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Research Article

Estimating Asian elephant, *Elephas maximus,* density through distance sampling in the tropical forests of Biligiri Rangaswamy Temple Tiger Reserve, India

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Abstract

To determine abundance, density and distribution of wild animals, it is crucial to estimate populations using reliable sampling techniques. In most earlier studies, elephant populations were estimated employing block counts or dung counts, which provide biased estimates due to limitations of the methods. We estimated an Asian elephant population using distance sampling, a quantitatively robust technique, in Biligiri Rangaswamy Temple Tiger Reserve, a critical elephant conservation area in the Nilgiri Biosphere Reserve in south India. We laid 33 transects with a total length of 93 km. We walked these transects five to 11 times amounting to a total of 795.5 km of walks. We collected data on location, number and age-sex classes through direct elephant sightings, using rangefinders, global positioning systems and compass. We used DISTANCE software for analysis. We estimated per km^2 cluster density as 0.69 elephant herds, mean cluster size as 2.44, and elephant density as 1.7 animals. This amounts to a total of 713 elephants in 610 km^2 of the sanctuary. A high percentage of males less than 30 years old and a low immature:adult female ratio indicated the severity of poaching in the recent past in the study region.

Keywords: Asian elephant, BRT Tiger Reserve, distance sampling, density

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Introduction

Population estimation, either by direct (observations) or indirect (nest or faecal) surveys, is crucial to determine abundance, density and distribution of wild animals [1-3]. In the case of large-bodied animals such as elephants, use of line transects based on direct sightings or indirect signs such as dung have been commonly applied to estimate density in the wild [4-6]. Other methods, such as mark-recapture and water hole count, have seldom been used to estimate density of wild elephants [2, 7-10]. In India, estimates of elephant densities in the forest areas often relied heavily on line transect dung count and block count methods [11]. However, these methods lack a strong theoretical basis and do not statistically address critical problems such as probability of detection of animals within the surveyed area. Further, use of the dung count method to estimate elephant densities is often limited by using known defecation rates [11] which are affected by factors such as season, rainfall, habitat types, size of boli etc. [12-13] or on the assumption of age-specific decay rates [14], thereby providing biased estimates. Population parameters such as density and age-sex ratios have also been estimated using distance sampling based on direct or indirect signs [15], capture-recapture [16] and population surveys [4]. More recent methods such as photographic techniques and acoustic sensors have seldom been used to estimate abundance of elephants in dense forest areas [7, 17-18]. Distance sampling offers a reliable estimation of animal densities [19] comparable to results of the mark-recapture method, and has also proved to be cost-effective and less disturbing to the environment [20].

The Asian elephant (*Elephas maximus*) is highly threatened by habitat fragmentation, habitat loss and human-elephant conflict in many parts of Asia [21-24]. In India, which hosts 60% of the global Asian elephant population, nearly two-thirds of the elephant population lives either close to or within human-dominated landscapes [25-26]. Southern India harbors half of India's Asian elephant population [27], and its Nagarahole-Nilgiris-Eastern Ghats Elephant Reserve, containing about 6300 elephants in an area of 12,000 km² [28], is an important conservation area with large wild lands available for elephants. However, these areas are also threatened by the development network and human density [25].

The Biligiri Rangaswamy Temple (BRT) Tiger Reserve within the Nilgiri Biosphere Reserve is a critical place for elephant conservation. There have been no standardized estimates of Asian elephants in BRT for the past three decades due to insurgency created by forest brigands. The available estimates are based on the state Forest Department's annual census programs, which were not based on spatially representative sampling efforts and tended to project unreliable densities [29]. However, in the adjoining forests of BRT in the Nilgiri Biosphere Reserve, elephant densities have been estimated to be 3.3 animals per km² [30] in Nagarahole Tiger Reserve and 4.41 elephants per km^2 in Mudumalai Tiger Reserve [31]. Earlier predictions of elephant densities using the dung-count method indicate 2–4 elephants per km², amounting to a total of 691-914 elephants in the BRT hills [28]. In order to provide more reliable results, we here report the abundance estimate of elephants using the distance sampling method with a special emphasis on age-sex ratios in the tropical forests of BRT. This information will serve two purposes. It will indicate the importance of this area and place it in a larger elephant conservation program surrounding this region. It will also provide base data for the future study of elephant population dynamics and development of effective conservation strategies.

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Methods

Study area

We carried out this study in the Biligiri Rangaswamy Temple Tiger Reserve, which lies between 11^0 40′-12^0 09′ N and 77^0 05′-77^0 15′ E, covering an area of 610 km² (Fig. 1). The altitude in this area varies between 600 m asl to 1800 m asl. The temperature varies spatially and temporally, with the minimum temperature between 8^0 C to 16^0 C and the maximum temperature between 20^0C to 38^0C. Rainfall varies from year to year in intensity and distribution, with the plateau lands receiving as low as 600 mm and the upper hills receiving over 3000 mm. The wide range of climatic conditions also contributes to the heterogeneous assemblage of habitats such as scrub, deciduous, riparian, evergreen, sholas, grasslands etc. The major forest types are evergreen forest (EF, 10.3%, which include evergreen forests, sholas and high altitude grass lands), moist deciduous forest (MDF, 25%), dry deciduous forest (DDF, 36.1%) and scrub forest (SF, 28.2%) [32]. There are many human enclaves inside the sanctuary, including settlements of indigenous people, temple staff, and private estates of commercial plantations growing coffee *Coffea arabica*, pepper *Piper nigrum*, cardamom *Elettaria cardamomum* etc.. Over 6000 tribal people living in 57 settlements in the sanctuary have caused high biotic pressure [33].

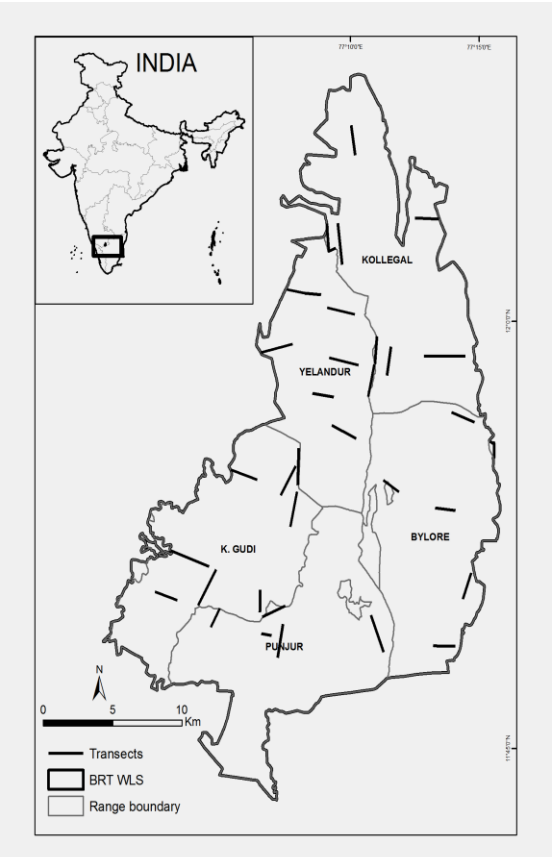

Fig. 1 Map showing the transects in the BRT Tiger Reserve

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Sampling methods

We used a combination of methods by adding 26 new random line transects to the seven existing transects being used for annual census by the Karnataka Forest Department. The length of transects ranged from 2 to 4 km, totaling a distance of 93 km. We made five to 11 repeated walks on transects [34], between 06.00 and 10.00 h and from 16.30 to 18.30 h during October 2009 and April 2010, as the visibility during these months is better than during the monsoon season between May and September. We walked a total of 795.5 km on the transects. During a transect walk, we recorded data on sightings of single individuals, number of individuals and their age- sex if sighted in a herd, animal-to-observer distance, and angle of detection from main bearing. We measured observer-to-animal distance using OPTI-LOGIC 1000 XL and OSPREY rangefinders, and the angle of detection from the transect line using a compass. When elephants were encountered in a herd (animals aggregating within 30 m radius) [30]), we recorded distance and angle to the centre of the herd. We recorded the coordinates for each sighting using handheld GARMIN eTrex H and GARMIN 72 GPS units.

We analyzed the data using DISTANCE version-5 [35] software and computed the estimate of density. We pooled the data from temporal replicates of each transect and treated the mean as a single sample (sample size = 33). We truncated the farthest sightings on transect to achieve a reliable density estimate [36]. However, we performed the density estimates using both truncated and un-truncated data. Checking for size bias in detection of animal clusters led to a non-significant regression equation at $\alpha = 0.10$ [37], and we therefore used the mean cluster size for analysis. We estimated variance in encounter rates of animals between transects empirically [36]. We judged the fit of possible alternative models to each specific dataset using Akaike's information criterion (AIC) value and goodness of fit tests generated by the program DISTANCE, and selected the best possible model. We generated encounter rate, average probability of detection, cluster density, cluster size and animal density using the selected model in program DISTANCE. For sightings in which age-sex of individuals could not be recorded, we recorded only group size. We divided animals into three age-sex classes, classifying animals younger than age 15 as immature and the rest as adult males and adult females following the indicators by Sukumar et al. [38].

Results

We recorded a total of 46 sightings of elephants on line transects. Data did not show heaping (Fig. 2). The estimate of cluster was 0.69 elephant herd per km^2 with a mean cluster size of 2.44 (Table 1). The density of individuals was estimated to be 1.7 elephants per km^2 (95% confidence interval of 1.17-2.46 elephants per km^2) and the percent coefficient of variation of density of individuals was 18.97. The minimum population density of 1.17 elephants per km^2 accounts for 713 elephants (lower CI) in BRT.

Table 1. Density estimate for elephants in the Biligiri Rangaswamy Temple Tiger Reserve

Data type	Sightings	Clusters/km^2	Mean cluster size	Density/km^2	% coefficient of variation	95%CI/km^2
Untruncated	46	0.68	2.60	1.78	16.93	1.27-2.48
Truncated	44	0.69	2.44	1.70	18.97	1.17-2.46

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The sightings ranged between 1 and 6 elephants with a mean of 2.4±1.44 (SD) elephants. Numbers of sightings in each size category are presented in Fig. 3. About 40% of the sightings were of single individuals. Most of these individuals were males, though a few solitary females were also sighted. About 70% of the adult males appeared to be less than 30 years old. The percentages of adult males, adult females and immature were 15.2, 62.9 and 22.0, respectively. This provided a ratio of 1:4.1 for adult males and females, and 1:0.35 for adult females to immature.

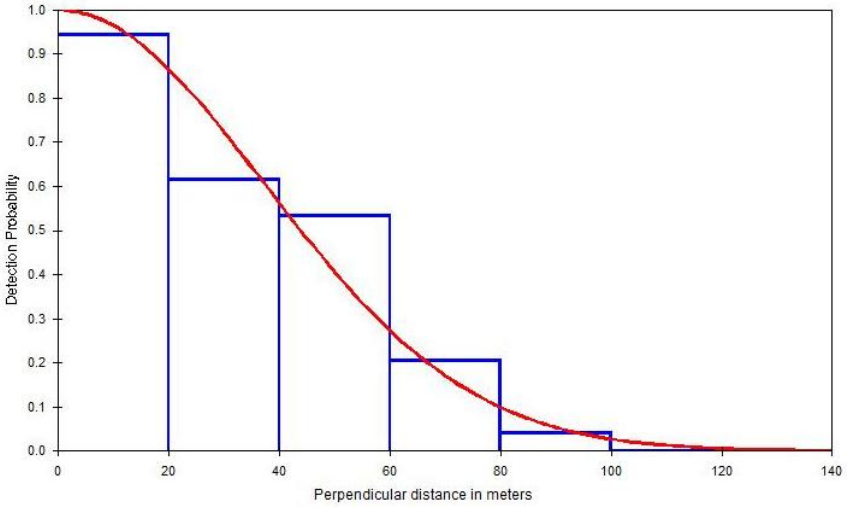

Fig. 2 Detection distances of elephants in BRT Tiger Reserve (for un-truncated data)

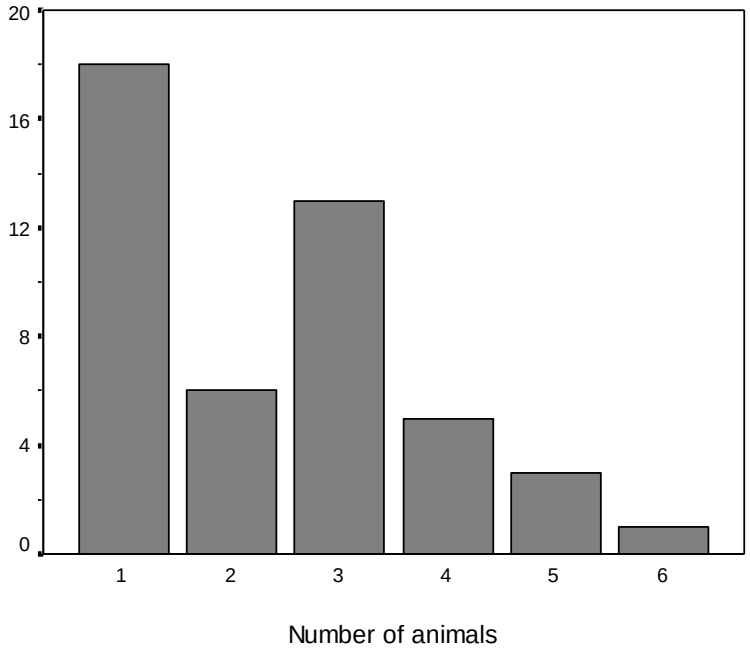

Fig. 3 Number of sightings of elephants in each size category

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Discussion

The population estimate of wild Asian elephants in range countries has been a matter of debate. Recent estimates of Asian elephants in India range between 27,669 and 27,719 [39]. The Project Elephant has officially declared 32 elephant reserves with an area of 60,000 km^2 to protect elephants, their habitats and corridors. Estimation of elephant densities has been crucial for designing appropriate management options for conservation of Asian elephants in protected areas. The current estimate for BRT is comparable to earlier studies [28]. Most of the estimates for Asian elephants in India are primarily based on intensive studies carried out at the regional level. The Nilgiri Biosphere Reserve (NBR), which accounts for the largest elephant population in India, occupies an important conservation area for elephants. The BRT Tiger Reserve within the NBR has not been rigorously studied to estimate elephant population for nearly three decades. However, as a part of synchronized elephant census program, a recent estimate of elephant population by using the transect dung/block count methods in BRT revealed 1.4 elephants/km^2 and 0.8 elephants/km^2, respectively, compared to the adjoining areas of Bandipur Tiger Reserve (1.8 elephants/km^2), Nagarahole National Park (1.6 elephants/km^2, [15]), Mudumalai Tiger Reserve (3.1/ km^2), Nilgiri north (0.5/ km^2), Satymangalam (0.3/ km^2, [40]), and Wayanad Wildlife Sanctuary (1.75/ km^2, [41]).

The above two methods have not been tested for scientific credence and have certain key limitations: (a) difficulty in counting all animals in a sample block, (b) observer's skill and experience and (c) assumption of detectability to be 1. The dung count method is usually carried out during the summer/dry period due to logistics and convenience, which causes biases in elephant density estimation [12]. Moreover, two of the three parameters (dung defecation and dung decay rates) in the dung count method have not been calculated prior to census [15] and are often used from earlier efforts carried out elsewhere. Liang *et al*. [42] and Hedges & Lawson [43] pointed out that dung decay rates vary by up to 72% across localities, seasons, and years in the same area. These shortcomings warrant use of other methods, such as line transect for direct observations of elephants/elephant herds, mark-recapture, photography, etc., to estimate elephant densities [7, 30-31]. This study produced a reliable estimate of elephants through direct observations on line transects that were repeatedly walked over a considerable period of time. The study estimated that there are around 700 elephants in BRT.

Whereas a substantial proportion of sightings was of solitary individuals, most of the herds sighted ranged between 2 and 4 individuals. Most of the adult males appeared to be less than 30 years old, suggesting the disappearance of old bulls due to poaching by forest brigands who operated in the Tiger Reserve for over three decades. This has possibly affected the distribution of elephants and resulted in small family units of a mother and dependent offspring in response to anthropogenic pressure [27, 44], which is a serious concern in the BRT. On other hand, it has been clearly established that mating success of bulls is highly dependent on the presence of the oldest males, which performed most of the mating and fathered the majority of infants in elephant herds [45].

Implications for conservation

Poaching pressures may seriously lower the infant-to-female ratio by affecting birth rates and disturbing the demographic structure, inhibiting the long-term survival of elephants [46, 47]. The skewed ratios of adult female to young may be due to heavy poaching pressures over a long period of time in the BRT. Likewise the 1:4.1 adult male to adult female ratio in BRT also reflects

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severe poaching on male elephants as the normal male to female ratios for elephants are considered to be 1:1.87 and 1:1.85 as reported for Rajajai National Park of India [48] and Ruhuna National Park of Sri Lanka [49] respectively.

Since the precise status of elephant densities and age-sex structure for the BRT conservation region was not available before now, the data reported in this article should become a starting point for enumerating elephant population dynamics and designing conservation programs accordingly.

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