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EVALUATION OF LINE TRANSECT SAMPLING TECHNIQUE IN ESTIMATING ELEPHANT ABUNDANCE IN FORESTS USING DUNG SURVEY

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ABSTRACT

Line transect sampling technique is widely applied for estimating the biological population in forests. Recently, this technique has been in use for the estimation of elephant abundance using dung survey. The method of transforming dung count into elephant density requires dung density, which is corrected by defecation and decay rate. In this paper, the performance of the line transect sampling technique (LTS) in dung surveys with particular reference to variation in the number of detections of dung piles caused by annual rainfall variability was evaluated. The dataset for this purpose was from the estimation of elephant population in the State of Kerala during the years 2005, 2007 and 2010, covering about 9000 km2. The study showed that the presence of dung piles and its detection probability were dependent on the level of rainfall in the two months preceding the date of dung survey. However, the LTS could provide comparable dung density estimates under the highly varying number of dung piles present in the area due to differences in the annual rainfall pattern.

Key words: Distance sampling, Detection probability, Elephant density, Rainfall variability.

Introduction

In estimating the abundance of wildlife populations, line transect sampling technique (LTS) is preferred as it is possible to develop density estimates based on detection probabilities even without encountering all the objects in the study area (Burnham *et al*., 1980; Buckland *et al*., 2001). The objects under reference can be like cluster of animals and indirect evidences such as dung piles of elephant and gaur. In LTS, the observer(s) perform a standardized survey along a series of lines with total line length of *L*, searching for objects of interest (Fig.1). For each object, the perpendicular distance (x) from the line to the object is recorded. In case of direct sighting of animals, radial distance *(r)* from the observer to the object along with the angle of sighting (θ) are recorded and perpendicular distances are worked out; x= r sin(θ). The key formula used in the estimation of object density is

$$\hat{d} = \frac{n\hat{f}(0)}{2L} \quad \text{...} \; (1)$$

where $\hat{f}$ is the probability density function evaluated at *x*=0.

$$\hat{f}(0) = \frac{1}{\int_0^{\omega} g(x)\,dx} \quad \text{.............................} \; (2)$$

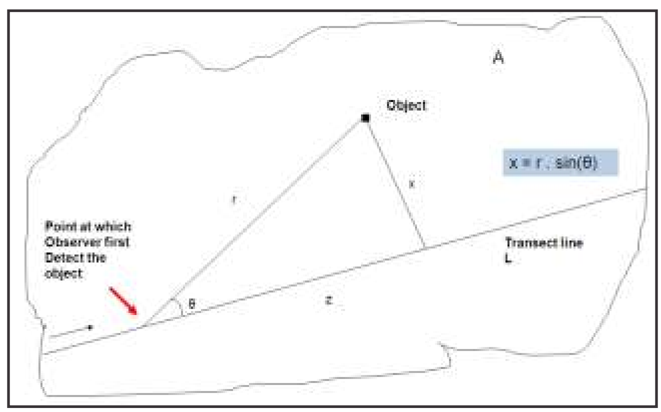

Fig. 1: Method of Line transect sampling- direct sighting

where *n* is the number of objects detected; ω is the half strip width and *g*(*x*) is the detection function, which is the probability of detecting an object, given that it is at distance *x* from the line. For example, *g*(4)=0.70 says the probability of detection is 0.70 at 4 m or whatsoever the measurement unit is used. The denominator part of equation (2) is also called as Effective Stripe Width (ESW). Since the equation (1) contains encounter rate (*n/L*) and detection probability, the variance in density is sum of variance of these two components.

In practice, some functional forms of *g(x)* considered include Uniform, Half Normal, Negative

Dung survey using line transect sampling technique is a potential method for the assessment of wild elephant population in Kerala forests as it provided comparable dung density estimates under varying annual rainfall conditions.

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Exponential and Hazard Rate. In order to improve the fit of the model, especially, the tail part of the detection curves, series expansion such as simple polynomial or higher order polynomial is added with the key detection function. One among the functional forms is chosen based on fit statistics/model selection criterion such as Chi-square test, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Buckland *et al*., 2001; Buckland *et al*., 2004).

Evaluation of LTS has been carried out for a number of species under different field settings and perspectives. LTS was evaluated for estimating density of bobwhites (Guthery, 1988), deer (White *et al*., 1989), macropod (Anderson *et al*., 1995), ungulates (Forcard *et al.,* 2002) and primates (Buckland *et al*., 2010a; Buckland *et al*., 2010b). Varman *et al.* (1995) made comparative assessment of direct survey and dung survey using LTS for elephants. Mercy and Jayaraman (1999) used random parameter model to calibrate the detection function for its variation from location to location. The same authors evaluated the detection function models for the indirect evidence of elephant and Gaur (Mercey and Jayaraman, 2004). Measurement errors in distance sampling were studied by Mercy and Jayaraman (2002) and Borchers *et al.* (2010). The effect of responsive movement of target animals from transect was studied by Turnock and Quinn (1991).

Detection probability of the objects of interest may vary according to both internal and external factors. The external factors include weather, light conditions, habitat type, observer and method of observation. The internal factors include species, age, sex, size of animals and size of groups. In monitoring wildlife population, the number of detections of the given object could vary considerably due to factors such as rainfall. In this paper, the performance of the LTS was evaluated against highly variable number of dung piles present in the study area due to rainfall differences and density estimates compared.

Data set used

Estimation of abundance of elephants by direct sighting over vast forest area is difficult. However, elephants leave dung which continues to be present in the area for a considerable time period. The estimation of elephant population through dung survey is practically an easy method. Of late, dung survey is employed to estimate the elephant abundance. The method of transforming dung count into elephant density requires dung density, which is corrected by defecation and decay rate (Barnes *et al*., 1997; Barnes and Dunn, 2002).

$$\text{Estimated elephant density, } \hat{D}_e = \frac{\text{Dung density}}{\text{Defecation rate}} \times \text{Dung decay rate}$$

While the experiments were conducted for estimating the dung decay rate, the defecation rate was obtained from other studies. LTS was employed to estimate the dung density across different Elephant Reserves Kerala State viz., Wayanad, Nilambur, Anamudi and Periyar during the years 2005, 2007 and 2010 covering about 9000km^2 (Sivaram *et al*., 2005; 2007 and 2010). The dung survey is usually conducted around first/second week of May (summer). The total forest area of each forest management unit (Wildlife Division/Sanctuary /Territorial Forest Division) in each Elephant Reserve was divided into number of geographically defined blocks utilizing the Survey of India maps. A sample of blocks was chosen using simple random sampling without replacement in each forest management unit for the dung survey. While 34% of the total blocks were covered during 2005, 50% were covered during 2007 and 2010. The maps with toposheet background showing sample blocks to be covered for the census were given to the field personnel for the random placement of transects, mostly of length 2 km, marked with paint/ coloured biodegradable ribbons along the gradient in the selected sample blocks. The line transects were covered on foot recording perpendicular distance to the geometric center of the elephant dung piles. The perpendicular distance to each of the dung pile detected was measured using a tape. The details of the number of transect sampled and detections made in each Elephant Reserve are given in table 1.

Table 1: Model selection criterion values for choosing the best detection probability model for estimating dung density (HN+SP indicates halfnormal distribution with simple polynomial model; NE+SP indicates negative exponential distribution with simple polynomial; *m*= number of parameters in the model)

Year	Elephant reserve	Detection probability model	AIC	BIC	m
2005	Wayanad	HN+SP	4372.8	4398.8	5
	Nilambur		2308.6	2322.1	3
	Anamudi		10154.0	10184.0	5
	Periyar		5839.0	5866.3	5
	Wayanad	NE+SP	4340.0	4355.7	3
	Nilambur		2303.8	2308.3	1
	Anamudi		10135.0	10154.0	3
	Periyar		5815.3	5831.7	3
2007	Wayanad	HN+SP	11483.0	11513.0	5
	Nilambur		4414.1	4429.6	3
	Anamudi		15126.0	15158.0	5
	Periyar		11121.0	11151.0	5
	Wayanad	NE+SP	11448.0	11466.0	3
	Nilambur		4381.0	4396.5	3
	Anamudi		15089.0	15108.0	3
	Periyar		11095.0	11120.0	4
2010	Wayanad	HN+SP	5026.4	5042.6	3
	Nilambur		2948.8	2963.2	3
	Anamudi		7607.5	7636.2	5
	Periyar		6394.4	6422.2	5
	Wayanad	NE+SP	4996.4	5018.0	4
	Nilambur		2921.3	2940.5	4
	Anamudi		7576.5	7593.7	3
	Periyar		6374.0	6390.6	3

Estimation

The perpendicular distances to dung piles formed the input data for the estimation of dung density. The dung density estimates were obtained using the equation (1) above. In this, the key component is the estimation of detection probabilities. A five per cent truncation of the largest perpendicular distance values was adopted to improve the precision of the density estimates. The results of the model selection criterion for the competing detection probability models are presented in table 2. The negative exponential with simple polynomial was found to be the best based on lower AIC and BIC and its non-significant chi-square values (P>0.05). However, half normal probability distribution with simple polynomial curve as series expansion was judged to be the next best model for all the years across Elephant Reserves (Fig.2,

Table 2: Dung density estimates in different elephant reserves of Kerala during the years 2005, 2007 and 2010

Date of dung survey	Elephant reserve	Total number of transects	Total length of transect (L) (km)	Total number of dung piles	Encounter rate (n/L)	Dung density (No./km^2)	Co-efficient of variation (%)	adjusted number of dung piles	adjusted dung density	% increase in adjusted number of dung piles	% increase in adjusted dung density (No./km^2)
6 May 2005	Wayanad	75	148	1356	9.2	2113.1	18.8	1495	2329.4	114.9	48.0
	Nilambur	88	180	662	3.7	577.6	15.7	674	588.1	92.7	116.6
	Anamudi	173	364	3115	8.6	1878.4	10.9	3332	2009.2	32.1	12.0
	Periyar	166	332	1753	5.8	1110.9	11.0	2224	1409.6	45.0	7.8
	Total	502	1024	6886							
9 May 2007	Wayanad	82	163	3213	19.7	3447.2	17.3	3213	3447.2		
	Nilambur	93	183	1299	7.1	1274.0	14.8	1299	1274.0		
	Anamudi	195	389	4400	11.3	2251.1	8.0	4400	2251.1		
	Periyar	214	421	3225	7.7	1520.0	8.3	3225	1520.0		
	Total	584	1156	12137							
16 May 2010	Wayanad	86	168	1642	9.8	2174.5	12.7	1598	2116.8	101.0	62.9
	Nilambur	95	191	897	4.7	908.45	9.6	860	870.8	51.1	46.3
	Anamudi	193	385	2315	6.0	1336.7	7.7	2341	1351.7	88.0	66.5
	Periyar	213	428	1915	4.5	956.54	8.9	1884	941.0	71.1	61.5
	Total	587	1171	6769							

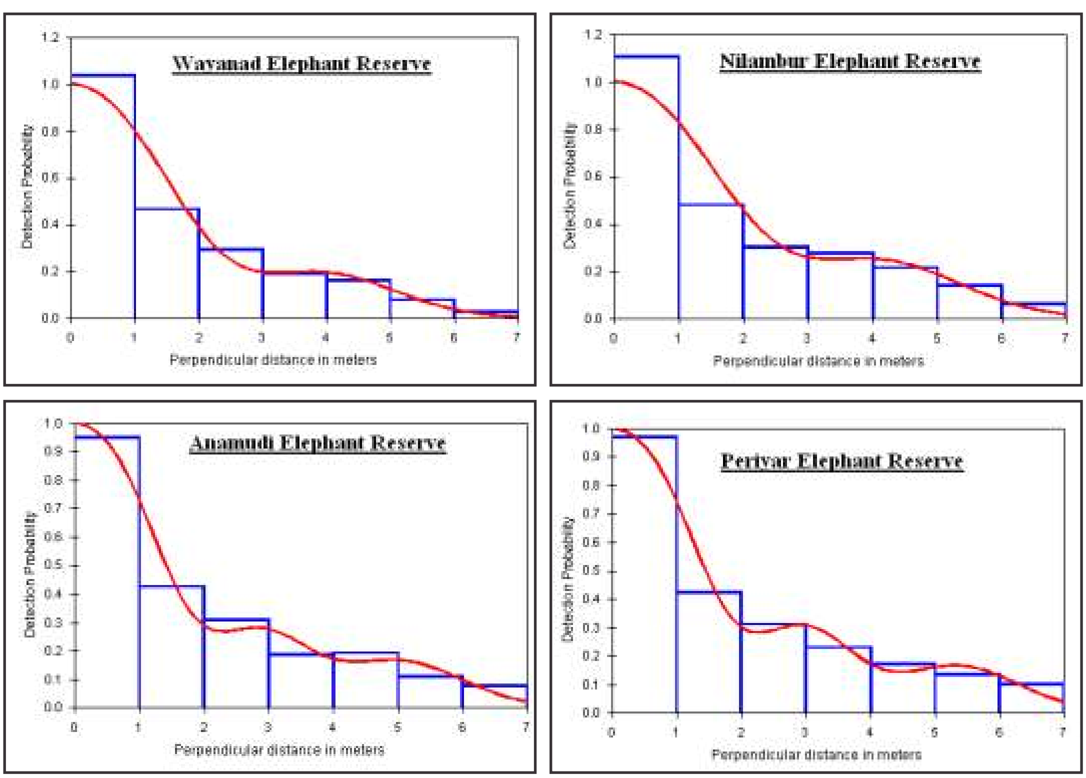

Fig. 2: Diagram depicting detection probabilities against distances to dung piles, 2010

detection curves are presented only for the year 2010 for want of space) though the chi-square values were significant. The negative exponential distribution overestimated the density due to the reason that too many distances were recorded as zero or small distances closer to zero leading to spiked distribution, which could be solved in future by changing field methods. The halfnormal distribution provided realistic density estimates and thus it was finally used for the density estimation. The software DISTANCE 5.0 Release 2 developed by Thomas *et al.* (2006) was used for all the calculations. For the purpose of objective temporal comparison, the number of dung piles and dung density were corrected for the differences in the sampling effort in different years of dung survey by considering 2007 as base year. Adjusted number of dung piles in the year 2005/2010 was found by multiplying the encounter rate (n/L) of the year 2005/2010 with the sampling effort (L) of 2007. Similarly, the adjusted dung density was worked out.

Results and Discussion

The average percentage increase in the number of dung piles and dung density worked out across different elephant reserves in the year 2007 was compared with the dung density in years 2005 and 2010 (Table 1). While the number of detections of dung piles increased by 71% in 2007 as compared to 2005, dung density increased by only 46%. Similarly, while there was about 77% increase in the number of detections, the percentage increase in dung density was just 59%. This indicated that the increase in dung density was not proportional to increase in the number of dung piles.

The reason for the disproportionate increase could be explained through temporal changes in the detection probability $\hat{f}$ (0) it is being another multiplicative factor in the density formula (2). $\hat{f}$ (0) was much lesser in 2007 than the other periods (Fig. 3). $\hat{f}$ (0) is inversely proportional to ESW. ESW is interpreted as the effective area under the detection probability function defined over the range of perpendicular distances. The maximum truncated perpendicular distance was similar (about 7-8 m) across the years and Elephant Reserves. However, the ESW was higher in 2007 as compared to 2005 and 2010 (Fig. 4). The difference was as high as 74% in Wayanad to 15% in Periyar and Anamudi. It seems that the increased ESW lessened the $\hat{f}$ (0) and in turn moderated the dung density in 2007. The reason for the increased ESW is due to enhanced detection probability $g(x)$ at the distance x. Since the detection probability is a fractional value, the changes in it will significantly influence the density estimates.

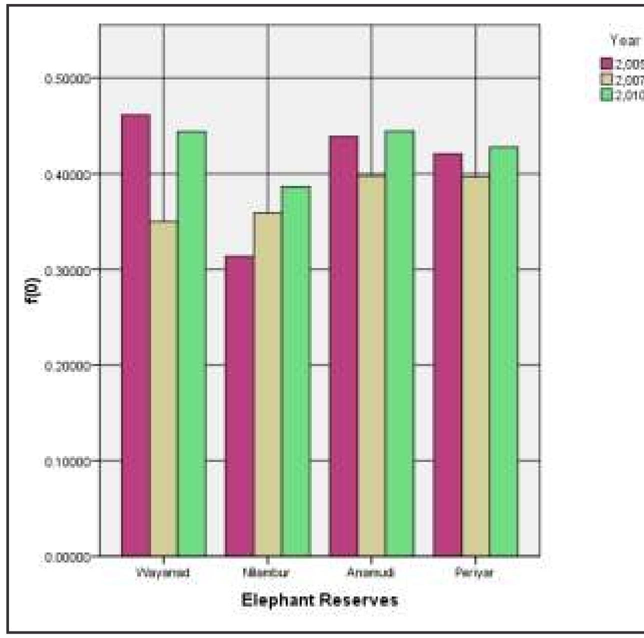

Fig. 3: Comparison of $\hat{f}$ (0) over the years 2005, 2007 and 2010

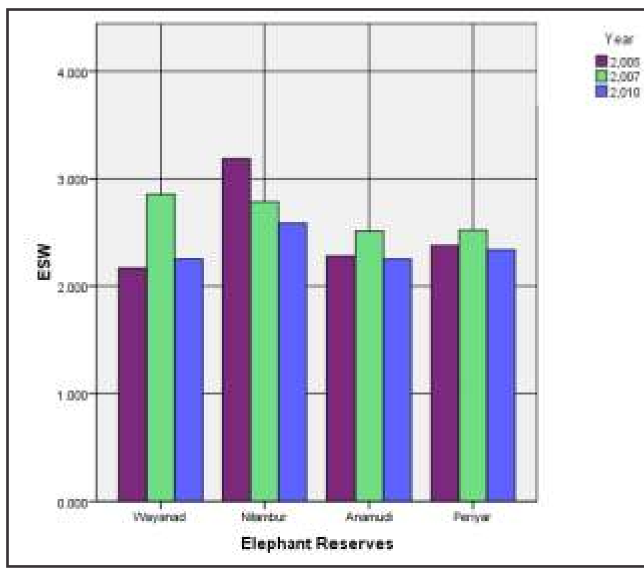

Fig. 4: Comparison of effective stripe width (m) over the years 2005, 2007 and 2010

The variability in number of detections and detection probability in the same study area over different years could be due to rainfall differences. This prompted us to compare the rainfall over the years. The dung piles could survive maximum of 120 days (Sivaram *et al*., 2005). So, the rainfall was examined retrospectively for about 120 days from the date of dung survey in each study year. Since the dung survey was conducted around first/second week of May it is enough if the rainfall is compared approximately from 1st February to the date of the dung survey. The monthly aggregated rainfall was worked out based on the daily rainfall data recorded by the major meteorological stations of Indian Meteorological

Department in the State, which are published in the daily newspaper archives of The Hindu (The Hindu, 2012). The rainfall during February and March was insignificant. Usually, the pre-monsoon rainfall is witnessed during the month of April and May. For the month of May, the total rainfall was worked out up to the date of dung survey (Fig.5). In the present context, the rainfall during April seems critical. A comparison of pre-monsoon rainfall reveals that the rainfall was much lower in April 2007 than 2005 and 2010 by the difference of 212% and 132 % respectively. Therefore, low pre-monsoon rainfall could be one of the reasons for the high number of detection of dung piles in

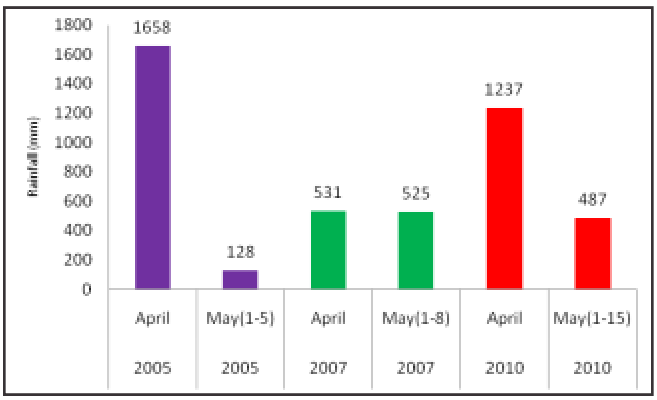

Fig. 5: Rainfall in April and May in the selected Meteorological Centers of Kerala State (2005, 2007 and 2010). In the month of May, the daily rainfall were added up to the dung survey dates given in the parenthesis

2007. Higher pre-monsoon rainfall could have led to the wash -out of the dung piles and there by lessened number of detections in 2005 and 2010.

On the other hand, lesser pre-monsoon rainfall in 2007 would have led to more visibility of dung piles at the longer distance from the line due to less undergrowth. This means that probability of detection of dung pile at the given distance x is more in 2007. Higher pre-monsoon rainfall in 2005 and 2010 would have led to more undergrowth thereby lesser visibility of dung piles at the longer perpendicular distances from the line and thereby the detection probability is less.

Conclusion

The study indicated that the presence of dung piles and detection probability of dung piles are dependent on the level of rainfall in the two months preceding the date of dung survey. Our findings corroborate with Barnes *et al.* (1997) and Barnes and Dunn (2002). However, the LTS could provide comparable dung density estimates under the highly varying number of dung piles present in the area due to differences in the annual rainfall pattern. This indicates that estimating elephant density through dung density is a potential method for the assessment of wild elephant population in Kerala forests provided other associated parameters defecation rate and decay rate are accurate.

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पशु-विष्ठा सर्वेक्षण का उपयोग करके वनों में हाथी प्रचुरता का आकलन करने में लाइन ट्रांजेक्ट सैम्पलिंग तकनीक का मूल्यांकन

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सारांश

वनों में जैविकीय आबादी का आकलन करने के लिए लाइन ट्रांजेक्ट सैम्पलिंग तकनीक का व्यापक रूप से उपयोग किया जाता है। हाल में पशु-विष्ठा सर्वेक्षण का उपयोग करके हाथी प्रचुरता का आकलन करने के लिए इस तकनी का उपयोग किया गया है। विष्ठा गणना को हाथी घनत्व में रूपान्तरित करने की विधि के लिए विष्ठा घनत्व की आवश्यकता होती है, जिसे मलोत्सर्ग और अपक्षय दर द्वारा ठीक करते हैं। इस शोधपत्र में सालाना वर्षा परिवर्तनशीलता द्वारा उत्पन्न विष्ठा ढेरों की खोजों की संख्या के विभिन्नता के विशेष संदर्भ के साथ पशु-विष्ठा सर्वेक्षण में लाइन ट्रांजेक्ट सैम्पलिंग तकनीक के प्रदर्शन को मूल्यांकित किया गया है। इस उद्देश्य के लिए आंकड़ा सेट करीब 9000 वर्ग कि.मी. को कवर करके वर्ष 2005, 2007 और 2010 के दौरान केरल राज्य में हाथी आबादी के आकलन से था। अध्ययन ने दर्शाया कि विष्ठा ढेरों की उपस्थिति और इसकी खोज संभावत: पशु-विष्ठा सर्वेक्षण की तारीख के पूर्व दो माहों में वर्षा के स्तर पर निर्भर थी। तथापि, सालाना वर्षा पैटर्न में विभिन्नताओं के कारण क्षेत्र में उपस्थित विष्ठा ढेरों की अत्यधिक अलग-अलग संख्या के अन्तर्गत लाइन ट्रांजेक्ट सैम्पलिंग तुलनीय विष्ठा घनत्व आकलन उपलब्ध करा सकती है।

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