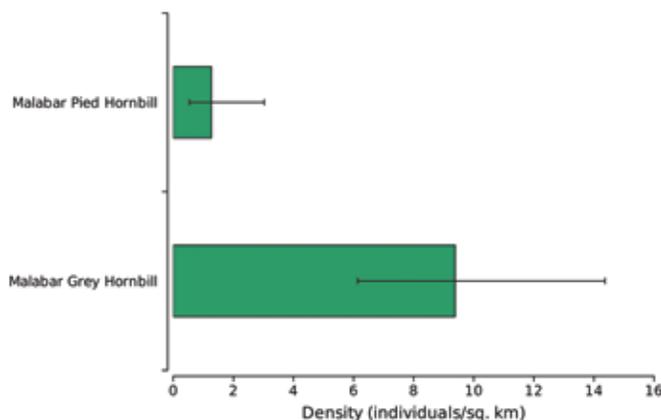


Fig. 4. Density of two hornbill species in the Dandeli-Goa region (error bars are 95% confidence intervals).

Bandipur) parts requires better documentation. The region adjoins the Mysore Plateau to the north, which appears to be an area where Indian Grey Hornbills are still relatively frequently seen.

Someshwara-Sharavati-Mookambika: In Karnataka, this area appears to be an important complex for conservation of hornbills, including the Malabar Pied Hornbill, after the Anshi-Dandeli region. Only limited time could be devoted to this region during the present survey. However, earlier reports (Balasubramanian 2004) and sight records of flocks (up to 32, H. N. Kumara & Sushma Rao, *in litt.*) indicate its potential.

Neyyar-Peppara-Kalakad-Mundanthurai Tiger Reserve: A large, contiguous tract of over 400 km² of tropical wet evergreen forest across the two wildlife sanctuaries in Kerala and the Kalakad-Mundanthurai Tiger Reserve make this an important conservation area. Malabar Grey, and Great hornbills are widespread in the evergreen forests, and Balasubramanian (2004) has recorded Malabar Pied Hornbill at Neyyar Wildlife Sanctuary and Tenmala reserved forests. We did not survey these areas.

Periyar: The tract of 777 km² under the Periyar Tiger Reserve has extensive wet evergreen, moist deciduous, and riverine habitats. While only Malabar Grey, and Great hornbills were

Table 2. Density estimation of hornbills in Anamalai-Parambikulam region using distance sampling: models and estimated detection parameters

Detail	Malabar Grey Hornbill			Great Hornbill		
	Wildlife Sanctuaries	Reserved Forests	Rainforest Fragments	Wildlife Sanctuaries	Reserved Forests	Rainforest Fragments
Number of transects	16*	8	4	16*	8	4
Number of repeats	5*	1	5	5*	1	5
Total line length, km	125.68	12.78	33.18	125.68	12.78	33.18
Number of clusters†	346	40	76	57	2	10
Model	Hazard-rate	Half-normal	Hazard-rate	-----Half-normal-----		
Adjustment	Cosine	Polynomial	Cosine	-----Cosine-----		
Detection probability (SE)	0.51 (0.02)	0.25 (0.03)	0.47 (0.03)	-----0.80 (0.14)-----		
Effective strip width, m (SE)	77.0 (3.0)	37.1 (4.5)	70.3 (5.3)	-----80.2 (13.8)-----		
Encounter rate, detections/km	2.75	3.13	2.29	0.28	0.16	0.24
Encounter rate %CV	5.38	15.81	11.47	16.9	70.7	35.4
Density of clusters, number/km ²	17.9	42.2	16.3	1.74	0.98	1.50
%CV of cluster density	6.67	19.90	13.70	24.10	72.77	39.31
95% CI of cluster density	15.7 – 20.4	28.3 – 62.87	12.4 – 21.4	1.08 – 2.80	0.26 – 3.63	0.70 – 3.23

* One transect in Parambikulam Wildlife Sanctuary was surveyed only once.
 † 'Clusters' in distance sampling terminology are detections, i.e. one or more birds detected together.

recorded here during the present survey, the Malabar Pied Hornbill has been recorded here in other surveys (Periyar Foundation, <http://www.periyarfoundation.org/pdf/birds.pdf>, accessed 16 April 2009).

Crucial reserved forests: Some key reserved forest (RF) areas in the southern region, especially those adjoining protected areas, appear important for hornbill conservation:

Kottiyoor RF (adjoining Aralam/Brahmagiri Wildlife Sanctuary).

New Amarambalam RF (adjoining Silent Valley National Park).

Vazhachal and Nelliampathy RFs (adjoining Anamalai-Parambikulam).

Goodarickal RF (adjoining Periyar Tiger Reserve).

Kulathupuzha-Palode RFs (adjoining Peppara-Kalakad-Mundanthurai Tiger Reserve).

Population density estimation in two important hornbill conservation landscapes

Dandeli—Goa

All four hornbill species occurred in the Dandeli-Goa landscape. While the Indian Grey Hornbill was only seen near Dandeli town, the other three species were seen in both Goa and Karnataka. The wider survey also revealed the importance of this landscape for the Malabar Pied Hornbill. Two-thirds of the 131 Malabar Pied Hornbills recorded during the entire survey were seen across the Dandeli-Goa landscape in Karnataka, Goa, and adjoining areas of Maharashtra (Amboli). Dandeli was particularly important as

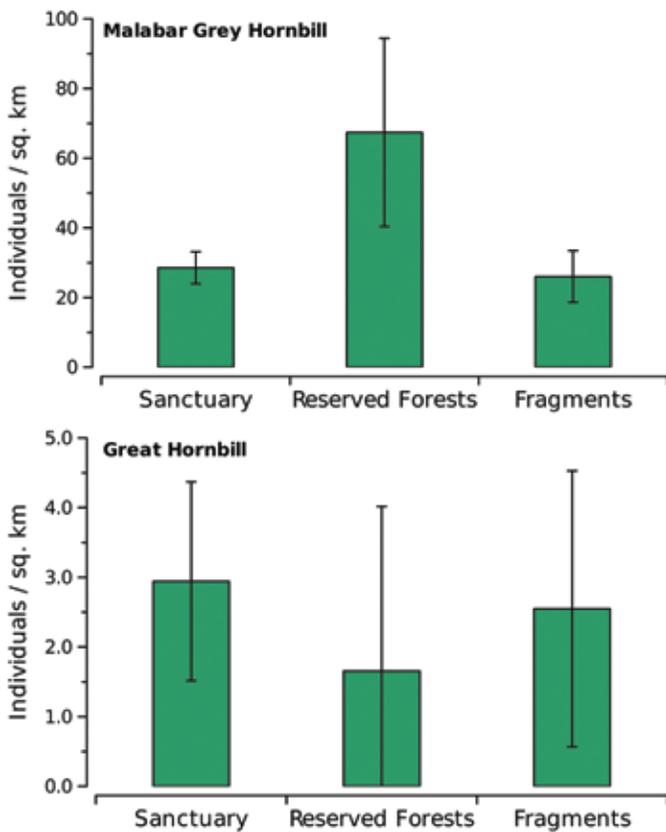


Fig. 5. Hornbill densities in Wildlife Sanctuaries (Indira Gandhi and Parambikulam), Reserved Forests, and rainforest fragments in the Anamalai Hills and Valparai plateau. Vertical bars are 95% confidence intervals.

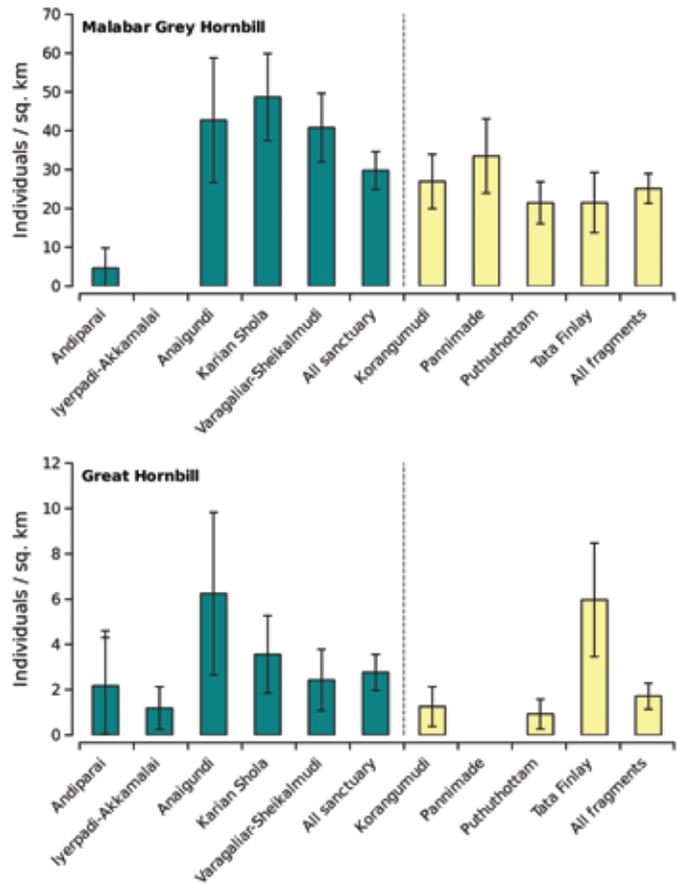


Fig. 6. Hornbill densities across sites within the Indira Gandhi Wildlife Sanctuary and rainforest fragments in the Valparai plateau. Vertical bars represent 95% confidence intervals.

large numbers (c. 80 birds) were seen using the forests in the area, and roosting in large flocks of up to 30 individuals along the Kali River in Dandeli, and Ganeshgudi. Transect data also revealed that the highest encounter rates of this species were in Mollem National Park and Wildlife Sanctuary (range = 0.13/km to 1.61/km across six transects), with high encounter rates in Madei Wildlife Sanctuary, Goa (0/km to 0.84/km across three transects), and Dandeli Wildlife Sanctuary, Karnataka (0/km to 0.6/km across three transects).

We were able to obtain initial density estimates of Malabar Grey and Malabar Pied Hornbills from the transect data in this region (Fig. 4). We obtained 56 detections of Malabar Grey Hornbills and estimated a density of 9.4 individuals per km² (95% confidence interval: 6.1–14.4 individuals/km²). We obtained 11 detections of Malabar Pied Hornbills and estimated a density of 1.3 individuals per km² (95% CI: 0.5–3.0 individuals/km²). It would be worthwhile establishing a system of transects for monitoring.

A large number of Malabar Pied Hornbills were also seen outside the existing protected areas in reserved forests and some disturbed areas around Dandeli. There appear to be a number of roost sites along the Kali River in Dandeli and Ganeshgudi (and possibly in other areas). During three evenings at different roosts, we counted 30 individuals at one roost site (Kali main bridge, 14 October 2005), 21 at another (Kali old bridge, 17 October 2005), and 24 in Ganeshgudi. More recently, an intensive study on the Malabar Pied Hornbill has been completed from this area (Vijayakumar 2007).

Anamalai—Parambikulam

In the Anamalai–Parambikulam region, hornbill densities were estimated from line transects distributed across three broad strata:

- Wildlife sanctuaries: Anamalai and Parambikulam Tiger Reserves.
- Reserved forests: Vazhachal–Sholayar and Malayattur.
- Rainforest fragments: four forest fragments on private lands in the Valparai plateau.

The 171.64 km of transect survey yielded 462 detections of Malabar Grey Hornbill and 69 detections of the Great Hornbill overall. Detection functions were estimated strata-wise for the Malabar Grey Hornbill; however, due to fewer detections of Great Hornbill, we used a global detection function across strata for estimation of this species. Details of sampling and parameters are provided in Table 2.

The estimated mean density of Malabar Grey Hornbills in reserved forests was 67.4 individuals/km² (Vazhachal–Sholayar, and Malayattur) with a 95% confidence interval (CI) of 40.4–94.4 individuals/km². This appeared to be significantly higher than 95% CI of densities in the wildlife sanctuaries (23.9–33.1 individuals/km²) or rainforest fragments (18.6–33.4 individuals/km²)—the latter two strata thus appearing not to differ significantly from each other (Fig. 5). This was partly because the transect sites within the sanctuaries included some higher altitude areas where hornbills were scarce or absent (see below). Great Hornbills did not show substantial variation across the three strata (Fig. 5) with broad overlap in the 95% CI among sanctuary (1.5–4.4 individuals/km²), reserved forest (0–4.0 individuals/km²), and fragments (0.6–4.5 individuals/km²).

A closer look at density estimates from the more intensively-sampled sites within the Anamalai Tiger Reserve and rainforest fragments on the Valparai Plateau indicated patterns of variation within strata (Fig. 6). Within the sanctuary, the mean density of Malabar Grey Hornbill was higher in three sites at middle elevations (700–1,000 m): Anaigundi Shola (42.7 individuals/km²), Karian Shola (48.7 individuals/km²), and Varagaliar–Manamboli–Sheikalmudi complex (40.8 individuals/km²). Malabar Grey Hornbills were scarce or absent (<3 individuals/km²) at the two other sites at higher elevations (>1,300 m, Fig. 6). The Malabar Grey Hornbill densities were broadly similar across the Valparai Plateau fragments (21.5–33.5 individuals/km²). Although the average densities in fragment sites tended to be lower than in the mid-elevation sites within the sanctuary, the 95% CI showed

overlap in most cases (Fig. 6). The pattern of Great Hornbill density across sites was similar to that of Malabar Grey Hornbill; the low density and large 95% CI in fragments was possibly due to lower or partial use of fragments by these birds during their wide-ranging movements.

An important location for Great Hornbills is a roost site in the Valparai Plateau, adjoining forests of the Manamboli range of Anamalai Tiger Reserve, in the Anali estate (Tata Coffee Ltd) and Senthil estate (private ownership). While Anali estate is predominantly under shade-coffee and *Eucalyptus* fuel plantations, Senthil estate has seen recent conversion from rubber and coffee to tea plantations, the latter characterised by little shade. Up to 60 Great Hornbills have been observed to use this roost site every year during the non-breeding season. As the site partly overlaps private tea and coffee estates, it requires the involvement of these private landowners in the protection of roosting trees, reduction of disturbances, and conservation of this important roost site.

Shortcomings of survey

The survey period had to be extended due to various difficulties of logistics including delayed permits, travel, and unpredictable weather patterns. A few of the sites could not be surveyed due to these constraints and as we ran short of time and funds. The survey was too rapid to give a suitable understanding of the current trends in distribution within each of the sites or of seasonal variation and patterns within sites. Among states, Tamil Nadu was poorly covered and requires more field survey in the future. Although some local knowledge is available, of the distribution of many species, the lack of published information and the preponderance of grey literature made it difficult, in many cases, to reliably collate past distribution information as we had expected to do. We were able to establish population baselines only in two regions and for three hornbill species. The survey sites did not adequately represent the distribution of the Indian Grey Hornbill, which is more of a species of the drier zone and eastern aspect of the Ghats.

Key findings and recommendations for future efforts

The results of the occurrence and distribution patterns of the four hornbill species in this survey are broadly concordant with earlier reports (Ali & Ripley 1983) and a more recent survey (Balasubramaniam *et al.* 2004, 2007). However, there has been little systematic effort at estimating abundance or population densities of hornbills in earlier work, and the present survey presents a baseline, across localities, of encounter rates as well as density estimates from select areas of importance.

The importance of moist forests for the Malabar Grey Hornbill and the larger hornbills also stands out. In addition, the Malabar Pied Hornbill appears to prefer lower elevation riverine areas, including many sites outside designated PAs—habitats prone to a range of threats such as encroachments, agriculture, monoculture timber plantations, hydro-electric and irrigation projects, tourism and urban development (e.g., Vazhachal–Athirapilly population along the Chalakudy River threatened by the proposed Athirapilly dam). It is also noted to be an apparently irruptive or dispersive migrant over a wide landscape in Goa (Lainer 2004). Although distributed more widely across localities in central India into Orissa, and in Sri Lanka, the Malabar Pied Hornbill appears to be currently patchily distributed along the Western Ghats with reports indicating declining populations particularly in the southern Western Ghats and Kerala (Sugathan & Varghese 1996; Sashikumar *et al.* 2005; Nameer & Praveen 2006; Praveen & Nameer 2009).



Malabar Grey Hornbill female feeding on *Vitex altissima*.

Photo: Kalyan Varma

Looking ahead, it is essential to establish baselines through population estimation, discovery and monitoring of nest and roost sites, especially in the sites and landscapes identified as critical for hornbill conservation by this survey. In some of the sites, sizable hornbill populations also occur in reserved forests outside designated protected areas. These require particular attention as these are also subject to greater pressures of hunting and resource extractions. The larger hornbills, particularly the Great Hornbill, are known to be nomadic during the non-breeding season. During these forays, they seem to track fruiting trees in habitats that they do not usually reside in and therefore can be seen in dry deciduous tracts adjoining evergreen forests. Therefore, it becomes necessary for the protection and conservation of areas much larger than their "preferred" or even nesting habitats.

Currently 10% of the land area of the Western Ghats receives some level of protection within 43 wildlife sanctuaries and 13 national parks (Rodgers *et al.* 2002; Kumar *et al.* 2004). Substantial areas of forest and natural vegetation also lie outside existing protected areas as reserved forests, protected forests, private forests, grasslands, and wetlands. Considering just the tropical wet evergreen forests of the Western Ghats, a recent assessment reports that only one-fourth of the total area (15,057 km²) of this forest type is relatively un-fragmented, with 74% lying outside protected areas (CEPF 2007). Information of the distribution and occurrence of species obtained over these landscapes can be used to design appropriate conservation strategies. In the landscape adjoining forest areas in the Western Ghats, large tracts of plantations are distributed (over 4,500 km² of tea and coffee plantations alone), which are also often important habitats for wildlife, or areas through which many wildlife species move (Raman & Mudappa 2003; Kumar *et al.* 2004; Raman 2006; Bali *et al.* 2007). In recent times, there has been increasing interest worldwide in the conservation value of countryside landscapes within and around existing conservation reserves. There is a need to promote hornbill conservation and the use of native shade trees among plantation owners, possibly linking with conservation incentive/certification schemes.

Line transects appear to be a useful and easily applicable method for monitoring hornbill populations (Raman & Mudappa 2003; Gale & Thongaree 2006). Besides monitoring by biologists—trained amateurs, volunteers, and forest department staff need to be involved in hornbill monitoring as successfully demonstrated in Kerala (Praveen & Nameer 2009). There is a need to develop a management and action plan for monitoring, protection, and conservation of critical hornbill populations. This has to be developed by a committee consisting of local forest department, NGOs, local people, and a field/conservation biologist acting as a facilitator. At a number of locations we found low awareness of hornbill species occurrence or abundance, even among forest staff in protected areas. Conservation education and awareness thus need to go hand-in-hand with all protection and conservation efforts.

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Malabar Grey Hornbill male.

Photo: Kalpana Varma

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Great Hornbill male.

Photo: Mudappa & Raman

APPENDIX

Details and locations of transects surveyed at various sites along the Western Ghats
(GA—Goa, MH—Maharashtra, KE—Kerala, KA—Karnataka, TN—Tamil Nadu).

State	Place	Date	Habitat*	Place	Tno	Start (N°)	(E°)	End (N°)	(E°)	Length (km)
GA	Bondla	08.02.2005	XDF	Through forest trail to orchard	1	15.43483	74.10067	15.43420	74.10527	1.83
GA	Bondla	08.02.2005	XDF	Behind canteen into forest	2	15.43662	74.10431	15.44337	74.11265	1.74
GA	Bondla	09.02.2005	XDF	Uphill	3	15.43624	74.10033	15.42782	74.10391	2.18
GA	Mollem	10.02.2005	MDF	Near RO into MDF	4	15.37582	74.23635	15.38110	74.24231	1.96
GA	Mollem	11.02.2005	MDF	Khas-Kond towards Old Surla trail	5	15.41047	74.21070	15.41055	74.21783	3.54
GA	Mollem	11.02.2005	SEF	Khas-Kond towards Tambdi Surla	6	15.42057	74.21080	15.43918	74.25275	7.72
GA	Mollem	12.02.2005	SEF	Mudco Bungalow to Tambdi Surla	7	15.41840	74.26756	15.41497	74.20872	1.86
GA	Mollem	12.02.2005	MDF	Mudco Bungalow to Tambdi Surla	8	15.41497	74.20872	15.43918	74.25275	1.10
GA	Mollem	13.02.2005	MDF	Dudhsagar road	9	15.34129	74.25221	15.33665	74.25941	1.89
GA	Madei	14.02.2005	MDF	Nanorem–Vainguinim–border	10	15.58281	74.21738			0.85
GA	Madei	14.02.2005	SEF	Nanorem–Vainguinim–border	11			15.57673	74.25016	3.27
GA	Madei	15.02.2005	MDF	Satorem to Derodem	12	15.61436	74.21510	15.61334	74.22242	1.19
GA	Cotigao	18.02.2005	SEF	Cusquem (Kuske) transect	13	15.01788	74.21239	15.02626	74.21632	2.12
GA	Cotigao	18.02.2005	SEF	Nadquem Keri route	14	14.98322	74.22384			1.88
GA	Netravali	19.02.2005	WEF	Salginim kuccha road	15	15.01988	74.24185	15.01466	74.24582	1.12
GA	Cotigao	20.02.2005	MDF+SEF	Endrem to Zambolem	16	14.95530	74.19593	14.94598	74.19808	1.55
MH	Tansa	02.04.2005	DDF	Savardo nala	1	19.53873	73.28320	19.53332	73.27786	1.41
MH	Kalsubai	04.04.2005	SEF	Kothale, on Tolar Khind	2	19.40751	73.81431	19.40333	73.81123	1.04
MH	Bhima	05.04.2005	HEF	Bakadevi to Veer waterhole	3	19.07792	73.53838	19.08165	73.54791	1.76
MH	Bhima	06.04.2005	HEF	Kotlun-Gupt Bhima-Bhima temple	4	19.05831	73.54447	19.06159	73.54154	2.55
MH	Borivili	07.04.2005	DDF	Bhoot bungalow road	5	19.18600	72.92090	19.19669	72.92160	2.04
MH	Tungar	08.04.2005	XDF	Tungarashwar Ashram road	6	19.41933	72.91130	19.42068	72.91670	1.68
MH	Matheran	13.04.2005	HEF	To Panorama viewpoint	7	19.00418	73.28510	19.01869	73.27960	2.20
MH	Phansad	14.04.2005	DTF	Chikalgan waterhole trail	8	18.44830	72.92979	18.45466	72.92541	3.01
MH	Mahabaleswar	15.04.2005	HEF	Gotinera to Jannimatha	9	17.90398	73.67551	17.90795	73.67084	1.56
MH	Koyna	18.04.2005	DTDE	Tambi to Maruti mandir	10	17.67228	73.74529	17.67181	73.73714	3.84
MH	Koyna	19.04.2005	WEF	Kusawade	11	17.64550	73.74269	17.65121	73.73046	2.01
MH	Koyna	20.04.2005	DTDE	Rohine camp	12	17.53232	73.77124	17.53353	73.76459	1.41
MH	Koyna	21.04.2005	WEF	Kurunjawade	13	17.54084	73.75740	17.53972	73.74837	1.39
MH	Radhanagari	23.04.2005	DTDE	Idarganj ridge top trail	14	16.36899	73.99578	16.35026	73.97145	2.95
MH	Radhanagari	24.04.2005	WEF	Dajipur Savrai Sada to Patacha Dang	15	16.47481	73.88975	16.48219	73.88245	21.68
KE	Vazhachal	09.02.2006	WEF	Mud road to Adichalthotti + Vazhachal rd	1	10.29142	76.81499	10.28371	76.80479	3.49
KE	Vazhachal	10.02.2006	WEF	Ambalapara towards Meenchalali	2	10.32521	76.73257	10.33386	76.72245	1.95
KE	Vazhachal	11.02.2006	WEF	Poringalkuthu to Orukumban	3	10.32418	76.64621	10.33194	76.63884	1.16
KE	Vazhachal	15.02.2006	WEF	Sheikalmudi–Mudiyankundru trail	4	10.33357	76.83002	10.33765	76.82821	1.07
KE	Vazhachal	16.02.2006	WEF	Melmadu to Ambalapara	5	10.34127	76.76520	10.33287	76.76474	1.29
KE	Nelliampathy	21.02.2006	WEF	Towards Anaimada through Minampara Estate	6	10.54201	76.70195	10.53720	76.70927	1.21
KE	Nelliampathy	22.02.2006	WEF	Mud road–Nemmara KFR I cane stand 1991	7	10.54374	76.67671	10.54766	76.68159	1.14
KE	Peechi	23.02.2006	DDF	Peechi behind pavilion	8	10.53538	76.37744	10.53048	76.37177	1.04
KE	Chimmony	25.02.2006	LEF	Thottappara trail	9	10.42553	76.46398	10.42474	76.47103	1.34
KE	Periyar	26.03.2006	MDF	Mullakudi road	10	9.58243	77.22203	9.57366	77.22580	1.47
KE	Periyar	28.03.2006	MDF	Anjuruli road	11	9.58524	77.16228	9.57760	77.16402	1.21

APPENDIX

Details and locations of transects surveyed at various sites along the Western Ghats
(GA—Goa, MH—Maharashtra, KE—Kerala, KA—Karnataka, TN—Tamil Nadu).

State	Place	Date	Habitat*	Place	Tno	Start (N°)	(E°)	End (N°)	(E°)	Length (km)
KE	Parambikulam	31.03.2006	LEF	Orukomban-Mudhuvarchal Road	12	10.38340	76.62411	10.39175	76.61870	1.21
KE	Goodrickal	04.04.2006	WEF	Chendamarakokka	13	9.45408	77.13031	9.45323	77.13374	1.22
KE	Silent valley	21.05.2006	WEF	Sairandhri	14	11.08443	76.46723	11.08509	76.45470	1.94
KE	Wayanad	23.05.2006	DDF	Ambukuthi vayal to Ayamangalam patch	15	11.66158	76.38345	11.65527	76.39286	1.41
KE	Aralam	24.05.2006	LEF	Uruppukunnu watchtower towards Parriputhode	16	11.95304	75.82525	11.96095	75.81708	1.34
KE	Malayattur	26.05.2006	LEF	Thalunkundam road towards Ernakulamkudi	17	10.21748	76.69526	10.22378	76.68397	1.47
KA	Anshi	12.10.2005	WEF	Trek route 1 near ANC	1	15.00978	74.38722	15.01992	74.38924	1.41
KA	Anshi	13.10.2005	WEF	Kadra viewpoint road	2	14.95057	74.37236	14.94625	74.38763	2.75
KA	Dandeli	15.10.2005	MDF	Shiroli-Mandurli road core area	3	15.11701	74.58702	15.13173	74.57415	3.32
KA	Dandeli	16.10.2005	MDF	Gund-Vagali trail	4	15.07548	74.52791	15.08078	74.53759	1.68
KA	Dandeli	17.10.2005	WEF+MDF	Kanchikallgudda viewpoint	5	15.04442	74.57093	15.02829	74.58039	2.96
KA	Talacauvery	06.05.2006	WEF	Talacauvery—Munrod tract	6	12.36608	75.48985	12.35531	75.48366	1.61
KA	Subrahmanya	07.05.2006	MDF	On Bisle Ghat Road	7	12.69387	75.61631	12.69395	75.62751	2.10
KA	Kudremukh	09.05.2006	WEF	From Bhadra river Kurinjal trail	8	13.19841	75.19506	13.20068	75.18714	1.34
KA	Someshwara	10.05.2006	MDF	From Sitanadi Nature Camp, Ikkodlu trail	9	13.48405	75.00561	13.46975	74.99970	1.59
KA	Mookambika	11.05.2006	MDF	Kothalamukki game road	10	13.83462	74.81025	13.83612	74.81436	1.41
KA	Sharavati	12.05.2006	WEF	Aedigudda-Nagavalli	11	14.06653	74.67269	14.07806	74.66906	1.47
KA	Shettihalli	13.05.2006	MDF	Anigeri trail	12	13.86593	75.42367	13.86396	75.41346	1.34
KA	Bhadra	14.05.2006	MDF	Kesave-Madla road	13	13.49044	75.61447	13.50683	75.61393	1.44
TN	Anamalai	02.09.2005	WEF	Sheikalmudi-Palaganar-Manamboli	1	10.32703	76.84983	10.33714	76.85175	1.28
TN	Anamalai	03.09.2005	WEF	Koomatti-Manamboli	2	10.40161	76.87666			1.66
TN	Anamalai	04.09.2005	WEF	Kumati-Varagaliar trek shed	3	10.40235	76.87916	10.40175	76.88884	1.42
TN	Anamalai	04.10.2005	WEF	Manamboli elephant transect	4	10.34827	76.89783			2.58
TN	Anamalai	2005–2006	WEF	Korangumudi	5	10.31412	76.91214	10.30872	76.90361	1.83
TN	Anamalai	2005–2006	WEF	Pannimade*	6	10.29677	76.89227			1.20
TN	Anamalai	2005–2006	WEF	Puthuthottam	7	10.33383	76.96735	10.33511	76.96461	2.45
TN	Anamalai	2005–2006	WEF	Tata Finlay	8	10.34755	76.93382	10.34705	76.93352	1.15
TN	Anamalai	2005–2006	WEF	Anaigundi	9	10.42175	76.83122			2.17
TN	Anamalai	2005–2006	WEF	Andiparai	10	10.39060	76.99438	10.40000	76.99117	2.08
TN	Anamalai	2005–2006	WEF	Karian Shola 1	11	10.47045	76.84110	10.49023	76.83065	2.85
TN	Anamalai	2005–2006	WEF	Karian Shola 2	12	10.46388	76.83660			2.85
TN	Anamalai	2005–2006	WEF	Iyerpadi	13	10.37308	76.99138	10.36070	76.99738	2.08
TN	Anamalai	2005–2006	WEF	Akkamalai	14	10.32815	77.02172	10.34570	77.02008	1.94
TN	Anamalai	2005–2006	WEF	Iyerpadi Church	15	10.36935	76.97515	10.37232	76.98078	1.70
TN	Anamalai	2005–2006	WEF	Varagaliar	16	10.42007	76.86811	10.71155	76.88231	2.11
TN	Anamalai	2005–2006	WEF	Banathiar	17	10.40335	76.87857	10.41370	76.88023	2.05
TN	Anamalai	2005–2006	WEF	Manamboli	18	10.34827	76.89783			1.80
TN	Anamalai	2005–2006	WEF	Sheikalmudi	19	10.32707	76.84982	10.33793	76.85755	1.87

* DDF—Dry deciduous forest, DTF—Dry thorn forest, DTDE—Dry thorn and degraded deciduous dry evergreen forest, XDF—Mixed deciduous forest, MDF—Moist deciduous forest, SEF—Semi-evergreen forest, LEF—low elevation wet evergreen forest, HEF—Sahyadri or northern wet evergreen forest, WEF—Wet evergreen forest. *—Location approximate.