Are red-listed species threatened? A comparative analysis of red-listed and non-red-listed plant species in the Western Ghats, India

N. A. Aravind[1], J. Manjunath[1], Dinesh Rao[1], K. N. Ganeshaiah[1,3,4], R. Uma Shaanker[1,2,4,*] and G. Vanaraj[1]

[1]Ashoka Trust for Research in Ecology and the Environment, #659, 5th 'A' Main, Hebbal, Bangalore 560 024, India
[2]Department of Crop Physiology and [3]Department of Genetics and Plant Breeding, University of Agricultural Sciences, GKVK, Bangalore 560 065, India
[4]Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore 560 065, India

Red lists of taxa are important documents guiding the prioritization of conservation efforts. However the actual process of arriving at red lists has been contentious, because of the paucity of hard ecological data. In this article, we examine the red listing of plant species at two geographical scales: regional and local in the Western Ghats, India. At the regional level, we compared the rarity (or abundance) of the red listed and the co-occurring non-red-listed species in fifteen sites across Western Ghats. For the local level analysis, we compared the distribution and demographic profile of red-listed medicinal plants with co-occurring non-red-listed species at two field sites in the Western Ghats. At both the regional and the local scales, our analyses showed that the red-listed species, as a group are not any more disadvantaged than the non-red-listed species. Our results lay caution on the process of inclusion of species in red-lists and urge the necessity of strong field data to make the red-listing process more robust.

IN an attempt to direct conservation efforts to species that might require it most, several organizations worldwide have developed red lists of taxa[1–6]. The IUCN red list includes categories such as extinct, extinct in the wild, threatened, endangered, vulnerable, etc.[1,2]. Among the various criteria adopted in the process of red-listing, is the ecological status of the taxa, as reflected by the reduction in population size and decrease in geographical distribution over time[1,2]. Following the criteria adopted by the IUCN, a number of country-specific red lists have been prepared[3–10].

While the red lists have been useful in providing guidelines for setting conservation priorities[1,2,11], little is known of the actual ecological status of the enlisted taxa. For example, how do the red-listed species compare with non-red-listed in their ecological status? Are red listed (RL) species relatively more 'threatened' with respect to their reproductive success than those non-red-listed? Are red-listed species more sparsely distributed than the co-occurring non-red listed? Does a *prima facie* case exist to step up efforts to conserve the red-listed species because of their lower abundances and declining reproductive potential?

In this article, we address these questions by analysing the status of red-listed species in relation to non-red listed species at both regional and local geographical scales. At the regional scale, we compare the relative abundance of red-listed with the non-red-listed species in the Western Ghats, a biodiversity hotspot in south India[12]. At a local scale, we compare the distribution and demographic profile of red-listed medicinal plants with co-occurring non-red-listed species at two forest sites in the Western Ghats. At both the geographical scales, we test the null hypothesis that red-listed species do not differ from co-occurring non-red-listed species with respect to their rarity and regeneration status. Based on the results, we urge on the need for rigorous field data to reinforce the preparation of red lists of taxa.

Materials and methods

Regional scale

Information on the vegetation composition and abundance of species was collated from ten independent studies carried out during 1992–2000, at 15 different sites along Western Ghats; Sanyasimalai located in the Eastern Ghats, for which the data was available, was also included in the analysis (Figure 1). For all sites (except for Charmadi and Kemmangundi), abundance data were available only for tree species. Accordingly, we considered the relative abundance of trees for these sites and for trees, shrubs and herbs at Charmadi and Kemmangundi. For each study, species were sorted from the most abundant to the least abundant and then categorized into three groups, viz. the 'top', 33.3% representing species that are highly abundant; the 'middle', 33.3% representing species with moderate abundance and the 'bottom', 33.3% the least abundant species. Further for each study, the species was classified as 'red-listed' or 'non-

*For correspondence. (e-mail: rus@vsnl.com)

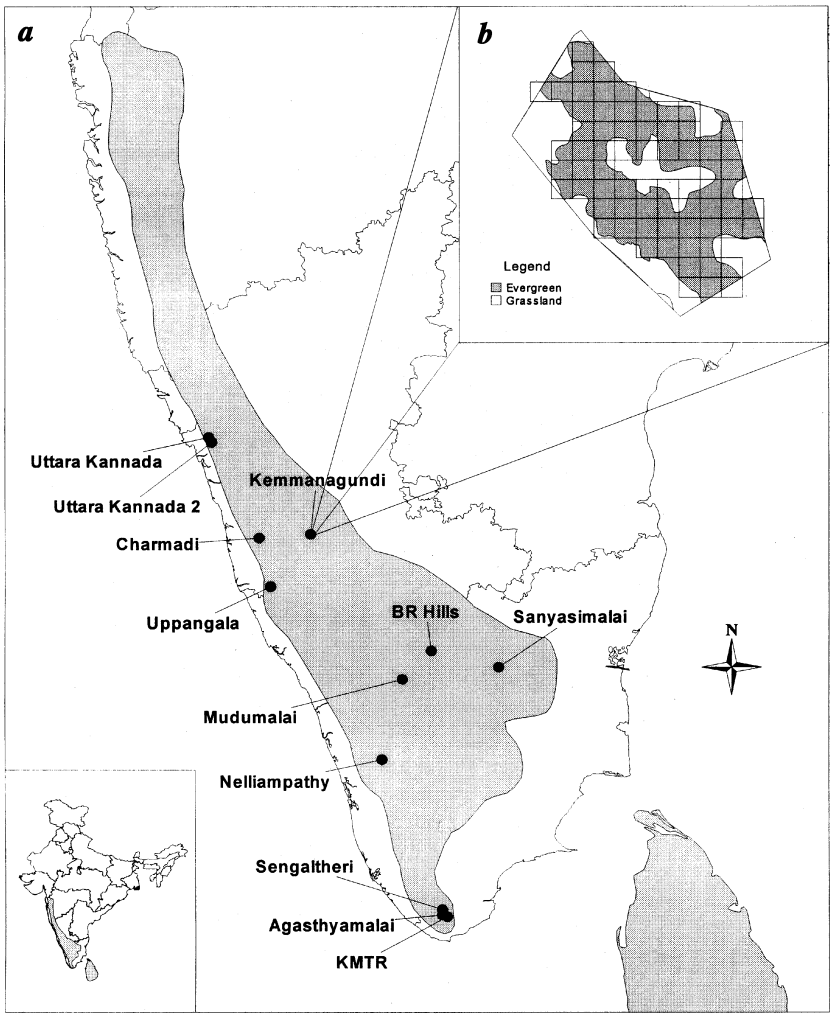

Figure 1. ***a***, Map of the Western Ghats showing the location of study sites for regional-scale analysis of red-listed and non-red-listed plants (see Appendices 1 and 2 for details). ***b***, Kemmangundi MPCA with sampling protocol followed for the study of demographic profile of red-listed and common plants.

red-listed' based on the red lists published by IUCN[1,2], BSI[3,5], FRLHT[8], and Ravikumar and Ved[9]. Even if any one of the three listings recorded a species as red-listed, it was included in the red-listed category.

We made a tacit assumption that species that are not red-listed are perhaps not threatened and hence serve as controls for evaluating the effectiveness of the process of red listing. This assumption could suffer from a potential shortcoming: species not red-listed might still be threatened but not yet enlisted owing to insufficient analysis. This could be particularly true because the very process of red listing is in a flux and is far from complete (www.redlist.org). However, functionally the non-red-listed species are treated as a group different in their conservation status from the red-listed, and hence our analysis aimed at comparing these two categories.

We tested whether the number of species in the three abundance categories was different between the red-listed and non-red-listed categories. For this, contingency tables were set up with three categories of abundance as rows and the red-listed and non-red-listed groups as columns; species from each site were assigned to the cells of these tables and were subjected to chi-square analysis[13]. Further based on the relative abundances of species in each of the studies, the upper and lower 15 ranks of abundance were generated. The percentage of red-listed species in the upper 15 ranks was compared with that in the lower 15 ranks. In this test, we assume that there is no difference in the per cent of red-listed species in the upper 15 and lower 15 ranks of abundance. Among the 15 studies, seven are from 'protected areas' and the remaining from reserve forests; however of the seven PAs, at BR Hills, there has been active extrac-

tion of non-timber forest products as well as medicinally important plants[14]. Using a non-parametric sign test, we also analysed for the differences between the red-listed and non-red-listed species in the number of species in the upper 15 and lower 15 ranks of abundances[15].

Local scale

We compared the relative abundance and regeneration of red-listed medicinal plant species with their co-occurring non-red-listed medicinal and non-medicinal species at two sites in the Western Ghats. Recently a red list of medicinal plants was developed for south India following the IUCN criteria and by periodic assessments conducted through the Conservation Assessment and Management Plan workshops (CAMP workshop). These workshops evaluate the status of the species based on several proximate measures of threat to a species[8,9,16]. Our rationale in this study was to compare the red-listed medicinal plant species with non-red listed (medicinal) species and ask if at local scales (a) the red-listed species are rarer in their occurrence than the non-red-listed species, and (b) if the red-listed species have a poorer regeneration status than the non-red-listed species.

Study sites: One of the sites, at Charmadi (75°26′9″ and 75°28′13″E and 13°3′52″ and 13°5′10″N) forms a part of the Charmadi–Kanappadi Reserve forest in Belthangadi range of Mangalore division, situated in the western slope of Western Ghats. The second site at Kemmanagundi (13°35′N and 75°45′E) is located in the Bababudan reserve forest of Chikamagalur district along the eastern slope of the Western Ghats (Figure 1). The two sites form part of a network of 33 Medicinal Plant Conservation Areas (MPCA) in southern India for the long-term conservation of medicinal plants[8]. However these sites are not part of the 'protected areas network' which by 'legislation' is protected almost entirely from human interferences. Thus both the local sites are potentially open for anthropogenic disturbances including extraction.

In each of these two study sites, the area (200 ha) was divided into grids of 200 m × 200 m. Species density, richness, and diversity, was enumerated by sampling four plots per grid. Two 10 m × 10 m quadrats at the southwest and northeast corners of each grid were enumerated for all individuals between 10 and 30 cm GBH of shrubs, and tree saplings[17]. One quadrat of 25 m × 20 m, approximately at the center of the grid, was enumerated for all individuals greater than 30 cm GBH (tree species). One 1 m × 1 m plot was laid at the centre of the 25 m × 20 m quadrat to enumerate all individuals with GBH less than 10 cm. All the species recorded in the two study areas were categorized into red-listed and non-red-listed groups as described earlier.

Analysis: The probability of occurrence of a species was calculated as the proportion of grids in which at least one individual of any size class of the species was found. As an index of dispersion of species, we computed the ratio of mean (m) to variance (s) for the number of individuals per grid; $s/m = 1$ indicates a random distribution, $s/m > 1$ refers to a clumped distribution and $s/m < 1$ refers to uniform distribution[18]. Number of seedling and sapling stage (<30 cm GBH) and adult plants (>30 cm GBH) were expressed as per cent in different size classes[17,19,20]. As a measure of the regeneration success of a species, we computed the number of regenerating individuals per adult for a given species in a grid. The number of saplings of a species (<30 cm GBH) per grid was counted and divided by the total number of adults of the corresponding species (>30 cm GBH) in that grid.

Non-parametric two-sample Kolmogorov–Smirnov test was performed to analyse the difference between red-listed and non-red-listed species in their probabilities of occurrence, adult-sapling ratio and size class distribution[13].

Results and discussion

Regional scale

Are red-listed species less abundant compared to non-red-listed species? To address this question, we examined the relative abundance of 500 species from ten locations collated from 15 different studies conducted in the Western Ghats. About ten per cent ($n = 49$) of the 500 species from 15 different studies at ten locations were red-listed by IUCN[1,2], BSI[3–5] and FRLHT[8,9]. Of the 15 studies, only in four the statistical evaluation of distribution of species in the three categories of abundance (top, middle and bottom) was possible; in the rest, the expected frequencies of the red-listed species was <5 rendering it unavailable for statistical treatment (Table 1). At two of the four sites (Kalakkad–Mundanturai Tiger Reserve (KMTR) and Sengaltheri), there was no significant difference between the distribution of red-listed and non-red-listed species in the different abundance categories. At two other sites (Uppangala and Charmadi), there were more than expected (based on random distribution) number of red-listed species in the higher abundance category (top), indicating that contrary to the generally held view, the red-listed species as a group are not necessarily low in abundance (Table 1).

The sign test showed that the red-listed and non-red-listed plants occurred in equal frequency in the upper and lower 15 ranks of abundance; so also the red-listed medicinal plants and non-red-listed plants (Table 2 and Appendices 1 and 2). Further, the sign test also showed that the red-listed species are no different from non-red-listed species in their frequency occurrence in the lower 15 ranks of abundance (Table 3); on the other hand there was a significantly higher per cent of red listed than non-red-listed species in the upper 15 ranks of abundance ($Z = 2.066$; $P = 0.039$; Table 3).

Table 1. Frequency of red-listed and non-red-listed species in three abundance categories in the Western Ghats. Details of the data collated are provided in Appendices 1 and 2. Rows for which the expected frequencies were <5 were not used for analysis. Values in parentheses indicate expected frequencies

Locality (vegetation type)	Category	Top	Middle	Bottom	Significance
BR Hills (Dry deciduous)	Red-listed	1	1	2	
	Non-red-listed	17	18	17	
KMTR (Evergreen)	Red-listed	3 (5)	6 (5)	6 (5)	$c^2 = 1.44$, $P = 0.487$
	Non-red-listed	27 (25)	24 (25)	24 (25)	
Mudumalai (Dry deciduous)	Red-listed	2	0	0	
	Non-red-listed	22	24	23	
Nelliampathy (Evergreen)	Red-listed	1	2	1	
	Non-red-listed	9	8	9	
Sanyasimalai (Semi evergreen)	Red-listed	2	3	0	
	Non-red-listed	24	24	27	
Sengaltheri (Evergreen)	Red-listed	4 (5.33)	8 (5.33)	4 (5.33)	$c^2 = 1.31$, $P = 0.3154$
	Non-red-listed	36 (34.67)	32 (34.67)	36 (34.67)	
Uppangala (Evergreen)	Red-listed	11 (6.53)	6 (6.73)	3 (6.73)	$c^2 = 6.48$, $P = 0.039$
	Non-red-listed	22 (26.47)	28 (27.27)	31 (27.27)	
Uttara Kannada (Evergreen)	Red-listed	1	1	2	
	Non-red-listed	38	38	37	
Uttara Kannada (Moist deciduous)	Red-listed	1	1	2	
	Non-red-listed	26	26	25	
Uttara Kannada 2 (Evergreen)	Red-listed	4	3	5	
	Non-red-listed	28	29	28	
Agasthyamalai (Hilltop evergreen)	Red-listed	2	1	1	
	Non-red-listed	7	8	8	
Agasthyamalai (West coast evergreen)	Red-listed	5	3	6	
	Non-red-listed	19	20	17	
Agasthyamalai (Wet evergreen)	Red-listed	8	4	3	
	Non-red-listed	19	22	23	
Charmadi (Evergreen)	Red-listed	16 (8.62)	6 (8.62)	4 (8.76)	$c^2 = 11.20$, $P = 0.0037$
	Non-red-listed	48 (55.38)	58 (55.38)	61 (56.24)	
Kemmangundi (Evergreen)	Red-listed	4	2	1	
	Non-red-listed	34	36	36	

Table 2. Sign test for occurrence of all RL species, and only for medicinal RL species in the upper (U) and lower (L) 15 ranks of abundance at different sites in the Western Ghats

Category	No. of non-ties	% U < L*	Z	Significance
All RL species	11	63.637	0.603	$P = 0.547$
Medicinal RL species	13	46.154	4.89×10^{-20}	$P = 1.000$

*Denotes the percentage of cases where RL species was lesser in the upper 15 ranks of abundance compared to the lower 15 ranks of abundance. Thus for the cases where all RL species were considered, in 11 of the 15 studies there were no ties; in 7 (~63.60%) there was greater percentage of RL species in the upper 15 ranks of abundance compared to the lower 15 ranks of abundance.

Table 3. Sign test for occurrence of RL and NRL species in the upper (U) and lower (L) 15 ranks of abundance at different sites in the Western Ghats

Category	No. of non-ties	% NRL < RL*	Z	Significance
U15RL and U15 (NRL)	15	20.000	2.066	$P = 0.039$
L15RL and L15 (NRL)	15	33.333	1.033	$P = 0.302$

*Denotes the percentage of cases where NRL species was lesser than RL species in the upper and lower 15 ranks of abundance.

These results indicate that at the regional scale, the red-listed species as a group do not seem to be any less abundant than the non-red-listed species. This is true for even the subset of the red-listed species such as the medicinal plants, where the levels of threat are generally assumed to be large.

Local scale

Distribution of red-listed medicinal plant species and non-red-listed medicinal species: At both Charmadi and Kemmangundi, the percentage of species occurring in different proportions of the grids was positively skewed. Almost 50 per cent of both red- and non-red-listed species occurs in <10% of grids, suggesting that both the categories are equally rare in their spatial distribution (Figure 2). In fact, a higher proportion of red-listed species occurred in more

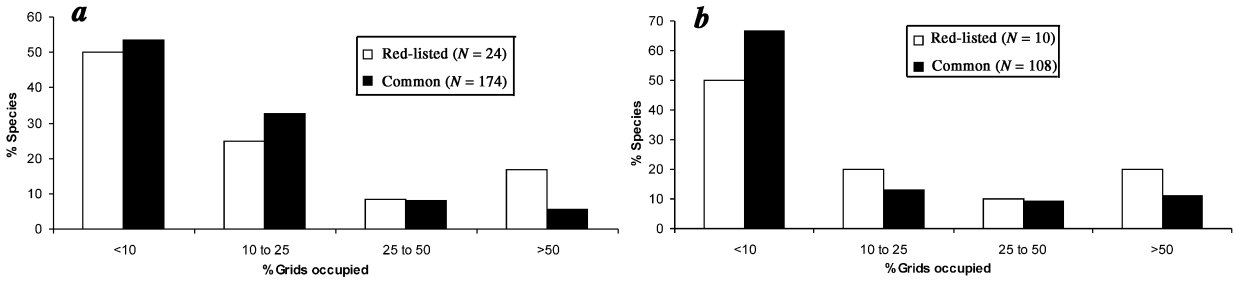

Figure 2. Per cent grid occupancy of red-listed and non-red-listed species in (***a***) Charmadi and (***b***) Kemmangundi.

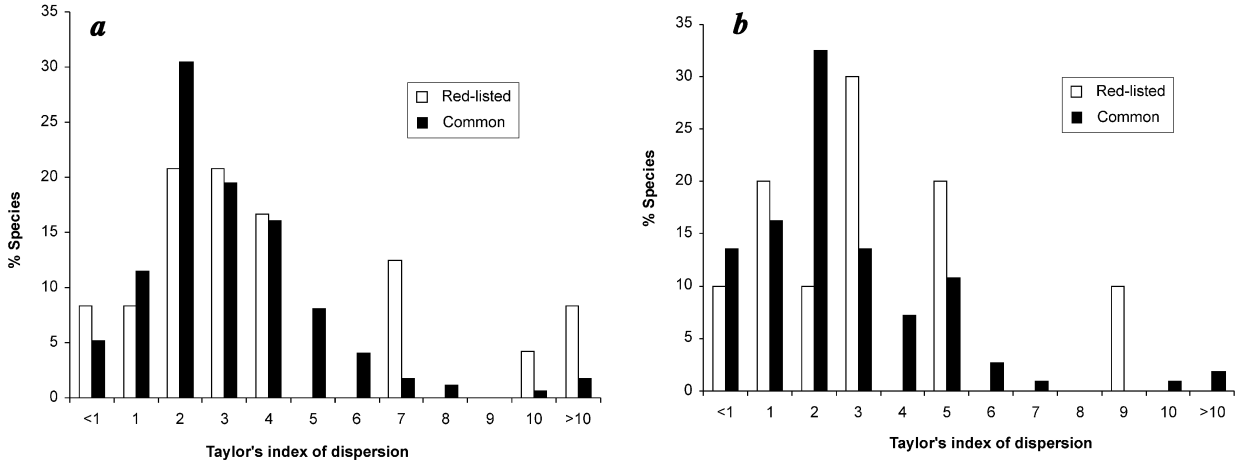

Figure 3. Frequency distribution of Taylor's index of dispersion for red-listed and non-red-listed species in (***a***) Charmadi and (***b***) Kemmangundi.

Table 4. G-test for frequency of RL and NRL species in the upper and lower 15 ranks of occurrence at two study sites in the Western Ghats. Values in parentheses are expected frequency

Site	Category	RL	NRL	*G*-test
Charmadi	Upper 15	4 (2)	11 (13)	$G(\text{adj}) = 0.174$
	Lower 15	3 (2)	12 (13)	$P = 0.677$
Kemmangundi	Upper 15	2 (2)	13 (13)	$G(\text{adj}) = -2.5 \times 10^{-14}$
	Lower 15	2 (2)	13 (13)	$P = 1.00$

than 50% of the grids, though the differences between red- and non-red-listed species were not significant. (Charmadi – KS test: $P > 0.05$, Kemmanagundi – KS test: $P > 0.05$).

Based on the relative abundance we identified two categories of species, viz. widely distributed (top 15 ranks) and sparsely distributed (bottom 15 ranks). The proportion of red- and non-red listed species in the two categories did not differ significantly, suggesting that at both sites red-listed species are as widely or sparsely distributed as the other species (Table 4).

Four species, viz. *Myristica dactyloides*, *Vateria indica*, *Garcinia indica* and *Artocarpus hirsutus* of the 24 red-listed species in Charmadi and two species, viz. *M. dactyloides* and *Mappia foetida* of the ten red-listed species in Kemmangundi occurred in the top 15 ranks of abundance in the respective sites. Among the species that occurred in the lower 15 ranks were *Terminalia arjuna*, *Piper nigrum* and *Rhaphidophora pertusa* out of the 24 red-listed in Charmadi and two, viz. *Piper mulleusa* and *Symplocos racemosa* of the ten red-listed in Kemmangundi.

At both sites most of the red listed and non-red-listed species exhibited clumped distribution in space (Figure 3; Charmadi – KS test: $P > 0.05$; Kemmangundi – KS test: $P > 0.05$). Among the red-listed species, *Aegle marmelos* in Charmadi and *Embelia ribes* in Kemmangundi showed uniform distribution. Among the red-listed species, *T. arjuna* in Charmadi and *Symplocos cochinsinensis* and *S. racemosa* in Kemmangundi exhibited random distribution.

Demographic profile of red and non-red-listed species

For the regenerating category (<30 cm GBH), there was no difference in the size class distribution between the red and non-red-listed species (Charmadi – KS test: $P > 0.05$; Kemmangundi – KS test: $P > 0.05$, Figure 4). However, for adult trees (>30 cm GBH), red-listed species appeared to have a greater proportion of older size class of plants than the non-red-listed species in Kemmangundi (>30 cm GBH; Charmadi – KS test: $P > 0.05$; Kemmangundi – KS test: $P < 0.05$; Figure 5).

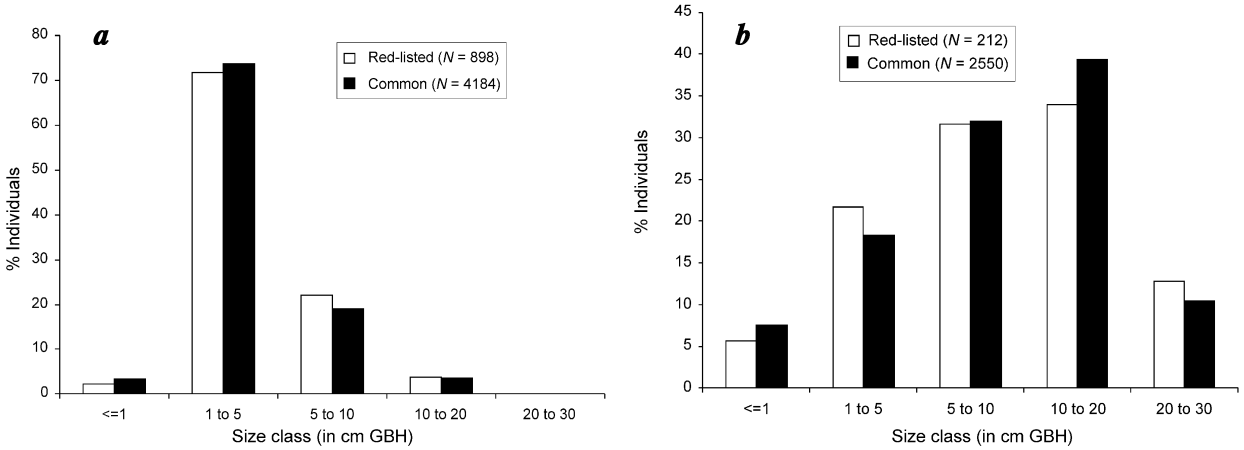

Figure 4. Size class distribution for regenerating class (<30 GBH) of red-listed and non-red-listed plants in (***a***) Charmadi and (***b***) Kemmangundi.

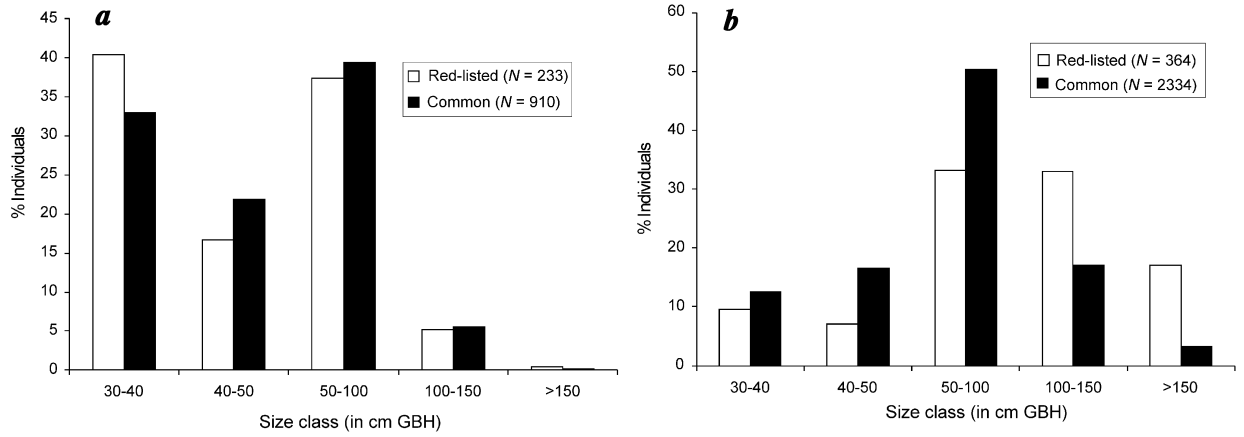

Figure 5. Size class distribution for adult trees (>30 GBH) of red-listed and non-red-listed plants in (***a***) Charmadi and (***b***) Kemmangundi.

Table 5. *G*-test for frequency of RL and NRL species in the upper and lower 15 ranks of sapling-to-adult ratios at two study sites in the Western Ghats. Values in parentheses are expected frequency

Site	Category	RL	NRL	*G*-test
Charmadi	Upper 15	2 (2)	13 (13)	G(adj) = 0.323
	Lower 15	1 (2)	14 (13)	P = 0.570
Kemmangundi	Upper 15	3 (2)	12 (13)	G(adj) = 0.219
	Lower 15	2 (2)	13 (13)	P = 0.640

Red and non-red-listed species did not differ for the saplings per adult at both the sites (Charmadi – KS test: $P > 0.05$; Kemmangundi – KS test: $P > 0.05$; Figure 6 *a* and *b*). Further, there was no significant difference between the red-listed and non-red-listed species in their sapling to adult ratios for the top 15 or bottom 15 species ranks (Charmadi: $c^2 = 0.37$, $P = 0.54$; Kemmangundi: $c^2 = 0.24$, $P = 0.62$) (Mann–Whitney test; Kemmangundi: $W = 2349.0$; $P = 0.860$; Charmadi: $W = 5018.0$, $P = 0.3390$).

Among the 24 red-listed species in Charmadi, only two, viz. *V. indica* and *Hydnocarpus pentandra* ranked among the upper 15 species in their sapling to adult ratio, while in Kemmangundi it was only three of the ten red-listed species, *M. foetida, M. dactyloides* and *Cinnamomum sulphuratum*. Among the lower 15 ranks of sapling to adult ratio were the red-listed species *T. arjuna* in Charmadi and *S. racemosa* and *S. cochinchinensis* in Kemmangundi (Table 5). These results also clearly indicate that the red-listed species as a group do not seem to be experiencing any reproductive stress different from the co-occurring non-red-listed species.

Our studies both at regional and local geographical scale indicate that the red-listed species are (a) as abundant as the non-red-listed species, (b) not more reproductively stressed than the non-red-listed species and (c) not necessarily more sparsely distributed than the non-red-listed species. Thus the red-listed species as a group seem to be indistinguishable from the other co-occurring non-red-listed species as far as their distribution and demographic profile are concerned. However, these results have to be weighed against a few caveats.

The first pertains to the very logic of comparing the red-listed with non-red-listed species. It may be argued that since the red-listing is a continuous process red list

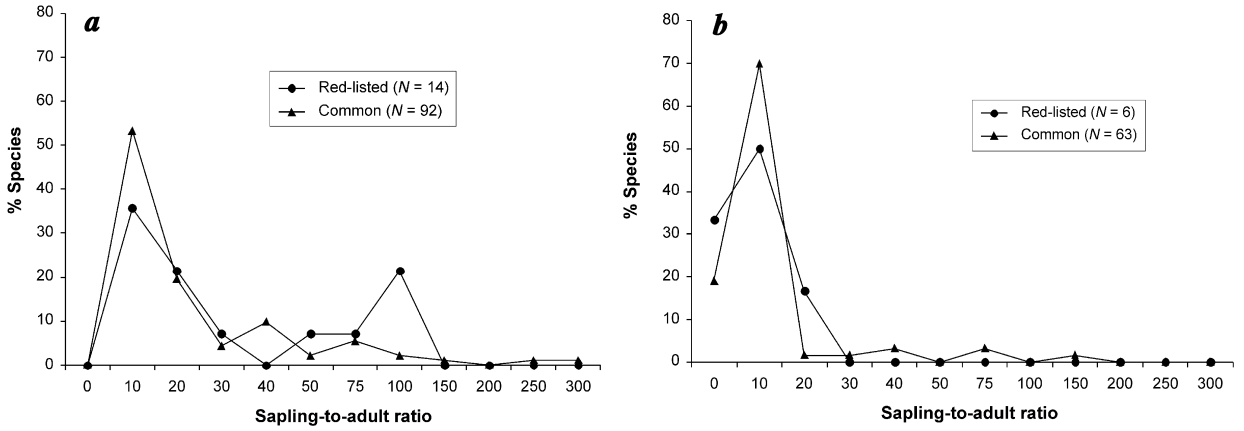

Figure 6. Sapling-to-adult ratio for red-listed and non-red-listed species in (***a***) Charmadi and (***b***) Kemmangundi.

Appendix 1. Proportion of RL species in the upper and lower 15 ranks of abundance at different sites in the Western Ghats

Locality (habitat)	1	2	3	4	5	6	7	8	9	Reference
BR Hills* (Dry deciduous)	3095	47	1.52	56	4	1	25	2	50	14
KMTR* (Evergreen)	2708	0	0.00	90	15	2	13.33	4	26.67	21
Mudumalai* (Dry deciduous)	25929	69	0.27	71	2	0	0.00	0	0.00	22
Nelliampathy (Evergreen)	2480	0	0.00	30	4	2	50	2	50	17
Sanyasimalai (Semi evergreen)	3260	125	3.83	80	5	2	40	0	0.00	19
Sengaltheri* (Evergreen)	2150	0	0.00	121	16	2	12.5	3	18.75	23
Uppangala (Evergreen)	1976	333	16.85	103	20	8	40	0	0.00	24
Uttara Kannada 1 (Evergreen)	3479	0	0.00	150	4	1	25	2	50	20
Uttara Kannada 1 (Moist deciduous)	1817	0	0.00	150	4	0	0.00	2	50	20
Uttara Kannada 2 (Evergreen)	15640	44	0.28	98	12	3	25	3	25	25
Agasthyamalai* (West coast evergreen)	–	–	–	71	14	3	21.43	3	21.43	26
Agasthyamalai* (Hilltop evergreen)	–	–	–	27	3	1	33.33	3	100	26
Agasthyamalai* (Wet evergreen)	–	–	–	79	15	3	20	5	33.33	26
Charmadi (Evergreen)	6252	1161	18.57	198	31	6	19.35	1	3.23	Present study
Kemmangundi (Evergreen)	2736	207	7.57	101	11	1	9.09	0	0.00	Present study

1, Total number of individuals; 2, Number of individuals of RL species; 3, Percentage of RL individuals; 4, Total number of species; 5, Number of RL species; 6, Number of RL species in upper 15 ranks; 7, Percentage of RL species in upper 15 ranks; 8, Number of RL in lower 15 ranks; 9, Percentage of RL species in lower 15 ranks.
*Indicates that these study sites are in PAs.

Appendix 2. Proportion of RL medicinal tree species in upper and lower 15 ranks of abundance at different sites in the Western Ghats

Locality (habitat)	1	2	3	4	5	6	7	8	9	Reference
BR Hills (Dry deciduous)	3095	47	1.52	56	3	1	33.33	2	66.67	14
KMTR (Evergreen)	2708	0	0.00	90	8	2	25.00	3	37.50	21
Mudumalai (Dry deciduous)	25929	69	0.27	71	1	0	0.00	0	0.000	22
Nelliampathy (Evergreen)	2480	0	0.00	30	3	2	66.67	1	33.33	17
Sanyasimalai (Semi evergreen)	3260	125	3.83	80	4	2	50.00	0	0.00	19
Sengaltheri (Evergreen)	2150	0	0.00	121	7	1	14.29	0	0.00	23
Uppangala (Evergreen)	1976	333	16.85	103	16	6	37.50	1	6.25	24
Uttara Kannada 1 (Evergreen)	3479	0	0.00	150	4	0	0.00	1	25.00	20
Uttara Kannada 1 (Moist deciduous)	1817	0	0.00	150	2	0	0.00	1	50.00	20
Uttara Kannada 2 (Evergreen)	15640	44	0.28	98	10	2	20.00	2	20.00	25
Agasthyamalai (West coast evergreen)	–	–	–	71	10	3	30.00	2	20.00	26
Agasthyamalai (Hilltop evergreen)	–	–	–	27	4	1	25.00	3	75.00	26
Agasthyamalai (Wet evergreen)	–	–	–	79	11	3	27.27	4	36.36	26
Charmadi (Evergreen)	6252	1161	18.57	198	21	4	19.05	1	4.76	Present study
Kemmangundi (Evergreen)	2736	207	7.57	101	10	1	20.00	0	20.00	Present study

1, Total number of individuals; 2, Number of individuals of RL species; 3, Percentage of RL individuals; 4, Total number of species; 5, Number of RL species; 6, Number of RL species in upper 15 ranks; 7, Percentage of RL species in upper 15 ranks; 8, Number of RL in lower 15 ranks; 9, Percentage of RL species in lower 15 ranks.

per se is a dynamic category and hence it is incorrect to categorize species and make the comparison. However, since the red-listed species constitute a small proportion of the total species evaluated[2], comparing these with the rest of the species as non-red-listed might be worthwhile for such analysis.

The second pertains to the possibility that the lack of differences between the red and non-red-listed species could be due to a sampling bias of the site of study. For example comparison of two categories in PAs might fail to show differences between them, as in these sites, the red-listed species are as well maintained as the non-red listed species. However as mentioned elsewhere, in our study, at the regional level only 7 of the 15 studies pertained to protected areas and of which one (BR Hills) was open to human disturbances. Further at the local scale, both the study sites are reserved forests and thus open to extraction.

Third, our study is limited to the data along the Western Ghats. However, species may occur beyond this region and hence the comparisons may not be appropriate, as the data from the entire distributional range of different species is not available. Therefore it would be important to validate our results using data at much broader scales.

The results of our study while having important implications for the preparation of red lists, do not detract the significance of the process. The study only lays caution on the exercise of preparing red lists of species towards setting conservation priorities. While red listing of species might still be valid for reasons of anticipated threats or market demands, we argue that the threats to species should be quantitatively assessed based on hard field data on the distribution and demographic profile. Such a process would make red listing more robust – a practice not rigorously adopted as of now.

1. IUCN, *Red List Categories*, IUCN Publications, Switzerland, 1994.
2. IUCN Species Survival Commission, IUCN Redlist categories: Version 3.1, IUCN (http://www.iucn.org/themes/ssc/redlists/ssc-rl-c.htm), 2003.
3. Nayar, M. P. and Sastry, A. R. K., *Red Data Book of Indian Plants*, Botanical Survey of India, Kolkata, 1987, vol. 1.
4. Nayar, M. P. and Sastry, A. R. K., *Red Data Book of Indian Plants*, Botanical Survey of India, Kolkata, 1988, vol. 3.
5. Nayar, M. P. and Sastry, A. R. K., *Red Data Book of Indian Plants*, Botanical Survey of India, Kolkata, 1990, vol. 3.
6. Ved, D. K. and Utkarsh, G., Conservation assessment of medicinal plants of peninsular India. http://www.frlht-india.org/html/ciipr.html, 2001.
7. Briggs, J. D. and Leigh, J. M., *Rare or Threatened Australian Plants*, Australian National Parks and Wildlife Service Special Publication No. 14, Australian National Parks and Wildlife Service, Canberra, 1988, revised edn.
8. C.A.M.P. Workshop Manual, *C.A.M.P. for Selected Species of Medicinal Plants of Southern India*, Zoo Outreach Organization and CBSG, India, 1995.
9. Ravikumar, K. and Ved, D. K., *Illustrated Field Guide to 100 Red-Listed Medicinal Plants of Conservation Concern in Southern India*, FRLHT, Bangalore, 2000.
10. Gardenfors, U., Classifying threatened species at national versus global levels. *TREE*, 2001, **16**, 511–516.
11. Possingham, H. P., Andelman, S. J., Burgman, M. A., Medellin, R. A., Master, L. L. and Keith, D. A., Limits to the use of threatened species lists. *TREE*, 2002, **17**, 503–507.
12. Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. and Kent, J., Biodiversity hotspots for conservation priorities. *Nature*, 2000, **403**, 853–858.
13. Sokal, R. R. and Rohlf, F. J., *Biometry*, W. H. Freeman and Company, New York, 1981, pp. 440–445.
14. Murali, K. S., Uma Shankar, Uma Shaanker, R., Ganeshaiah, K. N. and Bawa, K. S., Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 2. Impact of NTFP extraction on regeneration, population structure and species composition. *Econ. Bot.*, 1996, **50**, 252–269.
15. Siegel, S. and Castellan, Jr. N. H., *Nonparametric Statistics for the Behavioural Sciences*, McGraw-Hill, 1988, pp. 80–86.
16. Anon, *Amphibian Camp Handbook*, Declining Amphibian Population Task Force-South Asia and Zoo Outreach Organization, Coimbatore, 1998, pp. 1–2.
17. Chandrashekara, U. M. and Ramakrishnan, P. S., Vegetation and gap dynamics of a tropical wet evergreen forest in the Western Ghats of Kerala, India. *J. Trop. Ecol.*, 1994, **10**, 337–354.
18. Ludwig, J. A. and Reynolds, J. F., *Statistical Ecology: A Primer on Methods and Computing*, John Wiley, New York, 1988.
19. Kadavul, K. and Parthasarathy, N., Plant biodiversity and conservation of tropical semi-evergreen forest in the Shervarayan hills of Eastern Ghats, India. *Biodivers. Conserv.*, 1999, **8**, 421–439.
20. Bhat, D. M. *et al.*, Forest dynamics in tropical rain forests of Uttara Kannada district in Western Ghats, India. *Curr. Sci.*, 2000, **79**, 975–985.
21. Ganesh, T., Ganesan, R., Devy, M. S., Davidar, P. and Bawa, K. S., Assessment of plant biodiversity at a mid-elevation evergreen forest of Kalakkad–Mundanthurai Tiger reserve, Western Ghats, India. *Curr. Sci.*, 1996, **71**, 379–392.
22. Sukumar, R., Dattaraja, H. S., Suresh, H. S., Radhakrishnan, J., Vasudeva, R., Nirmala, S. and Joshi, N. V., Long-term monitoring of vegetation in a tropical deciduous forest in Mudumalai, Southern India. *Curr. Sci.*, 1992, **62**, 608–616.
23. Parthasarathy, N., Tree diversity and distribution in undisturbed and human impacted sites of tropical wet evergreen forest in southern Western Ghats, India. *Biodivers. Conserv.*, 1999, **8**, 1365–1381.
24. Pascal, J. P. and Pelissier, R. J., Structure and floristic composition of a tropical evergreen forest in south-west India. *Trop. Ecol.*, 1996, **12**, 195–281.
25. Daniels, R. J. R., Gadgil, M. and Joshi, N. V., Impact of human extraction on tropical humid forests in the Western Ghats in Uttara Kannada, South India. *J. Appl. Ecol.*, 1995, **32**, 866–874.
26. Varghese, A. O. and Balasubramanyan, K., Structure, composition and diversity of the tropical wet evergreen forest of the Agasthyamalai region of Kerala, Western Ghats. *J. South Asian Nat. Hist.*, 1999, **l4**, 87–134.

ACKNOWLEDGEMENTS. This work is funded by Foundation for Revitalization of Local Health Traditions, Bangalore. We thank the Karnataka Forest Department for permitting us to carry out research in field sites, and Utkarsh Ghate for providing CAMP data. We also thank Bipin Charles for providing map of the study sites. We acknowledge the able field assistance by Kethe Gowda, Jadeappa, Mari Kethe Gowda and Laxmikanth and the logistics arrangements by Ramesh and Laxmikanthaiah. We thank the reviewers for their helpful suggestions to improve the manuscript.

Received 4 June 2004; revised accepted 3 August 2004