IV. DISCUSSION

4.1. Age structure

The population dynamics of large herbivores can be strongly affected by a combination of stochastic environmental variations and density-dependent factors (Saether 1997). Food resources, habitat quality, weather, diseases and parasites, interspecific competition, predation, human activities and population density can account for the demographic variation observed among years within a population or across populations of a species (Gaillard et al. 1998). According to Bhima and Bothma (1997), for elephants, a short calving interval, a young age of first parturition, a high rate of increase, low poaching, generally good rainfall for many years and low intra-specific competition due to low densities are characteristics of young and increasing populations. These factors have also been previously noted to be among the most important factors influencing age distribution and numbers (Croze 1972, Corfield 1973, Ottichilo 1986, Poole 1989). According to Barnes et al. (1992) long years of ivory poaching could have both direct and indirect consequences on elephant population age structure, the direct result being the killing of the oldest animals, and the indirect effect being the loss of a whole generation of young animals. The lost generation could be due to the stress from prolonged and intense harassment by poachers. For example, stress could affect the cow's hormonal systems such that ovulation stops or foetus spontaneously abort (Geist 1971). According to Barnes and Kapela (1991) intense poaching not only results in the number of elephants being reduced, but also changes its
age structure, alters grouping pattern and changes gene frequencies. According to Poole (1989) ivory poaching has a fundamental impact upon every aspect of population biology of elephants.

Results of the present study show that the age structure of elephants in all the three populations considered was adult-dominated with the adults constituting at least 30% and even about 40% of the total population. Adult dominated age structures are reported to be characteristic of several other elephant populations also (Eisenberg and Lockart 1972, McKay 1973, Nettasinghe 1973, Iswaran 1981, Santiapillai et al. 1984, Sukumar 1985). According to Katugaha et al. (1999) adult dominated age structure is not unusual for elephants whose life span, gestation period and calving intervals are all extended.

The age structure in Nagarahole seems relatively healthy with a higher percentage of young (calves and juveniles) being recorded in the population and less skewed sex ratios in all age categories. The proportion of adult males in the Nagarahole population is higher than that in Mudumalai and Periyar, reflecting the relatively low pressure from ivory poaching in Nagarahole.

The percentage of adult male elephants is very low (1.6%) in the Mudumalai elephant population. The gradual decline of adult males 30 years or more, and the complete absence of males over 50 years indicate how seriously poaching has affected the adult male segments. Similarly in African elephants, a study by Barnes et al. (1991) showed the clear record of effect of poaching which took place over a period of five years in the Ruaha elephant
The proportion of adult males in the Mudumalai population is lower than that of Nagarahole National Park, even though it is relatively better than the Periyar population. Baskaran and Desai (2000) also found the number of males in the adult age classes to be very poor in Mudumalai during their survey in 2000, and they attributed ivory poaching to be the major cause.

The lower percentage of subadult males compared to females in the Mudumalai population is of concern as it probably indicates poaching even in this age class. The skewness was more marked in the upper age class (10-15 yrs) of subadults with a sex ratio of 1 male to 4 females. Sukumar (1985) also found that from the 5-7-age class onwards there was a sharp reduction in the number of males as a result of higher mortality from poaching in Nilgiri - Eastern Ghats. Therefore poaching has taken its toll from the sub-adult categories onwards. In the study area 25% of the poaching cases were recorded in the sub-adult categories. This is because there are only few adult males in the population and it may be very difficult for poachers to find those few adult males in a large area. So when they come across any males, even subadult males, they tend to poach them. The female segment, however, shows a more stable distribution.

The proportion of juveniles in the population depends on inter-calving interval of the species and the number of calves born in a given year. Therefore, the small variation observed in the percentage of juvenile segment in the present study across the study period could also be due to natural reproductive pattern of the species.
Age structure of Periyar population is not healthy due to the prominent shortage of males when compared to Nagarahole and Mudumalai. Ramakrishnan et al. (1998) stated that the low numbers of calves and juveniles seen at Periyar might be because of insufficient number of males in the population. Alternatively, infant mortality may have been very high, as suggested for the African elephant population of Ruaha, Tanzania (Barnes et al. 1991), but there is no reason or evidence to support this view at Periyar.

4.2. Sex ratio

The sex ratio or proportion of individuals in each sex is another important demographic feature. The importance (to population growth) of the number of males in a population depends upon the breeding system of the population ie., it is less important when a single male mates with many females, and more important when one male mates with one female (Cotgreave and Forseth 2002). McKay (1973) has stated that in such a polygynous, sexually dimorphic species as the elephant, the difference in the adult sex ratios observed in any area might be caused either by mortality incurred during dispersion of the animals or high mortality incurred among males (especially the tusker) from poaching. Some extent of skew in sex ratios may also result from-sex specific differences in the survival rate of elephants in the higher age classes (Jachmann 1980). In Sri Lanka, where most of the male elephants are makhnas (tuskless bulls) the ratio of adult male to female elephants has been reported to be about 1:3 (McKay 1973, Kurt 1974), which may therefore be considered the “natural” sex ratio in the Asian elephant. In
other elephant populations in Asia where males are selectively poached for their tusks, sex ratios are found to be skewed to a greater extent (Menon et al. 1997, Ramakrishnan et al. 1998). Sex ratio of adults cannot be viewed in isolation and it is important that the sex ratios for different age classes are also taken into account (Baskaran and Desai 2000).

The adult sex ratio observed in the Nagarahole population came the closest to the “natural” situation though even this was skewed beyond the normal expectation, indicating that low levels of poaching were operating here for some years. On the other hand, the sex ratios of adult and subadult categories in the Mudumalai and Periyar populations are of great concern. Poaching of adult males for ivory is the major cause for such a skewed sex ratio. A perusal of Forest Department records as well as mortality records of the present study showed that the rate of poaching of sub-adult and adult bulls in Mudumalai is about 2-3 animals per year. Earlier, Daniel et al. (1987) has also shown that the major cause for elephant mortality, especially most male mortality in the Mudumalai Wildlife Sanctuary area during their study was a result of poaching. Baskaran and Desai (2000) have also reported poaching to be a major threat to the elephant population in the Project Elephant Ranges 7 and 8 of India. According to Sukumar et.al. (1998) have the sex ratio in Periyar during the early 1970s was about 1:6 (based on limited data of Kurup 1971, and personal discussions with naturalist M. Krishnan who had observed and photographed several large tuskers here during the 1960s and early 1970s), which is indicative of low levels of poaching until that period. Ramakrishnan et al. (1998) have reported that the ratio of adult male to female in Periyar seemed to have progressively skewed from about 1:6 (1969) to 1:19 (1977-1979) and then skewed substantially to 1:71 (1980-1982) before
reaching a peak of 1:122 (1987-1989). It is important to remember that skewing of the adult sex ratio will proceed at a geometric rate if there are only few individuals of one sex with the progressive death of members of one sex, and thus the death of one or a few adult males will skew the ratio substantially as their numbers get reduced in the population. The authors have found that based on direct elephant sightings, the adult male to female ratio to be 1:101 in 1998. Thus there seems to be some recovery in the sex ratio in Periyar perhaps because of movement of a few sub adults to be classified into the adult category. But the situation in Periyar still needs continuous monitoring and constant vigil.

The skewed sex ratio does not seem so far to have adversely affected the fecundity rate/intercalving interval in Mudumalai population. The population data for 2001-2003 has to be compared with those available for earlier years to draw clear inferences; such data are available since about 1988 (R. Sukumar, unpublished data). Since elephants are long ranging animals there is the distinct possibility that the females in Mudumalai could have mated with males in adjacent areas such as Bandipur National Park or Wyanad Sanctuary where there are more males. Again because they are long lived, some effects may show up only after several years especially if there are genetic effects like inbreeding. However, we found that the intercalving interval in Periyar was significantly longer than those of Nagarahole and Mudumalai; the most plausible explanation for this is the extremely skewed adult sex ratios at Periyar for about two decades.
Poaching could mean a loss of genetic diversity in the affected population, which may subsequently lead to further erosion of genetic variability by genetic drift and reduction in fitness due to inbreeding. This reduction in offspring fitness because of parental homozygosity and therefore possible unmasking of deleterious recessive alleles is termed “inbreeding depression” (Charlesworth and Charlesworth 1987, Ralls et al. 1988). Data on inbreeding depression in natural populations, while limited, have shown influences on demography with inbred individuals showing markedly higher infant/neonatal mortality in olive baboons (Packer 1979), yellow baboon (Alberts and Altmann 1995), golden lion tamarins (Dietz and Baker 1993), and harbour seal (Coltman et al. 1998), lower overall/adult survival than non-inbred individuals in ungulates (Ralls et al. 1979), the white-footed mouse and song sparrow (Pusey and Wolf 1996), and lower reproductive fitness in the African lion (Packer and Pusey 1993), red deer (Slate et al. 2000), long finned pilot whale, grey seal and wandering albatross (Amos et al. 2001). Reduced fitness may be evident especially during stressful environments (Dahlgaard and Hoffmann 2000). Preliminary results of molecular genetic structure in the Periyar population already suggest significant inbreeding coefficients in the Periyar elephant population (Vidya et al. 2005).
4.3. Fecundity rate

In elephants, a peak calving in one year usually would result in poor calving in the following 2-3 years. This is because if a large number of females conceive in one year, they would not be available for conception in the next 2-3 years due to gestation (20-22 months) and subsequent lactational anoestrus, as observed elsewhere (Sukumar 1989). The average fecundity rates in the three populations (0.20 in Nagarahole, 0.19 in Mudumalai, and 0.15 in Periyar) are lower compared to 0.22 reported for the Eastern Ghats population during the early 1980s by Sukumar (1989 and 1989). However, Douglas-Hamilton (1972) has noted that the number of calves born to vary between 8 (0.082/adult female/year) and 34 (0.346/adult female/year) annually for 98 known adult female African elephants.

According to Sukumar et.al (1997) the fecundity in captive elephants in southern Indian timber camps was 0.095-calves/adult female/year. However, the fecundity observed during the past two decades (1969 - 1989) in the captive population (0.155/adult female/year) compares much more favourably with wild populations both in Asia and Africa (Laws et al. 1975, Sukumar 1989) and to the findings of the present study. The variation in fecundity observed between the three study areas could be due to different levels of ivory poaching. Jachmann (1980) and Laws et.al. (1975) also have suggested that hunting disturbances may influence natality. Drought may also affect the fecundity rate, as reported for African elephant population (Douglas-Hamilton 1972, Western et al.1983, Poole 1989). Laws et al. (1975)
have suggested that East African populations have variable birth rates, producing recruitment cycle related to rainfall patterns. But in Asian elephants there are no clear records to show that drought or rainfall have actually affected the fecundity rate (Sukumar 1989). Ramakrishnan et al. (1998) have reported that high rates of poaching and extreme skew in adult sex ratios to cause a decline in the birth rate of the elephant population in Periyar. Results of the present study clearly show that the high levels of poaching in the past in Periyar could have affected the birth rate of elephants. According to Jachmann (1980) poaching may also be an important variable influencing the reproductive output \(\text{via} \) parameters such as the quality of vacant habitat and intraspecific competition. Nutritional deficiency has also been suggested as one of the proximate factors affecting fertility (Laws and Parker 1968, Laws 1970).

Peak fertility seems to be reached in the 20-30 years age class in all the three elephant populations studied; the possible reason could be that animals in this age category are sexually more active than in other age classes. Physical and physiological condition of mothers could be expected to be relatively better for reproduction in 20-30 age classes when compared to other age classes. In corroboration with the present findings of fertility, Laws et al. (1975) have also reported maximum conception rates in the 31-35 years age groups.
In the present study the mean calving intervals have been calculated based on the number of mature females and number of calves recorded during the entire study period because the differences in birth rate from one year to next emphasize the dangers of extrapolating from one or two years of data only (Douglas-Hamilton 1972). The mean calving intervals during this study period have been 5.1 years for Nagarahole, 5.3 in Mudumalai, and 6.9 in Periyar. Earlier Daniel et al. (1987) have calculated the mean calving interval to be 4.5 years in the Mudumalai population. Sukumar (1989) has reported the fertility rate of 0.228 births per mature female per year with a mean calving interval of 4.4 years in one of the southern Indian populations from a sample of 23 calves per 101 adult females. The increase (if a real phenomenon) in mean calving interval from the previous studies to the present study, in concert with the increasing population size, could be indicative of density dependent effects on reproduction in Mudumalai.

Douglas-Hamilton (1972) has found the mean calving interval to be 4.6 years for the Lake Manyara elephant population. However the author felt that the calving interval may be shorter for a few particular individuals (Douglas-Hamilton 1972). Jachmann (1980) estimated the mean calving interval to be 3.9 ± 1.1 years, with a range of 2.2 to 5.3 years for the Kasungu National Park (Africa) elephant population. Whyte et al. (1998) have found a mean calving interval of 3.67 years from a sample 966 adult cows, at Murchison Falls Park, Africa. Laws, (1967) and Smuts (1977) have calculated the mean calving interval by placental scars counts (to have an independent check on the mean calving interval obtained from field data) and got a value of
between 4 and 5 years for Mkomazi and Kruger (Africa), elephant populations, respectively. Moss (2001) has reported an intercalving interval of 4.5 years in the well-documented Amboseli elephant population in Kenya. Thus the mean calving intervals observed in the present study are higher than these previous studies and would be interesting to examine further. The dependence of calving intervals on the availability of forage, especially in the light of recent heavy infestation by weeds of the Nilgiris region, may also be investigated in future studies.

4.4. Mortality

Mortality of elephants is from natural causes and also due to killing by man. It is very difficult to precisely assess the relative importance of different kinds of mortality on an elephant population. Sukumar (1985) has estimated that man was responsible for 18% of female and 70% of male deaths in the Nilgiri-Eastern Ghats elephant population of southern India. Other reasons for natural mortality are due to disorders of the gastrointestinal problems, pulmonary and cardiovascular disease, fall from the steep slopes (internal injuries), starvation due to old age (in old elephants due to wearing out of the last set of molar teeth), starvation due to lack of food especially in summer and few case of anthrax have also been recorded. Drought was suggested to be a major cause for high calf mortality in African elephants (Barnes 1982). At Amboseli a long drought between 1974 and 1978 caused a low birth rate and high calf mortality in African elephants, resulting in a “gap” in the age structure (Western et al. 1983, Poole 1989). During the present study period no severe drought occurred in any of the study areas. Another factor that could have caused calf mortality is the stress from poaching pressure. Barnes (1979)
has stated that the calves would die if their over-stressed mothers could not produce enough milk. According to Lindeque (1991) the only known mortality factor that could possibly affect all age categories is indiscriminate poaching. Other factors that could change elephant population age structure are diseases like anthrax, which has been recorded in Asian elephants from northeastern India (Choudhury 1999) and suspected in several deaths from the Nilgiris population. According to Lindeque (1989) disease and drought are the mortality factors that will affect selected sex and age groups more strongly than others. Mortality rates in most animals vary with age (Odum 1959). Laws (1966, 1969a) has shown that the mortality of most elephant populations can be divided into three phases, early calf mortality, constant adult mortality and old age mortality, and that in areas of heavy hunting pressure the males with their heavier ivory decline more rapidly.

During the period 1999-2003, 58 deaths (38 female and 20 males) were recorded in Mudumalai and its adjoining areas. But it is very difficult to estimate the true mortality rates in wild mammalian populations (Sukumar 1985), and the true mortality figure may be higher because many cases especially in younger age class go unnoticed, as they are small in size and decay rapidly. As a result such carcasses are very difficult to detect in the field. Laws (1969a) has stated the deaths in 0-5 year age class usually have to be assumed, due to unnoticed carcasses. From the cases of mortality that I recorded, the major cause of mortality was found to be natural deaths in females and ivory poaching and conflict related deaths in males. Since poaching contributes almost exclusively to male mortality, anti-poaching efforts should be strengthened in all three places and specially in Nagarhole since the park has the healthiest adult sex ratios in the whole of southern India.
Based on the calculation of instantaneous mortality for females, mortality was higher in the age classes of 30-60 years in Nagarahole followed by Mudumalai. Earlier Sukumar (1985) has also reported an increased mortality of 7% per annum in the higher age classes for the elephant population at Nilgiri - Eastern Ghats. Jachmann (1986) has found a mortality of 8.0% per annum from regression analysis, and cautioned that this figure must be considered an approximation because poaching in the Kasungu National Park is selective by age class. Laws et al. (1966 and 1969b) have also demonstrated that (excepting juvenile and old age) the mortality rate for much of the lifetime was nearly constant in a number of African elephant populations.

4.5. Population growth rate

The estimation of demographic parameters and their use in population modelling are crucial to assess trends and to elaborate upon conservation strategies of endangered species (Bibby 1994, Beissinger and Westphal 1998, Russell 1999, Caswell 2001). Moreover, since the simulations include different values of demographic parameter estimates, the best case scenarios could also be ascertained. However, many years of monitoring are required to provide more robust data on the effects of age on breeding (Hunter et al. 2000) or on other parameters with a degree of uncertainty.
In the Lake Manyara, Africa, which possessed a young elephant population, Douglas-Hamilton (1972) has found the elephant population to increase at the rate of 2-3% annually. Hanks et al. (1973) while observing an increase of 4% in the African elephant population, have opined that that could be the maximum rate of increase that an elephant population can expect to attain under “ideal” biological conditions. Whyte et al. (1998) have found the elephant population to grow at 5% annually in Kruger National Park, Africa. Moss (2001) has observed an average growth rate of 2.2% annually in Amboseli population in the near absence of poaching. Whitehouse and Kerley (2002) have observed the growth rate of elephants to be from 3.2% to 6.1% in Addo National Park over 50 years. Sukumar (1985, 1989) reported a maximum growth rate of 1.9% for an elephant population in the Eastern Ghats region of southern India, adjacent to Mudumalai. But in the present study, the average growth rates estimated for Nagarahole, Mudumalai and Periyar elephant population for twenty years (based on the Leslie matrix) were 0.67% per annum, 0.41% per annum and -0.29% per annum, respectively, in the short term.

The age-specific nature of fecundity rates also are important, as keeping the overall fecundity rates constant and interchanging fecundity rates among the different age-classes produced appreciably different results (data not shown). This is not to say that sex ratios are not important in determining growth rates. While Mudumalai showed a positive growth rate despite a skewed sex ratio, sex ratios in general most definitely influence growth rates through their influence on fecundity rates. A factor that must be seriously
considered is the possible influence of the disparate adult sex ratio on the fertility of the population (Sukumar 1985). In a polygynous species, a positive growth rate may continue to be seen until a particular skew in sex ratio is reached, after which there are not enough males to mate with available adult females. This will result in a lower rate of conception and longer inter-calving interval, which would reduce population growth rate. The Periyar population seems to have reached this state while Mudumalai has perhaps not. It is still not known what is the critical skew in sex ratio though it is likely to be more skewed than about 1:25. According to Sukumar (1989) as long as female mortality is fairly low the population could still have the capacity to increase or remain stable in spite of a decrease in fertility due to higher male mortality. However, in addition, it is possible that even before this critical point is reached after which growth rates become negative, there could be more-long term mild deleterious effects (including inbreeding depression and a loss of genetic variation through drift) affecting the genetic structure of the population.

The results of the present study indicate that the elephant population at Nagarahole and Mudumalai are growing at low but at healthy rates. These are high density elephant populations that cannot expand at high growth rates for too long a period. Thus, the projected growth rates of about 1- 1.5% per year, dropping in the short term to about 0.5% per year before stabilizing, indicate that some form of density dependent regulation could operate in these populations to control their number.
Periyar poses an interesting ecological and management dilemma. In spite of a high skewed sex ratio and a lowered birth rate, the population is either growing very slowly or stable in the short to medium term as anticipated (Sukumar 1989, Ramakrishnan et al. 1998). If protected from ivory poaching there is every chance that this population could recover in the medium to long term to a situation of a near – normal sex ratio and healthy demography. The genetic consequences of a very skewed sex ratio for several generations would however be deleterious to the population.

No single demographic and physiological parameter can accurately assess the condition of a population and predict future trends (Sukumar 1989). There is evidence that the dynamics of large mammal populations are influenced by stochastic environmental perturbations or long-term population cycles which are little understood (Sinclair and Norton-Griffiths 1979, Wu and Botkin 1980, Croze et al. 1981). However, for management goals that require an assessment of merely the present condition and possible short-term feature trends, both demographic and physiological parameters can be used profitably (Hanks 1981). In the present study only the demographic parameters of the study populations are discussed assuming that the elephants are in good physiological condition, an assumption that may not be true and needs to be tested in future research.
4.6. Management recommendations

1. The present study revealed that ivory poaching has substantially affected the sex ratio in two (sex ratio of adult male to adult female: Mudumalai 1:28 and Periyar: 1:80) out of the three sites where the present study was carried out. The skewed sex ratios observed in these areas are causes for concern. Ramakrishnan et al. (1998) have also reported that the increasingly female-biased adult sex ratios, particularly in southern India, could affect the elephant population seriously, by lowering the genetically effective population size, lowering birth rates and decreasing genetic viability due to inbreeding. From my simple population model I inferred the population growth rates stabilize at Mudumalai and Nagarahole beyond a decade, while they continue to drop at Periyar, and eventually become negative. In spite of a high skewed sex ratio and lowered birth rate in Periyar, the population is either growing very slowly or stable with the short to medium term as anticipated (Sukumar 1989, Ramakrishnan et al. 1998). If protected from ivory poaching there is every chance that this population could recover with medium to long term to a situation of a near normal sex ratio and healthy demography.

2. Elephants are known to range widely and there are elephant herds and bulls that range outside the PAs in the study areas in the Territorial Forest Divisions (Desai 1991, Baskaran et al. 1995). In general, protection against poaching and habitat loss and degradation is greater
in PAs than the territorial Forest Divisions due to insufficient financial support, anti-poaching camps, staff strength and infrastructure etc. When the elephant herds and bulls from PAs range outside in the Territorial Forest Divisions they are not protected from threats (poaching, habitat loss etc.) as much as in the PAs. Therefore management policies need to be changed to population (landscape) level rather than individual protected areas in order to conserve elephants (Sukumar 1989, 2003). Therefore, there is need for greater focus on and support to these vital but often ignored areas i.e., out side the protected areas as mentioned earlier by Baskaran and Desai (2000).

3. Since the present study areas are heavily affected by ivory poaching in the past only few males remain in the population and so the poaching of even a single adult male of such elephant populations at this stage will have adverse impacts on the population structure. Currently, increased anti-poaching efforts have been undertaken by the forest department, and these should be sustained and further strengthened. The anti-poaching effort in Periyar Tiger Reserve has also been innovative in involving previous poachers, who are knowledgeable about the terrain and elephant behaviour, in patrolling the forests. It appears that many of these poachers-turned-patroUers now take pride in their present job and are sincere in their conservation effort. The effectiveness of this patrolling is, however, not clear yet as very few tuskers remain and therefore infrequent poaching in the area cannot be unambiguously put down to anti-poaching efforts as may this also reflect the low economic benefits of ivory poaching at present.
4. Corridors are an important issue in terms of conservation of the species. Since the present study has shown skewed sex ratios in Mudumalai and Periyar, reviving broken corridors and augmenting or protecting the existing corridors with adjoining elephant populations or sub-populations are essential for allowing exchange of individuals, especially adult males, between populations to minimise inbreeding. Of course, facilitation of movement of individuals between populations will have to be accompanied by stricter protection in the larger area, as connecting areas in the current scenario will only lead to the poaching of males that move into the study populations. According to Saunders et al. (1991) the corridors facilitate major functions of exchange of genes between populations. Sukumar (1985) has stated that the Moyar valley is an important link between the habitats of the Nilgiris and the Eastern Ghats. Sivaganesan et al. (2000) have also reported that the Moyar valley corridor linking the Eastern Ghats is contiguous between the Sigur plateau and Mudumalai Wildlife Sanctuary on the east and Bandipur Tiger Reserve on the north. Thus, it is a crucial corridor for genetic flow between northern and eastern portion of the Nilgiri Biosphere Reserve.

5. Some studies (Baskaran et al. 1995, Sivaganesan et al. 2000) have already identified crucial corridors in and around Mudumalai Wildlife Sanctuary (Singara - Mavinalla and Moyar - Avarahalla) and management steps need to be taken on priority basis for preserving these corridors. Such management action not only helps in conserving the elephants in the landscape but also the other wildlife too.
6. Earlier study by Sukumar et al. (1998) suggested translocation of adult males from other areas into Periyar as a positive management option. A study of population genetic structure in southern India indicated that establishing connectivity to or translocating adult males from the Anamalai population (which is genetically similar to Periyar, Vidya et al. 2005) may help in reducing the skew in sex ratio in Periyar. Again, this has to be accompanied by stricter protection in both regions so that any new males that are brought in to or move into Periyar are not poached.

7. Nagarahole is one of the areas with high density of elephants in southern India. Even though patrolling and intelligence gathering on poaching should be a year round activity, efforts should be stepped up during March to May when there is usually a high concentration of elephants especially in the southeastern side of the park, where the Kabini reservoir is located. Given the high number of adult tuskers in the park (coupled with the scarcity of tuskers in the other elephant areas), poaching for ivory may become a serious threat in the near future in Nagarahole (Venkataraman et al. 2002). There are indications that the poaching has started already even though at a lower scale. So better protection and more intensive vigilance is a matter of urgency.

8. The population structure in these study areas should be monitored on a regular basis to understand the long term dynamics of the population, particularly the possible changes in the ratio of tuskers makhnas and the growth rate of the population, to assess the impacts of ivory poaching on natural selection of makhnas.