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Status of the Asian Elephant Population in Mudumalai Wildlife Sanctuary, Southern India

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Introduction

The elephant population in Mudumalai Wildlife Sanctuary has been estimated using various methods in the past. Total count method was used extensively by the Forest Department from the 1970 until 1980. Ratio method based on individually identified elephants was used by Daniel *et al*. (1987). In addition, line transect indirect method (dung count) was tested by Dawson (1990) and direct sighting method by Varman & Sukumar (1995). The Tamil Nadu Forest Department has been using the line transect (direct count) method to estimate the population of larger mammals since 1995. However, these efforts have been hampered by lack of equipment and trained personnel needed to ensure precision of measurements.

The results of these studies have varied widely and it is difficult for the managers to make realistic use of these widely varying figures. Additionally, focusing largely on estimating the elephant densities alone, recent studies have failed to account for other important aspects of elephant population demography like the age structure, sex ratio, etc. There has also been no attempt to compare the past and present population density or the age structure and sex ratio of the elephant population. Knowledge of the age structure of population is essential for investigating trends in recruitment, mortality and reproductive status of the population (Lindeque 1991; Stearns 1992). Needless to say that estimating elephant densities with reasonable accuracy and precision is the very first step in this direction, which is merely a gathering of data. Interpreting the results beyond this point has more implications for management.

The present study was done primarily to address this shortcoming. Taking the baseline study done in the mid-1980 (Daniel *et al*. 1987) as a starting point, the present study attempts to record the cumulative changes that have taken place in the elephant population in Mudumalai Wildlife Sanctuary over the past 12 years. The study by Daniel *et al*. (1987) used a reasonably accurate but time-consuming method of estimating the population using the ratio between known and unknown elephants encountered during the study. Elephants were individually identified using natural markings like tusk/tush size and shape, cuts and holes in the ears and tail length and hair pattern (Douglas-Hamilton 1972). The differences in the methods used to estimate population, minor differences in the area sampled and the inability to attribute absolute accuracy and the precision to the past and the present density estimates rule out estimating absolute changes in the densities. However, considering the time interval between the two studies and also management requirements of knowing gross changes and trends in the population, the present comparison and results should be more than adequate for management purposes. The limitations, as can be expected in any study, have been highlighted in the beginning itself not to detract from the merits of the study but to ensure that readers' focus and debate are channelled towards management implications of the results rather than remaining fixed totally and unproductively on the academic merits of the study. The study was carried out between January 1999 and February 2000 with three major objectives of estimating population density, the age–sex structure and determining the accumulated changes in the population over the past 12 years using the earlier study (Daniel *et al*. 1987) as baseline.

Methods

Study area

The study area, Mudumalai Wildlife Sanctuary, is located at the tri-junction of three southern states of India, namely Tamil Nadu, Karnataka and Kerala (Fig. 1). It lies between 11º 32' and 11º 45' N and 76º 20' and 76º 45' E and is a part of the Nilgiri Biosphere Reserve. The sanctuary is spread over 321 km^2 and bounded to the north by Bandipur Tiger Reserve and to the west by Wayanad Wildlife Sanctuary and to the south and east by Nilgiri North Forest Division. Mudumalai Wildlife Sanctuary is a part of Elephant Range 7, which is one of the 11 elephant ranges, declared by the Project Elephant, Govt. of India (Project Elephant: *Gajatme* 1993). This range extends over 12,900 km^2 of forest in the Western and Eastern Ghats. It has tenuous link with Elephant Range 8, which covers an area of 2385 km^2 and there is movement of elephants between Elephant Ranges 7 and 8 (Baskaran *et al*. 1995). These Ranges together cover an area of 15,000 km^2 and support a population of 8572 elephants (Project Elephant 2005). The large contiguous area and the large elephant population together represent the largest single Asian elephant population in Asia.

Population size

The elephant population density was estimated using the line transect method (Burnham *et al.* 1980). Mudumalai Wildlife Sanctuary has fairly good visibility and high elephant density that makes line transect a suitable method. Sampling was done using randomly located transects as follows. First, 2 2-km grid overlaid on 1:50,000 topographic maps of Mudumalai Sanctuary; all the grids were numbered. A total of 58 grids (blocks) were selected using systematic random sampling method. Within the selected grid, a transect of 2 km length was randomly laid but were aligned to ensure that they ran across altitudinal gradients or drainage patterns. Out of 58 transects, 50 were covered twice and eight were covered thrice (with one covered partially (1 km) in one of the survey). On transects, whenever elephants were sighted, sighting angle (using a compass), sighting distance (using a range finder), group size and age–sex classification were recorded.



Figure 1. Map showing the Mudumalai Wildlife Sanctuary (study area) and its adjoining forest divisions in different states of southern India.

Mean group (cluster) size (G) and its SE was estimated based on data where complete counts of individuals were obtained on transects. Grouping the data into 20 m perpendicular intervals, elephant cluster density (C) and its SE was estimated using the "*Fourier Series Estimator*" implemented in *'Transect'* programme. Individual elephant density (D) was arrived at by multiplying the mean group size (G) by the elephant cluster density (C). Standard error of individual elephant density (seD) was calculated using standard error of cluster density (seC) and standard error of mean group size (seG) using Goodman's (1960) formula: (seD) = C (seG) + G (seC) – (seC) (seG) and used the same to workout the 95% confidence limit of individual elephant density.

Population structure

In addition to data gathered during the transect work, data on age–sex structure of the population was gathered on an *ad hoc* basis whenever elephants were encountered in the study area. Elephants were classed into four age classes, i.e., calf (<1-year old), juvenile (>1 year to 5 years), sub-adult (for females > 5 years to <16 years and for males >5 years to 20 years) and adults (for females ≥16 years and for males ≥20 years).

The differentially structured age groups for male and female were adopted to allow comparison with the earlier study (Daniel *et al.* 1987), which used these criteria. During the 1985–1987 period females of 16 years and above were breeding, while males below 20 years (even though sexually mature) were being excluded from breeding by the older bulls. Currently, the lack of older bulls (due to selective poaching) allows the younger bulls to breed. Applying the old criteria may not represent the effective sex ratio but we feel that given the gross negative trend in the sex ratios, the marginal change of a corrected age classification would not bring any change in the outcome.

Sex classification was simple in the adult and sub-adult age classes as males have tusks (Fig. 2), which are clearly visible in these age classes. However, a small percentage of males (*makhnas*) do not have tusks but their identification (especially older sub-adults and adults) is fairly easy considering characteristic features such as the presence of penis sheath and the bulge of the penis below the anal region (in older males), slanting back, broad musculature of trunk base and the social context of the individual (a sub-adult or adult solitary elephant without tusks was suspected to be a *makhna* and an effort was made to confirm this). Though younger sub-adults may pose some problems, proper observations allow their identification. In the case of juveniles, differentiating a *makhna* from a female at this stage was not always possible, as the younger animals are short and the presence of tall grass makes identification a difficult task in some areas. In the case of calves, sex identification is very difficult (can be done only when the calf is clearly visible while urinating) and thus sex ratio was assumed as 1:1 for calves.



Figure 2. An adult bull in musth at Mudumalai.

Data was used for the analysis only when the entire herd could be classified into different age-sex categories. Solitary animals and herds were encountered on 142 occasions and data on the age structure could be obtained for all herd members only in 112 cases. The other 30 cases, where data on age structure could be obtained only for partial herd members were excluded from the analysis. However, a comparison made between the age structure estimated with and without them showed no significant difference between the two estimates indicating that the eliminated 30 cases are very similar to the 112 cases retained for the analysis. In the 112 cases, a total of 586 elephants were classified into the different age classes. All adults seen were classified and out of a total of 141 sub-adults recorded, the sex of only four individuals could not be determined. Sexing juveniles was difficult; especially those below two years of age, and 11% of the juveniles that could not be classified into sex classes were excluded from the analysis.

Results and discussion

Population size

From 247 km of walking along 58 line transects, 25 groups of elephants were recorded and the estimated results are presented in Table 1. The coefficient of variation estimated for the cluster density is 25% and this indicates that greater sampling effort would be needed to derive a more precise estimate. Taking the estimated cluster density of 0.45 (± SE 0.11) per km^2 and the mean group size of 5.32 (± SE 0.37) elephants, population estimated for Mudumalai Wildlife Sanctuary (area = 321km^2) is 768 (95% lower and upper confidence interval = 536–1001). The

Table 1. Population density (elephants/km^2) estimated based on line-transects in 1999–2000.

Parameter	Density	SE	95% CI	
			lower	upper
Cluster	0.450	0.113	0.229	0.671
Individual	2.39	0.723	1.67	3.12

present estimate (2.39 elephants/km^2) is much lower than the 3.58 elephants/km^2 estimated by Varman & Sukumar (1995). The study by Varman & Sukumar (1995) covered only part of the Mudumalai Wildlife Sanctuary and also relied more on temporal replicates of a few (5 transects) longer transects unlike the present study that extensively relied on spatial replicates using 58 transects across the Sanctuary with a minimum of two-time sampling of all the transects over a period of one year. The elephant density estimated by the present study is comparable with the density estimated earlier in 1999 by the Forest Department using line transect direct sighting method (2.46 elephants/km^2) using a similar layout of transects as the present study.

This estimate, however, cannot be viewed in isolation, as Mudumalai Wildlife Sanctuary is part of a larger elephant range that includes Elephant Ranges 7 and 8 and covers an area of over 15,000 km^2. Desai (1991) and Baskaran *et al*. (1995) have shown that elephants using Mudumalai Wildlife Sanctuary also range across into Bandipur National Park (Karnataka), Wayanad Wildlife Sanctuary (Kerala) and Nilgiris North Division (Tamil Nadu). Elephants from Mudumalai Wildlife Sanctuary have been shown to have home ranges of over 600 km^2 (Baskaran *et al.* 1995), which is nearly twice the size of Mudumalai Wildlife Sanctuary. Considering these facts, the population estimate should be viewed as an estimate of the average number of elephants using the Mudumalai Wildlife Sanctuary during the sampling period rather than as a fixed resident population.

The present population estimate is much higher than the earlier estimate of approximately 350 elephants (Daniel *et al.* 1987). The earlier study estimated the population size using the ratio method based on the ratio of known (individually identified elephants): unknown elephants in the population (Douglas-Hamilton 1972; Sukumar 1985). Though there is a possibility that the study of Daniel *et al*. (1987) could have underestimated the population to some extent, it is unlikely that there was gross underestimation. While differences in sampling methods and efforts could be responsible for some of the differences in the estimates, they are unlikely to account for such major changes. Therefore, the increase in population indicated by the present study can be considered significant even though the two sampling efforts cannot be compared directly. The earlier study (Daniel *et al.* 1987) had coarsely estimated growth rate at approximately 1~2% per year, despite the heavy male mortality due to poaching. The present population estimate indicates a significant growth over the past 12 years. Data on recruitment and mortality for different age classes could not be gathered in this study and hence it is not possible to ascertain if the present population is still growing. But managers should take into consideration the fact that the population was estimated to be growing even when there was heavy poaching during 1985–87 period (Daniel *et al*. 1987); therefore, it is likely that the current population will also be growing rather than stabilizing or declining.

The effect of male-biased poaching on the overall elephant population size would have been more severe in the initial stages when the sex ratios were closer to even, rather than, when they are heavily skewed in favour of females. For example, in a population of 25 males and 25 females, 20 males need to be killed to bring down the sex ratio from 1:1 to 1:5, but it requires only four additional males to be killed to further reduce the sex ratio from 1:5 to 1:25. With the highly reduced adult male population, the impact of poaching of adult males would not have a significant numerical impact on the elephant population size. Nevertheless, there is reason to believe that the declining sub-adult male population over the past 12 years, where the sex ratio has gone down from 1:1 to 1:2.9 (see below), would still have had an impact on the overall elephant population size. The contribution of adult and sub-adult males to the overall growth of the elephant population size would be limited due to poaching. However, there have been no real checks on the growth of female population

Table 2. Age structure and sex ratio of the elephants during 1985–87 (Daniel *et al*. 1987) and 1999–2000 (present study).

Age class	1985–1987 (n = 1449)		1999–2000 (n = 566)	
	Age structure (%)	Sex ratio (M:F)	Age structure (%)	Sex ratio (M:F)
Adult	39.3	1 : 4.9	41.5	1 : 29.4
Sub-adult	21.1	1 : 1.1	24.1	1 : 2.9
Juvenile	25.8	1 : 0.8	24.9	1 : 1.5
Calf	13.8	1 : 1*	9.5	1 : 1*

* assumed

and this would have contributed to the population growth. All these arguments lend support to the assessment that there is a high probability that the population is growing.

Population structure

Taking into consideration only the age structure of the population, there appears to be very little difference in the overall population age structure between 1985–87 and 1999–2000 (Table 2). However, major changes can be detected when we take into consideration both the age structure and sex ratios (Table 2). Number of males in the adult class is very poor (Fig. 3) and no adult males over 40 years of age were recorded during the study. The adult class has increased from 39.3 to 41.5% in the past 12 years. However, considering that the adult male population has declined from 1: 4.9 (male to female sex ratio) in 1985–87 to 1: 29.4 in 1999–2000, it is evident that the adult class is composed predominantly of females indicating a significant increase in the adult female population. This would be the result of continuous recruitment of sub-adult females into the adult class coupled with low adult female mortality. In the case of males, there would have been reduction of the adult class due to poaching as well as reduced recruitment from the sub-adult class due to the decline in the sub-adult males, which is again due to poaching.

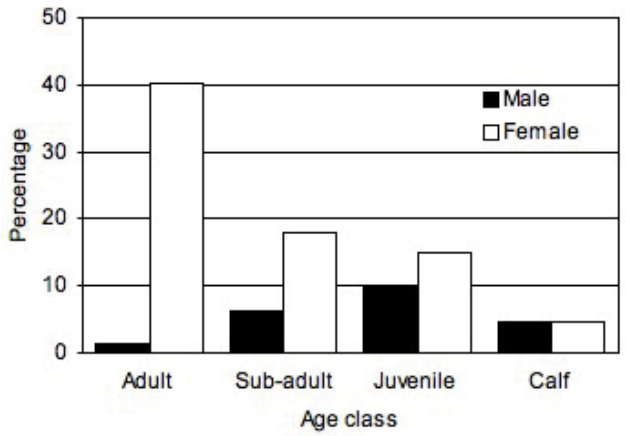


Figure 3. Percentage of various age and sex classes of elephants during 1999–2000.

In the case of sub-adults also, there was an increase from 21.1% in 1985–87 to 24.1% in 1999–2000. Here too, the proportion of males has declined from 1:1.1 recorded in the earlier study to 1:2.9 in the present study. This again indicates a large increase in the sub-adult female population. Additionally this situation also points to an increased recruitment into adult female class in the future. The increased sub-adult population recorded in the present study also indicates that breeding was not hampered in the 80s and early 90s despite the reduction in the adult males.

The juvenile class shows a marginal decline from 25.8% in 1985–87 to 24.9% recorded in the present study. As this class covers a four-year interval (>1 year to 5 years), which is less than the inter-calving interval of 4.7 years recorded in the earlier study (Daniel *et al*. 1987), changes of this magnitude can be natural as a result of variation in the number of females breeding in any given year described below in detail. Without long-term monitoring, it is difficult to attribute these changes to any specific cause. What is however evident is that despite the declining male population, the breeding does not appear to have declined at least until the mid-90s. This could be due to the polygamous nature of the males, which allows them to mate with multiple females. This should not be a reason for complacency as the situation is very serious as far as poaching of males is concerned.

The percentage of calves, though lower than the earlier study, may not be cause for worry, if it is

occurring naturally. The long inter-calving interval in elephants results in only a small and varying percentage of females calving in any given year. A high calving rate in any year is usually followed by lower calving rate in subsequent years, as there will be fewer females remaining to calve in the population (Douglas-Hamilton 1972; Daniel *et al.* 1987). However, reduction in the number of calves can be a cause for serious concern, if it is the result of reduced breeding due to lack of adult bulls. The highly skewed sex ratio in the present study points in this direction. However, a short-term study cannot really pinpoint the cause of lower calf numbers, as there is no data from the previous years for comparison. This highlights the need for systematic and long-term monitoring of elephant populations especially in the light of the adverse condition (poaching and anthropogenic pressures) the population is undergoing. Reduced breeding due to a decline in the male population could result in reduced recruitment into the population in future. Although this may appear to address the problem of growing elephant population, it cannot be considered as a management or conservation tool. The problem of declining male number (due to poaching) and the growing elephant population need to be addressed separately.

The adult male to adult female ratio has deteriorated from 1: 4.9 in 1985–87 to a very poor and alarming 1: 29.4 in 1999–2000. Daniel *et al*. (1987) had recorded a high level of poaching and reported 90% of the adult male and 100% of the sub-adult deaths were caused by humans. There is little doubt that poaching and other human-related causes of deaths are the main reason for the continued decline of the male population. What is even more worrying is the fact that the sex ratio in the sub-adult age class also shows a significant decline from 1: 1.1 in 1985–87 to 1: 2.9 in 1999–2000. This is especially alarming as it indicates that males are being eliminated even before they join the breeding pool. It also points to a very slow recovery of the adult male population in future due to reduced recruitment.

As discussed earlier the sharp deterioration in the adult sex ratios could result from a few adult males being killed. But the change in the sub-adult sex ratios, even though small, would be a consequence of higher level of killings as here the figures deviate from an initial 1: 1.1 ratio to the current 1: 2.9 indicating that large numbers would need to be killed to change the ratio from this level. The juvenile class also shows changes. A part of this could be due to natural reasons (random effect) as the ratio estimated earlier by Daniel *et al*. (1987) was 1: 0.8 in favour of males. Poaching of juvenile males has been recorded earlier on rare occasions but it is largely opportunistic; but the threat of juvenile males becoming targets of poachers cannot be ruled out. Even the marginal money derived from opportunistic poaching of such animals would significantly supplement a poacher's income, especially when larger males are becoming increasingly scarce and difficult to locate.

What is apparent from the analysis is that poaching has adversely affected the male population and now in a male-depleted population even low intensity poaching poses a serious threat to the population of Mudumalai Wildlife Sanctuary and adjoining areas. There is an urgent need to re-assess the status of the elephant population in the Elephant Ranges 7 and 8, not just densities alone but by focusing more on other demographic data that are of greater relevance for future management. These two Elephant Ranges form one of the best in Asia, both in terms of habitat and elephant population and their effective management and conservation should take the highest priority.

Conclusions and recommendations

Mudumalai Wildlife Sanctuary is too small an area to be viewed in isolation, as its elephant population (Fig. 4) is not restricted to the sanctuary. This population is affected by threats within Mudumalai and also from threats well outside the administrative boundary of the sanctuary. Two major issues emerge from the present study: first, the male-biased poaching, which is leading to a skewed sex ratio and the second is that the population is growing while habitat size in the area remains the same or declines due to loss, degradation and fragmentation. Mudumalai Wildlife Sanctuary represents a sub-sample of

the population in the Elephant Range 7; lessons learnt here are also broadly applicable to the Elephant Ranges 7 and 8. Needless to say, that over such large areas conditions and situations will vary and managers should take that into account.

Poaching remains the most urgent and immediate threat. Managers should recognize that elephants range outside their individual PAs due to their large home range sizes and the areas outside the PAs are more vulnerable to poaching because of their poor infrastructures and staff strength. Desai (1991) and Baskaran *et al*. (1995) have highlighted this problem. There is a need for greater focus on and support to these vital but often-neglected areas outside the PAs.

Managers should note that the skewed sex ratio means that very few males remain in the population. Under such circumstances, the poaching of even a single male will have a disproportionately large and adverse impact on the population. Therefore, what is seen as low intensity poaching at this stage still poses a serious threat. Current anti-poaching activities should be sustained and strengthened further.

The lower proportion of calves and juveniles in the population could be cause for worry, if it is due to reduced breeding as a consequence of the highly skewed sex ratio. This vital aspect points to the need for monitoring of all demographic parameters on a systematic basis in the future.

The elephant population of the sanctuary and its adjoining areas has grown significantly, while their habitats remain the same or in reality might have declined in both extent and quality due to anthropogenic pressures. Daniel *et al*. (1987) and Sivaganesan & Sathyanarayana (1995) have noted that elephants (and forest fire) were having an adverse impact on tree species in Mudumalai Wildlife Sanctuary. Daniel *et al*. (1987) suggested that while addressing the immediate threat of poaching, managers should take into consideration the problem of growing elephant populations and their impact on habitats. This aspect has all but been forgotten with all the action being focused on containing poaching. The impact that elephants have on their own habitat and how that in turn affects biodiversity is not clearly known in the Asian situation. The decline in preferred tree species recorded by Sivaganesan & Sathyanarayana (1995) and the recent proliferation of exotic weeds in the elephant habitats point to a worrying future. A study of this aspect is urgent especially, because elephants are keystone species and their overabundance could be more adverse than beneficial. Without a study that produces tangible results to give directions to management on how to deal with local overabundance, the debate can go on endlessly and fruitlessly.

It is not within the scope of this work to suggest management action required to meet this emerging (if not already serious) problem of local overabundance. There is an urgent need for further research, planning and action to tackle it.

There is a need to standardize data collection (on population) using robust methods. Capacity building by training and developing a core team of Forest Department staff and others (NGOs) is essential to systematically monitor elephant populations in the future. There is also a need to monitor the other aspects of elephant population and shift focus from primarily determining the densities.

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Figure 4. An elephant herd having a dust bath in Mudumalai Wildlife Sanctuary.