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An evaluation of detection function models used for estimating herbivore densities in tropical forests

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Abstract

Seven detection function models used in line transect sampling for estimating herbivore densities were evaluated using data from tropical moist deciduous forests. The data were collected from nine Wildlife Sanctuaries in Kerala during 1993 on the following species *viz*., elephant (*Elephas maximus*), gaur (*Bos gaurus*) and sambar (*Cervus unicolor*). Univariate half normal distribution was found promising with respect to accuracy and precision of the density estimates. The use of median in estimating average cluster size reduced animal densities to realistic values and provided more precise estimates. Bivariate detection function models were not effective as the size-bias parameter was not significant for most of the models considered.

Keywords : detection function, line transect sampling, total count, wildlife census

INTRODUCTION

Among the many methods available for censusing herbivores in tropical forests, line transect sampling is one which has been extensively used in India. Line transect sampling is a direct, cost effective method and involves only passive observations on the presence of animals. Modelling the detection function is an important task in estimating animal density using this method. A number of models originating from different contexts have been proposed which involve either parametric or nonparametric approaches. Burnham *et al*. (1980) introduced several criteria while choosing a model for the detection function and promoted the idea of a robust nonparametric estimation with the Fourier series. Another major development in this area was the introduction of bivariate functions including cluster size as an additional variable to account for the size-bias (Drummer 1991, Quang 1991, Laake *et al*. 1994). Varman and Sukumar, 1995 have evaluated different detection function models used in line transect sampling for spotted deer, sambar, elephant and gaur. Data used by them was generated over a period of two years. They reported that Fourier series and the half normal model consistently gave the least coefficient of variation. An attempt is made here to identify a suitable model for detection function for three herbivore species using line transect data generated from a vast area on a single day which will be more consistent.

MATERIALS AND METHODS

Data collected for the wildlife census, conducted in the State of Kerala, India, from nine wild life sanctuaries were used for the present study. Although different vegetation types exist in the sanctuaries, they were predominantly of moist deciduous type. The sanctuaries were Wayand, Tholpetty, Aralam, Parambikulam, Peechi-Vazhani, Idukki, Peppara, Neyyar and Periyar Tiger Reserve (Figure 1). The entire set of sanctuaries was considered as one stratum because of the lack of information on the extent covered by the different vegetation types. Moreover, the different types of habitat occur together as intermixed patches. Line transect sampling by direct sighting and total count (TC) were the methods employed. Line transect sampling was done on the 30 th April, 1993 and total count was done the next day. The species censused were elephant (*Elephas maximus*), gaur (*Bos gaurus*) and sambar (*Cervus unicolor*).

Total count

The forest area under each sanctuary was divided into blocks of size less than 10 km^2. The blocks were demarcated in the field by forest roads, rivulets or forest boundaries. Each block was searched completely for the presence of large mammals on foot by a team consisting of a trained volunteer, a forest staff and a tribal tracker. In spite of these measures, we are not likely to get totally reliable estimates of animal density through this method. But the estimate will serve as a basis for comparison with estimates provided by alternative methods. Number of clusters and size of each cluster sighted were recorded during the survey. The data from the blocks were pooled and density of each species was computed dividing the total number of animals sighted by the total area surveyed. Additional details of the census methodology are available in the census report (Anonymous, 1993). The total area of the sanctuaries was 1731.92 km^2 excluding the reservoirs.

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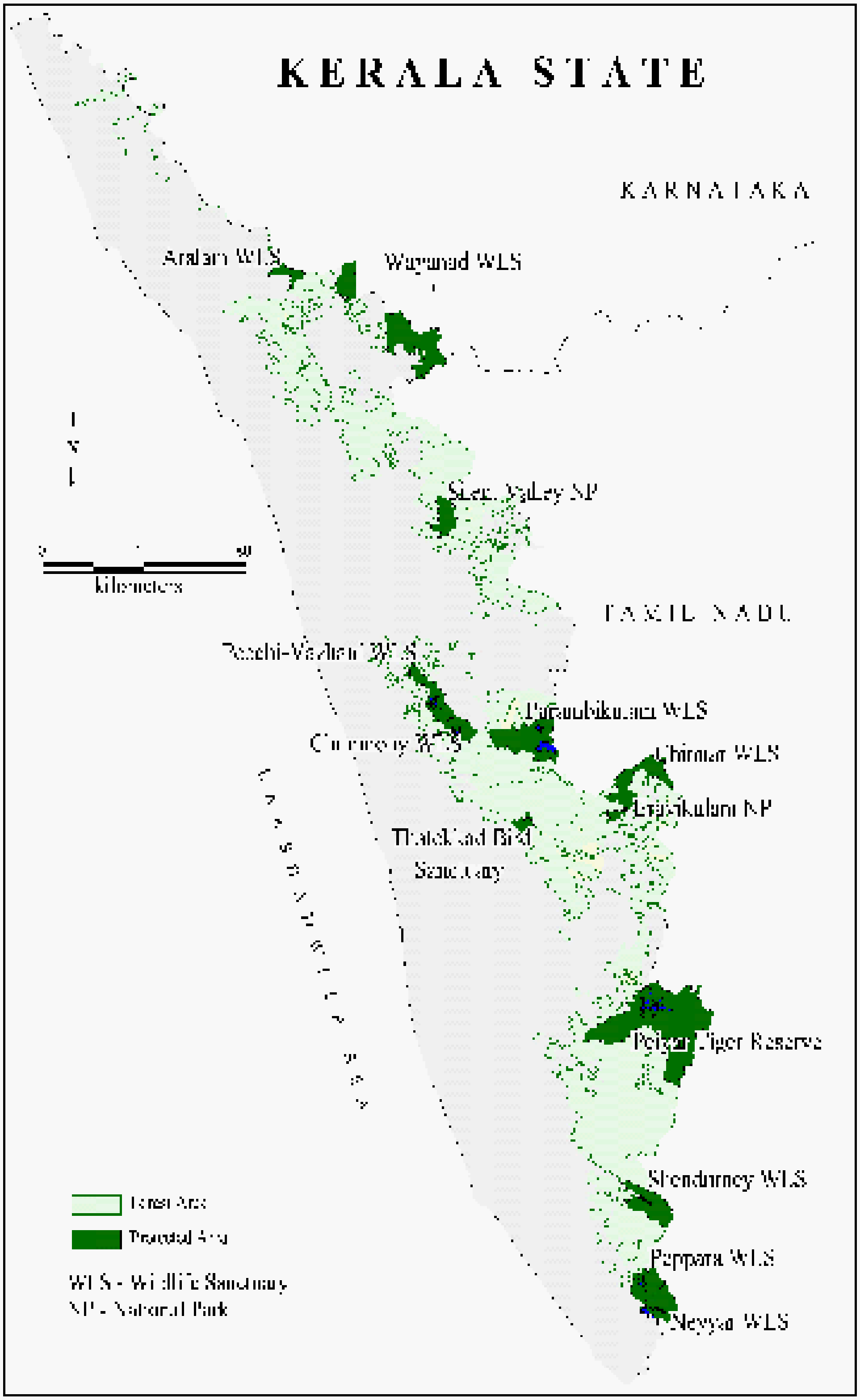

Figure 1. Protected areas in the Kerala part of the Western Ghats, South India

Line transect sampling

Randomly selected transects of about 2 km length were marked in the area map of each forest range with the help of forest officials. The positions of the transects were identified in the field and laid out by marking trees with paint. These transects were then covered on foot, recording the sighting distance (r) and the sighting angle (q) to the geometric centre of the herds sighted between 6.00 hours to 10.00 hours. Ocular estimation of the sighting distance was made. The sighting angle (q) was measured with a compass. The perpendicular distance (y) from the transect to the animal was then worked out using the formula y = r sin (q). The total length of the transects was 454.4 km. For the analysis, the data were truncated to a maximum perpendicular distance of 200 m. Detection function models provided in the programs, SIZETRAN (Drummer, 1991), DISTANCE (Laake *et al*., 1994) and NPARTRAN (Quang, 1991) were evaluated.

Data analysis

In the program SIZETRAN, both bivariate and univariate sighting models are employed for estimating probability density functions of perpendicular distances . The models used for this study are univariate negative exponential (UNE), univariate halfnormal (UHN), univariate Fourier series (UFS), bivariate negative exponential (BNE), and bivariate halfnormal (BHN). Modelling the bivariate detection functions was done by introducing the cluster size y as covariate into the univariate detection function via the ratio x/y^a. The parameter 'a' is referred as the size bias parameter. A value of a =0 implies that cluster size has no effect on the probability of detection. If the size bias has no effect on probability of detection, the mean cluster size is used for the estimation of density of animals. A likelihood ratio test for the presence of size bias was performed. The test statistic has an asymptotic χ^2 distribution with one degree of freedom. A χ^2 goodness-of-fit test for the detection function was performed on the transformed data $z=x/y^a$.

Semiparametric models are used in the program DISTANCE namely (Uniform + Cosine), (Uniform + Polynomial), (Halfnormal + Hermite) and (Hazard rate + Cosine). These were collectively referred to as polynomial adjustment models (PAM). The AIC (Akaike's information criterion) was used for selecting between models. A regression equation was fitted between logarithm of cluster size and probability of detection of perpendicular distances, g(x). The estimate of cluster size was calculated at the point g(0)=1.

In the program NPARTRAN, bivariate detection function using Fourier series (BFS) is employed. This program provides diagnostics for visibility bias and calculates bias-reduced estimates of both animal density and group density.

In all the univariate procedures, the average cluster size was estimated by arithmetic mean with variance s^2/n, where n is the number of herds. Alternatively, the average cluster size was estimated using median as well and the corresponding variance was computed by the formula reported by Kendall and Stuart (1977) which is $V(median)=1/4nf^2$ where n = number of cluster and f = the median ordinate. The animal density was then obtained by multiplying the density of clusters by the average cluster size. The variance of the estimate of animal density was then arrived at using the formula given by Goodman (1960).

RESULTS AND DISCUSSION

Distribution of the perpendicular sighting distances for the three species is given in Figure 2. The patterns show no signs of irregularities like heaping or evasive movement. A similar pattern was obtained by Varman and Sukumar (1995) for the four species studied by them. The density estimates and related statistics for the different models fitted are given in Table 1. One criterion used for choosing a good detection function model was to see how close the estimates are to the total count with respect to the number of clusters and the number of individuals. Total count was considered for comparison because the use of many detection functions resulted in unusually high density estimates. The next criterion applied was the precision of the estimates as done by Varman and Sukumar (1995).

The density estimates obtained through line transect sampling were in general higher than the total count. The distribution of cluster size for the three species is given in Figure 3. Since the distribution of cluster size was skewed for all the species, the arithmetic mean is not a good estimator of the average cluster size. Varman and Sukumar (1995) had used arithmetic mean as an estimator of average cluster size. The bivariate procedures have associated methods for estimating the average cluster size adjusted for size bias. However, when the median was used it reduced the density estimates of individuals to reasonable standards regardless of the nature of the detection function involved.

The models which provided estimates closest to that of total count and those having the least coefficient of variation with respect to the cluster density and also the animal density are given in Table 2. There is not much uniformity as regards to the best model as per the different criteria, but the following are evident from Table 1. For all the species, the UHN model gave estimates of cluster density close to that of total count. Although the coefficient of variation of the estimates provided by BFS model were lower in the case of elephant, the density estimates were not realistic in

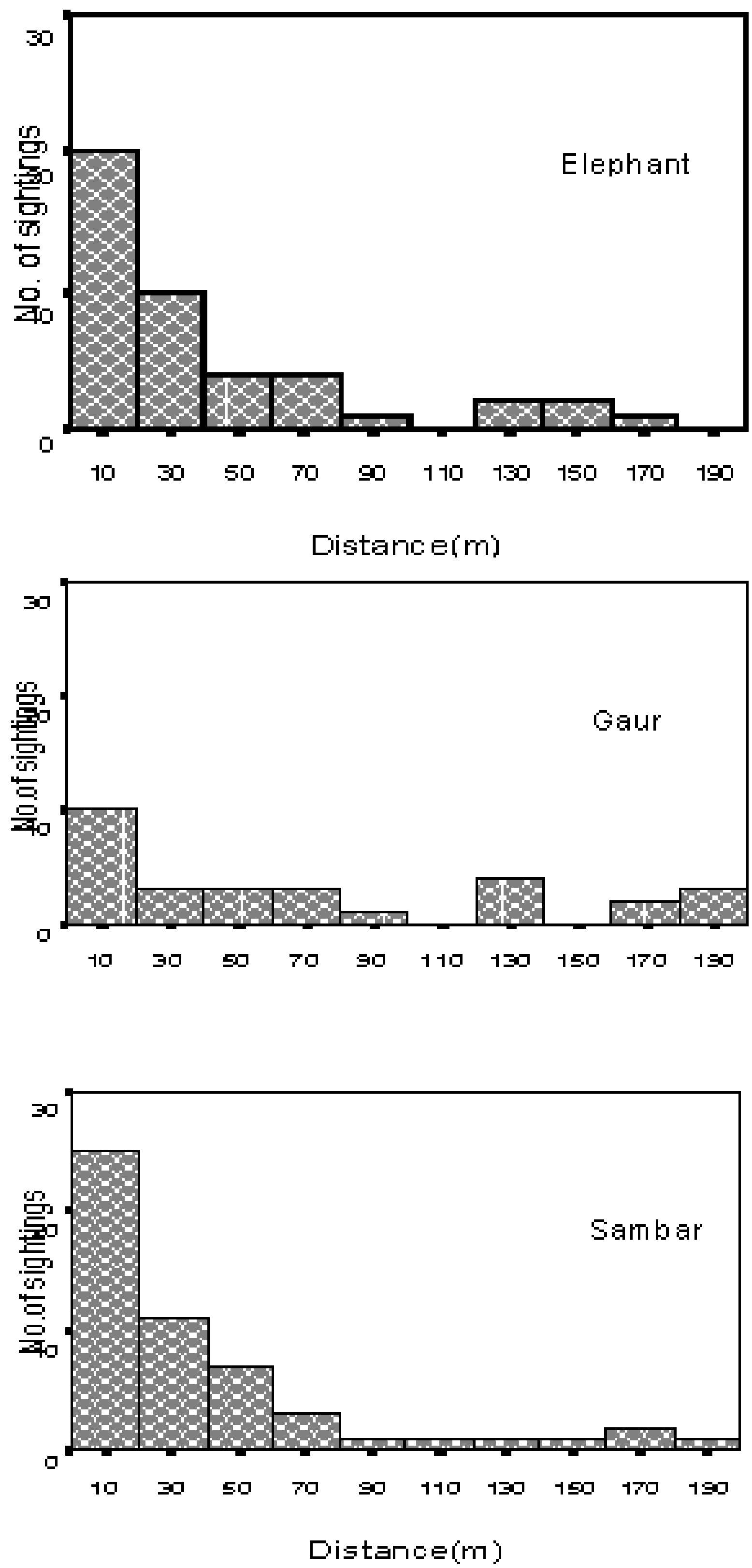

Figure 2. Distribution of perpendicular distances of sightings for the three species

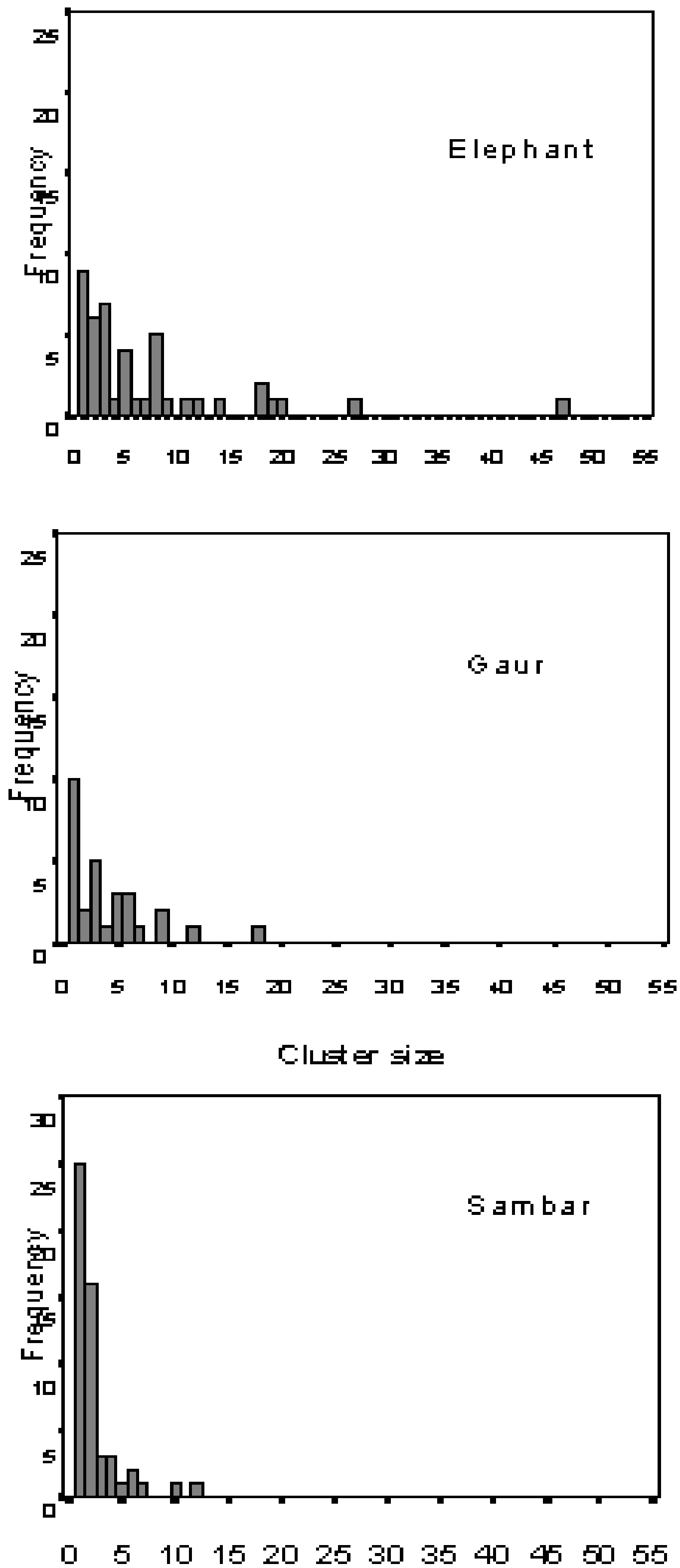
Elephant
Frequency
Gaur
Frequency
Cluster size
Sambar
Frequency
0 5 10 15 20 25 30 35 40 45 50 55

Table 1. Estimates of density obtained using different detection function models

Species	Model	Herd Density (no.km^{-2})	Adjusted mean herd size	Animal density using mean (no.km^{-2})	Median herd size	Animal density using median (no.km^{-2})	C^2 Value
Elephant	UNE	1.03 (21.57)	7.14 (18.41)	7.36 (28.64)	3.50 (23.69)	3.61 (33.02)	12.94^{NS}
	UHN	0.55 (18.77)	7.14 (18.41)	3.94 (26.52)	3.50 (23.69)	1.93 (16.65)	2499 *
	UFS	1.15 (22.94)	7.14 (18.41)	8.21 (29.72)	3.50 (23.69)	4.03 (37.94)	5.19 ^{NS}
	BNE	1.11 (28.77)	5.88 (17.07)	6.44 (32.16)	3.50 (23.69)	3.89 (41.06)	9.23 ^{NS}
	BHN	0.60 (22.80)	5.88 (17.07)	3.50 (26.95)	3.50 (23.69)	2.10 (19.66)	2278 *
	BFS	1.15 (16.99)	7.26 (23.42)	8.35 (25.33)	3.50 (23.69)	4.03 (33.54)	—
	PAM	1.14 (32.15)	7.14 (18.41)	8.10 (37.04)	3.50 (23.69)	3.99 (45.41)	—
	TC	0.05	5.26	0.26	4.00	0.20	—
Gaur	UNE	0.44 (26.74)	417 (17.56)	1.83 (32.34)	3.00 (18.00)	1.32 (14.16)	7.01 ^{NS}
	UHN	0.26 (23.29)	417 (17.56)	1.07 (29.46)	3.00 (18.00)	0.78 (7.57)	13.03 *
	UFS	0.51 (30.89)	417 (17.56)	2.15 (35.95)	3.00 (18.00)	1.53 (18.33)	18.06 *
	BNE	0.49 (35.68)	3.30 (16.70)	1.61 (37.30)	3.00 (18.00)	1.44 (19.48)	7.26 ^{NS}
	BHN	0.27 (27.96)	3.63 (17.04)	0.99 (31.24)	3.00 (18.00)	0.81 (9.03)	1451 *
	BFS	0.51 (23.86)	3.28 (26.22)	1.69 (25.74)	3.00 (18.00)	1.53 (15.31)	—
	PAM	0.82 (48.30)	242 (20.33)	1.98 (52.41)	3.00 (18.00)	2.46 (42.07)	—
	TC	0.03	466	0.14	3.00	0.09	—
Sambar	UNE	1.46 (19.62)	3.34 (31.16)	4.89 (37.32)	2.00 (11.38)	2.92 (33.03)	13.25^{NS}
	UHN	0.76 (17.05)	3.34 (31.16)	2.53 (35.91)	2.00 (11.38)	1.52 (15.48)	30.96*
	UFS	1.62 (21.49)	3.34 (31.16)	5.39 (38.44)	2.00 (11.38)	3.24 (39.15)	3.89 ^{NS}
	BNE	1.58 (23.10)	2.30 (17.51)	3.63 (27.50)	2.00 (11.38)	3.16 (40.67)	11.46^{NS}
	BHN	0.78 (19.46)	2.74 (23.82)	2.14 (29.78)	2.00 (11.38)	1.56 (17.55)	38.75*
	BFS	1.53 (17.40)	1.95 (30.33)	2.99 (22.58)	2.00 (11.38)	3.06 (31.69)	—
	PAM	1.64 (27.38)	1.74 (12.44)	2.86 (30.00)	2.00 (11.38)	3.28 (48.51)	—
	TC	0.06	3.08	0.18	2.00	0.12	—

Note : NS - Not significant, * - Significant at P=0.05 level. The values in the brackets denote coefficient of variation of the estimates.

Table 2. Two best models obtained for each species with respect to accuracy and precision of estimates.

Species	Herd density	CV of herd density	Animal density using median	CV of animal density using median
Elephant	UHN	BFS	UHN	UHN
	BHN	UHN	BHN	BHN
Gaur	UHN	UHN	UHN	UHN
	BHN	BFS	BHN	BHN
Sambar	UHN	UHN	UHN	UHN
	BHN	BFS	BHN	BHN

CV - Coefficient of variation

Table 3. Influence of group size (size bias) in the detection of animal groups

Species	Model	Sample size	Size bias parameter	P value of size bias parameter	Correlation between perpendicular distance and cluster size
Elephant	BNE	44	0.18	0.09	0.15 NS
	BHN		0.18	0.03	
Gaur	BNE	29	0.31	0.09	0.12 NS
	BHN		0.18	0.12	
Sambar	BNE	53	0.32	0.05	0.05 NS
	BHN		0.15	0.16	

NS - Non significant

those cases. In the case of animal density using median, UHN gave the least coefficient of variation in all cases. Varman and Sukumar (1995) found that cluster density estimates derived from the Fourier series and the half normal model had the lowest coefficient of variation and these two models also generated similar mean density estimates. Although the UHN model was not a good fit(χ^2 value in Table 1.) in the case of elephant, gaur and sambar, this model is to be preferred on account of the realistic estimates provided by the model. Moreover, the use of model fit as a criterion for choosing between models is de-emphasized by Burnham *et al*. (1980).

The size bias parameter, the probability level and the coefficient of correlation between distance and group size are given in Table 3. The size bias parameter is significant in the case of elephant and sambar in certain models. But Varman and Sukumar (1995) found that there was no statistically significant relationship between detectability of a group and the size of the group for any species. Even though the size bias parameter was significant for elephant and sambar in BHN and BNE models, respectively, there were no significant differences between densities obtained through the corresponding univariate and bivariate models (P>0.01). For gaur the size bias parameter was not significant.

CONCLUSIONS

Half normal distribution was found preferable as a detection function model in line transect sampling for the above three herbivore species in tropical moist deciduous forests. Since arithmetic mean is found to inflate the animal density estimates to very high levels, the median is preferable as a measure of average cluster size. Size of the cluster was not influencing the probability of detection.

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