

# Conservation planning for the Western Ghats of Kerala: I. A GIS approach for location of biodiversity hot spots

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**For the state of Kerala, we have attempted to identify potential areas for conservation by integrating several map themes, ranging from vegetation types, landuse/landcover, endemic plant and bird and larger mammal distribution and abundance. We also investigate the relationships between forest fragmentation and density of large mammals over the entire state. It is shown that there is a significant effect of shape of patches of evergreen forest on the lion-tailed macaque population. We conclude with an agenda and an action plan for biodiversity conservation planning for the Western Ghats of Kerala.**

THE Rio Declaration calls upon the Contracting Parties to draw National Biodiversity Action plans (NBA) for implementing the Convention on Biological Diversity (CBD)<sup>1</sup>. The post Rio Convention in 1997 has again called upon signatories to CBD to put the action plans and biodiversity legislation into practice. India is a signatory to CBD and efforts are underway to prepare comprehensive and site-specific NBA. For a mega-diversity country such as India where two globally recognized hot spots of biodiversity are known to exist, this indeed is a great task. In order to prioritize habitats and species for conservation and to reconcile development with biodiversity conservation goals, we would require spatially explicit data and information.

In this paper, we show how such an information and data base can be organized with the existing sources of data, at least as a 'first cut' draw up to plan more detailed site-specific studies; to take up management action plans for conservation, and to organize data bases. The study spanned the entire Western Ghats of Kerala. We address in this paper (i) an evaluation of status of habitats across all forest divisions of the state, (ii) assessment changes in the habitats over the last three decades, (iii) a geographical analysis of select endemic plant species distribution *vis-à-vis* protected areas, (iv)

examination of distribution and abundance patterns of six mammal species and relating to landscape variables, and (v) assessing the concordance of endemic bird species abundance with that of mammals.

## Study area

The study area which consists of all of the 20 forest divisions (Table 1) is confined to the Western Ghats. No attempt was made to cover mangroves and wetlands. The sources of map data, use of GIS systems, digitization, errors in data capture, accuracy and resolution of the maps are described elsewhere<sup>2</sup>. A substantial amount of information is available on endemic plants<sup>3-8</sup>, birds<sup>9,10</sup>, mammals<sup>11-19</sup>, human-animal conflicts<sup>20,21</sup> and spatial data use<sup>22,23</sup>.

## GIS approach

The approach used in this paper is to concentrate efforts in obtaining (i) distribution data of select endemic plant species from herbarium records to conduct a gap analysis of protected areas, (ii) distribution and abundance of key mammal species to obtain a comprehensive picture of status of localities outside the Protected Area (PA) system, and (iii) distribution and abundance of select endemic and IUCN bird threat categories in eight divisions to check concordance between bird and mammal 'hot spots'. In the final and concluding stage, prioritized areas for long-term conservation are suggested.

## The data

The data consist of (i) maps of vegetation and landuse/landcover respectively in 1961 and in 1988 and forest division boundaries, (ii) herbarium records of distribution of endemic taxa, (iii) census details of six mammals, viz. two megaherbivores (elephant and gaur), two primates (lion-tailed macaque and Nilgiri langur), one ungulate (sambar deer) and one carnivore (wild

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dog), (iv) quantitative field data on tree, shrub and herb layers in eight potential forest divisions of Kerala<sup>24</sup>, (v) avian abundance in these localities including endemic, rare and endangered species, and (vi) available checklist of birds. It may be mentioned here that due to availability of biological data at the forest division level and since forest managers and other users need information predominantly at the division level, GIS analyses were conducted on this spatial unit.

### Digitization and analysis

Landuse/landcover maps of 1:250,000 scale covering all of Kerala at division level depicting the forest habitats were digitized. The French Institute maps of 1:1 million scale depicting the forest types in 1961 were also digitized. Forest division boundaries as they existed in early 1990s were obtained and were used. However, there have been some changes in the number of divisions. Further details are given elsewhere<sup>2</sup>.

PC ARC/INFO 3.5, ERDAS Imagine 8.2 and IDRISI 4.1 were used for all analyses. The point data on geographical distribution of 100 endemic plant species were converted into an ARC/INFO coverage by importing the dBase file. The coverage was subsequently used in conjunction with other thematic details such as vegetation in ERDAS Imagine 8.2.

### Map classification agreement

The results of cross tabulation of two time interval data for the 20 divisions indicate an overall good agreement

between the two sources of data except for Thenmala and Kothamangalam divisions. The Kappa coefficient of agreement was found to be between 0.70 and 0.85 for Vazhachal, Parambikulam, Munnar, Wynaad and Periyar Wildlife divisions. However, the agreement for individual categories within each division was often found to be poor especially for the evergreen/semi-evergreen habitat. This is obviously due to transformation into other categories of habitat.

### Status of habitats

The division-wise details of habitats are given in Table 2. The four divisions of Ranni, Munnar, Periyar-Wildlife and Wayanad alone make up more than 50% of the evergreen/semi-evergreen habitat. The five divisions of Munnar, Palakkad, Nilambur, Ranni and Wayanad account for approximately 50% of the deciduous forest category. Approximately 50% of the forest plantations are located in Vazhachal, Parambikulam, Thenmala, Ranni and Chalakudi. About 50% of degraded areas are located in Palakkad, Munnar and Wayanad. The areal extent reported<sup>2</sup> differs from the present estimate because of lack of a geographical projection. However, this does not alter the conclusions of the study.

### Historical changes in habitat (1961–88)

The divisions that witnessed maximal changes of conversion from evergreen vegetation to deciduous vegetation were Nilambur, Palakkad, Kothamangalam and Parambikulam. Together, these four divisions contributed

Table 1. Area (km<sup>2</sup>) of forest cover in 1988 in various forest divisions of Kerala

| Division           | Deciduous | Degraded/<br>scrub | Evergreen/<br>semi-evergreen | Plantations | Non-forest | Total    |
|--------------------|-----------|--------------------|------------------------------|-------------|------------|----------|
| Chalakudi          | 157.45    | 0.00               | 33.36                        | 140.12      | 880.93     | 1211.86  |
| Konni              | 5.36      | 0.00               | 0.00                         | 132.62      | 693.93     | 831.91   |
| Kothamangalam      | 176.28    | 37.39              | 8.01                         | 80.12       | 109.52     | 411.32   |
| Kottayam           | 119.07    | 70.89              | 121.69                       | 42.82       | 2955.95    | 3310.42  |
| Kozhikode          | 131.56    | 23.92              | 192.72                       | 5.32        | 2646.58    | 3000.1   |
| Malayattoor        | 149.71    | 114.96             | 54.80                        | 24.05       | 2582.83    | 2926.35  |
| Munnar             | 434.04    | 289.73             | 415.45                       | 17.37       | 919.06     | 2075.65  |
| Nemmara            | 192.10    | 12.00              | 26.69                        | 17.34       | 858.74     | 1106.87  |
| Nilambur           | 422.93    | 37.25              | 186.25                       | 118.40      | 2286.82    | 3051.65  |
| Palakkad           | 430.15    | 310.17             | 146.45                       | 7.99        | 2921.85    | 3816.61  |
| Parambikulam       | 96.07     | 2.67               | 24.02                        | 196.13      | 93.38      | 412.27   |
| Periyar-WL         | 260.93    | 116.41             | 279.72                       | 17.40       | 121.76     | 796.22   |
| Punalur            | 4.02      | 1.34               | 0.00                         | 64.34       | 1237.11    | 1306.81  |
| Ranni              | 394.99    | 49.54              | 512.80                       | 168.74      | 2343.89    | 3469.96  |
| Thenmala           | 188.98    | 58.96              | 175.57                       | 182.23      | 148.74     | 754.48   |
| Thrissur           | 120.02    | 0.00               | 0.00                         | 85.33       | 1257.63    | 1462.98  |
| Thiruvananthapuram | 136.80    | 84.51              | 119.37                       | 88.50       | 1695.65    | 2124.83  |
| Vazhachal          | 44.05     | 24.03              | 141.50                       | 234.95      | 125.50     | 570.03   |
| Wayanad            | 327.96    | 133.80             | 217.58                       | 18.56       | 5021.49    | 5719.39  |
| Wayanad-WL         | 187.30    | 1.33               | 0.00                         | 37.20       | 67.74      | 293.57   |
| Total              | 3979.77   | 1368.9             | 2655.98                      | 1679.53     | 28969.10   | 38653.28 |

to over 60% of the change (Table 2). The increase of 194 km<sup>2</sup> of evergreen forests in Periyar-WL division could be ascribed to (i) actual change that has taken place, (ii) due to misclassification in 1960 mapping by the French Institute, and (iii) mapping errors/misclassification in 1988 mapping or a combination of all the above. These three causes may well be the reason for increase in all other divisions as well.

The deciduous forests have decreased in 10 out of 20 forest divisions. These are Thenmala, Vazhachal, Konni, Punalur, Thiruvananthapuram, Kozhikode, Ranni, Chalakudi, Kottayam and Malayattoor. In the remaining divisions, the increase ranged from 33 km<sup>2</sup> in Kothamangalam to 411 km<sup>2</sup> in Nilambur. The degraded/scrub category witnessed a decline in Periyar-WL. This decline is accompanied by an increase in deciduous, evergreen, plantations and non-forest categories.

The massive increase of forest plantations in Parambikulam from 1.62 to 47.57% of the area has important consequences for the management of forestry *vis-à-vis* biodiversity conservation. The marginal decline in the extent of plantations in Thrissur and Wayanad is perhaps due to the failure of plantations to rejuvenate after the extraction or due to errors in interpretations of satellite imagery. A study by Menon<sup>25</sup> indicates degradation of forests in Thrissur division.

### Old growth forest

It would be worthwhile therefore to analyse the extent of 'old growth forest' remaining intact especially for the evergreen habitat. An 'old growth' forest for the

purpose of this study may be defined as that category of evergreen/semi-evergreen forest that is common to 1961 and 1988 maps. We obtained such an estimate for all 20 divisions by taking the limits of evergreen forests from the French Institute Map and overlaying it on the landuse/landcover map. From these results, it is apparent that the extent of 'old growth' forests is only 37% of that of deciduous and evergreen/semi-evergreen forests. In the evergreen/semi-evergreen category, the largest extent (> 100 km<sup>2</sup>) prevails in the divisions of Ranni, Nilambur, Palakkad, Thenmala and Munnar. Eight divisions have less than 50 km<sup>2</sup> old growth and 3 divisions have between 50 and 100 km<sup>2</sup> (Table 3). Similarly the forest divisions harbouring more than 100 km<sup>2</sup> of 'old growth' deciduous forest are Munnar, Wynaad Wildlife and Ranni. Nine divisions have old growth spread over an area of 50–100 km<sup>2</sup>. It would be interesting to assess the composition, structure and dynamics of these old growth forests in contrast to the successional stages<sup>26</sup>.

### Endemic plant species

The choice of species (Appendix 1) was largely dictated by the availability of locality information of the specimens on herbarium sheets and does not denote that they occur in Kerala alone. A substantial number of these species seem to occur in moist deciduous habitat. The distribution maps indicate that most of the collections so far done are outside the protected areas (PA). This does not necessarily imply that present day PA system is inadequate. It is not exactly known how many of

Table 2. Area (km<sup>2</sup>) of forest cover in 1961 in various forest divisions of Kerala

| Division           | Deciduous | Degraded/<br>scrub | Evergreen/<br>semi-evergreen | Plantations | Non-forest | Total    |
|--------------------|-----------|--------------------|------------------------------|-------------|------------|----------|
| Chalakudi          | 268.21    | 0.00               | 74.73                        | 21.35       | 847.57     | 1211.86  |
| Konni              | 188.88    | 0.00               | 0.00                         | 2.68        | 651.07     | 842.63   |
| Kothamangalam      | 142.91    | 0.00               | 252.39                       | 0.00        | 18.70      | 414.00   |
| Kottayam           | 179.31    | 357.06             | 283.43                       | 0.00        | 2495.97    | 3315.77  |
| Kozhikode          | 273.75    | 0.00               | 300.36                       | 0.00        | 2436.61    | 3010.72  |
| Malayattoor        | 188.43    | 104.28             | 217.88                       | 0.00        | 2418.43    | 2929.02  |
| Munnar             | 225.71    | 268.61             | 599.72                       | 0.00        | 978.93     | 2072.97  |
| Nemmara            | 13.34     | 0.00               | 165.43                       | 0.00        | 930.76     | 1109.53  |
| Nilambur           | 11.98     | 0.00               | 689.00                       | 0.00        | 2342.69    | 3043.67  |
| Palakkad           | 102.58    | 31.98              | 615.13                       | 0.00        | 3077.60    | 3827.29  |
| Parambikulam       | 28.02     | 0.00               | 220.16                       | 25.35       | 138.73     | 412.26   |
| Periyar-WL         | 65.58     | 584.78             | 85.65                        | 0.00        | 64.22      | 800.23   |
| Punalur            | 184.97    | 0.00               | 0.00                         | 0.00        | 1119.16    | 1304.13  |
| Ranni              | 512.79    | 199.50             | 587.79                       | 57.59       | 2127.02    | 3484.69  |
| Thenmala           | 414.06    | 0.00               | 297.55                       | 0.00        | 57.63      | 769.24   |
| Thrissur           | 152.03    | 0.00               | 0.00                         | 92.01       | 1216.28    | 1460.32  |
| Thiruvananthapuram | 280.31    | 0.00               | 217.27                       | 0.00        | 1644.69    | 2142.27  |
| Vazhachal          | 245.63    | 0.00               | 236.27                       | 0.00        | 89.46      | 571.36   |
| Wayanad            | 70.38     | 25.23              | 285.45                       | 88.95       | 5184.43    | 5654.44  |
| Wayanad-WL         | 140.82    | 0.00               | 0.00                         | 0.00        | 131.50     | 272.32   |
| Total              | 3689.69   | 1571.44            | 5128.21                      | 287.93      | 27971.45   | 38648.72 |

these endemic species would occur in the PAs if a fresh survey were to be mounted now. A study in Shendurney<sup>7</sup> has shown the widespread occurrence of endemic species considered hitherto rare.

It is interesting to observe that the distribution of endemic trees for Kerala Western Ghats, carried out by the French Institute<sup>38</sup>, Pondicherry also follows similar pattern. It would therefore seem that existing information *per se* would be inadequate to rely upon assessing the gaps in coverage of PA system, and representativeness. In the absence of data, the best that can be done is to couple the available distribution data with the biophysical parameters such as rainfall, temperature and landuse to model a plausible functional relationship.

## Mammals

The choice of six mammal species is due to availability of consistent data and of representativeness of habitat of these species in evergreen and deciduous biomes. The census data of 1993 (KFD<sup>27</sup>) were used to derive

**Table 3.** An estimate of 'old growth' forest in different forest divisions of Kerala

| Division           | Deciduous      | Degraded/scrub | Evergreen/semi-evergreen | Plantation     |
|--------------------|----------------|----------------|--------------------------|----------------|
| Chalakkudi         | 81.39          | 0.00           | 20.01                    | 140.12         |
| Kothamangalam      | 69.43          | 37.39          | 8.01                     | 80.12          |
| Kottayam           | 64.16          | 15.90          | 15.87                    | 42.82          |
| Kozhikode          | 55.74          | 23.92          | 98.30                    | 5.32           |
| Konni              | 5.36           | 0.00           | 0.00                     | 132.62         |
| Malayattoor        | 61.57          | 28.01          | 9.32                     | 24.05          |
| Munnar             | 160.29         | 5.57           | 125.38                   | 17.37          |
| Nemmara            | 11.95          | 0.00           | 26.69                    | 17.34          |
| Nilambur           | 0.00           | 23.92          | 186.25                   | 118.40         |
| Palakkad           | 54.05          | 2.75           | 142.62                   | 7.99           |
| Parambikulam       | 15.99          | 2.67           | 21.34                    | 196.13         |
| Periyar-WL         | 17.46          | 95.80          | 44.14                    | 17.40          |
| Punalur            | 4.02           | 1.34           | 0.00                     | 64.34          |
| Ranni              | 117.91         | 9.35           | 286.39                   | 168.74         |
| Thenmala           | 68.37          | 58.96          | 134.00                   | 182.23         |
| Thiruvananthapuram | 95.21          | 84.51          | 95.28                    | 88.50          |
| Thrissur           | 65.26          | 0.00           | 0.00                     | 85.33          |
| Vazhachal          | 29.35          | 24.03          | 96.12                    | 234.95         |
| Wynaad             | 52.47          | 0.00           | 9.06                     | 18.56          |
| Wynaad-WL          | 129.21         | 1.33           | 0.00                     | 37.20          |
| <b>Total</b>       | <b>1159.19</b> | <b>415.60</b>  | <b>1318.78</b>           | <b>1679.53</b> |

**Table 4.** Density (per km<sup>2</sup>) classes of large mammals based on direct and indirect evidences (modified from KFD, 1994)

| Mammals                      | Density/km <sup>2</sup> |          |        |
|------------------------------|-------------------------|----------|--------|
|                              | Low                     | Medium   | High   |
| Elephant (individuals)       | ≤ 0.5                   | 0.5–1    | > 1    |
| Gaur (dung)                  | ≤ 500                   | 500–1000 | > 1000 |
| Lion-tailed macaque (number) | ≤ 0.5                   | 0.5–1    | > 1    |
| Nilgiri langur (number)      | ≤ 5                     | 5–15     | > 15   |
| Sambar deer (number)         | ≤ 1                     | 1–2      | > 2    |
| Wild dog (scats)             | ≤ 75                    | 75–150   | > 150  |

the ecological densities in each of the divisions. The data used are obviously based on both direct and indirect evidences and use less than desirable units such as individuals rather than troops for lion-tailed macaque and Nilgiri langur. The broad habitat categories of evergreen/semi-evergreen, deciduous and scrub were used. Ecological densities were obtained by using the habitat data. The mammal densities were categorized into high, medium and low for each of the species based on direct and indirect evidences (Table 4). Indirect evidences are used as surrogates for a number of 'difficult' species. Thus a given division can have ranking for all six species. Divisions were then prioritized based on these scores. Thus a division having 3 high and 3 medium densities is scored higher than a division having 3 high and 3 low density categories. A composite score was obtained by adding individual species rank. Thus a division can have a maximum value of 18 and a minimum of 0. This composite score was then used for prioritizing localities of long-term conservation significance. The actual values obtained through this method ranged from 13 in Parambikulam to 2 in Punalur and Kozhikode (Table 5, Figures 1–3).

It should be noted here that these abundance estimates are one-time census efforts and could vary over seasons. However, as the census was done in summer, where limiting factors such as fodder, water and fire play important role in habitat use, the abundance estimates would be of considerable management significance and hence merit broader conservation planning attention.

Table 6 gives distribution of various forest divisions in three abundance categories of mammals. It is striking to note that Nilgiri langur and Sambar do not either occur or do so in low abundance in a majority of

**Table 5.** Overall ranking of divisions for mammal density

| Division           | Elephant | Gaur | Nilgiri langur | Lion-tailed macaque | Sambar | Wild dog | Overall rank |
|--------------------|----------|------|----------------|---------------------|--------|----------|--------------|
| Parambikulam       | 1        | 3    | 3              | 3                   | 2      | 1        | 13           |
| Ranni              | 2        | 1    | 3              | 1                   | 3      | 2        | 12           |
| Nilambur           | 1        | 1    | 3              | 3                   | 2      | 2        | 12           |
| Nemmara            | 1        | 1    | 3              | 3                   | 2      | 1        | 11           |
| Thiruvananthapuram | 2        | 1    | 2              | 2                   | 2      | 2        | 11           |
| Periyar-WL         | 3        | 1    | 0              | 1                   | 0      | 3        | 8            |
| Thenmala           | 1        | 1    | 0              | 2                   | 0      | 3        | 7            |
| Wynaad-WL          | 2        | 2    | 0              | 2                   | 0      | 1        | 7            |
| Munnar             | 1        | 1    | 0              | 1                   | 0      | 3        | 6            |
| Palakkad           | 1        | 0    | 1              | 1                   | 1      | 2        | 6            |
| Malayattoor        | 1        | 1    | 0              | 2                   | 0      | 2        | 6            |
| Wynaad             | 1        | 1    | 1              | 0                   | 1      | 1        | 5            |
| Chalakkudy         | 1        | 1    | 0              | 1                   | 0      | 2        | 5            |
| Vazhachal          | 1        | 1    | 0              | 2                   | 0      | 1        | 5            |
| Konni              | 2        | 1    | 0              | 0                   | 0      | 2        | 5            |
| Kottayam           | 1        | 1    | 0              | 1                   | 0      | 1        | 4            |
| Kothamangalam      | 1        | 2    | 0              | 0                   | 0      | 0        | 3            |
| Thrissur           | 0        | 1    | 0              | 0                   | 0      | 2        | 3            |
| Kozhikode          | 0        | 1    | 0              | 0                   | 0      | 1        | 2            |
| Punalur            | 0        | 0    | 0              | 0                   | 0      | 2        | 2            |

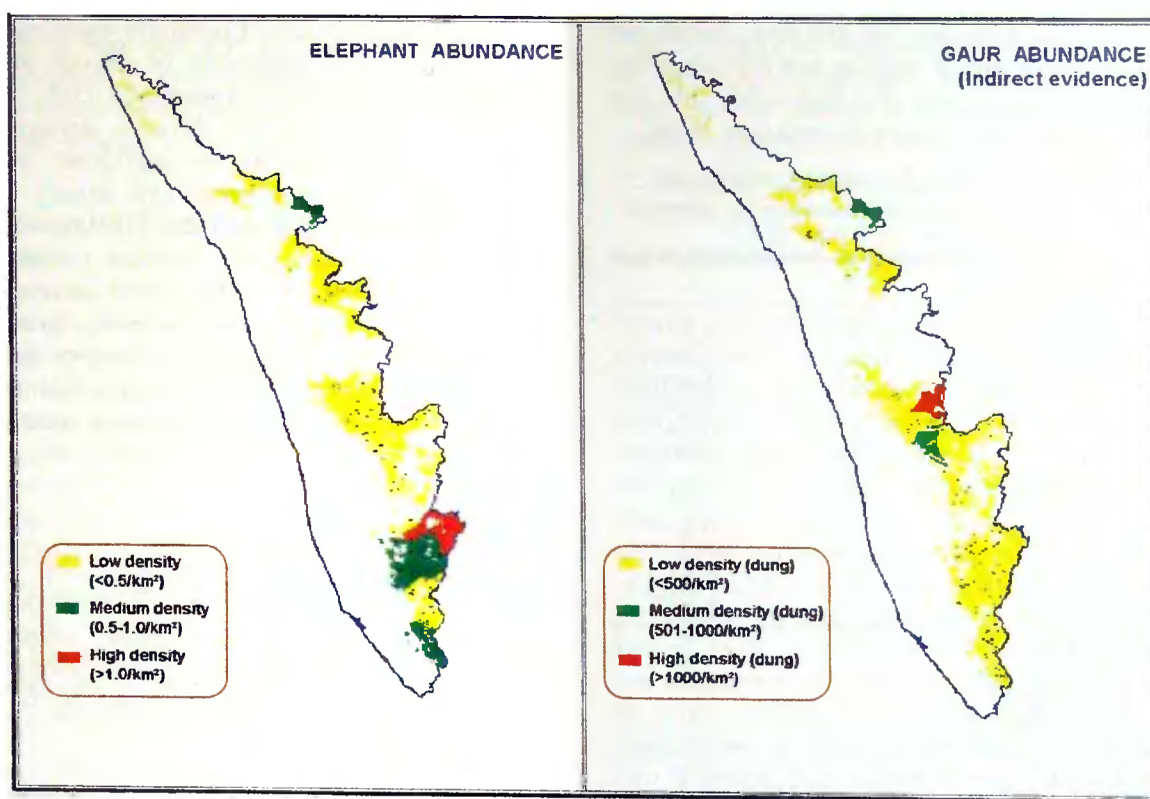


Figure 1. Megaherbivore abundance. [Source: Forest Statistics-1993, Govt of Kerala].

Table 6. Distribution of various forest divisions in Kerala with respect to mammal abundance

| Density category | Elephant   | Gaur   | Nilgiri langur  | Lion-tailed macaque  | Sambar  | Wild dog   |
|------------------|--|--|---|--|---|--|
| Nil              | Punalur, Thrissur, Kozhikode   | Punalur, Palakkad  | Punalur, Konni, Thenmala, Kottayam, Malayattur, Kothamangalam, Vazhachal, Chalakudy, Thrissur, Kozhikode, Munnar, Wynaad-WL, Periyar-WL | Punalur, Konni, Kothamangalam, Thrissur, Kozhikode, Wynaad     | Punalur, Konni, Thenmala, Kottayam, Malayattur, Kothamangalam, Vazhachal, Chalakudy, Thrissur, Kozhikode, Munnar, Wynaad-WL, Periyar-WL | Kothamangalam  |
| Low              | Thenmala, Kottayam, Malayattur, Kothamangalam, Vazhachal, Parambikulam, Chalakudy, Nemmara, Palakkad, Nilambur, Wynaad, Munnar | Thiruvananthapuram, Konni, Thenmala, Ranni, Kottayam, Malayattur, Vazhachal, Chalakudy, Nemmara, Thrissur, Nilambur, Kozhikode, Wynaad, Munnar, Periyar-WL | Palakkad, Wynaad  | Ranni, Kottayam, Chalakudy, Palakkad, Munnar, Periyar-WL       | Palakkad, Wynaad  | Kottayam, Vazhachal, Parambikulam, Nemmara, Kozhikode, Wynaad, Wynaad-WL                       |
| Medium           | Thiruvananthapuram, Konni, Ranni, Wynaad-WL  | Kothamangalam, Wynaad-WL   | Thiruvananthapuram  | Thiruvananthapuram, Thenmala, Malayattur, Vazhachal, Wynaad-WL | Thiruvananthapuram, Parambikulam, Nemmara, Nilambur   | Thiruvananthapuram, Punalur, Konni, Ranni, Malayattur, Chalakudy, Thrissur, Palakkad, Nilambur |
| High             | Periyar-WL   | Parambikulam   | Ranni, Parambikulam, Nemmara, Nilambur  | Parambikulam, Nemmara, Nilambur                                | Ranni   | Thenmala, Munnar, Periyar-WL   |

the divisions. The reasons may be due to excessive pressures—both direct and indirect—on these species. In fact, except for wild dog, all the five species are confined to 3–8 divisions at medium and high densities. Although many factors may be responsible for this decline, we analyse the changes at landscape level.

**Table 7.** Spearman rank correlation coefficient ( $r_s$ ) between animal density and landscape ecological parameters (a), perimeter/area ratios (P/A) and shape index (Di)

| Animal              | Parameter | N  | $r_s$   |
|---------------------|-----------|----|---------|
| Elephant            | P/A ratio | 20 | 0.312   |
|                     | Di        | 20 | 0.289   |
| Gaur                | P/A ratio | 20 | -0.251  |
|                     | Di        | 20 | -0.298  |
| Wild dog            | P/A ratio | 20 | 0.069   |
|                     | Di        | 20 | 0.049   |
| Sambar              | P/A ratio | 9  | 0.48    |
|                     | Di        | 9  | 0.537   |
| Nilgiri langur      | P/A ratio | 9  | 0.38    |
|                     | Di        | 9  | 0.38    |
| Lion-tailed macaque | P/A ratio | 20 | 0.563** |
|                     | Di        | 20 | 0.565** |

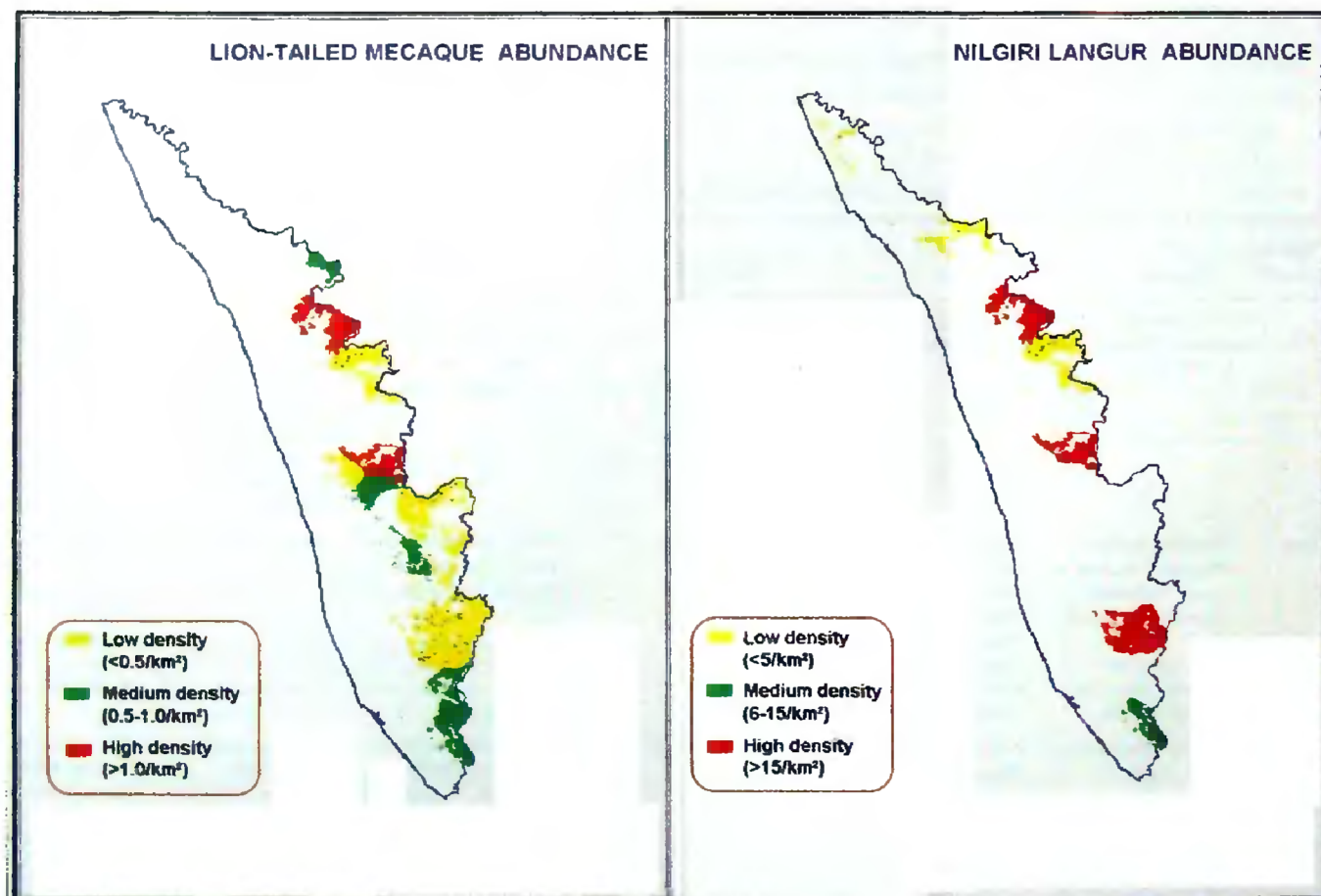
\*\*Significance at 0.01 level.

$$\text{Shape index (Di)} = \frac{\text{Perimeter}}{2/(\text{Area} \times B)}$$

In order to do so, we employ two indices, viz. perimeter/area and shape index of the forest fragments in each of the divisions. Essentially these two related indices indicate the availability of interior of a patch available to an organism. Spearman's rank correlation coefficient<sup>29</sup>  $r_s$  was computed between density and the landscape measure. There is significant correlation between landscape parameters and density of LTM ( $r_s = 0.563$ ;  $p < 0.01$ ;  $N = 20$ , Table 7). However, for the remaining five species, no significant correlation was found. It is necessary to include other parameters such as connectivity, patch size, porosity, juxtaposition, interspersation for evaluating the impacts of forest fragments on these species before we conclude the applicability or otherwise of these landscape measures.

### Bird species

There are 16 endemic bird species and many 'disjuncts' in Western Ghats<sup>9</sup>. The details of methodology for transect sampling, seasons and density estimation are given elsewhere<sup>30</sup>. The bird density was categorized into low, medium and high (Table 8) based on the transect



**Figure 2.** Primate abundance. [Source: Forest Statistics-1993, Govt of Kerala].



sample. The distribution of various forest divisions with respect to avian abundance is given in Table 9. It is worthwhile to note that sparrow hawk and Tytler's leaf warbler occurred at low abundances only in Nemmara. Thus, five of the eight divisions alone were ranked high and may be termed as 'hot spots'.

### Concordance of bird hot spots with that of mammals

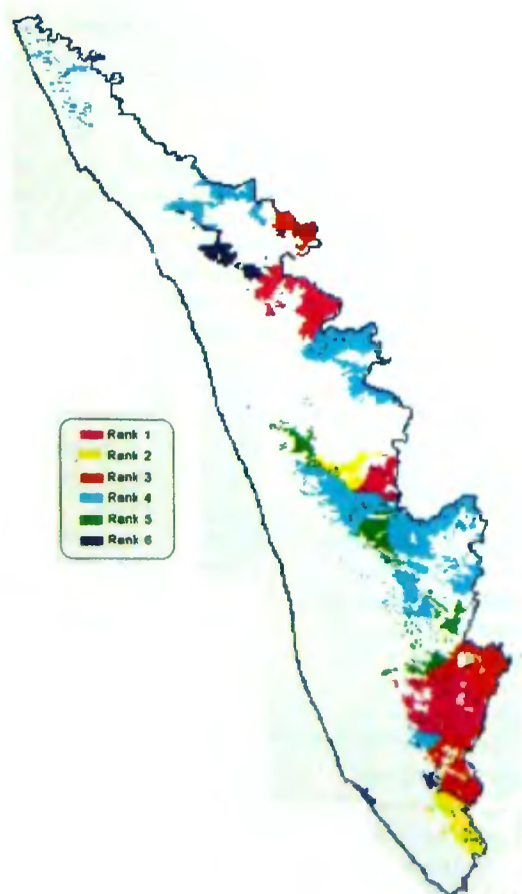
The forest divisions of Ranni, Nilambur and Nemmara alone have a high concordance of large mammal density with that of bird species. Thus the seven species, namely Malabar grey hornbill, crimson-throated barbet, rufous babbler, small sunbird, heart-spotted wood pecker, Indian edible-nest swiftlet and speckled piculet appear to be good avian indicators of abundance of Nilgiri langur, lion-tailed macaque and sambar. This has to be confirmed by conducting studies of larger spatial scales.

Unlike the situation prevailing in distribution mapping of plant species, bird species distribution is relatively well known and is being mapped for the Western Ghats of Kerala. A useful approach in conservation planning

would be to conduct a 'gap analysis of knowledge' first and then proceed with the available information. In case of birds, it may be worthwhile to model presence/absence of habitat, its fragmentation, plant species richness, length of dry season and host of macro and micro climatic variables. Such an analysis would atleast point to the lacunae existing in the present datasets<sup>31-35</sup>

### An agenda and action plan

From a perspective of large mammal and endemic bird species conservation, the much overlooked landmass of Nelliampathy and Anamalai, abutting the Palghat gap hold a lot of conservation promise on medium and long-term time scales. This tract includes the forest divisions of Nemmara, Parambikulam and Anamalais along with various private estates. The extent of landuse in this region should be carefully and critically evaluated to help design conservation goals. The landuse includes private forests, coffee and tea estates, forest tree plantations, hydel projects, cultivations and so on. Besides, we recommend the following: (i) A careful evaluation of forest habitats below 1000–1200 m. (ii) Immediate upgradation of conservation status of Ranni division. (iii) A critical examination of major anthropogenic pressures on all evergreen habitats including coffee, tea and cardamom estates. (iv) An assessment of hydrological values of catchment zones of major reservoirs and river valley projects. (v) Establishment of an ecological monitoring programme. (vi) Integration of biodiversity conservation into state perspective planning at different levels of organization under the aegis of recently



**Figure 3.** Significant localities of long-term conservation of larger mammals.

**Table 8.** Density (no. of birds/4 ha) classes of birds of IUCN categories of Western Ghats

| S.# | Bird                          | Density/4 ha |          |       |
|-----|-------------------------------|--------------|----------|-------|
|     |                               | Low          | Medium   | High  |
| 1   | Grey-headed bulbul            | ≤ 1          | 1–2      | > 2   |
| 2   | Malabar grey hornbill         | ≤ 3          | 3–6      | > 6   |
| 3   | Nilgiri wood pigeon           | ≤ 2          | 2–4      | > 4   |
| 4   | Blue-winged parakeet          | ≤ 1          | 2–10     | > 10  |
| 5   | Crimson-throated barbet       | ≤ 2          | 2–4      | > 4   |
| 6   | Rufous babbler                | ≤ 5          | 5–10     | > 10  |
| 7   | Small sunbird                 | ≤ 7.5        | 7.5–15   | > 15  |
| 8   | White-bellied blue flycatcher | ≤ 2.5        | 2.5–5    | > 5   |
| 9   | White-bellied tree pie        | ≤ 2          | 2–4      | > 4   |
| 10  | Tytler's leaf warbler         | ≤ 0.5        | 0.5–1    | > 1   |
| 11  | Besra sparrow-hawk            | ≤ 0.5        | 0.5–1    | > 1   |
| 12  | Great pied hornbill           | ≤ 0.5        | 0.5–1    | > 1   |
| 13  | Heart-spotted woodpecker      | ≤ 0.72       | 0.75–1.5 | > 1.5 |
| 14  | Indian edible-nest swiftlet   | ≤ 2          | 2–4      | > 4   |
| 15  | Rufous woodpecker             | ≤ 0.5        | 0.5–1    | > 1   |
| 16  | Speckled piculet              | ≤ 1          | 1–2      | > 2   |

IUCN categories of bird species:

Species 1–3: Threatened and endemic

Species 4–9: Common and endemic

Species 10: Threatened and non-endemic

Species 11–16: Near-threatened and non-endemic.

Table 9. Distribution of various forest divisions with respect to the IUCN bird species categories

| S. # | Species                       | Low                                   | Medium  | High   |
|------|-------------------------------|---------------------------------------|---|--|
| 1    | Grey-headed bulbul            | Nemmara                               | Nilambur  | —  |
| 2    | Malabar grey hornbill         | Nemmara                               | Thiruvananthapuram,<br>Chalakudi, Nilambur,<br>Wynaad, Idukki | Ranni  |
| 3    | Nilgiri wood pigeon           | Thiruvananthapuram                    | Wynaad, Idukki  | —  |
| 4    | Blue-winged parakeet          | Thiruvananthapuram,<br>Nilambur       | Ranni   | Chalakudi  |
| 5    | Crimson-throated barbet       | Nemmara, Wynaad                       | Thiruvananthapuram,<br>Chalakudi                              | Ranni, Nilambur,<br>Idukki                           |
| 6    | Rufous babbler                | Thiruvananthapuram,<br>Wynaad, Idukki | Chalakudi   | Ranni  |
| 7    | Small sunbird                 | Thiruvananthapuram,<br>Wynaad         | Ranni, Nemmara,<br>Idukki                                     | Chalakudi, Nilambur                                  |
| 8    | White-bellied blue flycatcher | Nilambur                              | Thiruvananthapuram  | —  |
| 9    | White-bellied tree pie        | Ranni                                 | Chalakudi   | —  |
| 10   | Tytler's leaf warbler         | Nemmara                               | —   | —  |
| 11   | Besra sparrow hawk            | Nemmara                               | —   | —  |
| 12   | Great pied hornbill           | Nemmara                               | Ranni   | —  |
| 13   | Heart-spotted woodpecker      | Nemmara                               | Wynaad  | Thiruvananthapuram,<br>Ranni, Chalakudi,<br>Nilambur |
| 14   | Indian edible-nest swiftlet   | Nilambur                              | Wynaad, Idukki  | Ranni, Chalakudi                                     |
| 15   | Rufous woodpecker             | Wynaad                                | Nilambur  | —  |
| 16   | Speckled piculet              | Wynaad                                | Chalakudi, Nilambur   | Thiruvananthapuram,<br>Ranni                         |

IUCN categories of bird species:

Species 1–3: Threatened and endemic

Species 4–9: Common and endemic

Species 10: Threatened and non-endemic

Species 11–16: Near-threatened and non-endemic.

established Biodiversity Board. (vii) Identification, synchronization and harmonization of various forest management practices being carried out by different agencies. (viii) A peoples' participatory programme in planning, executing and overseeing cooperative biodiversity management such as the peoples' Biodiversity Register.

## Appendix 1

Select endemic plant species of Western Ghats found in Kerala.

### Species

### Species

|                                  |                                     |
|----------------------------------|-------------------------------------|
| <i>Actinodaphne bourdillonii</i> | <i>Aprosa bourdillonii</i>          |
| <i>Actinodaphne tadulingam</i>   | <i>Aspidopterys canarensis</i>      |
| <i>Anaphalis travancorica</i>    | <i>Astergamia macrocarpa</i>        |
| <i>Anaphyllum wightii</i>        | <i>Atuna travancorica</i>           |
| <i>Antistrophe serratifolia</i>  | <i>Bentinkia condapanna</i>         |
| <i>Aphyllorchis montana</i>      | <i>Blepharistemma membranifolia</i> |
| <i>Apollonias arnottii</i>       | <i>Calamus travancoricus</i>        |

### Species

### Species

|                                   |                                  |
|-----------------------------------|----------------------------------|
| <i>Capparis fusifera</i>          | <i>Desmos viridiflorus</i>       |
| <i>Ceropegia beddomei</i>         | <i>Dysoxylon malabaricum</i>     |
| <i>Ceropegia decantiana</i>       | <i>Elaeocarpus venustus</i>      |
| <i>Ceropegia spiralis</i>         | <i>Eugenia discifera</i>         |
| <i>Ceropegia thwaitesii</i>       | <i>Euonymus angulatus</i>        |
| <i>Chilochista pusilla</i>        | <i>Exacum travancoricum</i>      |
| <i>Cinnamomum riparium</i>        | <i>Garcinia indica</i>           |
| <i>Cinnamomum travancoricum</i>   | <i>Glycosmis macrophylla</i>     |
| <i>Claxylon anamalayanum</i>      | <i>Glypopetalum grandiflorum</i> |
| <i>Cleistanthus travancoricus</i> | <i>Gymnostachyum latifolium</i>  |
| <i>Coleogyne mossiae</i>          | <i>Habenaria barnesii</i>        |
| <i>Crotalaria bidiei</i>          | <i>Habenaria multicaudata</i>    |
| <i>Crotalaria clarkii</i>         | <i>Humboldtia decurrens</i>      |
| <i>Crotalaria fysonii</i>         | <i>Indigofera constricta</i>     |
| <i>Crotalaria travancorica</i>    | <i>Indobanalia thyrisifolia</i>  |
| <i>Cryptocarya beddomei</i>       | <i>Ipsa malabarica</i>           |
| <i>Cyclostemon macrophyllum</i>   | <i>Janakia aryapathra</i>        |
| <i>Cyclostemon malabaricum</i>    | <i>Jerdonia indica</i>           |
| <i>Cynometra travancorica</i>     | <i>Kanjaram palghatense</i>      |
| <i>Dalbergia malabarica</i>       | <i>Kunstrela keralense</i>       |
| <i>Debregeesia ceylanica</i>      | <i>Lasianthus dichotomus</i>     |
| <i>Desmodium dolbiforme</i>       | <i>Loesnerilla bourdillonii</i>  |



| Species                            | Species                        |
|------------------------------------|--------------------------------|
| <i>Memeceylon lawsonii</i>         | <i>Phenophyllum lawsonii</i>   |
| <i>Memeceylon talbotianum</i>      | <i>Piper barberi</i>           |
| <i>Milletia rubiginosa</i>         | <i>Podocarpus wallichianus</i> |
| <i>Milusa nilghiricus</i>          | <i>Poeciloneron indicum</i>    |
| <i>Miquellia dentata</i>           | <i>Polygala ramsawamii</i>     |
| <i>Morinda reticulata</i>          | <i>Rawolfia beddomei</i>       |
| <i>Murdonia juncoideis</i>         | <i>Salacia beddomei</i>        |
| <i>Myristica fatua</i>             | <i>Sonerila nemakadensis</i>   |
| <i>Myristica malabarica</i>        | <i>Strobilanthus lawsonii</i>  |
| <i>Nilagirianthus lupinus</i>      | <i>Symplocos macrocarpa</i>    |
| <i>Nilagirianthus nilgherensis</i> | <i>Syzygium travancoricum</i>  |
| <i>Niligiranthus asper</i>         | <i>Thottea dinghoui</i>        |
| <i>Niligiranthus heyneanus</i>     | <i>Toxocarpus palghatensis</i> |
| <i>Niligiranthus urceolaris</i>    | <i>Vannila wightiana</i>       |
| <i>Oberonia chandrasekarnii</i>    | <i>Vateria macrocarpa</i>      |
| <i>Ophiorhiza brunonis</i>         | <i>Vernonia anamallica</i>     |
| <i>Ormosia travancorica</i>        | <i>Vernonia bourdillonii</i>   |
| <i>Orphea uniflora</i>             | <i>Vernonia bourneana</i>      |
| <i>Osbeckia lawsonii</i>           | <i>Vernonia peninsularis</i>   |
| <i>Ottonophellium stipulaicum</i>  | <i>Willisia selaginoides</i>   |
| <i>Peucedanum anamalayensis</i>    | <i>Zeylandium johnsonii</i>    |

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