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Biodiversity conservation in sacred groves of Manipur, northeast India: population structure and regeneration status of woody species

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Abstract. Sacred groves are forest patches conserved by the local people intertwined with their socio-cultural and religious practice. These groves harbour rich biodiversity and play a significant role in the conservation of biodiversity. Population structure and regeneration status of woody species were studied during 2001–2002 in the four sacred groves of Manipur, a state in north east India. A total of 96 woody species was recorded from the four groves, the highest being Konthoujam Lairembi sacred grove (55 species) and lowest in Heingang Marjing sacred grove having 42 species. The density–diameter distribution of woody species in the four groves showed highest stand density and species richness in the lowest girth class (30–60 cm) and decreased in the succeeding girth classes. Overall population structure of the groves based on the number of tree seedlings, saplings and adults, displayed a greater proportion of seedlings followed by saplings and adults while for the selected tree species it varied seasonally and recruitment of species increased during rainy season attaining peak during June. Regeneration status of the four sacred groves based on strength of different age groups in their population showed good regeneration. High occurrence of 'additional species' to the groves may be due to the invasion through dispersal from other areas. Possibly, the prevailing favourable microenvironmental conditions contributed to their establishment and growth in the groves. Absence of seedlings and saplings of some of the species in the groves may be due to their poor seed germination and establishment of seedlings in the forest.

Introduction

Sacred groves are forest patches rich in biodiversity, manifested by a range of traditions and cultural values of the indigenous people who protect the groves with the beliefs in nature worship inherited from their ancestors. They act as reservoirs of much local biodiversity preserving unique flora and fauna. The biological resources make indirect contributions to the welfare and stability of the local environment. Various medicinal plants are found abundantly in sacred groves and they are the vital source of wild cultivars and diverse gene pool. It is because of the local people and their strong socio-religious beliefs and taboos the conservation and protection of the groves is possible. As a result, sacred groves can help in assessing the potential values of forest communities of degraded ecosystem or man made forest.

The major component for the formation of forest communities is the woody species. The nature of forest communities largely depends on the ecological characteristics in sites, species diversity and regeneration status of species. Microenvironmental factors vary with seasonal changes which affect the growth stage i.e. seedling, sapling and young trees of the plant communities that maintain the population structure of any forest. Hence, it becomes an important issue to understand the tree diversity, population structure and regeneration status of forest communities for the maintenance of both natural and control forest. The satisfactory natural regeneration behaviour of the forests largely depends on population structure characterized by the production and germination of seed, establishment of seedlings and saplings in the forest (Rao 1988). Complete absence of seedlings and saplings of tree species in a forest indicates poor regeneration, while presence of sufficient number of young individuals in a given species population indicates successful regeneration (Saxena and Singh 1984). However, the presence of sufficient number of seedlings, saplings and young trees is greatly influenced by interaction of biotic and abiotic factors of the environment (Boring et al. 1981; Aksamit and Irving 1984). While several authors have predicted regeneration status of tree species based on the age and diameter structure of their population (Marks 1974; Bormann and Likens 1979; Veblen et al. 1979; Bhuyan et al. 2003). Various studies on population structure and regeneration status have been carried out by many workers in different forest ecosystems (Pritts and Hancock 1983; Saxena et al. 1984; Khan et al. 1987; Ashton and Hall 1992; Cao et al. 1996; Gunatilleke et al. 2001; Uma Shankar 2001). Tree population structure and its implication for their regeneration has been studied in different forest communities of India e.g. Garhwal (Baduni and Sharma 2001; Bhandari 2003), Himachal Pradesh (Sood and Bhatia 1991), Western Himalayas (Pande et al. 2002), Western Ghats (Parthasarathy 2001) and north eastern region (Yadava et al. 1991; Maram and Khan 1998; Bhuyan et al. 2002, 2003).

Studies on population structure and regeneration pattern of tree species in sacred groves are limited (Khan et al. 1986, 1987; Rao et al. 1990; Barik et al. 1996; Mishra et al. 2003). Though phytosociological and ethnobotanical investigations (Khumbongmayum et al. 2004, in press) have been carried out in sacred groves of Manipur, the studies on population structure and regeneration status are lacking in these groves which harbours rich biodiversity and diverse gene pool of many forest species. Therefore, an attempt has been made to study the population structure and regeneration status of woody species in the four selected sacred groves of Manipur viz., Konthoujam Lairembi, Mahabali, Langol Thongak Lairembi and Heingang Marjing groves.

Study sites

The state of Manipur is situated in the extreme northeastern corner of India and lies between 23°50′–25°42′ N latitudes and 92°58′– 94°45′ E longitudes. It is centrally located on the eastern arm of the Himalaya which separates India from Myanmar. Four sacred groves were selected in Imphal East and Imphal West districts on the basis of size, vegetation and location. The selected sacred groves are situated between 23°50′–25°41′ N latitudes and 93°2′–94°47′ E longitudes and they all have sub-tropical forests as their dominant vegetation. Two groves namely, Konthoujam Lairembi and Mahabali are located in valley and the other two groves, Langol Thongak Lairembi and Heingang Marjing, are located in hills. The four groves represent a rich vegetation of economic and medicinally important plant species which have been conserved and protected imbued with the religious beliefs and taboos of the local people. The Konthoujam Lairembi sacred grove is situated in the Konthoujam village, about 11 km west of the valley area of Imphal city. It lies at the elevation of 711 m, covering an area of ca. 1.41 ha. The Mahabali sacred grove is situated in the midst of Imphal city at 710 m altitude covering ca. 5.05 ha. The Langol Thongak Lairembi sacred grove is located in the Langol hill ranges about 5 km northwest of Imphal city covering ca. 5.05 ha. The altitude ranges from 800 m at the foot hills to 1050 m at the peak. The Heingang Marjing sacred grove is located in the Heingang village, to the north of Imphal city, at the elevation of 834 m covering an area of ca. 7.08 ha. Furthermore, the selected four sacred groves are least disturbed and protected by regulating the human interferences through religious proscription and prescription. Therefore, regeneration process of woody layer mainly depends on forest microclimate which in turn, might be altered due to various physico-chemical variables and seasonal changes.

In all the four sacred groves four layers of vertical stratification were observed. In Konthoujam Lairembi sacred grove, *Ficus benjamina* and *Saprosma* sp. were the dominant species and canopy is closed to each other while *Persea* sp. and *Ficus glomerata* dominate in the Mahabali sacred grove and the canopy of the topstorey layer is sparse. The two sacred groves located in the hill ranges are dominated by the *Pinus kesiya* and canopy coverage is relatively closed.

The climate of the study area is monsoonal with warm moist summer and cool dry winter. During the study period (2001–2002), the mean maximum temperature varied from 22 °C (January) to 30 °C (August) and mean minimum temperature varied from 5 °C (January) to 23 °C (July). The average relative humidity ranged from 58% (March) to 82% (October). The mean monthly rainfall was minimum in December (2.5 mm) and maximum in June (236 mm). The average annual rainfall was 1482 mm.

The soil of the two sacred groves situated in the plains is blackish in colour while it is yellowish red to reddish brown in the other two sacred groves which are located in hilly area. The soil is alluvial in nature and its texture is loamy sand. The soil is acidic with pH ranging from 5.4 to 6.59. The organic carbon content ranged from 4.85% to 5.37% while the total Kjeldhal nitrogen (TKN) ranged from 0.01% to 0.04%. In general the soils are poor in nitrogen.

Methods

Population structure of all the woody species occurring in each sacred grove was studied during 2001–2002 using quadrat method. For this purpose forty quadrats of 10 m × 10 m were laid randomly in each grove. Species were identified and density of all the individuals of seedlings (≤ 20 cm height) and saplings (< 30 cm collar circumference at the base and > 20 cm in height) of all the tree species were determined. While for trees (≥30 cm girth at breast height of 1.37 m), density and basal area of each individual was recorded. Similarity index (community coefficient) of woody species among the four sacred groves was calculated following the formula given by Jaccard (1912).

$$Cj = j/(a + b - j)$$

Where '*j*' is the number of species common to both stands, '*a*' is the number of species in stand A and '*b*' is the number of species in stand B.

Ten important tree species, *Marlea begoniaefolia*, *Eugenia praecox*, *Litsea polyantha*, *Persea* sp., *Heptapleurum hypoleucum*, *Oroxylum indicum*, *Saprosma* sp., *Wendlandia tinctoria*, *Quercus serrata* and *Litsea sebifera* were selected from the four sacred groves for studying detailed population structure. Among the 10 species, two (*Eugenia praecox* and *Litsea polyantha*) were common to the four groves. Population structure of the selected tree species was studied in each grove during December, 2001, May, 2002 and October, 2002 by periodic determination of densities of the individuals belonging to three different categories viz., seedlings, saplings and trees. Relative proportion (%) of the different diameter groups i.e. seedlings, saplings and trees, to the density of a given species or to total density of tree species in a stand was calculated and figures were drawn, with seedling population at the base of the bar.

Regeneration status of species was determined based on population size of seedlings and saplings (Khan et al. 1987; Uma Shankar 2001; Bhuyan et al. 2003): good regeneration, if seedlings > saplings > adults; fair regeneration, if seedlings > or ≤ saplings ≤ adults; poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults). If a species is present only in adult form it is considered as not regenerating. Species is considered as 'new' if the species has no adults but only seedlings or saplings.

Results

Woody species composition

A total of 96 woody species were recorded in the four groves. The Konthoujam Lairembi sacred grove recorded maximum (55) tree species followed by Heingang Marjing sacred grove (42 species) and Mahabali and Langol Thongak Lairembi sacred groves which had 38 species each. The calculated similarity index (community coefficient) of woody species among the sacred groves is given in Table 1. The highest similarity index value (0.35) was recorded between Langol Thongak Lairembi and Heingang Marjing sacred groves and lowest in between Mahabali and Heingang Marjing sacred groves (0.04). Out of the 10 species selected for studying their population structure, two species (*Eugenia praecox* and *Litsea polyantha*) were common to the four groves. *Marlea begoniaefolia* was common in both the groves located in the plains *i.e.* Konthoujam Lairembi and Mahabali sacred groves. *Heptapleurum hypoleucum* and *Saprosma* sp. are exclusive to the Konthoujam Lairembi sacred grove, while *Persea* sp. was exclusive to Mahabali sacred grove. *Wendlandia tinctoria*, *Quercus serrata* and *Litsea sebifera* were common to both the groves located in the hills namely, Langol Thongak Lairembi sacred grove and Heingang Marjing sacred groves. The total density per hectare of all seedlings, saplings and trees taken together ranged from 6353 in the Langol Thongak Lairembi sacred grove to 12192 in the Konthoujam Lairembi sacred grove (Table 2).

Girth class-wise species richness, tree density and basal area

The highest stand density and species richness of the woody species in four groves were recorded in the lowest girth class (30–60 cm). Stand density and species richness consistently decreased with increase in girth from 30–60 cm to >210 cm (Figure 1). In Langol Thongak Lairembi and Heingang Marjing sacred groves no tree was recorded in the girth class 180–210 cm. The highest contribution of stand density per girth class to total density for each grove was recorded in 30–60 cm girth class and maximum stand density (59.05%) was recorded in Langol Thongak Lairembi sacred grove, followed by Konthoujam Lairembi (55.43%), Mahabali (39%) and Heingang Marjing (38.81%). The basal area was maximum (44.63 m^2 ha^{-1}) in the highest girth class (>210 cm) at Mahabali and lowest in Heingang Marjing (1.15 m^2 ha^{-1}). The basal area distribution in different girth classes in two groves located in the plain area showed a similar pattern, and likewise the pattern shown by the two groves in the hills was also similar (Figure 1).

Table 1. Similarity index (community coefficient) of woody species among the four selected sacred groves.

Sacred groves	Mahabali	Langol Thongak Lairembi	Heingang Marjing
Konthoujam Lairembi	0.19	0.13	0.12
Mahabali		0.05	0.04
Langol Thongak Lairembi			0.35

Table 2. Density and regeneration status of woody species in four sacred groves of Manipur.

Species	Konthoujam Lairembi sacred grove				Mahabali sacred grove				Langol Thongak Lairembi sacred grove				Heingang Marjing sacred grove			
	No. of individuals/ha				No. of individuals/ha				No. of individuals/ha				No. of individuals/ha			
	Seedlings	Saplings	Trees	Status	Seedlings	Saplings	Trees	Status	Seedlings	Saplings	Trees	Status	Seedlings	Saplings	Trees	Status
Acacia auriculaeformis A. Curm ex. Benth.	–	–	–	–	–	–	–	–	–	–	–	–	3	#	#	New
Adenanthera pavonina Linn.	#	13	1	New	–	–	–	–	–	–	–	–	–	–	–	–
Albizia lebbeck (L.) Benth.	–	–	–	–	#	8	3	P	–	–	–	–	–	–	–	–
Albizia lucida (Roxb.) Benth.	–	–	–	–	–	–	–	–	35	130	18	F	53	78	5	F
Albizia odoratissima (Linn. f.) Benth	35	93	6	F	–	–	–	–	#	23	5	P	#	5	15	P
Albizia procera (Roxb.) Benth.	–	–	–	–	–	–	–	–	–	–	–	–	#	45	5	P
Albizia stipulata Boivin	–	–	–	–	–	–	–	–	#	8	3	P	#	13	18	P
Alnus nepalensis D. Don	–	–	–	–	–	–	–	–	–	–	–	–	#	3	3	P
Anthocephalus cadamba Roxb.	–	–	–	–	#	10	#	New	–	–	–	–	–	–	–	–
Anthocephalus chinensis (Lamk.) A. Rich. ex Walp.	–	–	–	–	#	#	3	N	–	–	–	–	–	–	–	–
Aphanamixis polystachya (Wall.) Parker	#	#	1	N	–	–	–	–	–	–	–	–	–	–	–	–
Aralia sp.	–	–	–	–	–	–	–	–	#	5	10	P	–	–	–	–
Ardisia sp.	–	–	–	–	–	–	–	–	–	–	–	–	#	5	5	P
Artocarpus heterophyllus Lam.	–	–	–	–	–	–	–	–	#	5	#	New	–	–	–	–
Artocarpus lakoocha Roxb.	313	#	13	F	100	38	8	G	–	–	–	–	–	–	–	–
Bauhinia purpurea Linn.	–	–	–	–	–	–	–	–	#	10	3	P	–	–	–	–
Bauhinia variegata Linn.	#	8	5	P	5	3	#	New	–	–	–	–	–	–	–	–
Bischofia javanica Blume	–	–	–	–	63	#	10	F	–	–	–	–	–	–	–	–
Bombax ceiba Linn.	–	–	–	–	–	–	–	–	#	8	5	P	#	5	#	New
Borassus flabellifer Linn.	–	–	–	–	20	#	#	New	–	–	–	–	–	–	–	–

Caryota urens Linn.	405	50	2	G	218	50	25	G	–	–	–	–	–	–	–	–
Castanopsis hystrix A. DC.	13	45	1	New	#	5	#	New	–	–	–	–	–	–	–	–
Celtis sp.	–	–	–	–	–	–	–	–	–	–	–	–	23	53	#	F
Celtis timorensis Linn.	5	18	3	F	35	38	3	F	10	#	#	New	#	23	#	New
Chukrasia tabularis Andr. Juss.	#	#	3	N	–	–	–	–	–	–	–	–	–	–	–	–
Cinnamomum sp.	28	18	#	New	–	–	–	–	–	–	–	–	–	–	–	–
Citrus maxima Merr	3	5	#	New	23	8	0	New	#	5	#	New	–	–	–	–
Cordia grandis Roxb.	#	#	2	N	–	–	–	–	–	–	–	–	–	–	–	–
Delonix regia (Boj.) Raf.	#	53	2	P	–	–	–	–	–	–	–	–	–	–	–	–
Elaeocarpus sp.	–	–	–	–	–	–	–	–	–	–	–	–	#	10	3	P
Engelhardtia colebrookiana Lindl.	–	–	–	–	–	–	–	–	25	38	#	New	65	143	35	F
Entada scandens Benth	#	#	1	N	–	–	–	–	–	–	–	–	–	–	–	–
Erythrina sp.	5	118	1	New	–	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus citriodora Hook.	–	–	–	–	–	–	–	–	10	10	#	New	#	3	3	P
Eugenia praecox Roxb.	808	100	3	G	435	353	0	New	515	163	10	G	635	230	30	G
Eugenia sp.	#	25	2	P	–	–	–	–	–	–	–	–	–	–	–	–
Ficus benghalensis Linn.	#	#	3	N	–	–	–	–	–	–	–	–	–	–	–	–
Ficus benjamina Linn.	#	#	13	N	–	–	–	–	–	–	–	–	–	–	–	–
Ficus glomerata Roxb.	#	5	6	P	0	13	38	P	–	–	–	–	–	–	–	–
Ficus hispida Linn. f.	18	35	3	F	78	78	115	F	3	38	#	New	#	30	#	New
Ficus religiosa Linn.	–	–	–	–	#	#	3	N	–	–	–	–	–	–	–	–
Ficus semicordata Buch. - Ham. ex J. E. Smith	–	–	–	–	#	15	#	New	#	18	#	New	30	83	18	F
Flacourtia jangomas (Lour.) Raeusch	#	5	#	New	#	5	#	New	–	–	–	–	#	8	8	P
Gardenia companulata Roxb.	#	#	4	N	#	35	98	P	–	–	–	–	–	–	–	–
Gmelina arborea Roxb.	8	18	7	F	–	–	–	–	–	–	–	–	–	–	–	–
Grevillea robusta A. Cum	40	23	#	New	–	–	–	–	–	–	–	–	–	–	–	–
Heptapleurum hypoleucum Kurz	223	78	6	G	–	–	–	–	–	–	–	–	–	–	–	–
*Khajok	–	–	–	–	–	–	–	–	–	–	–	–	#	5	3	P
Holigarna longifolia Roxb.	–	–	–	–	–	–	–	–	–	–	–	–	#	10	13	P
Lagerstroemia flos-regine Retz.	#	38	#	New	#	5	#	New	–	–	–	–	–	–	–	–

Table 2. Continued.

Species	Konthoujam Lairembi sacred grove				Mahabali sacred grove				Langol Thongak Lairembi sacred grove				Heingang Marjing sacred grove			
	No. of individuals/ha				No. of individuals/ha				No. of individuals/ha				No. of individuals/ha			
	Seedlings	Saplings	Trees	Status	Seedlings	Saplings	Trees	Status	Seedlings	Saplings	Trees	Status	Seedlings	Saplings	Trees	Status
Lannea coromandelica (Houtl.) Merr.	5	38	8	G	#	8	#	New	#	10	#	New	–	–	–	–
Lannea grandis A. Rich	#	20	12	P	#	28	8	P	–	–	–	–	–	–	–	–
Ligustrum robustum (Roxb.) Blume	#	68	25	P	–	–	–	–	–	–	–	–	–	–	–	
Litsea citrata Blume	68	43	10	G	68	103	#	New	70	70	8	G	555	375	28	G
Litsea polyantha Juss.	368	385	19	F	368	158	15	G	518	188	15	G	423	150	10	G
Litsea sebifera Thumb.	75	18	#	New	–	–	–	–	345	113	#	New	448	198	15	G
Litsea sp. (1)	#	23	3	P	–	–	–	–	–	–	–	–	–	–	–	–
Litsea sp. (2)	–	–	–	–	#	28	13	P	#	20	#	New	#	40	#	New
Mallotus phillippinensis (Lam.) Muell.- Arg.	68	218	18	G	143	163	10	F	100	130	3	F	158	93	5	G
Mangifera indica Linn.	15	5	16	F	108	48	15	G	–	–	–	–	–	–	–	–
Mangifera sp.	–	–	–	–	–	–	–	–	10	33	3	F	5	8	8	F
Marlea begoniaefolia Roxb.	233	330	11	F	285	115	18	G	–	–	–	–	70	13	#	New
Melia azedarach Linn.	#	3	2	P	70	#	#	New	#	3	3	P	48	3	#	New
Morus nigra Linn.	–	–	–	–	33	40	#	New	#	15	#	New	–	–	–	–
Oroxylum indicum (L.) Vent.	158	173	19	F	–	–	–	–	–	–	–	–	#	15	5	P
Parkia roxburghii G. Don	–	–	–	–	–	–	–	–	#	13	5	P	–	–	–	–
Pasania polystachya (Wall) Schootky	–	–	–	–	–	–	–	–	128	118	48	G	8	88	10	F
Persea sp.	–	–	–	–	2063	480	85	G	–	–	–	–	–	–	–	–
Phyllanthus emblica Linn.	#	10	#	New	#	23	#	New	30	20	3	G	3	15	5	F
Pinus kesiya Royle ex. Gordon	–	–	–	–	–	–	–	–	290	8	690	F	258	133	705	F

Prunus sp.	–	–	–	–	–	–	–	–	–	–	–	–	5	25	8	F
Psidium guajava Linn.	–	–	–	–	48	20	#	New	#	5	#	New	#	3	#	New
Quercus serrata Thumb.	–	–	–	–	–	–	–	–	665	213	40	G	530	425	128	G
Rhus semialata Murray	65	#	3	F	–	–	–	–	500	145	8	G	378	33	#	New
Rubia sp. (1)	13	83	6	F	–	–	–	–	–	–	–	–	–	–	–	–
Rubia sp. (2)	#	#	2	N	–	–	–	–	–	–	–	–	–	–	–	–
Santalum sp.	–	–	–	–	–	–	–	–	#	18	8	P	–	–	–	–
Saprosma sp.	5420	548	54	G	–	–	–	–	–	–	–	–	–	–	–	–
Schima wallichii (D.C.) Korth	#	15	16	P	128	28	#	New	88	115	53	F	108	78	83	F
Spondias pinnata (Linn.f.) Kurz	#	15	1	New	–	–	–	–	–	–	–	–	–	–	–	–
Syzygium cumini (L) Skeels	#	3	#	New	–	–	–	–	–	–	–	–	–	–	–	–
Syzygium jambos (Linn.) Alston	#	#	1	N	–	–	–	–	–	–	–	–	–	–	–	–
Syzygium sp.	–	–	–	–	–	–	–	–	#	13	30	P	–	–	–	–
Tamarindus indica Linn.	3	5	#	New	–	–	–	–	–	–	–	–	–	–	–	–
Terminalia citrina (Gaertn.) Flem.	–	–	–	–	–	–	–	–	38	73	13	F	–	–	–	–
Thevetia neriifolia Juss.ex Steud	#	5	#	New	–	–	–	–	–	–	–	–	–	–	–	–
Toona ciliata M. Roem	–	–	–	–	#	3	#	New	–	–	–	–	#	3	#	New
*Uha	#	13	15	P	–	–	–	–	–	–	–	–	–	–	–	–
Trema orientalis Blume	28	43	6	F	28	53	#	New	#	10	#	New	#	#	5	N
Vangueria spinosa Roxb.	#	48	17	P	30	43	110	F	–	–	–	–	#	8	#	New
Viburnum sp.	–	–	–	–	–	–	–	–	#	#	3	N	–	–	–	–
Wendlandia exerta DC.	–	–	–	–	–	–	–	–	–	–	–	–	#	63	3	P
Wendlandia tinctoria (Roxb.) DC.	–	–	–	–	–	–	–	–	38	153	15	F	168	245	23	F
Xylosma longifolium Clos	388	170	3	G	190	110	23	G	#	5	#	New	230	85	20	G
Zanthoxylum rhetsa (Roxb.) DC.	#	13	4	P	–	–	–	–	–	–	–	–	–	–	–	–
Zizyphus jujuba Lam.	–	–	–	–	8	25	5	F	–	–	–	–	–	–	–	–
	8803	3030	359	12192	4540	2123	600	7263	3415	1943	995	6353	4198	2840	1218	8255

Variance of means of density/ha of the four groves = 6601477.23, Significant at the 0.0005 level.

F – Fair regeneration, G – Good regeneration, P – Poor regeneration and N – No regeneration.

* – Vernacular name, _ absence of species, # – Absence of seedling/sapling/tree.

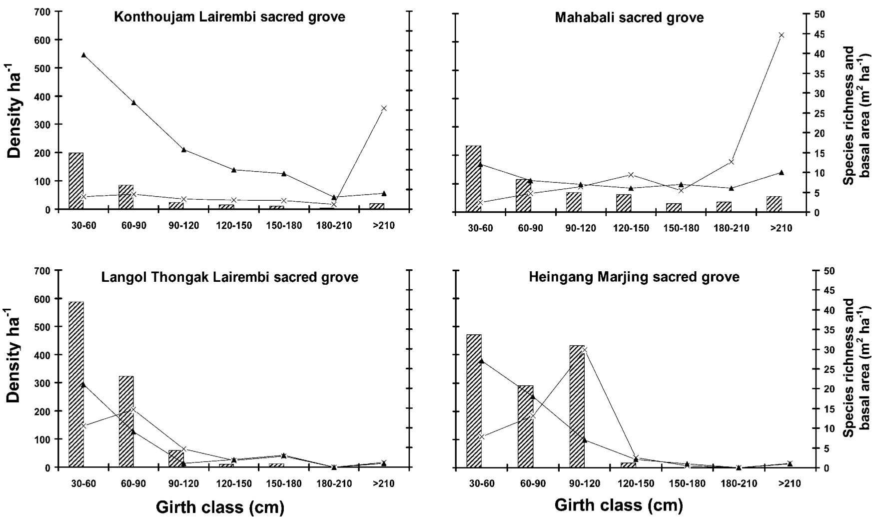

Figure 1. Density ha^{-1} (■), species richness (▲) and basal area (X; m^2 ha^{-1}) of woody species in different girth classes in the four sacred groves.

Population structure of woody species

The population structure of woody species in terms of the proportion of seedlings, saplings and adults in the four groves varied greatly (Figure 2). The relative proportion of seedlings ranged from 72% in Konthoujam Lairembi

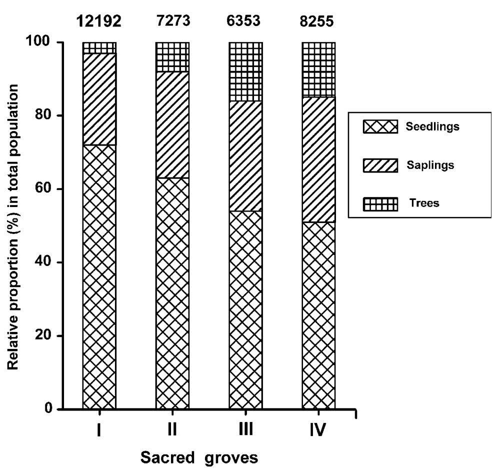

Figure 2. Population structure of all the woody species taken together in the four sacred groves of Manipur in December 2001. Total density of a particular grove is shown at the top of the corresponding bar. I – Konthoujam Lairembi sacred grove; II – Mahabali sacred grove; III – Langol Thongak Lairembi sacred grove and IV – Heingang Marjing sacred grove.

sacred grove to 51% in Heingang Marjing sacred grove. The highest percentage of adults was recorded in Langol Thongak Lairembi sacred grove (16%) and lowest in Konthoujam Lairembi sacred grove (3%).

The population structure of selected tree species in the concerned groves showed that seedlings constituted about 79% of the total density (3640 ha^{-1}) in Konthoujam Lairembi sacred grove, followed by 68% each in Mahabali (total density 1784 ha^{-1}) and Langol Thongak Lairembi (total density 1303 ha^{-1}) and 56% in Heingang Marjing (total density 1586 ha^{-1}). Density–diameter distribution in terms of seedlings, saplings and adults trees of selected tree species (Figure 3a and b) in the four groves indicates the higher proportion of seedlings than the saplings and trees except for *Marlea begoniaefolia* and *Litsea polyantha* in Konthoujam Lairembi sacred grove, *Eugenia praecox* in Mahabali, and *Wendlandia tinctoria* in Langol Thongak Lairembi and Heingang Marjing. *Saprosma* sp. in Konthoujam Lairembi had maximum (89%) seedling population and *Wendlandia tinctoria* in Langol Thongak Lairembi recorded minimum proportion of seedling population (16–34% of the total population).

During May (beginning of the rainy season in Manipur) seedling population of all the selected species in the studied groves was greater as compared to the other seasons except for *Litsea polyantha* in Konthoujam Lairembi and Mahabali sacred groves, *Litsea sebifera* in Langol Thongak Lairembi grove, and *Litsea sebifera* and *Wendlandia tinctoria* in Heingang Marjing which showed maximum seedling population in December. In general, seedling population size decreased substantially after the rainy season.

Sapling population did not show marked seasonal variation in density. Sapling population of *Marlea begoniaefolia* and *Litsea polyantha* in Konthoujam Lairembi and *Wendlandia tinctoria* in Langol Thongak Lairembi and Heingang Marjing groves was higher than the seedling population. Total sapling density per hectare was 645 in Konthoujam Lairembi, 499 in Heingang Marjing, 422 in Mahabali and 331 in Langol Thongak Lairembi sacred grove.

Adult tree population of *Saprosma* sp. and *Eugenia praecox* in Konthoujam Lairembi was very low. No adult individual of *Eugenia praecox* was recorded in the Mahabali sacred grove and the same was true for *Litsea sebifera* in the Langol Thongak Lairembi sacred grove.

Regeneration status of woody species

In Konthoujam Lairembi sacred grove, out of the 55 species, 15% showed good regeneration, 22% fair, 22% poor and 16% were not regenerating, while 14 species (25%) were represented only by seedlings or saplings. The species falling under the last category were regarded as the new arrivals in this grove. In Mahabali grove out of 38 species, 7 (19%) showed good regeneration, while 6 (16%) and 5 (13%) species exhibited fair and poor regeneration, respectively. Two species (5%) showed no regeneration and 18 species (47%) were ‘new’ to

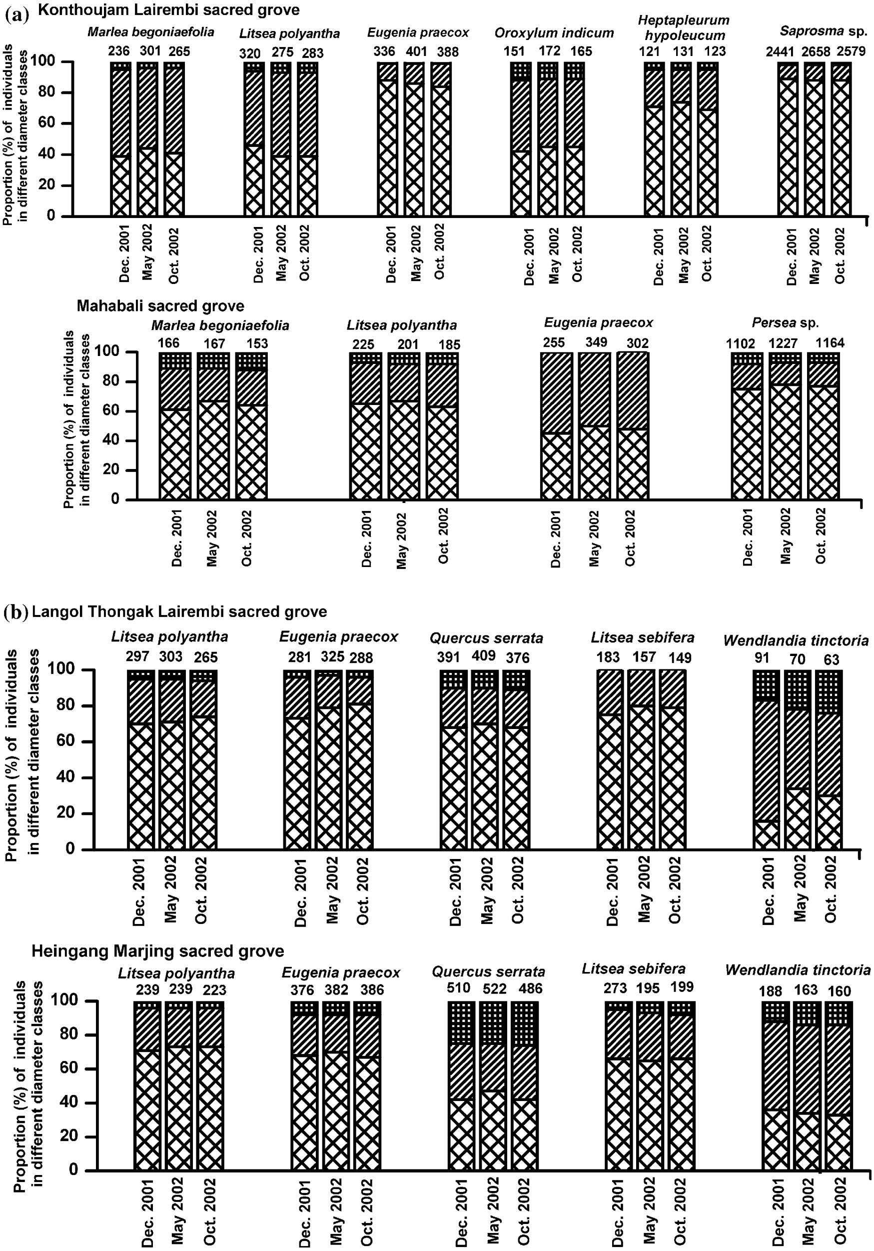

Figure 3. (a) Population structure of the selected woody species in the Konthoujam Lairembi sacred grove and Mahabali sacred grove. Percentages of the total density as seedlings (■), saplings (■) and trees (■) are given. Total density of a particular species is shown at the top of the corresponding bar; (b) Population structure of the selected woody species in the Langol Thongak Lairembi sacred grove and Heingang Marjing sacred grove. Percentages of the total density as seedlings (■), saplings (■) and trees (■) are given. Total density of a particular species is shown at the top of the corresponding bar.

this grove. Among the 38 species in Langol Thongak Lairembi, 9 species (24%) showed poor regeneration, while 7 (18%) species each showed good regeneration (proportion of seedlings > saplings > adults) and fair regeneration (proportion of seedlings > or ≤ saplings ≤ adults). Fourteen species (37%) were newly recruited to the grove, while one species (3%) did not show regeneration. In Heingang Marjing out of 42 species, 7 species (17%) exhibited good regeneration, 11 species (26%) exhibited fair regeneration and 12 species (29%) showed poor regeneration. Eleven species (26%) were categorised as new arrivals, and one species (2%) was found not regenerating (Table 2).

Discussion

Girth class-wise species richness, tree density and basal area

An analysis of population structure of woody species in the groves, based on the girth classes, shows that the abundance of a large number of tree species is stable. It was observed that about 50% of tree species showed reduced abundance in the succeeding girth classes. However, a drastic decrease in abundance was observed with increase in girth beyond a particular stage. The absence of a certain girth class e.g. 180–120 cm in Langol Thongak Lairembi grove and Heingang Marjing groves may indicate an interruption in the regeneration, resulting from the changing microclimatic conditions (Bankoti et al. 1986). The high value of basal area in the highest girth class in the Mahabali sacred grove could be attributed to the presence of *Ficus* species, which had big trees with large basal area. Langol Thongak Lairembi and Heingang Marjing groves recorded the lowest basal area in the highest girth class as compared to the other groves located in the plain area, which may be due to the dominance of *Pinus kesiya* trees having less girth in the groves located in the hilly area. There was a gradual decrease in species diversity and density with increase in girth class which is in conformity with the studies in the Western Ghats, India (Pascal and Pelisseir 1996; Parthasarathy and Karthikeyan 1997), Malaysia (Manokaran and LaFrankie 1990; Newbery et al. 1992), Costa Rica (Lieberman et al. 1985; Nadkarni et al. 1995), New Guinea (Paijmans 1970) and New Caledonia (Jeffre and Veillon 1990). These observations indicate that the groves have the potential of successful regeneration through seeds.

Population structure and regeneration status of woody species

The future community structure and regeneration status of the species could be predicted from the relative proportion of seedlings and saplings in the total populations of various species in the forest. The overall population structure of woody species in the four groves showed that contribution of seedlings to the total population was highest followed by saplings and trees. It shows regeneration of woody species in the four sacred groves is good and the future communities may be sustained. The differences in relative proportion of seedlings, saplings and trees among the four groves may be due to the interactive influence of an array of biotic and abiotic factors. In general, regeneration of species is affected by anthropogenic factors (Khan and Tripathi 1989; Sukumar et al. 1994; Barik et al. 1996) and natural phenomena (Welden et al. 1991).

Variation in the population structure of selected tree species in the four groves may be attributed to the differences in their habitat and prevailing microenvironmental factors. Jones et al. (1994) reported that seedling layer in various forests, differs in composition from their respective overstories. Tall height with relatively close canopy layer of the grove may favour germination of seeds and establishment of the seedlings and saplings. According to Espelta et al. (1995), canopy closure seems to promote seedling germination through changes in the environmental conditions on the forest floor, which might be related to decreasing radiation and water evaporation. The presence of greater number of seedlings may be ascribed to the availability of microsites, which facilitates regeneration through germination of large number of tree seeds. Tripathi and Khan (1990) stated that microsite characteristics of forest floor and microenvironmental conditions under the forest canopy also influence the regeneration of trees by seeds. Many workers have reported that tree species are able to survive and grow at reduced light intensities under the forest canopy (Atzet and Waring 1970; Emmingham and Waring 1977; Minore 1998). On the contrary, many workers have shown that open canopy may favour germination and seedling establishment through increased solar radiation on the forest floor and consequently increase in surface temperature, and reduced competition from the canopy layer (Khan et al. 1987; Srinivas 1992). While the reduction of seedling population in the four groves during the dry winter season may be due to adverse effects of soil moisture stress and unfavourable temperatures on survival of tree seedlings. Similar results have also been reported by several workers (Perira and Kozlowski 1977; Schulte and Marshall 1983; Kumar et al. 1994). Khan et al. (1986) also reported that survival of tree seedlings was lowest during the winter season in tropical deciduous and sub-tropical forests of Meghalaya state in India.

The low sapling population of selected species in the four groves despite the presence of high number of seedlings (except in case of *Marlea begoniaefolia* and *Litsea polyantha* in Konthoujam Lairembi grove and *Wendlandia tinctoria* in Langol Thongak Lairembi and Heingang Marjing groves) may be attributed to the adverse impact of environmental factors prevalent during the sapling growth. The greater populations of saplings of *Marlea begoniaefolia*, *Litsea polyantha* (Konthoujam Lairembi sacred grove) and *Wendlandia tinctoria* (Langol Thongak Lairembi and Heingang Marjing grove) than their seedlings could not be explained, however, it may be due to the poor seed set and seed germination. On the other hand, the species may also suffer high mortality at the seed/seedling stage due to herbivores and thus regeneration of such species may be periodic. The greater number of saplings clearly indicates that these species will persist and may determine the composition of future vegetation of the groves (Swaine and Hall 1988; Jayasingham and Vivekanantharaja 1994). Swaine and Hall (1988) stated that higher number of saplings alone may not represent future composition, because over a period environmental changes could nullify the effect. However, in the absence of catastrophic events the saplings will gradually form future crowns. Presence of species that are represented only by adults e.g. *Eugenia praecox* and *Litsea sebifera* without any seedlings and saplings may be due to their poor seed set, germination and establishment of seedlings in the forest. Species diversity and population structure will be stable or reduced and regeneration potential will be negligible if the number of species represented only by adults becomes higher in any forest.

Woody species represented only by their seedlings and saplings without any adult individuals were high in the four groves which indicate that large number of species were new colonizers in the groves and have managed to reach there due to invasion of 'new' species through seed dispersal from other areas. Invasion of new species to the groves may be regarded as a possible factor to the co-existence of the tree species.

The overall population structure of selected woody species reveals that seedling populations dominate tree populations and the fluctuation in population density in various seasons is related to the prevailing environmental factors. Germination of freshly dispersed seeds is high for most of the species during the monsoon season. Therefore, recruitment of all the species increased during the rainy season attaining peak during June, which is the wettest month. Similar observations have been reported in tropical dry forest at Pinkwae, Ghana (Lieberman and Li 1992; Swaine et al. 1990). The four groves showed good regeneration and exhibited high proportion of 'new' species facilitated by the dispersal of seed from the nearby forests and receiving favourable micro-environmental conditions for their germination and establishment of seedlings. It may be concluded that tree species richness and stand density decrease gradually with the increase in girth classes in the four groves. Moreover, the four groves reveals good regeneration and exemplify regeneration of tree species is largely depended on the prevailing environmental factors, and if the existing ecological factors are not jeopardized the future maintenance of the tree species in the groves will be sustained. However, differences in regeneration behaviour of various species would determine the structure and dynamics of the groves.

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