ASSESSMENT OF EDGE EFFECTS ON POPULATION STRUCTURE AND REGENERATION STATUS OF MOST PREFERRED FOOD PLANT SPECIES OF WESTERN HOOLOCK GIBBON: AN INITIATIVE FOR EMPOWERING THE CONSERVATION EFFORTS IN NAMDAPHA NATIONAL PARK, ARUNACHAL PRADESH, INDIA

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Submitted By

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(Project Investigator)

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Photo credit: Parimal Chandra Ray

Front cover: Collage Photographs: A male Western Hoolock Gibbon; A pair of Western Hoolock Gibbon (Top); Fruits of food plants (Bottom); Principal Investigator (Centre). A panaromic view of the habitat of Namdapha National Park (Bottom).

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Parimal Chandra Ray

(Principal Inverstigator)

Globally, primates are distributed in tropical or subtropical regions of the Americas, Africa and Asia with most diversified inhabitation records from tropical rainforest of the World. Among primates the gibbons, family Hylobatidae, are the only arboreal apes inhabiting the tropical evergreen, less seasonal part of semi-evergreen rain forests and semi-deciduous forests of North-east India (Srivastava, 1999) and Bangladesh (Chivers, 2001), through Myanmar (Tickell, 1864), south China (Anderson, 1878), Laos PDR, Vietnam, Cambodia, Thailand, the Malay Peninsula, Sumatra, to Java and Borneo (Chivers, 2001; Chatterjee, 2006). At present four genera of gibbons has been classified under the Hylobatideae on the basis of their diploid chromosome numbers: *Symphalangus* (50)*, Nomascus* (52)*, Hoolock* (38) and *Hylobates* (44)*,* which contains at least 14–19 gibbon species (Mootnick 2006; Thinh et al. 2010) (Fig 1a & 1b).

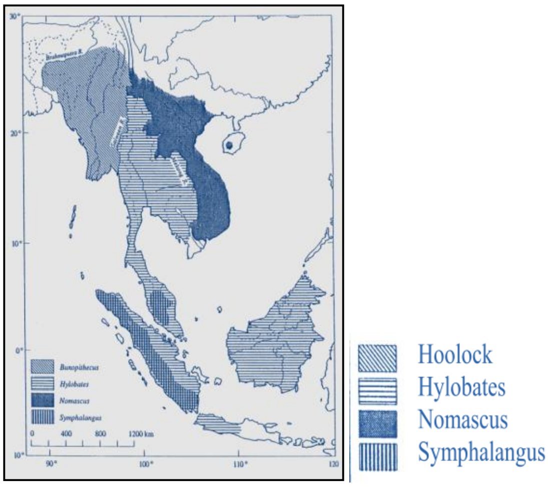


Fig. 1a: Distribution of genera Hoolock as per (Geissmann, 2002, 2007; Mootnick 2006; Thinh et al. 2010).

Fig. 1b: Distribution of species under genera Hoolock as per (Chivers 2001). Red circle indicating the *H. hoolock.*

In India a total of 32 taxa of primates have been recorded in the wild (Molur *et al.,* 2003). Of these, the Western Hoolock Gibbon (*Hoolock Hoolock*) and Eastern Hoolock Gibbon (*Hoolock leuconedys*) are the only two species of lesser apes found in India (Das *et al.,* 2006). Globally, Western Hoolock Gibbon or White-browed Gibbon (*H. hoolock*) occurs in altitudinal range between 50 to 1400 m (Das *et al.,* 2005) with the river Chindwin of Myanmar (Groves, 1972) forming its eastern limit, the forests of Sylhet, Chittagong (Gittins, 1980; Gittins and Akonda, 1982) and Mymensingh (Khan, 1984, 1985) of Bangladesh forming its western limit and the Noa - Dihing river of Arunachal Pradesh and Assam, India forms its northern most limit (Ray et al., 2015, Das *et al.,* 2006). Whereas, in the south its range is uncertain (Grooves, 1972) but, preliminary surveys in Myanmar indicated that it occurs at least as far south as Rakhine Yoma in south-west Myanmar (Giessmann *et al.,* 2008).

In India, Hoolock Gibbon distribution is strongly associated with the occurrence of continuous canopy, broad-leaved, tropical wet evergreen and semi-evergreen forests (Walker *et al.,* 2009) where, they perform strict arboreal as well as brachiatry mode of locomotion within highly monogamous and territorial family groups (Brockelman and

Srikosamatara, 1984; Das, 2002) and have been described as highly selective feeders that are largely dependent on small and scattered fruit patches (Chivers, 1984; Leighton, 1987). Thus, Hoolock gibbons are the most frugivorous among the primate's species and have been recorded as vital animal for seed dispersal in tropical forests (Corlett, 1998; McConkey, 2005), where they are maintaining floristic heterogeneity in forest stands (Howe and Vande Kerckhove, 1981; Bourliere, 1985). And they can logically be the 'flagship species' (Dietz *et al.,* 1994) for the conservation of forests, particularly Lowland tropical rain forest in northeast India.

Therefore, gibbons are regarded as an effective seed disperser in maintaining the ecology of tropical forest regeneration through the reproductive success and dispersion of some plants. However at present among all the gibbon species, the *H. hoolock* has a global population estimated to be about 5,000 animals: 2,600 to 4,450 in India and about 200 in Bangladesh (Molur *et al.,* 2005; Choudhury, 2006). They are perhaps under the greatest threat throughout their geographic range (Feeroz 1999, 2001; Choudhury 2001; Das *et al.,* 2009) due to habitat destruction (Chivers 2001; Molur *et al.,* 2005; Walker *et al.,* 2007) and bush meat hunting (Ahsan, 2001; Das, 2002; Biswas *et al.,* 2010; Rao *et al.,* 2010; Ray et al., 2015). Hence, because of these emerging threats, they have been categorized under the World's 25 most endangered primate species (Walker *et al.,* 2007). Whereas, at present they have also been globally listed as Endangered in India and Critically Endangered in Bangladesh by IUCN Red List of Threatened species (Molur *et al.,* 2003; Brockelman *et al.,* 2009) and listed in Schedule I of the Indian Wildlife (Protection) Act, 1972 and also in Appendix I of the CITES.

In India, *H. hoolock* is distributed throughout the north-eastern states except Sikkim (Srivastava, 1999) (Fig 1a). But in the past few decades in north-east region habitat degradation, destruction and fragmentation of forest have resulted in sharp decline of *H. hoolock* population (Das and Srivastava, 2001; Chetry *et al.,* 2003; Kumar *et al.,* 2009; Biswas *et al.,* 2010), particularly in Arunachal Pradesh and Assam, where most of the population are distributed. Estimates suggest that throughout its range, a 67% reduction in Hoolock gibbon habitat has occurred within ten years viz. from 168,000 sq. km in 1987 to 56,378 sq. km in 1997 (Anon., 1997). Most of the gibbon population in north-east India are found in the unprotected and small fragmented forest stands (Das *et al.,* 2004; Ray et al., 2015; Sarma *et al.,* 2012). Thus, substantial degradation of forest within protected and outside the protected areas may have a direct impact upon behavioural ecology, food habits and food preferences, population growth and distribution pattern of gibbon due to its total dependency on forest canopy for their survival (Choudhury, 1991; Srivastava *et al.,* 2001; Das *et al.,* 2004; Feeroz and Islam, 1992; Kakati, 1997, 2004).

Similarly, other anthropogenic threats like hunting of frugivorous or seed-dispersing animal such as *H. hoolock* and other primate species may be disrupting these critical seed dispersal and deposition processes (Chapman and Onderdonk,1998; Roldan and Simonetti, 2001). This phenomenon is particularly problematic for tropical forest restoration and regeneration, as degraded forests particularly their food plants often rely on the input of dispersed seeds to begin or accelerate their recovery (Chapman *et al.,* 1999; Oates, 1999; Struhsaker, 1999). Further the widespread regional reduction or extirpation of seed dispersal agents may pose a prominent threat to the structure, composition, and diversity of tropical forests (Chapman and Onderdonk, 1998). Thus, the role that a seed-dispersing animal play in plant regeneration, cannot be assessed only in terms of its dispersal effectiveness at the plant population level, but also must be evaluated in terms of its prevalence at the plant community level particularly their food quantity and food preferences. Thus, the aspect of population and regeneration studies of most preferred food plants species may have practical implications for habitat conservation and management of endangered species as well as other associated (sympatric species) animals.

So, in the above backdrop, this project with a few objectives was developed to be conducted in Namdapha National Park (NNP) of Arunachal Pradesh, India. NNP, in Northeast India is the largest continuous forest patch left in India for the conservation of many species. It is also important for the Western Hoolock Gibbon (Gibbon) which has been suggested to be have quite good population status and the behavior performance in this resource-rich habitat as compared to other areas in India (Ray et al., 2015, Das et al., 2006). Wherein, NNP is facing massive habitat destruction from various anthropogenic threats in and around its buffer and core zone (personal observations, Ray et al., 2015, Murali et al., 2011, Dutta et al., 2007). Hence, in this project I tried to understand the complex relationship between gibbons and their habitats by conducting my studies on the following approved objectives:

1. To study the influence of edge effects on the population structure and regeneration status of the most preferred food plant species of Western Hoolock Gibbon in Namdapha National Park.

2. To document and map the prevailing threats on both the gibbon habitat and their preferred food plant species in Namdapha National Park.

3. To develop and initiate a long-term, sustainable, community-based conservation management action plan for the survival of gibbons and associated species in Namdapha National Park.

STUDY AREA

The Namdapha National Park (27° 23 – 27° 39 N, 96° 15 – 96° 58 E) is located in Changlang district of Arunachal Pradesh, India, and covers an area of 1985 km^2 including 177 km^2 of area under a buffer zone (Nath *et al.* 2005). The park lies within the Himalayan and Indo-Burma global biodiversity hotspots (Conservation International 2005; Myers *et al.* 2000) at the junction of the Palearctic and Malayan bio-geographic realms resulting in a highly diverse mammalian assemblage as well biological diversity. Also, due to the altitudinal range variation of 200 to 4571 m asl, the climatic conditions are heterogeneous across the park. The temperature varies from 35°C to 0°C at lower altitudes and ranges to below freezing at higher elevations. Monthly precipitation ranges from a minimum of 1400 mm to a maximum of 2500 mm, 75% of which falls between April and October. Mean monthly relative humidity is high except during the winter months, and annually it varies from a minimum of 47% to a maximum of 93% (Kumar *et al*. 2009). This climate and terrain favour high habitat diversity, which includes eight types of vegetation, e.g., Alpine, Sub-alpine, mixed coniferous forest, wet temperate forest, sub-tropical pine forest, tropical wet evergreen forest, tropical broad-leafed forest, and bamboo (WWF 2011). However, Champion and Seth (1968) delineated three major forest types in park, viz., tropical, temperate, and alpine. Arunachalam *et al.* (2004) remarked that the park was perhaps to be the largest Dipterocarpus forest in the region with many endangered, endemic, locally threatened and extremely rare floral species. Although park is in a remote corner of the country, it has not escaped human interference; we found evidence of hunting and NTFP collection in many places and high anthropogenic pressure is reported by Arunachalam *et al*. (2004). Additional disturbances include road widening (Krishna *et al*. 2013) and deforestation to facilitate human settlement and jhoom cultivation for paddy and other cash crops within the core zone of the Park (unpublished, Ray et al., 2015). Various indigenous tribes and other communities reside in and around the park. The park area is dominated by Chakma, Nepali, Lisu, Singhpo and Mishmi tribes of state. Thus, the park is not only the abode of a rich biodiversity in terms of flora and fauna, but also of indigenous tribes which are dependent upon its resources.

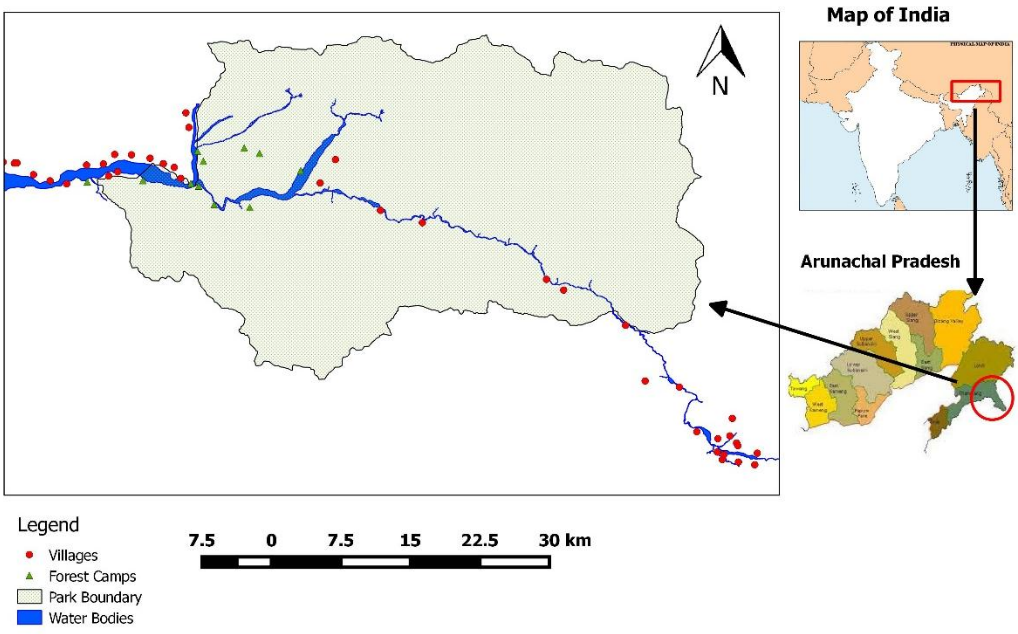


Fig 1c: Location map of Namdapha National Park of Arunachal Pradesh, India

This study and the design of this approved project was preliminary based on the data collected from a previous project funded by the Council of Scientific & Industrial Research (CSIR), India. Where, I already had the collected and analyzed data from several studies that are relevant to achieve the objectives of this project. And the following result of the previous research that has been used for designing of the base of this project were on:

1. Population status of gibbon in Namdapha National was already available to the Principal Investigator (PI) from his published research work i.e., (Ray et al., 2015).
2. Extensive study for period of one year (2012-2013) on seasonal feeding behaviour of two habituated gibbon groups was available to the PI (Unpublished data). In this result he had listed a total of 40 plant species in the gibbon diet. Further analysing the data as per following Sarkar (2000) he had identified the most preferred food plants species of gibbons (e.g. *Alinathus grandis, Chakrusia tubalaris, Neolamarckia cadmba, Melia azedarach, etc.*).

So, to carry out the research work on approved objectives the following activities and methodologies were adopted following protocol as suggested by various researchers:

Objective 1: As per the work flow for this objective I have selected a total of twenty eight (28) stratified random sampling transects of 1-2 km length at a gap distance of 50 m (2-5 km) from the forest edge to forest interiors within the suitable habitats of gibbon in NNP as shown in the (fig 1d). These selected stratified random sampling transects were mostly located across three study sites A, B and C as shown in below table (Table 1).

Within these selected sites, transects were laid for laying some nested quadrats of 10m × 10m size for the tree, 5m × 5m size for sapling and 1m × 1m for seedling size were laid randomly at a gap of 50 m to study the population structure and regeneration status of the top ten preferred food tree species of gibbons (Fig. 1e; 1f; 1g; 1h; Table 2).viz., *Randia cochinchinensis, Diospyros lotus, Chukrasia velutina, Morus levigata, Elaeocarpus ganitrus , Neolamarckia cadamba, Cinnamomum camphora, Alianthus grandis, Bombax ceiba and Artocarpus lacucha*. Again within each nested quadrat individual trees having ≥30 cm girth were treated as adults, 30−10 cm as saplings and ≤10 cm at the base as seedlings. Each individual tree and its respective girth was recorded at 1.37 m height from the base of an individual tree within the studied quadrat. Moreover, the seedlings and saplings of tree species will be photographed (for further identification) and counted within each quadrats.

Following the data collection basal area, density, and importance value index (IVI) were calculated as per following the formulae of Cottam and Curtis (1956). Finally, based on population size of seedlings, saplings, and adults, the regeneration status of most preferred food plant tree species of gibbon were grouped into five categories namely good, fair, poor, no regeneration and new following (Khan et al. 1987; Khumbongmayum et al. 2006). The Regeneration was considered as ‘good regeneration’ when seedling > sapling > adults. In cases where the seedlings > or ≤ saplings ≤ adults, it was termed as ‘fair regeneration’. The Regeneration was ‘poor regeneration’ if the species survives only in sapling stage and no seedlings are observed. If a species is only found to be present at the adult stage with no seedlings and saplings, it was termed as ‘no regeneration’.

Objective 2: As per the work flow for this objective I have collected the spatial location of all the stratified random sampling transects, quadrats and settlements using the GPS (as shown in Fig 1c; 1d). Additionly to this I have also collected the GPS locations of all the signs of anthropogenic disturbance at each nested quadrats such as hunting camps, cutting, lopping, cattle grazing, nearness to human habitation and NTFP collection. These locations were finally mapped using GIS software (QGis 2.2v and Arc GIS 9.3v) delinating the prevailing threats for both the gibbon habitat and their preferred food plant species in NNP.

Table 1: Showing details of transects laid for studying the population and regeneration related work in three selected survery sites.

Sl.No.	Survey Site	Name of Areas	No. of transects	Sampling Efforts (km)
1	Site A	Happy valley camp	02 of 1 km each	4
		Hornbill camp	02 of 1 km each	4
		Haldibari camp	02 of 1 km each	4
2	Site B	Deban camp	04 of 2 km each	8
3	Site C	Gibbons Land camp	04 of 2 km each	8
	Total			**28**

Location of Sampling sites and transects for Regeneration studied in Namdapha National Park, India

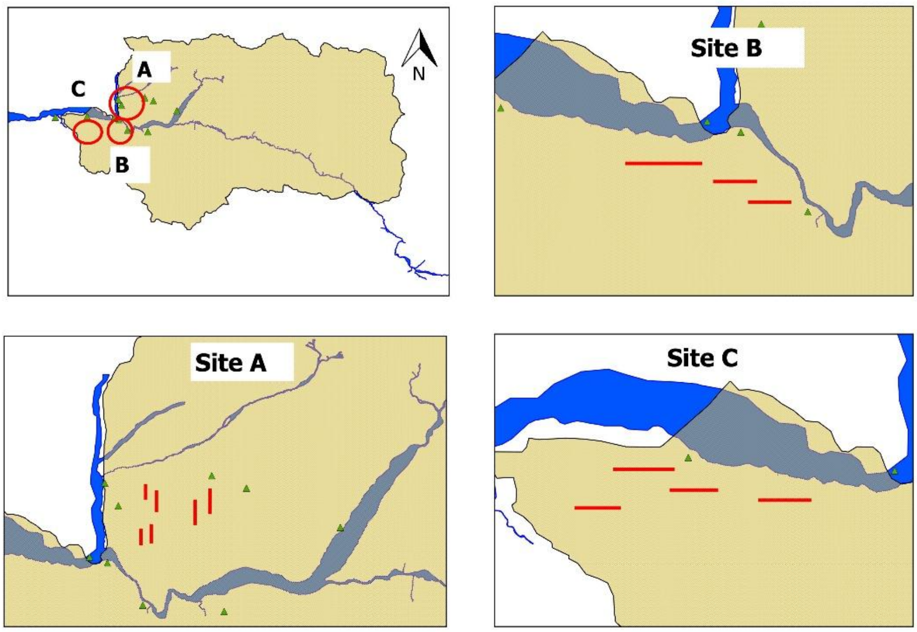


Fig 1d: Map showing the location of sampling sites (A, B & C) and transects laid for studying the population and regeneration status survey of most preffered food plants of western hoolock gibbon in Namdapha National park, India.

Fig. 1e: *Chukrasia velutina*

Fig. 1f: *Neolamarckia cadamba*

Fig. 1g: *Alianthus grandis*

Fig. 1h: *Bombax ceiba*

Table 2: List of most preferred annually top ten food tree species of western hoolock gibbon in Namdapha National Park, Arunachal Pradesh, India.

Sl. No	Family	Scientific Name	Total feeding records	Feeding Frequency (%)	Relative Dominance of the species	Selection Ratio
1	Rubiaceae	*Randia cochinchinensis*	25	1.60	0.03	55.49
2	Ebenaceae	*Diospyros lotus*	22	1.41	0.13	10.99
3	Meliaceae	*Chukrasia velutina*	314	20.08	3.74	5.37
4	Moraceae	*Morus levigata*	3	0.19	0.04	4.45
5	Eleocarpaceae	*Elaeocarpus ganitrus*	36	2.30	0.55	4.15
6	Rubiaceae	*Neolamarckia cadamba*	86	5.50	1.39	3.95
7	Lauraceae	*Cinnamomum camphora*	4	0.26	0.07	3.82
8	Simaroubaceae	*Alianthus grandis*	98	6.27	2.78	2.26
9	Bombaceae	*Bombax ceiba*	53	3.39	1.77	1.91
10	Moraceae	*Artocarpus lacucha*	5	0.32	0.20	1.59

Objective 3: As per the work flow for this objective I have conducted questionnaire-based interview surveys with the village priest, the head of hamlet (Gaonbura), village leaders and experienced hunters in the settlements located near or inside the park area (following Rao et al., 2010, Wang et al., 2007) to understand the socio-economic status of the major tribal communities (Chakma, Mismi and Lisu) that are residing in and around the villages in NNP. In the meantime I had also prepared some flyers and posters to be used while conducting some education cum mass awareness program in the peripheral villages located near the park boundary. During the timeframe of this objective I have delivered few talks to the local tribal community people, school students, and forest personnels as well as distributed some flyers and stickers to them for their better understanding towards the conservation of wildlife and gibbons in general.

RESULT & DISCUSSION

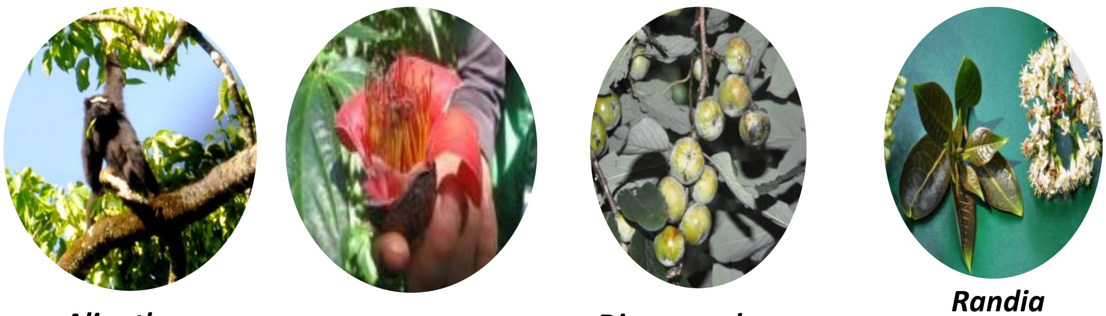
Objective 1: To study the influence of edge effects on the population structure and regeneration status of the most preferred food plant species of Western Hoolock Gibbon in Namdapha National Park.

Results:

Population structure:

The result on the population structure of ten selected preferred food tree species of western hoolock gibbon in terms of the proportion of adults, sapling and seedlings varied greatly in the three survey sites (Fig 1d). The relative proportion of seedlings was recorded highest in site B, while, it was lowest in survey site C. On the other hand, the relative proportion of saplings and adults were highest in survey site C followed by survey site A. The distribution of adults, saplings and seedlings along the three survey sites also showed variation among preferred food tree species (Table 3).

Among the ten selected tree species only two i.e., *Chukrasia velutina, and Alianthus integrifolia* showed a quite good population structure with all the life forms in all the three selected survey sites (Table 3). However, there is a variation in the density (ha^{-1}) of all the life forms in the three survey sites. In our study among the three survey sites the site B has exhibited the highest density (ha^{-1}) of seedlings for both the *Chukrasia velutina* and *Cinnamomum camphora* species. The seedlings density (ha^{-1}) of *Elaeocarpus ganitrus* and *Alianthus integrifolia* were found to be higher in survey site A (Fig 1d; Table 3). Overall the site A contributed more towards the population structure with more occurrences of adults and seedling density (ha^{-1}) then the site B and C (Fig.1d; Table 3).



Alianthus integrifolia ***Bombax ceiba*** ***Diospyros lotus*** ***Randia cochinchinensis***

Fig 1i: Few of the prefrerred food tree species of western hoolock gibbon in Namdapha National Park

Table 3: Distribution of adults, saplings and seedlings (density ha^{-1}) and regeneration status of preferred top ten food tree species of western hoolock gibbon in the three survey sites in Namdapha National Park, India.

Name of the preferred food tree species	**Site A**			**Status**	**Site B**			**Status**	**Site C**			**Status**
	AD	**SA**	**SE**		**AD**	**SA**	**SE**		**AD**	**SA**	**SE**	
Randia cochinchinensis	1	-	-	**NR**	-	-	-		-	-	-	
Diospyros lotus	1	-	-	**NR**	-	-	-		-	-	-	
Chukrasia velutina	8	-	91	**FR**	19	25	1263	**GR**	6	17	938	**GR**
Morus levigata	-	-	-		8	34	-	**PR**	-	4	-	**PR**
Elaeocarpus ganitrus	6	-	364	**FR**	4	-	-	**NR**	3	-	-	**NR**
Neolamarckia cadamba	3	-	-	**NR**	6	-	-	**NR**	3	-	-	**NR**
Cinnamomum camphora	2	-	818	**FR**	4	-	4211	**FR**	1	-	-	**NR**
Alianthus integrifolia	13	7	182	**FR**	6	17	-	**PR**	6	29	-	**PR**
Bombax ceiba	5	-	-	**NR**	-	-	-		4	-	-	**NR**
Artocarpus lacucha	1	-	-	**NR**	-	-	-		3	-	-	**NR**
Total	**39**	**8**	**1455**		**48**	**76**	**5474**		**27**	**50**	**938**	

AD= Adult, **SA**= Sapling, **SE**= Seedling, **GR**= Good regeneration, **FR**= Fair regeneration, **PR**= Poor regeneration, **NR**= No regeneration

Population Regeneration Status:

In our present study for the top ten preferred food tree species of *H. hoolock* recorded from survey site B, 17 % shows fair and good regeneration and rest 33 % have poor and no regeneration. In site A, 44 % shows fair regeneration and rest 56 % have no regeneration. On the other hand, in site C, 13% shows good regeneration, 25% poor regeneration and 63% no regeneration (Table 3).

Among the selected top ten food tree species only *Chukrasia velutina* shows good as well as fair regeneration in all the study sites having higher number of seedlings compared to saplings and adults (Table 3). However, there is no presence of sapling of this species in site A. Whereas, *Cinamomum camphora* has fair regeneration in both site B and site C with no regeneration in site C. *Elaeocarpus granitus* and *Alianthus integrifolia* has fair regeneration in site A. The records for the poor and no regeneration have been attributed by the rest of the other preferred food tree species of *H. hoolock* (Table 3).

Discussion:

Proportion of seedling, saplings and young trees are the characteristic features of the population structure of any forest community that can provide satisfactory information on the regeneration behaviour of the forests (Saxena and Singh 1984). Variations in the population structure of the ten selected food tree species of *H. hoolock* viz., *Randia cochinchinensis, Diospyros lotus, Chukrasia velutina, Morus levigata, Elaeocarpus ganitrus, Neolamarckia cadamba, Cinnamomum camphora, Alianthus integrifolia, Bombax ceiba* and *Artocarpus lacucha* in the three selected survey sites may be attributed to the differences in their habitat, mode of seed dispersal and prevailing disturbances factors that also effects the population structure of a tree species. 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).

The overall distribution patterns of population structure of selected tree species in different life forms reveals that seedling population of *Chukrasia velutina* and *Alianthus integrifolia* are dominating the population structure in site A and site B that might be potentially providing more favourable conditions for seedling growth of these two species. Moreover, the low relative proportion of saplings and seedlings density (ha^{-1}) of the *Bombax ceiba*, *Artocarpus lacucha, Randia cochinchinensis, Diospyros lotus* and *Neolamarckia cadamba* then its adult forms is might be due its seed dispersal mechanism that are probably dispersed by the dependent frugivore animal species. As in case of *Bombax ceiba* they have the anemophilic mode of seed dispersal and could probably be dispersed at a long distance from its parent tree and hence have not been covered in our studied quadrats. On the other hand, the species may also suffer high mortality at the seed/seedling and sapling stage due to herbivores and thus regeneration of such species may be periodic.

The low sapling population of selected tree species except in case of *Chukrasia velutina* and *Alianthus integrifolia* in the three selected survey sites may be attributed to the adverse impact of environmental factors prevalent during the sapling growth. Whereas, the greater number of saplings of these two species clearly indicates that these species will persist and may determine the composition of future vegetation of the three surveyed sites

(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. *Bombax ceiba*, *Artocarpus lacucha, Randia cochinchinensis, Diospyros lotus* and *Neolamarckia cadamba* 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. Moreover, in our present study *Bombax ceiba, Neolamarkia cadamba, Eleaeocarpus granitus* and *Alianthus integrifolia* were found to have similar kind of population structure as reported by Nath et al. (2005) with low density of both sapling and seedlings than that of adults.

Overall our study reported site A with high level of protection to be have the highest number of species, which shows fair regeneration. This could be due to enough solar radiation, nutrients availability etc. which help the tree species in better regeneration. Pokhreyal *et al.* (2010) also reported presence of tree species with higher proportion of fair regeneration from Phakot and Pathri Rao watersheds in Garhwal Himalaya. The seedling and sapling densities in forest understory's are not stable, rather it is dynamic in nature and this dynamism may vary among various species (Bazzaz, 1991). The change in density is due to mortality, which could include abiotic stresses such as light, drought and biotic factors that include herbivory, disease or competition (Augspurger, 1984). Successful regeneration of any type of species can only occur if the right amount of growing space becomes available for the establishment and subsequent growth of seedlings (Klinka *et al.* 1990). The difference in the regeneration status of the selected food tree species between the three surveyed sites (Table 3) is mostly because of the difference in the frequency of disturbances that this area poses. As in site C close to the western periphery of NNP, where only 12.5 % of the selected tree species have showed good regeneration with 25% poor and 62.5% no regeneration could be due to the frequency of higher anthropogenic disturbances. Whereas, the site A have quite higher percentage of species showing fair (44.4%) and no regeneration status (55.6%) then the other two disturbed areas. But, among all the surveyed sites only site B have contributed towards few occurrence of fair and good (16.6%), poor and no regeneration (33.3%).

Thus, reviewing the results and discussion of the present study it is concluded that the population structure and regeneration status of selected food tree species depend on influence of biotic and abiotic factors of the environment. The prevailing micro-environmental conditions of the three surveyed sites are providing a niche that can nurture rich plant biodiversity of ecological and economic importance. Higher survival and growth of tree seedlings in site A and site B exemplify the available micro-environmental factors in these areas such as light, water, nutrients etc. act as a sufficient resource for the survival and growth of tree seedlings.

Objective 2: To document and map the prevailing threats on both the gibbon habitat and their preferred food plant species in Namdapha National Park

Result:

The accomplishment of this objective was made through the collection of GPS locations for of all the signs of anthropogenic disturbance at each nested quadrats such as hunting pressure, cattle grazing, NTFP collection, human movement, and farming practices across the survey sites A, B & C as to map the threat assessment map for the gibbon in NNP (Pic 1 -4; fig 1j). In accordance to these anthropogenic disturbance data collection I have also mapped the areas having maximum protection from the forest department personals. All these collected locations were mapped for the study area as shown in (fig. 1j).

As per following the below map it has been evident that the percentage coverage of the threat categories and the level of protection has a significant contribution towards the variation of the population and regeneration status of the most preffered food plants of the gibbon in NNP. Overall, in the park the pressure of hunting is found to be highest in the Site A as compared to Site B and Site C. The other prominent threat factor grazing and NTFP collection is maximum in the areas close to the site C and minimum in site B. Whereas, And for others farming practices and human movement there is a close affinity with the occurance of the villages as well as the presence of the road that the locals use as to reach their concerned village destination as shown in the (Fig 1j).

Our result for the level of forest protection by the forest personnels has found to be more effectively monitored in site B followed by site C and site A.

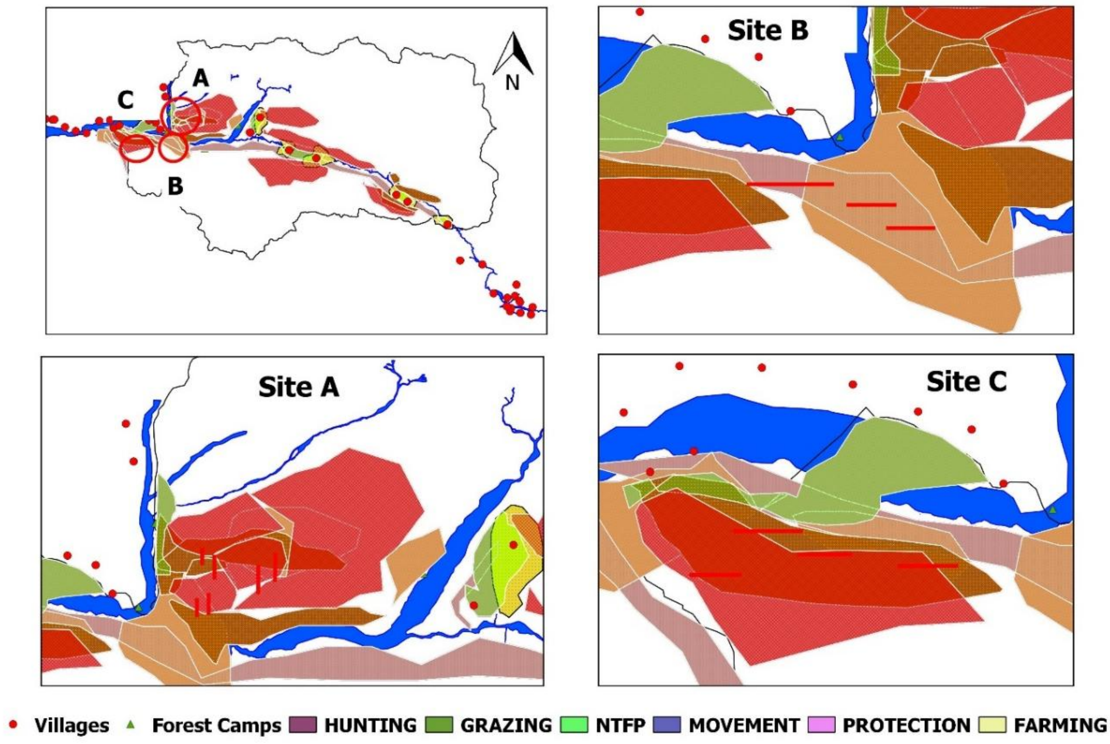


Fig 1j: Location of villages and forest camps near the survey sites in Namdapha National Park, India.

Pic 1: Human habitation near site B (Deban area) of Namdapha National Park

Pic 2: Local community in their paddy field during harvesting season.

Pic 3: Extraction of resin from *canarium strictum* near the buffer zone close to northeastern periphery of Namdapha National Park.

Pic 4: A machan build by hunters inside park for hunting activity.

Discussion:

The NNP has found to be have a quite diverse forms of threats due to the presence of various anthropogenic factors as shown in (fig 1j). These threats have a quite collateral association with the socio-economic condition of the local who are inhabiting the villages in and around the NNP. It has similarly evidence with that of previous reports of Arunachalam (2005); Murali et al, (2014); Ray et al., 2015; Kumar et al., (2009); Das (2006) in terms of the level of threats the NNP is facing with respect to the passing of the past one decade. It has been found that the level of forest protection has quite infulencial impact on the decrease of the increasing anthropogenic threats that the even the NNP is facing. So, in the limelight of the present increase of the pressure on the habitat of the gibbon in NNP it is really a cause of concern to be addressed as soon as possible to mitigate the issues. Moreover, in relation to the level of threats with the population and regeneration status of the most preffered food plants of the gibbon the result of this project showed that the level of the protection can greatly influence this factor. So, more the number of preffered food plant species having good and fair regeneration status is also a result of the same. In context to the present findings I can suggest that the NNP is potentially have sparse as well as continuous distribution of the preffered food plants of gibbon but, it is of immense need to enhance the level of protection to the areas having the presence of gibbon for the survival their food plants species in NNP.

Objective 3: To develop and initiate a long-term, sustainable, community-based conservation management action plan for the survival of gibbons and associated species in NNP.

Socio-economic profile:

Questionnere based socio-economic survey data revealed that the most of the communities have farming as their prime occupation towards supporting their livelihood. Which, mostly they do for their self-consumption and sometimes for sale if harvested in some huge quantities. Among the 13 villages (table 4), the villages that are located near northwest periphery zone mostly sold the cash crops (like; chillies, papad, ginger, etc.). Whereas, the communities of other zones sold the cash crops (like; *Amomum sp.*, *Sesamum indicum*, etc.). Moreover, the northwest periphery zones have somewhat moderate access to the governmental amenities as compare to other zones (Table 5).

Table 4 Villages, location and population size in the Namdapha National Park

Village name	Location	Population size
M'Pen I	NW	1350
M'Pen II	NW	597
Budhisatta	NW	385
Anandpur I	NW	330
Anandpur II	NW	254
Nandankanan	NW	442
Kathan	NW	184
38 mile	C	110
52 mile	C	220
65 mile	C	85
77 mile	C	36
Gandhigram	SE	3000
Ramnagar	SE	212

Location: NW = Northwest periphery; **Co** = Core Zone; **SE** = Southeastern periphery

The questionnaire survey on the frequency to the park visit by the villagers resulted in the fact that the communities located along all the zones frequently used to visit the park. And the longest extent of visiting for both hunting and NTFP collection was found to be maximum near core (up to 20 km) followed by southeastern (up to 14 km) and northwestern periphery (up to 10 km). But, the duration of these visits were somewhat higher near the core (up to 5 days) followed by southeastern (up to 4 days) and northwest (up to 3 days). Thus, from this survey it has also been reported that the zones that are located near core and southeastern periphery have more frequency of visiting to the park for the hunting rather than NTFP collection.

Table 5: Population pressure in northwestern, core and southeastern periphery of Namdapha National Park

Name of village	Location	Community profile				Occupation			Govt. Facilities available				Mode of utilization of forest resource			Need for hunting		
		C	M	L	N	F	SG	CG	R	H	S	E	Fu	Fo	O	Fo	LM	O
M'Pen I	NW	√			√	√			√		√		√	√		√	√	
M'Pen II	NW	√			√	√	√				√		√	√			√	
Budhisatta	NW	√		√	√	√	√		√		√		√	√	√	√	√	√
Anandpur I	NW	√			√	√	√		√		√		√	√				
Anandpur II	NW	√			√	√					√		√	√		√		
Nandankanan	NW	√			√	√					√		√	√		√		
Kathan	NW		√			√			√	√	√		√	√	√	√		√
38 mile	Co			√	√	√							√	√	√	√	√	√
52 mile	Co			√	√	√					√		√	√	√	√	√	√
65 mile	Co			√	√	√							√	√	√	√	√	√
77 mile	Co			√	√	√							√	√	√	√	√	√
Gandhigram	SE			√	√	√					√		√	√	√	√	√	√
Ramnagar	SE				√	√					√		√	√	√	√	√	√

Location: NW = **Northwest periphery; Co = Core Zone; SE = Southeastern periphery**
Community profile: C = Chakma; M = Mishmi; L = Lisu; N = Nepali.
Occupation: F = Farmers; SG = State Govt. employee; CG = Central Govt. employee.
Govt. facilities available: R = Roads; H = Hospitals; S = Schools; E = Electricity.
Mode of utilization of forest resources: Fu = Fuel; Fo = Fodder; O = Others.
Need for hunting: Fo = As food; LM = Local medicine; O = Others.

Discussion:

Semi-structured questionnaire based survey revealed that majority of villagers are practicing farming as their prime occupation and very few are in other sector like; governmental jobs, entrepreneur, etc. Mostly, villagers visit park for the extraction of non-timber forest products (NTFP) especially the bamboo, roofing materials, firewood collection, supplementary plants or plant parts as food or medicine and sometimes for hunting of fishes and other species viz., sambar, wild boar, barking deer, even birds, etc. These collected forest products are basically for their self utilisation and moreover from northwestern periphery, where sometimes the extraction of resin from dhuna tree (*Canarium strictum*) and other collected items were used for sale as wild vegetable and fragrance product respectively, in nearby local market i.e., Diyun and Miao area (Ray et al., 2015) But, among the three park zone and periphery all the villagers have different set of requirements from visiting the park. Thus, as from the southeastern periphery and core zone the intensity of visiting park and days they spent in park seasonally is quit higher than that of northwestern peripheral villagers. Our survey also reported that among all the three zones due to unavailability of basic governmental facilities i.e., roads, healthcare centre, electricity, employment, schools, etc. has led them to partly dependent upon the forest and its products.

If not checked then the consequences of the impact of the pressure due to these ongoing anthropogenic threats may directly degrade the quality of the habitat as a whole for the gibbons in general. We can now relate the impact of these pressure on the variation in the results for the population and regeneration status of the preffferd food plants of gibbon in NNP. Thus, in the present context of the projects overall findings it can be suggested that the pressure imposed from the human activities on the parks flora and fauna is of a major concern that has to be effectively managed by the forest personnels. Moreover, during the study period I have also tried to educate the local communities through the means of our distributing the education materials (flyres, stickers, etc.) especially to the school children’s and among the local peoples (fig 1k). The role of locals in conservation of any protected areas is of utmost importance that is also need to be looked for the conservation of Namdapha National Park.

Fig. 1 k: Some of the samples of the stickers that has been distributed among the local tibals for their better understanding towards the conservation of wildlife and gibbons in general.

CONCLUSION & RECOMMENDATION

The studies on the objectives for this project was immensely resulted into some facts and figures that must be taken into consideration to make any further conservation action plans for the conservation of western hoolock gibbon and their habitat. This only be acheveied through the close participation of the key stakeholders and local community peoples with the researcher and the forest personnels. The recomeendation that I want to suggest through this project report is mostly on the following issues:

- **Intensive research on concerned species:** This recommendation will be on to conduct more intensive form of reaerch initative to be carried out by either more researchers or forest personnels. This initiative will going to provide more results that might help in effective conservation of the target species and the parks biodiversity as a whole.
- **Monitoring of the habitat:** With respect to the availbilty of the previous and this report on the parks habitat quality in terms of the population and regeneration status of few or important food plants of gibbons in NNP, there should be an initative to monitor and enhance the protection of the concerned locations within the NNP.
- **Enhancing Forest protection:** Through the finding of this project it can be recommended for enhancing the level of protection in the areas that are close to the forest parks periphery. For this there should be a periodic monitoring of the issues like hunting, livestock grazing, NTFP collection, etc. This can only be achieve through the close coordination with the local communities that are dependent upon the forest and their resources.
- **Education and Capacity building program:** It has also been eveident that there is an immediate need of bringing the conservation issues of the species and their habitat as a whole in limelight. For that all key stakeholders must be considered while initiating the community participatory education and capacity building program.
- **Inclusion of results on multispecies level in park management action plan:** Moreover, the gibbons being a seed dispersers in NNP have a greater role to play in the conservation. Thus, I recommend the park mangers to do keep the findings on the gibbon of this project for prepration of the effective management action plan.

Published Abstract of Projects finding

Till the final completion of the projects objectives the Principal investigator has communicated and presented abstarcts in International and National conference respectively.

1. **Ray PC,** Kumar A, M. L. Khan **(2015)**. Value and Conservation need of *Canarium strictum* Roxb. In Namdapha National Park of Arunachal Pradesh, India. The DST sponsored National Seminar on *Sustainable Conservation Strategies for Bio-Resources of North East India* from **6th to 7th November, 2015** at Arya Vidyapeeth College, Guwahtai, India.
2. **Ray PC** and Kumar A (**2016**). Population structure and regeneration status of the most preferred food tree species of endangered western hoolock gibbon (*Hoolock hoolock*) in Namdapha National Park of Arunachal Pradesh, Northeast India. Accepted for oral presentation in *5th International Conference on Biodiversity-2016* which will be held from **10-12th March 2016** at Madrid, Spain. **(Conference Abstract). (Yet to be Attend).**

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