The elephant density of Ruhuna National Park as estimated by the dung count method, and a review of the methods used in Sri Lanka

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ABSTRACT *The density of the elephant population in Block I of Ruhuna National Park (141 km²), was estimated by indirect dung count method using data obtained from variable width transects. The dung density was found to be 527.10 (95% CL 198.54). The overall elephant density of the RNP-I was estimated to be 0.87 (Standard Error 0.12) km⁻². Although direct count methods have been used by several workers to estimate elephant population densities in Sri Lanka, indirect dung count method has been used only in one previous study. The various methods that have been used in the estimations of elephant density in Sri Lanka are discussed.*

Introduction

The Asian elephant *Elephas maximus* L. is considered a globally endangered species (IUCN, 1996). It occurs in 13 countries in Asia, including Sri Lanka, with a metapopulaiton of about 34,000 to 54,000, which is only one-tenth of that of the African elephant *Loxodonta africana* (Santiapillai & Jackson, 1990). In Sri Lanka it occurs in the Dry Zone (Fig. 1), mostly in Protected Areas.

The elephant is one of the most studied large mammals in Sri Lanka, but surprisingly authorities differ widely even in estimating the number of wild elephants in the country (McKay, 1973; Olivier, 1978; Hoffmann, 1978; Hendavitharana *et al,* 1994). There has been no rigorous scientific study to ascertain the size of the elephant population in any part of Sri Lanka, except by visual observation, the only exception being that of de Silva (1999) which estimated the elephant density in the Yala Protected Area Complex by the dung count method using fixed-width transects. Visual studies have been carried out by several workers in various areas, particularly in the Block I of the RNP (Eisenberg & Lockhart, 1972; McKay, 1973; Nettasinghe, 1973; Kurt, 1974; Ishwaran, 1981, 1993; Santiapillai *et al.*, 1984; Hendavitharana *et al.*, 1994; de Silva, *et al.*, 1995, 1997; de Silva *et al.*, (in press); Katugaha *et al.*, 1998).

The Ruhuna National Park (RNP) is situated in the south-eastern part of Sri Lanka (Figs.1 & 2) and has an extent of 979 km². The Block I (RNP-I) is in its south-western corner and has an extent of 141 km². It is the area of the RNP that is usually open to visitors for viewing animals. The present paper concentrates on the RNP-I, and deals with dung densities determined in variable-width transects. It also examines the advantages and disadvantages of the dung-count method and reviews the previous elephant density studies in Sri Lanka.

Study area and habitats

Ruhuna National Park (RNP) is divided into five blocks for administrative purposes but not with much attention to its ecology. Block I contains a variety of habitats and a good network of roads and tracks (Fig. 3). Its vegetation consists mainly of thorny-scrub and associated grassland, and dry evergreen forest.

The area of RNP has a known history of about 2,500 years and had once been a flourishing area of agriculture. It had an extensive system of irrigation reservoirs and rice fields and well developed human settlements by the 5th century AD, lasting until about the 12th century. Thus the forest cover in the area at present, whatever the type may be, is essentially secondary in character, developed during the last 500 years or so and has a very mixed composition. The area is scattered with irrigation reservoirs of varying sizes, most of which are in a completely dilapidated state and have developed into grassy-scrub areas; where there were extensive rice fields, grasslands have replaced them to day.

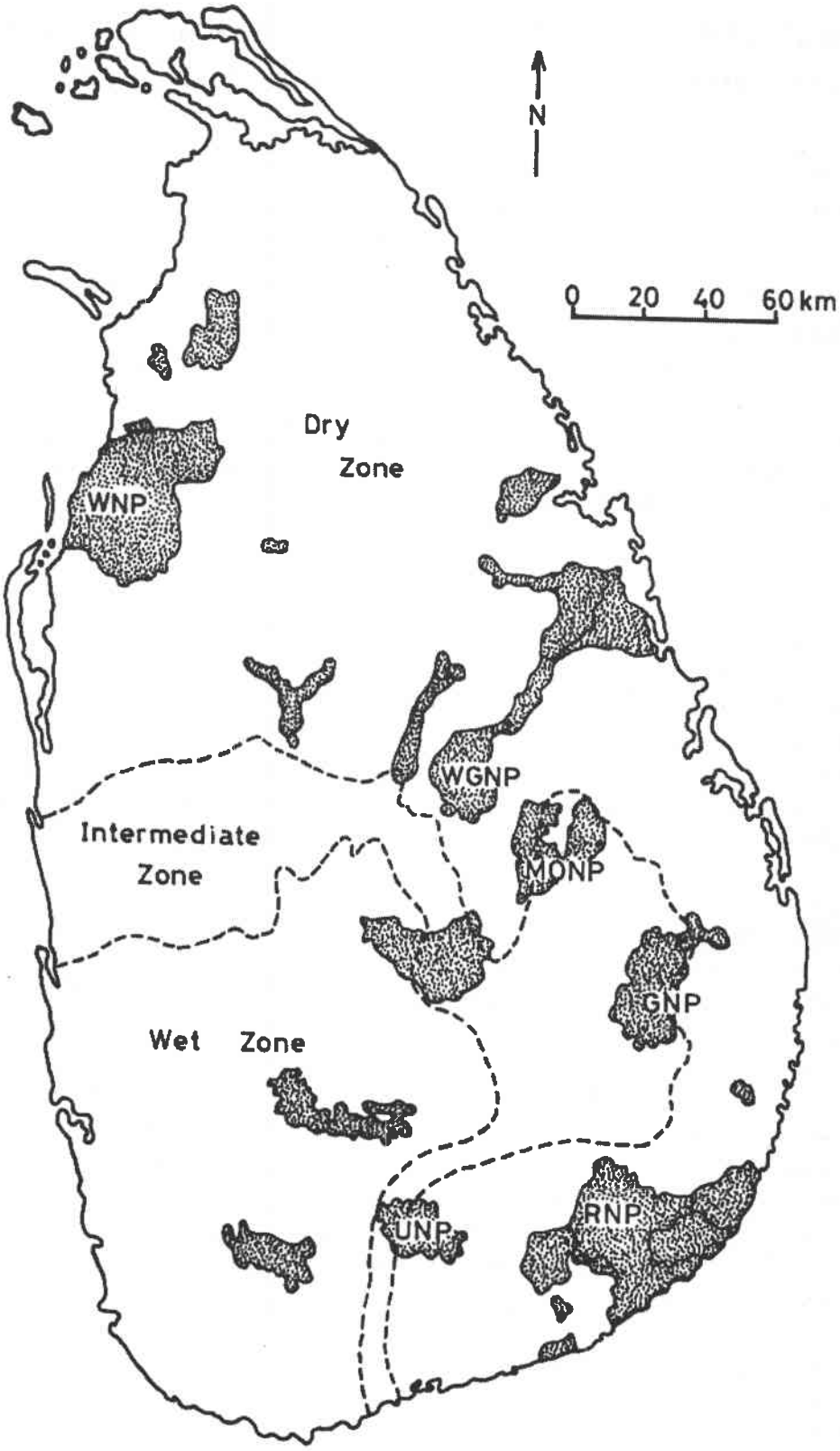

Fig. 1. Eco-climatic Zones and the major Protected Areas of Sri Lanka. GNP-Gal Oya National Park (NP); MONP-Maduru Oya NP; RNP- Ruhuna NP; UNP- Uda Walawe NP; WGNP- Wasgomuwa NP; WNP- Wilpattu NP

The vegetation of YPC is usually a mosaic of small areas of physiognomic types, some minor types occurring in small patches within a large area of a major type. The major physiognomic habitat types in RNP-I are the tropical thorn forest (thorn scrub), dry evergreen forest, riparian forest, forest-scrub, open scrub, grass-scrub, grassland with scattered trees, seasonally submerged grasslands, and sand dunes.

Methods

The study was carried out in August 1996, during the dry season (Fig. 4). In five transects (numbered 1-5 in Fig. 3) the perpendicular distance from a dung pile to the central line of each transect was measured. All transects were 2 km long except the 1st, which was 2.5 km. Elephant density was estimated as E = Yr/D, where E, Y, r and D are

$$\text{Elephant density} = \frac{\text{Dung density per km}^2}{\text{No. of days for total decomposition X No. of defecations per day}}$$

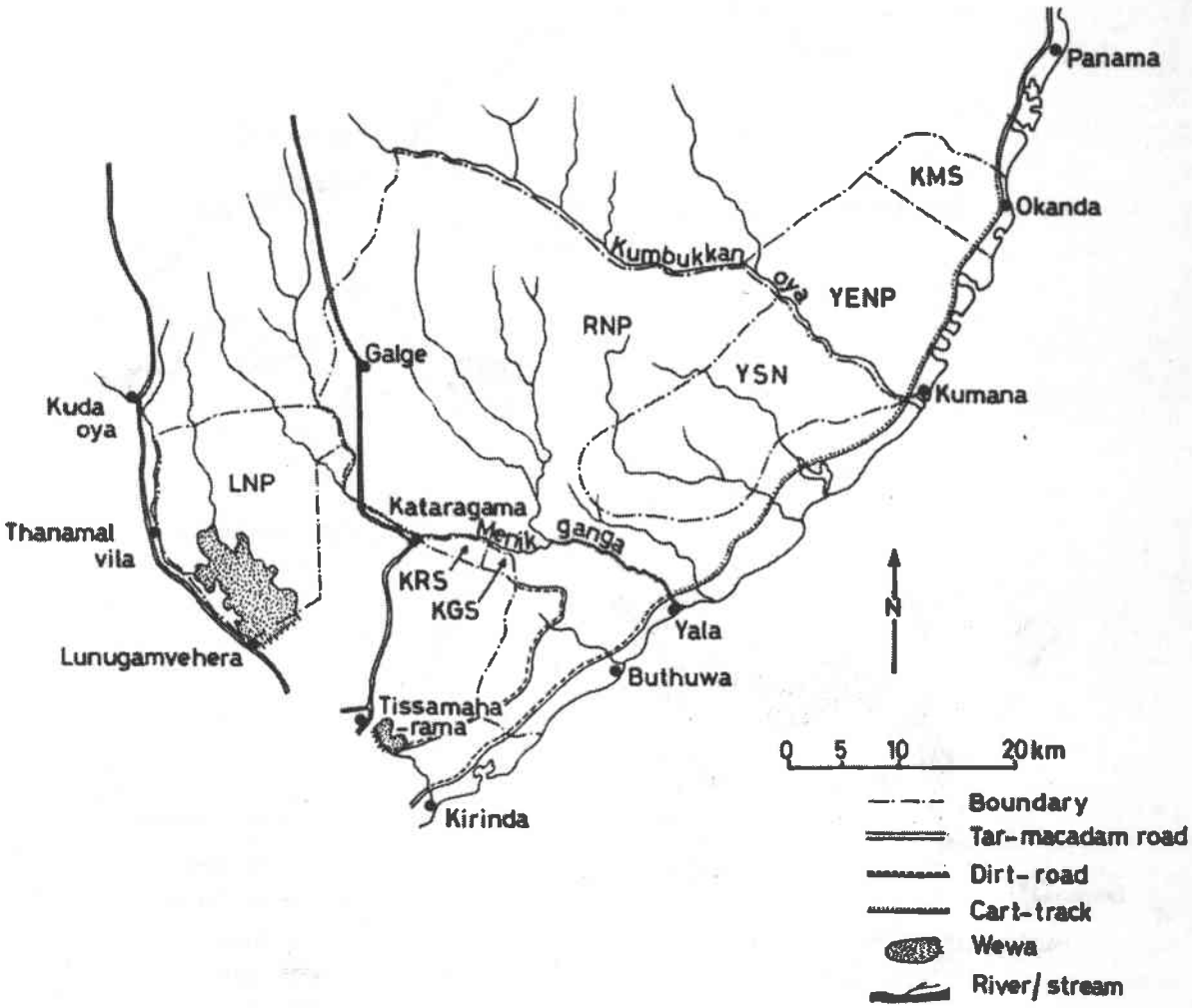

Fig. 2. Map of Ruhuna National Park and other adjacent Protected Areas
KGS- Kataragama Sanctuary; KMS- Kudumbigala Sanctuary; KRS- Katagamuwa Sanctuary; LMP- Lunugamvehera NP; RNP- Ruhuna NP; YENP- Yala East NP; YSN- Yala Strict Natural reserve

elephant density per km², dung density per km², dung decomposition rate per day and defecation rate per day, respectively.

The overall dung density of the variable-width transects was estimated using the computer software ELEPHANT from the Wildlife Institute of India at Dehra Dun. The average time taken for the total decomposition of dung and the average defecation rate were taken as 39.7 (Standard Error 1.0) days and 15.3 (Standard Error 3.1) times per day respectively, from a previous study (de Silva, 1999). The standard error (SE) of the mean density was estimated according to N.V. Joshi (in Varman *et al.*, 1995) using the formula,

$$(SE(E))^2 = (SE(Y) \times r/D)^2 + (SE(r) \times Y/D)^2 + (SE(D) \times Yr/D^2)^2.$$

Since the study was carried out within a single month, it was assumed that the dung piles would remain for approximately the same number of days in different habitats.

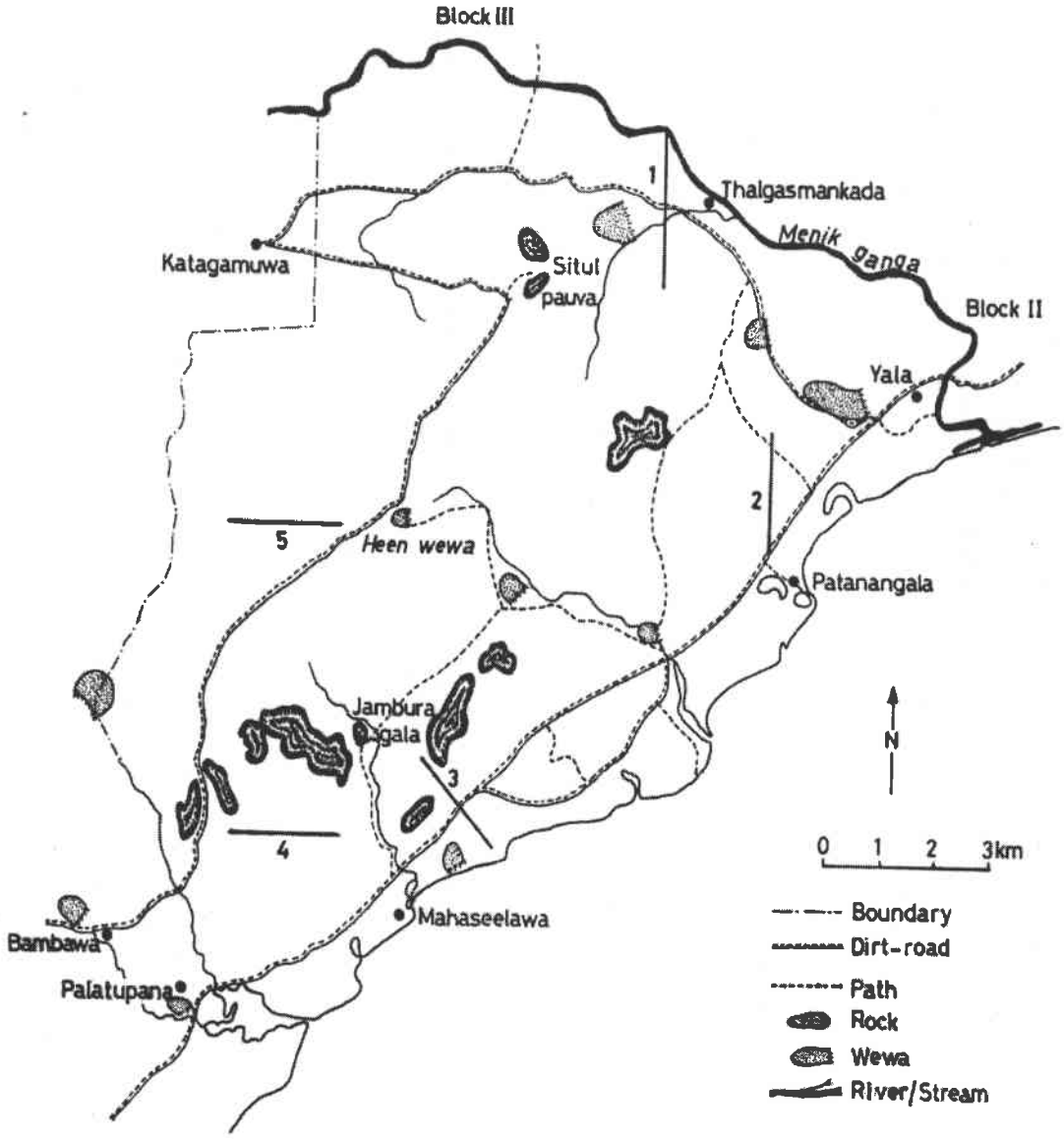

Fig. 3. Block I of Ruhuna National Park showing the locations of the five transects studied

Results

The mean dung density was 527.10 (SE 71.52). Therefore the elephant density works out to be 0.87 (SE 0.12) km^{-2}. Since the area of the Block I of the RNP is 141 km^2, the probable number of elephants in the area appears to be 123.

Discussion

Direct-count methods depending on the visual observation of animals, as well as indirect methods depending on the surveys of dung and other signs of activity have been used to estimate elephant densities in various habitats (Barnes & Jensen, 1987; Dawson, 1993; Dekker *et al.*, 1991; de Silva *et al*, 1995; Hendavitharana *et al.*, 1994; McKay, 1973; Sukumar, 1989).

Direct count methods could broadly be categorised into three types, viz. those using visual observations,

(a) on individuals and herds in defined areas,
(b) at waterholes, and
(c) along transects.

Indirect count methods could be broadly categorised into two types, viz. those using dung counts,

(d) in defined areas and belt transects, and
(e) along transects of variable width.

(a) Visual observations on individuals and herds in a particular area is the common method that has been used in Sri Lanka by many workers. The workers are familiar with a particular area and its elephant population. Thus, they could make a good estimate of the elephant number in that area. Usually, it takes much time, often more than a year to familiarize one with the elephants in a particular area. Tuskers are easy to identify from the characteristics of their tusks (de Silva *et al.*, 1997). Adult males also

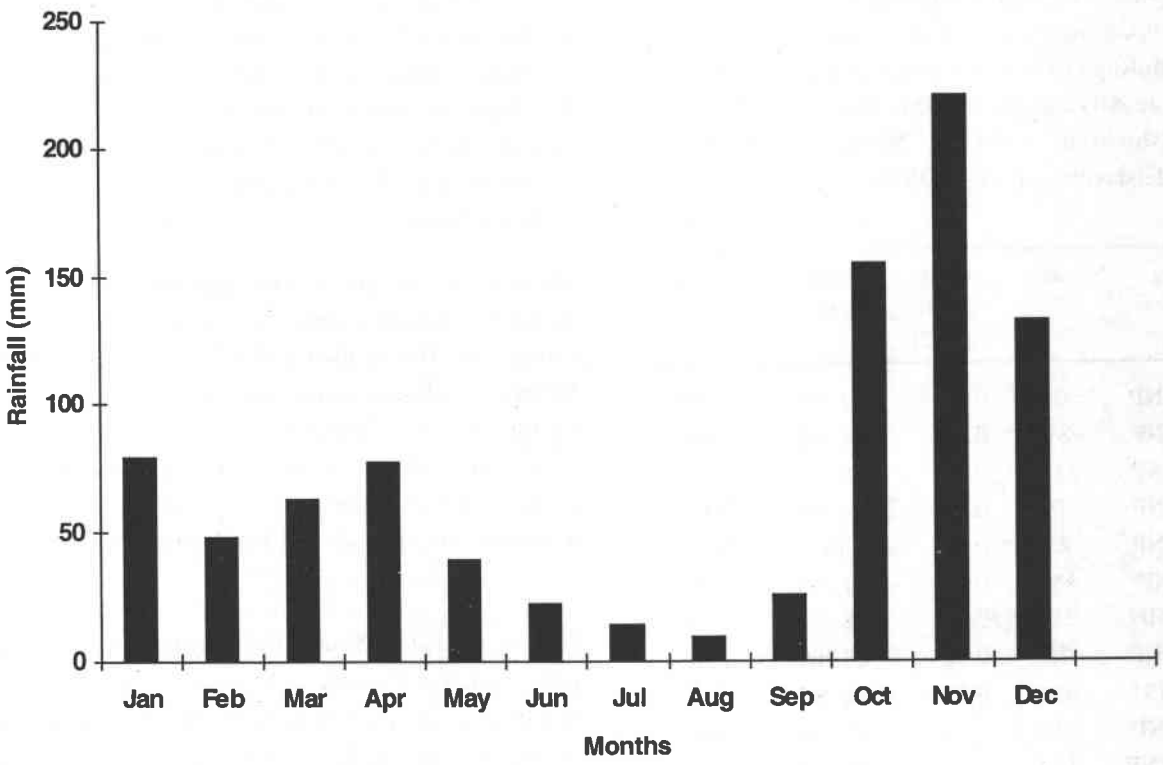

Fig. 4. The mean monthly rainfall at Palatupana (Block I) for the 15 year period 1980-1994

can be characterized by morphological as well as behavioural features. The herds can be identified by the number of juveniles and infants, characteristics of the adult females, and sometimes those of others. The method could be successfully used for a protected area or other demarcated areas.

Eisenberg & Lockhart (1972) were the first to use such individual identifications to work out the elephant density in the Wilpattu NP in northwest of Sri Lanka. Their study was followed by those of McKay (1973) in Gal Oya NP and environs and Ruhuna NP (Blocks I & II), Nettasinghe (1973) in Thamankaduwa area, and Kurt (1974) in Ruhuna NP (Table 1). The densities that were thus worked out for one or more areas sometimes have been extended to estimate the elephant population of the entire country by various workers (for a discussion see de Silva 1998).

Table 1 Estimates of densities of various elephant populations of Sri Lanka. (GNP:Galoya NP; LKNP:Lahugala-Kitulana NP; RNP:Ruhuna NP (Block I); RNP*:Ruhuna NP (Blocks I & II); WNP:Wilpattu N.P.; WsNP:Wasgomuwa N.P., TMN:Thamankaduwa area; YPC:Yala Protected Area complex). AN:Nettasinghe (1973); CS:Santiapillai *et al.* (1984); FK:Kurt (1974); GM:McKay (1973); JE:Eisenberg & Lockhart (1972); MS1:de Silva et al. (1995); MS2:de Silva (1999); NI1:Ishwaran (1981); NI2:Ishwaran (1993); WH:Hendavitharana *et al.* (1994).

Area	Number	Crude density (km^{-2})	Study period	Authority
GNP	310	0.19	'67-'69	GM
RNP	89	0.64	'68-'69	FK
RNP	21.6	0.15	'78-'80	CS
RNP	75	0.54	'91-'93	MS1
RNP	85	0.61	1993	WH
RNP*	150	0.63	'67-'69	GM
TMN	213	0.16	'68-'71	AN
WNP	70	0.12	'68-'69	JE
YPC	656	0.51	'95-'97	MS2
GNP	230		'75-'76	NI1
LKNP	150		'67-'69	GM
WsNP	65.8		'80-'82	NI2

(b) Waterhole counting method is based on the assumption that elephants will gather at waterholes for drinking. During the peak of the dry season only a few waterholes will contain water and the elephants will gather at these, particularly in the evenings, and are then easy to count. A method similar to this was carried out by the Department of Wildlife Conservation (DWC) in June 1993 (beginning of the dry season). The elephants were counted at various locations (not only at waterholes), mainly in the protected areas, by the DWC officials and local people who have a sound knowledge on where the elephants could be found during the period. The elephants were counted for six days in all 'elephant areas' of Sri Lanka except the northern region. The study involved some 800 individuals, including personnel from NGOs, who spent more than 57,000 man-hours in the field, recording elephants. The results indicated that there were *a minimum* of 1,967 animals in the regions surveyed (Hendavitharana *et al.*, 1994). It must be pointed out that in some regions only the readily accessible areas were subjected to the survey. For instance, in Blocks II, III, IV and V of RNP were only partially surveyed and that too only from the few available roads; the Yala Protected Area Complex, Yala SNR, Yala East NP and Kudumbigala sanctuary were not surveyed at all. Thus the survey resulted in only a partial count in some areas. But, this work remains the one and only attempt to estimate the elephant densities of the entire island by simultaneously studying the movement of elephant populations in different areas.

The method could give good results if proper precautions are taken, although it cannot be subjected to rigorous scientific tests. This method will also give demographic information on the population structure, group structure, etc., information that cannot be obtained by the indirect dung-count method. The method would obviously *underestimate* the population size since it is highly unlikely that all animals could be observed within the brief survey period.

de Silva *et al.*, (1995) used the daily observations of the park officials and guides to determine the monthly crude density of elephants in Ruhuna NP (Block I). In analyzing the observations, on the first run, they took weekly observations and eliminated the apparent repetitive observations by different game guards at the same time and same place.

The total number, the presence and number of tuskers, calves and juveniles in a group helped to eliminate the repeat observations of such groups. The times at which observations were made at different places also helped to determine the number of groups when two or more groups of similar composition were observed on the same day. After eliminating the apparent repetitions in the weekly observations, in the second run, the monthly observations were again examined and the apparent repetitions were eliminated. Such analysis indicated that the number of elephants monthly frequenting RNP-Block I varied from 36 to 108 with an average of 75. Therefore, the average crude density of elephants in the area was apparently 0.53 km^{-2} (range 0.26-0.77). The average crude density of adult elephants (including subadults) was 0.37 km^{-2}. These estimations give a *minimum* crude density as there could always be animals that were missed in the surveys.

(c) A better method is the visual counting of animals along transects (Dawson & Dekker, 1992). The method is good for areas where elephants could be seen easily. However, the method is quite impractical in the Sri Lankan situation because of poor visibility in scrub and forest habitats and the natural shyness of these animals. The groups (rather than the number of individuals within groups) are counted, each solitary individual being considered a group of one. From these, the mean group size is calculated. The sighting angle and sighting distance of each group are recorded from which the perpendicular distance from the centre of transect to the group sighted is calculated. From

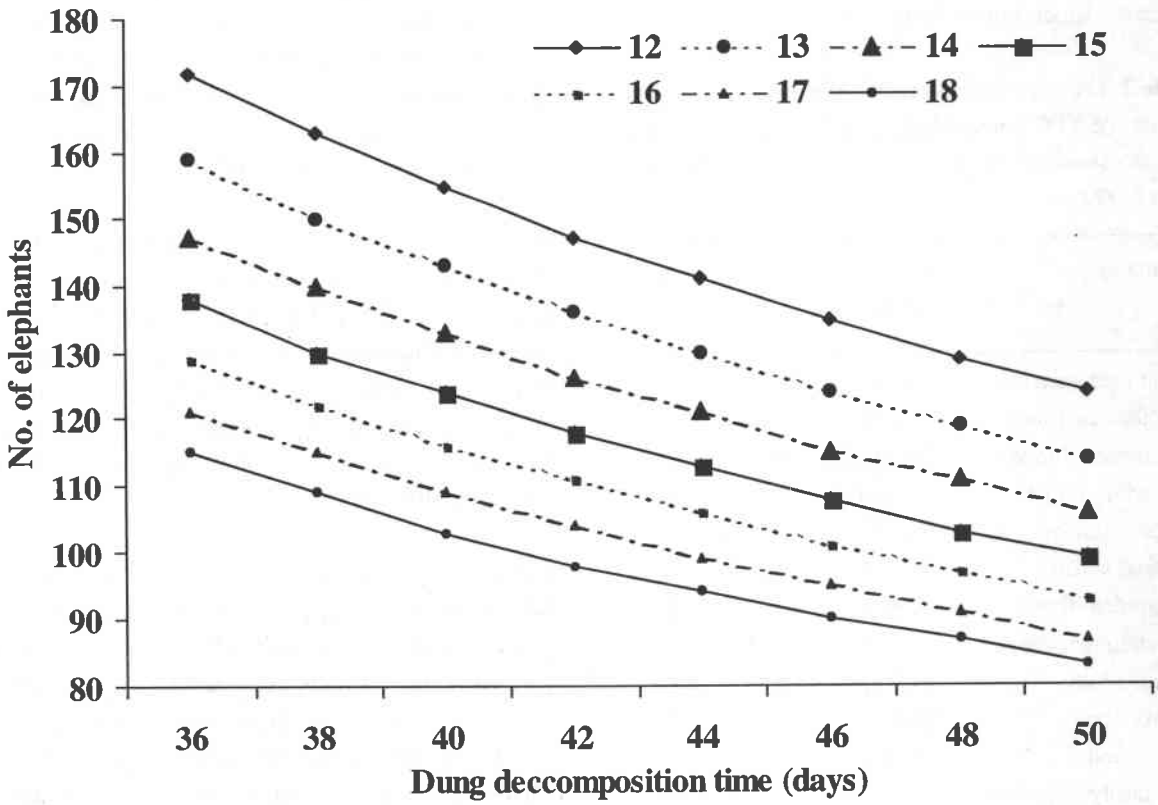

Fig. 5. The estimated number of elephants in Block I according to different defecation rates (12 - 18 times per day) and dung decomposition times

the perpendicular distances, the mean width and therefore the area of the transect can be computed. Since the number of groups in the transect is known, the density of groups in the transect can be estimated. The density of elephants in the transect is obtained by multiplying the density of groups by mean group size. The computations could be easily carried out using the computer software programme ELEPHANT (Wildlife Institute of India, Dehra Dun).

(d) In the dung count method, basically the dung piles of a particular area are counted and the density of elephants is worked out using the decomposition rate of dung and defecation rate. de Silva (1999) studied a total of 43 belt transects of varying length in twelve habitats in the Yala Protected Area Complex (YPC), transect width varying according to visibility within habitat. He worked out the elephant density for each habitat (Table 2) and from this the overall density for the YPC and its component reserves (Table 3) taking into account the approximate extent of each habitat in these. He thus estimated the elephant density in the Block I of the RNP to be 0.80 km^{-2}.

Table 2 The number and density of elephants in different habitats of YPC (except Yala East NP and Kudumbigala SA) as estimated by indirect dung count method by de Silva (1999).

Habitat	Total area in YPC (ha)	Elephant density (km^{-2})	No. of elephants
Semi-evergreen forest	3,329	0.00	0.00
Deciduous forest	31,184	0.21	65.5
Evergreen forest	29,138	0.42	122.4
Riparian forest	2,480	0.08	2.0
Thorn- scrub	4,213	0.91	38.3
Forest- scrub	23,652	0.70	165.6
Degraded forest (abandoned chena)	2,995	0.33	9.8
Open-scrub	14,737	0.58	85.5
Grass-scrub	10,943	1.03	112.7
Grassland	3,960	0.92	36.4
Seasonally submerged Grass cover	1,165	0.72	8.4
Sand-dunes	872	1.02	8.9
Total	**128,628**	**0.51**	**655.5**

Table 3 The average density and number of elephants in the components reserves of the YPC as estimated by de Silva (1999). (SNR:Strict Natural Reserve; SA:Sanctuary).

Component	Density (km^{-2})	Number
Yala SNR	0.61	176
RNP-Block I	0.80	113
RNP-Block II	0.70	70
RNP-Block III	0.52	212
RNP-Block IV	0.31	82
RNP-Block V	0.45	30
Kataragama SA & Katagamuwa SA	0.50	9
Total	**0.54**	**692**

(e) Dung piles can also be counted along transects of variable width. The perpendicular distance from each dung pile to the midline of the transect is measured and from these measurements the effective width of the transect is calculated. It is recommended that (a) a minimum of five transects from each stratum should be studied, (b) the transect length should not be less than 2 km, and (c) the total number of dung piles observed should not be less than 40 (Dawson & Dekker, 1992).

The accuracy of density estimates by dung count methods depends on the knowledge of defecation rates and dung decomposition rates. The representative defecation rate depends on the amount and nature of the food taken, and varies over a narrow and numerically low range (e.g. 12–18 times per day). Dung decomposition rates, on the other hand, can vary over a much wider and a numerically higher range (e.g. 40–80 days).

de Silva (1999) estimated the time interval between two defecations as 94.1 minutes (Standard Error 3.1, n=52) from daytime observations (0600 to 1830 hours) in RNP. This gives the defecation rate as 15.3 per 24 hours. On data collected from 37 wild elephants in Gal Oya area (situated to the north of RNP) (Fig. 1) in the dry zone, Vancuylenberg (1977) found that an elephant defecates 12 to 18 (modally 15) times a day. His data gives a mean defecation rate of 15.09 per 24 hours (SE 1.89). On the other hand, in the Mudumalai Wildlife Sanctuary (MWS) of southern India a defecation rate of 13.13 per day was

estimated by Dawson (1990) (see Dekker *et al.*, 1991), 15.08 per day by Desai (pers. comm.), and 16.33 per day by Watwe (see Varman *et al.*, 1955). (Dawson (1993) also used the defecation rate of 13.13 per day as an approximation in her study of elephants in Tabin Wildlife Reserve, Malaysia.)

On data from faeces distribution surveys and observations on a captured elephant Vancuylenberg (1977) found that defecation rates during daytime differed from those in the morning and in the night. Aananthasubramaniam (1992) also found defecation rate of domesticated elephants to be higher at night. On the other hand, other studies such as those of Sale *et al.* (1990), Coe (1972) and Wing & Buss (1970) found no temporal differences in the defecation rates.

Defecation rates should be estimated by observing the wild elephants while they feed and move in their natural habitat, a task that is difficult to carry out in most Sri Lankan habitats. Other approximations have been recommended, such as observing acclimatised domestic animals feeding entirely on provided natural fodder or feeding while free-ranging in the habitat(s) under study (Dekker *et al.*, 1991). Clearly, the composition and accessibility of food sources will affect the defecation rates, and environmental conditions will affect both the quality and quantity of food available. Also the defecation rates of different sexes and different age classes differ.

Dung decomposition rates are affected by several factors, mainly by environmental conditions, which could deter-

Table 4 Observations on dung decomposition by Ishwaran (1984) in the north-eastern part of Sri Lanka.

season	habitat	no. of dung piles	dung piles remaining after 30 days	status of dung piles at the end of observation period
Wet	Forest	7	4	4 remaining after 61days
		7	7	6 remaining after 52days
	Grassland	38	38	18 remaining after 52 days
Dry	Forest	8	8	8 remaining after 97 days
		4	4	4 remaining after 101 days
	Grass-Scrub	18	16	15 remaining after 98 days
	Grassland	7	7	1 remaining after 64 days
		7	7	7 remaining after 98 days
		2	2	2 remaining after 97 days
		2	2	2 remaining after 61 days

Table 5 Elephant density in the Block I of RNP according to different methods of estimation using dung count method. (* Density was computed by taking into account the dung densities in different habitats of YPC and the extent of each habitat in RNP-I). [1 & 2] de Silva (1999), [3] present study.

method	densities in different habitats[1]	transects of constant width[2]	transects of variable width[3]
Dung density(km^{-2}) (SE)	485.92*	460.15 (55.80)	527.10 (71.52)
Decay rate/day (SE)	0.0252 (0.0007)	same as in 1	same as in 1
Defecation rate/day (SE)	15.3066 (0.4655)	same as in 1	same as in 1
Elephant density (SE)	0.80	0.76 (0.09)	0.87 (0.12)

Table 6 Seasonal elephant density in Mudumalai Wildlife Sanctuary (Source: Varman *et al.*, 1955)

Season	Dry	Wet I	Wet II	Overall
Dung density (km^{-2}) (SE)	2126 (76.3)	3069 (148.9)	2706 (182.4)	2561
Decay rate/day (SE)	0.01 (0.0012)	0.013 (0.0013)	0.007 (0.0004)	0.0097 (0.002)
Defecation rate/day	16.33 16.33	16.33 16.33		
Elephant density (95%CI)	1.32 (1.19-1.47)	2.58 (2.26-2.86)	1.30 (1.10-1.46)	1.54 (1.01-2.08)
SE (Elephant density)	0.07	0.14	0.08	0.27

mine the activity of dung decomposition agents such as dung beetles, termites and even micro-organisms. For instance, dung decomposition in forest habitats appeared to be more rapid than in grassland habitats in RNP (de Silva, 1999). On the other hand, Ishwaran (1984) found that the dung decomposition is more rapid in the grassland habitat than in the forest habitats in the north-eastern part of Sri Lanka (Table 4). The difference is probably due to the nature of grassland; grasslands in the RNP being dominated by short grass species and those of the north-eastern part of Sri Lanka being dominated by tall grass species. Also the temperatures in the grasslands of RNP are higher. During the main rainy season (October to January) a dung pile in RNP would disappear in as little as a week (heavy rains tend to disintegrate and erode dung pellets; this also accelerates decomposition). Heavy rain especially affects 'amorphous-mass' dung piles at Stage D of decomposition (Dawson & Decker, 1992). Ishwaran (1984) also found that the dung decomposition rates in the north-eastern part of Sri Lanka during the wet season are higher than those during the dry season (Table 4). On the other hand drought conditions with high temperatures may reduce the decomposition process, even reducing the activity of micro-organisms. It was observed that in sand dunes of RNP, the total decomposition may take 80 days or more and that the macro-decomposing organisms such as beetles and their larvae, and termites, were not present (de Silva, 1999). Dawson (1993) found that for the total decomposition of elephant dung during the dry season in Tabin Wildlife Reserve in Malaysia, it took on average, 140.84 days and that there was a total absence of the activity of macro-decomposing agents such as dung beetles and termites.

The average time taken for the total decomposition of 25 dung piles in the grassland and grass-scrub habitats of the RNP was found to be 39.7 (Standard Error 1.0) days (de Silva 1999). On the other hand, the average time required for total decomposition of elephant dung in Mudumalai Wildlife Sanctuary (MWS) has been estimated as 78.74 days (i.e an average decomposition rate of 0.0127 day^{-1}) by Dawson 1990 see Dekker, 1991), 57.14 days (average decomposition rate of 0.0175) by Desai (pers. comm.) and 103.1 days (average decomposition rate of 0.0097) by Varman *et al.* (1995). In fact, the last authors note that the time taken for total dung decomposition in MWS could vary from 5 days to 273 days.

The dung count method assumes constant environmental conditions or a steady state so that dung decomposition rates as well as defecation rates remain constant. The number of dung piles deposited each day is assumed to be equal to the number of dung piles disappearing the same day. Furthermore, seasonal movements of elephants from area to area between seasons could affect the dung densities in a particular area. Therefore it is important to complete the survey in as short a time as possible within one season.

Subject to these limitations, the method could be used to estimate approximate mean densities. It provides a *rapid* and *crude* technique to estimate density and the *time* the animals spend in each habitat type (de Silva, 1999). However in MWS, the estimation of elephant density by direct counts (3.09 km^{-2}) was twice that estimated by dung count method (1.54 km^{-2}) (Varman *et al.*, 1995).

The elephant population in the in RNP-I is the most studied in Sri Lanka (Table 1). Most workers attempted to assess the elephant population by visual observations and thus obtained a minimum density. de Silva (1999) in assessing the elephant density in the entire YPC complex by dung count method, found the density in RNP-I to be 0.80 km^{-2} (Table 3). [In his study de Silva (1999) estimated the

dung densities in different habitats and used these dung densities to estimate the elephant densities in different components of the YPC (including RNP-I), taking into account the extent of each habitat in each component.]

When the number of dung piles in each of the nine transects in RNP-I (excluding the transects in the sand dune habitat because the latter were very short transects) in the previous study (de Silva 1999) were used to estimate the elephant densities without reference to the habitat, the density works out to be 0.76 km^{-2} (Table 5), which is slightly less than that calculated when the habitats were taken into consideration. [In the present study in the dry season of 1996, the five transects were positioned more or less in the same positions of five of the nine transects of the previous study, but the transect lengths were increased to 2 km or more, where necessary. The present study gave a higher density of 0.87 km^{-2}].

Obviously, the estimated elephant densities depend on the accuracy and applicability of dung decomposition rates and defecation rates to the particular study. The variation in the elephant number of RNP-I on different dung decomposition rates and defecation rates is shown in Fig. 5.

More elephants were observed in RNP-I during and following the main rainy season of October-December (de Silva *et al.*, 1955, 1957). McKay (1973) found that during the wet season there were about 1.7 times as many elephants as during the dry season in Gal Oya area and that this factor was more than six times in Lahugala area of Sri Lanka. Varman *et al.* (1995) showed that the elephant densities in the Mudumalai Wildlife Sanctuary differ in different seasons (Table 6). On the other hand, in Wasgomuwa National Park area of Sri Lanka, Ishwaran (1993) observed about twice as many elephants during the dry season as during the wet season.

Different densities in different seasons indicate that at least some elephants move from area to area when the season changes, obviously in search of more and better quality food, and more importantly water. In RNP, elephants used to move from Blocks III, IV and V of the RNP to Handapanagala area (outside RNP) because of the perennial irrigation reservoir in the latter area. Unfortunately, this route is now closed because of the development of the intervening area as a sugar plantation. Thus, it is interesting to study the distribution of the elephants in the component reserves of the YPC during the wet season.

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