J. South Asian Nat. Hist., ISSN 1022-0828. October, 1999. Vol. 4, No. 2, pp. 203–212, 4 figs., 6 tabs.

The elephant population of the Yala Protected Area Complex, Sri Lanka, estimated by the dung count method

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Abstract

The elephant population of the Yala Protected Area Complex (YPC) was studied by indirect dung count method. The YPC consists of one Strict Natural Reserve, two National Parks (NP) and three sanctuaries, and occupies an area of 1,518 km^2. The elephant densities in different habitats were estimated using the dung pile densities in belt transects and plots. Twelve distinct habitats were recognised. The highest density occurred in grass-scrub (1.03 km^{-2}) and the lowest in the riparian forest (0.08 km^{-2}). No dung piles were found in the moist semi-evergreen forest, which, however formed only a small part (about 2.2% by area) of the complex. The average elephant density of the entire YPC is estimated to be 0.51 km^{-2}. The component reserves of the YPC had different elephant densities, the highest observed being in the Block I of the Ruhuna NP (0.80 km^{-2}) and the lowest (0.31 km^{-2}) in the Block IV of the Ruhuna NP, the differences being attributable to their different habitats. The recent translocation of a large group of elephants may have increased the elephant density of the YPC to 0.66 km^{-2}. When the habitat differences are not taken into account, the study indicated a higher density of 0.61 km^{-2} than when the particular habitats were treated separately (0.51 km^{-2}).

Introduction

The Asiatic elephant, wherever it naturally occurs, is considered to be endangered (IUCN, 1996). In Sri Lanka it occurs largely in protected areas but moves also into cultivated lands and rural villages, and is hence prone to intense conflict with man. In view of the level of conflict showing no signs of abating, the Yala Protected Area Complex (YPC) could become one of the few future refuges of wild elephants of Sri Lanka.

The YPC, situated in south-eastern Sri Lanka (Fig. 1), has an extent of 1,518 km^2. It consists of one Strict Natural Reserve (Yala SNR), two National Parks (Ruhuna NP and Yala East NP) and three Sanctuaries (Kataragama SA, Katagamuwa SA and Kudumbigala SA).

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 (McKay, 1973; Barnes & Jensen, 1987; Sukumar, 1989; Dekker et al., 1991; Dawson, 1993; Hendavitharana et al., 1994; de Silva et al, 1995).

Direct visual count methods along transects or in plots are impractical in the Sri Lankan situation because of poor visibility in scrub and forest habitats and the natural shyness of these animals. Although such counts are possible in grassland habitats, these form only a small part of the total habitat of YPC. The indirect dung count method was therefore used in the present study.

Several authors have reported on the large mammal species, including elephants, of Ruhuna NP, especially its Block I (McKay, 1973; Kurt, 1974; Santiapillai et al., 1984; de Silva, et al., 1995, 1997). The present study is the first to deal with the elephant population of the entire YPC and is perhaps the first estimation of elephants by dung count method in an area in Sri Lanka.

Study area and habitats

The major types of natural forest present in the YPC are (a) tropical thorn forest, (b) dry evergreen forest, (c) moist deciduous forest, and (d) moist semi-evergreen forest (Anon., 1988). The development of distinct forest types (see Table 1) appears to depend largely on the quantum and spatial distribution of rainfall.

The YPC area has a known history of about 2,500 years, during most of which (especially between the 5th and 12th centuries) it has supported a flourishing agriculture, particularly of rice. It had an extensive irrigation system, including reservoirs and canals. The present vegetation is therefore essentially secondary, having developed during the last five centuries (this is especially true of the moist deciduous forest). Irrigation reservoirs of various sizes, many of them dilapidated, are scattered throughout the YPC: grassy-scrub vegetation has developed in these, while the former paddy (rice) fields have given way to grasslands.

The major habitat types of YPC are described below.

Tropical thorn forest (TT). The tropical thorn forest is a low-stature, open, thorny scrub with isolated trees or groups of trees. The thorny scrub usually does not exceed 5 m in height while isolated trees and tree-groups reach heights of about 12 m. There are relatively extensive grasslands containing short grass interspersed with the thorn forest especially in the coastal area. This forest type occurs in the western part and the coastal area of RNP-Block I.

Dry evergreen forest (DE). The dry evergreen forest is of medium stature, with emergents, the undergrowth being thick with shrubs and herbs wherever the canopy is relatively open. The main canopy species, *Drypetes sepiaria,* reaches 12 m, while the main emergent species, *Manilkara hexandra,* grows to about 20 m. Small trees and shrubs form the understory. This forest type is the principal component of YPC (Table 1).

Moist deciduous forest (MD). This is medium to high-stature forest with emergents, with a canopy about 20 m high. A significant extent of the Blocks III, IV and V of the RNP is occupied by this forest type. Emergents rise to about 3-5 m above the canopy, and comprise of both deciduous and evergreen species. The main canopy consists of evergreen species. Because of greater sunlight penetration through the main canopy, the shrub layer is usually well grown. Most shrub species are deciduous or thorny, the forest often being difficult to penetrate.

Moist semi-evergreen forest (MS). This is also medium to high-stature forest with emergents. In this habitat, there is little undergrowth, but a thick layer of leaf litter is present on the ground. The crowns of trees often interlock each other, albeit with frequent gaps. This habitat occurs in the northern part of Block IV, which lies almost at the border of the intermediate eco-climatic zone (Anonymous, 1988). The dominant tree species are different from those of the MD forest.

Müeller-Dombois (1968) recognised 25 terrestrial, physiognomic habitat types in RNP-Blocks I, II and

Table 1. The extent of the different components of the YPC and the distribution of the four forest types in each. (Grasslands are not taken into account.)

Component	Extent (ha)	Forest Type (%)			
		Tropical thorn	Dry evergreen	Moist deciduous	Moist semi-evergreen
Yala SNR	28,905		»100		
RNP	97,881				
Block I	14,101	>65	<35		
Block II	9,931	<10	>90		
Block III	40,775		<40	>60	
Block IV	26,418			>85	<15
Block V	6,656			>90	<10
Yala East NP	18,748				
Block I	885		»100		
Block II	17,863		»100		
Katagamuwa SA	1,004		»100		
Kataragama SA	838		»100		
Kudumbigala SA	4,403		»100		
Total	151,779				

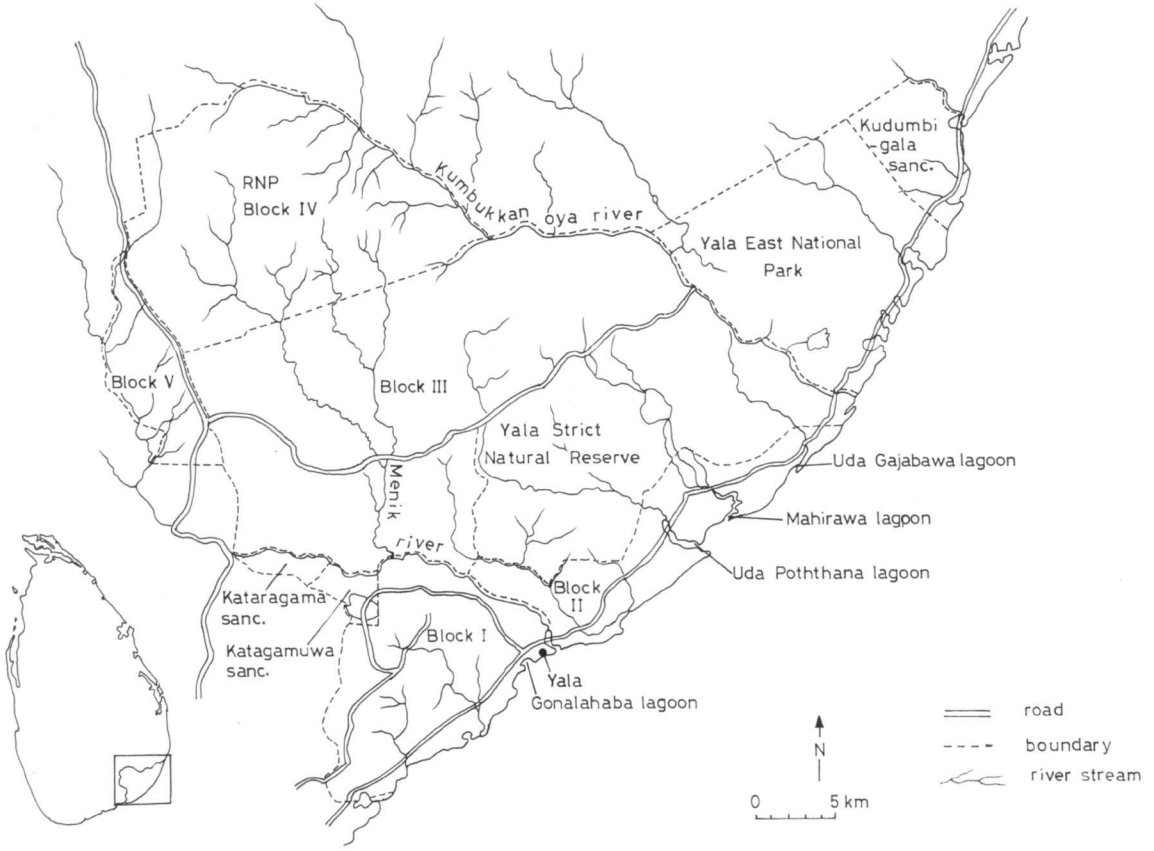

Figure 1. Yala Protected Area complex.

III (Blocks IV and V were not at that time annexed to RNP), viz.,

Forest cover types

1. Low to medium-stature forest with scattered emergents - f
2. High-stature forest along almost permanent streams (alluvial forest) - af
3. Discontinuous low to medium-stature forest with scattered emergents - df
4. Forest-scrub - fs
5. Discontinuous forest-scrub - dfs
6. Open forest-scrub - ofs
7. Forest-scrub islands - (fs)

Scrub cover types

8. Scrub - s
9. Scrub with scattered trees - s(t)
10. Discontinuous scrub - ds
11. Discontinuous scrub with scattered trees - ds(t)
12. Open scrub - os
13. Open scrub with scattered trees - os(t)
14. Scrub islands - (s)

Herbaceous cover types

15. Short-grass cover - g
16. Short-grass cover with scrub islands - g(s)
17. Short-grass cover with forest-scrub islands - g(fs)
18. Short-grass cover with scattered trees - g(t)
19. Short-grass cover with scrub islands and scattered trees - g(s,t)
20. Short-grass cover with sections of sparse cover near water - g(w)
21. Sparse herbaceous and suffrutescent cover - r
22. Sparse herbaceous cover with forest-scrub islands - r(fs)
23. Sparse herbaceous and suffrutescent cover in beach and dune areas - b
24. Similar to 23 but with scrub islands - b(s)
25. Similar to 24 but with trees or even forests - b(fs)

The vegetation of YPC is mostly a mosaic of small areas of physiognomic types, some minor types occurring in small patches within a larger area of a major type. It is not practicable to evaluate the importance of such small patches of habitat for a large herbivore such as the elephant by the dung count

Table 2. Major habitats studied in YPC.

Habitats	Forest type	Physiognomic types of Mueller-Dombois (1968)
1. Moist Semi-evergreen forest	MS	
2. Moist Deciduous forest	MD	f, df
3. Dry Evergreen forest	DE	f, df
4. Thorn scrub (TS)	TT	ds, dst, os, os(t), s(t), s
5. Riparian forest (RF)	MD, DE	af
6. Forest-scrub (FS)	MD, DE	fs, (fs)
7. Degraded forest (Abandoned chena) (AC)	DE	
8. Open scrub (OS)	MD, DE	dfs, ofs, os, os(t), s(t), s
9. Grass cover with scattered scrub (GS)	DE	g(s), g(fs), os, os(t), (s)
10. Grassland with scattered trees (GT)	TT	g, g(s,t), g(t)
11. Seasonally submerged grass cover (GC)	DE	g(w)
12. Sand-dunes (SD)	TT	b, b(s), b(fs)

method. Thus, in the present study the major physiognomic habitat types described below were recognised in YPC among the four kinds of forest. Each of these habitat types may include one or more of the physiognomic categories recognised by Müeller-Dombois (1968) (Table 2).

The first four types of habitats are as described earlier.

Riparian forest (RF) (in MD, DE and TT). This is the riparian gallery forest habitat with a preponderance of evergreens found in association with Menik and Kumbukkan Rivers. This habitat is composed of discontinuous medium to high-stature forest with tree crowns interlocking or touching. There is little penetration of sunlight through the canopy and therefore little undergrowth; the ground is covered with a thick layer of leaf litter.

Forest-Scrub (FS) (in MD and DE). This widely-distributed habitat is composed of small patches of closed forests in a scrub matrix, sometimes with scattered trees in the scrub. Occasional tall trees sometimes reach 30 m in height. The composition varies according to the area (type of forest) with which it is associated, but the differences lie more in the relative abundance of various species than in the actual species present.

Degraded forest (Abandoned chena) (AC) (in MD and MS). This type of habitat is commonly seen in RNP-Block V towards the Menik river in areas in which chena (shifting) cultivation has been practised until recently. The area before disturbance contained MD and MS forests and signs of this still persist in the form of tall trees. The vegetation is mainly in the form of scattered scrubs and herbs with interspersed forest patches.

Open scrub (OS). This is scrub habitat with scattered emergent trees and intermixed grass cover and herbs. The tree species depend on the type of forest with which it is associated.

Grass-scrub (GS). These are grassy areas interspersed with islands of shrubs and individual trees. The tree species depend on the forest with which it is associated, as in open-scrub. These grasslands are often invaded by weeds.

Grassland with scattered trees (GT). This short grass habitat is found closer to the sea in Blocks I and II. Trees, shrubs and herbs are present scattered in the habitat.

Seasonally submerged grass cover (GC). This type of habitat is found mainly in Block II where the Menik River and streams (Katupila Ara, Agara Ara, Kurunde Ara) inundate the low lying areas during the main rainy season. The grassy plains are mainly ancient paddy fields. In Block I, this type of habitat is found in small, low-lying, periodically inundated, grassy areas associated with the reservoirs such as Vilapala Wewa, Digan Wala, Koma Wewa and Kotabendi Wewa.

Sand-dunes (SD). This habitat is found along the coast. In sand-dune habitats, only about 15% of the total area is covered by vegetation, the rest consisting of exposed sand. The vegetation is mainly shrubby in the dunes proper and herbaceous in the beach terrace. The dunes proper contain scattered vegetation as well as vegetation formed into islands, which vary in size up to about 300 m^2. The shrubs grow to a height of 2–3 m. The shrub vegetation consists of species commonly found in the adjoining forest-scrub area. The tree species and most of the shrub species in the sand dunes are of low stature and some are procumbant; some show stunted growth.

Although mangroves form another distinct habitat in YPC, this habitat is not treated here since it

occupies only very small areas in river estuaries and lagoons and in any event is not an important elephant habitat.

Materials and Methods

Different habitats of the YPC were studied for the presence of dung piles. The study was carried out in June, July and August, 1995, during the dry season (Fig. 2).

Elephant density km^{-2} (d), was estimated as follows:

$$d = \frac{\text{No. of dung piles per km}^2}{\text{No. of days for total decomposition} \times \text{No. of defecations per day}}$$

A total of 43 belt transects of varying length were studied (Fig. 3). The transects that were in habitats other than the sand-dunes were 1.2 to 2.5 km in length. These transects were placed in different habitats by studying aerial photographs. Transect width varied according to visibility within each habitat. In the forest habitats of TT forest, MD forest, DE forest and MS forest, 4 m wide belt transects were applied, whereas in other more open habitats (Riparian forest, Forest-scrub and Degraded forest) 6 m belt transects were studied. In Open scrub, Grass-scrub, Grassland with scattered trees and seasonally submerged grass-cover transects of 8 m width were studied. Because of the high visibility in sand-dunes, transect width was increased to 10 m (the sand-dune field in the Gonalahaba-Yala area was selected for the study). In this habitat, six equidistant transects were placed, the position of the first being selected randomly. The number of transects in this habitat was increased because of their shorter length. The transects were placed perpendicular to the shoreline, extending from the beach scarp to the most distal dune, and had a length varying from 147 to 255 m.

Also, along each transect (except in sand-dunes), approximately at 100 m intervals, plots of 10 m X 10 m were studied for the presence of dung piles. This was because, the dung piles/pellet groups of the other herbivores were studied in these plots, the dung piles of elephants being counted simultaneously. In the sand-dune habitat, fifty 10 m × 10 m random plots were studied.

A sufficient number of one-day old dung piles for analysis was not found in the individual habitats and therefore all dung piles (of all ages) were counted. Since the study was carried out within a single dry season, it was assumed that the dung piles would remain for approximately the same number of days in different habitats.

The rates of decomposition of 25 dung piles were monitored in the grassland and grass-scrub habitats in Blocks I and II. The average time taken for total decomposition from Stage I to Stage V was 39.7 (Standard Error 1.0) days. Different stages recognised were according to Dekker et al. (1991), and are as follows: Stage I-fresh dung; II-all boli intact; IIIa-less than half the boli broken up, IIIb-more than half the boli broken up, IV-all boli broken up to amorphous mass; V-traces of dung pile barely visible. Thus, the time taken for total decomposition was assumed to

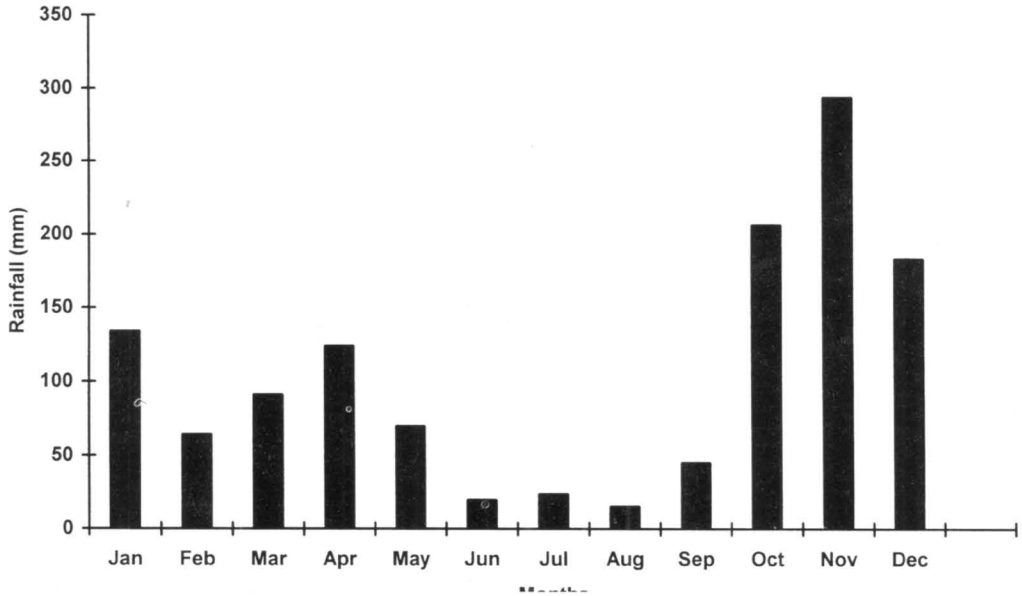

Figure 2. The average of the mean monthly rainfall at different locations (Palatupana, Kataragama, Okkampitiya, Panama) around YPC of the 15 year period of 1980 to 1994. The locations of rainfall stations are shown in Fig. 1.

Table 3. Estimated number and density of elephants in different habitats of YPC (except Yala East NP and Kudumbigala SA) as estimated by indirect dung count method.

Habitat	No. of dung piles	Extent of area studied (ha)	Total area in YPC (ha)	Elephant density (km^{-2})	No. of elephants
Semi-evergreen Forest	0	1.75	3,329	0.00	0.00
Deciduous Forest	4	3.18	31,184	0.21	65.5
Evergreen Forest	9	3.49	29,138	0.42	122.4
Riparian Forest	1	1.99	2,480	0.08	2.0
Thorn-Scrub	12	2.17	4,213	0.91	38.3
Forest-Scrub	31	7.31	23,652	0.70	165.6
Degraded Forest (Abandoned Chena)	6	2.99	2,955	0.33	9.8
Open-Scrub	23	6.54	14,737	0.58	85.5
Grass-Scrub	19	3.03	10,943	1.03	112.7
Grassland	30	5.34	3,960	0.92	36.4
Seasonally submerged Grass cover	16	3.67	1,165	0.72	8.4
Sand-dunes	18	1.44	872	1.02	8.9
Total	169	42.90	128,628	0.51	655.5

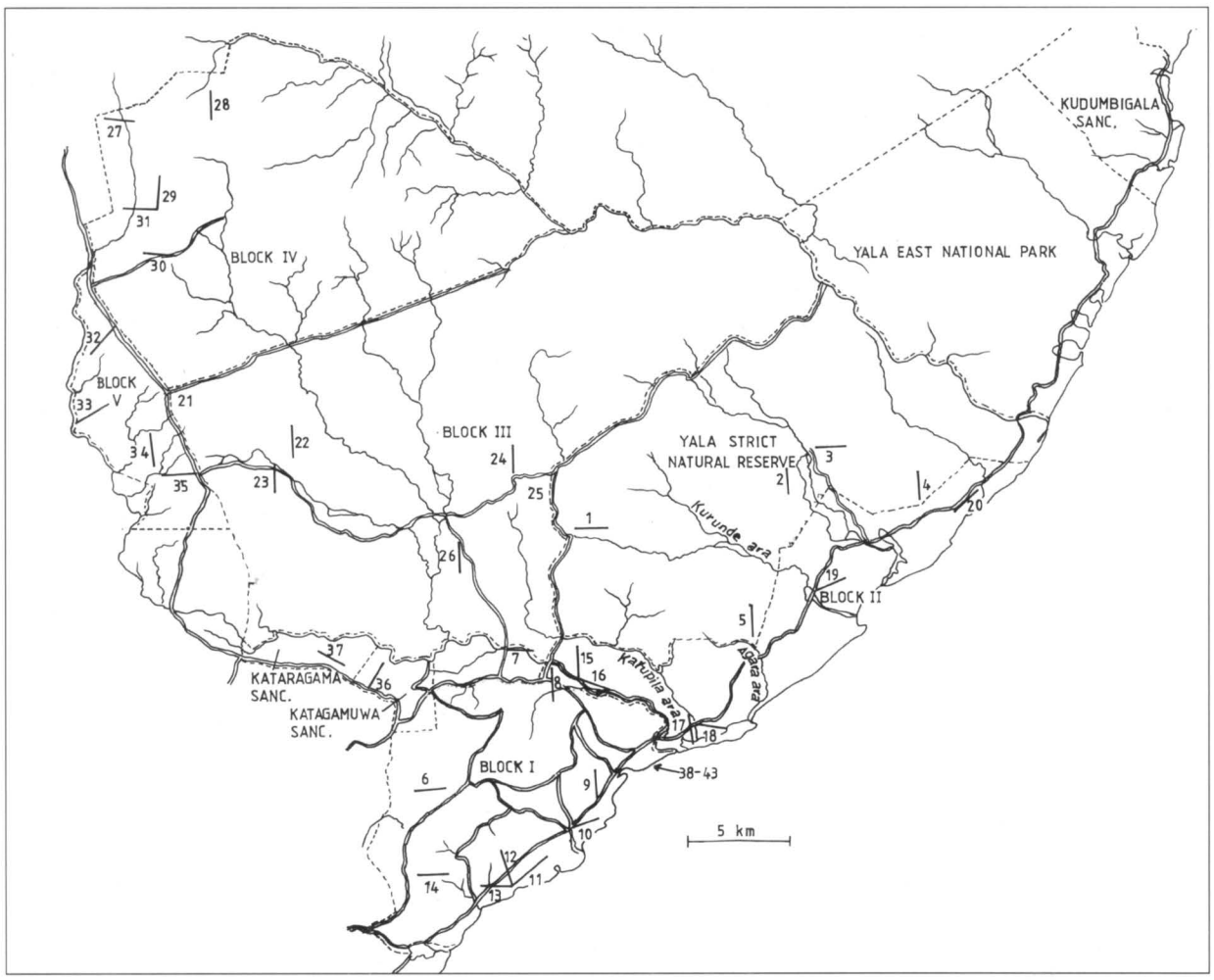

Figure 3. The location of transects (1-43) studied in the in the YPC.

be 39.7 days in all habitats except in sand-dunes. In sand-dunes, although one-day old dung piles (Stage I) could not be found, the time taken for decomposition from Stage II to Stage IIIa, Stage IIIa to Stage IIIb, and Stage IIIb to Stage IV were estimated. These indicated that the time taken for total decomposition (Stage I to Stage V) could be 80 days or more. Thus, 80.0 days was taken as the time for total decomposition in this habitat, although this could be higher. It was noted that there was no activity of macro-dung decomposition agents such as dung-beetles, earthworms and termites, beetle and other dung larvae in the sand-dunes, although activities of such agents were observed in other habitats.

Proper defecation rates could not be estimated in the present study, as animals could not be observed in the night. The daytime observations (0600 to 1830 hours) indicated that the time interval between two defecations is 94.1 minutes (Standard Error 3.1, n=52). This gives the defecation rate as 15.3 per 24 hours. Vancuylenberg (1977) on data collected from 37 wild elephants in Gal Oya area (situated to the north of YPC) in the dry zone found that an elephant defecates 12 to 18 (modally 15) times a day. His data indicate a defecation rate of 15.09 (Standard Error 1.89) per 24 hours. From faeces distribution surveys and observations on a captured elephant he found that defecation rates differ in the morning hours and in the night. On the other hand, in the Mudumalai Wildlife Sanctuary (MWS) of southern India a defecation rate of 13.133 per day was estimated by Dawson (1990) (see Dekker, et al., 1991). (Dawson (1993) used the same defecation rate as an approximation in her study of elephants in Tabin Wildlife Reserve, Malaysia.) Desai (pers. comm.) found the defecation rate in the elephants in the MWS (at a different time) to be 15.08 per day. Varman et al. (1955) used a defecation rate of 16.33 per day in their work in MWS. Thus, 15.3 times a day was used in the present study as the defecation rate in estimating the elephant densities.

Yala East National Park and the Kudumbigala sanctuary were not studied because of the uncertain security situation in these areas. Therefore, the study was restricted to Yala SNR, Ruhuna NP and Katagamuwa and Kataragama sanctuaries.

Results

Dung piles were not found in the Semi-evergreen Forest habitat. However, this habitat formed only about 2.2% of the total area of the YPC. Of the other eleven habitat types, the highest elephant density occurred in grass-scrub and the lowest in the riparian forest (Table 3). The high density observed in sand dunes could be spurious as the decay of dung in this habitat could take longer than the estimated 80 days. However, since the overall area of the habitat is small, its estimated elephant denisty will not significantly affect the estimated overall elephant densities of the YPC or its components. The total number of elephants in the area studied (YPC excluding Yala East NP and Kudumbigala Sanctuary) was estimated to be 656 and the overall density to be 0.51 km^{-2}.

The densities estimated in different components of the YPC by taking into account the extent of different habitats studied in each component are given in Table 4.

Since the habitats of the Yala East National Park (187.48 km^2) and Kudumbigala Sanctuaries (44.03 km^2) are broadly similar to those of the Yala SNR, it is reasonable to assume that the overall elephant density in Yala SNR (0.61 km^{-2}) holds approximately for these two protected areas as well. Thus, it can be estimated that 141 elephants occur in both Yala East NP and Kudumbigala SA. Therefore, there could be about 797 elephants in the entire YPC (an average density of 0.53 km^{-2}).

Table 4. The average number and density of elephants in different components of the YPC as estimated from the densities of different habitats.

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

If the habitat differences (except the sand-dunes) are not taken into account then the number of elephants in the entire YPC (including Yala East NP and Kudumbigala SA) works out to be 926, an average density of 0.61 km^{-2}.

Among the dung piles recorded from transects of all habitats, there were only 4 fresh (less than 24-hours old) dung piles. If 15.3 is taken as the average defecation rate per 24 hours, then the number of elephants in the area studied works out to be 785, an average density of 0.61 km^{-2}. This is higher than the density estimated by counting all dung piles and taking the time taken for total dung decomposition as 39.7 days. However, if the number of fresh dung piles were 3, then the density would be only 0.46 km^{-2}

and if the number of fresh dung piles were 5, then the density would be 0.76 km^{-2}. This shows that if only the fresh dung piles are taken into account, then to obtain a reliable estimate of the elephant density, the sampling intensity should be much higher than that used in the present study (42.90 ha) and probably in the range of over 10 km^2 (1,000 ha).

Discussion

The accuracy of density estimates by the dung count method depends on 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). Mean dung decomposition rates, on the other hand, can vary over a much wider and a numerically higher range (e.g. 40–80 days).

Defecation rates should be estimated by observing the wild elephants while they feed and move in their natural habitat, a task which is difficult to carry out in most Sri Lankan habitats, especially at night. 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, principally environmental conditions, which could determine the activity of dung decomposition agents such as the 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. The drought conditions with high temperatures may reduce the decomposition process, even reducing the activity of micro-organisms. Dawson (1993) found that for the total decomposition of elephant dung during the dry season in Tabin Wildlife Reserve in Malaysia it took, on the average, 140.84 days and that there was a total absence of the activity of macro-decomposing agents such as dung beetles and termites. It was also observed that in sand-dunes of the YPC, the total decomposition may take more than 80 days and that the macro-decomposing organisms such as beetles, termites, beetle and other dung larvae were not present. On the other hand, during the main rainy season (October to January) a dung pile in YPC may disappear in as little time as a week (heavy rains tend to erode and disintegrate dung pellets; this also accelerates decomposition). Heavy rain especially affects 'amorphous-mass' dung piles (Stage D). Dawson (1990 in Dekker, 1991) estimated that in Mudumalai Wildlife Sanctuary (MWS) in southern India, it takes 78.74 days on average for total decomposition of elephant dung (an average decomposition rate of 0.0127). Desai (pers. comm.) notes that elephant dung decomposition rate in MWS (at a different time) was 0.0175 (i.e. it took 57.14 days on average for total decomposition). On the other hand, Varman et al. (1995) found that the time taken for total dung decomposition in MWS could vary from 5 days to 273 days with an average of 103.1 days (i.e. an average decomposition rate of 0.0097 day^{-1}).

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

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 should be equal to the number of dung piles disappearing the same day. Also, 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 time as possible within one season.

Usually, when estimating dung densities, the perpendicular distances from the dung pile to the centre of transect are measured and the effective width of the transect calculated subsequently. However, in the present study, transects of constant width were used.

The density of elephants estimated in the present study is higher than that estimated by several other authors for the RNP and other protected areas of Sri Lanka (Table 5). The estimated densities for RNP by these authors are for the Block I except that of McKay (1973), which is for both Blocks I and II. The densities estimated during the present study for Blocks I and II are higher (0.80 and 0.70 km^{-2}, respectively, Table 4). It must be noted that the other authors estimated elephant densities by visual counts, and the densities obtained are minimum densities. Santiapillai & Jackson (1990) give the elephant population in both Ruhuna NP (perhaps they mean YPC) and the nearby Pelwatta area as a minimum of 350 and a maximum of 400 animals.

The average density of 0.51 km^{-2} for YPC estimated in the present study is rather close to the elephant

Table 5. Densities estimated by visual counting of various elephant populations in Sri Lanka. (For comparative purposes, data of a South Indian population are also given.) (GNP-Gal Oya National Park; LNP-Lahugala N.P.; RNP-I,II-Ruhuna N.P.-Block I,II.; WNP-Wilpattu N.P.; WsNP-Wasgamuwa N.P., TMN-Thamankaduwa area). (*area surveyed was not defined)

Area	Number	Crude density (km^{-2})	Study period	Authority
GNP	310	0.19	67-69	1
	230	*	75-76	2
LNP	150	*	67-69	1
RNP-I	89	0.64	68-69	3
	21.6	0.15	78-80	4
	75	0.54	91-93	5
	85	0.61	93	6
RNP-I & II	150	0.63	67-69	1
TMN	213	0.16	68-71	7
WNP	70	0.12	68-69	8
WsNP	65.8	*	80-82	9
S. India	260.6	0.56	81-83	10

1. McKay (1973); 2. Ishwaran (1981); 3. Kurt (1974); 4. Santiapillai, et al. (1984); 5. de Silva, et al. (1995); 6. Hendavitharana, et al. (1994); 7. Nettasinghe (1973); 8. Eisenberg & Lockhart (1972); 9. Ishwaran (1993); 10. Sukumar (1989).

Table 6. The numbers of elephants present in the various components of the YPC according to the 1993 survey and present work. (n.s.-not surveyed)

Component	1993 Survey		Present work
	Hendavitharana *et al.* (minimum no.)	de Silva (unpubl.) (probable no.)	
Yala SNR	n.s.		165
Block I	89	118	105
Block II	0	16	67
Block III	19	29	199
Block IV	18	70	85
Block V	0	8	31
Kataragama	3	20	5
Katagamuwa	1	4	7
Total	130	265	664

density of 0.56 km^{-2} estimated for the southern Indian population by Sukumar (1989) (Table 5), despite the habitat differences.

In the survey carried out in 1993 by the DWC by visual counting, the *minimum* number of elephants in the parts of YPC surveyed was found to be 130 (Hendavitharana, et al., 1994); however, reviewing the original data indicated that the number of elephants sighted could have been as high as 265 (Table 6). Only the readily accessible areas of the various components of the YPC were subjected to the 1993 survey.

Dawson (1993) using the indirect dung count method found that the overall elephant density in the Tabin Wildlife Reserve in Malaysia was 0.26-0.36 km^{-2} with a mean density of 0.30 km^{-2}. She found the elephant densities to vary in different parts of the reserve and recognised areas of high use, moderate use and low use. These areas had densities of 0.87 km^{-2} (range 0.80-0.96), 0.44 km^{-2} (0.37-0.51) and 0.17 km^{-2} (0.14-0.22), respectively. Varmen et al. (1995) found different elephant densities in different seasons in MWS. They found the elephant densities to be 1.32, 2.58 and 1.30 km^{-2} in Dry, Wet I and Wet II seasons.

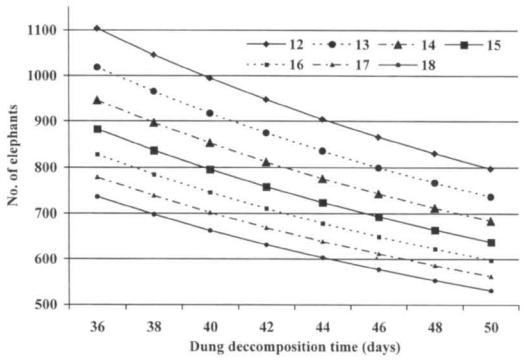

Figure 4. The estimated number of elephants in YPC (including Yala East NP and Kudumbigala Sanctuary - see text) according to different defecation rates (12 to 18 times per day) and dung decomposition times.

The present study shows the importance of determining elephant densities in different habitats separately. Without reference to particular habitats, the study showed a higher density of 0.61 km^{-2} than when the particular habitats are treated separately (0.51 km^{-2}).

The importance of accurate determination of the defecation rate and the decomposition rate in determining the elephant numbers is illustrated in Fig. 4.

In August 1995, a group of elephants that was isolated in the Handapanagala-Pelwatta area (about 15 km to the north-west of the boundary of RNP-Block IV), because of their traditional migratory routes were developed for sugar plantations, was driven to Blocks IV and V of RNP. Most of these elephants came from the RNP itself, and used to move into the Handapanagala-Pelwatta area during the dry season because of the perennial source of water in the reservoir there. Because of the establishment of the sugar factory and plantations protected by electrified fences in between the RNP and the Handapanagala area while the elephants were in the Handapanagala-Pelwatta area, these elephants could not move back to the RNP. The isolated group, which was originally estimated to consist of 155 animals by visual counting, was subsequently reduced to 134 animals by mortalities caused by farmers in crop defence. Although the visual count of the group at the time of the drive was 134 animals, the DWC

officials involved in the drive found that there were 184 animals in the group that they drove to the RNP. Subsequently additional 17 solitary adult males were tranquillised and translocated to RNP making the total number of elephants translocated 201 (N. Atapattu, pers. com.). Thus, the elephant population in YPC must have been increased from 797 (during the time of the present study) to 998 animals (after the translocation). Therefore, the current average crude density of elephant in YPC could be as high as 0.66 km^{-2}. How the translocated animals established themselves within YPC has not been studied, but preliminary observations indicate that they have settled mainly in Blocks III and IV.

Thus the density of elephants in the YPC, especially in the RNP, is high in comparison to the estimates by dung-count method in other reserves such as the Tabin Wildlife Reserve in Malaysia (Dawson, 1993). The YPC also contains significant numbers of other large herbivores such as the water buffalo (*Bubalus bubalis*), the sambar (*Cervus unicolor*) and the spotted deer (*Axis axis*). Thus, a question posed by many conservationists is whether the herbivore carrying capacity of the YPC, especially that of the RNP, has already been exceeded.

Acknowledgements

I am thankful to the former Directors of the Department of Wildlife Conservation of Sri Lanka, Messrs W.A. Jayasinghe and C.P. Attanayake, for granting permission to carry out this work, and to Messrs B.A. Muthubanda (former Park Warden of the Ruhuna National Park), B.V.R. Jayaratne (former Deputy Park Warden of Ruhuna National Park) and W. A. Sarath, (former Wildlife Ranger, Moneragala) for their help during the study. Thanks are also due to various Wildlife Guards, especially Wimal Kodituwakku who accompanied my team to different areas of YPC and helped us in many ways during the study. I am very grateful to John F. Eisenberg of Florida Museum of Natural History, University of Florida, and Hans Kruuk of Institute of Terrestrial Ecology, Scotland, for reading the manuscript carefully and suggesting valuable improvements. Thanks are also due to T.S.B. Alagoda of Dept. of Zoology, University of Peradeniya, for drawing the figures.

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