Short-term population dynamics of tree species in tropical forests at Kodayar in the Western Ghats of Tamil Nadu, India

Somaiah Sundarapandian1, P. Sudhakar Swamy
Department of Plant Sciences, School of Biological Sciences, Madurai Kamaraj University, Madurai – 625021, India
1Present address: Department of Ecology and Environmental Sciences, School of Life Sciences, Pondicherry University, Puducherry - 605014, India
E-mail: smspandian65@gmail.com

Received 5 June 2013; Accepted 10 July 2013; Published online 1 September 2013

Abstract
The population dynamics of tree species were studied in both deciduous and evergreen forests at Kodayar in the Western Ghats of Tamil Nadu. The mortality of trees was less than the number of new recruits, resulting in a net gain in population density and basal area. The increase in net population density and basal area of tree species could be because of their entry into the adult stage from the already existing sapling and seedling bank. Greater mortality of juveniles than that of adults could be due to intense competition for limited available resources at the juvenile stage. The present study concludes that to a larger extent, the forest ecosystems here are at building phase. Long-term studies are needed to understand the regeneration niche.

Keywords regeneration; tree population dynamics; tree mortality; tree recruitment; Western Ghats.

1 Introduction
A tropical forest is a complex and dynamic biotic community, which has a tremendous power of self maintenance through regeneration. In trees, as in almost all organisms, mortality is high in the early stages of life, so that the selection of survivors and the determination of species composition of the forest operate most strongly in young plants; hence the importance of the regeneration “niche” (Grubb, 1977) and the ecologist’s interest are majorly focused in recording short-term changes in population of seedlings and saplings (Swaine and Hall, 1988). Recruitment of viable seeds, their germination, seedling establishment and seedling growth are indicators of the regeneration potential of a plant community. Several long-term studies of tree population dynamics were available in both tropical and temperate forests (Lieberman and Lieberman, 1987; Manokaran and Kochummen, 1987; Hubbell and Foster, 1992; Sukumar et al., 1992; Korning and Henrik, 1994; Condit, 1995; Bhat et al., 2000; Lwanga et al., 2000; Sheil et al., 2000; Rees et al., 2001; Battles et al., 2003; Takahashi et al., 2003; Nagamatsu et al., 2003; Fashing et al., 2004; Phillips et al., 2004: Kariuki et al., 2006)
whereas short-term dynamics of tree populations were reported in few forest ecosystems (Manokaran et al., 1992; Hubbell and Foster, 1992; Homma et al., 2003; Miura and Yamamoto, 2003). However, studies on juvenile tree population dynamics in forest ecosystems in the Western Ghats are very few (Sukumar et al., 1992; Bhat et al., 2000).

Western Ghats of India, because of its geographical location, stable geological history, equable climate, has heavy rainfall and good soil conditions which supports a variety of tropical forest ecosystems. Phyto-geographically these forests are rich, not only with high species diversity but also with several palaeo-endemic species which are botanically a "relict" of an ancient and unique vegetation (Champion and Seth, 1968). During the last few decades these forests were subjected to unscientific exploitation particularly for agriculture, construction of hydro-electric project, raising monoculture plantations (Hevea braziliensis M. Arg.- Rubber, Acacia mangium - Acacia and Tectona grandis L. - Teak) and other developmental activities. Regeneration in many Indian forests, including the forests of Western Ghats, is inadequate to replace the adults (Sukumar et al., 1992). Therefore, in the present study an emphasis was laid to understand the regeneration niche with reference to community dynamics.

Successful conservation of these forest will ultimately depend upon an understanding of forest ecosystem dynamics (Sussman and Rakotozafy, 1994). The ever increasing demand for forest products and forest land, together with the alarming rate of population growth has put the remaining patches of forests on the verge of extinction (Bekele, 1994). A detailed quantitative and qualitative description and regeneration status of the remaining forests are necessary and timely as it will form the basis for future plans to manage and restore these vanishing resources. As part of an integrated research project, a general hypothesis was framed to test the effect of regeneration niche on species composition and ecosystem structure in tropical forest at Kodayar. The evergreen forests are transformed into semi-evergreen and moist deciduous forests because of various biotic and abiotic stresses. Therefore, the present study intends to study the short-term population dynamics of trees (>10 cm GBH; >3 cm DBH) over a three year period.

2 Materials and Methods

2.1 Study area

The study area at Kodayar, tropical forests here comes under the administrative division of Veerapuli and Kalamalai reserve forest and falls within the range of Agastyalalai biosphere reserve, is also one of the hot spots of biodiversity centers in India. Kani tribes (local tribals) are part of the ecosystem here. This forest area has 30 Kani settlements which occupy an area of 6.85 Km$^2$. It is located 400 Km south of Madurai (77°15' E, 8°29' N) and it is at 250-650 m elevation in the Kanyakumari district of Tamil Nadu, South India (Fig. 1). The mean annual rainfall (from south west and north east monsoon) recorded in the study sites was 2338 mm, of which 81% occurred from June to November (Fig. 2). December to March represents a brief dry period. Average monthly maximum and minimum temperatures were 30°C and 26°C in summer and 28°C and 24°C in winter, respectively.

Four different study sites (two each in deciduous forest closer to the village (250 m MSL) and subjected to anthropogenic pressures, and evergreen forest (500 - 650 m MSL)) were selected at Kodayar forest ecosystem for the present study (Table 1). Each study site had divided in to three sub-sites. The species that dominate in site I are Terminalia paniculata Roth, Careya arborea Roxb., Buchanania lanzan Spr., Emblica officinalis Gartner, Dillenia pentagyna Roxb., Pterocarpus marsupium Roxb. and T. arjuna W. & A (Table 2). The herbaceous community is mostly dominated by monocotyledons such as Themeda cymbaria Hack., Themeda sp., Globba orixensis Roxb., Imperata cylindrica Dur. & Sch. and Thespesia lampas Dalz. Site I has been subjected to annual wild fire. Site II is dominated by T. paniculata followed by Aporosa lindleyana Baill. and Xanthophyllum flavescens Roxb. Understorey vegetation is dominated by dicotyledon species such as...
Helicteres isora L. and Chromolaena odoratum L. Site II has also been subjected to anthropogenic perturbations. Site III and IV are undisturbed evergreen forests. The species that dominate these sites are Hopea parviflora Bedd., Syzygium laetum Gandhi, followed by Artocarpus heterophyllus Lam., Isora brachiata Roxb., Syzygium sp., Vateria indica L. and Xanthophyllum flavescens Roxb. Understorey vegetation was dominated by Psychotria nigra L., Psychotria sp. Calamus sp., Memecylon sp. and Isonandra lanceolata W. The contribution of grasses is much lower in site III and IV than in other sites except under open canopies. The species composition was also varied and dominated by Oplismenus compositus Beauv., Panicum sp. etc. under open canopies in the evergreen forests.

Fig. 1 Map of the study area showing location of the study.

Fig. 2 Temperature and rainfall pattern for the study area at Kodayar in the Western Ghats of Tamil Nadu.
### Table 1
Stand characteristics of deciduous (site I and II) and evergreen (III and IV) tropical forest sites at Kodayar in the Western Ghats of Tamil Nadu.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Site I</th>
<th>Site II</th>
<th>Site III</th>
<th>Site IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of species*</td>
<td>58</td>
<td>77</td>
<td>125</td>
<td>158</td>
</tr>
<tr>
<td>Number of tree (&gt;10 cm DBH) species</td>
<td>15</td>
<td>22</td>
<td>37</td>
<td>45</td>
</tr>
<tr>
<td>Tree density (&gt;10 cm DBH) (No./ha)</td>
<td>450</td>
<td>352</td>
<td>748</td>
<td>862</td>
</tr>
<tr>
<td>Basal area of trees (m²/ha)</td>
<td>28.05</td>
<td>33.77</td>
<td>81.38</td>
<td>90.44</td>
</tr>
<tr>
<td>Species type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evergreen species</td>
<td>3</td>
<td>11</td>
<td>37</td>
<td>43</td>
</tr>
<tr>
<td>Species diversity index (tree)</td>
<td>2.20</td>
<td>2.37</td>
<td>2.65</td>
<td>2.61</td>
</tr>
<tr>
<td>Dominance index (tree)</td>
<td>0.142</td>
<td>0.157</td>
<td>0.146</td>
<td>0.153</td>
</tr>
<tr>
<td>Species richness (tree)</td>
<td>3.87</td>
<td>5.80</td>
<td>9.14</td>
<td>7.61</td>
</tr>
<tr>
<td>Evenness index (tree)</td>
<td>1.87</td>
<td>1.77</td>
<td>1.69</td>
<td>1.58</td>
</tr>
<tr>
<td>Level of disturbances</td>
<td>Very high (Fire)</td>
<td>Moderate</td>
<td>Little</td>
<td>Little</td>
</tr>
</tbody>
</table>

*includes trees, shrubs, herbs and all climbers in the study sites (0.5 ha in all the study sites except site III - 0.25 ha)

### Table 2
Phytosociological analysis of tree community (> 10 cm DBH; values based on 50 quadrats of 10 x 10 m in all the study sites except for site III- 25 quadrats) in the deciduous (site I and II) and evergreen (III and IV) tropical forest sites at Kodayar in the Western Ghats of Tamil Nadu. D - density; B.A. - basal area.

<table>
<thead>
<tr>
<th>Name of the species</th>
<th>Site I</th>
<th>Site II</th>
<th>Site III</th>
<th>Site IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>B.A</td>
<td>D</td>
<td>B.A.</td>
</tr>
<tr>
<td></td>
<td>No/ha</td>
<td>m²/ha</td>
<td>No/ha</td>
<td>m²/ha</td>
</tr>
<tr>
<td><em>Aglaia barberi</em> Gamble</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Antiaris toxicaria</em> Leach.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Antidesma zeylanicum</em> Lam.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><em>Aporosa lindleyana</em> Baill.</td>
<td>-</td>
<td>-</td>
<td>52</td>
<td>3.57</td>
</tr>
<tr>
<td><em>Artocarpus heterophyllus</em> Lam.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><em>A. hirsuta</em> Lam.</td>
<td>-</td>
<td>4</td>
<td>0.13</td>
<td>-</td>
</tr>
<tr>
<td><em>Baccaurea courtallensis</em> M. Arg.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Beilschmiedia gemmiflora</em> Kosterm.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><em>Beryya cordifolia</em> (Willd.) Burret.</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>0.03</td>
</tr>
<tr>
<td><em>Bridelia crenulata</em> Roxb.</td>
<td>14</td>
<td>0.19</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Buchanania lanzan</em> Spr.</td>
<td>74</td>
<td>2.53</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Calophyllum polyanthum</em> Wall. Ex Choisy</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><em>Carallia brachiata</em> (Lour.) Merr.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Careya arborea</em> Roxb.</td>
<td>52</td>
<td>2.42</td>
<td>12</td>
<td>1.05</td>
</tr>
<tr>
<td><em>Canthium curtailensis</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><em>C. malabarica</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td><em>Cullenia excelsa</em> Wt.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><em>Cycas sp.</em></td>
<td>2</td>
<td>0.07</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Species</td>
<td>Code</td>
<td>Exponent</td>
<td>Width</td>
<td>Exponent</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------</td>
<td>----------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>Dalbergia latifolia Roxb.</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>0.49</td>
</tr>
<tr>
<td>Dillenia pentagyna Roxb.</td>
<td>42</td>
<td>1.90</td>
<td>8</td>
<td>0.70</td>
</tr>
<tr>
<td>Dimocarpus longan Lour.</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>0.03</td>
</tr>
<tr>
<td>Diospyros bourdilloni Brandis</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>32</td>
</tr>
<tr>
<td>D. paniculata Dalz.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dipterocarpus indicus Bedd.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Dysoxylum beddomei</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Emblica officinalis Gaertn.</td>
<td>42</td>
<td>0.68</td>
<td>4</td>
<td>0.07</td>
</tr>
<tr>
<td>Eugenia thwaitesii Duthie</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ficus hispida L.f.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ficus sp.</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>0.09</td>
</tr>
<tr>
<td>Garcinia travancorica Bedd.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Gluta travancorica Bedd.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>48</td>
</tr>
<tr>
<td>Gomphandra tetrandra Sleumer</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Gordonia obtusa</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Grewia tiliaefolia Vahl.</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>0.06</td>
</tr>
<tr>
<td>Holarrhena sp.</td>
<td>-</td>
<td>-</td>
<td>44</td>
<td>1.23</td>
</tr>
<tr>
<td>Hopea parviflora Bedd.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>244</td>
</tr>
<tr>
<td>Hopea sp.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hunteria corymbosa Roxb.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Hydnocarpus alpina Wt.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>48</td>
</tr>
<tr>
<td>Hymenodictyon oritense (Roxb.)</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>0.03</td>
</tr>
<tr>
<td>M. philippensis M.Arg.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>Mangifera indica L.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Mesua ferrea L.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Myristica dactyloides Gaertn.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>24</td>
</tr>
<tr>
<td>Neolitsea zeylanica (Nees)Merr.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Odina wodier Roxb.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Olea dioica Roxb.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Phaeanthus malabaricus Bedd.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Polyalthia wightii Thw.</td>
<td>2</td>
<td>0.03</td>
<td>12</td>
<td>2.03</td>
</tr>
<tr>
<td>Prunus ceylanica (Wt.) Miq.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pterocarpus marsupium Roxb.</td>
<td>36</td>
<td>6.36</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pterospermum diversifolium Bl.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P. rubiginosum W. &amp;Arn.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sapindus emarginatus Vahl.</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>0.38</td>
</tr>
<tr>
<td>Schleichera oleosa (Lour.)Oken.</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>0.44</td>
</tr>
<tr>
<td>Scolopia crenata (W. &amp; A.)Clos.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Stereospermum personatum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>(Hassk.) Chatterjee</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syzygium laetum Gandhi</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>S. gardneri Thw.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>S. mundagam (Bourd.) Chithira</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>Syzygium sp.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
2.2 Methods
Thirty randomly located 10 m × 10 m study plots (permanent quadrats; 10 in each sub-site) were established in all the study sites. All the living trees (≥10 cm GBH- Girth at breast height) were tagged, identified and measured the girth at 1.3 m (breast) height. All the study plots (permanent quadrats) were recensused after three years. In second census (after three years from the initial census) new recruits into the ≥10 cm GBH categories were also taken into account. The diameter increment, mortality and recruitment of trees were calculated based on initial and final census data (Lieberman et al., 1985; Manokaran et al., 1992).

Percentage of annual mortality was calculated as (Sheil et al., 1995):

\[
\text{Annual mortality} = (1 - (N_t/N_0)(1/ny)) \times 100\%
\]

where \(N_t\) = number of survivors at time \(t\), \(N_0\) = original number of trees, \(ny\) = number of years between samples.

One way ANOVA was used to find out significant differences among the sites in the density of the soil seed bank and the mortality and recruitment rates of trees.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Site I</th>
<th>Site II</th>
<th>Site III</th>
<th>Site IV</th>
<th>Sig. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>Total number of trees (&gt;10 cm GBH) at the beginning of the study period trees/ha</td>
<td>740&lt;sup&gt;a&lt;/sup&gt;</td>
<td>570&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1320&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1530&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Total number of trees (&gt;10 cm GBH) at the end of the study period trees/ha</td>
<td>810&lt;sup&gt;a&lt;/sup&gt;</td>
<td>660&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1370&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1700&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Number of dead trees during the three years study period trees/ha</td>
<td>80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>220&lt;sup&gt;c&lt;/sup&gt;</td>
<td>240&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Number of newly recruited trees during the three years study period</td>
<td>150&lt;sup&gt;a&lt;/sup&gt;</td>
<td>140&lt;sup&gt;a&lt;/sup&gt;</td>
<td>270&lt;sup&gt;b&lt;/sup&gt;</td>
<td>410&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Basal Area</td>
<td>Basal area (m²/ha) at the beginning of the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
study period\(^{\text{a}}\) & 30.4\(^{\text{a}}\) & 30.2\(^{\text{a}}\) & 81.8\(^{\text{b}}\) & 107\(^{\text{c}}\) & *** \\

Basal area (m\(^{2}\)/ha) of dead trees during three years study period\(^{\text{b}}\) & 2.7\(^{\text{a}}\) (8.9\%) & 0.9\(^{\text{b}}\) (3\%) & 7.8\(^{\text{b}}\) (9.5\%) & 8.7\(^{\text{c}}\) (8.11\%) & *** \\

Basal area (m\(^{2}\)/ha) of new recruits during the three years study period\(^{\text{c}}\) & 0.42\(^{\text{a}}\) (1.4\%) & 0.41\(^{\text{a}}\) (1.4\%) & 1.08\(^{\text{b}}\) (1.3\%) & 1.86\(^{\text{c}}\) (1.7\%) & *** \\

Increase in basal area (m\(^{2}\)/ha) of existing survival species\(^{\text{d}}\) & 4.4\(^{\text{a}}\) (14.5\%) & 3.3\(^{\text{a}}\) (10.9\%) & 7.7\(^{\text{b}}\) (9.4\%) & 12.8\(^{\text{c}}\) (11.9\%) & *** \\

Basal area (m\(^{2}\)/ha) at the end of the study period. A-B+C+D & 32.52\(^{\text{a}}\) & 33.01\(^{\text{a}}\) & 82.88\(^{\text{b}}\) & 112.96\(^{\text{c}}\) & *** \\

Different letter(s) on the same rows indicates significant differences; *** P<0.01, ** P<0.05

### 3 Results

Population dynamics and structural attributes of trees in all the study sites are given in Table 3. Evergreen forest sites (III & IV) had significantly (P< 0.05) greater density and basal area per hectare than deciduous forest sites (I & II). Similar trends were observed for mortality and recruitment in these sites. Mortality was lower in all the study sites than recruitments. As a result, there was a net gain in population density over three years. Similarly an increase in basal area per hectare also was observed.

<table>
<thead>
<tr>
<th>Name of the species</th>
<th>Site 1</th>
<th>Site II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Alstonia scholaris</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aporosa lindleyana</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Artocarpus hirsutus</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Buchanania lanzan</td>
<td>140</td>
<td>130</td>
</tr>
<tr>
<td>Bridelia crenulata</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Careya arborea</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>Cassia fistula</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Cycas sp.</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Dalbergia latifolia</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dillenia pentagyna</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Dimocarpus longan</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Emblica officinalis</td>
<td>110</td>
<td>100</td>
</tr>
<tr>
<td>Ficus sp.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Grevia tiliaeolia</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Helicteres isora</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Holarrhena pubescens</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Isora brachiata</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Macaranga peltata</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mallotus philippensis</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4 Tree (>10 cm GBH) population dynamics (recruits and deaths during three years study period) in the deciduous (site I and II) tropical forest sites at Kodayar in the Western Ghats of Tamil Nadu.

IAEES  www.iaees.org
Table 4 and 5 showed the contribution of individual species to total tree population structure in all the study sites. *T. paniculata* and *B. lanzan* showed greater density in site I, while in site II, *H. isora, A. lindleyana* and *T. paniculata* showed greater density. However, in evergreen forest sites (III & IV), *H. parviflora*, *Syzygium laetum, I. brachiata, V. indica, X. flavescens* and *Gluta travancorica* showed greater density. *I. brachiata, Ficus, Olea dioica, D. longan* and *X. flavescens* were common species found in both deciduous and evergreen sites. Percentage of mortality was significantly (P<0.05) greater in evergreen forest (16.67% in site III; 15.69% in site IV) than in deciduous forests (10.81% in site I; 8.77% in site II). Percentage of mortality of trees ranged from 4.5 in *H. parviflora* to 66.7% in *Orophea erythrocarpa*. *Bredelia crenulata, O. dioica, Nothopegia travancorica, O. erythrocarpa, Agrostistachys indica, Antidesma zeylanicum, Ficus sp., H. alpina, I. lanceolata* and *Syzygium sp.* had high rates mortality (≥50%) whereas species with greater densities such as *B. lanzan, E. officinalis, T. paniculata, S. laetum, I. brachiata* and *H. parviflora* had lower rates mortality (≤10%). However, no mortality was observed in 9 species in site I, 16 species in site II, 11 species in site III and 17 species in site IV during the three year study period.

**Table 5** Tree (>10 cm GBH) population dynamics (recruits and deaths during three years study period) in the evergreen (site III and IV) tropical forest sites at Kodayar in the Western Ghats of Tamil Nadu.

<table>
<thead>
<tr>
<th>Name of the species</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aglaia barberi</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Agrostistachys indica</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>10</td>
<td>50</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Alstonia scholaris</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Antidesma zeylanicum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>10</td>
<td>50</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Artocarpus hirsutus</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Baccaraea courtallensis</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Canthium dicoccum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Chionanthus malabaricus</td>
<td>30</td>
<td>20</td>
<td>33</td>
<td>10</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>C. leprocarpa</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>20</td>
<td>33</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Dimocarpus longan</td>
<td>30</td>
<td>20</td>
<td>33</td>
<td>10</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Diospyros sp.</td>
<td>50</td>
<td>40</td>
<td>20</td>
<td>10</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>25</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Diospyros pruriens</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>40</td>
<td>-</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td>Species</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>----</td>
<td>------</td>
<td>----</td>
<td>-----</td>
<td>------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dipterocarpus indicus</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eugenia sp.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ficus sp.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garcinia travancorica</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gluta travancorica</td>
<td>100</td>
<td>70</td>
<td>30</td>
<td>20</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gomphandra tetandra</td>
<td>40</td>
<td>20</td>
<td>50</td>
<td>20</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hopea parviflora</td>
<td>300</td>
<td>270</td>
<td>10</td>
<td>-</td>
<td>210</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hopea sp.</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydnocarpus alpina</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isonandra lanceolata</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ixora brachiata</td>
<td>120</td>
<td>100</td>
<td>17</td>
<td>10</td>
<td>170</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ixora sp.</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kingiodendron pinnatum</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lepisanthes decipiens</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mallotus philippensis</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mangifera indica</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measua ferrea</td>
<td>20</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myristica dactyloides</td>
<td>50</td>
<td>40</td>
<td>20</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. malabarica</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neolitsea zeylanica</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nothopegia travancorica</td>
<td>20</td>
<td>10</td>
<td>50</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olea dioica</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orophea erythrocarpa</td>
<td>30</td>
<td>10</td>
<td>67</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phaeanthus malabaricus</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>70</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prunus ceylanica</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychotria sp.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>50</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pterospermum diversifolium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. rubiginosum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scoparia crenata</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>20</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stereospermum personatum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syzygium gardneri</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. laetum</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>20</td>
<td>280</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. mundagam</td>
<td>20</td>
<td>20</td>
<td>-</td>
<td>20</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syzygium sp.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vateria indica</td>
<td>120</td>
<td>100</td>
<td>17</td>
<td>10</td>
<td>170</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitex altissima</td>
<td>50</td>
<td>40</td>
<td>20</td>
<td>40</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xanthophyllum flavescens</td>
<td>110</td>
<td>100</td>
<td>9</td>
<td>20</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>140</td>
<td>130</td>
<td>7</td>
<td>20</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A = Initial density (No./ha); B = Density (No./ha) at recensus (survival of tagged trees); C = Mortality (%); D = New recruits (No./ha); E = Final density (No./ha).

Recruitment of juveniles (>10 cm GBH- < 30 cm GBH) were significantly (P<0.01) greater in evergreen forests than in deciduous forests (Tables 3, 4, and 5). The species with greater tree density such as T. paniculata and E. officinalis (site I), I. brachiata and V. indica (Site III & IV) showed poor regeneration (≤11.8%). Even though H. parviflora had greater density (site III & IV), no juveniles were found during the study period. A. lindleyana and M. philippensis were new recruits in site I and II respectively. However, the adults of these were not accounted in the initial census. There was no recruitment of 6 species in site I, 12 species in site II, 10 species in site III and 15 species in site IV.
Tree population showed an increase in density per ha after three years in the second census. Net change in population size remains the same for 9 species in site I, 14 species in site II, 14 species in site III and 21 species in site IV. An increase in population size was recorded for 7 species in site I, 5 species in site II and 5 species in site III and 12 species in site IV whereas reduction in net change in population size was accounted for one species in site I, 6 species in site III and 3 species in site IV. In all the study sites the percentage of mortality was low but recruitment was moderately higher.

The mortality of tree species in two size classes is presented in Table 6. In general, smaller trees (tree sapling stage; >3 cm - <10 cm DBH) had greater mortality rates than larger trees. Larger trees (>10 cm DBH) such as *Ficus* sp., *Mesua ferrea*, *V. indica* and one unidentified tree died during the study period. The dominant tree species in evergreen forests such as *G. travancorica*, *H. parviflora*, *I. Brachiata*, *Psychotria* sp. and *S. laetum* showed a high percentage of mortality at the juvenile stage.

<table>
<thead>
<tr>
<th>Species</th>
<th>Site I</th>
<th>Site II</th>
<th>Site III</th>
<th>Site IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td><em>Agrostistachys indica</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Antidesma zeylanicum</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Aporosa lindleyana</em></td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Bridelia crenulata</em></td>
<td>12.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Buchanania lanzan</em></td>
<td>12.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Chionanthus malabaricus</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td><em>C. leprocarpa</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
</tr>
<tr>
<td><em>Careya arborea</em></td>
<td>12.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Dillenia pentagyna</em></td>
<td>12.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Dimocarpus longan</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td><em>Diospyros sp.</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td><em>Emblica officinalis</em></td>
<td>12.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Ficus sp.</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
</tr>
<tr>
<td><em>Gluta travancorica</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>13.6</td>
</tr>
<tr>
<td><em>Gomphandra tetrandra</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9.1</td>
</tr>
<tr>
<td><em>Helicteres isora</em></td>
<td>-</td>
<td>60</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Holarrhena pubescens</em></td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Hopea parviflora</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>13.6</td>
</tr>
<tr>
<td><em>Hydnocarpus alpina</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
</tr>
<tr>
<td><em>Isandra lanceolata</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
</tr>
<tr>
<td><em>Isora brachiata</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9.1</td>
</tr>
<tr>
<td><em>Mallotus philippensis</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.3</td>
</tr>
<tr>
<td><em>Mesua ferrea</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
</tr>
<tr>
<td><em>Myristica dactyloides</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td><em>Nothopegia travancorica</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td><em>Olea dioica</em></td>
<td>12.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Orophea erythrocarpa</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td><em>Phaeanthus malabaricus</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
</tr>
<tr>
<td><em>Prunus ceylanica</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
</tr>
<tr>
<td><em>Psychotria sp.</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.3</td>
</tr>
<tr>
<td><em>Scolopia crenata</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
</tr>
</tbody>
</table>
**Syzygium laetum**

**Syzygium sp.**

**Terminalia paniculata** 12.5

**Vateria indica**

**Vitex altissima**

**Xanthophyllum flavescens**

**Others** - 12.5

---

**Fig. 3** Size class distribution of initial census and recensus (after three years from the initial census) of juvenile (>3-<10 cm DBH) population in tropical forests at Kodayar in the Western Ghats of Tamil Nadu.
Fig. 4 Size class distribution of initial census and recensus (after three years from the initial census) of adults (>10 cm DBH) tree population in tropical forests at Kodayar in the Western Ghats of Tamil Nadu.

The size class distributions of the initial census and recensus (after three years from the initial census) are given in Fig. 3 and 4. The DBH distribution of tree species in both the deciduous and evergreen forests showed a “L” shaped curve. The DBH distribution of saplings (>3 cm - <10 cm DBH) also showed a similar pattern for both the forests except in site I. In all the study sites, the 10-20 cm DBH size class increased from initial census to recensus. A decline of the 9-10 cm DBH size class was observed in all the study sites at the time of
recensus. However, the 3-4 cm DBH size class distribution was comparatively greater at the time of final-recensus.

Percentage of mortality of juveniles and adult trees were significantly (P<0.05) greater in evergreen forest (site III & IV) than in deciduous forests (site I & II; Table 7). However, stand half-life values showed lower in evergreen forests compared to deciduous forests in case of both juvenile population and adult population.

<table>
<thead>
<tr>
<th>Study location</th>
<th>Plot area (ha)</th>
<th>Time interval</th>
<th>Mortality (%)</th>
<th>Annual Mortality (λ)</th>
<th>Percentage of Annual Mortality</th>
<th>Stand half-life t (0.50) Years</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Selva Costa Rica</td>
<td>4 - 4.4</td>
<td>13</td>
<td>20.9 - 25.3</td>
<td>0.018</td>
<td>-</td>
<td>-</td>
<td>31 - 39</td>
</tr>
<tr>
<td>Kade, Ghana</td>
<td>2</td>
<td>12</td>
<td>19.8</td>
<td>0.022*</td>
<td>-</td>
<td>-</td>
<td>38</td>
</tr>
<tr>
<td>Barro Colorado Island, Panama,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young forest</td>
<td>5</td>
<td>5</td>
<td>8.7</td>
<td>0.018*</td>
<td>-</td>
<td>-</td>
<td>53</td>
</tr>
<tr>
<td>Old forest</td>
<td>2</td>
<td>5</td>
<td>5.2</td>
<td>0.011*</td>
<td>-</td>
<td>-</td>
<td>68</td>
</tr>
<tr>
<td>Bukit Lagong, Malaysia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sepilok, Malaysia</td>
<td>1.6</td>
<td>10</td>
<td>12.3</td>
<td>0.013*</td>
<td>-</td>
<td>-</td>
<td>53</td>
</tr>
<tr>
<td>Pasoh Forest Reserve, Malaysia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All species</td>
<td>50</td>
<td>3</td>
<td>6.88</td>
<td>0.024</td>
<td>2.34</td>
<td>34.1</td>
<td>Manokaran et al. (1992)</td>
</tr>
<tr>
<td>21 common species</td>
<td>50</td>
<td>3</td>
<td>6.90</td>
<td>0.024</td>
<td>2.35</td>
<td>28.7</td>
<td></td>
</tr>
<tr>
<td>Whole plot</td>
<td>50</td>
<td>3</td>
<td>3.81</td>
<td>0.013</td>
<td>1.28</td>
<td>53.2</td>
<td></td>
</tr>
<tr>
<td>Western Ghats, Kodayar, India</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site I</td>
<td>0.3</td>
<td>3</td>
<td>10.81</td>
<td>0.038</td>
<td>3.74</td>
<td>17.83</td>
<td>Present study</td>
</tr>
<tr>
<td>Site II</td>
<td>0.3</td>
<td>3</td>
<td>8.77</td>
<td>0.031</td>
<td>3.01</td>
<td>22.30</td>
<td></td>
</tr>
<tr>
<td>Site III</td>
<td>0.3</td>
<td>3</td>
<td>16.67</td>
<td>0.061</td>
<td>5.89</td>
<td>11.06</td>
<td></td>
</tr>
<tr>
<td>Site IV</td>
<td>0.3</td>
<td>3</td>
<td>15.69</td>
<td>0.060</td>
<td>5.21</td>
<td>11.84</td>
<td></td>
</tr>
<tr>
<td>Pasoh Forest Reserve, Malaysia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All species</td>
<td>50</td>
<td>3</td>
<td>7.63a</td>
<td>0.027a</td>
<td>2.60a</td>
<td>25.84a</td>
<td></td>
</tr>
<tr>
<td>19 common species</td>
<td>50</td>
<td>3</td>
<td>7.68a</td>
<td>0.027a</td>
<td>2.63a</td>
<td>25.68a</td>
<td>Manokaran et al. (1992)</td>
</tr>
<tr>
<td>Whole plot</td>
<td>50</td>
<td>3</td>
<td>3.93a</td>
<td>0.014a</td>
<td>1.33a</td>
<td>51.55a</td>
<td></td>
</tr>
<tr>
<td>Western Ghats, Kodayar, India</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site I</td>
<td>0.3</td>
<td>3</td>
<td>24.1c</td>
<td>0.092c</td>
<td>8.79c</td>
<td>7.18c</td>
<td>Present study</td>
</tr>
<tr>
<td>Site II</td>
<td>0.3</td>
<td>3</td>
<td>22.9e</td>
<td>0.087c</td>
<td>8.31c</td>
<td>7.63c</td>
<td></td>
</tr>
<tr>
<td>Site III</td>
<td>0.3</td>
<td>3</td>
<td>53.76c</td>
<td>0.143c</td>
<td>13.35c</td>
<td>4.48c</td>
<td></td>
</tr>
<tr>
<td>Site IV</td>
<td>0.3</td>
<td>3</td>
<td>32.93c</td>
<td>0.133c</td>
<td>12.46c</td>
<td>4.91c</td>
<td></td>
</tr>
</tbody>
</table>

*Annual mortality was calculated by using the formula \( \lambda = \log_e \left( \frac{N_0}{N_1} \right) / t \); where No = beginning population, N1 = end population, and t = time interval between the measurements. a = 1 - < 5 cm diameter class; b = >5 cm diameter class; c = >3 - < 10 cm diameter class; d = >10 cm diameter class.
Discussion

One of the characteristic features of tropical forests is high species richness. Mean total number of tree species (≥10 cm GBH) recorded in the study plots (permanent quadrats) ranged 17-37 per 0.1 ha. This value is at the lower side of the ranges (20-223) given for wet evergreen forests (Proctor et al., 1983; Whitmore, 1975) and tropical forests in the Western Ghats (Pascal, 1988). The tree density (>10 cm DBH) and basal area recorded in the present study (permanent quadrats) are greater than those values reported by others (Campbell et al., 1986; Thompson et al., 1992; Rao and Mishra, 1994; Ganesh et al., 1996). This differences could be due to smaller sampling size, species composition, age and degree of disturbances (Sundarapandian and Swamy, 2000; Swamy et al., 2000).

Generally, plant recruitment and mortality depend upon variable climatic events. Germination and emergence of certain woody plants are episodic as it is observed in the present study. The increase in population density and basal area of tree species is because of the entry of juveniles from already existing saplings and seedlings (<3 cm DBH) into the adult (>10 cm DBH) phase as reported by Battles et al. (2003). The population structure, characterised by the presence of sufficient population of seedlings, saplings and adults recorded in the present study, indicates successful regeneration of forest tree species and the presence of saplings under the canopies of adult trees also indicates the future composition of a community (Saxena and Singh, 1984; Pokhriyal et al., 2010). Mortality was greater at the juvenile stage (>3 cm - < 10 cm DBH) than for adult trees (>10 cm DBH) in the present study. Annual mortality (λ) also showed a similar trend. Similar results were reported in Malaysian forests (Table 7; Kochummen et al., 1990; Manokaran et al., 1992). This pattern suggests that at the understory level, competition for light is greatest and the juvenile tree population is highly vulnerable, but once stems attain a certain size, mortality rate declines (Uhl, 1982; Lieberman et al., 1985; Manokaran et al., 1992; Nascimento and Proctor, 1997). The comparison of annual mortality and stand half-life showed that the present study values are lie within the range of available reports (Table 7). However, variation in the values of annual mortality and half-life period among the studies available may be due to variations in stand size, census intervals and tree size classes taken into an account (Lewis et al., 2004).

Patterns of mortality and recruitment vary considerably from place to place over the same period. In the present study, both mortality and recruitment were greater in evergreen forests than in deciduous forests. Low recruitment in deciduous forest could be attributed to annual wild fires caused by human interference. For example, in the present study, site I had no adult of Dalbergia latifolia, but the juveniles appeared during the rainy season. This could be ascribed to persistent soil seed bank or immigration of seeds from neighbouring areas and also through vegetative reproduction (from the existing root suckers). However, the survivorship of these juveniles was very poor and also greatly affected by wild annual fires caused by anthropogenic perturbations (Boyer, 1974; Fairfax et al., 2009). Greater recruitments to compensate mortality resulted in a net gain of population in evergreen forest. This could be attributed to favourable micro-climatic conditions for better growth and survival of seedlings. Similarly net gain of 10% from initial population was observed in BCI (Hubbell and Foster, 1992).

Regeneration is the process of silvigenesis by which trees and forests survive over time (Bhuyan et al., 2003). Halle et al. (1978) proposed a unifying model of the sylvigenetic cycle, which describes a forest as a dynamic system with successional consequences of ever-changing composition and structure; a stable homeostatic phase is followed by a dynamic growing phase after smaller or larger breakdowns of forest structure. The present study concludes that these forests at Kodayar are at a building phase, largely in areas where they are subjected to natural and/or anthropogenic perturbations, and showed net increases in tree
density and basal area. However, long-term studies are needed to understand the regeneration niche for individual species.

Acknowledgements
We thank the Department of Environment and Forest, Government of India for financial assistance through research grant. We thank the Forest Officials for giving us permission to do the work.

References
Boyer WD. 1974. Impact of Prescribed Fires on Mortality of Released and Unreleased Longleaf Pine Seedlings. USDA Forest Service Research Note, USA
Campbell DG, Daly DC, Prance GT, et al. 1986. Quantitative ecological inventory of terra firme and varzea tropical forest on the Rio Xingu, Brazilian Amazon. Brittonia, 38: 369-393
Champion HG, Seth SK. 1968. A Revised Survey of Forest Types of India. Manager of Publications, New Delhi, India
Pascal JP, 1988. Wet Evergreen Forests of the Western Ghats of India. Institute Francais de Pondicherry, Pondicherry, France
Saxena AK, Singh JS. 1984. Tree population structure of certain Himalayan forest associations and implications concerning their future composition. Vegetatio, 58: 61-69


