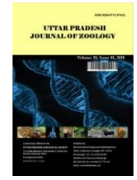
UTTAR PRADESH JOURNAL OF ZOOLOGY

41(11): 40-55, 2020
ISSN: 0256-971X (P)



HABITAT CHARACTERISTICS OF HOOLOCK GIBBON (*Hoolock hoolock* (HARLAN, 1834)) IN AND AROUND INNER-LINE RESERVE FOREST, CACHAR, BARAK VALLEY, SOUTHERN ASSAM, INDIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Tunira Bhadauria, Feroz Gandhi P. G. Degree College, India.
Reviewers:
(1) Emmanuel Danquah, Kwame Nkrumah University of Science and Technology, Ghana.
(2) Junir Antonio Lutinski, Brasil.

Received: 08 February 2020
Accepted: 13 April 2020
Published: 03 September 2020

Original Research Article

ABSTRACT

Hoolock gibbons (*Hoolock hoolock* Harlan, 1834) are endangered (A4acd ver3.1) small apes occurring in Bangladesh, India, Myanmar, and south China. In India they only occur in the north eastern states. The Inner-line reserve forest of Barak Valley is one of the habitat of Hoolock gibbon where these gibbon groups were surveyed and habitat assessment was done. The gibbon population was estimated by the modified line-transect method [1,2] and the direct count method. Following Kumar et al. (2009)[3], the line transects were laid in a stratified random design to cover all selected areas in the forest. During the survey period 33 individuals (9 groups and one solitary individual) were encountered from 10 different forest patches in the Inner-line reserve forest and its adjoining areas. Strip sampling was done to assess the habitat characteristics of the gibbon groups. A total of 143 tree species belonging to 45 families were identified with their Importance Value Index (IVI) value in the 10 representative sites of the study area. Average canopy cover (%), tree height (m) and tree DBH (≥10cm) were found to be 55.95±1.8, 19.2±0.95 and 23±0.98 respectively. *Artocarpus chama* Buch- Ham., *Syzygium cumini* L., *Diospyras taposia* Ham., *Dysoxylum gobora* Miq., *Toona ciliata* M. Roem., *Chrysophyllum roxburghii* G.Don . were the tree species having the highest IVI value in the gibbon habitat. Principal component analysis (PCA) showed that the gibbon habitat is highly correlated with tree canopy cover, tree abundance and food tree abundance in the study site.

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Keywords: Endangered animal; strip sampling; importance value index; principal component analysis; canopy cover; tree abundance.

1. INTRODUCTION

India harbours 32 taxa of primates in the wild [4]. Of these, the Western Hoolock Gibbon (*Hoolock hoolock* Harlan, 1834) and Eastern Hoolock Gibbon (*Hoolock leuconedys* Groves, 1967) are the two lesser ape species that occurin India [5]. Western Hoolock Gibbon (*H hoolock* Harlan, 1834) is the species that occurs in northeastern India south of the Brahmaputra River [6,7], Bangladesh [8,9]. Along the range of their distribution in India and Bangladesh, Hoolock's survival is strongly associated with the occurrence of contiguous canopy, broad-leaved, tropical wet evergreen and semi- evergreen forests [8,9]. Assessing the number of Hoolock Gibbons is a key to the understanding of their status and for developing a conservation plan to prevent extinction of the species. Generally, assessing primate populations is a difficult task that invariably leads to inaccurate estimates [10,11]. This is particularly true for gibbon species, due to the fact that they use the forest canopy for movement and foraging [12].The western hoolock gibbon (*Hoolock hoolock*) is globally threatened because of a combination of habitat loss, fragmentation and hunting [13].

All gibbon species have undergone massive declines in population size primarily due to habitat destruction and alteration. Among the 13gibbon species, hoolock gibbons *Hoolock hoolock* (Harlan, 1834) are perhaps under the greatest threat throughout their geographic range [14-20]. The principal cause of population decline is presumed to be habitat destruction [*e.g.*,21,22,23]. Hoolock gibbons are distributed in various northeastern states in India, with a current total population of more than 2600 individuals [20].

The northeast region in India with highest primate diversity has the most intense conservation problems and social unrest in this region has increased pressure on the forest in the form of selective logging and encroachment. Gibbons are brachiators and depend solely on the continuity of the forest canopy [24]. Habitat loss in the form of breaking of the continuity of forest canopy have restricted and isolated their populations to smaller patches (sub-populations), even within a forest [25].Although, the distribution range of the species has remained almost the same, expansion of human habitation, destruction of habitat for agriculture including jhum cultivation, and poaching have resulted in a sharp decline in the populations, besides severely fragmenting all their major habitats [26]. Developing a long-term strategy for primate conservation is of utmost importance, given the rapid loss of habitat and poaching.

The Inner-Line Reserve Forest in Barak Valley, Assam, is one of the largest landscapes left for western Hoolock gibbons, which have a substantial population in the area [27]. About 20% of the Inner-Line Reserve Forest falls within the neighbouring Mizoram state, with another part (46%) lying in the Hailakandi district of Assam (Map-1). This landscape is facing much encroachment, particularly from illegal timber harvesting and procuring of non-timber forest products. The Inner-Line Reserve Forest is very important for primate conservation, as it supports eight different primate species [16]. The purpose of this study is to identify the population status of Western Hoolock gibbon in the secluded habitat, and to form a database that would throw some light on the factors that act as barrier in the survival of the gibbons in the region. The Inner-Line Reserve Forest in Barak Valley, Assam, is one of the few largest landscapes left for western hoolock gibbons, which have a substantial population in the area [27]. About 20% of the Inner-Line Reserve Forest falls within the neighbouring Mizoram state, with another part (46%) lying in the Hailakandi district of Assam. This landscape is facing much encroachment, particularly from illegal timber harvesting and procuring of non-timber forest products. As canopy-dependent animals, gibbons are particularly vulnerable to habitat loss and disturbance due to human activities [28]. The Hoolock gibbon's area of occupancy has declined by more than 30% in the past decade due to habitat loss, habitat fragmentation, and human encroachment. There has also been a reduction in the quality of remaining habitat fragments due to loss of fruiting trees and sleeping trees and the creation of gaps in the canopy [24].

In course of this work, the habitat characteristics of Hoolock gibbons in and around the Inner-line reserve forest have been studied to examine the variables like tree species richness, composition, diversity that are important in assessing the quality of habitat in the isolated areas of Inner Line Reserve Forest (ILRF) where gibbons are fighting for their survival in the inhabited area.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in the Inner-Line Reserve Forest and its adjoining areas of Cachar district, which is situated in the Barak Valley of Southern Assam (Fig. 1). Total area of the forest is 424km^2 and lies between 24° 22$^/$ N and 25°8 $^/$N Latitude and

92°24/ E and 93°15/ E Longitude. Manipur and Mizoram border lies in the east and South respectively of the said reserved forest. The vegetation is mixed evergreen and deciduous forest. The most common deciduous trees are *Artocarpus lakoocha*(Roxb.), *Dillenia indica*(L.),*Careya arborea*(Roxb.), *Acanthocephalus cinensis*(Roxb.), *Mangifera indica*(L.), *Stereospermum personatum*(Hassk.) and *Dysoxylum benectariferum*(Hook.F.). Important evergreen trees are *Ficus bengalensis*(L.), *Syzygium jambulana*(L.),*Garcinia cowa*(Roxb.) and *Pterospermum acerifolum*(L.). Most of these trees make up a closed canopy about 20–30m above the ground. Various species of bamboo *(Bambusa cacharensis*(R.B.Mazumdar), *ambusavulgaris* (Schrad), *Bambusa balcooa*(Roxb.), *Schizostachyum dullooa (*Gamble), *Bambusa nutans*(Wall), *Bambusa assamica*(Barooah & Borthakur),*Gigantochloa albociliata*(Munro)and cane *(Saccharum procerum*Roxb., *Saccharum montanum*Retz., *Erianthus fulvus*Kunth.) are also found in the area. Close to the reserve forests, all adjacent forest patches are surrounded by jhum fields (shifting cultivation), mostly near the villages. Cultivated orchard fruit trees (mango, jackfruit, orange and guava) also form part of the habitat.

2.2 Habitat Assessment in the Areas

Habitat assessment studies were done by strip sampling method [29 and 30] in daytime to characterize the different habitats, where hoolock gibbon was encountered in the surveyed areas. The population was estimated by the modified line-transect method [1,2] and the direct count method. Following Kumar et al. [3], the line transects were laid in a stratified random design to cover all selected areas in the forest. To assess the habitat (vegetation characteristics) in those ten sites, a total of 100 numbers of plots were laid down (20 X 10m each); 10 plots in each site at 50 m interval.

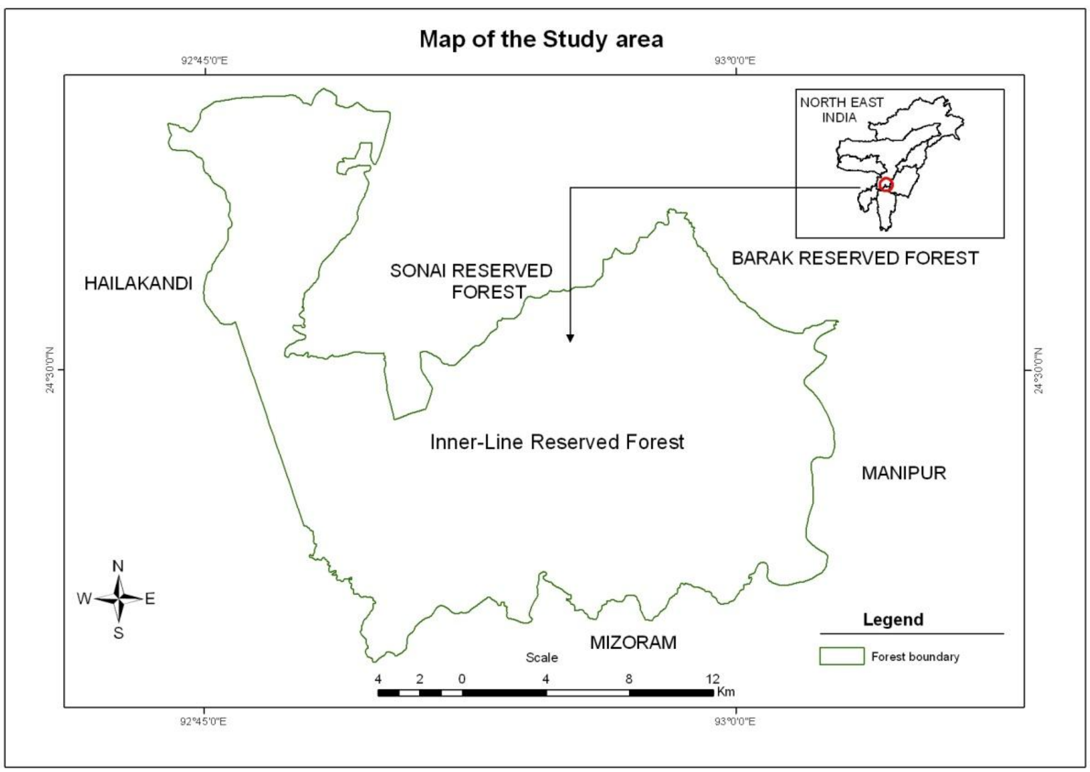

Fig. 1. Location map of the study area

In each plot the following data were recorded:

1. Canopy cover at 20m, at each 5m interval throughout the plot, using visual estimation (Point intercept method [31], by the same observer throughout the survey;
2. Diameter at breast height (DBH) of all trees having ≥ 10cm DBH; DBH was then converted into cross-

sectional area using the formula cross-sectional area = $(DBH/2)^2$ X π and used as an indicator of tree biomass.

3. Height of all trees exceeding 10cm DBH, placing each tree into classes from 05m to 35m+by using clinometer;
4. Local name of the species of all measured trees(Initially plants were identified by local name with the help of local field assistants and later on plant species were identified with the help of standard field guide following Hajra and Jain [32] and Kanjilal et al. [33].
5. Total number of trees in the plot.
6. Total cross-sectional area of all trees (exceeding10cm DBH).
7. Total cross-sectional area of large trees (exceeding20cm DBH).
8. Total cross-sectional area of known gibbon food trees (exceeding10cm DBH).
9. Total cross-sectional area of large food trees (exceeding20cm DBH).

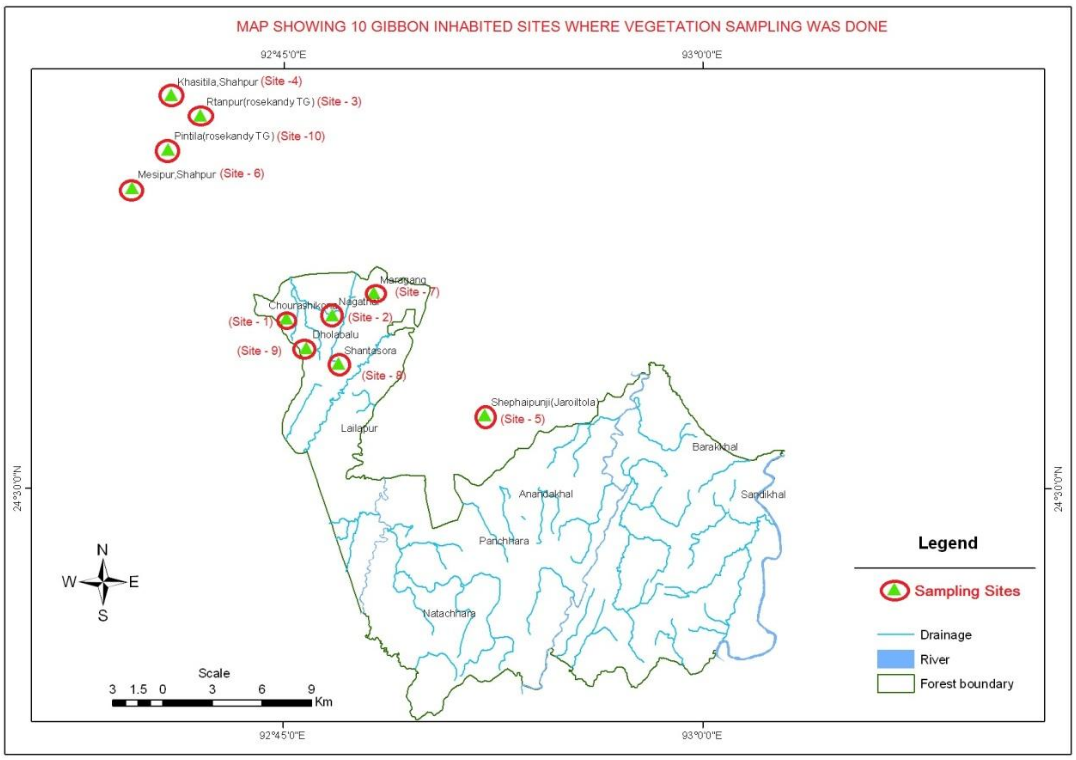

Fig. 2. Map showing 10 sampling sites where gibbons encountered and vegetation sampling was done

Tree species that represent food resources for western hoolock gibbon were assessed following Chetry et al. [34], Muzaffar et al. [35] and Mathur et al. [36]. For every identified genus we calculated the relative density [RD = (number of individuals of a *taxon* / total number of plots) X 100], the relative frequency [RF = (number of plots containing a *taxon* / total number of plots) X 100] and the relative dominance [RDo = (basal area of a *taxon* / total basal area of *taxa*) X 100] and thus the Importance Value Index(IVI = RD + RF + RDo) per each identified genus, following Hadi et al. [37]. All the calculations done using MS Excel, 2010.

All vegetation characteristics were then averaged for each study site, except median tree height which was directly calculated for all measured trees within a study site. Measures of species diversity were then added to the analysis: species richness, defined by the number of tree species identified in each study site; Shannon-Wiener's diversity index and Simpson's diversity index, calculated as described in Ganzhorn [38] and Douglas [39]. Both Shannon-Wiener and Simpson's indexes were calculated, as both are biased towards either dominant species (Simpson's index) or rare species (Shannon-Wiener index) [40].

Shannon index of diversity (H), Evenness index [41], Margalef index [42] and Simpson dominance index (D) [43,44] were calculated by using PAST software to analyze species diversity and dominance in the community.

Principal Components analysis (PCA) or Ordination diagram were prepared by the use of the software CANOCO 4.5. It is a graphical representation of relationship between different variables. Relationship among the habitat (sites), vegetation variables and number of Hoolock gibbon were examined using PCA.

3. RESULTS

A total of 143 tree species belonging to 45 families were identified across the study area (10 sites) in this study. Species richness and diversity indices for each of the survey sites are shown in Table 1 and all vegetation variables, averaged for each site, are presented in Table 2. And the mean average vegetation variables across the gibbon habitat are shown in Table 3.

The average species richness found across the gibbon habitat is; S= 90±5.53. The sites 3, 4, 5, and 9 have the highest species richness i.e. S= 114, S= 109, S= 101 and S= 102 respectively. Food tree abundance is also high in sites no. 3, 4, 5, 7, 9 and 10. And canopy cover is high in sites 3, 4, 5, 6 and 9. Significant difference was found in canopy cover (%) between the sites ($H_{observed}$-28.375> $H_{critical}$-16.919, p= 0.05), at df =9. In case of tree abundance and food tree abundance between the sites there was no significant difference was found in Kruskal-Wallis non-parametric test; tree abundance ($H_{observed}$-9.771> $H_{critical}$-16.919, p= 0.05), and in case of food tree abundance ($H_{observed}$-14.294> $H_{critical}$-16.919, p= 0.05), at df= 9.

The dominant tree species all over the study sites are *Vitex altissima* L.f., *Zanthoxylum rhesta* Roxb., *Mangifera sylvatica* Roxb., *Ficus benghalensis* L., *Hydnocarpus kurzii* Warb., *Artocarpus chama* Buch-Ham., *Artocarpus lakoocha* Roxb., *Ficus auriculata* Lour., *Gmelina arborea* Roxb., *Plumeria acuminata* Ait., *Syzygium fruticosum* DC., *Anthocephalus cadamba* Miq., *Castonopsis indica* DC., *Chrysophyllum lanceolatum* DC., *Mesua ferra* L., *Bombax ceiba* L., *Garcinia cowa* Roxb., *Elaegnus caudata* Schlechi ex.

In respect of different sites the relative frequency (RF), relative density (RD), and relative dominance (RDo) and importance value index (IVI) values varied between species. The RF, RD, RDom and IVI of all the tree species found across the gibbon habitat are shown in Appendix- A. The top fifteen species found to have highest IVI (importance value index),are *Artocarpus chama* Buch- Ham., *Syzygium cumini* L., *Syzygium fruticosum* DC., *Diospyras taposia* Ham., *Dysoxylum gobora* Miq., *Toona ciliata* M. Roem., *Chrysophyllum roxburghii* G.Don, *Gmelina arborea* Roxb., *Artocarpus lakoocha* Roxb., *Madhuca indica* Gmel., *Cynometra polyandra* Roxb.*Castonopsis indica* DC., *Euphorbia pulcherrima* Willd., *Mesua ferra* L., and *Vitex altissima* L.f. Among all the species *Artocarpus chama* has the highest IVI value (Table 4). Average vegetation characteristics in gibbon habitat area are shown in Table 3.

3.1 Principal Components Analysis (PCA)

PCA or Ordination diagram is a graphical representation of relationship between variables. Relations among the different habitat sites, vegetation variables and number of hoolock gibbon were examined using PCA. (Diagram A). The Eigen values and the cumulative frequency of the Principle components analysis are shown in the below Table 5.

Table 1. Tree species richness and diversity indices at each site

Site name	Species richness (S)	Shanon-Wiener index (H)	Evenness (J)	Simpson's index (C)	Margalef index
Site 1 Chourashikona	61	3.7	0.6631	0.966	11.04
Site 2 Nagathal (Khasipunji)	68	3.864	0.7007	0.965	12.56
Site 3 Ratanpur (R T E)	114	4.496	0.7867	0.985	19.42
Site 4 Khasitila (RTE)	109	4.457	0.7909	0.985	18.62
Site 5 Shephaipunji (Jarultola)	101	4.375	0.7861	0.983	17.44
Site 6 Mesipur (RTE)	92	4.334	0.8287	0.984	15.73
Site 7 Maragang	82	4.217	0.8269	0.982	14.73
Site 8 Shantasora	94	4.383	0.8518	0.985	16.5
Site 9 Dholabalu	102	4.455	0.8441	0.986	17.57
Site 10 Pintila (R T E)	78	4.142	0.8067	0.981	13.36

Table 2. Average vegetation characteristics for the forest types of the Inner-line reserve forest during the study period where gibbon groups were encountered. Allvalues are given with standard errors

Sites	Mean canopy cover (%)	Median tree height (m)	Mean DBH (cm)	Mean DBH of large trees (DBH>20cm)	Mean DBH of food trees	Mean DBH of large food trees (DBH>20cm)	Biomass of all trees (cm2)	Biomass of large trees (cm2)	Biomass of food trees (cm2)	Biomass of large food trees (cm2)	Mean abundance of all trees (no./plot)	Mean abundance of food trees (no./plot)
Site1	49.5±2.8	16-20	20±0.85	31±1.66	20±1.70	32±2.19	437±59.97	948±148	464±134	995±198	22.9±2.19	13.1±1.31
Site2	47.5±2.5	11-15	20±0.99	34±2.04	22±1.32	36±2.63	487±67	1150±170	561±91	1310±222	20.8±3.81	11.3±1.76
Site3	56.5±3.3	16-20	29±1.21	38±1.61	32±1.74	41±2.22	1068±127	1588±190	1330±191	1877±269	33.7±0.75	19.5±0.95
Site4	61.5±2.4	21-25	27±1.14	34±1.52	31±1.83	37±2.34	913±164	1306±244	1236±278	1679±387	33±0.82	16.5±1.81
Site5	62±2.8	16-20	22±0.84	32±1.31	25±1.26	34±1.87	563±64	992±121	717±102	1208±178	30.9±1.54	16.8±1.35
Site6	58.5±4.2	21-25	26±0.98	34±1.40	30±1.72	38±2.27	777±96	1208±157	1072±182	1553±269	32.5±0.89	14.1±1.50
Site7	53.5±2.9	16-20	23±0.95	32±1.28	23±1.22	34±1.87	582±69	972±114	622±92	1118±172	24.4±1.67	15.1±1.30
Site8	49.5±2.2	11-15	22±0.70	30±0.94	22±0.92	30±1.21	498±42	798±70	486±51	788±85	28±1.40	14.1±1.42
Site9	63.5±2.2	21-25	22±0.59	29±0.71	22±0.84	29±1.11	465±37	715±61	489±60	765±101	31.4±1.77	17.7±1.96
Site10	57.5±4.0	16-20	21±0.57	28±0.76	21±0.74	29±1.05	415±33	698±59	429±46	731±84	31.9±1.46	19.6±1.89

Table 3. Average vegetation characteristics of the gibbon habitat

S. no.	Variables	Mean
1	Canopy cover (%)	55.95±1.8
2	Tree height (m)	19.2±0.95
3	DBH (≥10 cm)	23±0.98
4	DBH of large trees (DBH≥20 cm)	32±0.93
5	DBH of food trees (≥10 cm)	25±1.42
6	DBH of large food trees (DBH≥20 cm)	34±1.28
7	Tree biomass (cm^2)	621±71
8	Large tree biomass (cm^2)	1038±89
9	Food tree biomass (cm^2)	741±108
10	Large food tree biomass (cm^2)	1202±127
11	Tree abundance (no./plot)	29±1.46
12	Food tree abundance (no./plot)	16±0.86
13	Tree density (tree/ha)	1447±74
14	Food tree density (tree/ha)	806±42
15	Species richness (taxa/site)	90±5.53

Table 4. Top fifteen tree species having highest IVI value in gibbon inhabited area in the study site during the study period

S. no.	Tree species	Family	IVI
1	*Artocarpus chama* Buch- Ham.	Moraceae	11.06
2	*Syzygium cumini* L.	Myrtaceae	7.26
3	*Syzygium fruticosum* DC.	Myrtaceae	6.54
4	*Diospyras taposia* Ham.	Ebenaceae	6.00
5	*Dysoxylum gobora* Miq.	Meliaceae	5.87
6	*Toona ciliata* M. Roem.	Meliaceae	5.75
7	*Chrysophyllum roxburghii* G.Don	Sapotaceae	5.27
8	*Gmelina arborea* Roxb.	Verbenaceae	5.13
9	*Artocarpus lakoocha* Roxb.	Moraceae	4.99
10	*Madhuca indica* Gmel.	Sapotaceae	4.95
11	*Cynometra polyandra* Roxb.	Leguminosae	4.94
12	*Castonopsis indica* DC.	Fagaceae	4.76
13	*Euphorbia pulcherrima* Willd.	Euphorbiaceae	4.26
14	*Mesua ferra* L.	Clusiceae	4.16
15	*Vitex altissima* L.f.	verbenaceae	3.66

Table 5. Eigen value and cumulative frequency of PCA

Axes	1	2	3	4	Total
Eigenvalues	0.457	0.416	0.083	0.021	1.000
Cumulative% variance	45.7	87.2	95.5	97.6	

Table 6. PCA Correlation matrix of all the vegetation sampling site

Correlation matrix							
Vegetation variables	**Canopy cover**	**Tree height**	**DBH (≥10cm)**	**DBH of food trees (≥10cm)**	**Tree biomass**	**Tree abundance**	
Canopy cover							
Tree height	0.249						
DBH(≥10cm)	0.148	**0.919**					
DBH of food trees (≥10cm)	0.049	**0.905**	**0.987**				
Tree biomass	-0.220	**-0.916**	**-0.918**	**-0.942**			
Food tree biomass	**-0.742**	-0.624	**-0.669**	-0.555	0.545		
Tree abundance	**0.690**	**0.713**	**0.749**	**0.699**	**-0.779**	**-0.855**	
Food tree abundance	0.241	**0.906**	**0.955**	**0.945**	**-0.946**	**-0.676**	**0.818**

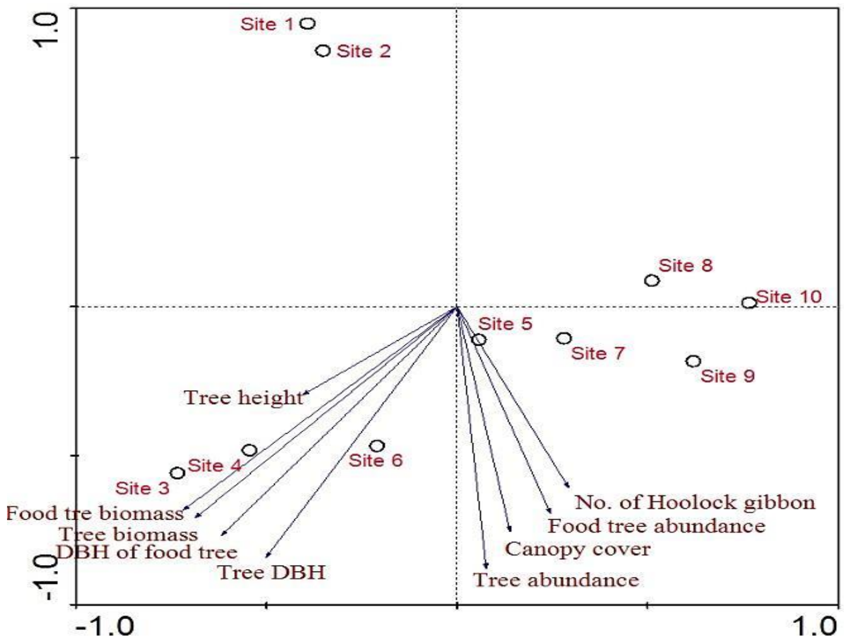

Fig. 3. PCA or ordination diagram of the gibbon habitat during vegetation sampling

The ordination diagram depicts the relative importance of variables (arrows) and explains the variability and co-relation among them. From the biplot ordination diagram we can see that most of the variables are strongly correlated with each other such as tree biomass and food tree biomass, tree DBH and DBH of food tree but food tree abundance is inversely correlated with tree DBH and DBH of food tree. The number of hoolock gibbon was found to be highly correlated with canopy cover, tree abundance and abundance of food tree.

Relative position of sites (circles) in the biplot with respect to the vegetation variables depicts the status of each variable in that particular site. The position of site 5 which is closer to food tree abundance, canopy cover and tree abundance, shows that the mentioned variables are higher in that site (i.e. 5), but tends to be very low in site 1 and 2 which is opposite to the site 5. Similarly, in site 6 the DBH of all trees tends to be high and in site 4 tree biomass and food tree biomass tend to be high. In the diagram the sites 7, 8, 9, and 10 were found to be clumped in the right lower quadrat which is opposite to the tree DBH, tree biomass, DBH of food tree and food tree biomass, which shows that the variables were found to be low in all those sites. The positions of site 3, 4 and 6 shows that all the variables (such as tree biomass, food tree biomass, DBH of food trees and DBH of all trees) are much more similar.

The direction and the length of each arrow in PCA ordination diagram indicate the direction and rate of maximum changes in each variable [41]. Thus the length of tree height was found minimum which represents that there are no maximum changes in the variable and it does not impact in the association of the other variables with sites. The length of other variables were found to be much more equal which indicates that they are much more equally responsible for the association ship of the sites to the variables. The PCA revealed one correlation matrix which is shown Table 6.

4. DISCUSSION

Globally, primate population declines have occurred as a result of habitat destruction, among other things such as human population pressure and political unrest [45]. Extricating the root cause of population declines in such a variety of factors those influence primate populations is often difficult. The use of a large number of small plots for habitat measurements proved efficient in this study and allowed the detection of fine-scale differences in vegetation characteristics. Gibbon population was found to be highly correlated to vegetation parameters, in particular canopy cover (i.e. 50-70%) and tree height (16- 25m) (Fig. 3). As gibbons preferentially use high canopy layers throughout their activity budget [46, 40, 47], this result is not surprising, although gibbons have proved to be relatively adaptable to disturbances of canopy cover following logging by shifting their use of canopy layers to the lower canopy [47]. Canopy cover and tree height have been found to influence the density of other arboreal primates (like, Tana red colobus and Orang Utang) [48, 49], as gaps in canopy impair their travelling. Other variables that were found to be correlated with gibbon density in this study were the density of large trees and the availability of food trees. Felton et al. [49] reported a similar correlation between orangutan density and density of large trees in a peat-swamp forest in West Kalimantan. Similar results were reported for greater dwarf lemurs [50] and primate species along the Tana river [51]. All the authors proposed that this relationship was due to greater availability of food where more large trees were present, which is in conformity with results linking food abundance to primate densities [e.g. 51, 52, 53]. The correlation between cross-sectional areas of food trees was weak in this study, primarily due to large variations between plots; it is supported by the results of other studies on gibbons [52] which found that gibbon density was strongly influenced by the availability of their preferred food trees. Area of natural forests and plantations were not linked to Hoolock gibbon numbers, whereas area of agricultural land and edible plant species richness were both significantly linked. Higher edible plant species richness was directly related to Hoolock gibbon numbers, while the area of agricultural land was inversely linked [35]. In this study the food tree abundance found to be nearly 50% of the total tree abundance. Alternatively, this could be due to the gibbons' extensive range of food trees inthe study area.

Borah and Garkoti [54], studied Tree Species Composition and Diversity, inundisturbed and disturbed forests of Barak Valley, South Assam, and reported 137 species and out of which the main dominant species were *Cynometra polyandra*(Roxb.), *Palaquium polyanthuss*(Blume), *Tetrameles nudiflora*(R.Br.), *Artocarpus chama*(Buch-Ham), *Dysoxylum binectariferum*(Hook. F.),*Tetrameles nudiflora*(R.Br.), *Mitragyna rotundi-folia*(Roxb.), *Schima wallichii*(DC), *Stecospermum chelonoides*(L.f.), *Castanopsis purpurella*(Miq) *etc.* Borah et al. [55] studied on Tree species diversity in tropical forests of Barak valley in Assam, India and reported a total of 222 tree species were recorded from 152 genera and 65 families. Euphorbiaceae was the most species rich family with 23 species. Out of 65 families, 30 families were recorded with only one species while 10 families were recorded with two species. *Artocarpus chama* (Buch-Hum) was the most abundant and frequently occurred species. In the present study, we also found a total of 143 tree species belonging to 45 families were found. The dominant species presently revealed are *Vitex altissima* L.f., *Zanthoxylum rhesta* Roxb., *Mangifera sylvatica* Roxb., *Ficus benghalensis* L., *Hydnocarpus kurzii* Warb., *Artocarpus chama* Buch- Ham., *Artocarpus lakoocha* Roxb.,*Ficus auriculata* Lour., *Gmelina arborea* Roxb., *Plumeria acuminata* Ait., *Syzygium fruticosum* DC., *Mangifera indica* L., *Anthocephalus cadamba* Miq., *Castonopsis indica* DC., *Chrysophyllum lanceolatum* DC., *Mesua ferra* L., *Bombax ceiba* L., *Garcinia cowa* Roxb., and *Elaegnus caudata* Schlechi ex.

Tree species richness was within the range reported for similar forests in the region [56, 57, 58]. The species richness was comparable with that in the tropical forests in Luquillo Mountain in Puerto Rico[59]. Ray et al. [60] in Namdapha national park habitat study revealed a total of 122 species of trees (girth at breast height ≥30 cm) in the three forest types, representing 73 genera in 41 families, with the highest number of tree species in wet evergreen forest (93) followed by tropical broad-leaved forest (52) and wet temperate forest (40). However, present species richness values were lower than that of tropical wet evergreen forests(149 species) in Western Ghats [61]. Consistent with the findings of Nath et al. [58] but contrary to the findings of Upadhaya et al. [57], the species richness declined with disturbance (90 species). Species richness was not uniformly distributed in present study forests rather the mosaic of both low and high diversity patches were spread along the landscape. In this respect, the present study forests are somewhat similar to the rainforests, which have often been described as harbouring patchy vegetation [62], primarily due to gap phase. In present study,majority of species showed contagious distribution. Thisis likely to be related to seed dispersal mechanism of the species and gap formation [63].

The tree density in the present study (430 trees ha^{-1} to 1445 trees ha^{-1}) forests was comparable to that of the tropical forests of Western Ghats (446-1576 trees ha^{-1}) [64,61,65] and was within the range reported for several other tropical forests (550-1800 trees ha by Visalakshi [66]. Lower densities of different species in present disturbed sites (i. e. sites 1, 2, 8 and 9) were due to the chronic disturbance in those forests. The disturbance is continuously occurring in there and species are not getting sufficient time for the recovery. Similar to the findings of Thorington et al. [67] for tropical forests in Barro Colorado Island, Panama and Parthasarathy and Karthikeyam [65] for forests ofWestern Ghats, in present study forests several species(42-52 %) were represented by a few individuals only.

Tree size class distribution can be used as indicators of changes in population structure and species composition [68]. The treepopulation structure observed in present study is similar to those reported from the forest at Costa Rica [69], Eastern Ghats [70], and sub-tropical humid forest of Meghalaya [57]. All the studies reported preponderance of young individuals. In present study maximum trees were found in 10-60 cm girth sized. Absence of individuals of higher girth classes in disturbed forest indicate that these forests were under anthropogenic pressure. A gradual decrease in basal area and density of trees beyond 30-60 cm GBH class again indicate that as the individuals of large size were not available for further extraction people have shifted to trees in the lower girth.

The influence of logging on gibbon populations has been the focus of several studies [e.g. 71,72], as it constitutes a major threat to gibbons. Selective logging, which targets large, commercially valuable trees, has been shown to reduce canopy cover and continuity, as well as to restrict the availability of food for the gibbons [72]. Because of their dietary flexibility, gibbons may be relatively resilient to logging: Meijaard et al. [72] listed five studies having found gibbon densities equal or higher after selective logging. Six studies cited in the same review found decreased gibbon densities after logging. Since gibbon density is highly correlated to canopy cover and tree height, the results of the present study seem to indicate that gibbons in the ILRF may have been positively affected by logging in near future.

5. CONCLUSION

Hoolock gibbons are mostly arboreal, canopy-dependent frugivorous primates which live in small family groups, feeding mainly on *Ficus* spp. Immediate intervention is needed to conserve this vulnerable species; various degrees of habitat degradation have created an alarming situation for this creature. Proper adoption and implementation of conservation measures would perhaps be of immense help in enabling the left out species of gibbon to grow and thrive well in the forest of Inner-fine reserve forest areas of Cachar, Assam. More pro-active measures from the law enforcement / implementing authorities would definitely help to ameliorate the scenario of the study area and would perhaps help to restore its past glory in terms of faunestic composition in general, and more particularly Hoolock gibbons. Adequate protection, ban on timber logging, control of *jhum* cultivation and poaching, and conservation education/awareness and mass involvement of local communities can help this valuable species to survive in their natural habitats in the Inner-line reserve forest, Cachar, Assam.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix - A. Identified tree species across the habitat and their relative calculated parameters

Tree species	Family	Habit	RF	RDen	Rdom	IVI
Drymicarpus racemosus Hook.f.	Anacardiaceae	T	0.42	0.42	0.70	1.54
Linnea grandis A. Rish.	Anacardiaceae	T	0.62	0.59	0.70	1.92
Mangifera indica L. *	Anacardiaceae	T	0.83	0.63	0.89	2.34
Mangifera sylvatica Roxb. *	Anacardiaceae	T	0.42	0.42	0.00	0.84
Rhus semialata Murr.	Anacardiaceae	ST	0.62	0.59	0.84	2.05
Semecarpus anacardium L.	Anacardiaceae	ST	1.32	1.46	0.86	3.63
Spondias pinnata Kurz. *	Anacardiaceae	T	0.90	0.73	0.01	1.64
Annona squamosa L.	Annonaceae	ST	0.14	0.07	0.70	0.91
Polyalthia longifolia Thw.	Annonaceae	T	0.69	0.63	0.86	2.18
Alstonia scholaris R. Br. *	Apocynaceae	T	0.90	0.90	1.41	3.21
Plumeria acuminata Ait.	Apocynaceae	T	0.76	0.87	0.84	2.47
Sterospermum chelonoides DC.	Bigoniaceae	T	0.90	0.87	0.71	2.48
Bombax ceiba L. *	Bombaceae	T	0.62	0.52	0.00	1.15
Bombax insigne Wall.	Bombaceae	T	0.28	0.31	0.71	1.30
Bursera serrata Coleb.	Burseraceae	T	0.76	0.80	1.67	3.23
Canarium benghalense Roxb.	Burseraceae	T	0.90	0.97	0.89	2.77
Garuga floribunda Deen. *	Burseraceae	T	0.62	0.63	0.02	1.26
Bauhinia malabarica Roxb.	Caesalpiniaceae	ST	0.28	0.31	0.48	1.07
Bauhinia purpurea L.	Caesalpiniaceae	ST	0.62	0.63	0.00	1.25
Caesalpania pulcherrima Sw.	Caesalpiniaceae	ST	0.21	0.24	0.72	1.17
Cassia fistula L.	Caesalpiniaceae	T	0.42	0.45	0.72	1.59
Saraca asoca Roxb.	Caesalpiniaceae	T	0.42	0.31	0.86	1.59
Tamarindus indica L. *	Caesalpiniaceae	T	0.28	0.14	0.72	1.14
Crataeva religiosa Frost. f.	Capparaceae	T	0.35	0.35	0.72	1.42
Garcinia assamica Kost.	Clusiceae	T	0.69	0.76	0.72	2.18
Garcinia cowa Roxb. *	Clusiceae	ST	1.04	1.08	0.02	2.14
Garcinia pedunculata Roxb. *	Clusiceae	T	0.07	0.07	0.22	0.36
Mesua ferra L. *	Clusiceae	T	1.60	1.70	0.86	4.16
Termanilia chebula Retz. *	Combretaceae	T	0.55	0.56	0.72	1.84
Termanilia myriocarpa Heurck et Muell.	Combretaceae	T	0.35	0.24	0.73	1.32
Terminalia arjuna DC.	Combretaceae	T	0.42	0.28	0.86	1.55
Terminalia belerica Roxb. *	Combretaceae	T	0.49	0.56	0.01	1.05
Dipterocarpus manni King ex Kanjilal	Dipterocarpaceae	T	0.49	0.42	0.73	1.63
Dipterocarpus turbinatus Gaertn.	Dipterocarpaceae	T	0.49	0.49	0.01	0.98
Shorea assamica Dyer	Dipterocarpaceae	T	0.69	0.73	0.73	2.16
Vatica lanceifolia (Roxb.) Blume	Dipterocarpaceae	T	0.35	0.31	0.80	1.46
Diospyras taposia Ham.	Ebenaceae	T	2.36	2.74	0.90	6.00
Cordia fragrantissima Kurz.	Ehretiaceae	T	0.42	0.52	0.74	1.68
Elaeocarpus floribundus Bl. *	Elaeocarpaceae	T	0.83	0.63	0.01	1.47
Elaeocarpus robustus Roxb.	Elaeocarpaceae	T	0.83	0.87	0.84	2.54
Elaeocarpus sphaericus Gaertn.	Elaeocarpaceae	T	0.76	0.63	0.06	1.45
Aleurites moluccana (L.) Willd.	Euphorbiaceae	T	0.35	0.38	0.27	1.00
Antidesma acidum Retz.	Euphorbiaceae	ST	0.21	0.10	0.75	1.06
Antidesma ghaesembilla Gaertn.	Euphorbiaceae	T	0.35	0.45	0.59	1.38
Antidesma velutinosum Blume	Euphorbiaceae	T	0.28	0.35	0.81	1.43
Baccaurea remiflora Lour. *	Euphorbiaceae	ST	0.35	0.21	2.45	3.00
Balakata baccata (Roxb.) Esser	Euphorbiaceae	T	0.35	0.42	0.49	1.25
Bischofia javanica Bl. *	Euphorbiaceae	T	0.49	0.49	0.75	1.72
Bridelia stipularis Bl.	Euphorbiaceae	T	0.49	0.42	0.75	1.65
Croton roxburghii Balak.	Euphorbiaceae	T	0.62	0.59	0.75	1.96
Drypetes assamica Hook.f.	Euphorbiaceae	T	0.35	0.28	0.75	1.37
Endospermum chinense Benth.	Euphorbiaceae	T	0.21	0.10	0.85	1.16

Tree species	Family	Habit	RF	RDen	Rdom	IVI
Euphorbia neriifolia L.	Euphorbiaceae	ST	0.42	0.38	0.75	1.54
Euphorbia pulcherrima Willd.	Euphorbiaceae	ST	1.53	1.84	0.89	4.26
Glochidion lanceolarium (Roxb.) Voigt	Euphorbiaceae	ST	0.14	0.14	0.20	0.48
Sapium baccatum Roxb. *	Euphorbiaceae	T	0.35	0.56	0.88	1.79
Sapium eugeniaefolium Benth.	Euphorbiaceae	T	0.49	0.52	0.76	1.76
Trewia nodiflora L.	Euphorbiaceae	T	0.49	0.45	0.00	0.94
Castanopsis purpurella (Miq.) Balak.	Fagaceae	T	0.42	0.24	0.85	1.51
Castonopsis indica DC. *	Fagaceae	T	1.60	1.39	1.77	4.76
Casearia glomerata Roxb.	Flacourtiaceae	T	0.35	0.38	0.00	0.73
Flacourtia cataphracta Roxb.	Flacourtiaceae	ST	0.55	0.38	0.76	1.69
Gynocardia odorata R. Br.	Flacourtiaceae	T	0.35	0.28	0.76	1.38
Hydnocarpus kurzii Warb. *	Flacourtiaceae	T	1.25	1.35	0.03	2.63
Engelhardtia spicata Lechan ex Bl.	Juglandaceae	T	0.76	0.83	0.76	2.35
Couroupita guianensis Aublet.	Lacythidaceae	T	0.69	0.90	0.76	2.35
Lagerstroemia reginae Roxb.	Lacythidaceae	T	0.62	0.63	0.76	2.01
Garcinia xanthochymus Hook.f.	lamiaceae	T	0.55	0.59	0.86	2.00
Vitex peduncularis Wall. Ex. Schauer	Lamiaceae	T	0.21	0.17	0.73	1.12
Alseodaphne owdenii Parker.	Lauraceae	T	1.18	0.97	0.89	3.04
Beilschmiedia assamica Meissn.	Lauraceae	T	0.62	0.76	0.64	2.03
Cinamomum cacharensis R. N. Parker.	Lauraceae	ST	1.18	1.28	0.76	3.22
Cinamomum cecicodaphne Meissn.	Lauraceae	T	0.69	0.66	0.00	1.36
Cinamomum tamala Buch- Ham.	Lauraceae	ST	0.69	0.69	0.64	2.02
Cryptocarya amygdalina Nees.	Lauraceae	T	0.69	0.69	0.63	2.02
Albizia lebbeck (L.) Benth.	Leguminosae	T	0.42	0.42	0.89	1.73
Cynometra polyandra Roxb.	Leguminosae	T	1.04	0.83	3.06	4.94
Lagerstroemia speciosa (L.) Pers.	Lythraceae	T	0.42	0.45	0.86	1.72
Magnolia insignis Wall.	Magnoliaceae	T	0.69	0.63	0.00	1.32
Kydia calycina Roxb.	Malvaceae	T	0.28	0.24	0.81	1.33
Pterygota alata (Roxb.) R.Br.	Malvaceae	T	0.69	0.90	0.50	2.10
Azadirachta indica A. Juss.	Meliaceae	T	0.69	0.45	0.00	1.15
Cedrela febrifuga C. DC.	Meliaceae	T	0.76	0.66	0.76	2.18
Dysoxylum gobora Miq. *	Meliaceae	T	2.08	2.08	1.70	5.87
Toona ciliata M. Roem. *	Meliaceae	T	1.60	1.67	2.49	5.75
Walsura robusta Roxb.	Meliaceae	ST	0.35	0.28	0.76	1.39
Acacia auriculiformis A. Cunn ex Benth.	Mimosaceae	T	0.49	0.52	0.63	1.64
Acacia catechu Willd.	Mimosaceae	ST	0.28	0.21	0.76	1.25
Acacia lebek Benth.	Mimosaceae	T	0.49	0.45	0.77	1.70
Parkia bigemium Benth.	Mimosaceae	T	0.42	0.42	0.01	0.84
Samanea saman Merr.	Mimosaceae	T	1.46	1.42	0.02	2.90
Artocarpus chama Buch- Ham. *	Moraceae	T	3.33	4.10	3.63	11.06
Artocarpus gomeziana Wall.	Moraceae	T	0.28	0.24	0.77	1.29
Artocarpus heterophyllus Lamk. *	Moraceae	T	0.55	0.38	0.86	1.79
Artocarpus lakoocha Roxb. *	Moraceae	T	2.36	2.47	0.17	4.99
Ficus auriculata Lour. *	Moraceae	T	1.39	1.39	0.01	2.79
Ficus benghalensis L. *	Moraceae	T	0.90	0.56	0.86	2.32
Ficus benjamina L. *	Moraceae	T	1.04	1.32	0.79	3.15
Ficus fistulosa Reinwdt. Ex Bl. *	Moraceae	ST	0.69	0.83	0.01	1.53
Ficus glomerata Roxb. *	Moraceae	T	0.14	0.14	0.77	1.05
Ficus heterophylla L.f. Supl. *	Moraceae	ST	0.28	0.31	0.01	0.60
Ficus hirta Vahl.	Moraceae	ST	0.42	0.56	0.01	0.98
Ficus hispida Vahl. *	Moraceae	ST	0.62	0.63	0.01	1.25
Ficus lamponga Miq. *	Moraceae	ST	0.28	0.38	0.52	1.18
Ficus racemosa L. *	Moraceae	ST	0.55	0.59	0.69	1.83
Ficus religiosa L. *	Moraceae	T	1.04	0.73	0.87	2.64
Morus australis Poir.	Moraceae	ST	0.49	0.45	0.80	1.74
Morus laevigata Wall. *	Moraceae	T	0.62	0.63	0.80	2.05

Tree species	Family	Habit	RF	RDen	Rdom	IVI
Moringa oleifera Lamk.	Moringaceae	ST	0.35	0.21	0.80	1.36
Myrica esculenta Buch- Ham.	Myricaceae	T	0.21	0.21	0.80	1.22
Eucalyptus maculata Hook.	Myrtaceae	T	0.21	0.14	0.80	1.15
Syzygium balsameum Wall.	Myrtaceae	T	0.42	0.42	1.35	2.19
Syzygium cumini L. *	Myrtaceae	T	3.54	3.58	0.15	7.26
Syzygium fruticosum DC. *	Myrtaceae	T	2.15	2.22	2.17	6.54
Syzygium jambos L.	Myrtaceae	T	0.28	0.14	0.55	0.96
Syzygium operculatum (Roxb.) Nied.	Myrtaceae	ST	0.28	0.21	0.00	0.49
Lingustrum robustum Bl.	Oleaceae	T	0.42	0.42	0.80	1.64
Olea dioica Roxb.	Oleaceae	T	0.21	0.24	0.54	0.99
Butea monosperma Lamk.	Pailionaceae	T	0.42	0.38	0.81	1.60
Dalbergia sisoo Roxb.	Pailionaceae	T	0.49	0.49	0.01	0.98
Derris indica Lamk.	Pailionaceae	T	0.28	0.28	0.54	1.09
Erythrina indica Lamk.	Pailionaceae	T	0.83	0.56	0.86	2.25
Eurya acuminata DC.	Pentaphylacaceae	T	0.07	0.03	0.00	0.10
Dillenia indica L. *	Ranunculaceae	T	1.04	1.08	0.86	2.98
Dillenia pentagyna Roxb.	Ranunculaceae	T	0.35	0.35	0.00	0.70
Magnolia pterocarpa Roxb.	Ranunculaceae	T	0.35	0.35	0.00	0.70
Michelia champaca L.	Ranunculaceae	T	0.49	0.59	0.81	1.88
Xerospermum glabratum (Kurz.) Radlk	Rhamnaceae	ST	0.28	0.14	0.81	1.22
Carallia brachiata Merr.	Rhizophoraceae	ST	0.55	0.63	0.01	1.19
Anthocephalus cadamba Miq. *	Rubiaceae	T	1.46	1.32	0.86	3.64
Zanthoxylum rhesta Roxb.	Rutaceae	T	0.21	0.21	0.81	1.23
Chrysophyllum lanceolatum DC.*	Sapotaceae	T	0.97	1.15	0.01	2.13
Chrysophyllum roxburghii G.Don*	Sapotaceae	T	2.22	2.15	0.90	5.27
Madhuca indica Gmel. *	Sapotaceae	T	2.01	2.05	0.89	4.95
Mimusops elengi Roxb.	Sapotaceae	T	0.35	0.38	0.53	1.26
Ailanthus integrifolia Lamk.	Simaroubaceae	T	0.55	0.56	0.00	1.11
Sterculia villosa Roxb. *	Sterculiaceae	T	0.83	0.90	1.67	3.41
Tetrameles nudiflora R.Br.	Tetramelaceae	T	0.42	0.42	0.89	1.73
Callicarpa arborea Roxb.	Verbenaceae	T	0.28	0.31	0.74	1.33
Gmelina arborea Roxb. *	Verbenaceae	T	1.87	2.36	0.90	5.13
Premna benghalensis Cl.	Verbenaceae	T	0.35	0.31	0.86	1.52
Tectona grandis L.f.	Verbenaceae	T	0.35	0.42	0.81	1.57
Vitex altissima L.f. *	verbenaceae	T	1.04	0.94	1.69	3.66

*T= Tree; ST= Shrub-tree; * = Food tree; RF= Relative frequency; RD= Relative density; RDo= Relative dominance; IVI= Importance value index*