activity of bats only on the night of the eclipse and compared them with those of bats observed on the next full moon night that occurred on 12 April 1979. In contrast, moonlight did not modify the activity pattern of the microchiropteran bat *Myotis lucifugus*[23]. In this study the authors[23] observed bat activity only for one hour at the beginning and one hour at the end of the night. However, moonlight did influence the foraging activity of the same species in an another study[24]. Reith[25] suggested that the bats shift their activity by flying more under canopy or in shadow on moonlit nights. Such microhabitat shift during bright moonlight was also observed on ten species of vespertilionid bats[26].

The reduced feeding activity of bats during bright moonlight is generally viewed as an adaptation to avoid nocturnal predators[3,27]. We have noted a barn owl *Tyto alba* and an Indian great horned owl *Bubo bubo* perching on trees in the vicinity of our orchard. However, we have not observed predation on fruit bats while they were foraging. Interestingly, red fig-eating bats *Stenoderma rufum* did not modify their activity in response to moonlight possibly because of absence of bat predators in the study area[28]. We have previously observed that a *C. sphinx* chased away a conspecific that was feeding on a fruit *in situ* in a *Psidium guajava* tree during a full moon night. Our study clearly shows that bright moonlight suppresses the foraging activity of fruit bats in the orchard.

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Conservation of a flagship species: Prioritizing Asian Elephant (*Elephas maximus*) conservation units in southern India

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The Asian elephant (*Elephas maximus*) is believed to number about 45,000 in the wild and is distributed across several populations over South and Southeast Asia. It is an important flagship species for the conservation of biodiversity as well as being a cultural symbol of the people of this region. We analyse a Geographical Information System database of administrative forest divisions constituting four Project Elephant Reserves designated for southern India, in an attempt to prioritize them for specific conservation action and funding allocation. We compute a conservation value for each of these divisions by using five variables characterizing habitat, population and biodiversity attributes. We also compute threat values for each, using two variables which represent the most significant threats. Based on a cluster analysis we demonstrate that divisions with high conservation values have large elephant distribution areas, preferred habitat areas and elephant

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numbers as dominant attributes. Divisions with the lowest conservation values are characterized by high levels of habitat fragmentation.

Based on results obtained from the conservation valuation which allow for the zonation of elephant habitats, we recommend conservation action specific to resultant zones. On resolving divisions into clusters, each having specific dominant attributes, we further suggest divisions that could be targeted either for elephant or biodiversity/habitat conservation.

WHILE conservationists express dismay over the fate of African elephants (*Loxondonta africana*), there may be as many as 600,000 free-ranging African elephants distributed over several large populations[1]. In contrast, there are possibly no more than 45,000 Asian elephants left in the wild, with only 20 populations having more than several hundred individuals each[2,3]. The southern Indian elephant populations, among the largest in Asia[4], are spread over a large area along the Western Ghats, one of the global 'hot spots' of biodiversity, and a part of the Eastern Ghats. Conservation action here requires a strategic framework based on an objective assessment of the variation in elephant habitat and population attributes and threats. Project Elephant, instituted and funded by the Government of India since 1992, aims to conserve elephant populations, their habitats and overall biodiversity in eleven designated elephant reserves across the country[5,6]. These reserves represent the most important elephant populations by virtue of their population size and habitat area.

The delineation of elephant reserves has benefited greatly from past studies where the location of populations and the extent of available habitat for each population has been determined with some accuracy. Furthermore, conservation of elephants within these habitats is greatly facilitated by the existence of administrative forest divisions. We therefore focus on prioritizing elephant-bearing forest divisions. Structured administration of elephant habitats in large parts of southeast Asia is still in its infancy. A landscape approach similar to the prioritization and delineation of tiger conservation units (TCUs)[7] may be more appropriate for stimulating conservation action here.

The largest and most viable populations of the Asian elephant (*Elephas maximus*) in the wild today are in India (22,000–28,000)[2]. Here, the elephant's range includes the northeastern states of Arunachal Pradesh, Assam, Meghalaya (a few elephants are also found in Tripura, Mizoram and Nagaland) and West Bengal, the northern states of Uttaranchal and Uttar Pradesh, the east-central states of Orissa and Jharkhand (carved out of Bihar) and four southern states of Tamil Nadu, Karnataka, Kerala and Andhra Pradesh[8]. In southern India, elephants are spread over the hill forests of the Western and Eastern Ghats[9]. The Asian elephant is globally categorized as endangered (A1cd) (IUCN 1996) (Appendix I) (CITES) and nationally listed under Schedule 1 of the Indian Wildlife (Protection) Act, 1972.

Elephant habitats in southern India encompass a wide range of climatic and geographical zones and consequently diverse vegetation types. These harbour high levels of species endemism and biological diversity, particularly among the herpetofauna and vascular plants[10,11]. The Western Ghats, for example, has 14 endemic mammals and 19 endemic birds (Daniels, R. J. R., unpublished data), and approximately 352 endemic tree species[11,12]. Forest types range from mid-elevation evergreen forests, occupying areas in which average annual rainfall is as high as 9000 mm, to thorn scrub with rainfall as low as 600 mm.

Loss of elephant habitat through spread of agriculture, including commercial plantations of tea and coffee, and developmental activities such as hydroelectric and irrigation projects, roads, railway lines and mining, have been the most significant threats to elephant habitats. In most range areas, habitat fragmentation and loss have caused an escalation of elephant–human conflict, as elephants foray into agricultural lands to feed on cultivated crops. Manslaughter by elephants and injuring and killing of elephants by irate farmers accompany this conflict. An average of 50 people are killed by elephants every year, a significant proportion of these occurring within settlements and cultivation. In Karnataka alone, at least ten animals are killed every year as a result of human–elephant conflict. The conflict creates adverse sentiments among local communities against the setting-up of protected areas and other conservation strategies targeting wildlife habitats. Poaching for ivory selectively removes male elephants, resulting in skewed sex ratios and causing deleterious demographic consequences[13].

The purpose of the paper is to offer a strategic framework, which attempts to capture the variation in habitat, population attributes and threat factors. We use a combination of these to generate conservation values for administrative forest divisions comprising Project Elephant Reserves in southern India. Keeping the flagship concept in mind, biodiversity-related variables such as level of endemicity of various plant and animal taxa have also been incorporated into the conservation valuation. We then demonstrate that this process allows for the zonation of elephant habitats which could then be targets of varying levels of conservation action. Using cluster analysis we also demonstrate how these conservation values could be interpreted in terms of varying potential for elephant, biodiversity and habitat conservation strategies and funding.

Elephant distribution data within the four elephant reserves in southern India were collected by field visits to all elephant range areas described in the past literature[4,8,9,14–19]. These data on elephant distribution were modified to incorporate temporal changes mainly caused by factors such as habitat loss through encroachments, developmental activities such as construction of reservoirs and large-scale landscape transformation (e.g. recent conversion to commercial plantations such as tea and coffee). Presence of elephants was verified by direct sighting, indirect evidence such as dung, and interviews with local villagers, forest department staff and researchers working in the concerned areas. In certain cases distribution was inferred based on forest contiguity and quality, even if an intervening stretch of forest was not surveyed, but had elephants in the adjacent tracts. All spatial data on elephant distribution were transferred to tracings of toposheets which were then digitized to produce distribution layers for areas surveyed in the four reserves.

Elephant density estimates were obtained from the records of the forest department. Estimates used here are based on census figures obtained during the simultaneous (in the southern states) census conducted in May 1993. In Tamil Nadu and Karnataka, random block counts that sampled about 30% of the forest division area were carried out. No statistical confidence limits have been presented for these results. Estimates for Kerala were obtained from dung counts with 95% confidence limits[19]. The dung counts were necessary as the forests here mostly comprised moist deciduous and wet evergreen vegetation with low visibility.

Vegetation types of forest areas constituting elephant habitats were obtained from secondary sources or derived from our interpretation of satellite imagery. Vegetation maps produced by the French Institute, Pondicherry (list provided in Appendix 1) were digitized for elephant reserves 7 and 8. Each vegetation type was represented by single or multiple polygons with a unique identifier. Vegetation maps of 1:250,000 scale are not available for forest areas within elephant reserves 9 and 10. Satellite images were acquired (Appendix 1) for first carrying out unsupervised classification. Areas having a unique and unknown vegetation type (obtained from the unsupervised classification) were identified and visited in the field for recording dominant tree species at sample sites. Eventually, a supervised classification was carried out with a total of 220 training sites representing coordinates within 22 vegetation types, plantations and mosaics of natural vegetation types with plantations.

Most forest areas within elephant habitats of southern India are gazetted reserved forests and have boundaries clearly marked on Survey of India toposheets (scales 1:250,000 and 1:50,000) (Appendix 1). Forest maps of the study area were reconstructed using a combination of 1:25,000 scale toposheets, 1:50,000 scale toposheets (when forest boundaries and other features in 1:250,000 scale maps were unclear or the 1:250,000 scale map was outdated) and satellite imagery. Subsequently, a number of new enclaves within forests, not represented in the toposheets, were incorporated into the forest map which was then used as the primary layer in the Geographical Information System (GIS) database. Boundaries of administrative units were obtained from the cartography section of the forest departments.

The number of poaching incidents was obtained from the forest division offices. To obtain the annual rate, the number of incidents where only tuskers were killed was divided by the number of years for which records were available. In some cases animals were killed, presumably for tusks, but tusks were not removed because of immediate detection by the authorities. The rates were computed for poaching incidents during the years 1990–97.

Data on the number of reported elephant raids on crop fields within each administrative division were obtained from the forest division offices. Farmers file compensation claims at the local division office providing details on the location of the raided agricultural lands, type and quantity of crops damaged and economic loss incurred. Each claim therefore could be thought of as representing one raid. This was converted to a rate by dividing the number of raids by years for which records were available. Some states such as Tamil Nadu began the practice of paying compensations only recently. The records therefore may not reflect actual raiding intensities. However, states like Karnataka have been providing relief for several years and records may provide more reliable indications of relative raiding intensities. Looking at a combination of reliable records existing for divisions, field investigators' subjective assessment of raiding intensities and earlier survey work[9,20], all divisions were ranked in terms of the prevailing levels of crop-raiding. Based on this ranking system, values for divisions having unreliable records were extrapolated by placing them among divisions ranked according to reliable records.

The division-wide distribution of endemic mammals, birds and trees was obtained from established sources[12,21–26]. By considering the existing knowledge of species distributions, the location of collection of type specimens and other information contained in the above references, the presence or absence of the above taxa was inferred for each division. The index of endemicity was simply the total number of endemic species belonging to the above taxa. We did not consider other taxa within the Western Ghats. This is because taxonomic uncertainties do exist, in terms of the relatively greater difficulties faced by systematists in correctly ascertaining the taxomomic status of an organism. Furthermore, it is difficult to access adequate information against which confirmation is possible[27]. This may not however be true for certain invertebrate taxa such as Lepidopterans[28].

Analysis was carried out at the level of a forest division. Digitized input such as forest boundaries, vegetation maps, elephant distributions and administrative unit boundaries comprised separate layers in the GIS database. Each of these layers was clipped with the forest division boundary and the following four spatial elephant-related variables calculated. In addition to these, the number of endemic species was used for calculating conservation values.

For Karnataka and Tamil Nadu, the elephant numbers obtained from a 30% random block sampling of the division were extrapolated to the total forest area within the division. For Kerala the elephant densities, as obtained from the dung counts, were used to obtain actual numbers of the entire elephant distribution area within the division.

Fragmentation indices for forest divisions were calculated by dividing the total forest perimeter within a division by the total forest area. High values indicate a higher perimeter to area ratio, implying that the forest perimeter is either very convoluted or long and narrow. An increase in the number of enclosures within tracts of forest adds to the perimeter, decreases the forest area and increases the value of the index.

The elephant distribution area within a division was the actual area over which it ranged. While determining the preferred habitat area, the total area of each vegetation type within a division was first computed. The preferred habitat area was then the total of each type excluding wet evergreen forest, crop-lands and plantations (with the exception of teak *Tectona grandis*) as well as those falling on steep hill slopes and hills above 1400 m asl, as these are known to support low or negligible density of elephants[9].

The primary issue in multi-criterion evaluation is the treatment of several criteria to form a single index of evaluation. In the subsequent analysis, the criteria were the variables characterizing elephant populations, habitats and biodiversity. Multi-criterion evaluation and the calculation of conservation value (*S*) are discussed elsewhere[29], but are briefly described below.

A continuous grading system was developed for assessing the importance of criteria to a dependent variable, the conservation value (Table 1). In the pair-wise comparison matrix in Table 2, the rationale behind the relative importance of row variables over column variables towards the conservation value is the following. Quite unequivocally, high levels of fragmentation of habitat or its absence, is the most important criterion influencing a division's conservation value positively or negatively. In southern India, fragmentation is rather irreversible, except in unique cases. This criterion was therefore considered more important than others. Within a division a large elephant distribution area is a desirable criterion but unless accompanied by significant preferred habitat area, may have elephants living under sub-optimal conditions. Preferred habitat area is therefore considered more important than elephant distribution area. Elephant numbers could be increased by conservation action if distribution area and preferred habitat area are adequate and levels of fragmentation low. We assign lower importance to elephant numbers than the fragmentation index, elephant distribution and preferred habitat areas. Finally, the level of endemism has been arbitrarily taken to be moderately less important than the other four criteria. For the pair-wise comparison matrix, a consistency ratio indicates the

Table 1. Whole numbers and reciprocals indicate that a criterion is more or less important to the conservation value, respectively. Such comparisons are made in a pair-wise manner as elaborated in Tables 2 and 3

Relative importance	Description
1/9	↑ Less important
1/7	
1/5	
1/3	
1	↓ More important
3	
5	
7	
9	

Table 2. Relative importance of criteria (compare row variable over the column variable)

	Fragmentation index	Elephant number	Elephant distribution area	Preferred habitat area	Number of endemic species
Fragmentation index	1				
Elephant number	1/3	1			
Elephant distribution area	1/3	3	1		
Preferred habitat area	1/3	3	3	1	
Number of endemic species	1/5	1/3	1/5	1/5	1

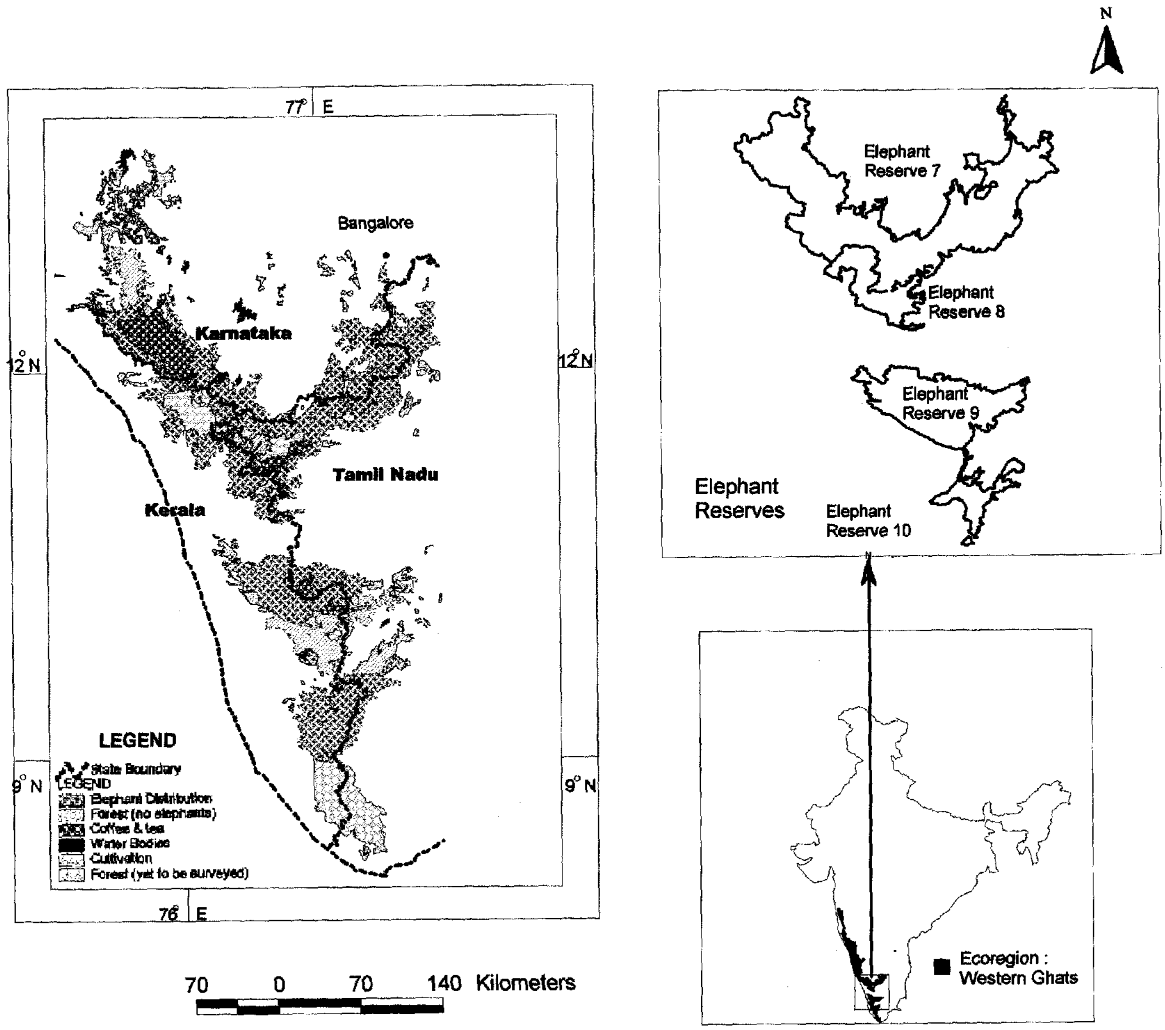


Figure 1. Extent of forests and elephant distribution and land usage within southern India.

Table 3. Weights derived by calculating principal eigenvector of pair-wise comparison matrix. The consistency ratio of the pair-wise comparison matrix is 0.09

Parameter	Eigenvector
Fragmentation index	–0.42
Elephant number	0.1
Elephant distribution area	0.17
Area of preferred habitat	0.27
Number of endemic species	0.05

probability that the matrix has been generated by chance alone. Consistency ratios of less than 0.1 are acceptable, while anything above this value calls for a re-evaluation.

For continuously varying factors (in this case citeria) a weighted linear combination is most commonly used. Criteria are combined by applying a weight, where the weightage factor (w_is) for each criterion was derived from the principal eigenvector of the pair-wise comparison matrix (Table 3). Computation of the principal eigenvector of the pair-wise comparison matrix is an iterative process which returns the best fit of weights. Thus

$$S_j = \sum_i \pm W_i x_{ij}, \tag{1}$$

where S_j is the conservation value for division j, w_i is the weight of criterion i, and x_{ij} is the score of criterion i for division j.

The sign of the weighted term indicates whether it was a positive or negative criterion influencing S_j. The criteria were scaled from 0 to 1. They were then multiplied by 255 (which is the maximum number of unique colours a pixel can have). A linear combination of the

Table 4. Distance from the origin of cluster centres with respect of criteria

Cluster	Fragmentation index	Elephant number	Elephant distribution area	Area of preferred habitat	No. of endemic species
1	64.34	7.56	17.77	7.79	166.39
2	48.19	50.21	140.8	78.71	192.97
3	178.33	8.56	26.89	20.65	19.53
4	28.97	50.99	82.73	48.07	19.99
5	26.04	38.21	223.97	208.02	0
6	12.23	222.63	163.38	142.68	27.57

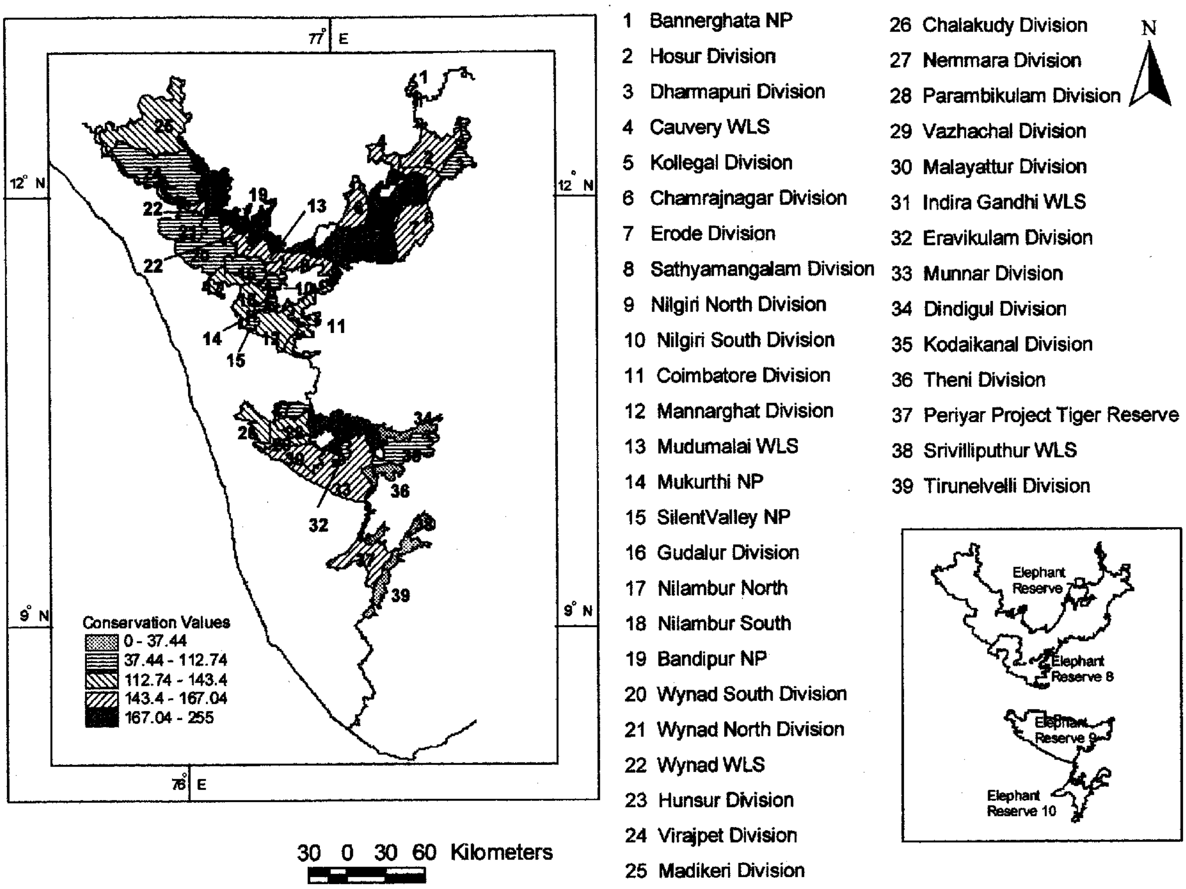


Figure 2. Conservation values of 39 forest divisions.

Table 5. Dominant and sub-dominant criteria of clusters

Cluster	Dominant and sub-dominant criteria
1	Number of endemic species and fragmentation levels
2	Number of endemic species and elephant distribution area
3	Fragmentation levels
4	None
5	Elephant distribution area and preferred habitat area
6	Elephant number and elephant distribution area

weighted criteria gave us the conservation value (*S*) for each division. A 'conservation value map' was then obtained.

Selective poaching for ivory skews sex ratios in favour of females[13], while elephant–human conflict results in damage to life and property, escalating antagonism among affected people towards state conservation efforts. The annual rates of poaching and crop-raiding were also scaled between 0 and 255. As crop-raiding by elephants is considered less of a direct threat than poaching for males and can be mitigated with less effort, the scaled crop-raiding rate was subjectively weighed down by 1/3 and added to the scaled poaching rate.

We used a *K*-means cluster analysis (SPSS for Windows, Version 6) to partition divisions in terms of homogeneities of magnitudes of criteria. The aim of this algorithm is to initially partition 39 divisions in five dimensions (five criteria) into *k* clusters. We ultimately present the results of partitioning into six clusters, given that partitioning into fewer or more clusters causes a loss of resolution or increases the complexity of interpretation of the clusters, respectively. In the first iteration the centroid of each cluster is calculated. Coordinates of the centroid and each division in a five-dimensional space are the distances from the origin with respect to each of the five criteria. The square error for all divisions (which is the square of a given division's distance in five-dimensional space from its cluster's centroid) is calculated. In the next step of iterations, divisions are reassigned to clusters and the process is repeated till the square errors summed over all divisions are minimized. In all iterations the number of clusters remains constant at *k*. The distance from the origin of the cluster centre with respect to each of the criteria is given in Table 4 and cluster membership is given in Table 5.

For conservation of elephant habitats in southern India, the four reserves (Figure 1) protecting 22,113 km^2 out of a total elephant range of 24,622 km^2 (distribution encompasses intact and degraded forests only) are critical because several small, isolated populations (with the possible exception of Bhadra) to the north of these reserves, along the Western Ghats, are of questionable viability. Furthermore, one of these reserves (elephant reserve 7) encompasses 12,583 km^2 and is possibly the largest intact elephant landscape in the country. Further south, another contiguous block of forest (Agastyamalai) exists, but has a relatively low elephant density and population size (Figure 1).

Table 6. Conservation values of forest administrative divisions within Project Elephant Reserves in southern India

No.	Division	Conservation value	Cluster membership	Threat value
1.	Sathyamangalam	255	5	41.2
2.	Bandipur NP and PTR	239	6	255
3.	Hunsur	203.3	6	50.8
4.	Indira Gandhi WLS	195.6	2	18.8
5.	Kollegal	195	5	90.3
6.	Hosur	167	4	21.1
7.	Chamrajnagar	164	4	64.5
8.	Erode	162.9	4	2.6
9.	Mudumalai WLS	156.2	4	31.6
10.	Munnar	156	4	2.4
11.	Nilgiri North	154.5	4	14.0
12.	Malayattur	152.3	4	27.0
13.	Wynad WLS	152	4	43.1
14.	Cauvery WLS	151.4	4	46.6
15.	Periyar PTR	149.2	4	0.4
16.	Parambikulam WLS	143.4	4	54.2
17.	Vazhachal	141.2	4	0.5
18.	Mannarghat	139.3	4	0.2
19.	Coimbatore	136.1	4	40.0
20.	Nilambur South	135.8	4	10.3
21.	Madikeri	132.7	2	74.6
22.	Chalakudy	120.2	4	17.7
23.	Nilambur North	116.3	4	12.1
24.	Gudalur	112.7	4	20.8
25.	Dharmapuri	112.3	4	1.9
26.	Silent Valley NP	110.7	1	0.1
27.	Mukurthi NP	103.7	1	0
28.	Kodaikanal	103.7	1	0.9
29.	Virajpet	102.6	1	55.3
30.	Nemmara	102.3	4	20.6
31.	Eravikulam NP	102.3	1	14.3
32.	Nilgiri South	85	1	0.6
33.	Wynad North	78	1	7.1
34.	Wynad South	68.9	3	4
35.	Bannerghata NP	64.8	3	30.8
36.	Theni	37.4	3	1.5
37.	Tirunelvelli	32.9	3	13.6
38.	Dindigul	7.7	3	1.4
39.	Srivilliputhur WLS	0	3	0.4

NP, National Park; WLS, Wildlife Sanctuary; PTR, Project Tiger Reserve.

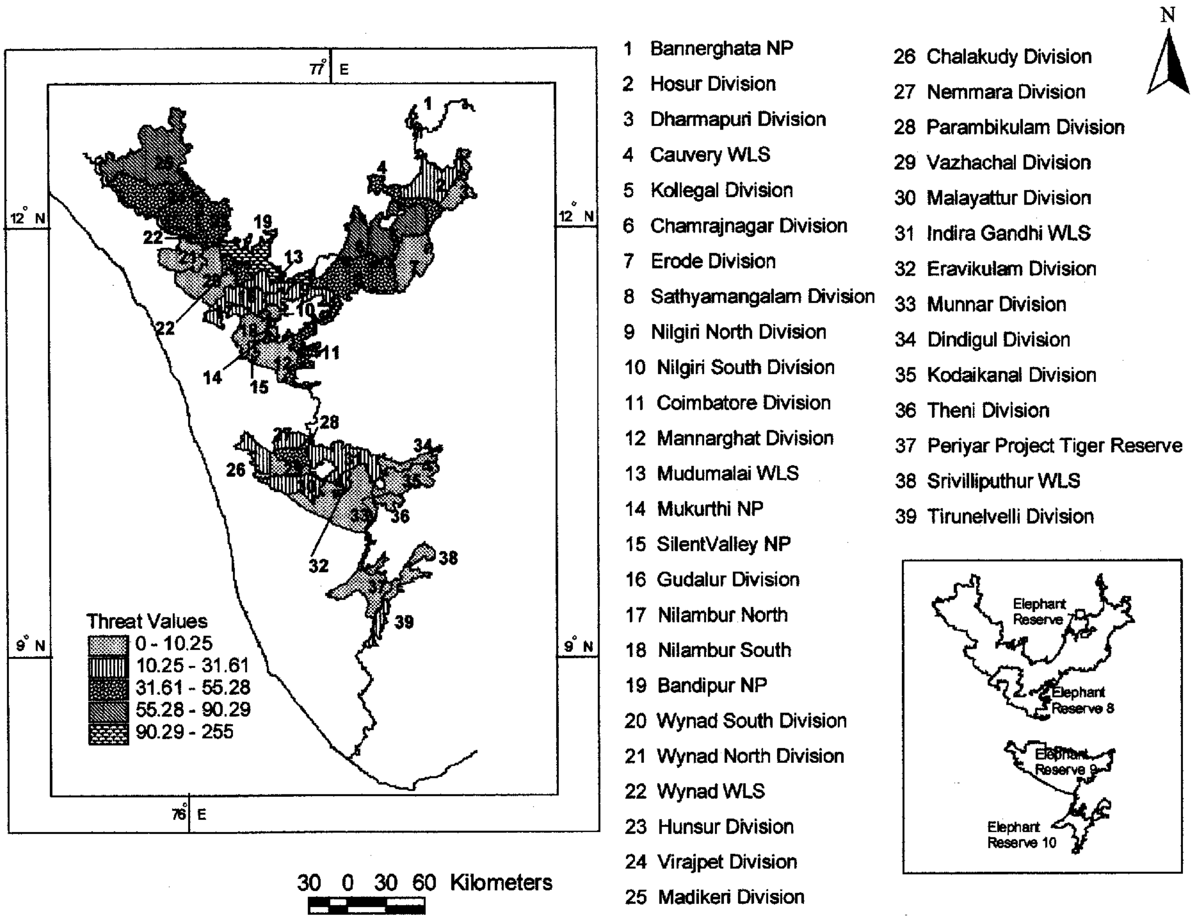


Figure 3. Threat values of 39 forest divisions.

Conservation values for 39 forest administrative divisions (Table 6) were grouped into classes and each class was assigned a unique shading (Figure 2). The class with the highest conservation values (Table 6) includes Sathyamangalam Division (1), Bandipur National Park (2), Hunsur Division (3) and Indira Gandhi Wildlife Sanctuary (4). Cluster analysis (Table 4) indicates that the conservation values of these divisions are high because of large elephant distribution and preferred habitat (5; Table 5), a large number of endemic species and elephant distribution area (2: Table 5) and high elephant numbers and large elephant distribution area (6; Table 5). The divisions with the lowest conservation values are Tirunelvelli Division (37), Dindigul (38) and Srivilliputhur Wildlife Sanctuary (39). All these divisions, in addition to three others (34, 35, 36), belong to a cluster whose dominant criterion is a high level of fragmentation.

Cluster 4 comprises 20 divisions which have no dominant criterion. Cluster 1 contains seven divisions which are unique in terms of the number of endemic species they harbour. Four of these divisions contain montane forests and grasslands which account for the high level of endemicity. The remaining three have mid and low-elevation evergreen forests which are also considered vegetation types with high levels of biodiversity.

Divisions with high conservation values also have high threat values ($r = 0.52$, $P < 0.01$; $df = 38$; Pearson's product moment correlation; threat values are given in Table 6 and Figure 3). To understand this further, we also correlated the threat value with four criteria (fragmentation index, elephant numbers, elephant distribution area and preferred habitat area) in a multiple regression. Only elephant number returned a significant correlation ($r = 0.43$; $P < 0.01$; $df = 38$). This clearly indicates that a large number of elephants results in more intense crop-raiding and attracts ivory poachers.

The design of a conservation strategy based on the analysis of our GIS database follows two levels. The first level involves the spatial relationship of an assemblage of divisions with varying conservation values. On examining elephant reserve 7 in Figure 2, we find three contiguous divisions, the Sathyamangalam Division (1), the Bandipur Project Tiger Reserve (3) and the Hunsur

Wildlife Division (4) with high conservation values. Further east, we have divisions with relatively lower conservation values. There almost appears to be a west-to-east gradient of decreasing conservation values. This may, on one hand, reflect a shift from the larger, more intact forests along the foothills of the Western Ghats to smaller, more fragmented tracts as one moves eastwards. On the other hand, this could also reflect a simple gradient in the efficacies of management given that most eastern divisions are not protected areas. We can therefore declare a set of divisions as 'core zones' and 'augmentation zones' in order to maintain a single, large viable population. In this case the divisions, Sathyamangalam (1; Table 6), Bandipur National Park (2) and Hunsur (3) could comprise the 'core zone' and Hosur (6), Cauvery Wildlife Sanctuary (14), Kollegal (5), Chamrajnagar (7), Erode (8), Mudumalai Wildlife Sanctuary (9), Nilgiri North (11) and Wynad Sanctuary (13) could comprise the 'augmentation zone' of the elephant reserve.

The value of other divisions resides on facilitating the natural movement of elephants. Conservation values, largely influenced by elephant-related criteria, could be greatly enhanced within this 'augmentation zone', if they are specifically targeted for funding and pragmatic management strategies. Strategies could possibly include direct conservation measures for increasing elephant numbers and improving the quality of habitat. These include greater law enforcement to curb poaching, identifying, securing and augmenting elephant 'corridors', and replacing monoculture plantations with natural vegetation. Such strategies could be distinct from those utilized in the core area, where elephant numbers are high and good quality habitat exists. The latter could primarily focus on capacity building of field staff for increased efficiency in management and enforcement. Elephant–human conflict is high around such areas and it is essential that such conflicts be addressed on a high priority to ensure sustained acceptance among local people of protected areas. Designing an elephant reserve would therefore benefit from such spatial analysis and an examination of the key problems threatening elephants and habitats within specific divisions. However one must note that conservation values in certain smaller divisions (e.g. Mudumalai Sanctuary) with high elephant numbers may be somewhat lower, because of lower elephant distribution areas and preferred habitat areas. These divisions may be re-assigned to the core zone after examining the individual criteria.

Appendix 1.

Vegetation maps analysed:

1. Institut de la carte internationale du tapis vegetal, 1985, Nilgiri Hills, India. Maps of the main vegetation types from Landsat imagery.
2. Pascal, J-P., Forest map of south India, Mercara-Mysore, Karnataka and Kerala Forest Departments and the French Institute, Pondicherry.

Statistics of imagery analysed

Path and row	Date	Percentage cloud cover	Band combinations classified
P025 R 061 of IRS-1B, LISS II	5 August 1997	2–5	3, 2,1 out of 4 bands
P025 R 062 of IRS-1B, LISS II	5 August 1997	2–5	3, 2, 1 out of 4 bands
P026 R 061 of IRS-1B, LISS II	5 August 1997	2–5	3, 2, 1 out of 4 bands
P026 R 062 of IRS-1B, LISS II	5 August 1997	2–5	3, 2, 1 out of 4 bands

Survey of India topographical sheets used and year of survey

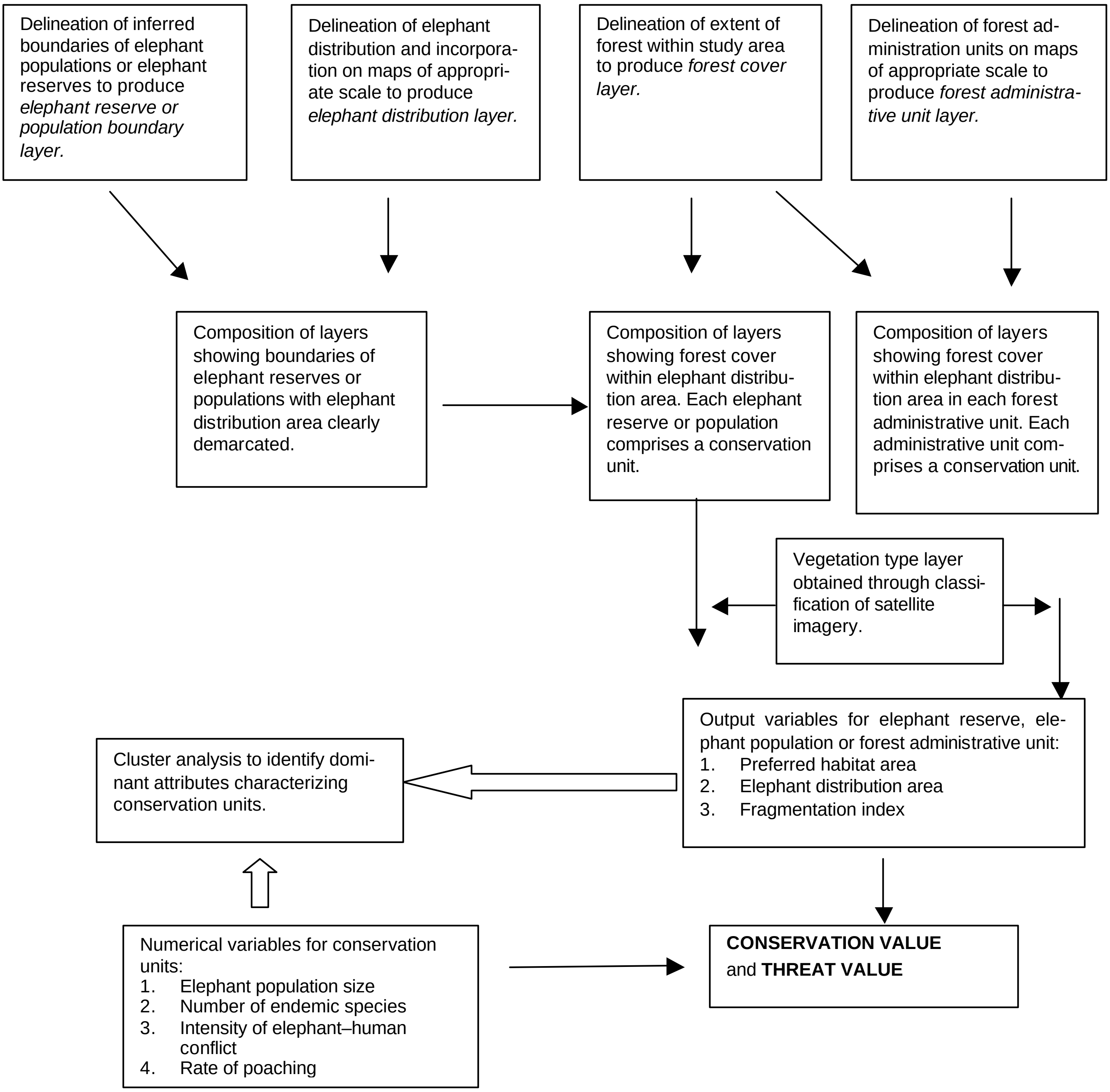
Map number	Year(s) of survey
48 O	1975–76, 1977–79
48 P	1967–69
57 D	1971–73
57 H	1970–75
58 A	1966–68, 1967–73, 1975–77
58 B	1966–67, 1968–69, 1975–77
58 C	1965–67, 1968–69, 1976–77
58 E	1967–68, 1969–70, 1971–74
58 F	1971–73, 1976–77
58 G	1975–77
58 H	1914–15, 1917–20 (forest boundaries not subjected to verification)

Appendix 2.

Conservation units could be:

1. Geographical areas holding unique elephant populations. The boundary of the geographical area may be inferred. The actual elephant distribution within may be less than the inferred area. Such conservation units are appropriate for parts of southeast Asia where delineation of protected areas or forest administrative units is still to occur.
2. Elephant reserves, each of which holds single populations, e.g. Project Elephant Reserves in India.
3. Forest administrative units, e.g. forest divisions in India.

The conservation valuation process described in this paper is summarized in the flow chart given below.



The second level involves classifying divisions in accordance with dominant criteria and analysing these criteria more objectively. This exercise, in addition to providing an intrinsic understanding of conservation values, allows for objective decision making for fund allocation and the design of conservation strategies. For example, clusters 1 and 2 (Table 5) both have number of endemic species as a dominant criterion. However cluster 2 is also characterized by a large elephant distribution area in contrast to cluster 1. The divisions in cluster 2 may therefore be targeted for conservation funding and action more pertinent to promoting the elephant as a flagship species. Consequently, divisions in cluster 1 may be tacitly omitted from elephant conservation funding schemes, given that biodiversity conservation funding may also promote elephant conservation. Similarly, divisions in clusters 5 and 6 are distinct in having elephant distribution area and elephant numbers as the dominant criterion, respectively. This implies that augmenting elephant numbers in divisions comprising cluster 5, given that large elephant distribution and preferred habitat area exist, is a priority. Divisions in cluster 3 are highly fragmented. Large-scale habitat restoration programmes, not necessarily falling under the purview of elephant conservation funding, may once again indirectly promote elephant conservation.

On comparing our method with that used for delineating TCUs[7], we would like to highlight an important difference. There has been less emphasis on incorporating prevailing administrative boundaries (except for degree of overlap with protected areas) into the analysis and the TCUs delineated are largely independent of the existing protected-area system. Our analysis is however highly influenced by the existing forest administration system, both in terms of data collection and ultimate conservation valuation which allows for prioritization of existing elephant conservation units (ECUs). It does not prescribe redefinition of ECUs and at the most, only suggests areas for augmentation. However, it does permit zonation of ECUs into priority and non-priority areas. This is where the aims of the two techniques converge. The number of criteria used in our analysis is greater than that used for the TCUs. This was feasible given that the elephant populations of southern India are better studied than are tigers in most of south and southeast Asia and the units of data collection, the forest divisions, are relatively smaller and better monitored, facilitating collection of better-quality data.

Extensive surveys of elephant habitats and regular censusing of populations in southern India have facilitated the prioritization of habitats and populations. In recent times there has been a steady increase in our understanding of the status and distribution of elephants and other large mammals of southeast Asia[30]. However, the above analysis has not incorporated prevailing political scenarios, which eventually do influence government will in implementing conservation action. Variance in government will for conservation is of less significance in south India. This is not necessarily true for a number of southeast Asian range states (e.g. Indonesia, Cambodia). We would therefore urge that this factor be incorporated realistically and imaginatively in an analysis of populations and habitats using the framework described above, for other range states in southeast Asia. Furthermore, given that isolation of elephant populations is of great concern in southeast Asia, levels of genetic diversity among populations should also be included as an important criterion.

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Identification and usage of multiples in crustal seismics – An application in the Bengal Basin, India

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Multiple seismic phases associated with deeper horizons have been observed in long-range seismic refraction sections. These have been successfully distinguished from the primary events and utilized to build crustal velocity–depth section along Gopali–Port Canning profile, Bengal Basin.

PHASE identification is the basic component of seismic data processing. The phase may correspond to primary events like refraction, reflection, diffraction and converted wave. In addition, multiples of various kinds are observed in some cases depending on the geological setting of the region. These phases in favourable circumstances can be identified and distinguished from the primary using the difference in their arrival times. These multiples (conventionally viewed as 'noise') have been utilized as 'seismic signals' to build up velocity–depth models[1–3].

Crustal velocity–depth section[4] was built along a profile in West Bengal Basin (Figure 1; first arrival refraction and later arrival wide-angle reflections) using only primary phases. Crustal section along this profile, viz. Gopali–Port Canning provided velocity–depth details of the sedimentary column, basement and sub-basement crust. Subsequently, an additional layer has been introduced[5] at the lower crustal level utilizing only primary phases. As the record sections of Gopali–Port Canning contain significantly high amplitude multiples, 2D velocity–depth sections down to the basement have been built[2,3] by using free surface multiple diving waves and multiple reflections. These velocity–depth sections, generated by using multiples were better constrained to claim higher accuracy. These sections have brought into focus the finer variations in the velocity gradients in different shallower layers, which otherwise could not have been obtained from the processing of primary phases alone.

The multiples associated with deeper layers have neither been identified nor utilized earlier. Refraction seismograms of Gopali–Port Canning profile are seen to have several strong phases even at a distance of 80 to 130 km away from the source. These phases are seen intermixing with the primary phases. Seismograms of all the shot points contain the phases that are identified as peg-leg multiples[6–8] and reflected refractions[1,9,10]. These are the multiple events reflected from deeper boundaries (basement, sub-basement and the Moho). In the subsequent exercise, modelling of primary events along with the multiples has been carried out. These newly identified phases have thus been utilized to test and modify the crustal velocity model derived earlier[5]. In the process nearly all the prominent phases, which were present in the observed seismograms but remained unexplained have been synthetically reproduced, for increasing confidence in the constructed model.

Multiples are reflections that have undergone more than one bounce. It means that the wave gets reflected by the same or another reflector one or more times and returns to the surface to be recorded by the geophones[11].

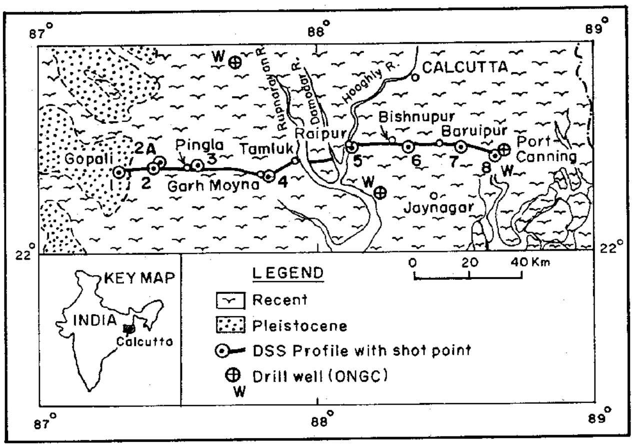

Figure 1. Location map of Gopali–Port Canning profile in West Bengal Basin on the geological map of the region.

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