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Original Article

An overview of various Sampling Method to Assess the Abundance of Prey of Large Carnivores': A special focus to Line Transect based Distance sampling method

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ABSTRACT
Success of most conservation efforts depends on availability of reliable scientific information on predation ecology, biology and population dynamics and habitat use of the concerned species. The evidence of evolutionary history suggests that ungulate communities act as determinant of large carnivore distribution and abundance across the distributional range in tropical forest. So carnivore density is positively related to prey abundance particularly wild ungulates and large wild ungulates with wider spatial distribution play a significant role in deciding the occurrence of large carnivores. Moreover, a threshold of prey abundance that determines poor or good quality of habitat reflecting the breeding possibility is important for developing necessary conservation action. Thus, reliable scientific information on the abundance of ungulate is critical for guiding large carnivore conservation action from local management intervention to regional conservation planning in the various large carnivores occupied landscape. As obtaining reliable field techniques to estimate ungulate abundance is often a major challenge for field managers and biologists, particularly in various forests especially in tropics where ungulate numbers are depressed by hunting, this review article may augment the domain knowledge and helped to develop model based framework for estimation of prey species. After reviewing various studies across the globe on ungulate abundance estimation techniques, line transects techniques under distance based sampling method found to be more reliable and widely applicable with least precision. This critical review article also gave an insight on analytical progress of line transect based distance sampling method and their uses in various forest ecosystem.

KEYWORDS: Distance sampling method, line transects, prey abundance.

INTRODUCTION

Population estimation of wild animals is of prime importance to ecologists and managers. Understanding animal abundance, distribution and movement pattern is a very important aspect of wildlife management. Since ungulates make up the major part of large carnivore's diet (Schaller, 1967; Seidensticker, 1976; Johnsingh, 1983; Karanth and Sunquist, 1995; Karanth and Nichols, 1998; Biswas and Sankar, 2002; Bagchi et al., 2003; Jathanna et al.,2003; Acharya et al.,2007; Andheria et al.,2007; Edgaonkar, 2008; Ramesh, 2010; Majumder et al.,2012), understanding herbivore abundance serves as an important part of studies on predator ecology (Karanth and Sunquist, 1995). Different forest ecosystems and their available prey resources helped to form different large sized carnivore associations in India, eg. tiger (Panthera tigris), leopard (Panthera pardus) and dhole (Cuon alpinus) association in tropical moist, rain and dry deciduous forests; tiger, leopard and striped hyena (Hyaena hyaena) association in tropical moist and dry-deciduous forests and lion (Panthera leo parsica) and leopard association in semi-arid forest. Thus, estimating prey species abundance serves as a resource base estimation for large carnivores - which are focal species for conservation efforts (Majumder, 2011).

Large carnivores population and distribution in tropical forest, which formerly inhabited vast tracts of forested landscape, has now been pushed to a corner due to increasing human habitation and poaching, also causing a sharp decline in ungulate populations. The reasons for lower large carnivore densities are likely a combination of factors, including over-hunting of potential prey by local communities (Karanth, 2004; Kawanishi and Sunquist, 2004) and naturally low cervid abundance in tropical forest where conditions are too wet (above 1900 mm/yr; Eisenberg, 1980; Vongkhamheng, 2011). It follows logically that any large scale effort of tiger conservation (Jhala et al.,2005) should be preceded by an equal scale of ungulate density estimation studies - which would help to determine the capacity and suitability of different habitats to support tigers. In such a scenario, it is imperative that a suitable method of ungulate density estimation be chosen, - and that it be subjected to technical innovations to suit the specific nature and vast scale of the envisaged survey (Jhala et al.,2005). Obviously, for the innovations to be scientifically acceptable, it is important that they neither compromise with the fundamental assumptions of established population estimation protocols, nor fall short of meeting the exacting rigours of technical research. Also, as this estimation method is intended to be institutionalized with the forest department as a long term monitoring protocol (Jhala et al.,2005) - the ultimate aim is to evolve a methodology that gives density estimates with acceptable accuracy and precision without requiring too much of resources or technical expertise.

This review article aim to bring all scattered literature on prey population monitoring techniqes with a special focus on distance based sampling method and their uses in various forest ecosystem under one umbrella so it can be ready reference for managers and bilogists working on prey population monitoring to conserve large carnivores in their respective landscape. It can also help to augment the domain knowledge and helped to develop model based framework for estimation of prey species.

Overview of Different sampling methods

Different sampling methods have been followed by wildlife biologists to estimate carnivore's prey. They are both direct and indirect sampling method. Sale and Berkmuller (1988) have given general guidelines to be followed in wildlife surveys.

Direct sampling method: They suggested that direct sighting methods to be followed in high prey density area and indirect methods to be followed in low prey density area. Population estimation of different prey species can be arrived at through direct sampling, which involves counting individuals animals. In African savanna forest, population estimation by aerial method is largely used as for the open area. Game species of the open plains, or species living in large herds, or confined within an open enclosure, are those most satisfactorily censused by total counts. Total counts have been made both aerially and from the ground. Total counts on large areas are subjected to vegetation cover limitations and high cost. Earlier and even today, population of prey species is determined by water-hole count in many areas. Chamaille- James et al.,(2007) used both aerial and waterhole methods to estimate population of african elephants (Loxodonta africana) in Hwange National Park, Zimbabwe. Aerial count method is not suitable for poorly visible, thicket dwelling species. Over estimation is one of the major disadvantages of water-hole count method.

Indirect sampling method: Population of herbivore can also be estimated by indirect sampling, in which animal signs, such as dung or tracks, are used (Eberhardt, 1978). The study of indirect evidence is found to be most practical procedure for assessing the presence of large mammals in certain places where direct method cannot be followed (Rabinowitz, 1993). Rabinowitz et al.,(1995) used this method assess the status of Sumatran rhinoceros and other large mammal species in Tamanthi Wildlife Sanctuary, Myanmar.

Thinh et al.,(2002) used indirect trail survey method to assess prey population of tiger in Bach Ma National Park, Vietnam and found that Artiodactyla species are the main food of tiger such as: wild pig, Sambar, Common muntjac, Serrow (Capricornis sumatraensis) and lesser Mouse deer (Tragulus javanicua).

Pellets or dung provide information such as a population's distribution, size and diet however, it is difficult to obtain for elusive species (Putman, 1984). Pellet group counts, drive counts and track counts were used to estimate population abundances of one small and four large species of duiker (Cephalophus sp) in a moist evergreen forest in north eastern Zaire by Koster and Hart (1988). In their study all methods showed potential as population indices for assessing trends of rare and elusive species in forest environments. To understand population structure of prey species, dung and pellet count method is not applicable. Brown et al.,(1995) point out that in certain cases, the distribution patterns seen may not be best explained by environmental conditions, such as when time lags in responses to environmental changes decreases the correspondence between environmental conditions and abundance, of when territoriality and aggregation for group benefits changes distribution in a way different from that expected by availability resources.

Most emphasis on studying ungulate habitat interactions has been given to the animals of the African Savannah (Ferrar and Walker, 1974; Hirst, 1975; Dunbar, 1978; Jarman and Sinclair, 1979; Ben-Sahar and Skinner, 1988) in the North American continent (Mackie, 1970; Edge et al.,1987; Jenkins and Wright 1988) and also in Europe (Schwartzand and Ellis, 1981; Putman, 1986). Rovero and Marshall, (2004) used line transect counts to collect data on population abundance of forest antelopes from three moist forest sites in the Udzungwa Mountains, Tanzania. These studies provided the first account of the abundance of forest antelopes in the Udzungwa Mountains and confirms that methodological problems — such as poor antelope detectability due to under storey vegetation and difficulties in identifying antelope species — were inherent in estimations of forest antelope density by line transects counts. Srikosamatara (1993) using line transects, direct and indirect counts, estimated density and biomass of four ungulate species, elephant (Elephas maximus) and seven other mammal species in Huai Kha Khaeng Wildlife Sanctuary, western Thailand. Treydte et al.,(2006) using data from walking transects, estimated the size of native ungulate populations on an abandoned cattle ranch in a coastal savannah in Tanzania, now included in the new Saadani National Park. They found that habitat restoration through wildlife can be observed and quantified on Mkwaja Ranch which will be of importance for future management of native ungulates reclaiming abandoned rangeland. Bardsen and Fox (2006) found in Aru Basin, Tibet that with increased sampling effort and a more effective design in future surveys, line transect sampling could be a useful methodology for assessment of chiru (Pantholops hodgsonii) population. As the deer species favours grassy areas in moist pockets, Nayak (2007) studied age and sex structure of barasingha (Cervus duvauceli branderi) in Kanha National Park following direct sighting method.

Wildlife managers in India have claimed significant success in increasing large herbivore densities in nature reserves through curbing of forest fires, logging, poaching and livestock grazing along with the development of water resources (Panwar, 1987). However, lacking the necessary professional skills, they have so far not collected quantitative data using valid methods, either to substantiate these claims or to formulate management strategies (Karanth, 1987).

Past studies in the Indian sub-continent that have addressed this issue are few. Studies that looked at ungulate abundance include those by Schaller, 1967; Eisenberg and Lokhert, 1972; Berwick, 1974; Seidensticker, 1976; Dinerstein, 1979; Tamang, 1982; Johnsingh, 1983; Sankar, 1994; Varman and Sukumar, 1995; Khan et al.,1996; Karanth and Sunquist, (1992, 1995); Karanth and Nichols, (1998, 2000); Ahrestani, 1999; Kumar, 2000; Biswas and Sankar, 2002; Bagchi et al.,2003; Jathana et al.,2003; Acharya et al.,2007; Edgaonkar, 2008; Avinandan et al.,2008; Khudsar et al.,2009; Ramesh, 2010; Majumder et al., 2012).

The first scientific study to consider ungulate abundance on the sub-continent was Schaller's (1967) long term study on tigers and their prey in Kanha. Using direct count and belt transects, he estimated the densities and biomass of wild ungulates. The biomass of wild ungulates was found to range between 937-1178 kg/ km². However, when the contribution of domestic ungulates was considered the estimate went up to 3880-4103 kg / km², a biomass density comparable to that found in Wyoming and Rhodesia.

Daniel (1967) also used direct count method to estimate blackbuck populations at Point Calemere Sanctuary in Tamil Nadu and found population nearly 750 while Nair (1976) following the same technique found 333 animals.

Eisenber and Lockhart (1972) used direct as well as pellet count method to estimate abundance of ungulates and other wildlife in Wilpattu, Srilanka. They observed that a biomass density in Wilpattu was a sixth of that seen in the steppe and savanna habitats of East Africa.

Ungulate densities in Nepal were estimated by Seidensticker (1976), Dinerstein (1979) and Tamang (1982). Seidensticker (1976) used successive belt transects (a precursor of the line transects method) to estimate densities of the large herbivores in the tall grass and reverine forest habitat of Chitwan. Dinerstein's (1979) study in the Royal Karnali-Barida Wildlife Reserve used pellet group counts, vehicle transects and count from observation platforms.

Johnsingh (1983) used direct counts to estimate the abundance of herbivores in Bandipur. The earlier studies used methods such as belt transects, block counts, road side counts and counts from observation towers to arrive at an estimate of herbivore densities. Using this method, Goyal et al.,(1986) studied food preference and habitat use of chinkara (Gazella bennetti) near Jodhpur, Rajasthan. Kunhunu (1989) studied dietary relationship among chinkara, blackbuck (Antelope cervicapra) and nilgai (Bosephalus tragocamelus) along with domestic livestock in Jodhpur. Haque (1990) studied chital (Axis axis), sambar (Rusa unicolor), nilgai and blackbuck alongside feral cattle in Keoladeo-Ghana National Park. Mathur (1991) studied three sympatric ungulates—chital, sambar and nilgai in three different areas: Sariska National Park, Rajasthan; Tadoba National Park, Maharashtra and Kanha National Park, Madhya Pradesh. Resources were found to be partitioned mainly by use of different habitats.

Sankar (1994) studied three sympatric species of ungulates – chital, sambar and nilgai along with the domestic livestock in Sariska Tiger Reserve (Sariska), Rajasthan. Varman and Sukumar (1995) used line transect methods in Mudumalai. They evaluated the efficiency of different models, field and analytical technique in density estimation.

Karanth and Sunquist (1992) used line transect technique to monitor ungulate prey population in Nagarhole National Park since mid 1980s. Besides, they have successfully applied the techniques to several other habitats of India: Bandipur, Pench, Kanha, Bhadra, Ranthambhore and Kaziranga. Khan et al.,(1996) estimated ungulate densities in Gir forest of Gujarat using roadside counts and line transect methods for lion and leopard. This study was compared with the densities estimated by Berwick in 1974 and it was found that densities of all the species except nilgai and wild pig (Sus scrofa) had gone up substantially with the chital showing the maximum increment of 13-20%.

Acharya (1997) studied on habitat occupancy by wild ungulates in Pench Tiger Reserve using both line and belt transect. He estimated ungulate densities by line transect where as belt transect at each 200 meter point on the transect was used to quantify for habitat parameters.

Effect of anthropogenic disturbance on habitat occupancy by tiger prey species was studied in Panna National Park (Panna), Madhya Pradesh by Mathai (1999). The study was conducted between November 1998 and April 1999. Line-transect method and pellet-count technique were used to estimate prey species abundance. Abundance estimates were used as a measure for intensity of habitat use by the species.

Both, Biswas and Sankar (2002) and Majumder et al.,(2012) used line transect methods to estimate densities of ungulates in Pench Tiger Reserve and observed that Pench harbours very high prey density and tigers are mostly dependent on the wild ungulates rather than on domestic livestock as is the case in many other areas in the Indian subcontinent. Vattakaven (2002) used vehicle based line transects to estimate overall prey densities for medium body sized carnivores in Velavadar National Park and found overall ungulate densities 60.8/ km² in this area.

Bagchi et al.,(2003) using line transect method in Ranthambore found that parts of Ranthambhore have high prey abundance, thus making it important for long-term tiger conservation. Ecological densities of large herbivores were estimated using the line transect method in the tropical moist forests of Bhadra Tiger Reserve, southern India by Jathana et al.,(2003). A comparison with densities estimated for these species in other well-protected parks showed that the chital, gaur (Bos gaurus) and sambar densities in Bhadra were extremely low. The main causal factors for these low densities seem to be poaching and livestock grazing.

In the recent most period Mitra (2004) estimated densities and biomass of wild ungulates in Kanha National Park and also developed habitat specific Effective Strip Widths (ESW) and Detection Models for different habitat types in Kanha. He reported wild prey biomass (including langurs) to be ranging from 4333 to 7715 kg/km² in different types of habitats, thereby signifying that there has been a mostly successful exclusion of livestock population allowing the wild prey base to increase and reach the natural carrying capacity of the system. Regarding the Effective Strip Width (ESW), the average ESW of ungulate sightings are overall larger than those attained by the visibility data. This is attributed to the movement of the ungulates away from the transect line prior to detection.

Banerjee (2005) has developed habitat specific Effective Strip Width models in Kuno Wildlife Sanctuary.

Response of large carnivores on their prey was evaluated phase wise in two different study sites of India; Sariska and Panna. In Sariska, Avinandan et al.,(2008) assessed prey availability when tiger was present where as two other studies were conducted after complete extirpation of tigers (Sankar et al.,2008) and after tiger was reintroduced (Sankar et al.,2010) where as in Panna, Chundawat and Sharma (2008) assed prey densities of tigers when tiger was present and Ramesh (2010) studied when tiger completely extirpated from this study site. In both of these cases, line transects found to be suitable method to assess fluctuation of prey bases during presence and absence of tiger.

Though line-transect sampling methods using direct observation of animals have been used extensively in the dry tropical forest to estimating ungulate population densities, but the method requires numerous sightings of animals to obtain reliable estimates (Karanth and Sunquist 1992; Vongkhamheng 2011). Thus, where encounter rates are low, as in tropical rainforests, the method does not work because the number of animals seen is insufficient to fit the reliable detection function (Buckland et al.,2001; Williams et al.,2002).

Vongkhamheng (2011) presented results of the first systematic assessment of ungulate abundance in the field in Lao PDR using occupancy model to extract ungulate abundance index. A single season heterogeneity Royle-Nichols model generated the abundance index of animal clusters (or groups) per sampling unit (3.25-km2 sub-grid cell) for five species of ungulates (Gaur, Muntjac, Sambar, Serrow and wild pig). The results showed that smaller-sized prey species were relatively more abundant than those larger-sized prey species. On average, prey population density was 5.25 ungulates per km2.

Gopalaswami et al.,(2012) estimated tropical forest ungulate densities from sign surveys using abundance models of occupancy. The potential utility of this approach extends beyond sign surveys of forest ungulates to a wider range of animal monitoring contexts, including those based on scent-station surveys and camera trap surveys of elusive mammals (Gopalaswami et al.,2012).

Jenks et al.,(2011) used relative abundance indices (RAIs) from camera-trapping to test wildlife conservation hypotheses at Khao Yai National Park, Thailand and observed Barking deer and Eurasian wild pig were the two most common herbivore species detected during camera trap surveys. This method had drawn criticism as RAIs cannot be synonymous with an actual index of relative abundance because they have not been correlated with data on population size of each species.

Sathyakumar et al., (2014) used a combination of method viz camera trap, sign survey, trail sampling and scanning to estimate population of mountain ungulates-major prey species of leopard, where, camera trapping was found to be the most applicable field method for solitary ungulates especially goral (Naemorhedus goral) Barking deer (Muntiacus muntjak) and serow (Capricornis thar) followed by sign survey and trail sampling. Scanning method was not recommended in a mountainous terrain to estimate ungulate population.

Line transect based Distance Sampling Method and its analytical progress

The theory of line transect sampling has been developed along rigorous statistical principles since 1968. Gates (1969) derived an estimator based on radial distance. Anderson and Pospahala (1970), studied waterfowl nesting by line transects. Seber (1973) presented a general model structure for line transects sampling and gave an approached based on effective strip width. Sen et al.,(1974) discussed the estimation of wildlife densities using both right angle and radial distances. Burnham and Anderson (1976) gave a general mathematical theory of line transect which supplied a framework for either parametric or non parametric density estimation based on either right angle or sighting distances. Pollock (1978) considered a family of density estimators for line transects sampling. Anderson et al.,(1978) provided guidelines for field sampling including practical considerations. A log linear approach to estimate population size using the line transects method was given by Anderson et al.,(1978). He emphasized that it is crucial to conduct observations allowing straight lines and obtain accurate measurements of distance and sighting animals. Care must be taken so that objects directly on the transect lines are detected with probability one. Eberhardt (1978) addressed the general question of determining sample size for population studies. Line transect based on right angled distances were discussed by Eberhardt (1979). Some parametric models for line transect sampling have been introduced by Ramsey (1979) and Quinn and Gallucci (1980).

A parametric generalization of the Hayne estimator for line transects sampling and robust estimation from the line transects data was given by Burnham (1979). A generalization of Hayne –type estimator as an application of line transects sampling was given by De Vries (1979). Alldredge and Gates (1985) discussed line transect estimators such as exponential or half normal for left truncated distributions. The Fourier series model for analyzing perpendicular distance data from the line transect sampling was proposed by Crain et al.,(1979). Burnham et al.,(1980) provided a major monograph on line transect sampling theory and application. This extensive work provided a review of previous methods gave guidelines for field use and identified a small class of estimators that seemed generally useful. Usefulness was based on four criteria: Model robustness, Pooling robustness, Shape criterion and Estimator efficiency. Laake et al.,(1979) and Gates (1980) produced comprehensive computer software packages, TRANSECT and LINETRAN respectively, for the analysis of line transect data. Buckland (1982) discussed Fourier series model as a powerful procedure for analyzing line transect data. Three solutions for finding confidence interval, one using Monte Carlo techniques, another making use of replicate lines and the third based on Jackknife method are discussed and compared (Mercey 1998). Radial distance models for the line transect method was discussed by Hayes and Buckland (1983). They compared, modified and generalized Hayne's model.

Burnham and Anderson (1984) suggested that for reasons of efficiency and validity, transect count studies should record perpendicular distance data.

Buckland (1985) discussed perpendicular models for line transects sampling and found the hazard rate model to be the most promising. Zahul (1989) gave a model for line transect sampling for the purpose of estimating animal population density which makes no assumption about the value of the detection probability along the transect or about the form of the detection probability function other than continuity. Confidence limits for line transect estimates based on shape restrictions were prepared by Routledge and Fyfe (1992), while Buckland (1992) used fitting density functions with polynomials.

Quinn (1979), Rao and Portier (1981) and Cook and Martin (1974) proposed estimation technique to clustered populations. The approach of Cook and Martin (1974) was incorporating some constant p as the probability of detecting an individual animal such that $0 < p < 1$ and that the detection of individual animals in the same group are independent Bernoulli tests (Mercey1998). Quinn (1979), however, examined the effect of pooling data over the various cluster sizes. Tacha et al.,(1982) discussed radial distance models for the line transects methods.

Drummer and McDonald (1987) introduced cluster size variable as a covariate in the detection functions. Drummer (1991) gave a computer software package called SIZETRAN to cater the needs of computations. Seber (1992) had given an extensive review of statistical methodology involved in estimating animal abundance. He broadly grouped the methods as applicable to closed populations, that is, unchanging except for known removals during the period of investigation and as those for open population where migrations, births, and deaths occur. He had discussed the use of plots, strips, lines and points for estimating population density or for providing an index of density based on indirect signs (Mitra 2004). Eberhardt and Simmons (1987) discussed calibrating population indices by double sampling. This technique is based on an approach known as ratio estimation which depends on knowing the value of an auxiliary variable (here index of abundance) over all sampling units in a study site. Simulations were conducted to check the existing equation for estimating means and variances. Rivest and Crepeau (1990) gave a two phase sampling design for the estimation of moose population. The two phases correspond two different ways of search, an airplane search and a helicopter search. Regression of helicopter search on the variables of airplane search was used to estimate the population size.

Quang (1990) gave methods for establishing confidence interval for density in line transects sampling. When the probability density function of perpendicular distances is peaked at zero or it is long tailed, the bias reduction offered an improvement. Turnock and Quinn (1991) discussed effects of responsive movement on abundance estimation using line transect sampling. They presented and compared two approaches to correct estimators with auxiliary information on movement; a correction factor approach and a decomposition approach. The later was preferred over the former. The methods were illustrated with survey data of Dall's porpoise in the Gulf of Alaska.

Brown (1984) discussed the line transect estimators such as exponentials or half normal for left truncated distributions. A parametric estimator derived from an aerial survey using dolphin data was used. Quang (1991) reported a program NPARTRAN for line transect data analysis, giving confidence limits for line transect estimates based on shape restrictions.

A computer program DISTANCE (Laake et al.,1993) was developed to allow comprehensive analyses of the type of distance data. The program is written in FORTRAN and runs only on any IBM PC compatible micro computer with 640 K of RAM (Buckland et al.,1993). A math coprocessor is desirable but not required. The program DISTANCE 5.0 allows more concentration on the results and interpretation of biology of population, its habitat and survey part rather than on computational details. Marques et al.,(2007) studied the use of multiple covariates in an analysis of a point-transect survey of Hawaii Amakihi (Hemignathus virens) using DISTANCE 5.0. The main use of these methods is to increase the reliability of density estimates made on subsets of the whole data (e.g., estimates for deferent habitats, treatments, periods, or species), to increase precision of density estimates or to allow inferences about the covariates themselves.

Uses Distance Sampling Method and its conservation implication

The accuracy of density estimates depends on how well the underlying assumptions were met. There were different techniques to estimate biological population of herbivores. However, these methods do not reliably take into account factors such as probabilities of detecting animals and their non random distribution in space. Often, the uncertainty regarding the estimate is not even considered. As a result, recent studies have made use of advances in population estimating techniques, and have used sample survey methods such as line transects to estimate mean densities and their associated variance in a quantitative, model based framework. The DISTANCE software has been well programmed covering different aspects like robust models, choice of model, analysis, and statistical inference for the unbiased, reliable, and efficient prey species densities estimation. Line transects have been used widely to estimate density and biomass large of carnivore prey (Biswas and Sankar, 2002; Bagchi et al.,2003; Harihar, 2005; Ramesh, 2010) (Table 1). Since deriving prey species densities and biomass is essential in studies pertaining to predator ecology (Karanth and Sunquist 1995), line transect sampling in conjuncture with distance sampling methods are used. In most studies prey species estimates are derived for the entire respective protected area (Karanth and Nichols, 1998, 2000).

Table 1. Biomass Estimates of Ungulate prey species of different large carnivores using Distance Sampling Method (DSM)

Country	Location	Forest type*	Biomass (kg/km^2)	Methods	Author
Bangladesh	Sunderban EWS	Mangrove+ Land	1038-2074	DSM	Khan, (2004)
Bhutan	Jigme Singye Wangchuck National Park	TF	379-615	DSM	Wang, (2010)
Cambodia	Mondulkiri Protected Forest	Lower Mekong Dry forest Eco-region	540	DSM	Gray *et al.,*(2012)
Cambodia	Seima Protection Forest	Both Deciduous and Evergreen	162	DSM	O' Kelly *et al.,*(2012)
China	Eastern Wanda Mountain	Broadleaf conifer Yao mixed Forest	524-579	DSM	Zhou *et al.,*(2011)
India	Kanha	TMD	3902	DSM	Karanth and Nichols (1998)
India	Nagarahole	TMD	7638	DSM	Karanth and Nichols (1998)
India	Bandipur	TDD	3382	DSM	Johnsingh (1983)
India	Bhadra	TMD	1244.8	DSM	Jathanna (2001)
India	Kaziranga	TMD and AGD	4252	DSM	Karanth and Nichols (1998)
India	Ranthambore	SA and TDD	6429.8	DSM	Bagchi *et al.,*(2003)
India	Chilla	TDD and TMD	6878.2	DSM	Harihar (2005)
India	Bori-Satpura	TDD and TMD	1721.8	DSM	Edgaonkar (2008)
India	Panna	TDD	4057	DSM	Chundawat and Sharma

					(2008)
India	Mudumalai	TDD and TMD	8365.2	DSM	Ramesh (2010)
India	Sariska	TDD and TT	10072.8	DSM	Sankar *et al.,*(2010)
India	Pench TR	TDD and TMD	5780	DSM	Majumder *et al.,*(2012)
Indonesia	Bukit Barisan Selatan	Lowland tropical rainforest	400	DSM	O'Brien *et al.,*(2003)
Malaysia	Taman Negara	Lowland tropical rainforest	266-426	DSM	Kawanishi and Sunquist (2004)
Nepal	Bardia	R and GL	1882	DSM	Karki (2011)
Nepal	Chitwan	R and GL	2272	DSM	Karki (2011)
Nepal	Suklaphanta Wildlife Reserve	GL	9584	DSM	Karki (2011)
Thailand	Huai Kha Khaeng Wildlife Sanctuary	GL, R and EG	1250	Distance sampling of droppings from line transects calibrated against defecation and decomposition rates	Srikosamatara (1993)

NP= National Park, TR= Tiger Reserve, * Forest types- TMD= Tropical Moist Deciduous, TDD= Tropical Dry Deciduous, SA= Semi Arid, R= Riverine, GL=Grass land, AGD= Alluvial floodplain grassland, TT= Tropical Thorn, EG- Evergreen, TF- Temperate Forest, EWS- East Wildlife Sanctuary, DSM- Distance Sampling Method

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