Bhagwat, S., Kushalappa, C., Williams, P., Brown, N. 2005. The role of informal protected areas in maintaining biodiversity in the Western Ghats of India. *Ecology and Society* **10**(1): 8. [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art8/

Research

The Role of Informal Protected Areas in Maintaining Biodiversity in the Western Ghats of India

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ABSTRACT. Although it is widely believed that an important function of protected areas is to conserve species that are unable to survive elsewhere, there are very few empirical studies in which a comparison is made between biodiversity of protected areas and that of the cultivated landscape surrounding them. We examined the diversity of trees, birds, and macrofungi at 58 sites in three land-use types in a tree-covered landscape in Kodagu district in the Western Ghats of India. Ten forest reserve sites in the formal protected area, and 25 sacred groves and 23 coffee plantations in the neighboring cultivated landscape were sampled. A total of 215 tree, 86 bird, and 163 macrofungus species were recorded. The forest reserve had a large number of trees that were restricted in their distribution, and the sacred groves had a large number of macrofungi. We observed that deciduous trees and non-forest-dwelling birds increased, and evergreen trees and forest-dwelling birds decreased with increasing intensity of land management. We found that trees having non-timber uses and macrofungi useful to the local people, as well as those with medicinal properties, were abundant in sacred groves. We found no significant differences in the distribution of endemic and threatened birds across the three land-use types. Although endemic trees were more abundant in the forest reserve than in sacred groves, threatened trees were more abundant in sacred groves than in the forest reserve. We attribute the high diversity in sacred groves to the native tree cover in shade coffee plantations. We conclude that informal protected areas are as important as formal ones for biodiversity conservation in Kodagu. We recommend that a conservation strategy that recognizes informal protection traditions is essential for successful biodiversity conservation in regions where formal reserves are surrounded by a matrix of cultivated land.

Key Words: *biodiversity conservation; endemic and threatened species; medicinal plants; non-timber forest products; protected areas; sacred groves; Western Ghats of India*

INTRODUCTION

One potential objective in designating a protected area is to conserve elements of biodiversity that are unable to survive elsewhere (Kramer et al. 1997, Bruner et al. 2001). However, there is growing recognition that the landscape matrix surrounding protected areas also plays an important role in protecting many species (Halpin 1997, Hannah et al. 2002). It has been shown that the distribution patterns of many of the species that are currently of the greatest international conservation concern do not coincide with broader diversity patterns (Prendergast et al. 1993, Oliver and Beattie 1996, Lawton et al. 1998, Williams et al. 2000, Perfecto et al. 2003). They may not, therefore, be adequately protected in areas set aside for biodiversity conservation. Successful conservation management requires an understanding of species' distributions (Roy 2003), including which species are restricted to protected areas and which are adequately protected outside these areas. There are very few empirical studies where such a comparison is made (but see Fabricius et al. 2003, Velazquez et al. 2003), nor where the effectiveness of protected areas is compared with the surrounding landscape matrix from a range of stakeholder viewpoints, including that of the local people (but see Fabricius and Burger 1997, Khan et al. 1997).

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In this paper, we examine the distribution of biodiversity in a protected area and in the adjoining cultivated landscape, including sacred groves and coffee plantations, in the Western Ghats of India. We measure biodiversity of three contrasting groups of organisms: trees, birds, and macrofungi. We ask: Where in the landscape are species useful to the local people? Where are endemic and threatened species distributed? We discuss implications for landscape-scale biodiversity conservation.

METHODS

Study Area

The Kodagu district of Karnataka State in the Western Ghats of India extends between 11°56’ – 12°52’ N and 75°22’ – 76°11’ E (Pascal and Meher-Homji 1986) (Fig. 1). The formal network of protected areas (the forest reserve) in the region consists of three wildlife sanctuaries and one national park, which stretch continuously along the western and the southwestern boundaries of the district, occupying about 30% of the area (Fig. 2). Plantations of shade-grown coffee occupy much of the remaining landscape (about 60%). Here, coffee bushes are grown beneath a high tree canopy to shade the plantations. Approximately 8% of the total area is occupied by treeless land uses, such as paddy cultivation. The study region has a high density of sacred groves—one grove in every 300 ha (Kushalappa and Bhagwat 2001). These groves range in size from a fraction of a hectare to a few tens of hectares (S.A.B. and C.G.K., personal observation), and are often surrounded by shade-grown coffee cultivation. Sacred groves occupy only about 2% of the study area (Fig. 2).

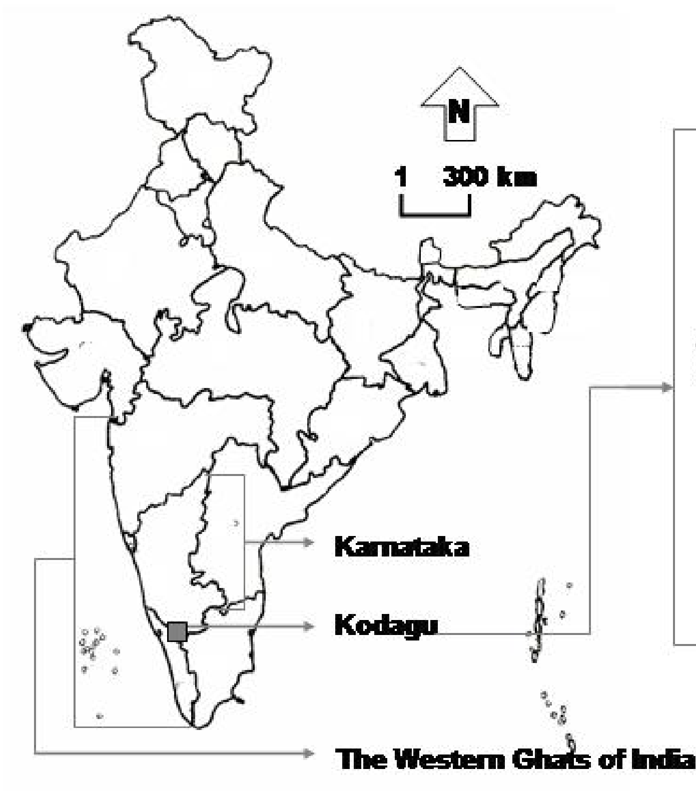
Sampling Design

We selected 58 sites in three land-use types—the forest reserve, sacred groves, and coffee plantations —in a 600-km^2 area in southwestern Kodagu (Table 1). We sampled trees, birds, and macrofungi at ten forest reserve sites, 25 sacred groves, and 23 coffee plantations in 1999 and 2000. We selected sacred groves so that they were well distributed across the study area, and across the range of different patch sizes (min. 0.2 ha, max. 48.1 ha, mean 13.2 ha, median 7.35 ha), as well as different distances from the forest reserve (min. 1 km, max. 8.6 km, mean 4.4 km, median 4.55 km) (Table 1). We ensured that sampling sites in coffee plantations and forest reserve sites were also well distributed across the study area (Fig. 2). The forest reserve is a relatively homogenous and unbroken stretch of forest. We sampled more sites in sacred groves and coffee plantations than in the forest reserve, in order to take into account the heterogeneity of the cultivated landscape. Our strategy was to sample, at random, a predetermined number of individuals (observations in the case of birds and macrofungi) at each site, rather than sampling equal areas (Condit et al. 1996, Bibby et al. 1998), in order to overcome the problem of variable sizes of sampling sites and differences in the biological and ecological characteristics of organisms in question. We identified trees and birds to species, and macrofungi to recognizable taxonomic units according to their morphological features (i.e., morphotypes, referred to as species hereafter).

At each site, we selected a baseline (between st and fn in Fig. 3) that often ran along a natural or human-made linear landscape feature (e.g., cart track, path, fence, boundary, stream) across the extent of the area. In most cases, this landscape feature was <1 m wide and canopy covered, thus minimally disturbed by human activity. Although the starting point of transect was on the baseline, the rest of the transect was perpendicular to the baseline, away from it. Furthermore, our objective was to obtain a sample of biodiversity that represented all habitats within the site rather than the “best” one. Therefore, we assumed that the proximity of baseline to human-made landscape features in our sampling design is acceptable.

Before visiting a sampling site (for tree sampling), we generated random numbers in multiples of five. The starting points of individual transects were in the same sequence as the random numbers (Fig. 3). For example, if the first random number was 100, we placed transect No. 1 at 100 m from the starting point along the baseline on a randomly chosen side —left or right. After completing the sampling along the first transect, we placed the second transect at a distance equal to the second random number (e.g., 225 m, Fig. 3) from the starting point. We continued laying transects until we had counted at least 1000 trees ≥1 cm diameter at breast height (dbh) in sacred groves and forest reserve sites, and 100 trees ≥10 cm dbh in coffee plantations, where small stems are regularly cut back. We repeated the process at each

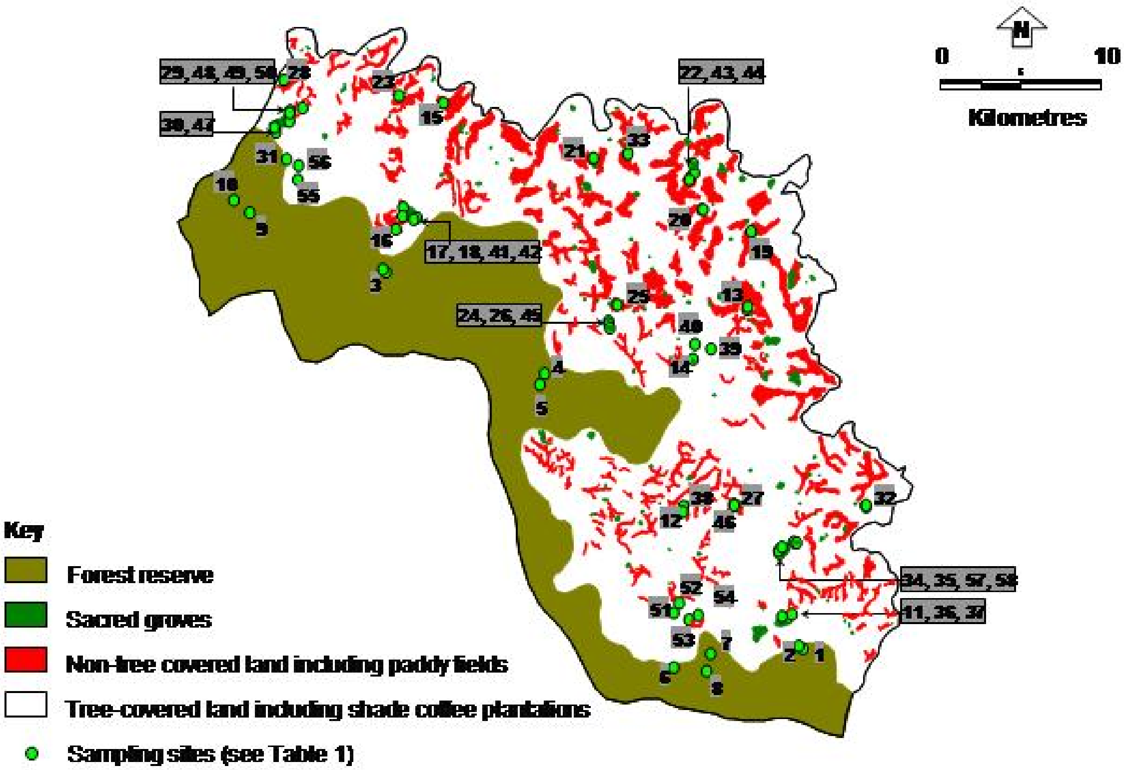
Fig. 1. The study area, showing Kodagu District in Karnataka State, India; sampling sites were located in the southwestern part of the district, where the continuous forest reserve adjoins cultivated landscape consisting of coffee plantations, and sacred groves.



site. The lengths of transects varied between 20 and 100 m in accordance with patch sizes. We demarcated the baseline by painting blue arrows on adjacent trees. The direction of the baseline was usually along a cardinal direction. Therefore, we established vegetation transects exactly along a north–south line if the baseline was roughly east–west, and vice versa. Seventy-five percent of our sampling sites were <5 ha in size. As a result, the framework of baseline and transects was spread across the entire area of most sampling sites, allowing us to obtain a sample that characterized the biodiversity of the whole site. We used the same framework of baseline and transects to sample birds and macrofungi.

We used the fixed radius point count method (Hutto et al. 1986) for bird sampling. The sampling team consisted of at least three people—two of them made observations and one recorded—so as to minimize errors in locating and counting birds. We carried out between five and fifteen 12-minute point counts at each site until we made at least 50 individual bird sightings (e.g., Thiollay 1994). At

Fig. 2. Landscape map of the study area in Kodagu, Western Ghats of India, showing landscape composition and land uses studied; sampling sites are numbered according to the list in Table 1.



each point, all birds seen within a 25-m radius through a pair of binoculars (7 × 50 magnification) were recorded by species. We normally began sampling at 7:00 a.m., and continued until the required number of observations was made.

We sampled macrofungal sporocarps in a ≥500-m^2 area along 5-m wide transects at each site (e.g., Senn-Irlet and Bieri 1999) on three different occasions during the monsoon season (June–September). A team of at least four people, two on either side of the central line, walked along the transects to ensure that all macrofungal sporocarps within the transect belt were recorded. We made at least 50 observations of macrofungal sporocarps. Some macrofungi produce single sporocarps, and others produce clusters. We recorded each cluster as one observation, regardless of the number of sporocarps in that cluster.

Species Attributes

The aim of our sampling was to measure the species diversity of trees, birds, and macrofungi. We did not "look" for species with specific attributes during

Table 1. List of sampling sites in Kodagu, Western Ghats of India; the sites are identified by alphanumeric codes consisting of abbreviated village names and sampling reference numbers

Sampling site	Altitude (m)	Size (ha)	Distance from the reserve (km)
Forest reserve			
1. Bgrf31	870	NA	0
2. Bgrfr32	870	NA	0
3. Hgrf43	878	NA	0
4. Kurfn49	927	NA	0
5. Kurfs50	923	NA	0
6. Thrfc41	856	NA	0
7. Thrfn03	833	NA	0
8. Thrfs40	832	NA	0
9. Torfe36	857	NA	0
10. Torfw35	857	NA	0
Sacred groves			
11. Bgdsg30	935	21.59	1.4
12. Bkdsg26	855	9.4	2.7
13. Brdsg21	812	1.3	5.3
14. Brlsg01	799	2.4	1.7
15. Btdsg42	879	12.1	4.8
16. Hgdsg18	917	2.4	1
17. Hglsge16	912	39.7	6.3
18. Hglsgw15	912	39.7	6.9
19. Htdsg57	822	8.9	8.2
20. Icdsg53	858	4	8
21. Kbdsg51	843	12.4	4.3
22. Kdpaim54	966	6.6	8.6
23. Ktdsg44	918	0.2	5.1
24. Kudsg45	860	3.7	1.9

(con'd)

25. Kuhdsg48	857	3.2	2.8
26. Kulsg47	847	1.4	2.2
27. Pdlsg27	870	7.1	4.9
28. Pldsg13	930	2.1	2.5
29. Pllsge08	935	48.1	1.4
30. Pllsgw11	956	48.1	4.7
31. Topaij39	910	NA	1.6
32. Tslsg58	820	14	6.4
33. Vbdsg52	824	7.6	5.7
34. Wndsg24	845	2.3	4.4
35. Wnlsg22	849	18.8	4.3
Coffee Plantations			
36. Bgcofd33	935	NA	1.3
37. Bgcofs34	935	NA	1.4
38. Bkcofc29	855	NA	2.9
39. Brcofj02	799	NA	2.7
40. Brcofn20	799	NA	2.3
41. Hgcofa19	912	NA	1.2
42. Hgcofu17	912	NA	1.5
43. Kdcofl55	866	NA	8.3
44. Kdcofs56	866	NA	8.5
45. Kucofp46	860	NA	2.1
45. Pdcofc28	870	NA	4.7
47. Plcofc10	956	NA	3.4
48. Plcofd12	910	NA	1.2
49. Plcofh09	935	NA	1.5
50. Plcofr14	902	NA	2.1
51. Thcofa04	847	NA	1.8
52. Thcofb05	865	NA	1.7

(con'd)

53. Thcofg06	836	NA	8.8
54. Thcofs07	836	NA	8
55. Tocofc38	910	NA	8
56. Tocofj37	910	NA	7
57. Wncofd25	845	NA	4.5
58. Wncofl23	849	NA	4.1

sampling, however, we categorized species according to their attributes when analyzing the data.

We classified trees into evergreen and deciduous categories, based on the published information (Pascal 1988, Keshavamoorthy and Yoganarasimhan 1989). We determined habitat preferences of bird species by prior knowledge or personal field observations, or based on species accounts in the field guides by Ali (1996) and Grimmett et al. (1998). We classified macrofungi according to their habitat preferences into two groups, namely, those fruiting on litter and those fruiting on wood, based on the information from the available literature (e. g., Jordan 1995) supplemented by field observations.

We determined the proportion of species endemic to the Western Ghats in different land-use types in this study, based on the *Atlas of Endemics* prepared by Ramesh and Pascal (1997). We also classified trees as non-threatened and threatened species based on the International Union for Conservation of Nature and Natural Resources (IUCN) threat categories (IUCN 2004) and examined their occurrence in different land-use types.

We classified species either as useful (for their non-timber product and medicinal value) or not useful to local people, and examined in which part of the landscape useful species persisted best. We consulted the *Wealth of India* (Council for Scientific and Industrial Research (CSIR) 1989) database for information on the usefulness of species, and a medicinal plants database prepared by Foundation for Revitalization of Local Health Traditions (FRLHT) to categorize species according to those with known medicinal properties and those without (FRLHT 1999).

Statistical Analyses

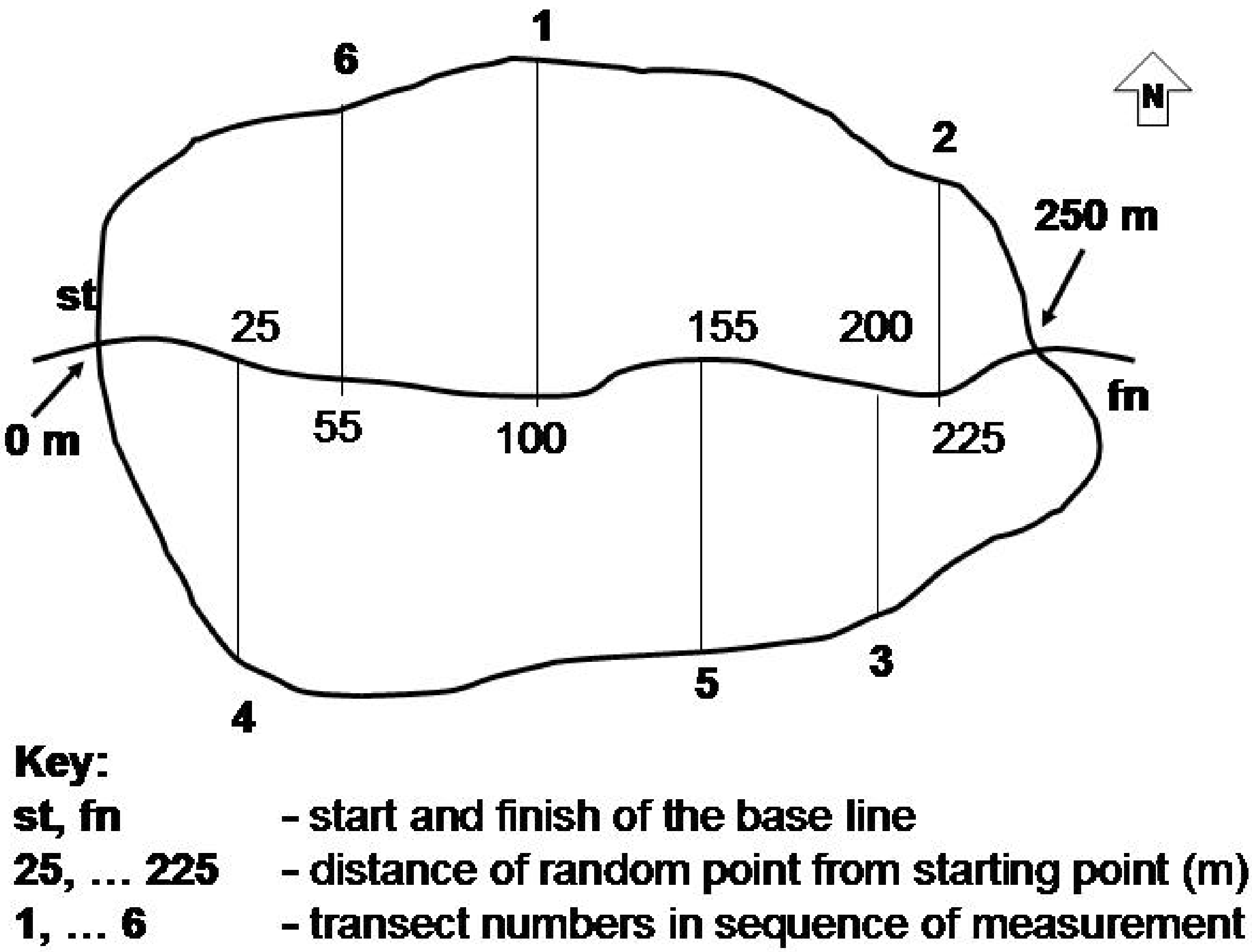
Although we sampled a predetermined number of individuals (for trees) or observations (for birds and macrofungi) at each site (see above), the numbers of sites sampled in the three land-use types were different (ten forest reserve sites, 25 sacred groves, and 23 coffee plantations). Therefore, we calculated the expected distribution of species by adjusting the species number to the sample size in the respective land-use type. Species that were found only in a single type were referred to as “restricted,” those shared by any two of the three types as “shared,” and those found in all three types as “widespread.’ To compare the composition of restricted, shared, and widespread species, we used χ^2 test.

To measure pairwise similarity in species composition of the three land-use types, we used Jaccard’s Similarity Index, $S_j = j/(a + b - j)$, where “j” is the number of species found in both land-use types, “a” is the number of species in the first land-use type, and “b” is the number of species in the second land-use type (Magurran 1988).

To compare habitat preferences of species across the three land-use types, we used the Kruskal-Wallis analysis of variance (ANOVA) by ranks (StatSoft 1984–2003).

To compare the occurrence of endemic and threatened species, and useful and medicinal species across the three land-use types, we used the Kruskal–Wallis test (SPSS 1989–1999).

Fig. 3. A schematic diagram of a representative sampling site in Kodagu, Western Ghats, India: a base line runs across the patch and the framework of transects is placed at random points along the baseline, on a randomly chosen side.

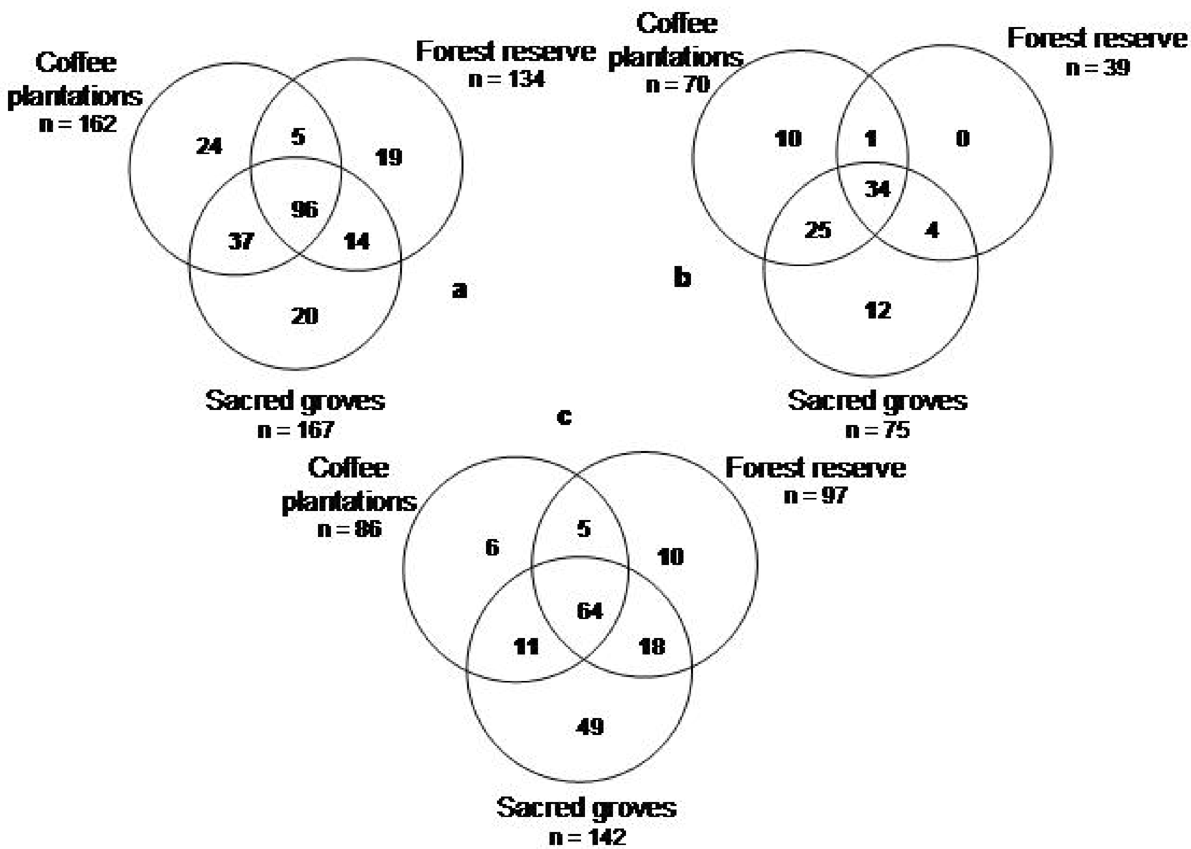


RESULTS

Distribution of Species

We recorded a total of 215 tree species, 86 bird species, and 163 macrofungus species in the forest reserve, sacred groves, and coffee plantations. Their distribution in the three land-use types is shown in Fig. 4. The forest reserve and sacred groves were 58% similar, the forest reserve and coffee plantations 52% similar, and sacred groves and coffee plantations 69% similar in their tree species composition according to Jaccard's Similarity Index. These figures were 50%, 47%, and 69%, respectively, for birds; and 52%, 61%, and 49%, respectively, for macrofungi. The observed number of restricted tree species was higher than expected in the forest reserve, but lower in the sacred groves (χ^2 test, $\chi^2 = 6.992$, df = 2, p-value < 0.05). Coffee plantations had nearly the same numbers of observed and expected tree species. The observed numbers of restricted bird species were not significantly different to the expected numbers (χ^2 test, $\chi^2 = 2.631$, df = 2, p-value = 0.0977) in any of

Fig. 4. Numbers of restricted and shared species of a) trees, b) birds, and c) macrofungi in Kodagu, Western Ghats of India.



the three land-use types. The distribution of macrofungal species between the three land-use types was significantly different from expected (χ^2 test, $\chi^2 = 26.262$, df = 2, p-value < 0.0001) because of the high numbers found in sacred groves.

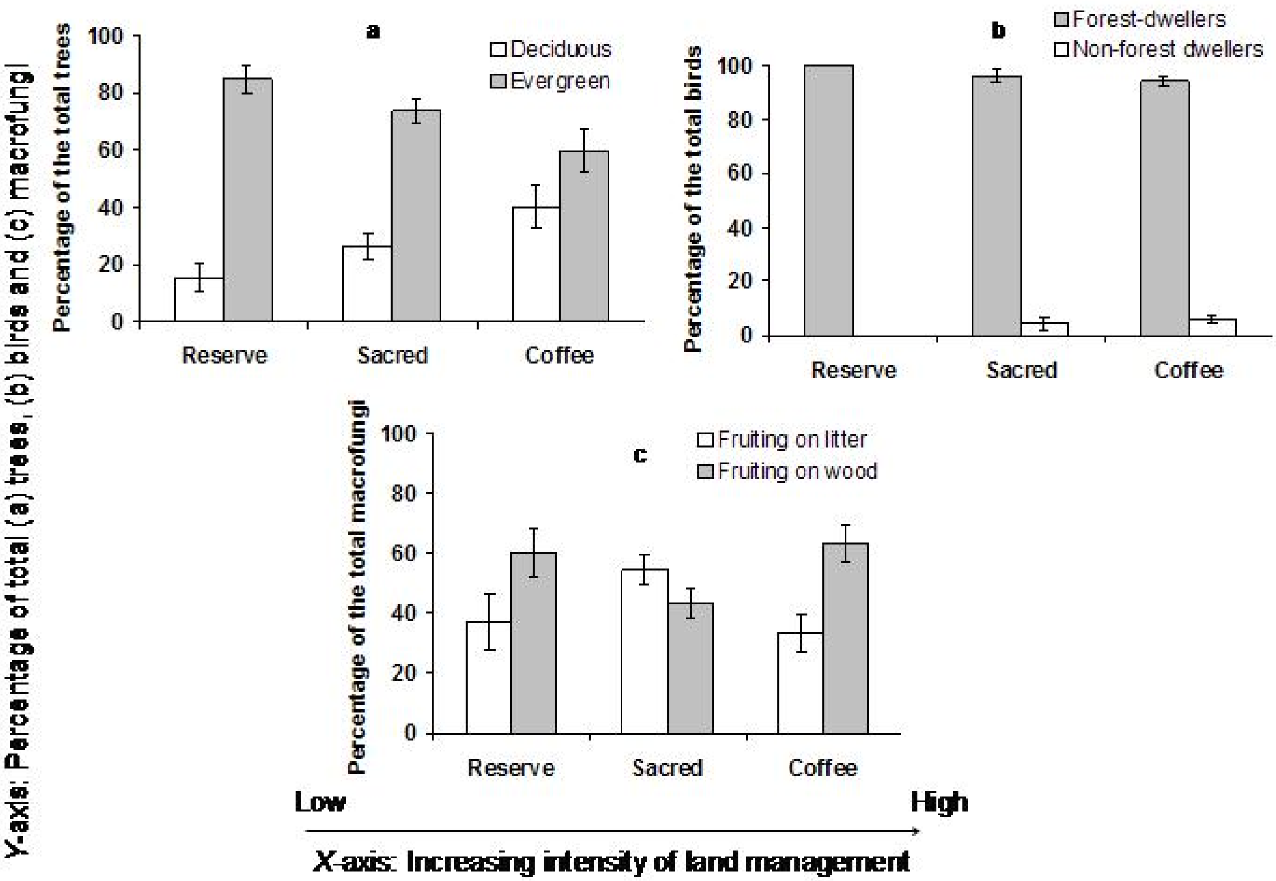
Species Attributes

Trees

The proportion of evergreen tree species declined and that of deciduous tree species increased with increasing human intervention in land management (Kruskal-Wallis ANOVA by ranks, H = 20.884, df = 2, N = 58, p-value < 0.001) (Fig. 5a).

Sixty-three percent of tree species in the Western Ghats forests are reported to be endemic (Pascal and Pelissier 1996). Endemic trees were significantly more frequent in the forest reserve (Kruskal–Wallis test, $\chi^2 = 12.754$, df = 2, p-value < 0.005), and non-endemic trees were significantly more frequent in coffee plantations (Kruskal–Wallis test, $\chi^2 = 8.306$, df = 2, p-value = 0.016) (Table 2). Threatened trees

Fig. 5. Habitat preferences of a) trees, b) birds, and c) macrofungi in Kodagu, Western Ghats of India; Reserve = forest reserve, Sacred = sacred groves, Coffee = coffee plantations. Note: error bars indicate 95 confidence limits.



were significantly more frequent in sacred groves, and non-threatened ones were significantly less frequent (Kruskal–Wallis test, $\chi^2 = 11.465$, df = 2, p-value = 0.003) compared with the forest reserve and coffee plantations (Table 2).

A total of 70% of species in Kodagu region yield useful non-timber forest products. The useful trees were significantly more frequent in coffee plantations (Kruskal–Wallis test, $\chi^2 = 7.553$, df = 2, p-value < 0.05), and those that had no known use were significantly more frequent in the forest reserve (Kruskal–Wallis test, $\chi^2 = 7.224$, df = 2, p-value < 0.05). Trees with medicinal properties were significantly more frequent in coffee plantations (Kruskal–Wallis test, $\chi^2 = 6.992$, df = 2, p-value < 0.05) compared with the forest reserve and sacred groves.

Birds

Almost 80% of bird species (68 out of 86) in Kodagu prefer tree-covered to open habitats. Coffee

Table 2. The distribution of endemic, threatened, useful, and medicinal trees in Kodagu, Western Ghats of India

Attribute	**Forest reserve No. of Species**	**Sacred groves No. of Species**	**Coffee plantations No. of Species**
Endemicity			
Endemic	50	47	39
Non-endemic	84	120	123
Threat status			
Threatened	26	32	27
Non-threatened	108	135	135
Use value			
Useful	83	112	118
No known use	51	55	44
Medicinal value			
Medicinal	33	42	48
Non-medicinal	101	125	114

plantations, with the most open canopies, had the highest proportion of non-forest dwellers, and the forest reserve, with the most closed canopy, had no non-forest-dwelling birds. The proportion of forest-dwelling bird species decreased with the intensity of land management, and that of non-forest dwellers increased (Kruskal-Wallis ANOVA by ranks, H = 16.544, df = 2, N = 58, p-value < 0.001) (Fig. 5b).

There was no significant difference in the distribution of endemic birds (Kruskal–Wallis test, $\chi^2 = 2.631$, df = 2, p-value = 0.268). Very few birds in the region are threatened; their numbers were not sufficient to analyze the differences in their occurrence across the land-use types (Table 3).

Macrofungi

Although a large majority of sporocarps belonged to macrofungi fruiting on litter and those fruiting on wood, there were small proportions that belonged to either coprophilous macrofungi (growing on cattle dung, e.g., *Coprinus* sp.) or entomopathogenic macrofungi (parasitic on insects, e.g., *Cordyceps* sp.). The proportional distributions of sporocarps of macrofungi fruiting on litter and on wood are shown in Fig. 5c; the proportions of sporocarps belonging to coprophilous and entomopathogenic macrofungi were negligible (1.8%, 2.1%, and 3.8% in the forest reserve, sacred groves, and coffee plantations, respectively), and are not shown. Macrofungal species fruiting on litter were significantly more frequent in sacred groves, and those of macrofungal species fruiting on wood were significantly less frequent compared with the forest reserve and coffee plantations (Kruskal-Wallis ANOVA by ranks, H = 19.601, df = 2, N = 58, p-value < 0.001), suggesting that the gradient of land management intensity does not have an effect on habitat preference of macrofungi.

Macrofungi such as some *Agaricus* spp., and some from the family Tricholomataceae, are reported to be edible, and a few others, such as *Ganoderma* spp. and *Phellinus* spp., are used locally for medicine. The edible (Kruskal–Wallis test, $\chi^2 = 12.437$, df = 2, p-value < 0.005) and medicinal (Kruskal–Wallis

Table 3. The distribution of endemic and threatened birds in Kodagu, Western Ghats of India

Attribute	**Forest reserve No. of Species**	**Sacred groves No. of Species**	**Coffee plantations No. of Species**
Endemicity			
Endemic	12	14	13
Non-endemic	27	61	57
Threat status			
Threatened	1	2	2
Non-threatened	38	73	68

test, $\chi^2 = 19.077$, df = 2, p-value < 0.0001) macrofungi were significantly more frequent in sacred groves than in the forest reserve and coffee plantations (Table 4.

DISCUSSION

Distribution of Biodiversity in the Landscape

Tree and bird species compositions of sacred groves and coffee plantations were most similar, and those of forest reserve and coffee plantations most dissimilar. This suggests that absence of human activity may be important in different species assemblages in the two parts of the landscape. We also found that intensity of land management influenced occurrence of evergreen and deciduous trees, and forest-dwelling and non-forest-dwelling birds in our sampling sites. The patterns of distribution of macrofungal species were different. The macrofungal assemblages in forest reserves and coffee plantations were most similar, and those of sacred groves and coffee plantations most dissimilar, suggesting the possibility that sacred groves shelter a distinctive assemblage. The distribution of macrofungal species across the three land-use types was significantly different from expected because of high numbers found in sacred groves, possibly because of a greater microhabitat heterogeneity that sacred groves provide in the landscape.

Distribution of endemic and threatened species

The forest reserve in Kodagu is important for conservation of endemic species. We found that many evergreen tree species, endemic to the Western Ghats, are restricted to the forest reserve (Table 5). The endemics are believed to be vulnerable to extinction (Bierregaard et al. 1997) because of their narrow distributions. These are also possibly habitat-specialist species that benefit from less disturbed, uninterrupted forest habitat within the reserve. The level of endemism in birds of the Western Ghats is low compared with trees (World Conservation Monitoring Centre (WCMC) 1992): 16% of the birds in the study area are endemic, in contrast to 63% of trees. We found no significant differences in the distribution of endemic birds between the forest reserve and the cultivated landscape. The ability of habitat-specialist birds to move freely, in contrast to trees, may be a factor that allows them to use both formally and informally protected parts of the landscape.

We found that sacred groves in Kodagu are important for protecting threatened trees, birds, and a distinctive macrofungal flora (cf. Jaffre et al. 1998). They shelter assemblages of species of conservation importance. We found that tree species such as *Actinodaphne lawsonii*, *Hopea ponga*, *Madhuca neriifolia*, and *Syzygium zeylanicum* that are listed as threatened (FRLHT 1999, IUCN 2004), were restricted to sacred groves. Other threatened species such as *Michelia champaca* and endemic species such as *Pittosporum dasycaulon* are found

Table 4. The distribution of macrofungal sporocarps with and without utility value to the local people of Kodagu, Western Ghats of India

Attribute	Forest reserve No. of species	Sacred groves No. of species	Coffee plantations No. of species
Utility value			
Edible	13	16	13
Non-edible	84	126	73
Medicinal value			
Medicinal	17	22	15
Non-medicinal	80	120	71

in sacred groves and coffee plantations, but not in the forest reserve. Between 17% and 90% of stems of the threatened and endemic species were between 1 and 10 cm dbh, suggesting that these species are able to regenerate in sacred groves. As these species cannot regenerate in coffee plantations, where all small individuals are regularly cut back, their future survival will require propagation as shade trees to maintain tree cover in the landscape. The bird species such as the Loten's sunbird (*Nectarinia lotenia*), an endemic, and the Nilgiri Flycatcher (*Eumyias albicaudata*), an endemic and threatened bird, are restricted to sacred groves and coffee plantations. Forty-nine out of 163 species of macrofungi are restricted to sacred groves, possibly as a result of the high habitat heterogeneity of sacred groves.

Distribution of useful species

The cultivated landscape with its plantations and sacred groves is of direct value to the local people. We found that the useful and medicinal trees are more abundant in the cultivated landscape than in the formally protected one. This can be ascribed to the selective use of certain species by local people and their maintenance through traditional knowledge of their uses (cf. Colding and Folke 1997, 2001). Boraiah et al. (2003) have also found that the sacred groves of Kodagu have a greater number of medicinal plant species than the forest reserve. It is likely that the proximity of sacred groves to human settlements has resulted in a greater familiarity of the local people with the plant wealth of sacred groves. This may mean that people have been more likely to "discover" medicinal values of plants within sacred groves, and to select them for domestication. For example, *Cinnamomum macrocarpum* is a tree that yields valuable NTFPs, such as the bark, used in spices. Other parts of the tree are also used in medicinal preparations, and the tree is listed by FRLHT (1999) as a priority species for conservation. Although the tree is widespread over the entire landscape, its selective use and retention is reflected in its size-class distributions (Fig. 6). Large size classes are found only in coffee plantations, presumably because they are retained by the landowners for periodic harvesting of the bark, which fetches a good market price. The species regenerates better in sacred groves than in the forest reserve, therefore, possibly maintaining healthy populations in the cultivated landscape.

We also found that useful and medicinal macrofungi are more frequently encountered in the cultivated landscape. Tropical forests are known to provide a large range of non-wood products that are important for the local economy (Myers 1988). In a study in the northeast of Peru (Pinedo-Vasquez et al. 1990), 60% of species were found to be useful to the local people for food, construction, craft, medicine, etc. Macrofungi are also one of the important non-timber forest products in the local economy in many tropical regions (Hartshorn 1995). In the Western Ghats, as elsewhere in the tropics, rural livelihoods depend on the non-wood products found in the neighboring forest. The cultivated landscape in

Table 5. Evergreen tree species restricted to the forest reserve in Kodagu; those marked with an asterisk are species that are also endemic to the Western Ghats of India

Evergreen tree species and their families	
* *Aglaia elaeagnoidea* (Meliaceae)	* *Humboldtia brunonis* (Fabaceae - Caesalpinioideae)
Agrostistachys meeboldii (Euphorbiaceae)	* *Litsea glabrata* (Lauraceae)
* *Baccaurea courtallensis* (Euphorbiaceae)	*Litsea insignis* (Lauraceae)
* *Blachia denudata* (Euphorbiaceae)	* *Mallotus stenanthus* (Euphorbiaceae)
* *Diospyros pruriens* (Ebenaceae)	*Memecylon wightii* (Melastomataceae)
* *Drypetes oblongifolia* (Euphorbiaceae)	*Mitrephora heyneana* (Annonaceae)
* *Elaeocarpus munronii* (Elaeocarpaceae)	*Polyalthia coffeoides* (Annonaceae)
* *Garcinia indica* (Clusiaceae)	* *Schefflera capitata* (Araliaceae)
Garcinia pictoria (Clusiaceae)	*Syzygium lanceolatum* (Myrtaceae)
* *Heritiera papilio* (Sterculiaceae)	

Kodagu caters to this need, possibly reducing resource-use pressure on the forest reserve.

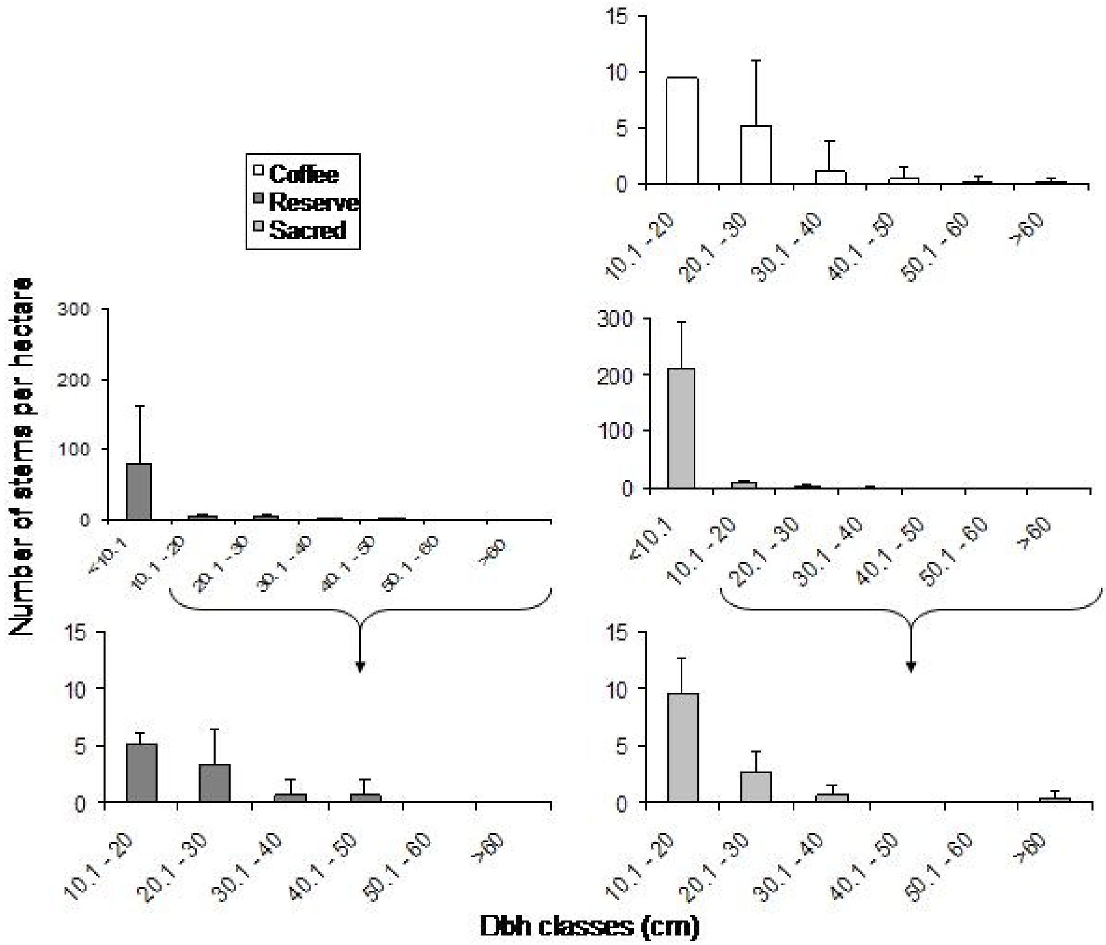
Role of Tree Cover in Maintaining Biodiversity

Although the species composition of the cultivated landscape in Kodagu has been highly influenced by the intensity of land management, more than 75% of this landscape is still under tree cover. This is because planters have retained many native trees to provide shade for coffee plantations. The tree-covered landscape may be an important factor in maintaining forest-dwelling biodiversity in sacred groves (Bhagwat et al. in press).

The tree cover in the landscape possibly reduces the severity of microclimatic changes, such as higher temperatures, increased wind speed, lower humidity,and lower soil moisture, introduced by forest fragmentation (Geiger 1965, Kapos et al. 1997, Freidenberg 1998). As a result, there may be less edge-related disturbance, and more habitat available for forest-dwelling species and less for non-forest-dwelling species. Consequently, sacred groves may support more forest-interior species than would be the case in a landscape where forest patches are surrounded by arable land alone. The tree cover also possibly facilitates movements of organisms such as birds through the landscape matrix surrounding sacred groves, which these organisms can use for foraging and other resources as well. As a result, coffee plantations may be harboring transitory individuals that are not able to reside within plantations alone. The plantations may also be harboring more individuals of forest-dwelling species than would be the case in a purely arable landscape matrix. As a consequence, coffee plantations in Kodagu may be harboring a greater number species than would be the case in an arable matrix.

Andrén (1994) found that, in landscapes with less than 30% cover of suitable habitat, habitat loss was a good predictor of diversity. However, in landscapes with higher habitat cover, habitat loss was not a good predictor of diversity in birds and mammals. O’Neill et al. (1988) in their spatial analysis have also observed that, above 30%, suitable habitat becomes almost continuous across the landscape. Many organisms are able to move easily across such landscape. For highly mobile organisms, this critical cover threshold will be much lower than for relatively less mobile ones. As a

Fig. 6. *Cinnamomum macrocarpum*, which is medicinal and also yields other valuable non-timber forest products, regenerates better in sacred groves (*n* = 19); the trees in the largest size classes are retained in coffee plantations (*n* = 18), but are absent from the forest reserve (*n* = 5) in Kodagu, Western Ghats of India. Note: error bars indicate 95% confidence limits.



consequence of the relatively continuous landscape, the sacred groves in Kodagu may not actually be perceived as "patches" by the organisms using them. Therefore, the diversity of trees, birds, and macrofungi was relatively similar between the forest reserve, sacred groves, and coffee plantations, despite the variation in intensity of land management. To maintain the integrity of the Kodagu landscape, active plantation of native trees in coffee estates, biodiversity-friendly coffee cultivation, and creation of a market for organically grown coffee may be essential (Bhagwat et al. in press).

Role of Informal Protected Areas in Conservation

Although the tree cover in the cultivated landscape in Kodagu has been valuable for maintaining landscape-scale diversity, the conservation ethic of the local people of protecting forest patches has also played a significant role in providing suitable habitat for many forest-dwelling organisms. Traditional societies are known to base their resource management on different rationales than most Western nature management and conservation systems (Colding and Folke 2001). Sacred groves in the Western Ghats are believed to have existed for more than two millennia (Gadgil 1992, Chandran 1997), and are present in high densities in Kodagu (Kushalappa and Bhagwat 2001). Every village in Kodagu is known to have at least one, and up to 12, sacred groves (S.A.B. and C.G.K., personal observation). In many biodiversity-rich developing countries, informal institutions are neglected, and formal protection has been the major approach to protecting biodiversity (Colding and Folke 2001). Despite the widespread presence of sacred groves, they are not included in the regional conservation design in the Western Ghats.

Brown (2003) has suggested that the conservation management institutions in tropical regions should take into account the complexity of ecosystems in question. Although the forest reserve in Kodagu provides a continuous habitat to species with large home ranges and those with special habitat requirements, the presence of sacred groves in the cultivated landscape ensures landscape-scale heterogeneity of habitats beneficial to many other organisms. The sacred groves also contribute to the protection of ecosystems, such as lowland marshes and swamps, outside the formal protected area. Furthermore, sacred groves and coffee plantations in Kodagu shelter species of trees and macrofungi useful to the local peoples' livelihoods. These species are in low numbers in the adjacent forest reserve (e.g., Fig. 6), possibly because of the lack of human activity in maintaining the populations of useful species. Although anthropogenic disturbance can be important in developing diversity and resilience in ecological systems, the formal conservation institutions often seek to minimize this disturbance (Brown 2003). In Kodagu, the forest reserve alone will not be adequate to maintain biodiversity; sacred groves are important.

There is now growing consensus among conservation planners that forest patches such as sacred groves are likely to be the key to maintaining biodiversity in the increasingly urbanized world. In recent years, the conservation community has also come to realize that the long-term survival of biodiversity depends on the effectiveness with which such forest remnants can be managed. Colding and Folke (2001) have proposed that conservation planners should devote careful consideration to already existing, local, informal institutions, and involve local people in planning. Berkes (2004) has argued that there has been a shift in ecology and applied ecology toward a systems view of the environment, a perspective that sees humans as part of the ecosystem. In Kodagu, biodiversity conservation will benefit from such an approach.

Prescribed Conservation Measures

Official recognition of sacred grove traditions

In modern-day India, although many traditions are eroding, a large number of sacred groves are still conserved through taboos and religious beliefs. Chandrakanth et al. (1990) suggest that such sacred acts should be recognized by the government. The fifth IUCN World Parks Congress in Durban (September 2003) acknowledged that local communities all over the world have conserved many sites through traditional means, but their importance has been neglected in formal conservation circles. The Congress recommended that the importance of community-conserved areas should be recognized (Kothari 2003). Although official recognition at the national and the international level will be important for land-tenure security of sacred groves in Kodagu, participation of local people in their management will also be essential (e.g., Colding and Folke 2001).

A system of rewards for effective protection

Many sacred groves in Kodagu are still well protected. Maintaining sacred groves is considered important to the local people (e.g., Chandrakanth and Nagaraja 1997) because of the cultural and spiritual appeal that such landscapes have (Posey 1998, McNeely 2003). However, some sacred groves have come under threat because of encroachment by neighboring coffee plantation owners (Bonn 2000). It has been suggested that a system of rewards may work for the effective protection of sacred groves (e.g., Chandrashekara and Sankar 1998). Sacred groves are important sources of non-timber forest products. Local people depend on them for fuelwood, green fodder, medicinal herbs, and other livelihood necessities. An organized system for harvesting, utilizing, and marketing such products may be necessary. The profit generated from such enterprises can be shared equitably between the government and the local community. Such initiatives also need to be complemented by appropriate legislation that can provide the necessary land-tenure security and resource-use rights to the local communities.

Toward joint planning and management

Khare et al. (2000) have found that foresters and villagers in some parts of India view joint forest management (JFM) very differently: many forestry department officials see JFM primarily as a means of ensuring the rehabilitation of degraded forests, but village communities view it as a solution to the growing shortage of biomass, a means of obtaining the daily requirements of forest products, and a way to increase income. It is necessary to bring foresters and villagers together to initiate a dialogue and to reach agreement on the objectives of JFM of sacred groves. In recent years, the government departments, non-government organizations, and local communities in Kodagu have undertaken coordinated efforts to develop and implement conservation strategies for sacred groves. The regional forest departments, in consultation with local people and organizations, will need to explore ways to manage sacred groves for maintaining biodiversity in Kodagu.

We suggest that informal community-managed areas are equally as important to conservation as formal protected areas (e.g., Margules and Pressey 2000, Sinclair et al. 2000, Bhagwat et al. 2001, Brooks et al. 2001, Wilshusen et al. 2002). In Kodagu, the integrity of the cultivated landscape should be maintained through the initiative and involvement of the local people. We recommend that a conservation strategy that recognizes the importance of informal protection approaches is essential for successful biodiversity conservation.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol10/iss1/art8/responses/

Acknowledgments:

This project was funded by a research grant to Oxford Forestry Institute, UK, from the Conservation, Food and Health Foundation, Boston, Massachussetts, USA. S.A.B.'s doctoral research at the Department of Plant Sciences was supported by the Rhodes Trust, the Radhakrishnan Memorial Bequest, Linacre College, and the University of Oxford Graduate Studies Committee. We thank Md. Ashfaq, K.T. Boraiah, H.R. Kamal Kumar, K.M. Nanaya, C. Shivanad, and B.S. Tambat for their assistance during the fieldwork in Kodagu. The co-supervision of S. Jennings and P. Savill during S.A.B.'s doctoral research is gratefully acknowledged. The discussion with R. Whittaker and M. Swaine was very useful. The comments from Dick Vane-Wright and two anonymous reviewers were very valuable in improving the manuscript. S. A.B. is grateful to the Biodiversity World project (www.bdworld.org) for supporting his current post-doctoral position at the Natural History Museum. The cost of publishing this article was paid for by the Resilience Alliance.

LITERATURE CITED

Ali, S. 1996. *The book of Indian birds*. Oxford University Press, Mumbai, India.

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos* **71**:355–366.

Balmford, A., and A. Long. 1994. Avian endemism and forest loss. *Nature* **372**:623–624.

Berkes, F. 2004. Rethinking community-based conservation. *Conservation Biology* **18**(3):621–630.

Bhagwat, S. A., C. G. Kushalappa, P. H. Williams, and N. D. Brown. 2005. A landscape approach to biodiversity conservation of sacred groves in the Western Ghats of India. *Conservation Biology* in press.

Bhagwat, S., N. D. Brown, T. Evans, S. B. Jennings, and P. S. Savill. 2001. Parks and factors in their success (Letters to Science). *Science* **293**:1045–1047.

Bibby, C., M. Jones, and S. Marsden. 1998. *Bird surveys*. Royal Society for the Protection of Birds, Sandy, Bedfordshire, UK.

Bierregaard, R. O., W. F. Laurance, J. W. Sites, A. J. Lynam, R. K. Didham, M. Andersen, C. Gascon, M. D. Tocher, A. P. Smith, V. M. Viana, T. E. Lovejoy, C. E. Sieving, E. A. Kramer, C. Restrepo, and C. Moritz. 1997. Key priorities for the study of fragmented tropical ecosystem. Pages 515–525 *in* W. F. Laurance, and R. O. Bierregaard, editors. *Tropical forest remnants: ecology, management and conservation of fragmented communities*. The University of Chicago Press, Chicago, Illinois, USA.

Boraiah, K. T., R. Vasudeva, S. A. Bhagwat, and C. G. Kushalappa. 2003. Do informally managed sacred groves have higher richness and regeneration of medicinal plants than state-managed reserve forests? *Current Science* **84**:804–808.

Brooks, T., A. Balmford, N. Burgess, J. Fjeldsa, L. A. Hansen, J. Moore, C. Rahbek, and P. Williams. 2001. Toward a blueprint for conservation in Africa. *Bioscience* **51**:613–624.

Brown, K. 2003. Integrating conservation and development: a case of institutional misfit. *Frontiers in Ecology and the Environment* **1**(9):479–487.

Bonn, E. 2000. An economic framework to land extensification. Pages 79–88 *in* P. S. Ramakrishnan, U. M. Chandrashekara, C. Elouard, C. Z. Guilmoto, R. K. Maikhuri, K. S. Rao, S. Sankar, and K. G. Saxena, editors. *Mountain biodiversity, land use dynamics, and traditional knowledge.* Man and the Biosphere Programme, Oxford and IBH Publishing, New Delhi, India.

Bruner, A. G., R. E. Gullison, R. E. Rice, and G. A. B. da Fonseca. 2001. Effectiveness of parks in protecting tropical biodiversity. *Science* **291**:125–128.

Chandrakanth, M. G., J. K. Gilless, V. Gowramma, and M. G. Nagaraja 1990. Temple forests in India's forest development. *Agroforestry Systems* **11**:199–211.

Chandrakanth, M. G., and M. G. Nagaraja. 1997. Existence value of Kodagu sacred groves: implications for policy. Pages 217–224 *in* A. Agarwal, editor. *The challenge of the balance: environmental economics in India*. Centre for Science and Environment, New Delhi, India.

Chandran, M. D. S. 1997. On the ecological history of the Western Ghats. *Current Science* **73**:146–155.

Chandrashekara, U. M., and S. Sankar. 1998. Structure and functions of sacred groves: case studies in Kerala. Pages 323–335 in P. S. Ramakrishnan, K. G. Saxena, and U. M. Chandrashekara, editors. *Conserving the sacred for biodiversity management.* Oxford and IBH Publishing, New Delhi, India.

Colding, J., and C. Folke. 1997. The relations among threatened species, their protection, and taboos. *Conservation Ecology* **1**(1):6 (Online.) URL: http://www.consecol.org/vol1/iss1/art6/

Colding, J., and C. Folke. 2001. Social taboos: "invisible" systems of local resource management and biological conservation. *Ecological Applications* **11**(2):584–600.

Condit, R., S. P. Hubbell, J. V. Lafrankie, R. Sukumar, N. Manokaran, R. B. Foster, and P. S. Ashton. 1996. Species-area and species-individual relationships for tropical trees: a comparison of three 50-ha plots. *Journal of Ecology* **84**:549–562.

Council for Scientific and Industrial Research (CSIR). 1989. *The useful plants of India.* Council for Industrial and Scientific Research, New Delhi, India.

Fabricius, C., and M. Burger. 1997. Comparison between a nature reserve and adjacent communal land in xeric succulent thicket: an indigenous plant user's perspective. *South African Journal of Science* **93**:259–262.

Fabricius, C., M. Burger, and P. A. R. Hockey. 2003. Comparing biodiversity between protected areas and adjacent rangeland in xeric succulent thicket, South Africa: arthropods and reptiles. *Journal of Applied Ecology* **40**:392–403.

Freidenberg, L. K. 1998. Physical effects of habitat fragmentation. Pages 66–79 *in* P. L. Fielder, and P. M. Kareiva, editors. *Conservation biology for the coming decade.* Chapman and Hall, New York, New York, USA.

Foundation for Revitalisation of Local Health Traditions (FRLHT). 1999. *Priority list of medicinal plants in South India*. Foundation for Revitalisation of Local Health Traditions, Bangalore, India.

Gadgil, M. 1992. Conserving biodiversity as if people matter: a case study from India. *Ambio* **21**:266–270.

Geiger, R. 1965. *The climate near the ground.* Harvard University Press, Cambridge, Massachussetts, USA.

Grimmett, R., C. Inskipp, and T. Inskipp. 1998. *Birds of the Indian Subcontinent.* Christopher Helm A & C Black, London, UK.

Halpin, P. N. 1997. Global climate change and natural-area protection: management responses and research directions. *Ecological Applications* **7**:828–843.

Hannah, L., G. F. Midgley, and D. Millar. 2002. Climate change-integrated conservation strategies. *Global Ecology and Biogeography* **11**:485–495.

Hartshorn, G. S. 1995. Ecological basis for sustainable development in tropical forests. *Annual Review of Ecology and Systematics* **26**:155–175.

Hutto, R. I., S. M. Pletschet, and P. Hendricks. 1986. A fixed-radius point count method for non-breeding and breeding season use. *Auk* **103**:593–602.

International Union for Conservation of Nature and Natural Resources (IUCN). 2004. *2004 IUCN red list of threatened species.* IUCN Species Survival Commission, Gland, Switzerland. (Online.) URL:http://www.redlist.org/

Jaffre, T., P. Bouchet, and J. M. Veillon. 1998. Threatened plants of New Caledonia: is the system of protected areas adequate? *Biodiversity and Conservation* **7**:109–135.

Jordan, M. 1995. *The encyclopaedia of fungi of Britain and Europe*. David & Charles, London, UK.

Kapos, V., E. Wandelli, J. L. Camargo, and G. Ganade. 1997. Edge-related changes in environment and plant responses due to forest fragmentation in Central Amazonia. Pages 33–44 *in* W. F. Laurance and R.O. Bierregaard, editors. *Tropical forest remnants: ecology, management and conservation of fragmented communities.* The University of Chicago Press, Chicago, Illinois, USA.

Keshavamoorthy, K. R., and S. N. Yoganarasimhan. 1989. *Flora of Coorg.* Vimsat Publishers, Bangalore, India.

Khan, M. L., S. Menon, and K. S. Bawa. 1997. Effectiveness of the protected area network in biodiversity conservation: a case-study of Meghalaya state. *Biodiversity and Conservation* **6**:853–868.

Khare, A., M. Sarin, N. C. Saxena, S. Palit, S. Bathla, F. Vania, and M. Satyanarayana. 2000. *Joint forest management: policy, practice and prospects.* World Wide Fund for Nature-India; International Institute for Environment and Development, New Delhi, India; London, UK.

Kothari, A. 2003. *Recommendation 26: community conserved areas.* WPC Recommendation 5.26, Vth IUCN World Parks Congress, Durban, South Africa. (Online.) URL: http://www.iucn.org/themes/wcpa/wpc2003/pdfs/outputs/recommendations/approved/english/html/r26.htm.

Kushalappa, C. G., and S. Bhagwat. 2001. Sacred groves: biodiversity, threats and conservation. Pages 21–29 *in* U. R. Shaankar, K. N. Ganeshaiah, and K. S. Bawa, editors. *Forest genetic resources: status, threats, and conservation.* Oxford and IBH, New Delhi, India.

Kramer, R., C. van Schaik, and J. Johnston. 1997. *Last stand: protected areas and the defence of tropical biodiversity.* Oxford University Press, New York, New York, USA.

Lawton, J. H., D. E. Bignell, B. Bolton, G. F. Bloemers, P. Eggleton, P. M. Hammond, M. Hodda, R. D. Holt, T. B. Larsen, N. A. Mawdsley, N. E. Stork, D. S. Srivastava, and A. D. Watt. 1998. Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. *Nature* **391**:72–76.

Magurran, A. E. 1988. *Ecological diversity and its measurement.* Chapman and Hall, London, UK.

Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. *Nature* **405**:243–253.

McNeely, J. 2003. *Recommendation 13: Cultural and spiritual values of protected areas*. WPC

Recommendation 5.13, V[th] IUCN World Parks Congress, Durban, South Africa. (Online.) URL: http://www.iucn.org/themes/wcpa/wpc2003/pdfs/outputs/recommendations/approved/english/html/r13.htm.

Myers, N. 1988. Tropical forests: much more than stocks of wood. *Journal of Tropical Ecology* **4**:209–221.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**:853–858.

Oliver, I. O., and A. J. Beattie. 1996. Designing a cost-effective invertebrate survey: a test of methods for rapid assessment of biodiversity. *Ecological Applications* **6**:594–607.

Olson, D. M., and E. Dinerstein. 1998. The global 200: a representation approach to conserving the earth's most biologically valuable ecoregions. *Conservation Biology* **12**:502–515.

Olson, D. M., and E. Dinerstein. 2002. The Global 200: priority ecoregions for global conservation. *Annals of the Missouri Botanical Garden* **89**:199–224.

O'Neill R. V., B. T. Milne, M. G. Turner, and R. H. Gardner. 1988. Resource utilisation scales and landscape pattern. *Landscape Ecology* **2**:63–69.

Pascal, J. P. 1988. *Wet Evergreen forests of the Western Ghats of India: ecology, structure, floristic composition and succcession.* Institut français de Pondichéry, Pondicherry, India.

Pascal, J. P., and V. M. Meher-Homji. 1986. Phytochorology of Kodagu (Coorg) district, Karnataka. *Journal of Bombay Natural History Society* **83**:43–56.

Pascal, J. P., and R. Pelissier. 1996. Structure and floristic composition of a tropical evergreen forest in southern India. *Journal of Tropical Ecology* **12**:191–214.

Perfecto, I., A. Mas, T. Dietsch, and J. Vandermeer. 2003. Conservation of biodiversity in coffee agroecosystems: a tri-taxa comparison in southern Mexico. *Biodiversity and Conservation* **12**:1239–1252.

Pinedo-Vasquez, M., D. Zarin, P. Jipp, and J. Chota-Inuma. 1990. Use-values of tree species in a communal forest reserve in northeast Peru. *Conservation Biology* **4**:405–416.

Posey, D. A. 1998. *Cultural and spiritual values of biodiversity*. IUCN, United Nations Environment Programme, Gland, Switzerland.

Prendergast, J. R., R. M. Quinn, J. H. Lawton, B. C. Eversham, and D. W. Gibbons. 1993. Rare species, the coincidence of diversity hotspots and conservation strategies. *Nature* **365**:335–337.

Ramesh, B. R., and J. P. Pascal 1997. *Atlas of endemics of the Western Ghats (India): distribution of tree species in the evergreen and semi-evergreen forests.* Institut français de Pondichéry, Pondicherry, India.

Roy, P. S. 2003. Biodiversity conservation—perspective from space. *National Academy Science Letters-India* **26**:169–184.

Senn-Irlet, B., and G. Bieri. 1999. Sporocarp succession of soil-inhabiting macrofungi in an autochtonous subalpine Norway spruce forest of Switzerland. *Forest Ecology and Management* **124**:169–175.

Sinclair, A. R. E., D. Ludwig, and C. W. Clark. 2000. Conservation in the real world. *Science* **289**:1875.

SPSS. 1989-1999. *SPSS for Windows* Release 10.0.5. SPSS Inc., Chicago, Illinois, USA.

StatSoft. 1984–2003. *Statistica 6.1.* Statsoft Inc., Tulsa, Oklahoma, USA.

Thiollay, J.-M. 1994. The role of traditional agroforests in the conservation of rain forest bird diversity in Sumatra. *Conservation Biology* **9**:335–353.

Velazquez, A., G. Bocco, F. J. Romero, and A. P. Vega. 2003. A landscape perspective on biodiversity conservation—the case of central Mexico. *Mountain Research and Development* **23**:240–246.

World Conservation Monitoring Centre (WCMC). 1992. *Global biodiversity: status of the Earth's living resources*. World Conservation Monitoring

Centre, Chapman and Hall, London, UK.

Williams, P. H., N. D. Burgess, and C. Rahbek. 2000. Flagship species, ecological complementarity and conserving the diversity of mammals and birds in sub-Saharan Africa. *Animal Conservation* **3**:249–260.

Wilshusen, P. R., S. R. Brechin, C. L. Fortwangler, and P. C. West. 2002. Reinventing a square wheel: critique of a resurgent “protection paradigm”' in international biodiversity conservation. *Society & Natural Resources* **15**:17–40.

APPENDIX 1. Checklist and distribution of tree species in three land-use types in the Kodagu district of Karnataka State in the Western Ghats of India (* indicates presence)

Scientific name of species	**Forest reserve**	**Sacred forests**	**Coffee plantations**
Acrocarpus fraxinifolius	*	*	*
Acronychia pedunculata		*	*
Actinodaphne bourdillonii	*	*	*
Actinodaphne lawsonii	*		
Actinodaphne malabarica	*	*	*
Aglaia anamallayana	*	*	
Aglaia barberi	*		*
Aglaia elaeagnoidea	*		
Aglaia jainii	*	*	*
Aglaia simplicifolia	*	*	
Agrostistachys meeboldii	*		
Albizzia amara		*	*
Albizzia chinensis			*
Albizzia lebbek			*
Alstonia scholaris	*	*	*
Antidesma menasu	*	*	*
Antiaris toxicaria		*	
Aphananthe cuspidata	*	*	*
Aphanamixis polystachya	*	*	*
Apodytes beddomei	*	*	*
Aporosa lindleyana		*	*
Archidendron monadelphum	*	*	*
Ardisia solanacea		*	
Areca catechu			*
Artocarpus heterophyllus	*	*	*
Artocarpus hirsuta	*	*	*

(con'd)

Baccouria courtallensis	*		
Beilschmiedia wightii	*	*	*
Bischofia javanica	*	*	*
Blachia denudata	*		
Bombax ceiba			*
Bombax malabaricum		*	
Bridelia retusa			*
Calophyllum polyanthum	*	*	*
Callicarpa tomentosa	*	*	*
Canthium dicoccum		*	*
Canarium strictum	*	*	*
Careya arborea		*	*
Carallia brachiata			*
Caryota urens		*	*
Cassia fistula		*	*
Cassine glauca		*	*
Casearia ovata	*	*	
Casearia rubescens			*
Casearia wynadensis		*	
Ceiba pentandra			*
Celtis philippensis	*	*	*
Celtis tetrandra		*	
Chionanthus malabaricum	*	*	*
Chrysophyllum lanceolatum	*	*	*
Cinnamomum macrocarpum	*	*	*
Cinnamomum sulphuratum			*
Citrus reticulata			*
Clausena dentata	*	*	*
Cleidion spiciflorum	*	*	

(con'd)

Clerodendron viscosum	*	*	*
Coffea arabica		*	
Cryptocarya bourdillonii	*	*	*
Chrysophylum lanceolatum		*	
Cytheroxylon subserratum			*
Dalbergia latifolia	*	*	*
Dillenia pentagyna	*	*	*
Dimocarpus longan	*	*	*
Diospyros candolleana	*	*	*
Diospyros montana		*	*
Diospyros paniculata	*		*
Diospyros pruriens	*		
Diospyros sp.	*	*	
Diospyros sylvatica	*	*	*
Drypetes elata	*	*	*
Drypetes oblongifolia	*		
Dysoxylum malabaricum	*	*	*
Elaeocarpus munronii	*		
Elaeocarpus serratus	*	*	*
Elaeocarpus tuberculatus	*	*	*
Emblica officinalis			*
Erythrina indica		*	*
Euonymus indicus	*	*	*
Evodia lunu-ankenda	*	*	*
Excoecaria crenulata		*	*
Fragraea ceilanica		*	
Ficus amplissima		*	*
Ficus asperima		*	*
Ficus beddomei	*	*	*

(con'd)

Ficus benghalensis			*
Ficus callosa		*	*
Ficus glomerata			*
Ficus hispida		*	*
Ficus microcarpa		*	
Ficus mysorensis	*	*	*
Ficus nervosa	*	*	*
Ficus racemosa		*	*
Ficus sp.		*	*
Ficus tsjahela	*	*	*
Ficus virens	*	*	*
Flacourtia montana		*	*
Garcinia gummi-gutta	*	*	*
Garcinia indica	*		
Garcinia morella	*	*	*
Garcinia pictorius	*		
Glochidion bourdillonii	*	*	*
Glochidion malabaricum		*	
Glyricidia maculata			*
Gmelina arborea		*	*
Grevillea robusta			*
Grewia tiliaefolia			*
Harpullia arborea		*	*
Heritiera papilio	*		
Holigarna arnottiana	*	*	*
Holigarna beddomei	*	*	*
Holigarna grahamii	*	*	*
Holigarna nigra	*	*	*
Homalium travancoricum	*	*	

(con'd)

Homalium zeylanicum		*	*
Hopea parviflora		*	*
Hopea ponga		*	
Humboldtia brunonis	*		
Hydnocarpus alpina	*	*	
Hydnocarpus pentandra	*	*	*
Isonandra lanceolata		*	
Knema attenuata	*	*	*
Kydia calycina			*
Lagerstroemia lanceolata	*	*	*
Lannea coromandelica			*
Laportea crenulata	*	*	
Leea indica		*	
Lepisanthes deficiens	*	*	*
Ligustrum perottetti		*	*
Litsea floribunda	*	*	*
Litsea glabrata	*		
Litsea insignis	*		
Litsea mysorensis	*	*	*
Litsea oleoides	*	*	*
Litsea stocksii	*	*	
Lophopetalum wightianum	*	*	*
Macaranga peltata	*	*	*
Madhuca neriifolia		*	
Mallotus philippensis	*	*	*
Mallotus stenanthes	*		
Mangifera indica	*	*	*
Margaritaria indica	*	*	*
Mastixia arborea	*	*	*

(con'd)

Maytenus rothiana	*	*	
Memecylon malabaricum	*	*	
Memecylon talbotianum	*	*	*
Memecylon umbellatum		*	*
Memecylon wightii	*		
Mesua ferrea	*	*	*
Michelia champaca		*	*
Microtropis wallichiana	*	*	
Mimusops elengi	*	*	*
Mitrephora heyneana	*		
Mitragyna tubulosa			*
Myristica dactyloides	*	*	*
Neolitsea zeylanica	*	*	*
Nothopegia beddomei	*	*	*
Nothapodytes foetida	*	*	*
Ochna lanceolata	*		*
Olea dioica	*	*	*
Oroxylum indicum			*
Otonephelium stipulaceum	*	*	*
Pajanelia rheedii	*	*	*
Palaquium ellipticum	*	*	*
Pavetta sp.	*	*	*
Persea macrantha	*	*	*
Pittosporum dasycaulon		*	*
Polyalthia coffeoides	*		
Polyalthia fragrans			*
Pongamia pinnata		*	*
Premna tomentosa		*	*
Prunus ceilanica	*	*	*

(con'd)

Psidium guajava			*
Pterocarpus marsupium		*	*
Schefflera capitata		*	
Schefflera micrantha	*	*	*
Schleichera oleosa		*	*
Schefflera sp.		*	*
Schefflera wallichiana		*	
Scleropyrum pentandrum	*	*	*
Scolopia crenata	*	*	*
Spondias indica		*	
Spondias pinnata	*	*	*
Stereospermum chelonioides	*	*	*
Sterculia guttata	*	*	*
Stereospermum personatum		*	*
Streblus asper			*
Strombosia ceylanica	*		*
Symplocos macrophylla	*	*	*
Symplocos racemosa	*	*	*
Syzygium cumini	*	*	*
Syzygium gardnerii	*	*	*
Syzygium hemisphericum	*	*	*
Syzygium heyneanum	*	*	
Syzygium lanceolatum	*		
Syzygium mundagam	*	*	*
Syzygium munronii	*	*	
Syzygium phyllareoides		*	*
Syzygium rubicundum	*		*
Syzygium zeylanicum		*	
Tabernaemontana heyniana	*	*	*

(con'd)

Terminalia bellarica	*	*	*
Toona ciliata	*	*	*
Trema orientalis		*	*
Trichilia connaroides	*	*	*
Turpinia malabarica	*	*	*
Unidentified		*	
Vateria indica	*	*	*
Vepris bilocularis	*	*	*
Vernonia monosis		*	*
Viburnum punctatum	*	*	*
Villebrunea integrifolia	*	*	*
Vitex altissima		*	*
Xanthophyllum flavescens	*	*	*
Xanthoxylum rhetsa		*	
Xeromphis spinosa		*	*

APPENDIX 2. Checklist and distribution of bird species in three land-use types in Kodagu District, Karnataka State in the Western Ghats of India (* indicates presence)

Common name	**Scientific name**	**Forest reserve**	**Sacred forests**	**Coffee plantations**
Asian Brown Flycatcher	*Muscicapa dauurica*		*	
Asian Fairy Bluebird	*Irena puella*	*	*	*
Asian Koel	*Eudynamic scolopacea*		*	*
Alexandrine Parakeet	*Psittacula eupatria*		*	
Asian Paradise Flycatcher	*Terpsiphone paradisi*		*	*
Ashy Woodswallow	*Artamus fuscus*			*
Banded Bay Cuckoo	*Cacomantis sonneratii*		*	
Black-crested Bulbul	*Pycnonotus melanicterus*	*	*	*
Brown-cheeked Fulvetta	*Alcippe poioicephala*	*	*	*
Black-hooded Oriole	*Oriolus xanthornus*			*
Black Bulbul	*Hypsipetes leucocephalus*		*	*
Black Drongo	*Dicrurus macrocerus*	*	*	*
Black Eagle	*Ictinaetus malayensis*			*
Black-naped Monarch	*Hypothymis azurea*	*	*	*
Black-rumped Flameback	*Dinopium benghalense*		*	*
Blue-capped Rock Thrush	*Monticola cinclorhynchus*	*		*
Black-shouldered Kite	*Elanus caeruleus*		*	
Blue-winged Leafbird	*Chloropsis cochinchinensis*		*	*
Baya Weaver	*Ploceus philippinus*		*	*
Chestnut-bellied Nuthatch	*Sitta castanea*		*	*
Crimson-backed Sunbird	*Nectarinia minima*	*	*	*
Common Chiffchaff	*Phylloscopus collybita*		*	*
Crimson-fronted Barbet	*Megalaima rubricapilla*	*	*	*
Chestnut-headed Bee-eater	*Merops leschenaulti*		*	*
Common Flameback	*Dinopium javanense*	*	*	*
Common Iora	*Aegithina tiphia*	*	*	*

(con'd)

Common Myna	*Acridotheres tristis*		*	*
Common Tailorbird	*Orthotomus sutoris*			*
Common Woodshrike	*Tephrodornis pondicerianus*		*	*
Crested Serpant Eagle	*Spilornis cheela*	*	*	*
Chestnut-shouldered Petronia	*Petronia xanthocollis*		*	
Chestnut-tailed Starling	*Sturnus Malabaricus*		*	*
Dark Fronted Babbler	*Rhopocichla atriceps*	*	*	
Eurasian Golden Oriole	*Oriolus oriolus*	*	*	*
Emerald Dove	*Chalcophaps indica*		*	
Green Bee-eater	*Merops orientalis*		*	*
Grey-headed Canary Flycatcher	*Culicicapa ceylonensis*	*	*	*
Gold-fronted Leafbird	*Chloropsis aurifrons*		*	*
Greater Coucal	*Centropus sinensis*		*	*
Greater Racket-tailed Drongo	*Dicrurus paradiseus*	*	*	*
Greater Flameback	*Chrysocolaptes lucidus*	*	*	*
Hill Myna	*Gracula religiosa*	*	*	*
House Sparrow	*Passer domesticus*		*	
House Crow	*Corvus splendens*		*	
House Swift	*Apus affinis*	*	*	*
Heart-spotted Woodpecker	*Hemicircus canente*		*	*
Indian Scimitar Babbler	*Pomatorhinus horsfieldii*	*	*	*
Jungle Myna	*Acridotheres fuscus*		*	*
Jungle Prinia	*Prinia sylvatica*	*	*	*
Large-billed Crow	*Corvus macrorhyncus*	*	*	*
Loten's Sunbird	*Nectarinia lotenia*		*	*
Long-tailed Shrike	*Lanius schach*			*
Malabar Grey Hornbill	*Ocyceros griseus*	*	*	*
Mountain Imperial Pigeon	*Ducula badia*	*	*	*

(con'd)

Malabar Parakeet	*Psittacula columboides*	*	*	*
Malabar Trogon	*Harpactes fasciatus*	*	*	
Malabar Whistling Thrush	*Myophonus horsfieldii*	*	*	*
Nilgiri Flycatcher	*Eumyias albicaudata*		*	*
Nilgiri Wood Pigeon	*Columba elphinstonii*	*	*	*
Orange-headed Thrush	*Zoothera citrina*	*		
Oriental Magpie Robin	*Copsychus saularis*		*	*
Oriental White-eye	*Zosterops palpebrosus*			*
Pale-billed flowerpecker	*Dicaeum erythrorhyncus*	*	*	*
Plum-headed Parakeet	*Psittacula cyanocephala*	*	*	*
Purple-rumped Sunbird	*Nectarinia zeylonica*		*	
Puff-throated Babbler	*Pellornium ruficeps*	*	*	*
Purple Sunbird	*Nectarinia asiatica*		*	
Rose-ringed Parakeet	*Psittacula krameri*			*
Red-vented Bulbul	*Pycnonotus cafer*			*
Red-whiskered Bulbul	*Pycnonotus jocosus*		*	*
Scarlet Minivet	*Pericrocotus flammeus*	*	*	*
Shikra	*Accipiter badius*	*	*	*
Small Minivet	*Pericrocotus cinnamomeus*			*
Spotted Dove	*Streptopelia chinensis*		*	*
Tickell's Blue Flycatcher	*Cyornis tickelliae*	*	*	*
Velvet-fronted Nuthatch	*Sitta frontalis*		*	*
Vernal Hanging Parrot	*Loriculus vernalis*		*	*
White-browed Fantail	*Rhipidura auriola*		*	
White-bellied Treepie	*Dendrocitta leucogastra*	*	*	*
White-bellied Woodpecker	*Dryocopus javensis*	*	*	*
White-cheeked Barbet	*Megalaima viridis*	*	*	*
White-eyed Buzzard	*Butastur Teesa*	*	*	
White-throated Kingfisher	*Halcyon smyrnensis*		*	*

(con'd)

White-browed Wagtail	*Motacilla maderaspatensis*		*	
Yellow-browed Bulbul	*Iole indica*	*	*	*
Yellow-footed Green Pigeon	*Treron phoenicoptera*		*	*

APPENDIX 3. Checklist and distribution of macrofungal morphotypes in three land-use types in Kodagu District, Karnataka State in the Western Ghats of India (* indicates presence; collection information and images of the macrofungal morphotypes can be found in the BRAHMS Database of Western Ghats Macrofungi)

Name of morphotype	**Forest reserve**	**Sacred forests**	**Coffee plantations**
Agaricus sp. (brown)		*	*
Agaricus sp.	*	*	*
Amanita sp.		*	
Ascomycetes (yellow-colored, ball-like sporocarps)	*	*	*
Ascomycetes (elephant dung)	*	*	*
Ascomycetes (spoon)		*	
Ascomycetes (thread)		*	
Astraeus sp.		*	
Auricularia sp.	*	*	*
Boletus sp.		*	*
Callocybe sp.	*	*	
Unknown (Chili-red)	*		
Clavaria sp. (brown)		*	
Clavaria sp.	*	*	*
Clavaria sp. (orange)	*	*	*
Clavaria sp. (purple)		*	
Clavaria sp. (*Ramaria* like)	*		
Clavaria sp. (tree)	*	*	
Clavaria sp. (white)	*	*	
Clitocybe sp.	*	*	*
Collybia sp. (brown in color)	*	*	*
Collybia sp. (*Hygrophorus* like)		*	*
Collybia sp. (unknown)	*	*	*

(con'd)

Coprinus sp.	*	*	*
Cordyceps sp. (club)		*	
Cordyceps sp. (orange)	*	*	
Cordyceps sp. (tree)		*	
Coriolus sp. (*Foemes* like)		*	
Coriolus sp. (hirsute)	*	*	*
Coriolus sp.		*	
Cortinarius sp.	*	*	*
Cortinarius sp. (brown)			*
Cortinarius sp. (cyboid)	*	*	
Cortinarius sp. (*Hebeloma* like)		*	
Cortinarius sp. (*Inocybe* like)		*	
Cortinarius sp. (rusty)		*	
Crepidotus sp.	*	*	*
Daedalopsis flavida	*	*	*
Daldinia sp.	*	*	*
Dictyophora sp.		*	
Entolomataceae		*	*
Entolomataceae (pink)		*	
Entolomataceae (white)		*	
Ganoderma sp. (big fruiting body)	*	*	*
Ganoderma sp. (black)	*	*	*
Ganoderma sp. (brown)	*	*	*
Ganoderma sp. (orange colored)	*	*	*
Ganoderma sp. (pink)	*		*
Ganoderma sp. (velvet)		*	*
Ganoderma sp. (white)	*		

(con'd)

Geastrum sp.	*	*	*
Hexagonia sp.	*	*	
Hygrocybe sp.	*	*	
Hygrophorus citratus		*	
Hygrophorus sp.	*	*	*
Hygrophorus sp. (red)		*	
Leotia bulgaria		*	*
Leotia sp. (*Peziza* like)		*	
Leotia sp. (brown)	*	*	*
Leotia sp. (orange)	*	*	*
Lycoperdon sp.	*	*	*
Marasmius sp. (bells)		*	
Marasmius sp. (black)		*	
Marasmius sp.	*	*	*
Marasmius sp. (oyster)	*	*	*
Marasmius sp. (small)		*	
Marasmius sp. (white)	*		
Microporus sp. (black)	*	*	
Microporus sp. (brown)	*	*	*
Microporus sp. (black and white)			*
Microporus sp. (brick)	*	*	*
Microporus sp. (orange)	*		*
Microporus sp.	*	*	*
Microporus sp. (oyster)			*
Microporus sp. (pink)	*	*	
Microporus sp. (spoon-like)	*	*	*
Microporus sp. (trumpet-shaped)	*	*	*

(con'd)

Microporus sp. (velvet)	*	*	
Microporus sp. (white)	*		
Morchella sp.	*		*
Mycena sp. (brown)	*	*	
Mycena sp. (leaf)	*	*	*
Mycena sp. (rufous)	*	*	*
Mycena sp.	*	*	*
Mycena sp. (white)	*		
Myxomyceteae	*	*	*
Nidularia sp. (*Cyathus* like)		*	
Otidia sp. (black)			*
Otidia sp. (*Marasmius* like)	*	*	*
Otidia sp. (orange)		*	
Otidia sp. (*Scutellinia* like)		*	
Peziza sp. (disk)	*	*	
Phallus sp. (*Mutinus* like)		*	
Phallus sp. (stalk)		*	
Phellinus sp.	*	*	*
Physarium sp.		*	
Physarium sp. (white)		*	
Pleurotus sp. (orange)		*	
Pleurotus sp. (oyster)			*
Pleurotus sp.	*	*	*
Polyporus sp. (black)			*
Polyporus sp. (brown)	*	*	*
Polyporus sp. (button)	*	*	*
Polyporus sp. (club)		*	

(con'd)

Polyporus sp. (*Coriolus* like)	*	*	*
Polyporus sp. (grey)	*	*	*
Polyporus sp. (*Hexagonia* like)	*	*	*
Polyporus sp. (orange)	*	*	*
Polyporus sp. (oyster)		*	
Polyporus sp. (pink)	*	*	
Polyporus sp. (polyporous)	*	*	*
Polyporus sp. (resupinate)	*	*	*
Polyporus sp. (rusty)	*	*	*
Polyporus sp. (scars)		*	
Polyporus sp. (spoon)	*		
Polyporus sp.	*		
Polyporus sp. (sulfur)	*	*	
Polyporus sp. (trumpet)	*	*	*
Polyporus sp. (tubes)	*	*	*
Polyporus sp. (velvet)		*	*
Polyporus sp. (white)	*	*	
Rhizopogon sp.	*	*	
Russula sp. (brown)		*	
Russula sp. (pink)		*	
Russula sp. (purple)		*	
Russula sp. (red)		*	
Sarcocypha sp. (orange)	*	*	
Sarcocypha sp.	*	*	*
Schizophylum sp.	*	*	*
Tephrocybe sp.		*	
Termitomyces sp.	*	*	

(con'd)

Tremella sp. (jelly)	*	*	*
Tremella sp. (orange)	*	*	*
Tricholomataceae (*Armillaria* like)		*	*
Tricholomataceae (black)		*	
Tricholomataceae (brown)	*	*	*
Tricholomataceae (campanulate)		*	
Tricholomataceae (gills)		*	
Tricholomataceae (grey)	*		
Tricholomataceae (huge)		*	
Tricholomataceae (large, edible)	*	*	*
Tricholomataceae	*	*	*
Tricholomataceae (mucilage and brown)	*	*	*
Tricholomataceae (orange)		*	*
Tricholomataceae (*Oudemansiella* like)		*	
Tricholomataceae (oyster)	*		*
Tricholomataceae (pink)	*		
Tricholomataceae (purple)	*	*	*
Tricholomataceae (red)			*
Tricholomataceae (ring)		*	
Tricholomataceae (small, edible)		*	*
Tricholomataceae (silver)		*	
Tricholomataceae (trumpet)	*	*	*
Tricholomataceae (white)	*	*	*
Xylaria sp.		*	*
Xylaria sp. (balls)	*	*	
Xylaria sp. (carrot)		*	
Xylaria sp. (club-shaped)	*	*	*
Xylaria sp. (long)		*	
Xylaria sp. (monstrous)		*	

(con'd)

Xylaria sp. (rod-like)	*	*	*
Xylaria sp. (short)	*	*	*
Xylaria sp. (thin)	*	*	*