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Nesting requirements of the rock bee *Apis dorsata* in the Nilgiri Biosphere Reserve, India

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Abstract: We estimated the nest densities of rock bee (*Apis dorsata*) within Nilgiri Biosphere Reserve (NBR), Western Ghats, India, during January to June 2007. Randomly chosen five km long transects covering various habitat types spread across 5 protected areas, were walked by at least 3 persons including professional honey hunters. Variable width line transect method was used and all nests located on either side of the transect line were recorded and their approximate distance to the transect line assessed. The program 'DISTANCE' was used to estimate nest densities. The number of cliff faces along the transect line; a measure of honey hunter pressure and harvest intensity per km^2 were also recorded. There was significant variation in nest densities between sites. Sathyamangalam area had the highest nest densities due to the presence of cliffs. This area also had the highest harvest intensity and honey hunter pressure. Conservation of nesting habitats such as cliffs and tall trees are important for maintaining viable populations of this important species.

Resumen: Estimamos las densidades de nidos de la abeja de la roca *(Apis dorsata)* en la Reserva de la Biosfera Nilgiri, Ghates Occidentales, India, de enero a junio de 2007. Al menos tres personas, incluyendo cazadores profesionales de miel, hicieron caminatas a través de transectos de 5 km de largo seleccionados aleatoriamente y que abarcaban varios tipos de hábitats. Se utilizó el método de transecto de ancho variable y todos los nidos localizados a cada lado de la línea central del transecto fueron registrados y se evaluó su distancia aproximada a la línea central del transecto. Las densidades de nidos fueron estimadas por medio del programa 'DISTANCE'. También se registraron el número de caras de acantilados a lo largo del transecto, una medida de la presión de cacería de miel y la intensidad de la cosecha por km^2 a lo largo del transecto. Las densidades de nidos variaron significativamente entre sitios. El área Sathyamangalam tuvo la mayor densidad de nidos debido a la presencia de los acantilados. Esta área también tuvo la mayor intensidad de cosecha y la mayor presión por parte de los cazadores de miel. La conservación de hábitats de anidamiento como los acantilados y los árboles altos son importantes para mantener poblaciones viables de esta importante especie.

Resumo: Estimaram-se a densidade dos ninhos da abelha das rochas *(Apis dorsata)* na Reserva da Biosfera de Nilgiri (NBR), Gates Ocidentais, Índia, de Janeiro a Junho de 2007. Transeptos de cinco km de comprimento escolhidos casualmente e cobrindo vários tipos de

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habitats espalhados através de 5 áreas protegidas, foram percorridas pelo menos por 3 pessoas, incluindo colectores profissionais de mel. Foi utilizado o método de largura variável do transepto e todas os ninhos localizados em qualquer lado da linha foi registado e as suas distâncias aproximadas à linha do transepto foram avaliadas. Usou-se o programa DISTANCE para estimar a densidade dos ninhos. O número de faces dos penhascos abruptos ao longo do transepto, a medida da pressão dos colectores de mel e a intensidade da colheita por km^2 foi igualmente registada. Encontrou-se uma variação significativa na densidade dos ninhos entre sítios. A área de Sathyamangalam apresentou a densidade mais alta de ninhos devido à presença de penhascos. Esta área também tem a maior intensidade de colheita e pressão de colectores. A conservação dos habitats de criação, tais como os penhascos e árvores altas é importante para a manutenção de populações viáveis desta importante espécie.

Key words: *Apis dorsata*, India, nest densities, nest site limitation, Nilgiri Biosphere Reserve, Western Ghats.

Introduction

The distribution of species across landscapes is affected by multiple factors operating at different scales which include habitat characteristics, predation pressure and availability of breeding sites (Andren 1992; Karveiva & Wennergre 1995). For social insects such as honey bees, food limitation, nest predation, and the spatial dispersion of forage plants, nesting sites and nest-building substrates may be important factors influencing population size and reproduction (Deslippe & Savolainen 1994; Eltz *et al.* 2002; Westrich 1996). Significance of forage plants was demonstrated in a study where the nest densities of stingless bees varied 20-fold in relation with floral resources (Eltz *et al.* 2001). For social bees that nest on trees or rock faces, nest height, which places nests out of reach of terrestrial predators such as humans and bears, is probably an important factor influencing nest site selection. Nest site predation of Meliponine colonies by tool using humans and chimpanzees averaged 12 % per year in Uganda and decreased with increasing nest height (Kajobe & Roubik 2006).

The rock bee, *Apis dorsata* Fabricius nests on single combs which can be as large as 150 cm in width, suspended from cliff faces or branches of lofty trees. The hives are often in aggregations. This species defends its nests aggressively when disturbed (Seely *et al.* 1982). Likely nest predators are bears, humans and raptors such as Honey-Buzzard *Pernis ptilorhyncus* (Laurie & Seidensticker 1977; Seely *et al.* 1982). It is an economically important species of as a crop pollinator (Crane 1999; Neupene *et al.* 2006) and as a source of honey and wax that are harvested by local communities (Crane 1999). Many indigenous communities in the Nilgiri Biosphere Reserve have specialised traditional skills for safely collecting honey from *Apis dorsata* nests (Keystone Foundation 2007).

To better understand the nesting behaviour of *Apis dorsata* in contrasting landscapes with different levels of protection and honey exploitation, we assessed nest densities within five protected areas (PAs) within the Nilgiri Biosphere Reserve. These included two National Parks with a high degree of protection where collection of forest products is banned, two Wildlife Sanctuaries where collection of forest products such as honey for household use is permitted and one Reserve Forest where limited commercial extraction is permitted. *Apis dorsata* migrate locally probably in response to varying floral resources (Dyer & Seely 1994) and can respond rapidly to mass flowering events by rapid expansion of population size (Itioka *et al.* 2001). Local migration has been recorded in the Nilgiri Biosphere Reserve in southern India (Leo 2008; Pratim Roy, personal observation) and in the Kakachi region of the Kalakad-Mundanthurai Tiger Reserve (Davidar *et al.* 1993). Local migration in response to flowering events suggests that food limitation is less of a constraint for *Apis dorsata* colonies than nest site limitation. *Apis dorsata* tended to visit about 27 % of the flowering plants in the Nilgiris, which were visited by other species of bees as well (Thomas *et al.* 2009a), suggesting lower levels of floral specialization.

We predicted that *Apis dorsata* nest densities

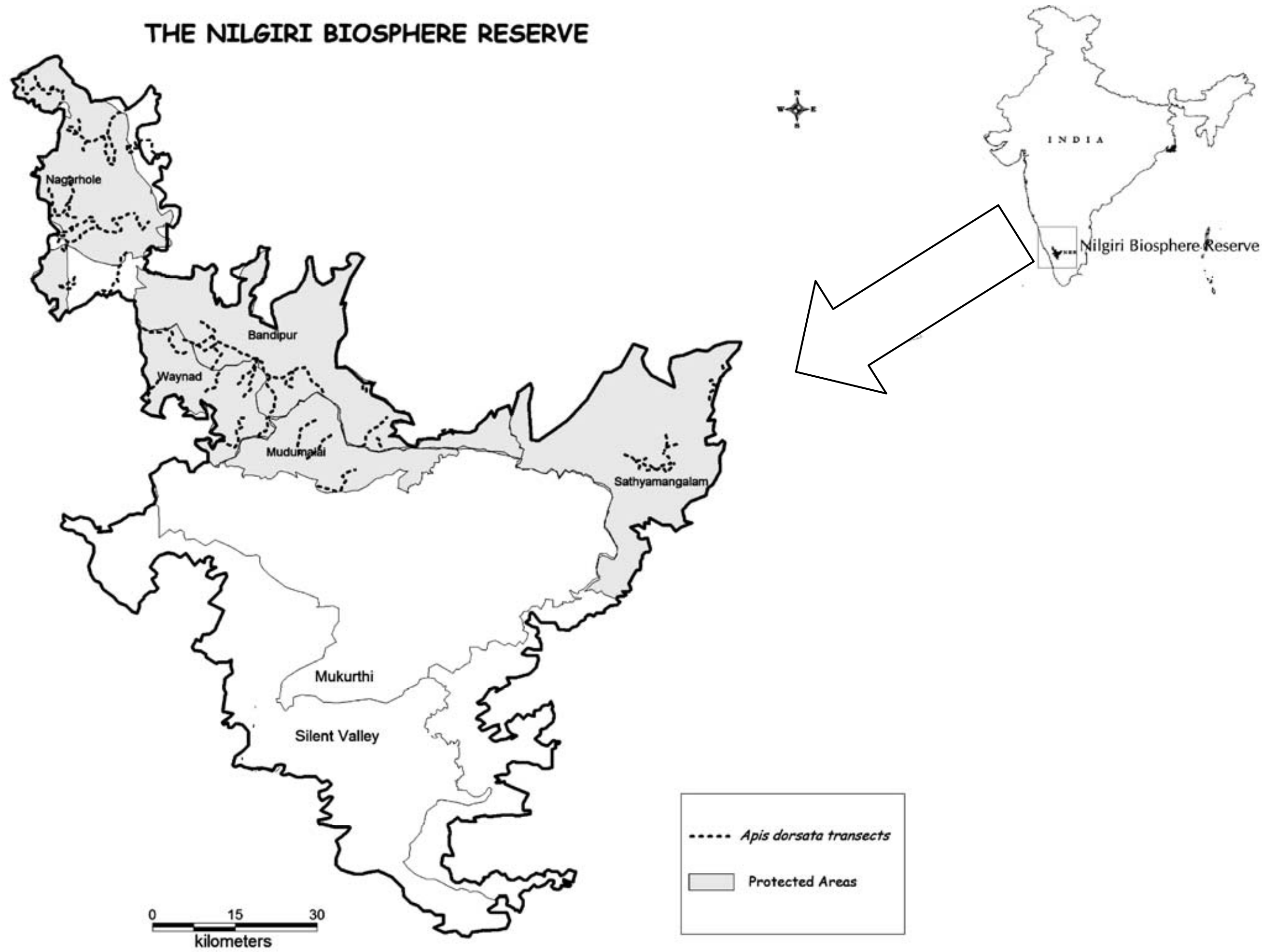

Fig. 1. Map of the Nilgiri Biosphere Reserve with location of the study sites and transects (AD Survey Tracks = Transects used to survey *Apis dorsata*).

in the landscape would be related to the availability of nesting sites, such as cliff faces, and would differ with regard to the level of prohibition of honey harvesting, i. e., increasing levels of forest protection.

Material and methods

Study area

The Nilgiri Biosphere Reserve (NBR) forms a part of Western Ghats chain of mountains in the Indian peninsula (5520 km^2; 10º 45' to 12º N latitude and 76º to 77º 15' E longitude), spread across the three states viz., Karnataka, Kerala and Tamil Nadu. The reserve encompasses five protected areas including a large tract of Reserved Forests (Fig. 1). Altitude of the reserve ranges from 250 to 2650 m above sea level. The intensity of rainfall brought by the south-west and north-east monsoon differs across topographic and altitudinal gradients (Lengereke 1989). The NBR has a wealth of biological and cultural diversity (Hockings 1989).

The study was conducted during the dry season (January - June) of 2007 in five protected areas within NBR: the Bandipur National Park (BNP), the Nagarhole National Park (NNP) the Mudumalai Wildlife Sanctuary (MWS), the Sathyamangalam Reserve Forest (SRF) and the Wayanad Wildlife Sanctuary (WWS). National Parks have the highest level of legal protection, Wildlife Sanctuaries come next and the Reserved Forest had the lowest level of protection (Table 1). Bandipur, Mudumalai and Nagarhole had predominantly moist and dry deciduous forests, whereas Sathyamangalam and Wayanad had a mixture of wet evergreen and deciduous forests.

Table 1. Abundance of *Apis dorsata* nests on trees and cliffs in various PAs of Nilgiri Biosphere Reserve and honey harvest pressure.

Site	Total number of nests	% nests on tree	% nests on cliff	Cliff faces (N)	Mean (±SD) colony size (N*)	Harvest intensity km^{-1}	Honey hunting pressure
Bandipur NP	92	66	34	4	5 ± 6 (18)	0	3
Mudumalai WLS	394	88	12	1	19 ± 26 (21)	0.044	2
Nagarhole NP	249	100	0	0	4 ± 7 (62)	0.012	4
Sathyamangalam RF	1153	2	98	23	36 ± 85 (31)	0.192	6
Wynaad WLS	181	100	0	0	3 ± 4 (69)	0.019	5

N*=number of sightings.

Colony surveys

The survey for *Apis dorsata* colonies was carried out between January and June 2007, which represents the major flowering season for plants in the region (Murali & Sukumar 1994). After June, *Apis dorsata* migrate to other areas in response to the South-west monsoon (Leo 2008).

We used the variable width line transects with distance estimation to assess nest densities in each site (Emlen 1971; Emlen 1977). A fundamental assumption of the method is that all objects on the transect line are detected and the probability of detection decreases monotonically with increasing perpendicular distance from the transect line. The detection function can provide estimates of error and reliable estimates of density (Diefenbach *et al.* 2007). A 5 km long transect was the sampling unit and each transect was walked in one direction once in the morning hours by 3 - 6 experienced observers including tribal honey collectors. The length of transect was measured using a pedometer. When a nest or a cluster of nests was detected, approximate perpendicular distance to the transect line and number of nests per cluster were recorded.

The density estimation method for line transects and point counts takes into account the detection function where all individuals on the transect would be detected and the number detected would decrease monotonically with increasing distance from the observer (Buckland *et al.* 2001). Keeping this assumption in view, the program Distance 4.1 (Thomas *et al.* 2010) was developed to estimate densities using both point counts and line transects. This program calculates the estimated strip width and provides alternative detection functions using the Akaike Information Criterion (Akaike 1974). We used this program to calculate densities to standardize the density estimates. This was because the habitat characteristics in each site differed and the detection function therefore, would also differ. Since the program automatically selects the best fit model for each dataset, the density estimates would be more comparable.

At least two transects were walked within each forest range (administrative unit) lying within a protected area. Minimum of five hours were taken to complete each transect. Depending on the area to be covered the number of days spent in each area varied. In Sathyamangalam the sampling was more intensive and at least three, five km transects were walked in the forests around each of the five honey hunter villages making a total of 16 transects. This was because the accessibility to this region was higher because it had a lower level of protection. The lengths of all transects in each study area were summed to give the overall transect length. The occurrence of cliffs was noted and the number of cliff faces measured in each site using digitised topographic maps published by the Survey of India.

Honey harvest intensity

A measure of honey harvest intensity was obtained by recording the number of nests that were harvested along each transect line. The honey had been harvested either partially or fully. Partially harvested hives were characterized by partially damaged combs. In many cases the honey collectors remove the whole comb and leave a clearly identifiable mark on the branches at the point of attachment. Sometimes ladders or ropes used for honey harvest were left behind indicating the harvest. The total number of nests harvested per km of walk transect gave an index of harvest

Table 2. The results of the distance sampling method using Distance 4.1 (Buckland *et al.* 2001).

Site	Transect length (km)	Estimated strip width (m)	Density (km^{-2})	95 % CI		CV
				Lower	Upper	
Bandipur	60	34	0.34	0.15	0.76	0.41
Mudumalai	40	47	0.78	0.27	0.49	0.60
Nagarhole	50	16	1.67	0.06	2.6	0.24
Sathyamangalam	75	25	3.3	1.4	7.7	0.45
Wynaad	60	24	0.56	0.28	1.14	0.36

Table 3. Spearman's rank correlation coefficients of selected variables.

Parameters	% Nests on tree	% Nests on cliff	Number of cliff faces	Nest cluster size	Harvest intensity	Honey hunter pressure	PA
Mean nest cluster size	-0.87*	0.87*	0.87*	1.00			
Harvest intensity	-0.36	0.36	0.36	0.60	1.00		
Honey hunter pressure	-0.15	0.15	0.15	0.53	0.40	1.00	
PA	-0.43	0.43	0.43	0.53	0.95*	0.53	1.00
Nest densities (km^{-2})	-0.21	0.21	0.21	0.50	0.70	0.50	0.53

PA = protected area
*$P = 0.05$

intensity. We developed an indicator of 'honey hunting pressure' by estimating the number of specialized honey hunters from *adivasi* (tribal) groups such as the Irulas, Kurumbas, Soligas and others, in each site using household data from each region (Snehlata Nath, unpublished data). We estimated the number of honey hunters in each region and rated them on a scale of 1 to 6, from 1 being the site with the least honey hunting groups to 6, having the maximum honey hunting groups.

Data analyses

The line transect option was selected in the Distance program (version 4) with line length (in km), the perpendicular distance to each nest (in m), and cluster size (number of nests) where relevant. The program selected the best fit model using the Aikake Information Criterion, and gave estimates of strip width for each site, density and confidence intervals (Thomas *et al.* 2010).

Spearman's rank correlation was used to assess whether nest density was associated with harvest intensity, indicators of honey hunter pressure, level of protection and availability of cliffs in the different sites. The number of nests per aggregation on a tree or a cliff was listed with pooled data from all sites and a Mann Whitney U test was used to see whether there were significant differences in sizes of aggregations between trees and cliffs. Systat version 10, SPSS Inc (Chicago, USA) was used for the statistical tests.

Results

Colony numbers in most sites were small with an average of 3 - 9 nests per site except for Sathyamangalam with an average of 36 nests and Mudumalai with 19 nests (Table 1). This is because Sathyamangalam had a rugged terrain with a higher proportion of cliff faces than the other sites, and about 98 % of the nests recorded in Sathyamangalam were aggregated on cliffs (Table 1). There was a nine-fold difference in nest densities between sites (Table 2). The average size of the aggregation (mean ± SD) on cliffs (42 ± 87) was significantly higher than those on trees (5 ± 12, Mann Whitney U test, U = 4084, n = 206, $P < 0.0001$). Harvest pressure was generally low, with the highest levels being in Sathyamangalam which also had the most honey hunters. The nest densities at the landscape level were not significantly associated with any variables but the average size of nest clusters increased with the percentage of nests on cliffs (r_s = 0.87, P = 0.05), and the proportion of cliff faces recorded in the region (r_s = 0.87, P = 0.05). The size of the nest cluster decreased when nests were located on trees (r_s = -0.87, P = 0.05, Table 3), because trees have limitations on the number of nests they can harbour and very tall trees conducive to nesting clusters, were rare in Sathyamangalam. Harvest intensity increased with decreasing levels of protection because harvesting was banned in sites with higher levels of protection ($r_s = 0.95$, $P < 0.05$).

Discussion

Our study is the first attempt to look at the nest densities of the rock bee in five PAs of the NBR. We demonstrate the differences in nest densities in these areas to show that when cliffs are available, colonies are larger and nests are located preferentially on cliffs. Harvest intensities varied between sites, and were highest in Sathyamangalam Reserved Forests, which had the highest nest densities, highest levels of honey hunter pressure and also, highest harvest intensities. Sathyamangalam also had the lowest level of forest protection. This suggests that *Apis dorsata* populations can withstand a degree of harvest, especially when inaccessible nest sites such as cliff faces are available, which provide protection against predators and over-harvesting. Honey hunting is an ancient vocation that requires special skills and tools given the inaccessibility of the nests and aggressive nature of rock bees (Crane 1999). The traditional honey collectors in the NBR harvest honey after the honey cells are fully capped. Generally, they remove only honey portion of the comb without disturbing the colony. Honey collection from the cliffs is extremely difficult that involves hanging in the mid air suspended on ropes or vines combined with severe attack by the bees and at a time not more than 4 to 5 nests can be harvested from a colony that may last only for 2 to 3 hours.

Our findings has significant implications for the conservation and management of honey bees at the landscape scale. Since *Apis dorsata* use mainly cliffs and tall trees for nesting (Seeley *et al.* 1982; Thomas *et al.* 2009b), availability of such sites is a major limiting factor that determines their distribution and abundance. Over the geographical range of *Apis dorsata* in Asia, the rate of deforestation is very high (Laurance 2007) and selective logging of tall trees can affect the nesting of bees. Hence, protection of *Apis dorsata* nesting sites such as rock faces and large trees is crucial for maintaining the viable populations of this keystone pollinator. We believe that the traditional honey hunting, especially from the rocks, may be a sustainable practice. However, honey collection with modern tools such as nets and climbing gear by traditional as well as non-traditional collectors is likely to result in over harvest and decline in bee populations. Long term studies on bee populations, impact of varying intensity of honey collection on bee populations and year to year variation in honey production would be crucial for understanding the limits of honey collection in the NBR.

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