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The elephant populations of India—Strategies for conservation

R SUKUMAR
Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India

Abstract. Between 17 and 22 thousand elephants are found in 4 distinct regions—the northwest (525), northeast (8725–12130), central (2300) and south India (5750–7150). Elephants largely prefer the deciduous forests where both browse and grass are available. Annual home range size usually varies between 100 and 500 km^2. The major threats to the elephant include loss of habitat due to spread of agriculture, degradation of habitat through human impact, developmental projects such as hydroelectric dams and poaching of males for ivory. Suggestions for conservation of the elephant have been made. These include the maintenance of minimum viable populations, habitat integrity, habitat mosaic and reduction in poaching. Measures to reduce crop depredation by elephants such as the use of high-voltage electric fences are recommended.

Keywords. Asian elephant; *Elephas maximus*; elephant distribution; ivory poaching; minimum viable population.

1. Introduction

Despite the long and spectacular evolutionary history of the Proboscidea, extending back to the Eocene, there are only two living representatives—the African elephant (*Loxodonta africana*) and the Asian elephant (*Elephas maximus*). While an estimated 1·3 million *Loxodonta* range over a vast area of the African continent (Douglas-Hamilton 1980), *Elephas* has been reduced to a number of relatively small populations comprising 36–54 thousand individuals in South and Southeast Asia (Olivier 1978a; Sukumar 1985).

During the past century between 30 and 50 thousand elephants have been captured for domestication in the Indian sub-continent alone. The offtake has been consistently very much higher in the northeast than in south India. The reason for this disparity lies in the method of capture. In the north elephants have been traditionally captured in stockades and thus entire herds are taken at one time. By contrast, in the south elephants were usually captured solitarily in pits. The Kheddah method introduced by Sanderson (1878) was confined only to the Mysore State and less than 2000 elephants were captured between 1874 and 1971.

At present between 17 and 22 thousand elephants are confined to forested, hilly tracts of northwest, northeast, central and south India (figure 1). Only a brief account of elephant status and distribution in these 4 major regions will be given here. More detailed descriptions are available elsewhere (Daniel 1980; Sukumar 1985) based on the surveys carried out by the Asian Elephant Specialists Group (AESG) of the International Union for the Conservation of Nature and Natural Resources (IUCN).

2. Status and distribution of the elephant in India

2.1 *Northwest India*

An isolated population of about 525 elephants inhabits the *terai* belt along the Himalayan foothills in Uttar Pradesh (Singh 1978). The important elephant areas are

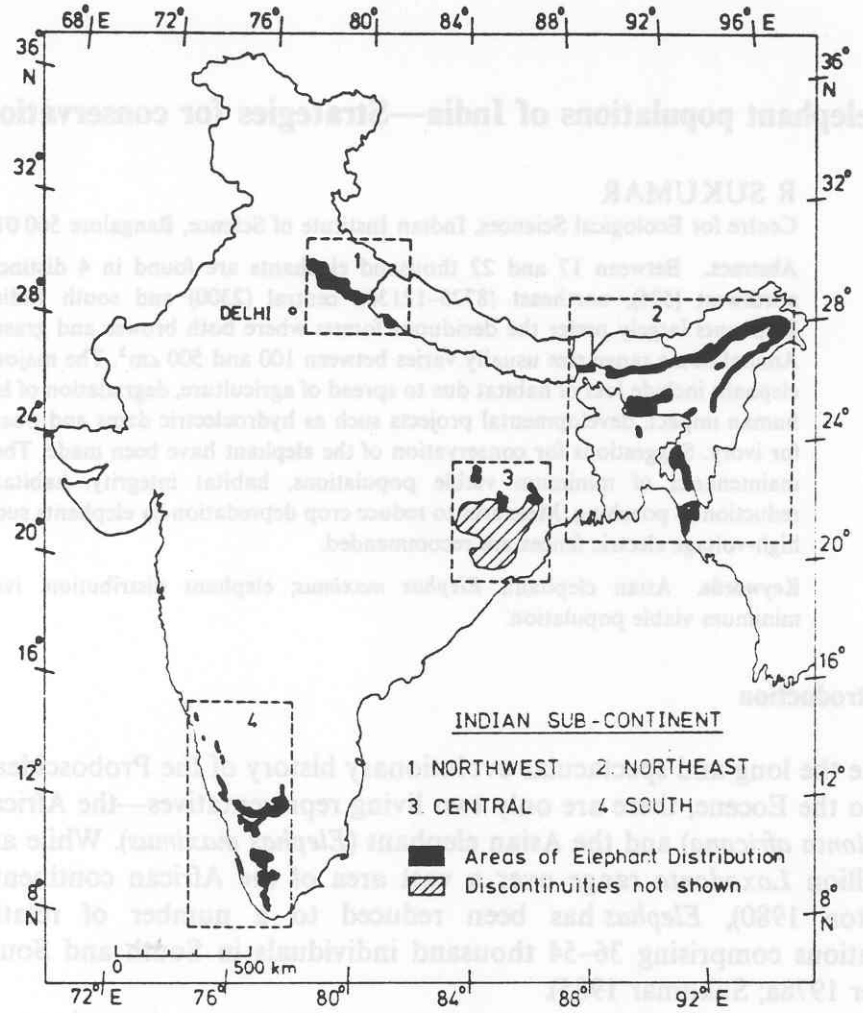

Figure 1. Elephant distribution in the Indian sub-continent.

the Corbett National Park and Landsdowne Forest Division. Threats to the habitat from the Ramganga reservoir, the Rishikesh-Chilla power channel and a paper mill have been discussed by Singh (1978).

2.2 *Northeast India*

The elephant habitats in this region are being mapped by the Northeast India Task Force of the IUCN/AESG in collaboration with the concerned state forest departments (Choudhury 1980, 1983; Northeast India Task Force 1981).

In the northeastern region only a series of fragmented elephant habitats exist. These extend from the Himalayan foothills of the Bhutan-north West Bengal border eastwards into the states of Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura and Meghalaya. Some of these populations also extend into Bangladesh and Burma.

In northern West Bengal, out of an estimated 155 elephants about 80 elephants range as a distinct population to the west of the Torsa river, while the rest are found to the east of the Torsa and are continuous with Assam. This is part of a larger area

which extends in a belt along the sub-Himalayan hills and plains of Arunachal Pradesh and Assam to the north of the Brahmaputra river. In Arunachal Pradesh alone the forest department has estimated 2000–4300 elephants within a 20000 km^2 area of mostly rugged terrain. These elephants also move into the border zones of Assam. In Assam itself the forest department has estimated 1200 elephants for the Manas Tiger Reserve and 400 for the Darrang West and East Divisions.

It is not clear whether the elephants to the north of the Brahmaputra river are linked with those to the south of the river. Some maps in the above mentioned reports show a continuous range in Arunachal Pradesh–Assam which extends in a horseshoe shape through the Tirap district in the southeast into Nagaland. However, Choudhury (1983) indicates that the elephants to the south of the Brahmaputra constitute separate populations. One such population is found in the Dibang-Tirap (estimate included with Arunachal Pradesh) and Dibrugarh region (200 elephants). Another major population of about 1900 elephants inhabits the Kaziranga Wildlife Sanctuary (780), Sibsagar and Nagaland hills. The large population in the Garo hills–Khasi hills of Meghalaya, estimated at 2500–3500 elephants, is certainly isolated from the others in the northeastern region. Smaller populations have been described for the Jainti hills–North Cachar region (150–175), South Cachar (100–150) and Tripura (120–150). The picture in the states of Manipur and Mizoram is not clear but the numbers are certainly low.

Apart from the tremendous human pressure on the habitat for shifting cultivation and the tradition of capturing elephants in large numbers, the prospects for the conservation of the elephant in northeast India are seriously affected by a volatile socio-political situation.

2.3 *Central India*

Information for this region comes mainly from the efforts of the Central India Task Force of the IUCN/AESG (Shahi 1980). The bulk of the elephant population is found in the state of Orissa. An estimated 20000 km^2 of deciduous forest spread over 21 forest divisions including the Simlipal Tiger Reserve, is believed to hold about 2000 elephants. The elephant range also extends into the adjoining states of Bihar and West Bengal. In Bihar the adjacent tracts are Singhbhum (area 2250 km^2, 200 elephants) and Dalbhum (70 elephants). A population of 40 elephants is isolated within the 1000 km^2 Palamau region. Incursion into West Bengal is sporadic.

2.4 *South India*

The elephant populations of South India have been studied and characterized better than those in other parts of the country (Krishnan 1972; Nair and Gadgil 1978; Nair *et al* 1980; Sukumar 1985). The elephant is distributed over forested hilly tracts of the Western Ghats and adjacent Eastern Ghats in the states of Karnataka, Kerala and Tamil Nadu. Along the sharp rainfall gradient from west to east in the Western Ghats, there is a striking transition in vegetation from wet evergreen forest and evergreen shola-grassland through semi-evergreen, moist deciduous and dry deciduous forest to scrub or thorn jungle. Elephants are found in the entire spectrum but attain the highest density in the deciduous belt. Their status and distribution can be conveniently described under sub-regions.

Table 1. Population status of the elephant in India.

1. *Northwest India*	
Uttar Pradesh	525
2. *Northeast India*	
West Bengal	155
Arunachal Pradesh	2000–4300
Assam	
Manas Tiger Reserve	1200
Darrang West and East	400
Dibrugarh	200
Kaziranga-Naga hills	1900
Meghalaya	
Garo-Khasi hills	2500–3500
Jainti-Cachar	250–325
Tripura	120–150
Manipur, Mizoram	?
3. *Central India*	
Orissa	2000
Bihar	310
4. *South India*	
North Kanara-Crestline	100
Malnad-Bhadra	100–150
North Wynad-Nagarhole	600–800
Bandipur-Mudumalai-Nilgiris	1200–1500
Nilambur-Palghat hills	300–500
Eastern Ghats (South)	1800–2000
Anamalais-Palani hills	800–1000
Periyar-Varushanad hills	700–900
Agasthyamalai hills	150–200
Total	17310–22115

See text for sources of information

2.4a *North Kanara: Crestline of Karnataka Western Ghats*: The North Kanara district of Karnataka is the northern limit of elephant distribution in South India. There has been considerable incursion into the forests by cultivation, mining and the giant Kalinadi hydroelectric project. To the south, the crestline of the Western Ghats with its high rainfall evergreen forest and grassland extends as a narrow belt down to the Brahmagiri hills. In both these regions only a few scattered herds of elephants occur at a low density (Nair and Gadgil 1978). Perhaps less than 100 elephants are found here.

2.4b *Malnad plateau-Bhadra*: This habitat lies to the east of the crestline, separated from it by a wide belt of coffee plantations and cultivation. An irrigation project on the Tunga-Bhadra rivers is situated here. Elephants inhabit the Bhadra and Shettihally Wildlife Sanctuaries (area 827 km^2) and number about 100–150 individuals.

2.4c *North Wynad-Nagarhole-Kakankote*: The deciduous forests of the Kerala North Wynad, Nagarhole National Park and Kakankote (total area 1250 km^2)

stretch from south of the Cauvery river to the Kabbini river. Extensive plantations of teak are seen at Nagarhole. This is an important region holding 600–800 elephants.

2.4d *Bandipur-Mudumalai-South Wynad-Nilgiris North and East*: The Kabbini reservoir has left only a 6 km wide corridor between the forests of Kakankote and Bandipur. The deciduous forests extending south from the Kabbini to the slopes of the Nilgiris constitute one of the finest elephant habitats in South India. The perennial Moyar river is an important water source. This region includes the Bandipur Tiger Reserve (874 km^2), Mudumalai Wildlife Sanctuary (321 km^2) and the Kerala South Wynad (251 km^2). In addition, the semi-arid Sigur plateau to the east of Mudumalai and the northern and eastern slopes of the Nilgiris (700 km^2) are contiguous. Between 1200 and 1500 elephants may be present in the entire region.

2.4e *Nilambur-Nilgiris west and south Palghat hills*: To the west and south of the Nilgiris are the well preserved wet evergreen forests, shola-grasslands and semi-evergreen forests of Nilambur, New Amarambalam, Upper Bhavani-Kundah, Silent valley and Attapadi. In the rain shadow southeastern slopes are the dry forests of the Coimbatore Division, through which flows the Bhavani river. South of Attapadi, the forested hills end at the Palghat gap. Between 300 and 500 elephants occur at a low to medium density in this 1700 km^2 area.

2.4f *Eastern Ghats (south)*: This vast hilly region with a forested area of 7000 km^2 is contiguous with the Nilgiris on the southwest. Vegetation is largely dry deciduous and scrub but moist deciduous forest and evergreen shola-grasslands are found on the Biligirirangan hills. The Cauvery which flows through this region is forested on both its banks for a stretch of nearly 100 km. The constituent forest divisions are Bangalore, Mandya, Kollegal and Chamarajanagar (Karnataka), Hosur, Dharmapuri, Erode and Satyamangalam (Tamil Nadu). A detailed study on elephant ecology has recently concluded in the Chamarajanagar and Satyamangalam Divisions (Sukumar 1985). For the entire Eastern Ghats a reasonably accurate estimate is 1800–2000 elephants.

2.4g *Nelliampathis-Anamalais-Palani hills*: South of the Palghat gap, the great hill chain of Nelliampathis, Anamalais and Palanis forms a continuous elephant habitat. This includes the Parambikulam and Anamalai Sanctuaries. An entire spectrum of vegetation types is seen. The habitat has been disturbed by a series of hydroelectric projects and its associated canals. Elephants are absent towards the eastern portion of the Palanis. About 800–1000 elephants may inhabit this region.

2.4h *Periyar-Elamalai-Varushanad hills*: From the High Ranges at the southern end of the Anamalais, the Periyar plateau stretches south till the Shencottah gap. The Periyar Tiger Reserve has been constituted around the reservoir on the Periyar river. On the plateau the vegetation varies from evergreen to moist deciduous, while dry forest is seen on the eastern slopes of the Srivilliputhur range of Madurai district. An estimate of 700–900 elephants has been made for the region.

2.4i *Agasthyamalai-Ashambu hills*: The Shencottah pass maintains a tenuous link between the Periyar plateau and Agasthyamalai, but it is not clear whether elephant

move across the railway line and highway in this corridor. This region includes the Neyyar, Mundanthurai and Kalakad Sanctuaries. Elephants are largely confined to the interior evergreen and semi-evergreen forests and grasslands. A tentative estimate of 150–200 elephants has to be taken.

3. Ecological requirements of the elephant

Elephants inhabit an entire spectrum of vegetation types from wet evergreen forests to semi-arid scrub zones. In the Himalaya, elephants are known to ascend upto 4000 metres above mean sea level, and they are also found in the dry thorn forests in coastal southeastern Sri Lanka. But they attain the highest densities in the moist and dry deciduous forests. The carrying capacity of prime deciduous habitats may be upto 3 elephants/km^2 compared to only 0·1/km^2 in the evergreen belt.

Due to its large body size the elephant consumes an enormous quantity of plant fodder, estimated at 1·5% (dry weight) of its body weight every day. Thus, an 'average' elephant weighing 1·8 tons requires 27 kg dry (about 108 kg fresh) matter daily. To achieve this intake the elephant has to be a generalist feeder, sampling a wide variety of plants. Though over a hundred plant species may be consumed in the wild, the bulk of the diet consists of just a few botanical taxa—the order Malvales and the families of Leguminosae, Palmae and Gramineae. In one area over 80% of the elephant's diet consisted of under 25 plant species from the above mentioned taxa (Sukumar 1985). With the aid of its trunk the elephant is able to exploit a wide range of feeding levels from tiny ground herbs to stout overhead tree branches.

The optimal diet is one of a seasonal alternation between a predominance of grass or browse. After the rainy season commences the fresh growth of tall grasses, especially in fire-burnt areas, attracts intensive utilization by elephants. During this period the grasses have a high protein content. Later, when the grasses mature they become silicaceous and unpalatable. Elephants now switch over to browse, which is especially important during the dry season as it retains a higher protein value than grasses.

The seasonal movement pattern of elephants is largely geared to optimizing its diet and also obtaining sufficient water. Elephants are far ranging animals. There is no evidence for territoriality in elephants but different 'clans' (each clan consists of many related elephant families numbering between 50 and 200 individuals) consistently range over particular areas which overlap with adjacent ones. The annual home range may be typically between 100 and 500 km^2 depending on the habitat factors. The relatively large home range requirement has important implications for conservation planning.

4. Conservation strategies

4.1 *Minimum viable population size*

Any animal population in the wild undergoes normal fluctuations in response to extrinsic or intrinsic factors. It is well known that a species whose population dips below a certain viable size is prone to extinction due to stochastic events such as a

disease epidemic or adverse climate (Shaffer 1981; Soule and Wilcox 1980). This viable size varies from one species to another.

There is also the consideration of the genetic viability of a population. In small populations the gene frequencies change randomly from generation to generation with a fixation or a loss of alleles. This process is known as genetic drift. Ultimately, this leakage of alleles leads to an increase in homozygosity (Frankel and Soule 1981). The central question in conservation genetics is the relationship between genetic variation and the fitness of the species. This can be considered both on a short-term and a long-term scale.

In the short-term the most serious consequence of an increased homozygosity is inbreeding depression (Ralls *et al* 1979; Soule and Wilcox 1980; Frankel and Soule 1981). The immediate effect of intensive inbreeding is a loss of fitness-lowered fertility, higher juvenile mortality, depressed growth, etc. Based on experiences with breeding of domestic mammals, it has been suggested that a minimum of 50 effective breeding individuals is needed to keep inbreeding depression to a negligible level of below 1% inbreeding per generation (Franklin 1980).

The issue of long-term fitness of a population, in terms of evolutionary potential, is still rather speculative. There have been attempts to derive the minimum population size above which the effects of genetic drift can be countered through natural selection or by gain from mutation (Franklin 1980; Frankel and Soule 1981). From both angles a figure of about 500 effective breeding individuals has been derived. Populations maintaining this effective size can be expected to remain viable from an evolutionary viewpoint.

A clarification has to be made here regarding the 'effective population size'. The census figure N for a species constitutes the genetically effective population size N_e only under idealized conditions such as an equal sex ratio of breeding individuals, an equal number of progeny per mating pair per generation and no fluctuation in population size. Of these the most important issue for elephants is the sex ratio. Due to a higher mortality of male elephants (compared to females) due to natural causes and poaching, the sex ratio of adults is usually unequal. At best it may be 1 male:2 females; at worst it may go upto 1:20 or even more disparate as in parts of south India. The more unequal the sex ratio, the greater will be the amount of genetic drift. The formula for calculating the effective population size N_e is given by

$$N_e = \frac{4N_m N_f}{N_m + N_f},$$

where N_m and N_f are the number of breeding males and females, respectively. The more skewed the sex ratio, the lower will be the value of N_e.

What are the implications of conservation genetics theory for the elephant populations in India? In south India the largest population inhabiting the Nagarhole-Nilgiris-Eastern Ghats belt consists of 3600–4300 elephants. Of these 7% are adult males and 35% are adult females (Sukumar 1985). Thus, there are atleast 252 males and 1512 females capable of breeding. Using the formula given above this translates into an effective population size of 840 breeding individuals—a comfortable level to counter the loss of genetic variation through drift. Unfortunately, the same is not true of other elephant populations in south India. Large populations do exist in the Anamalais and the Periyar plateau, but rampant poaching especially in the latter

area has drastically reduced the number of male elephants resulting in a highly disparate sex ratio.

In northeast India the 3 large populations are those in the Arunachal Pradesh-north Assam region, the Kaziranga-Naga hills, and the Garo hills-Khasi hills of Meghalaya. Since 50% of the male elephants are *makhnas* (tuskless males) the sex ratio is not likely to be as highly skewed as in south India due to pressure from poaching, though the frequency of *makhnas* could increase in the population.

4.2 *Minimum viable area and habitat integrity*

This leads to the related concept of the minimum viable habitat area necessary for the long-term survival of a species. The principles of 'island biogeography' as enunciated in the classical work of MacArthur and Wilson (1967) have been extended to the design of terrestrial nature reserves (Wilcox 1980). The fundamental principle is that in a smaller 'island' area the rate of extinction of species will be higher than in a large area. In an insular habitat the species most vulnerable to extinction are usually the *K*-selected ones with low reproductive rates and those at the summit of trophic levels (Terborgh 1976). The question of new colonization of habitat patches, while possible for taxa such as birds, does not usually arise in the case of elephants. It is a matter of either having one large elephant population ranging freely over a large area, or allow it to break up into a series of smaller populations in fragmented patches. Clearly for the elephant a single large area is desirable.

What would be the minimum viable area for the conservation of the elephant? This is related to the minimum viable population size and to the carrying capacity of the habitat. Assume that the minimum size needed is 500 breeding individuals and with the prevailing sex ratio (1 adult male: 5 adult females) this translates into a total population size of 2200 elephants. Further assume that the crude carrying capacity of a given area is 0·5 elephant/km^2 and the population is close to this level. A minimum area of 4400 km^2 would be needed for its long-term conservation. This area would vary with different values of the parameters; the above typical situation is merely to give an idea of the scale at which one should think when planning reserves for elephant conservation.

For a species with a large home range and a need for seasonal movement from one habitat type to another, further human encroachment reducing and fragmenting the habitat would affect the conservation prospects. Habitat reduction also intensifies the incidence of crop raiding by elephants (Sukumar 1985). In the Bannerghatta-Anekal-Kanakapura ranges of Karnataka, the habitat has been reduced to a long, narrow strip only 2–3 km broad in places. If elephants move through this belt the chances that they would come into contact with cultivation are very high. Forays by elephants into cultivation are very common here: in January 1985 a herd of 9 elephants strayed into the suburbs of Bangalore City, a distance of 15 km from their habitat.

Agents of habitat fracture in south India are mainly agriculture and dams. In the Eastern Ghats the numerous enclaves of cultivation have made large dents on habitat integrity. All over the Western Ghats tea and coffee plantations have made considerable inroads into the natural habitat. These are mainly responsible for the discontinuity in elephant distribution in south India. In recent years a portion of the

elephant habitat on the southwest of the Nilgiris (Nilambur-Attapadi) has been virtually cut off from the larger Nilgiri-Eastern Ghats region by tea plantations in the Gudalur Division. The practice of slash and burn—shifting cultivation is a major threat to the habitat in the northeastern states (Choudhury 1980).

Hydroelectric and irrigation dams are common all over the Western Ghats. These have submerged river valleys which are prime habitats for elephants. Many such projects, as in the Anamalai hills of Tamilnadu-Kerala, have also disrupted the traditional movement pattern of elephants and served to localize herds to smaller areas. Not all dams have led to habitat disruption. The century-old reservoir on the Periyar river in Kerala forms the nucleus of an important wildlife sanctuary with a perennial source of water for animals.

It has been suggested that a disease epidemic is likely to cause the extinction of an entire animal population in a large area. If distributed over numerous smaller habitats the species as a whole would still survive even if one population becomes extinct. This point is valid. But it is not a justification for fragmenting a large area if the option to retain it intact is available. The Asian elephant today exists over a broad area of the Indian sub-continent in a number of discrete populations. It is in that sense buffered against extinction through an epidemic in one region. Thus an effort should be made to keep intact as many large areas as possible along with a number of smaller viable ones. Then one would not run the risk of 'keeping all the eggs in one basket'.

4.3 *Maintenance of habitat quality*

The habitat has to provide the basic resources of food and water for elephants. In most areas elephants have to share these resources with people. Sites of human settlement are usually prime habitats such as valleys with the best water sources, fertile soil and a high potential plant productivity. There is intense competition between elephants and people for water in many regions (e.g. Eastern Ghats). By a proper landuse planning the elephant's access to important water sources has to be ensured.

Human manipulation of the habitat has altered the vegetation structure from primary or climax stage to secondary or early seral stages. What are the consequences of this change for elephants? It is well known that the highest herbivore densities are often found in habitats manipulated by man. For instance, in the Serengeti region man's impact through burning of the grassland and grazing of domestic livestock is ancient. The highest animal densities are found in such areas of past and present pastoral activity (Bell 1971). Conversion of a climax vegetation such as the evergreen rain forests to secondary forms causes a corresponding increase in elephant density (Olivier 1978b). In a climax rain forest the bulk of the plant biomass is trapped in the upper canopy and unavailable for animals. In secondary vegetation, pioneer and light demanding *r*-selected plants such as grasses, bamboos and *Kydia calycina* provide abundant food for elephants.

A model depicting the changes in carrying capacity and elephant density along two gradients in vegetation is shown in figure 2.

4.3a *Across forest types*: Elephant density increases from evergreen forest through

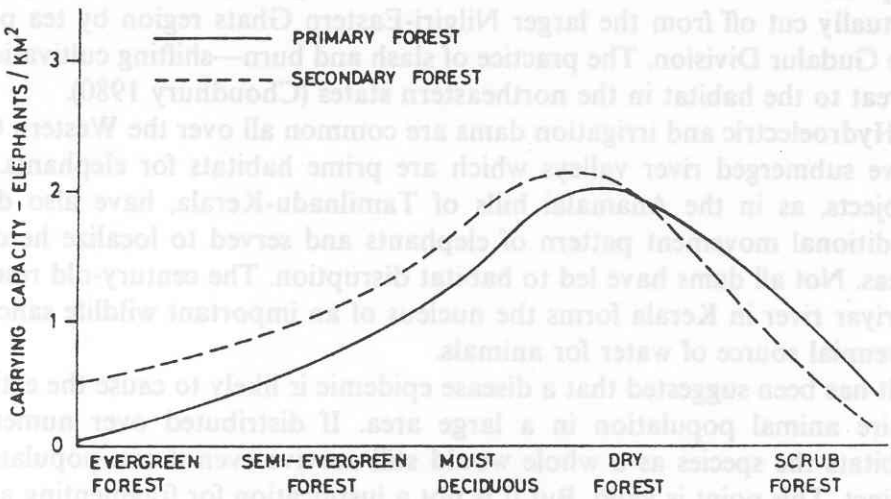

Figure 2. Carrying capacity of primary versus secondary forest.

the semi-evergreen type only until the deciduous forest. Beyond this there is a decline as the vegetation progressively changes into poor scrub.

4.3b *Within forest types*: The process of change from climax to early seral stage does not elicit the same response in the different vegetation types. The highest relative increase in carrying capacity may occur in the evergreen forest, but beyond the deciduous forest it is unlikely that this trend would continue. Xerophytic vegetation is characteristically short-statured and ensures a high proportional browse availability for elephants. Further exploitation of the dry zone scrub would reduce the carrying capacity. This model, of course, does not take into consideration other factors such as water availability. A scrub habitat along a perennial river may support a higher density than a dry deciduous forest with scarcity of water.

Undoubtedly, the optimum environment for elephants is one with a diversity of habitat types. This would include the moist and dry deciduous forest, scrub (which provide abundant leguminous browse shrubs such as *Acacia* spp.), riverain or gallery forest and patches of swampy grasslands. Alluvial floodplains of large rivers are also favoured when associated with a habitat mosaic. This diversity in habitat types enables the elephant to optimize its diet depending on seasonal changes in plant phenology.

It is often inevitable that elephant and man have to share the habitat and resources. Human land-use need not always be incompatible with the elephant's need. It is not possible to generalize for all areas; each situation has to be considered separately.

(i) Selective logging in forest habitats is not detrimental to the elephant. In certain moist vegetation types this may actually create a more favourable niche.

(ii) Elephants may adapt themselves to certain monoculture plantations such as teak, provided the understorey vegetation has sufficient food plants. The Nagarhole National Park has a high elephant density even in the teak plantations. However, this should not be taken as a justification for raising plantations on a large scale. In many instances other disturbances associated with plantations depress herbivore densities.

(iii) Invasion by noxious weeds such as *Lantana* and *Eupatorium* is a consequence of disturbance to the natural vegetation, especially clear-felling an area or even just clearing the understorey vegetation. This is undesirable as both these species are not consumed by herbivores and further suppress the growth of indigenous plants. With the intensive exploitation of bamboos in many areas, it is possible that *Lantana* may now be occupying this niche.

(iv) The role of fire in altering the plant community needs further study. Burning of grassland in the African savannas helps in maintaining a high diversity and density of grazing ungulates. In the deciduous forests of south India, too, elephants prefer to feed on freshly growing grass in burnt areas after the rains commence. However, the effect of fire on the woody vegetation has to be also considered. In particular, the deflection of the woody plant succession towards a 'fire climax' may be undesirable if unpalatable trees such as *Anogeissus latifolia* become dominant because of their resistance to fire.

(v) Should wildlife managers purposely manipulate the habitat so as to maintain a high carrying capacity for elephants? I personally consider human attempts at 'management' of natural habitats and animal populations unnecessary except under certain pressing circumstances. As argued earlier, habitat manipulation is likely to increase carrying capacity only in evergreen-moist deciduous vegetation. Tropical evergreen forests represent a relatively stable climax with their own unique assemblage of plants and animals. It is unwise to disturb this community for the sake of increasing elephant numbers. In the dry deciduous and xerophytic vegetation any conversion to secondary forms will not benefit the elephant.

Where the elephants range over a sufficiently large area, it is not necessary to manipulate the habitat even if this means that they will exist at only a low density. An artificial build up of the elephant population will result in increased crop raiding, damage to trees and crash in numbers during drought. If elephants are confined within a smaller area, then some management may be justified in order to maintain a viable population size.

4.4 *Reduction of poaching*

The levels of poaching in south India seem to have reached unacceptable levels during the past few years. In the states of Karnataka, Kerala and Tamil Nadu about 100–150 male tuskers were shot annually during 1980–83 (Sukumar 1985). With a mean tusk weight of 9·5 kg, even taking the lower figure of 100 elephants and 190 tusks (assuming some were one-tusked), this supplied 1800 kg of ivory valued at Rs. 2,700,000 to the illegal trade.

It may be impossible to completely eliminate poaching; it would be unrealistic to expect to do so with the limited manpower available. If one has to live with a certain amount of poaching, then what would be a 'safe level' of male mortality at which the adult sex ratio would not become very disparate? The sex ratio, of course, depends not just on the male mortality but also on the differential mortality between the sexes and, thus, the female mortality must also be considered. Female mortality, however, usually varies within a small range (2–5% per annum) over most of its sub-adult and adult life span (5–50 years).

Computer simulations, using the age-structured Leslie matrix model, have shown that at current levels of poaching in parts of south India the adult sex ratio could

reach 1 male: 10–20 females. The implications of this disparity have been discussed earlier. If the male mortality rate due to both natural causes and poaching is kept below 8% per annum, the adult sex ratio may be pegged at 1 male: 5 females (Sukumar 1985). This calls for a regular monitoring of the elephant population numbers, mortality and sex ratio.

4.5 *Reduction of crop damage by elephants*

Raiding of agriculture crops by elephants is common over most of its range. Further, people guarding their fields may be sometimes killed by elephants. These have served to label the elephant as a pest to human interests. Conservation of the elephant will never gain acceptance among the vulnerable villagers as long as this state of affairs is not rectified.

This is easier said than done. The main problem is to find an economically feasible solution to keep elephants away from fields. Simple methods like bursting of fire crackers are useless against these intelligent mammals which have learnt to recognize such bluffs. Trenches are expensive and, moreover, have a high risk of failure since elephants often learn to fill the trench by digging the soil with the forefeet and then crossing over.

The high-voltage electric fence (of a non-fatal type) seems to have the best potential. This consists of one or more strands of galvanized steel wires strung at appropriate heights (1–2 m for elephants) above the ground by hardwood posts. The posts are protected by vertical wires and insulators may be provided at places where the wires come into contact with the posts. The heart of the fence is the 'energiser' which passes every second an electric pulse of 5000 volts at a duration of 3/10000 second. Due to the high voltage but short duration of the electric pulse, any animal coming into contact with the wire receives a severe jolt but is no danger of dying or even any serious injury. The energiser may be powered by a 12 V car battery, from the 230 V mains or even by solar cells.

Numerous experiments with electric fencing in Africa (Piesse R L, unpublished results) and Malaysia (Blair 1980) have shown that it is generally effective against elephants. During a period of 32 days in 1982, a total of 259 elephants made 184 contacts with an electric fence in Namibia-Etosha, but not a single elephant got through. In Malaysia a few thousand kilometres of fencing have been erected around oil palm and rubber plantations. One trick that an elephant may try is use its tusks (non-conductor) to break the wire. It must be emphasized that the electric fence is not strictly a physical barrier but more of a 'psychological bluff'.

The elephant is an integral part and a grand symbol of Indian culture. Any plan which focuses on elephant conservation need not be incompatible with the conservation of biological diversity. Elephants still range over a number of biogeographic regions in the Indian sub-continent. The protection of representative areas in each of these regions would contribute significantly to the conservation of the overall biological diversity.

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