



Analysis of threatened endemic trees of the Western Ghats of India sheds new light on the Red Data Book of Indian Plants

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Abstract. The Red Data Book of Indian Plants (RDB) is a reference manual that lists threatened angiosperms, gymnosperms and pteridophytes. Because it is widely used as an analytical tool and is a major reference for impact assessments on vegetation, it is important that the RDB be as comprehensive and up to date as possible. This study is an attempt to cross-check the listings in the RDB using vegetation inventories and another reference manual, the Atlas of Endemics of the Western Ghats, India [Ramesh and Pascal 1997. Atlas of Endemics of the Western Ghats (India). French Institute of Pondicherry, India]. Field inventories across the Western Ghats gave an estimate of the species relative abundances and the Atlas provided quantitative information on the number of records for the endemic species in herbaria, literature, and during field surveys. The results of this analysis indicate that the RDB and the Atlas agree statistically regarding the conservation status of endemic trees. However, the proportion of threatened species per Atlas record category behaves erratically, indicating that some threatened endemic trees are not listed in the RDB. Our results suggest that the status of threatened plant species should be reexamined on a priority basis using quantitative methodology. An updating of the RDB is urgently needed, particularly for the endemic plants of the Western Ghats. We provide a list of species that are likely to be threatened, yet are not listed.

Introduction

There is an international effort to identify species that face extinction in order to make conservation efforts more efficient. Since its creation, the International Union for the Conservation of Nature and Natural Resources (IUCN) has attempted to list species that are threatened with extinction globally. The criteria used to define the categories of threatened species change with new information (IUCN 2001) and the lists of threatened species are accordingly upgraded. The Red List of Threatened Plants (Walter and Gillett 1998) is the most recent attempt to inventory the threatened plant species of the World.

The Red Data Book of Indian Plants (RDB), published by the Botanical Survey of

India (Nayar and Sastry 1987, 1988, 1990), focuses exclusively on the Indian flora, more precisely on threatened angiosperms, gymnosperms and pteridophytes. It is a major publication for several reasons. Scientists studying rarity use it as an analytical tool and the accuracy of their results depends on the accuracy of the RDB. Impact studies refer to the RDB to assess the menace of projects on plant species. Customs Agencies need the RDB to guide them in controlling the illegal trade of biological material under CITES. Finally, conservation organizations utilize the RDB to prioritize their efforts. Due to its widespread use, the RDB has reached the status of a standard reference guide with important implications for research, conservation and for the economy.

The most recent edition of the RDB is based on the criteria of Lucas and Synge (1978). Since then, the criteria used to define the categories of threatened species have been refined considerably (IUCN 2001). It has been shown that about 10% of all plant taxa are threatened globally (IUCN 1994), which gives an estimate of ca. 1500 of the 15000 plants recorded for the Indian subcontinent. The RDB however, contains only 814 species (5.4%) (Nayar and Sastry 1987). The relatively small proportion of threatened plants represented in the RDB is puzzling. It is important to know whether or not it represents an accurate estimate of the proportion of threatened plants in the Indian flora.

Data on plant species and their distribution in the Western Ghats are increasingly available, which permits us to cross-check the listings in the RDB for a particular flora. The recently published Atlas of Endemics of the Western Ghats (India) by Ramesh and Pascal (1997) examines endemic evergreen and semi-evergreen forest trees and shrubs with a girth at breast height (GBH) greater than 10 cm. It contains quantitative information on the number of records of endemic species in herbaria, in literature, and in field surveys. The Atlas does not give information on abundance, but ecological inventories can be used to estimate the relative abundance of species.

The objective of this study was to test whether the RDB provides a comprehensive list of the threatened endemic rain forest tree taxa (species, varieties or subspecies) of the Western Ghats of India. In order to accomplish this task, we (i) listed the threatened endemic trees and shrubs of the evergreen and semi-evergreen forests of the Western Ghats, on the basis of Ramesh and Pascal (1997) and the RDB; (ii) compared the Atlas data with data gathered during ecological inventories; (iii) compared the RDB categories with the Atlas' records; and (iv) suggest a list of potentially threatened taxa to be considered for inclusion in the RDB.

Methods

The Atlas of Endemic Trees included 352 tree and shrub species, subspecies, and varieties with a GBH greater than 10 cm. Three sources of data were used for compiling the Atlas: herbaria (almost 6000 specimens checked in the major international, national and regional herbaria), literature (935 records), and field surveys by teams of the French Institute of Pondicherry (India), which spanned more than 15 years (4369 entries). The Atlas records were a composite of records (i)

Table 1. Species in increasing number of records in the Atlas and species occurring in the Red Data Book.

| Species | Family | Records | | | | | | Range (km) | Red Data Book status | Comments in the RDB |
|---|-----------------------------|----------------|----|----|----|----|---|------------|-------------------------------|---------------------|
| | | H. L. F. I. Σ. | | | | | | | | |
| | | H. | L. | F. | I. | Σ. | | | | |
| <i>Actinodaphne lanata</i> Meisn. | Lauraceae | 1 | | | | | 4 | Endangered | | |
| <i>Berberis nilghiriensis</i> Ahrendt | Berberidaceae | | | | 1 | | 4 | Endangered | | |
| <i>Buchanania barberi</i> Gamble | Anacardiaceae | | | | 1 | | 4 | Endangered | | |
| <i>Canthium pergracilis</i> (Bourd.) Gamble | Rubiaceae | | 1 | | | | 4 | | | |
| <i>Cinnamomum chemungianum</i> Mohan and Henry | Lauraceae | 1 | | | | | 4 | | | |
| <i>Cinnamomum goaense</i> Kosterm. | Lauraceae | | | | 1 | | 4 | | | |
| <i>Cinnamomum heyneanum</i> Nees | Lauraceae | | | | 1 | | 4 | | | |
| <i>Cinnamomum walaiavarens</i> Kosterm. | Lauraceae | 1 | | | | | 4 | | | |
| <i>Croton lavianus</i> Nimmo | Euphorbiaceae | 1 | | | | | 4 | | | |
| <i>Cynometra beddomei</i> Prain | Fabaceae (Caesalpinioideae) | | 1 | | | | 4 | | | |
| <i>Drypetes trananacorica</i> (Bourd.) S.K. Jain | Euphorbiaceae | 1 | | | | | 4 | | | |
| <i>Eugenia argentea</i> Bedd. | Myrtaceae | 1 | | | | | 4 | Extinct? | | |
| <i>Ficus angladei</i> CEC Fisher | Moraceae | | | | 1 | | 4 | | | |
| <i>Garcinia imberitii</i> Bourd. | Clusiaceae | 1 | | | | | 4 | | | |
| <i>Glochidion sisparsense</i> Gamble | Euphorbiaceae | | 1 | | | | 4 | | | |
| <i>Homalium jainii</i> Henry and Swamin. | Flacourtiaceae | 1 | | | | | 4 | | | |
| <i>Hopea canarensis</i> Hole | Dipterocarpaceae | 1 | | | | | 4 | | | |
| <i>Hopea jacobii</i> C.E.C. Fisch. | Dipterocarpaceae | | | | 1 | | 4 | Rare | Known from type only | |
| <i>Humboldtia unijuga</i> Bedd. var. <i>trijuga</i> Joseph and Chandras. | Fabaceae (Caesalpinioideae) | 1 | | | | | 4 | | | |
| <i>Ilex gardneriana</i> Wt. | Aquifoliaceae | | | | 1 | | 4 | Extinct? | | |
| <i>Ixora johnsoni</i> J. Hk. | Rubiaceae | | | | 1 | | 4 | | | |
| <i>Ixora saulierei</i> Gamble | Rubiaceae | | | | 1 | | 4 | | | |
| <i>Litsea nigrescens</i> Gamble | Lauraceae | 1 | | | | | 4 | | | |
| <i>Melicope indica</i> Wt. | Rutaceae | | 1 | | | | 4 | Vulnerable | Imminent danger of extinction | |
| <i>Microtropis densiflora</i> Wt. | Celastraceae | | | | 1 | | 4 | | | |
| <i>Nothopegia aureo-fulva</i> Bedd. | Anacardiaceae | | | | 1 | | 4 | | | |
| <i>Nothopegia beddomei</i> Gamble var. <i>wynaadica</i> Ellis and Chandr. | Anacardiaceae | | 1 | | | | 4 | Endangered | | |
| <i>Nothopegia castaneifolia</i> (Roth) Ding Hou | Anacardiaceae | | | | 1 | | 4 | | | |
| <i>Pittosporum viridulum</i> Nayar, Giri and Chandras | Pittosporaceae | | 1 | | | | 4 | | | |

Table 1. (continued)

| Species | Family | Records | | | | | Range (km) | Red Data Book status | Comments in the RDB |
|---|-----------------------|---------|----|----|----|----|------------|----------------------|----------------------|
| | | H. | L. | F. | I. | Σ. | | | |
| <i>Psychotria beddomei</i> Deb. and Gang. | Rubiaceae | 1 | | | | 1 | 4 | | |
| <i>Schefflera rostrata</i> (Wt.) Harms var. <i>micrantha</i> (Clarke) Mahesh. | Araliaceae | | 1 | | | 1 | 4 | | |
| <i>Sophora wightii</i> Baker | Fabaceae (Faboideae) | 1 | | | | 1 | 4 | | |
| <i>Symplocos pulchra</i> Wt. ssp. <i>coriacea</i> Gopalan and Henry | Symplocaceae | 1 | | | | 1 | 4 | | |
| <i>Syzgium bourdillonii</i> (Gamble) Rathak. | Myrtaceae | 1 | | | | 1 | 4 | Extinct? | |
| <i>Syzgium courtallense</i> (Gamble) Alston. | Myrtaceae | 1 | | | | 1 | 4 | Endangered | |
| <i>Syzgium microphyllum</i> Gamble | Myrtaceae | 1 | | | | 1 | 4 | | |
| <i>Syzgium palghatense</i> Gamble | Myrtaceae | | | | 1 | 1 | 4 | Extinct? | |
| <i>Syzgium utilis</i> Rathak. and N.C. Nair | Myrtaceae | | | | 1 | 1 | 4 | | |
| <i>Syzgium zeylanicum</i> (L.) DC. var. <i>ellipticum</i> Henry, Chandrase and Nair | Myrtaceae | 1 | | | | 1 | 4 | | |
| <i>Actinodaphne campanulata</i> J. Hk. var. <i>obtusata</i> Gamble | Lauraceae | 1 | 1 | | | 2 | 4 | | |
| <i>Atuna indica</i> (Bedd.) Kosterm. | Chrysobalanaceae | | 2 | | | 2 | 4 | | |
| <i>Elaeocarpus blascoi</i> Weibel | Elaeocarpaceae | 2 | | | | 2 | 4 | | Known from type only |
| <i>Elaeocarpus gaussonii</i> Weibel | Elaeocarpaceae | 2 | | | | 2 | 4 | | Known from type only |
| <i>Vateria macrocarpa</i> B.L. Gupta | Dipterocarpaceae | 1 | 1 | | | 2 | 4 | | |
| <i>Polyalthia shendurani</i> Baska and Sasi. | Amonaceae | 2 | | | | 2 | 6 | | |
| <i>Symplocos oligandra</i> Bedd. | Symplocaceae | 2 | | | | 2 | 6 | | |
| <i>Litsea beddomei</i> J. Hk. | Lauraceae | 2 | | | | 2 | 8 | | |
| <i>Memecylon subramanii</i> Henry | Melastomataceae | 2 | | | | 2 | 8 | | |
| <i>Pseudoglochidion anandayanum</i> Gamble | Euphorbiaceae | 2 | | | | 2 | 8 | | |
| <i>Inga cynometroides</i> Bedd. | Fabaceae (Mimosodeae) | | 2 | | | 2 | 12 | | Indeterminate |
| <i>Isora lawsonii</i> Gamble | Rubiaceae | | 2 | | | 2 | 12 | | Extinct? |
| <i>Diospyros sulcata</i> Boud. | Ebenaceae | 2 | | | | 2 | 16 | | |
| <i>Glochidion ellipticum</i> Wt. var. <i>raphitii</i> Gamble | Euphorbiaceae | 2 | | | | 2 | 20 | | |
| <i>Symplocos monantha</i> Wt. | Symplocaceae | 1 | 1 | | | 2 | 32 | | |
| <i>Canthium ficiforme</i> J. Hk. | Rubiaceae | 1 | | | 1 | 2 | 36 | | |
| <i>Psychotria macrocarpa</i> J. Hk. | Rubiaceae | 1 | 1 | | | 2 | 48 | | |
| <i>Ardisia blatterii</i> Gamble | Myrsinaceae | 2 | | | | 2 | 56 | | |

| | | | | | | | | |
|---|---|---|---|---|-----|-----------------------------|------------|----------------------|
| <i>Palaquium ravii</i> Sassi. | 2 | 1 | 1 | 2 | 64 | Sapotaceae | Endangered | |
| <i>Eugenia discifera</i> Gamble | 1 | | | 2 | 84 | Myrtaceae | | |
| <i>Syzygium stocksii</i> (Duthie) Gamble | | | 2 | 2 | 84 | Myrtaceae | | |
| <i>Etodia lanu-ankenda</i> (Gaertn.) Merr. var. <i>irunelvelica</i> Henry and Chand. | | | 1 | 1 | 112 | Rutaceae | | |
| <i>Euonymus paniculatus</i> Wt. ex Lawson | 2 | | | 2 | 112 | Celastraceae | | |
| <i>Rapanea striata</i> Mez. | 1 | | | 2 | 112 | Myrsinaceae | | |
| <i>Aglaia malabarica</i> Sasidharan | 1 | | 1 | 2 | 116 | Meliaceae | | |
| <i>Syzygium parameswaranii</i> Mohanan and Henry | 2 | | | 2 | 116 | Myrtaceae | | |
| <i>Koelodepus calycinum</i> Bedd. | 2 | | | 2 | 120 | Euphorbiaceae | | |
| <i>Syzygium myhendrae</i> (Bedd. ex Brandis) Gamble | | | 1 | 1 | 120 | Myrtaceae | | |
| <i>Psychotria nilgiriensis</i> Deb. and Gang. var. <i>astephana</i> (J. Hk.) Deb. and Gang. | 2 | | | 2 | 128 | Rubiaceae | | |
| <i>Memeylon sisparsense</i> Gamble | | | 2 | 2 | 152 | Melastomataceae | | Known from type only |
| <i>Actinodaphne salicina</i> Meisn. | 2 | | | 2 | 160 | Lauraceae | | |
| <i>Schefflera chandrasekharanii</i> Raman. and Rajan | 1 | | 1 | 2 | 160 | Araliaceae | | |
| <i>Syzygium chavarun</i> (Bourd.) Gamble | | | 1 | 2 | 188 | Myrtaceae | | |
| <i>Xylocarpus latifolium</i> J. Hk. and Thoms. | 1 | | | 2 | 188 | Flacourtiaceae | | |
| <i>Syzygium beddomei</i> (Duthie) Chithra | 1 | | | 2 | 192 | Myrtaceae | | |
| <i>Aglaia indica</i> (J. Hk.) Harms | 1 | | | 2 | 256 | Meliaceae | | |
| <i>Maesa velutina</i> Mez. | 1 | | 1 | 2 | 312 | Myrsinaceae | | |
| <i>Euonymus serratifolius</i> Bedd. | 1 | | 1 | 2 | 360 | Celastraceae | | Endangered |
| <i>Ardisia amplexicaulis</i> Bedd. | 1 | | 2 | 2 | 364 | Myrsinaceae | | |
| <i>Julostylis polyandra</i> Ravi and Anil | 2 | | | 2 | 640 | Malvaceae | | |
| <i>Humboldtia unijuga</i> Bedd. var. <i>unijuga</i> | 2 | | | 3 | 8 | Fabaceae (Caesalpinioideae) | | Endangered |
| <i>Eugenia singampattiana</i> Bedd. | 3 | | | 3 | 32 | Myrtaceae | | Extinct? |
| <i>Eugenia indica</i> (Wt.) Chithra | 2 | | | 3 | 100 | Myrtaceae | | |
| <i>Humboldtia boardiloonii</i> Prain | 1 | | 1 | 3 | 100 | Fabaceae (Caesalpinioideae) | | Endangered |
| <i>Symplocos nairii</i> Henry, Gopalan and Swamin. | 2 | | | 3 | 116 | Symplocaceae | | |
| <i>Anacotosa densiflora</i> Bedd. | 3 | | | 3 | 140 | Oleaceae | | |
| <i>Cleistanthus travancorensis</i> Jabl. | 2 | | 1 | 3 | 288 | Euphorbiaceae | | |
| <i>Tarenna monosperma</i> (Wt. and Arn.) Raju | 2 | | | 3 | 288 | Rubiaceae | | |
| <i>Eugenia cotoniifolia</i> Jaesq. ssp. <i>codyensis</i> (Munro ex Wt.) Ashton | 1 | | 1 | 3 | 460 | Myrtaceae | | |
| <i>Poeciloneuron pauciflorum</i> Bedd. | 2 | | | 3 | 800 | Clusiaceae | | Indeterminate |
| <i>Byrsophyllum tetrandrum</i> (Bedd.) J. Hk. ex Bedd. | 4 | | 1 | 4 | 20 | Rubiaceae | | Known from type only |
| <i>Eugenia floccosa</i> Bedd. | 3 | | | 4 | 20 | Rubiaceae | | |
| <i>Dialium travancoricum</i> Bourd. | 2 | | 1 | 4 | 28 | Myrtaceae | | Indeterminate |
| <i>Tarenna agumbensis</i> Sunderar. | 4 | | | 4 | 72 | Rubiaceae | | Vulnerable |
| | | | | 4 | | | | Danger of extinction |

Table 1. (continued)

| Species | Family | Records | | | | | | Range (km) | Red Data Book status | Comments in the RDB |
|---|----------------------------|---------|---|---|---|---|-----|---------------|-----------------------------|---------------------|
| | | H | L | F | I | Σ | | | | |
| <i>Chionanthus linocardioides</i> (Wt.) Bennet and Raiz. | Oleaceae | 2 | 2 | | | 4 | 116 | | | |
| <i>Cryptocarya amandaliayana</i> Gamble | Lauraceae | 3 | | | 1 | 4 | 180 | | | |
| <i>Polyalthia rufescens</i> J. Hk. and Thoms. | Ammonaceae | 4 | | | | 4 | 180 | Vulnerable | | |
| <i>Nostolachma crassifolia</i> (Gamble) Deb. and Lahiri | Rubiaceae | 1 | | 2 | 1 | 4 | 188 | | | |
| <i>Scygiun rama-varna</i> (Bourd.) Chithra | Myrtaceae | 4 | | | | 4 | 200 | | | |
| <i>Orophia thomsoni</i> Bedd. | Ammonaceae | 2 | | | 2 | 4 | 204 | | | |
| <i>Glochidion pauciflorum</i> Gamble | Euphorbiaceae | 3 | | | 1 | 4 | 412 | | | |
| <i>Cryptocarya stocksii</i> Meissn. | Lauraceae | 4 | | | | 4 | 584 | | | |
| <i>Aglia littoralis</i> Mq. | Meliaceae | 4 | | | | 4 | 680 | | | |
| <i>Actinodaphne bournei</i> Gamble | Lauraceae | 4 | 1 | | | 5 | 16 | Endangered | Possibly extinct | |
| <i>Photinia serratifolia</i> (Desf.) Kalkman var. <i>tomentosa</i> (Gamble) Vivek. and Shetty | Rosaceae | 4 | 1 | | | 5 | 20 | | | |
| <i>Litsea travancorica</i> Gamble | Lauraceae | 4 | 1 | | | 5 | 28 | | | |
| <i>Goniolalamus rhynchantherus</i> Dunn. | Ammonaceae | 5 | | | | 5 | 34 | Rare | Few trees observed recently | |
| <i>Lastianthus rostratus</i> Wt. | Rubiaceae | 5 | | | | 5 | 92 | | | |
| <i>Drypetes porteri</i> (Gamble) Pax and Hoffm. | Euphorbiaceae | 3 | | 2 | | 5 | 132 | | | |
| <i>Lastianthus ciliatus</i> Wt. | Rubiaceae | 2 | 3 | | | 5 | 132 | | | |
| <i>Dysoxylum beddomei</i> Kosterm. | Meliaceae | 2 | 2 | 1 | | 5 | 136 | | | |
| <i>Dysoxylum ficiforme</i> (Wt.) Gamble | Meliaceae | 5 | | | | 5 | 136 | | | |
| <i>Ardisia sonchifolia</i> Mez. | Mysinaceae | 4 | 1 | | | 5 | 144 | | | |
| <i>Sageraea grandiflora</i> Dunn. | Ammonaceae | 5 | | | | 5 | 172 | Endangered | | |
| <i>Madhuca bourdillonii</i> (Gamble) H.J. Lam. | Sapotaceae | 5 | | | | 5 | 248 | Extinct? | | |
| <i>Hopea erosa</i> (Bedd.) Van Slooten | Myrtaceae | 2 | 2 | | 1 | 5 | 376 | Endangered | | |
| <i>Meteromyrtus wynaadensis</i> (Bedd.) Gamble | Rubiaceae | 5 | | | | 5 | 412 | Endangered | | |
| <i>Glochidion tomentosum</i> Dalz. | Fabaceae (Caesalpinoideae) | 3 | 2 | | | 5 | 444 | | | |
| <i>Cynometra bourdillonii</i> Gamble | Fabaceae (Caesalpinoideae) | 3 | 2 | | | 5 | 500 | | | |
| <i>Buchanania lanceolata</i> Wt. | Anacardiaceae | 5 | 1 | | | 6 | 52 | | | |
| <i>Drypetes wightii</i> (J. Hk.) Pax and Hoffm. | Euphorbiaceae | 6 | | | | 6 | 116 | | | |
| <i>Aluna travancorica</i> (Bedd.) Kosterm. | Chrysobalanaceae | 3 | 3 | | | 6 | 124 | | | |
| <i>Cinnamomum filipedicellatum</i> Kosterm. | Lauraceae | 3 | 2 | | 1 | 6 | 164 | | | |
| <i>Chionanthus leprocarpa</i> Thw. var. <i>courtalensis</i> (Bedd.) K.K.N. Nair | Oleaceae | 3 | 3 | | | 6 | 168 | Indeterminate | Not collected in 100 years | |
| <i>Psychotria globicephala</i> Gamble | Rubiaceae | 5 | | 1 | | 6 | 256 | Endangered | | |
| <i>Dimorphocalyx beddomei</i> (Benth.) Airy Shaw | Euphorbiaceae | 3 | | 3 | | 6 | 360 | Endangered | | |
| <i>Saprosma fragans</i> Bedd. | Rubiaceae | 4 | | 2 | | 6 | 380 | | | |

Table 1. (continued)

| Species | Family | Records | | | | | | Range (km) | Red Data Book status | Comments in the RDB |
|--|-----------------------------|---------|---|---|---|----|-----|------------|-------------------------------|---------------------|
| | | H | L | F | I | Σ | | | | |
| <i>Eugenia rotteriana</i> Wt. and Arn. | Myrtaceae | 3 | | 7 | | 10 | 136 | | | |
| <i>Syzygium benthamianum</i> (Wt. ex Duthie) Gamble | Myrtaceae | 10 | | | | 10 | 332 | | | |
| <i>Cynometra travancorica</i> Bedd. | Fabaceae (Caesalpinioideae) | 6 | 3 | 1 | | 10 | 392 | | | |
| <i>Orophea uniflora</i> J. Hk. and Thoms. | Ammonaceae | 8 | 2 | | | 10 | 424 | Vulnerable | | |
| <i>Elaeocarpus venustus</i> Bedd. | Elaeocarpaceae | 3 | 4 | 4 | | 11 | 128 | Vulnerable | | |
| <i>Hopea glabra</i> Wt. and Arn. | Dipterocarpaceae | 9 | 1 | | 1 | 11 | 280 | | | |
| <i>Cinnamomum riparium</i> Gamble | Lauraceae | 6 | 2 | 3 | | 11 | 480 | | | |
| <i>Garcinia ribro-echinata</i> Kosterm. | Clusiaceae | 4 | | 8 | | 12 | 112 | | | |
| <i>Actinodaphne campanulata</i> J. Hk. var. <i>campanulata</i> | Lauraceae | 9 | 3 | | | 12 | 128 | | | |
| <i>Casearia wynadensis</i> Bedd. | Flacourtiaceae | 9 | 1 | 1 | 1 | 12 | 240 | | | |
| <i>Ochrianauclea missionis</i> (Wall. ex G. Don.) Ridgd. | Rubiaceae | 7 | 1 | 3 | 1 | 12 | 440 | | | |
| <i>Memeylon heyneanum</i> Benth. ex Wt. and Arn. | Melastomataceae | 10 | 2 | | | 12 | 452 | | | |
| <i>Cleistanthus malabaricus</i> M. Arg. | Euphorbiaceae | 4 | 5 | 3 | | 12 | 636 | | | |
| <i>Hydnocarpus macrocarpa</i> (Bedd.) Warb. ssp. <i>macrocarpa</i> | Euphorbiaceae | 10 | 2 | | | 12 | 760 | | | |
| <i>Blachia reflexa</i> Benth. | Euphorbiaceae | 9 | 1 | 3 | | 13 | 184 | Endangered | | |
| <i>Actinodaphne lawsonii</i> Gamble | Lauraceae | 10 | | 3 | | 13 | 268 | Vulnerable | | |
| <i>Syzygium malabaricum</i> (Bedd.) Gamble | Myrtaceae | 13 | | 3 | | 13 | 280 | | | |
| <i>Enonymus angolanus</i> Wt. | Celastraceae | 11 | 2 | | | 13 | 284 | Endangered | | |
| <i>Litsea glabrata</i> J. Hk. | Flacourtiaceae | 13 | | | | 13 | 412 | | | |
| <i>Actinodaphne angustifolia</i> (Bl.) Nees | Lauraceae | 9 | 4 | | | 13 | 580 | | | |
| <i>Ardisia rhomboides</i> Wt. | Lauraceae | 8 | 5 | | | 13 | 792 | | | |
| <i>Memeylon depressum</i> Benth. ex Triana | Myrsinaceae | 10 | 3 | 1 | | 14 | 324 | | | |
| <i>Drypetes confertiflorus</i> (J. Hk.) Pax and Hoffm. | Melastomataceae | 11 | 2 | 1 | | 14 | 588 | | | |
| <i>Ocotropis travancorica</i> Bedd. | Euphorbiaceae | 9 | | 5 | | 14 | 680 | | | |
| <i>Psychotria nudiflora</i> Wt. and Arn. | Rubiaceae | 11 | | 4 | | 15 | 112 | | | |
| <i>Glycosmis macrocarpa</i> Wt. | Rubiaceae | 15 | | | | 15 | 172 | | | |
| <i>Syzygium occidentale</i> (Bourd.) Gandhi | Rutaceae | 4 | 4 | 7 | | 15 | 472 | Vulnerable | | |
| <i>Elaeocarpus recurvatus</i> Corner | Myrtaceae | 11 | 4 | | | 15 | 788 | | | |
| <i>Diospyros pruriens</i> Dalz. | Elaeocarpaceae | 15 | 1 | | | 16 | 172 | Vulnerable | | |
| <i>Terminalia travancorensis</i> Wt. and Arn. | Ebenaceae | 10 | 3 | 4 | | 17 | 380 | | | |
| <i>Isonandra perronitiana</i> DC. | Combretaceae | 11 | 3 | 3 | | 17 | 444 | | | |
| | Sapotaceae | 9 | 3 | 5 | | 17 | 580 | | Very rare in threatened spots | |

| | | | | | | | | | | |
|--|--|--|----|----|----|----|-----|---|----|------------|
| <i>Mitisa wightiana</i> J. Hk. and Thoms. | | | | | | | 3 | 3 | 17 | 660 |
| <i>Glochidion malabaricum</i> Bedd. | | | 4 | 3 | 10 | 17 | 780 | | | |
| <i>Symplocos macrocarpa</i> Wt. ex Cl. ssp. <i>macrocarpa</i> | | | 8 | 6 | 4 | 18 | 68 | | | |
| <i>Vernonia travancoricola</i> J. Hk. | | | 15 | 3 | 3 | 18 | 132 | | | |
| <i>Diospyros arata</i> Kosterm. | | | 3 | 15 | | 18 | 172 | | | |
| <i>Cinnamomum wightii</i> Meissn. | | | 13 | 2 | 3 | 18 | 180 | | | |
| <i>Bentickia condappana</i> Berry | | | 8 | | 10 | 18 | 200 | | | Vulnerable |
| <i>Diospyros humilis</i> Bourd. | | | 9 | 9 | 9 | 18 | 216 | | | |
| <i>Humboldtia decurens</i> Bedd. ex Oliv. | | | 15 | | 3 | 18 | 220 | | | Vulnerable |
| <i>Microtropis latifolia</i> Wt. | | | 16 | 1 | | 18 | 444 | | | |
| <i>Gymnacranthera canarica</i> (King) Warb. | | | 17 | | 1 | 18 | 524 | | | |
| <i>Schefflera capitata</i> (Wt. and Am.) Harms | | | 8 | 1 | 9 | 18 | 568 | | | |
| <i>Mallotus beldamei</i> J. Hk. | | | 15 | 1 | 2 | 18 | 704 | | | |
| <i>Actinodaphne hookeri</i> Meissn. | | | 18 | | | 18 | 708 | | | |
| <i>Spondias indica</i> (Wt. and Am.) Airy Shaw and Forma | | | 17 | 1 | | 18 | 900 | | | |
| <i>Microtropis microcarpa</i> Wt. | | | 17 | 1 | | 19 | 176 | | | |
| <i>Litosanthes venulosus</i> (Wt. and Am.) Deb. and Gang. | | | 16 | | 3 | 19 | 224 | | | |
| <i>Goniothalamus wynaadensis</i> (Bedd.) Bedd. | | | 9 | | 10 | 19 | 284 | | | |
| <i>Psychotria anomallayana</i> Bedd. | | | 17 | 2 | | 19 | 304 | | | |
| <i>Phacanthus malabaricus</i> Bedd. | | | 10 | 4 | 5 | 19 | 372 | | | Vulnerable |
| <i>Symplocos wynadense</i> (O.K.) Noot | | | 17 | 1 | | 19 | 392 | | | |
| <i>Aglia elaeagnoides</i> (Juss.) Benth. var. <i>bourdillonii</i> (Gamble) K.K.N. Nair | | | 9 | | 11 | 20 | 52 | | | |
| <i>Saprosma corymbosum</i> Bedd. | | | 10 | 5 | 5 | 20 | 56 | | | |
| <i>Litsea wightiana</i> (Nees) J. Hk. var. <i>tomentosa</i> Meissn. | | | 17 | 3 | | 20 | 156 | | | |
| <i>Syzgium tamilaadensis</i> Rathak. and Chithra | | | 12 | 4 | 4 | 20 | 416 | | | |
| <i>Actinodaphne tadlingamii</i> Gamble | | | 14 | 1 | 5 | 20 | 612 | | | |
| <i>Nothopegia heyneana</i> (J. Hk.) Gamble | | | 11 | 2 | 7 | 20 | 628 | | | |
| <i>Drypetes malabarica</i> (Bedd.) Airy Shaw | | | 4 | 3 | 14 | 21 | 248 | | | |
| <i>Dipterocarpaceae bourdillonii</i> Brandis | | | 12 | 1 | 8 | 21 | 412 | | | |
| <i>Ixora leucantha</i> Heyne | | | 21 | | | 21 | 740 | | | |
| <i>Ixora elongata</i> Heyne ex G. Don. | | | 19 | | 2 | 21 | 828 | | | |
| <i>Aglia exstipitata</i> (Griff.) Balak. | | | 9 | | 13 | 22 | 228 | | | |
| <i>Pterospermum reticulatum</i> Wt. and Am. | | | 14 | 1 | 7 | 22 | 768 | | | Vulnerable |
| <i>Kingiodendron pinnatum</i> (Roxb. ex DC.) Harms | | | 28 | 2 | 23 | 53 | 604 | | | Vulnerable |
| <i>Elaeocarpus munronii</i> (Wt.) Mast. | | | 44 | 1 | 20 | 65 | 628 | | | Vulnerable |

H. = records in herbaria, L. = records in literature, F. = field records, I. = records in herbaria or literature without proper indication of site collection, and Σ. = total number of records in the Atlas.

in the herbaria, (ii) in literature, and (iii) in herbaria and literature without proper indication of site collection (Table 1).

Species ranges were assessed by measurements on the Atlas' maps. The evergreen and semi-evergreen rainforests lie mostly on the western slope of the Western Ghats (Figure 1) in a narrow belt parallel to the coast. The oreographic effect largely overshadows the longitudinal effect. In this study, species ranges were equated to the latitudinal range. The distance (in kilometers) between the two most distant points of observation, as reported in the Atlas, parallel to the coast was used to calculate the range of each species. When a species was observed only once, the range was arbitrarily considered to be 4 km (1 mm on the 1/4000000 maps of the Atlas). Because the spatial data have been gathered over a long period, the species ranges may be larger than the present range.

Fifteen plant inventories were used to assess the relative abundances of the species. These plant inventories ranged from 8° 25' to 14° 50' N latitude and the plot sizes ranged from 0.09 to 30 ha. The inventories fall into two categories according to the lower size limit for trees chosen by the authors, i.e. 10 cm GBH or 10 cm diameter at breast height (DBH) (Table 2). Because relative abundances of species change with different size limits, comparisons with the Atlas data were done for both categories of inventories independently. The total number of field records was obtained by summing records for each species for each lower size category, over all the inventories. We then compared the number of records in herbaria with the



Figure 1. The location of the Western Ghats of India.

Table 2. Location and other information pertaining to inventory plots used for the analyses.

| Site | Coordinates | Number of species | Number of endemic species | Plot size (ha) | Lower tree size: 10 cm | References |
|-------------|-------------------|-------------------|---------------------------|----------------|------------------------|-----------------------------------|
| Sengaltheri | 8°33' N-77°32' E | 83 | 22 | 1 | DBH | Parthasarathy (1999) |
| Veerapauli | 8°29' N-77°15' E | 74 | 13 | 0.3 | DBH | Swamy et al. (2000) |
| Kakachi | 8°33' N-77°30' E | 90 | 33 | 3.82 | DBH | Ganesh et al. (1996) |
| Chinnapul | 8°45' N-77°17' E | 27 | 8 | 0.09 | GBH | Davidar, unpublished |
| Kamikatti | 8°45' N-77°15' E | 32 | 25 | 0.09 | GBH | Davidar, unpublished |
| Kaiketan | 9°05' N-77°16' E | 44 | 13 | 0.09 | GBH | Davidar, unpublished |
| Varagaliar | 10°25' N-76°52' E | 148 | 43 | 30 | DBH | Ayyappan and Parthasarathy (1999) |
| Attapadi | 11°00' N-76°30' E | 32 | 9 | 0.2 | GBH | Pascal (1988) |
| Kadamakkal | 12°32' N-75°40' E | 56 | 24 | 0.16 | GBH | Pascal (1988) |
| Uppangala | 12°30' N-75°39' E | 90 | 38 | 3.12 | DBH | Pascal and Pélissier (1996) |
| Naravi | 13°10' N-75°10' E | 30 | 17 | 0.16 | GBH | Pascal (1988) |
| New | 13°20' N-75°10' E | 25 | 10 | 0.14 | GBH | Pascal (1988) |
| Kogar | 14°00' N-74°40' E | 114 | 49 | 2.12 | GBH | Garrigues (1999) |
| Halagale | 14°21' N-75°06' E | 22 | 7 | 0.16 | GBH | Pascal (1988) |
| Magod | 14°51' N-74°44' E | 33 | 10 | 0.16 | GBH | Pascal (1988) |

number of records in the inventories using a Spearman rank-order correlation coefficient (r_s), a non-parametric statistic, as the data were not normally distributed (Siegel and Castellan 1989). The range of the species and the number of records in herbaria were also compared using the Spearman correlation coefficient.

The mean number of records and the mean range per conservation category were calculated. The number and proportion of threatened species was compared to the total number of records below the first quartile of the frequency distribution of species rank.

Results

The species were ranked according to the number of Atlas records. We listed 232 species with fewer than 22 records (the first quartile of the rank records) in the Atlas, as well as species mentioned in the RDB together with their threat status (Table 1). All the 'rare' species were changed to 'vulnerable' to follow the nomenclatural recommendations of the IUCN (1994). Species with indeterminate status or with comments in contradiction with the threat category (reported in Table 1) were excluded from the calculation of the number of records per threat category of Figure 3.

Of the 352 species reported in the Atlas, 50 species (14%) belonging to 19 families were listed as threatened in the RDB (Table 1). Five species with indeterminate status (not observed since the type collection) were recorded by the French Institute in the Atlas prior to 1997 (Ramesh and Pascal 1997). These species are: *Memecylon sisparens*, *Miliusa nilagirica*, *Palaquium bourdilloni*, *Phaeanthus malabaricus* and *Poeciloneuron pauciflorum*.

There was a strong correlation between the range rank and the herbaria record rank ($r_s = 0.79$; $n = 352$; $P < 10^{-4}$). In the inventories with GBH > 10 cm, weak but significant relationships were observed between a species' abundance and (i) the herbaria rank records ($r_s = 0.36$; $n = 90$; $P < 0.001$), and (ii) the species range ($r_s = 0.31$; $n = 90$; $P < 0.005$). Identically, in the inventories with DBH > 10 cm, significant relationships were observed between a species' abundance and (i) the herbaria rank records ($r_s = 0.29$; $n = 93$; $P < 0.01$), and (ii) the species range ($r_s = 0.32$; $n = 93$; $P < 0.005$).

For each rank record of the Atlas, we calculated the proportion of species observed in the major inventories. This proportion decreased with decreasing number of records in the Atlas (Figure 2). The distribution of the species proportions followed a logistic model ($y = 0.193 e^{0.15x} / (1 + 0.193 (e^{0.15x} - 1))$; $r^2 = 0.67$, $F_{2,30} = 62.212$, $P < 10^{-4}$).

The number of records changed significantly with increasing threat (Figure 3; $F_{2,30} = 7.897$, $P < 0.002$). The Bonferroni test indicates that the category 'vulnerable' is significantly different from the two categories 'possibly extinct' ($P = 0.008$) and 'endangered' ($P = 0.005$). The number of threatened species increased with decreasing number of records, but the proportion of threatened species did not follow any particular pattern (Figure 4).

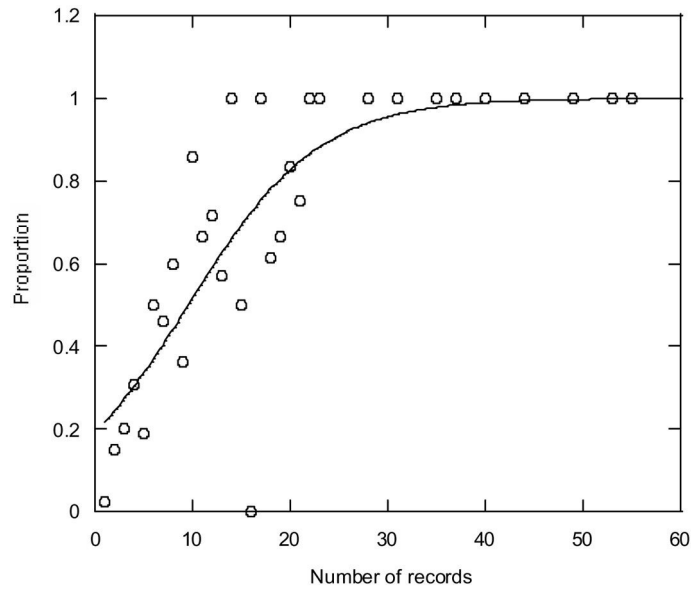


Figure 2. Proportion of species observed in the pooled inventories in relation with the number of records in the Atlas.

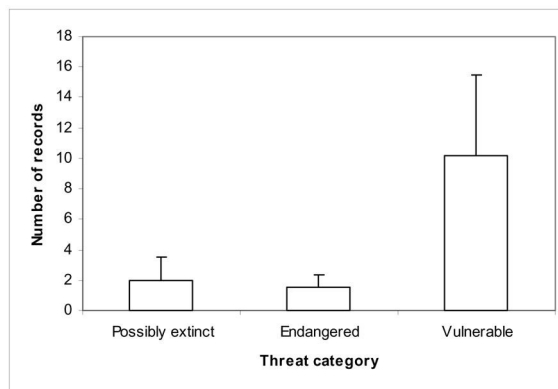


Figure 3. Number of records by threat category.

Discussion

Of the 63% endemic tree species of the evergreen rainforest and semi-evergreen forests of the Western Ghats (Ramesh et al. 1993), 14% (50 species) were threatened according to the RDB. Of the 4500 angiosperm species (3.8% of threatened plants) from southern India, Daniels et al. (1995) listed 171 threatened species. Matthew (1999a) reported 167 plants under stress or suspected to be

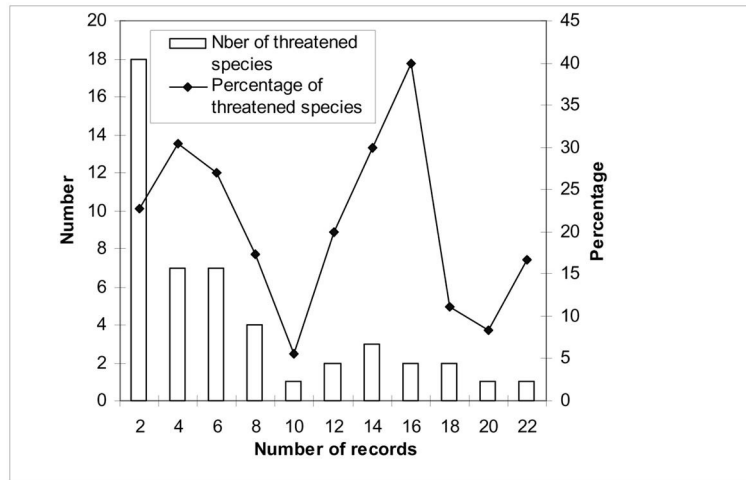


Figure 4. Number of threatened species and percentage of threatened species in the different record categories of the Atlas; rare species only.

extinct, out of 3015 species (5.5% of threatened plant species) identified in the dry part of Tamil Nadu as well as the Palnis. A fair number of introduced plants rightly appear in Matthew's floras (Matthew 1983, 1999b), on which his work on threatened species was based. Consequently, the figure of 5.5% underestimates the number of indigenous plants under stress. But even then, the particular assemblage studied here, consisting exclusively of endemic species, contains a relatively higher proportion of threatened species than does the widespread flora of the Deccan plateau.

The Atlas records (i) correlate with the range and abundance of species in real communities; (ii) indicate the likelihood of finding the species in inventories; and (iii) increase with decreasing level of threat. These points indicate that the Atlas records and the RDB agree broadly in classifying species. However, the proportion of threatened species varies erratically within each record category, instead of increasing in the less recorded species categories. The lack of trend suggests that the RDB may have failed to detect some threatened species.

A priori, the number of records in herbaria cannot be expected to be a good estimator of the total species abundances. Some species such as *Mangifera indica* L., which are both frequent and widely distributed, are relatively poorly recorded. Field collections are not performed uniformly with the same intensity by different botanists. Ruokolainen et al. (2002) have suggested that widely distributed rain forest tree species are better represented in herbaria. Our results seem to support this suggestion. Firstly, there was a strong correlation between the range rank and the herbaria record rank. Rare species usually have smaller ranges than abundant species (Gaston 1994). Similarly, herbaria records and range produced patterns analogous to those of real communities. Secondly, there was a weak but significant

correlation between the herbaria rank records and the relative abundances (as well as ranges) of species in inventories. However, despite a significant trend, the correlation was too weak to infer species rank abundances from herbaria records.

The relationship between the number of Atlas records and the proportion of threatened species (in each record category) observed in major inventories was best fit by the logistic model. The probability of finding a species belonging to a particular threat category in the field decreases with the diminishing number of records in the Atlas. Conversely, when the mean number of records was plotted against the threat category (Figure 3) the category 'vulnerable' was distinct from the categories 'threatened' and 'possibly extinct'. Because it is rarely possible to ascertain whether a tree species is extinct or highly endangered, the absence of difference between the last two categories is expected.

These findings show that the number of records in the Atlas is a good indicator of threat. However, the proportion of the threatened species varies erratically with the number of Atlas records (Figure 4). It is not clear why the lowest category (1 and 2 records), with 79 species, contains proportionally fewer species than the two higher categories. Another divergence between the Atlas and the RDB can be detected in Figure 3. The mean number of records for the category 'vulnerable' is approximately 10. The cumulative frequency for 10 records included 169 species when actually only 37 threatened species had been recorded. These disagreements seem to indicate that the RDB does not record all the threatened species. Actually, the species least recorded in the Atlas have not been observed at all in field surveys. For instance, none of the 39 species recorded once in the Atlas were recorded in the field. Of these only 10 appear in the RDB. The 29 remaining species should probably be included in the RDB. If so, the number of threatened tree species of the Western Ghats will significantly increase.

An urgent re-assessment of the threat categories of the least recorded species in the Atlas of endemics is therefore highly desirable. Table 1 can be used to prioritize a revision, since it is sorted in decreasing order of suspected threat. Five species, i.e. *Memecylon sisparense*, *Miliusa nilagirica*, *Palaquium bourdilloni*, *Phaeanthus malabaricus* and *Poeciloneuron pauciflorum*, known only from type specimens, have been recently recorded (Ramesh and Pascal 1997) and their status is no more indeterminate. *Elaeocarpus munronii*, *Kingiodendron pinnatum* and *Pterospermum reticulatum* were often recorded and frequently observed in the inventories.

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