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Species diversity and vegetation structure across various strata in natural and plantation forests in Katerniaghat Wildlife Sanctuary, North India

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Abstract: Katerniaghat Wildlife Sanctuary (KWS) in Bahraich district of Uttar Pradesh, encompassing about 400 km^2 area, represents a typical Terai ecosystem characterized by extensive alluvial plains, hygrophilous grasslands and tropical moist deciduous forests. A large proportion of the natural forest in the sanctuary has been converted into commercial plantations. We studied species diversity, structure and concentration of dominance of woody plants at various strata of natural and plantation forests within the sanctuary. The study sites included three categories of natural forests *viz*., sal mixed, miscellaneous and riverine and three types of plantation forests i.e., sal, sal under planting and teak plantations. All categories of vegetation except riverine forests were deciduous in nature. Tree densities were higher in plantations as compared to natural forests. Basal area of trees ranged from 24.84 m^2 ha^{-1} (riverine forest) to 45.55 m^2 ha^{-1} (sal mixed forest). However, there was no significant difference in overall basal area between natural (35.9 m^2 ha^{-1}) and plantation forests (32.3 m^2 ha^{-1}). Species richness was highest (4.31) in riverine forest and lowest (1.31) in sal plantation.

Resumen: El Santuario de Vida Silvestre Katerniaghat en el distrito Bahraich de Uttar Pradesh, el cual abarca un área de alrededor de 400 km^2, representa un típico ecosistema Terai caracterizado por extensas planicies aluviales, pastizales higrófilos y bosques tropicales húmedos caducifolios. Una gran proporción del bosque natural en el santuario ha sido trasformado en plantaciones comerciales. Estudiamos la diversidad de especies vegetales, la estructura y la concentración de la dominancia en varios estratos de bosques naturales y de plantación dentro del santuario. Los sitios de estudio incluyeron tres categorías de bosques naturales, es decir, mixto de *sal*, misceláneo y ribereño, y tres tipos de bosque de plantación, es decir, *sal*, *sal* bajo plantación y plantación de teca. Todas las categorías de vegetación, excepto el bosque ribereño, fueron de naturaleza caducifolia. Las densidades de árboles fueron mayores en las plantaciones que en los bosques naturales. El área basal de los árboles fluctuó de 24.84 m^2 ha^{-1} (bosque ribereño) a 45.55 m^2 ha^{-1} (bosque mixto de *sal*). Sin embargo, el área basal total no difirió significativamente entre los bosques naturales (35.9 m^2 ha^{-1}) y los de plantación (32.3 m^2 ha^{-1}). La riqueza de especies tuvo su máximo (4.31) en el bosque ribereño y su mínimo (1.31) en la plantación de *sal*.

Resumo: O Santuário de Vida Selvagem de Katerniaghat (KWS) no distrito de Bahraich no Uttar Pradesh, abrangendo uma área de cerca de 400 km^2, representa um ecossistema Terai típico caracterizado por extensivas planícies aluviais, pastagens hidrófilas e florestas húmidas decíduas tropicais. Uma grande proporção das floresta naturais no santuário foi convertida em plantações comerciais. Estudou-se a diversidade das plantas, as estrutura e concentração da

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dominância de vários estratos das florestas naturais e de plantação dentro do santuário. As estações estudadas incluíram três categorias de florestas naturais viz. shorea mista, várias e ribeirinhas e três tipos de florestas de plantação i.e, shorea, shorea sob plantação e plantações de teca. Todas as categorias de vegetação, excepto as florestas ribeirinhas, eram de natureza decídua. As densidades das árvores eram mais elevadas nas plantações quando em confronto com as florestas naturais. A área basal das árvores oscilou de 24,84 m^2 ha^{-1} (floresta ribeirinha) a 45,55 m^2 ha^{-1} (floresta mista de shorea). Contudo, não se verificou uma diferença significativa entre a área basal global entre as florestas naturais (35,9 m2 ha^{-1}) e as de plantação (32,3 m^2 ha^{-1}). A riqueza específica era mais alta nas floresta ribeirinha (4,31) e mais baixa (1,31) na plantação de shorea.

Key words: Basal area, concentration of dominance, heterogeneity, population density, species richness, Shannon-Wiener's index.

Introduction

Wildlife Protected Areas (PAs) in India have had a relatively long history of forest management and exploitation as majority of the PAs were originally reserved or other categories of government owned forests where focus of management was timber production, meeting the biomass demands of local communities or soil and water conservation (Rodgers & Sawarkar 1988). Several reserved forests having high abundance of wildlife were notified as National Parks (where legally all exploitation of forest resources is prohibited) or Wildlife Sanctuaries (where some exploitation and development may be allowed) during 1970's and 1980's. However, impacts of past management practices on vegetation and wildlife habitats were quite long lasting in many PAs. Such impacts have rarely been documented.

Katerniaghat Wildlife Sanctuary (KWS) is one such PA, which was established in 1975 in the Bahraich district of Uttar Pradesh (UP) covering 400.69 km^2 in the Terai Landscape. Terai Landscape is one of the two distinct eco-climatic zones parallel to sub-Himalayan tracts in north India *viz.,* other being Bhabhar. It is rather narrow and relatively dry having low water table, while the Terai is much more extensive and wet. The Terai landscape is listed among the important ecoregions of the world, well known for its unique biodiversity and high productivity. Despite its ecological importance as home to a large number of threatened and charismatic species of flora and fauna this area has been neglected in terms of ecological studies and biodiversity assessments. This landscape has undergone drastic transformations due to expansion of agriculture, replacement of natural forest with commercial plantations of exotic species, industrialization and urbanization. As a result, natural habitats have fragmented and degraded causing local extinction of several species (Johnsingh *et al.* 2002).

Several authors have dealt with the vegetation structure and composition in Terai region. Panigrahi *et al.* (1969) compared the flora of Terai forests and grasslands of UP. Pandey & Shukla (2003) assessed the species composition, regeneration pattern and conservation status of managed sal (*Shorea robusta* Gaertn. f.) forests in Sohagibarawa sanctuary near Gorakhpur. The biotic pressures and their impact on regeneration and growth of wild plants in tropical moist deciduous forest of this region have been documented by Pandey (2000). Champion & Seth (1968) compared various communities associated with sal forests along moisture gradients. Regeneration pattern, plant diversity in degraded sal forest of north - eastern UP were assessed by Pandey & Shukla (1999, 2001). Several studies have analyzed community structure in sal forests e.g., Gupta & Shukla (1991); Singh *et al.* (1995); Pandey (1999); Shankar (2001); Kumari & Tripathi (2007); Maliya & Singh (2003) and Maliya (2007). The structure of a rehabilitated forest established on barren land was studied in response to natural succession and degree of soil amelioration/land renewal over period of time (Tripathi 2001; Tripathi & Singh 2005). However,

patterns of plant species diversity within the past plantation and natural vegetation have not been documented in most parts of Terai.

This paper deals with the plant species diversity, structure and composition across various strata within natural and plantation forests within the KWS. Distribution of selected indicator taxa and their abundance have been compared. Results are discussed along with the management implications.

Material and methods

Study area

The study was conducted in KWS (27°55' to 28°25' N latitudes and 81° to 81°25'E longitudes), which is located in Bahraich district of UP. It is spread over an area of 400 km² and represents a typical Terai ecosystem characterized by extensive alluvial plains, wetlands, hygrophilous grasslands, woodlands and moist forests. Established in 1976, this sanctuary is located close to Indo-Nepal border. *Shorea robusta* represents the climax species along with other associates such as *Adina cordifolia* (Roxb.) Hook. f., *Syzygium cuminii* (L.) Skeels, *Terminalia alata* Heyne ex Toth, *Aegle marmelos* (L.) Correa, *Acacia catechu* Willd., and *Mallotus philippensis* (Lamk.) Muell.-Arg. Understorey species in sal forest include *Murraya koenigii* Spreng., *Clerodendrum viscosum* Vent., *Tiliacora acuminata* (Lamk.) Miers. and *Ichnocarpus frutescens* (L.) R. Br. (Anonymous 2005). Mammalian fauna reported from the sanctuary are tiger (*Panthera tigris*), common leopard (*Panthera pardus*), striped hyaena (*Hyaena hyaena*), sloth bear (*Melursus ursinus*), sambar (*Cervus unicolor*), spotted deer (*Axis axis*), wild pig (*Sus scrofa*), swamp deer (*Cervus duvauceli duvauceli*), blue bull (*Boselaphus tragocamelus*), Indian porcupine (*Hystrix indica*) and common langur (*Semnopithecus entellus*). The sanctuary is rich in avifauna, common species being Little grebe (*Podiceps ruficollis*), black kite (*Milvus migrans*), black francolin (*Francolinus francolinus*), red jungle fowl (*Gallus gallus*), Indian peafowl (*Pavo cristatus*), Egyptian vulture (*Nephron percnopterus*), ring dove (*Streptopelia orientalis*) and common grey hornbill (*Tockus birostris*). In addition, Gharial (*Gavialis gangeticus*), Maggar crocodile (*Crocodilus palustris*), Gangetic softshell turtle (*Aspidertus gangeticus*) and many species of fishes are found in the river Gerua that flows through the sanctuary area (Anonymous 2005). The local people heavily depend on the natural resources of the sanctuary which include fuel wood, fodder, thatch grass, non-wood forest produce and fish.

Based on the physiognomy following categories of vegetation can be recognized in the study area: riverine forests, mixed sal forest, teak (*Tectona grandis* L. f.) plantation, sal plantation, sal under-planting for gap filling, woodlands and alluvial grasslands. Except riverine forests which are characterized by the dominance of moist evergreen species, all other categories are deciduous in nature. During 1950's and 60's the UP Forest Department introduced commercial species such as teak and *Eucalyptus* in this sanctuary. Sal, a native species was also promoted through silvicultural operations to augment the timber production and to increase the revenue for the state.

Methods

A total of 18 sites representing various categories of natural forests and plantations were selected for vegetation sampling. At each site 13 quadrats (15 m x 20 m) were laid to quantify various layers. The size of the quadrat used in this study was decided based on the species area curve method following Misra (1968). In each quadrat the individual trees were enumerated and for each tree girth at breast height (GBH) i.e., at 1.37 m from the ground were recorded. Individuals of shrubs, climbers and tree seedlings were enumerated within each quadrat. The vegetation was stratified into four categories *viz.,* over-storey, under-storey, ground layer (all woody species < 50 cm in height) and climbers and the species were identified with the help of local floras *viz.,* Duthie (1960); Singh (1997) and Gaur (1999). The structure and composition of vegetation across vegetation types have been compared in terms of frequency, density, abundance, and basal area of major species. Importance Value Index (IVI = relative frequency + relative density + relative dominance) and species diversity index ($H' = - \Sigma\ pi\ ln\ pi$; where, pi= ni/N; and ni = abundance of each species, N= total abundance of all species) were derived from the primary data separately for each layer following Misra (1968) and Shannon & Weaver (1963) respectively. Concentration of

dominance (Cd = Σ (ni/N)²) was calculated following Simpson (1949). Species richness index (d) indicating the mean number of species per sample (Margalef 1958) was calculated as d = S/√N, where, S= number of species, N= number of individuals of all species. Equitability or evenness (e = H/log S, where, H= Shannon Wiener's index and S = number of species) was computed following Pielou (1966). Species heterogeneity, defined as the reciprocal of Simpson's index or under root of concentration of dominance (Cd), was also determined as 1/Σ pi or 1/ √ Cd.

Species distribution pattern was examined through the mean variance ratio and abundance/ frequency (%) ratio (Curtis & Cottam 1956) and it was categorized into regular (< 0.025), random (0.025 - 0.05) and contagious (> 0.05). Based on the number of individuals species were grouped into very rare (represented by < 2 individuals), rare (2 - < 10 individuals), common (10 - < 25 individuals), dominant (25 - < 50 individuals) and predominant (> 50 individuals) following Kadavul & Parthasarthy (1999).

Results

Species richness, diversity and evenness

Species diversity, richness, heterogeneity and equitability across various layers in natural and plantation forests have been given in Table 1. Understory exhibited highest richness and diversity of woody vegetation. Climbers had lowest richness and diversity in natural as well as plantation forests. Although richness of ground layer (saplings and seedlings was higher in plantation forest but diversity value was lower (H = 1.46) compared to natural forest (H = 2.05). As expected, vegetation of ground layer in plantation was more even (e = 0.72) as compared to natural forest (e = 0.67). Overall richness in the natural forests (85) was higher compared to plantations (71). Species area relation was almost similar in natural and plantation forests (Fig. 1). However, in plantation forest species accumulation curve leveled off rapidly. Species saturation limit was about 25 in plantation forest against 50 in natural forests.

Table 1. Species diversity in the natural and plantation forests of Katerniaghat Wildlife Sanctuary, India.

Parameters	Habit	Natural Forest Mean ± SE	Plantation Forest Mean ± SE	LSD_{05}
Species richness (number)	Overstorey	21±4	17±3	2
	Understorey	38±5	21±4	8
	Groundlayer	18±5	27±6	5
	Climber	8±2	6±1	NS
Shannon Wiener's index (H)	Overstorey	1.19±0.17	0.62±0.16	0.49
	Understorey	2.21±0.11	1.44±0.12	0.34
	Groundlayer	2.05±0.19	1.46±0.16	0.51
	Climber	0.99±0.14	0.56±0.23	NS
Heterogeneity	Overstorey	1.96±0.31	1.21±0.06	0.66
	Understorey	2.23±0.10	1.71±0.12	0.34
	Groundlayer	2.35±0.28	1.65±0.18	0.64
	Climber	1.93±0.38	1.16±0.05	NS
Equitability (e)	Overstory	0.81±0.06	0.41±0.07	0.19
	Understorey	0.74±0.02	0.61±0.06	0.12
	Groundlayer	0.67±0.05	0.72±0.07	NS
	Climber	0.66±0.03	0.61±0.21	NS
Richness index (d)	Overstorey	1.24±0.18	0.76±0.18	NS
	Understory	1.65±0.22	0.71±0.04	0.47
	Groundlayer	0.72±0.14	0.33±0.07	0.32
	Climber	0.37±0.05	0.09±0.05	0.10

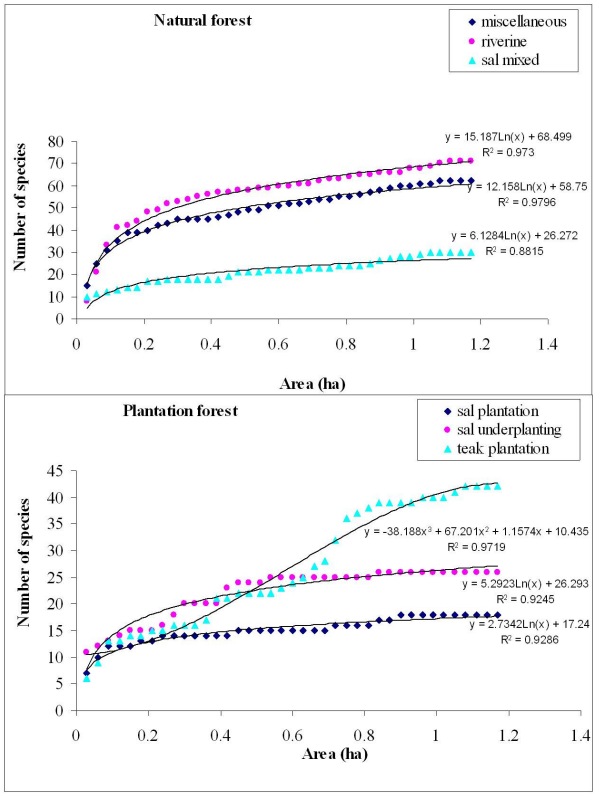

Fig. 1. Species area relation of different forests types in Katerniaghat Wildlife Sanctuary.

The sampled area within KWS (7.02 ha, containing 234 quadrats of 15 x 20 m size) yielded 99 species of woody vascular plants and climbers which belong to 40 families. This represents nearly 41% of all the species recorded from the sanctuary (Upreti *et al*. 2007). Moraceae (6), Euphorbiaceae (5), Mimosaceae (4) and Verbenaceae (4) had the maximum number of woody species. Among growth forms trees contributed 46%, followed by shrubs (26%), saplings (18%) and climbers (10%). Forest vegetation constituted 29 over-storey species, 64 under-storey, 57 ground layer and 7 climbers. *Rauvolfia serpentina* and *Uraria picta* turned out to be the rarest species on the basis of their low population size in the study area. Species common to six forests types include *Haldina cordifolia*, *Syzygium heyneanum*, *Mallotus philippensis*, *Glycosmis arborea*, *Aegle marmelos*, *Tiliacora acuminata*, *Ichnocarpus frutescens* and *Callicarpa macrophylla*.

Population structure, patterns of distribution and dominance

Plant community structure in terms of density, basal area and concentration of dominance has been compared for natural and plantation forests in Table 2. The high population density in plantation forests compared to natural forest for over-storey and under-storey vegetation did not correspond to the ground layer. The natural forest had higher density of plants at ground layer (3429 ± 452 plants ha^{-1}) as compared to plantation forest

Table 2. Plant community structure in the natural and plantation forests of Katerniaghat Wildlife Sanctuary, India.

Parameters	Habit	Natural Forest Mean ± SE	Plantation Forest Mean ± SE	LSD_{05}
Density (No.ha^{-1})	Overstorey	57±11.5	148±24.8	59
	Understorey	641±79.6	896±292	NS
	Groundlayer	3429±452	1865±199	1066
	Climber	716±95	1985±356	794
Basal Area (m^2 ha^{-1})/basal cover	Overstorey	19.23±3.59	22.87±1.67	NS
	Understorey	16.65±2.85	9.5±0.84	6.41
	Groundlayer*	216±59	81±3.66	127
	Climber*	26.63±2.86	71.3±17.7	38
Concentration of dominance (Cd)	Overstorey	0.39±0.05	0.72±0.06	0.15
	Understorey	0.17±0.01	0.39±0.05	0.11
	Groundlayer	0.27±0.07	0.32±0.06	NS
	Climber	0.44±0.04	0.81±0.05	0.12

* basal cover

(1865±199 plants ha^{-1}). However, the species richness at ground layer was higher in plantation forests. The plant count in natural and plantation forests varied significantly in all strata except a close similarity for under-storey.

Various layers of natural and plantation forests have been compared in terms of dominant species giving IVI values of three top ranking species (Table 3). In overstory vegetation, *Syzygium heyneanum* dominated all the forest types except sal mixed forest. Similarly, *Haldina cordifolia* was dominant in miscellaneous and sal

Table 3. Importance Value Index (IVI) of three dominant species of each stratum in the natural and plantation forests of Katerniaghat Wildlife Sanctuary, India. Values are mean ± SE

Species	Miscellaneous Forest	Sal Mixed Forest	Riverine Forest	Teak Plantation	Sal Plantation	Sal Forest Under Planting
Overstorey:						
Haldina cordifolia (Roxb.) Ridsd.	57.2±27	13.1±8.1	-	-	-	15±9.47
Anogeissus pendula Edgew.	-	19.39±9.72	-	-	-	-
Ficus glomerata Roxb.	-	-	64.83±46	-	-	-
Holoptelea integrifolia (Roxb.) Planch.	-	-	-	14.8±14	-	-
Melia azedarach L.	51.26±24.23	-	-	-	-	-
Shorea robusta Gaertn. f.	-	-	-	-	258±14.7	197.4±18.7
Syzygium heyneanum Wall. ex. Wight & Arn.	29.4±13.9	-	90±54	12.17±1.5	38.8±1.73	23.67±5.29
Tectona grandis L..f.	-	-	-	238±23	-	-
Terminalia alata Heyne ex Toth.	-	57.58±15.6	-	-	-	-
Trewia nudiflora L.	-	-	58±54	--	-	-
Understorey:						
Acacia catechu Willd.	20.96±17.65	-	-	-	-	-
Aegle marmelos (L.) Correa	-	-	-	-	-	25.37±6.2
Calamus tenius Roxb.	-	-	22.96±1.4	-	-	-
Ehretia laevis Roxb.	-	-	-	-	49.6±1.73	-
Madhuca longifolia Macb.	-	-	-	-	57.12±27.8	-
Mallotus philippensis (Lamk) Muell. - Arg.	91.66±20.17	65.6±1.98	56.4±22	50.68±7	-	29.2±5.3
Shorea robusta Gaertn. f.	-	67.11±7.84	-	-	99.85±37	-
Streblus asper Lour	20.33±10.33	-	-	-	-	-
Syzygium heyneanum	-	-	37.1±17	-	-	-
Tectona grandis L. f.	-	-		104.86±40	-	136.96±3.8
Terminalia alata Heyne ex Toth.	-	31.05±8.68	-	-	-	-
Trewia nudiflora L.	-	-	-	50.35±43	-	-
Ground layer:		-		-		
Callicarpa macrophylla Vahl.	34.06±10.24	-	-	-	-	-
Clerodendrum viscosum Vent	23.26±6.27	72.13±33	22.1±7.8	33.55±5.5	42.8±12.67	-
Crotalaria albida Heyne	-	-	-	40.66±38	-	-
Glycosmis arborea (Retz.) correa		41.93±41		-		
Glycosmis pentaphylla (Retz.) correa	46.93±0.03	89.51±44		-	-	-
Madhuca longifolia Macb.	-	-	-	124.63±58	-	-
Mallotus phillipensis (Lamk) Muell.-Arg.	-	-	-	-	59.6±1.82	47.46±11
Murraya koenigii Sprenge	-	-	-	-	59.6±1.87	39.2±0.067
Putranjiva roxbergii Wall.	-	-	19.56±2.93	-	-	-
Schleichera oleosa (Lour.) Oken	-	-	-	-	-	55.29±22
Climber:						
Ampelocissus latifolia (Roxb.) Planch	-	15.11±6.79	-	-	-	-
Cissampelos pareira L.	14.56±6.88	-	-	-	-	-
Ichnocarpus frutescens (L.) R.Br.	78.86±10.93	106.89±8	87.3±18	181.46±55	58.18±1.07	55.85±10.4
Tiliacora accuminata (Lamk.) Miers	111+0.19	178±1.83	78.9±14.5	112.83±53	241.8±1.83	240.4±8.4

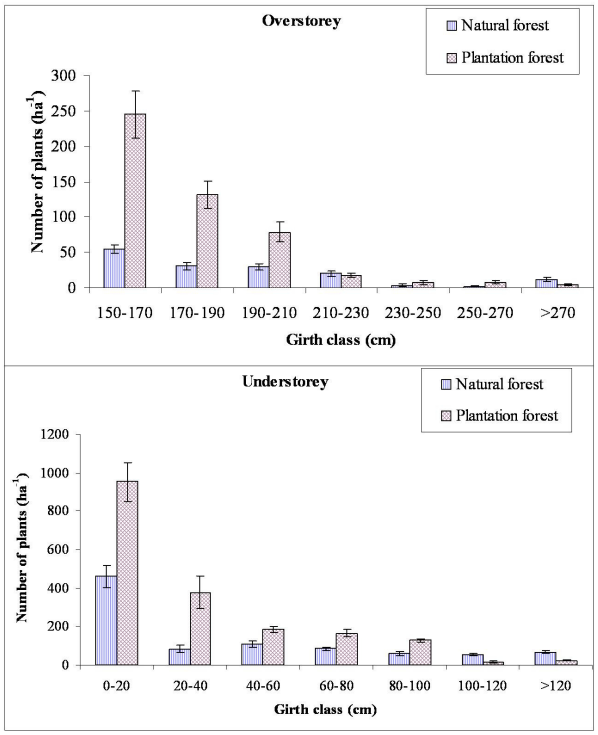

Fig. 2. Population distribution along with size class of different forests in Katerniaghat Wildlife Sanctuary.

mixed forest. In understorey vegetation, *Mallotus philippensis* was consistently dominant across all the categories of forests except in sal plantation. *Shorea robusta* and *Terminalia alata* dominated in sal mixed forest and *Shorea robusta, Madhuca longifolia* and *Ehretia laevis* dominated in sal plantation. Among climbers *Ichnocarpus frutescens* and *Tiliacora acuminata* were present in all the forests whereas *Ampelocissus latifolia* and *Cissampelos pareira* were relatively high in sal mixed and miscellaneous forest, respectively. Population of top canopy species (girth class range 150 - 270 cm) decreased with the increase in girth class (Fig. 2). The decrease was more pronounced in plantation forests as compared to natural one which indicates the relatively young age of the managed forests.

Most of the tree species (74 - 94%) showed contagious distribution while a few (6 - 30%) had random distribution (Table 4). Regular distribution was exhibited by only two to five species (< 8%). Species are more regular in natural forest in comparison to plantation forest. In sal mixed forest (natural) and teak plantation, regular species are conspicuously absent.

Discussion

Species richness in a forest depends on climatic, edaphic and biotic factors (Ayappan & Parthasarathy 1999). As expected, the riverine forests had the highest species richness and diversity followed by miscellaneous forest. The high species richness in riverine forest may be attributed to higher soil moisture and nutrients, greater micro-topographic variation and habitats per unit area. Sal plantation (managed forest) had least species richness (Fig. 3) which may be attributed to dense canopy cover. *Tiliacora acuminata*, one of the common under-storey species in the sal forests of Terai, is known to suppress the ground vegetation. Richness of woody species in the study area was much higher compared to a rehabilitated tropical forest of about

Table 4. Number of species in each forest showing different population distribution statistics.

	Forest types					
	Miscellaneous Forest	Sal Mixed Forest	Riverine Forest	Teak Plantation	Sal Plantation	Sal Under Planting
Pattern						
Regular	2	0	5	0	1	2
Random	15	8	5	4	4	3
Contagious	78	33	52	58	15	31
Count category						
Very rare	18	9	0	28	2	9
Rare	38	17	43	19	6	16
Common	13	7	23	2	2	4
Dominant	5	5	13	3	1	4
Predominant	18	12	26	11	14	12

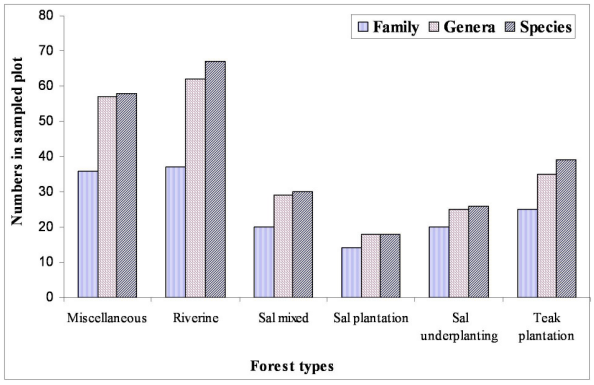

Fig. 3. Number of family, genera and species in sample plot of different forests in Katerniaghat Wildlife Sanctuary (sample plot area in each forest = 1.17 ha).

40 years age in an adjacent district (Tripathi 2001). However, the species richness was lower compared to eastern Terai and a humid evergreen tropical forest of the Andaman & Nicobar Islands (Pandey & Shukla 2003; Tripathi *et al.* 2004). Tree species richness in KWS (44 tree species within 7.02 ha) was lower compared to several other forests such as humid tropical evergreen forest (61 ha^{-1}), tropical rainforests (43 ha^{-1}), tropical moist forests (45 ha^{-1}), temperate forests (50 ha^{-1}), (Brockway 1998; Strasberg 1996; Tripathi 2001; Tripathi *et al*. 2004).

Basal area is an important indicator of tree stocking which reflects stand volume or biomass. In KWS basal area of trees varied from 24.84 m^2 ha^{-1} (riverine forest) to 45.55 m^2 ha^{-1} (sal mixed forest). For over-storey vegetation the basal area was greater in plantation forest (22.87 m^2 ha^{-1}) corresponding to population density whereas, in under-storey, natural forest had greater basal area (16.65 m^2 ha^{-1}) than the former one. On an average, the total basal area was slightly higher in natural forest than plantation forest. These values are quite comparable to that of a rehabilitated forest at Lucknow, in the same region but remained below the level of a humid tropical evergreen forest of Andaman Island (Tripathi & Singh 2005; Tripathi *et al.* 2004, 2006). Basal area in these forests was higher than the dry tropical forest of Vindhyan region in north India (Singh & Misra 1979; Singh & Singh 1991).

The species diversity was higher in the natural forest as compared to plantation forest for all strata except in case of climbers. The high species diversity in natural forest implies that it provides suitable habitat and forage for the large herbivores such as sambar, spotted deer and wild pig. The natural forest also showed more heterogeneous composition of species in comparison to plantation forest. It appears that as many as 16 species e.g., *Bombax ceiba, Ficus religiosa, Hymenodictyon excelsum, Sterculia villosa, Albizia lebbeck, Azadirachta indica, Buchanania lanzan, Calamus tenius, Carea arborea, Clerodendrum seratum, Grewia glabra,* and *Smilax prolifera* were in very low abundance in managed forest. At the same time five species *viz*., *Ficus bengalensis, Ficus semicordata, Madhuca indica, Toona ciliatea* and *Ziziphus rugosa* seemed to have regenerated well in managed forests which were not found in natural forest. Substantial differences in many parameters between natural and plantation forest indicated that managed forest should be promoted to accommodate the natural assemblage of plant communities for a better stability and resilience of the ecosystems. Thus, species of early successional stages could be promoted in commercial plantations thereby enhancing the overall biodiversity at a landscape level. In other words, uniform treatment may promote dominance of fewer species and could lead to reduction in species diversity.

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