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Population Density and Age-Sex Composition of Large Mammals in Tropical Forests, Southern India
Mohanarangan Ashokkumar and Rajaratinavelu Nagarajan

Abstract

The population density, structure, and biomass of mammal species were investigated in the tropical forest of Southern India. The population of large mammals was estimated using distance sampling methods at the Mudumalai Tiger Reserve in the dry seasons from 2004 to 2007. The estimated densities of larger ungulate species such as elephant and gaur were 4.8/sqkm and 7.9/sqkm. Medium-sized ungulate species such as sambar, chital, barking deer, and wild pig densities were 71, 279, 11, and 0.4/sqkm, respectively. The estimated density of primate species, i.e., common langur, was 14.9/sqkm. The smaller rodent species, black-naped hare, had a lower density of 1.3/sqkm, which could be attributed to the nocturnal behaviour of hares. Among these mammal species, barking deer and black-naped hare are solitary species, while others are gregarious. The study area supports herbivore biomass density of 15,198 kg/sqkm. Comparison with earlier estimates, the densities of elephant and gaur is increasing in the study area. The population density of large mammals is compared to other areas and discussed.

Keywords: large mammal population, Mudumalai Tiger Reserve, ungulate densities in tropical forest, elephant, gaur, chital

1. Introduction

The assessment of population is the key to understand the demography of animals and for evaluating management effectiveness. Therefore monitoring of population is a crucial component in animal ecology and wildlife conservation. Evaluation of population density and biomass have been used to investigate the complex relationship between a species and its environment [1] and their inter-specific relationship in a community [2]. Management strategies in protected areas must be based on an understanding of the functional relationship between habitat conditions, animal population and the dynamics of these populations. Large herbivores are particularly difficult to conserve, because of their relatively low population densities, unique habitat needs, crop raiding tendencies and their consumption and disturbances due to people [3]. However, herbivores’ conservation is crucial because apart from being important economic, nutritional and aesthetic resources, large herbivores directly or indirectly influence forest structure, regeneration and predatory species [4].
They also play an important role in conservation of large carnivore population, especially tigers. Furthermore, the selective predation of particular prey species, age and size class allowed the coexistence of three carnivores [5–7]. The coexistence of Tigers and Leopard in the tropical forest was due to the specialisation on different sized prey species [7] or based on spatial or temporal partitioning of resources [8]. Therefore it is important to identify the available prey species and their role in shaping the community structure of the carnivores.

Mudumalai Tiger Reserve is part of Nilgiri biosphere reserve with contiguous forest area of about 5520 km², supports largest Asian elephant population in India [9]. Study area has heterogeneous habitat, ranging from tropical moist deciduous to thorn forest. These habitats differ in their extent of cover and support diverse ungulate and primate species [10]. This area also supports the highest gaur population in India [11, 12]. The gaur population had recovered significantly since the outbreak of Rinderpest epidemic in the mid 1960s which nearly wiped out the MTR population [13]. The present study provides baseline data on age-sex composition of elephant, gaur, and other mammal species. Our main objective is to obtain base-line estimates of population density and age-sex composition in the area to enable the formulation of viable management strategies.

2. Methods

2.1 Study area

Mudumalai Tiger Reserve is located in the Nilgiris District of Tamil Nadu (11° 32’ and 11° 42’ N and 76° 20’ and 76° 45’ E; Figure 1). It extends over an area of 321 km² and forms a part of the Nilgiri Biosphere Reserve. The sanctuary is located in the Western Ghats, which is one of the 34 Biodiversity hotspots of the world [14]. The altitude varies from 485 to 1226 m above MSL with a general elevation of about 900 to 1000 m. The annual rainfall is varied from 1001 mm to 1648 mm. Sanctuary receives rain both from southwest (May to August) and northeast (September to December).
monsoons. The study area has three major forest type namely tropical moist deciduous forest, dry deciduous forest and tropical thorn forest [15]. The dominant tree species associations are “Acacia-Ziziphus” association characterising tropical thorn forest, “Anogeissus – Tectona” and “Anogeissus – Terminalia – Tectona” association describing the tropical dry deciduous forest and “Lagerstroemia – Terminalia – Tectona” characterising the tropical moist deciduous forest. The presence of areas of open grassland, numerous permanent water resources and salt licks has resulted in highly productive landscape. The large herbivores include elephant (Elephas maximus), three species of cervids, Chital (Axis axis), Sambar Deer (Rusa unicolor) and Barking Deer (Muntiacus muntjak), two species of antelopes, viz., the Four-horned Antelope (Tetracerus quadricornis) and the Blackbuck (Antilope cervicapra) are the dominant mammals of this area. In addition predators like Tiger (Panthera tigris), Leopard (Panthera pardus) and Wild dog (Cuon alpinus) can be seen. The Gaur and other herbivores are threatened by habitat degradation from overgrazing and human disturbances.

Densities of herbivores were estimated using distance sampling [16–18]. A total of 24 transects, each 2–4 km in length were monitored within a 321 km$^2$ survey area encompassing the different habitats from 2004 to 2007. Transects were placed randomly, with stratification by broad forest type (Moist deciduous forest, Dry deciduous forest and Thorn forest; Figure 1). Twelve surveys were repeatedly conducted on 24 line transects established throughout the sanctuary from 2004 to 2007 during the dry season in December to March and this provided adequate spatial replicates of the study area (643 km total), covering all vegetation types. On every walk, species, group size, age-sex composition, sighting angle using hand held sighting compass and sighting distance measured by a manual range finder. Population density of large herbivores was estimated using the software Distance v6 Release 2 [19]. To model detection functions to estimate species density the data for each species per transect was examined for signs of evasive movement and peaking at distances from the line of walk. Following this, the data were either truncated or re-classed so as to ensure a reliable fit of key functions and adjustment terms to the data. The Akaike Information Criterion (AIC) and $\chi^2$ goodness-of-fit test were used to judge the fit of the model. Using the model thus selected, estimates of group density, group size and individual density were derived [19].

In addition to transects, road-strip counts were conducted on a monthly basis in the different vegetation types (1262.5 km total). A total distance of 830, 308 and 124.5 km was sampled in DDF, MDF and TF respectively. In each sighting of gaur, we recorded group size and composition. Only groups where all the individuals counted were used for group size analysis. The sighting data from transect and road-strip count were pooled together to compute season-wise and habitat wise estimate on mean group size and sex ratios and median group size. Mean group sizes obtained from line transect counts actually indicate the size of ‘clusters’ [16] of animal species being sampled, rather than of social groups. Though these clusters are not always identical to social groups it has been used for population analysis [7]. In addition group size data from transects, counts from road-side counts, foot trails and waterholes were also used to calculate mean group size and group structure. For comparing grouping tendencies of different species the percentage of observed groups in categories such as: solitary animals, family associations (2–3 individuals) consisting of pairs of adult females with their yearlings and young, small groups (4–10 individuals), medium sized groups (11–30 individuals) and large groups of above 30 individuals.
2.2 Population structure

The proportion of different age-sex classes in the population was calculated using transects count supplemented with counts from road-side counts, foot trails and waterholes. The physical characteristics described in the literature [20–22] and observation in captive animals to establish the age-sex categories for classification. Chital, Sambar and gaur were classified as adult male (AM), adult female (AF), Sub-adult male (SAM), Sub-adult female (SAF) and young (YG). Younger elephants (<15 years) were classified by comparing their height to the oldest adult female in the group. Elephants were placed in broad age groups such as calves (<1 year), juveniles (1–5 years), sub-adults (5–15 years) and adults (>15 years) [7, 10].

The mean biomass densities (in kg/km\(^2\)) in the study area were derived from multiplying mean ecological density for each species by its average unit weight. Biomass density was estimated from published data on body weights [20, 23, 24] and population structure data from study area.

3. Results

Barking deer and sambar are essentially non-social species with solitary individuals, pairs or family association comprising 80% and 84% groups seen, respectively (Table 1). Though solitary individuals accounted for 16% and 25% of elephant and gaur most of these individuals are appeared to be adult males. These two species seems to occupy an intermediate position in terms of sociality with the group size frequencies being relatively evenly distributed among family associations, small groups and medium sized groups. At the other end of the scale, chital and common langur were clearly social groups with solitary individuals comprising less than 5% of all animal classified. The exceptionally large groups of 148 for chital and 32 for gaur were probably temporary agglomerations of several groups.

The study area harboured high ungulate density of 55.4 ± 5.83 animals/km\(^2\). Among the different species chital was the most abundant species with the highest density (29.8/km\(^2\); Table 2). The next abundant species was Common langur 11.9 ± 2.31/km\(^2\). Gaur and sambar were the abundant species and their densities were 7.1 ± 1.47/km\(^2\) and 4.2 ± 0.62/km\(^2\) respectively. Barking deer density (0.6 ± 0.20/km\(^2\)) was relatively lower than other large herbivores. Among different species chital had the highest group density (3.6 ± 0.55/km\(^2\)). Species such as Gaur and sambar had higher density but with lower group density (1.3 ± 0.18/km\(^2\) and 1.7 ± 0.22/km\(^2\)). The ecological density varied with group size of different herbivore species. Though there is relatively less variation in the group density among Gaur, sambar and elephant the density estimate varied because of variation in the group size. Among the different species chital and Gaur had higher group size of 8.3 ± 0.85 individuals and 5.59 ± 0.84 individuals respectively. The solitary species such as barking deer, giant squirrel and black naped hare density did not show any variation between the group density and actual density. Overall elephant density was 4.8 ± 0.92/km\(^2\) with mean group size of 4.3 ± 0.40 individuals (Table 2).

3.1 Population structure

The adult sex ratios in ungulate species seem to be female biased. The adult male–female sex ratios favour females by 1:33.8 for elephant, 1:4 for gaur and 1:2 for chital in exception equal (1,1) sex ratio was observed in sambar. The composition of adult male
### Table 1.
Grouping characteristics among large herbivore species: Group size classes, range of observed group size, \( n = \) sample size in Mudumalai Tiger Reserve.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Species</th>
<th>n</th>
<th>Range of observed group size</th>
<th>Percentage in each group size class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Barking deer</td>
<td>22</td>
<td>1–2</td>
<td>22.7 0.0 0.0</td>
</tr>
<tr>
<td>2</td>
<td>Chital</td>
<td>534</td>
<td>1–150</td>
<td>15.2 36.0 33.1</td>
</tr>
<tr>
<td>3</td>
<td>Sambar</td>
<td>150</td>
<td>1–28</td>
<td>32.7 22.7 7.3</td>
</tr>
<tr>
<td>4</td>
<td>Gaur</td>
<td>423</td>
<td>1–47</td>
<td>23.4 16.1 34.8 24.0 1.7</td>
</tr>
<tr>
<td>5</td>
<td>Elephant</td>
<td>210</td>
<td>1–25</td>
<td>16.2 37.1 41.9 4.8 0.0</td>
</tr>
<tr>
<td>6</td>
<td>Four horned antelope</td>
<td>6</td>
<td>1</td>
<td>100.0 0.0 0.0 0.0 0.0</td>
</tr>
<tr>
<td>7</td>
<td>Mouse deer</td>
<td>4</td>
<td>1</td>
<td>100.0 0.0 0.0 0.0 0.0</td>
</tr>
<tr>
<td>8</td>
<td>Wild pig</td>
<td>29</td>
<td>1–17</td>
<td>44.8 6.9 41.4 6.9 0.0</td>
</tr>
<tr>
<td>9</td>
<td>Giant squirrel</td>
<td>20</td>
<td>1–3</td>
<td>70.0 30.0 0.0 0.0 0.0</td>
</tr>
<tr>
<td>10</td>
<td>Common langur</td>
<td>117</td>
<td>1–32</td>
<td>0.9 94.5 56.4 32.5 0.9</td>
</tr>
<tr>
<td>11</td>
<td>Bonnet monkey</td>
<td>4</td>
<td>4–22</td>
<td>0.0 0.0 50.0 50.0 0.0</td>
</tr>
<tr>
<td>12</td>
<td>Black-naped hare</td>
<td>27</td>
<td>1–2</td>
<td>80.0 20.0 0.0 0.0 0.0</td>
</tr>
</tbody>
</table>

### Table 2.
Ecological density (±standard error), group density (±SE) and group size (±SE) of large mammals in Mudumalai Tiger Reserve during the study period.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Species</th>
<th>Density / km(^2) ± SE</th>
<th>Group density / km(^2) ± SE</th>
<th>Group size ± SE</th>
<th>Density / km(^2) ± SE</th>
<th>CV (%)</th>
<th>95% confidence interval lower</th>
<th>95% confidence interval upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gaur</td>
<td>1.26 ± 0.18</td>
<td>5.6 ± 0.84</td>
<td>7.1 ± 1.47</td>
<td>20.9</td>
<td>4.69</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Chital</td>
<td>3.59 ± 0.55</td>
<td>8.3 ± 0.85</td>
<td>29.8 ± 5.50</td>
<td>38.4</td>
<td>20.8</td>
<td>42.8</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sambar</td>
<td>1.71 ± 0.22</td>
<td>2.4 ± 0.19</td>
<td>4.2 ± 0.62</td>
<td>15.0</td>
<td>5.11</td>
<td>5.60</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Barking deer</td>
<td>0.53 ± 0.18</td>
<td>1.1 ± 0.08</td>
<td>0.6 ± 0.20</td>
<td>34.0</td>
<td>0.31</td>
<td>1.15</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Elephant</td>
<td>1.11 ± 0.19</td>
<td>4.3 ± 0.40</td>
<td>4.8 ± 0.92</td>
<td>19.5</td>
<td>3.25</td>
<td>6.90</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Wild pig</td>
<td>0.12 ± 0.06</td>
<td>1.9 ± 0.59</td>
<td>0.2 ± 0.13</td>
<td>35.0</td>
<td>0.08</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Common langur</td>
<td>2.42 ± 0.42</td>
<td>4.9 ± 0.41</td>
<td>11.9 ± 2.31</td>
<td>19.4</td>
<td>8.13</td>
<td>17.4</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Giant squirrel</td>
<td>1.33 ± 0.29</td>
<td>1.2 ± 0.06</td>
<td>1.6 ± 0.35</td>
<td>21.9</td>
<td>1.04</td>
<td>2.46</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Black naped hare</td>
<td>1.25 ± 0.51</td>
<td>1.0 ± 0.00</td>
<td>1.3 ± 0.51</td>
<td>41.0</td>
<td>0.57</td>
<td>2.74</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Mouse deer</td>
<td>0.11 ± 0.09</td>
<td>1.0 ± 0.00</td>
<td>0.1 ± 0.09</td>
<td>0.03</td>
<td>0.03</td>
<td>0.50</td>
<td></td>
</tr>
</tbody>
</table>
was lowest (1.65%) among the elephants (Figure 2a). Totally 120 gaurs were sighted during the study period. The composition of adult female (50.79%) was highest in the group. The sub-adult male and female consisted of 16% of the populations. Totally 78 sambar deer were sighted and in which 85% consisted of Adult male and adult female (Figure 2b). The calf consisted of 10.34%, the sub-adult male had the lowest composition of 0.49%. While considering age distribution, the proportion of pre-reproductive age classes (sub-adults, juveniles and calves) is 53% in elephant, 36.6% in gaur, 26.4% in chital and 14% in sambar.

4. Discussion

Barking deer and sambar are solitary species. Other than adult males which tend to be solitary, gaur and elephant usually live in small groups. Occasionally they form medium to large groups particularly at favoured feeding sites. Chital is the most gregarious ungulate and commonly form medium to larger groups. The social organisation of elephant and gaur are based around the family unit or the herd consisting of
one or more related adult females and their offspring [20, 25–27]. In elephants the most cohesive unit is the family unit and it represents a tightly knit unit both socially and structurally [28]. At puberty, young females remain with the natal group, while the males leave the herd and they tend to form temporary groups with weak social bonds [29]. Little however is known about gaur social structure or about male dispersals.

We looked at the pattern of densities in relation to body size and diet [30] of individual species. Densities of smallest ungulates barking deer is lower than densities of considerably larger species such as chital, sambar and gaur. Because barking deer found in Moist deciduous forest and it selectively feeds on rich but scarce food items such as shoots and fruits [20]. Moist deciduous forest consists of only 33% of the different vegetation types of the study area. Their solitary nature and territorial spacing mechanisms may also contribute to their relatively low densities. Chital which are primarily grazers [22] are most abundant in the study area. Dry deciduous with extensive short grass clearing. Moist deciduous forest with and swamp microhabitat and Open grass lands in thorn forest support high density of chital in Mudumalai Tiger Reserve.

Sambar which is predominantly browsers [20] distributed relatively higher density in Moist deciduous forest in the Western part of the study area. They feed during evening and night hours and rest in large number in open swamp areas in Moist deciduous forest. As could be predicted from body size and diet of sambar are less abundant than chital. However densities of gaur a larger species are higher than sambar. Gaur are mixed feeders and they graze intensively in open swamp areas in Moist deciduous [31] and coarse grass in dry deciduous forest. They also seem to browse on the profuse secondary growth of Bamboo (*Bambusa arundanacia*) in Thorn forest in areas with less human disturbance [10].

Elephant density is higher than earlier estimate (2.4/km$^2$) [32]. Earlier studies in the year 1980s [25] indicated a much lower density (1/km$^2$) for the study area. Despite poaching reducing the male numbers and keeping them dispersed breeding is taking place and the population is increasing. The specialist folivore common langur is more abundant than generalist bonnet macaque in the study area. Wild pig that feed selectively on variety of plant and animal foods such as roots, tubers, fruits insects and carrion [33], found in relatively low density (0.4/km$^2$) in the study area. The factors such as nocturnal feeding habitat and incidence of Anthrax in wild pig in the study area during the study period might reduce wild pig population density. Further monitoring and diseases control measures were taken by the forest department.

The adult sex ratios of ungulate species seem female biased. In ungulate species such as chital, sambar and gaur the males more solitary habits, proneness to injuries from intra-specific aggression, lack of alertness during rut and dispersal behaviour of makes them more vulnerable to predation [20, 24]. Whereas in elephant selective poaching of adult males especially tuskers caused skewed sex ratio (1:34). An earlier study in this area [25] had reported that the adult male to female ratios were far less skewed (1:4.7) than the current ratio of 1:34. This indicates that the adult male population has declined significantly from the mids 1980's. This decline in adult male population in elephants is largely due to poaching of males for their tusks [27].

The biomass of large herbivores is compared with other tropical forests (Table 3). MTR supported very high biomass density (15,198 kg/km$^2$) than similar tropical forests in Southern India. It was almost equal to that of Nagarahole (14,744 kg/km$^2$ [3]) and Bandipur National park (14,520 kg/km$^2$ [24]) and more than Kanha (1592 kg/km$^2$ [20]) and Pench (6013 kg/km$^2$ [34]) of Central India. Furthermore it was higher than Chitwan, Nepal [35]. Tropical humid forests were generally considered to be poorer habitats than Savannas in terms of supporting high biomass (Eisenberg, 1980) [30].
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But several Savanna and Woodland habitats of Africa seem to support lower biomass densities than MTR [36–38]. For example the biomass estimates from the lowland rain forests of Gabon and Serengeti were considerably lower [38]. Whereas Manyara Lake park and Mara Plains in Kenya and Rwenzori Park in Uganda supported biomass densities higher than that of MTR [36].

5. Conclusions

Mammal population density and social organisation were studied in the tropical forests of Southern India. Among ungulates, the solitary, specialist species barking deer occurred at lower densities. Chital is primarily grazer, highly gregarious and the most abundant species in the study area. Sambar is browser, distributed at higher densities at Moist deciduous forest. Elephant densities are increasing when compared to earlier estimate. But the sex ratio of elephant is highly skewed due to selective poaching of males for their tusks. Mudumalai supports higher biomass densities of mammal species than similar tropical forests in India.
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Conflict of interest

We do not have any conflict of interest to disclose.

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