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DISTRIBUTION OF WESTERN HOOLOCK GIBBONS AND NUTRITIONAL STATUS OF FOOD PLANTS IN CACHAR DISTRICT OF ASSAM, INDIA: REACHING OUT TO LOCAL COMMUNITIES FOR CONSERVATION

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Abstract

Western hoolock gibbon (*Hoolock hoolock*) is listed as an endangered mammal in IUCN Red List. It is also listed in CITES Appendix I and in the Schedule I of the Indian Wildlife (Protection) Act, 1972. In the present work the status and distribution of Western hoolock gibbons in Cachar district of Assam, India was explored by conducting field studies from September 2012 to August 2013 using line transect and call count methods. Group composition, group size and adult sex ratio of nine gibbon groups and one solitary male were recorded. Groups comprised 36 % adult males, 32 % adult females, 10 % sub-adult males, 11 % juveniles and 11 % infants and the encounter rate was 0.17. Group size ranged from 2 to 5 and mean group size was 2.8 ± 1.1. Nutritional status of food plants consumed by Western hoolock gibbons were analyzed and chemical composition was determined. Proximate analysis revealed that the mean value of crude protein (9.73 ± 0.4), crude fibre (16.1 ± 0.6), ether extract (1.07 ± 0.06), NFE (66.24 ± 0.43) and ash (7.03 ± 0.27) in plant samples. A moderate positive correlation was noted between higher protein content and higher crude fibre content in food plants (r = 0.48), which is likely to influence food selection and feeding pattern. Timber felling, fuel-wood collection, agriculture and expansion of tea estates were identified as major threats to conservation of Western hoolock gibbons. The present study recommends taking up awareness programmes and formulation of policy interventions involving the local communities to arrive at a participatory biodiversity conservation plan at local levels particularly involving the village councils (*gram panchayats*).

Keywords: Western hoolock gibbon, distribution, Cachar, food plant, nutrition, conservation, policy, local community

INTRODUCTION

One of the most primitive of living apes, Western hoolock gibbon (*Hoolock hoolock*) occurs in the tropical rainforests of South and Southeast Asia (Romero-Herrera *et al.*, 1973; Alfred, 1992; Gupta, 1994; Das *et al.*, 2003). Western hoolock gibbon has been recorded from seven states in the North-eastern region (Mukherjee, 1986; Choudhury, 2001; Kakati *et al.*, 2009) of India. Western hoolock gibbons are also found in Myanmar and Bangladesh (Kakati *et al.*, 2009; Walker *et al.*, 2009; Deb *et al.*, 2014).

In recent decades, forested regions are becoming more and more fragmented owing to increased population, food shortage, urbanization and clearing for settlements and agriculture. Large-bodied primates like Western hoolock gibbons are most affected because of forest thinning, loss of important food trees, hunting and trade for medicine (Choudhury, 1996; Molur, 2005; Walker and Molur, 2007). Western hoolock gibbons are primarily frugivorous, arboreal, territorial and monogamous. Being important seed dispersers they are vital for forest regeneration and provide ecosystem services (Choudhury, 1991; Kakati, 2004; Gupta and Sharma, 2005; Brockelman *et al.*, 2008).

Studies on Western hoolock gibbons (Mukherjee, 1982; Mukherjee *et al.*, 1988) in Tripura and Arunachal Pradesh of India showed that in contiguous forests they have large home ranges between 200 and 400 hectares. However, forest fragmentation over time has reduced their home range between 8 and 63 hectares (Tilson, 1979; Gittins, 1984; Mukherjee, 1986; Sati and Alfred, 1986; Alfred, 1992; Feeroz and Islam, 1992; Choudhury, 1996; Kakati, 2004; Gupta, 2005). The effects of forest fragmentation has more immediate effects on large-bodied species such as Western hoolock gibbons as they are habitat specialists (Kakati, 1997; Kakati *et al.*, 2009). Exhaustive survey conducted to assess hoolock gibbon population across its geographic range in India reported that though gibbons have large distribution range but most of the populations are small and isolated (Das *et al.*, 2005; Das *et al.*, 2009). Studies also revealed that their population cannot sustain in the absence of contiguous forest patches. Many forest patches contain only a single pair of gibbons (Das and Bhattacherjee, 2002; Das *et al.*, 2009).

As frugivores, gibbon guts are adapted to digest fruits. However, Western hoolock gibbons have been reported from fragmented and disturbed forests consuming a high proportion of leaf due to lack of fruits (Kakati, 1997; Kakati *et al.*, 2009). Acute food supply is believed to cause deficiency of nutrients which may ultimately lead to a variety of immune dysfunctions and an impaired resilience. Living in degraded habitats may also lead to increased parasitic load (Deb *et al.*, 2014) which may affect their survival, growth and fecundity.

In the present study, nutritional status of food plants and distribution of Western hoolock gibbons in forest patches of Cachar district were documented along with their group composition and encounter rate. Subsequently to locating the focal group, their feeding behaviour was studied. Collected food plant samples from the study area were analyzed to ascertain the chemical composition in order to reveal the nutritional status of plants consumed by Western hoolock gibbons. Key threats in each study area were recorded as well as conservation issues were noted with the aim of devising policy interventions at the village level involving local communities for conservation of endangered Western hoolock gibbons.

MATERIALS AND METHODS

Study site

With a geographical area of 78,438 square kilometres i.e. about 2.4 percent of India's total geographical area, the state of Assam provides shelter to 2.57 percent of the human population of the country most of which live in the lush and verdant valleys of its two major river systems – the Brahmaputra valley and the Barak valley. There are twenty seven districts in Brahmaputra valley and three districts in Barak valley – namely Cachar, Karimganj and Hailakandi. The hill districts separate the two valleys and are less densely populated. According to the 2011 Census of India, the human population of Assam stands at 31,169,269 of which 15,954,927 are men and 15,214,345 are women (ESI, 2012). The present study was conducted in Cachar district of Barak Valley in Assam (Fig. 1). The district lies between 92°24′E and 93°15′E longitude and 24°22′N and 25º8′N latitude. The landmass is heterogeneous and composed of high hills, hillocks, valleys and lowlands. The principal river Barak is fed by its tributaries. The forests of Cachar district can be classified into two broad types – Cachar tropical evergreen and Cachar semi evergreen (Champion and Seth, 1968).

According to the 2011 census, Cachar district has a total human population of 1,736,319 with a sex ratio of 958 women to 1000 men. The general elevation of the land surface ranges from 450m

1: *Broad study area*

to 1100m (Cachar-District, 2017). Prominent flora of Cachar tropical evergceen and semi-evergreen forests include monkey jack (*Atrocarpus chaplasha*), Himalayan mango (*Mangifera spp.*), ping (*Cynometra polyandra*), beechwood (*Gmelina arborea*), Asian clumping bamboo (*Melocana baccifera*). (FSI, 2015). The present study was conducted in 14 forest patches of Cachar district. The areas were selected on the basis of secondary data and forest records. The study sites included the following villages - Irongmara village woodlot, Raraipunjee village woodlot, Dharmikhal village woodlot, Rosekandy tea estate, Silcoorie tea estate, Bhubankhal village woodlot, Moniarkhal tea estate, Ecoforest of Assam University campus, Binnakandy tea estate, West Jalenga tea estate, Borojalenga village woodlot, Anandakhal village woodlot, Dwarbond village woodlot and Chandighat tea estate.

The topography of the study area in Cachar district varies from hillocks to plain areas and low lying areas which are often wetlands supporting a range of biodiversity. The study area experiences good rainfall during monsoon and rains in the months of April and May is also fairly common. This causes inundation during incessant rainfall where river Barak and its tributaries swell up.

Study animal

Western hoolock gibbon belonging to the family Hylobatidae is the westernmost of the nine species of lesser apes of South Asia (Geissmann, 2007). Geographical distribution has also been studied by several researchers (Tilson, 1979; Mukherjee, 1982; Alfred and Sati, 1986; Choudhury, 1987; Choudhury, 1990; Choudhury, 1991; Gupta and Sharma, 2005; Brockelman *et al.*, 2008). Western hoolock gibbon has been categorized as endangered by IUCN (Geissmann, 2007) and is listed in CITES Appendix I as well as in Schedule 1 of India's Wildlife (Protection) Act, 1972. The adult male is entirely black with continuous white eyebrows and a specific genital tuft about 2 to 3 inches long and while the female is light brown with white rings around eyes and muzzle (Mootnick and Groves, 2005).

Field work

During the study period, field stations were set up at two villages namely Irongmara and Amraghat for the smooth conduct of the study. Coordinates of the encounters were determined using a hand-held Global Positioning System device eTrex 10 (Garmin, Kansan, USA). These coordinates were plotted on computer for map preparation. A pedometer was used to measure distance walked on foot and final distance was calculated. Pedometer was accurate to within ± 5 % error (Susan and Cara, 2003; Ryan *et al.*, 2006). Observation was done using a binocular Olympus Zoom DPS I 8–16 × 40 (Olympus, Tokyo, Japan) and the images were captured using a digital camera Nikon L-510 (Nikon, Tokyo, Japan). Photography was difficult due to the shy nature of the gibbons and their arboreality being often obscured by foliage. Data was regularly entered on MS-excel sheet for analysis.

Procedure

Literature review was conducted followed by a reconnaissance survey in Cachar district during which secondary information were collected from local villagers including the village heads of the corresponding village council, locally known as *gram panchayats*. Surveys were carried out at sites where gibbons were reported wherever there was an availability of logistic support, friendly and cooperative local communities and security. To assess the population status of Western hoolock gibbons in the forest patches and adjoining areas, modified line transect method was used (Burnham *et al.*, 1980; NRC, 1981; Kakati *et al.*, 2009; Islam *et al.*, 2014, 2006). The number of groups that sang was used as the indicator of number of groups present (Brockelman and Ali, 1987, Choudhury, 1996; Gupta, 2005). Following Kakati *et al.* (2009), western hoolock gibbon individuals were classified into different age and sex classes. Reconnaissance survey was conducted in 15 sites from January 2012 to July 2012 and intensive sampling was carried out from September 2012 to October 2013. Transects were laid on a total of 14 sites and data was gathered. Overall a total of 120 man days and 1080 man hours were devoted. Whenever and wherever possible during the study period, scan sampling was carried out from early dawn to dusk i.e. from 4 am to 11 am and from 2 pm to 4 pm. Encounter rate was also calculated (Pramod *et al.*, 2012).

Chemical analysis

Samples of the fruit parts were obtained from Rosekandy tea estate and were subjected to proximate analysis. Food samples were dried in hot air oven so that it is devoid of any moisture. Moisture in sample can lead to fungal infections and the sample can be destroyed as the nutritional qualities get hampered. Samples were milled in a grinder and stored in air-tight containers for further chemical analysis. Weende system of analysis or proximate analysis, the most widely used method for determining the composition of feedstuff was used to partition the fruit parts into five fractions: ash, crude protein, ether extract (fat), crude fibre and nitrogen-free extract (NFE) (Wiafe, 2015). The crude protein (CP) was determined as Kjeldhal nitrogen × 6.25. Ether extracts (EE), crude fibre (CF), NFE and ash were also determined (AOAC, 2005).

Statistical analysis

All means were reported with standard errors. Pearson's correlation coefficient was used to analyze relation between the absence or presence of Western hoolock gibbon(s) and the quality of forest cover. The Kruskal-Wallis One way ANOVA was used to assess differences between the forest cover with absence or presence of Western hoolock gibbon(s).

RESULTS

Status and Distribution

Western hoolock gibbons were recorded from forest patches, village woodlots bordering forests, and tea estates. Maximum numbers of Western hoolock gibbons were recorded from Rosekandy tea estate area adjoining the innerline reserve forest. During the reconnaissance survey, the case of a female hoolock gibbon was documented. It was captured inside Rosekandy tea estate and was later handed over to the forest department. Line transect study was laid out in all the 14 study sites. A total of nine family groups with 27 individuals were recorded and 1 solitary male gibbon from Silcoorie tea estate was also noted (Tab. I). During the study, 12 Western hoolock gibbons were recorded from Rosekandy tea estate, 6 from Raraipunjee village woodlot, 5 from Bhubankhal village woodlot and 4 from Anandakhal village woodlot. The solitary male which was recorded from Silcoorie tea estate was stranded in a small fragment of tree cladded area with 10 to 15 trees (Fig. 4). The areas where no presence of Western hoolock gibbons was recorded were – Irongmara, Dharmikhal village woodlot, Moniarkhal tea estate, Ecoforest of Assam University, Binnakandy tea estate, West Jalenga tea estate, Borojalenga village woodlot, Dwarbond village woodlot and Chandighat tea estate.

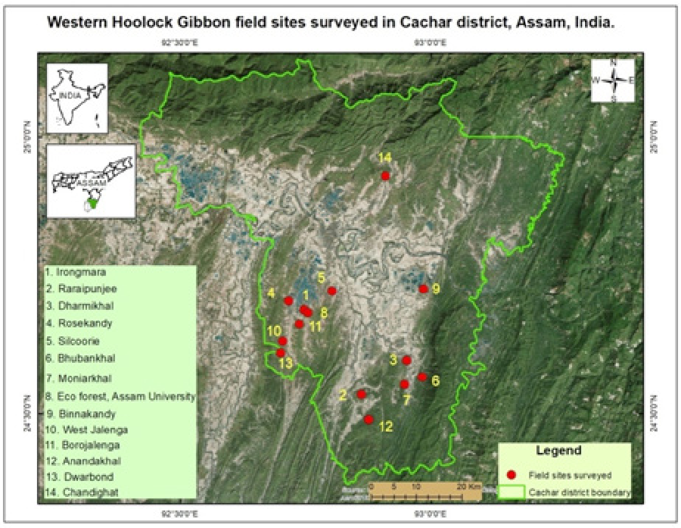
Although other primate species, such as rhesus macaque (*Macaca mulatta*), Phayre's leaf monkey (*Trachypithecus phayrei*), capped langur (*Trachypithecus pileatus*) and pig tailed macaque (*Macaca leonina*) were recorded from the above mentioned areas but no Western hoolock gibbon sighting could be confirmed neither any calls were heard. Fig. 2 shows the details of all the sites whereas Fig. 3 highlights the sites where Western hoolock gibbons were sighted or at least calls were heard.

Encounter rate

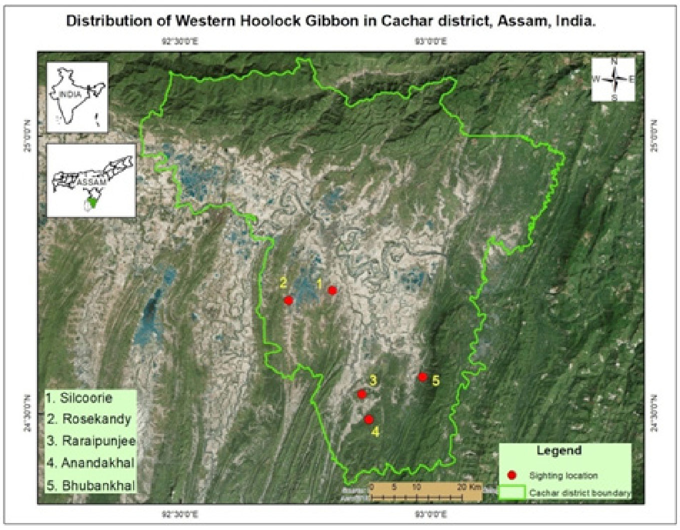
Most the forest patches in the present study were small, fragmented and with low forest cover. Western hoolock gibbons were recorded from only 5 of the 14 study sites. The encounter rate was 0.17 for 105 sq. km. survey area. The sites where most Western hoolock gibbons were encountered were in close proximity to a large forest. All the sites with no Western hoolock gibbon population were fragmented or semi-fragmented and some with high human habitation. Such habitats may not be able to support a sufficiently large gibbon population. Higher encounter rate is an indicator of healthy population of a species. The encounter rate from the present study also highlights low population and density of Western hoolock gibbons in the study sites.

Group Composition

Of all the encounters with nine Western hoolock gibbon groups and 1 solitary male, the age and sex profiles were as follows: 36 % adult males,



2: *Field sites surveyed for the presence of Western hoolock gibbons in Cachar district, Assam, India*



3: *Distribution of Western hoolock gibbons in Cachar district, Assam, India*

4: *A male Western hoolock gibbon in Cachar district, Assam, India*

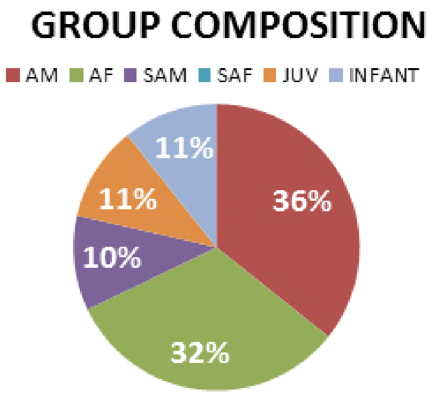
I: *Status of Western hoolock gibbons in Cachar district, Assam, India*

Sl. No.	Site	GPS Location	Area Surveyed	No. of Groups	No. of Encounters	Total Population	Mode
1	Irongmara	24°41′19.50″N 92°44′50.81″E	3.1 km	0	–	–	–
2	Raraipunjee VW	24°32′7.12″N 92°51′43.76″E	5.6 km	2	3	6	Song, sighting
3	Dharmikhal VW	24°35′46.53″N 92°57′5.55″E	4.1 km	0	–	–	–
4	Rosekandy TE	24°42′14.20″N 92°42′58.26″E	20.2 km	3	5	12	Song, sighting
5	Silcoorie TE	24°43′18.56″N 92°48′13.87″E	6.6km	1	1	1	Song, sighting
6	Bhubankhal VW	24°33′59.95″N 92°58′58.61″E	11 km	2	7	5	Song, sighting
7	Moniarkhal TE	24°33′12.08″N 92°56′49.79″E	11 km	0	–	–	–
8	Ecoforest of Assam University	24°41′0.19″N 92°45′17.63″E	3.4 km	0	–	–	–
9	Binnakandy TE	24°43′32.00″N 92°59′5.89″E	7.8 km	0	–	–	–
10	West Jalenga TE	24°37′54.40″N 92°42′16.94″E	6.3 km	0		–	–
11	Borojalenga VW	24°39′43.43″N 92°44′16.71″E	7.2 km	0		–	–
12	Anandakhal VW	24°33′14.51″N 92°55′42.56″E	7.9 km	2	2	4	Song, sighting
13	Dwarbond VW	24°36′34.92″N 92°42′2.55″E	4.2 km	0		–	–
14	Chandighat TE	24°55′48.18″N 92°54′33.86″E	6.8 km	0		–	–

* T E – Tea Estate, VW – Village Woodlot

32 % adult females, 10 % sub adult-males, 11 % juveniles and 11 % infants (Fig. 5). A total of 28 individuals were recorded from nine groups and 1 solitary male. No sub-adult female was recorded during the study period although it is assumed that the individual was missed or it may be a case of improper identification. The estimated adult sex ratio was 1.25 males: 1 female. In the current study, the group size ranged from 2 to 5 and mean group size was 2.8 ± 1.1. Out of the total population the immature class comprising of sub-adults, juveniles and infants made up to 34 % whereas adults formed 66 % of the population.

During the study, almost 90 % of Western hoolock gibbon individuals were recorded through direct methods owing to open and fragmented forests and only 10 % were recorded through indirect methods. The most diverse group was recorded from Rosekandy tea estate. Out of the three gibbon groups in Rosekandy, 3 individuals were adult males, 3 adult females, 2 sub-adult males, 2 juveniles and 2 infants. In the woodlots and nearby forested areas of Raraipunjee, there were 2 adult males, 2 adult females, 1 juvenile and 1 infant. No sub-adult male or sub-adult female was observed in Raripunjee. The two groups of Anandakhal consisted of 2 adult males and females. Out of the two groups observed in Bhubankhal, one group consisted of adult male and adult female only while the other group comprised of adult male, adult female with one sub-adult male (Tab. II).



5: *Average group composition of Western hoolock gibbons in Cachar district, Assam, India*

II: *Group size and group composition of Western hoolock gibbons in Cachar district, Assam, India*

Site	No. of Groups	AM	AF	SAM	SAF	JUV	Infant	Group Size
Silcoorie	1	1						1
Rosekandy	1	1	1	1		1	1	5
	1	1	1			1		3
	1	1	1	1			1	4
Dharmikhal	0							
Moniarkhal	0							
Binnakandy	0							
Irongmara	0							
West Jalenga	0							
Borojalenga	0							
Chandighat	0							
Dwarbond	0							
Anandakhal	1	1	1					2
	1	1	1					2
Bhubankhal	1	1	1	1				3
	1	1	1					2
Raraipunjee	1	1	1				1	3
	1	1	1			1		3
Ecoforest of Assam University	0							
Total	10	10	9	3	0	3	3	28

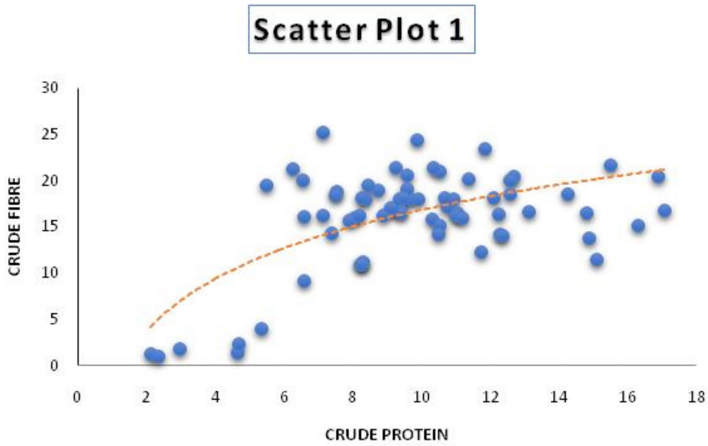
*AM – Adult Male , AF – Adult Female , SAM – Sub Adult Male, SAF – Sub Adult Male, JUV – Juvenile

Nutritional analysis

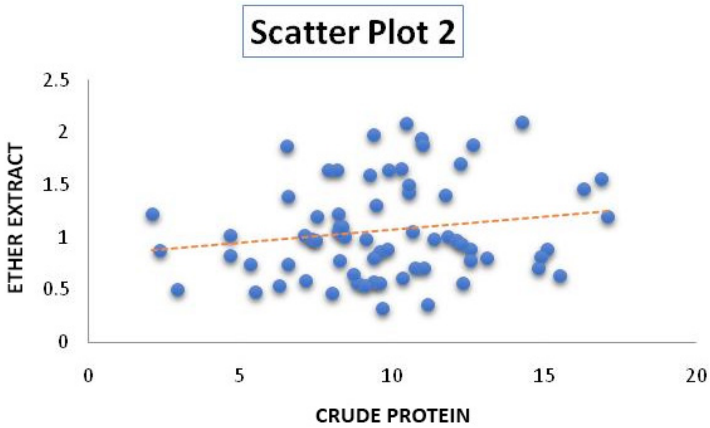
Nutritional status of food plants consumed by Western hoolock gibbons was analyzed and chemical composition was determined. Proximate analysis of 23 food plants was conducted where crude protein, crude fibre, NFE and ash contents were experimentally determined. Proximate analysis revealed the mean values of crude protein (9.73 ± 0.4), crude fibre (16.1 ± 0.6), ether extract (1.07 ± 0.06), NFE (66.24 ± 0.43) and ash (7.03 ± 0.27) in plant samples. ANOVA revealed that there is

		Crude Protein		Crude Fiber		Ether extract		Nitrogen Free Extract		Total Ash	
Sl. No.	**Plant Name**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
1.	***Ficus auriculata Lour.***	16.1400	1.0013	14.5467	2.6902	1.1833	0.2854	63.7900	2.0418	3.4067	1.3741
2.	***Dillenia pentagyna Roxb.***	7.9867	2.2244	17.9833	1.6381	0.4567	0.1168	66.4633	1.0887	5.8300	0.8542
3.	***Aegle marmelos L.***	9.8833	0.7321	17.7133	1.2143	0.7167	0.1401	69.4300	2.5811	6.6633	1.3835
4.	***Termenelia chebula Retz.***	7.9467	0.7969	17.0967	1.6992	0.5700	0.0917	69.9167	1.8523	3.8533	0.7357
5.	***Termenalia bellerica Roxb.***	8.4233	1.2379	18.3367	1.8299	1.3967	1.0537	67.1533	2.6358	8.3867	4.4056
6.	***Ficus glomerulata Roxb.***	10.6600	1.7545	17.1100	1.3374	1.1800	0.4187	66.5500	1.0860	8.2800	0.8147
7.	***Garcinia cowa Roxb.***	10.5567	1.2307	20.8767	2.7486	1.0800	0.3208	68.8933	2.3889	6.1767	0.7106
8.	***Mikania micarantha Kunth***	3.2233	1.2952	1.5533	0.2650	0.9167	0.3758	63.6800	2.0499	8.8700	1.6010
9.	***Ficus racemosa Vahl.***	14.1233	1.7859	18.8433	2.5981	0.7733	0.1739	65.1833	1.5487	9.0667	2.3066
10.	***Albizia lebbek Benth***	11.2133	2.5826	14.0633	2.7184	0.8400	0.0872	62.6933	1.6020	7.3600	0.7111
11.	***Eleocarpus floribundus Bl.***	12.7400	1.9476	14.8700	1.4936	0.7000	0.1253	65.6367	2.9319	3.5733	0.6726
12.	***Atrocarpus lakoocha Roxb.***	14.0167	2.9813	19.0367	1.2757	1.8700	0.2787	63.8033	1.4066	6.9033	2.1024
13.	***Ficus hispida Vahl.***	7.8200	1.7749	23.2467	2.7937	1.2600	0.5323	63.6567	2.5413	6.8800	1.5566
14.	***Ziziphus jujube Lamk.***	9.0267	1.6992	14.3367	2.8692	1.5333	0.4271	71.7467	1.3274	4.7167	0.5260
15.	***Syzygium fruticosum DC.***	4.10	1.58	2.52	1.49	0.82	0.07	66.06	1.23	8.50	1.64
16.	***Tamarindus indica***	7.39	0.84	11.55	2.61	1.16	0.21	73.84	2.56	5.27	1.39
17.	***Castonopsis indica DC.***	8.77	1.97	18.58	2.71	0.89	0.37	66.78	2.50	10.23	2.74
18.	***Mangifera sylvatica Roxb.***	10.08	2.28	19.97	1.71	1.53	0.40	65.98	2.11	9.38	0.96
19.	***Emblica officianalis Gaertn.***	10.93	1.73	17.72	2.17	0.56	0.21	66.31	2.51	6.56	1.94
20.	***Psidium guajava L.***	7.30	0.97	18.70	2.57	1.05	0.56	68.45	2.44	8.31	1.20
21.	***Spondias pinnata Kurz.***	11.49	0.89	14.67	2.04	1.53	0.15	63.77	2.13	7.43	0.73
22.	***Ficus heterophylla L.f. Supl.***	10.52	0.90	19.69	1.32	0.87	0.27	59.17	1.77	9.24	1.16
23.	***Ficus benghalensis L.***	9.52	1.16	16.83	2.23	1.65	0.44	64.48	2.85	6.69	1.56

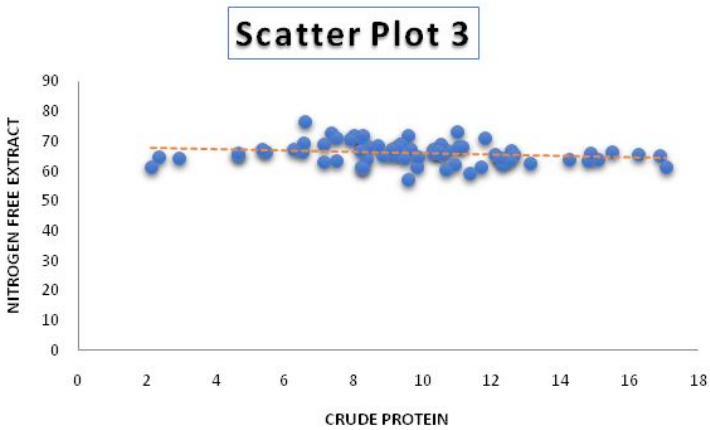
6: *Proximate analysis of food plants consumed by Western hoolock gibbons in Cachar district, Assam, India*



7: *Correlation between crude protein with crude fibre (r = 0.47)*



8: *Correlation between crude protein and ether extract (r = 0.17)*



9: *Correlation between crude protein and NFE (r=0.17)*

significant interaction between the plant fractions ($p < 0.05$). But no significant difference was observed between the means of the observation grouped by content ($p > 0.05$). Higher protein content in plant were correlated to higher crude fibre content in plants ($r = 0.48$), which can be considered as a moderate positive relationship. But it was observed that the correlation of crude protein with ether extract and NFE were not significant. This showed the relationship between these fractions and the food plant selection and feeding pattern of gibbons. NFE provides an estimate of crude starch and sugar content of a feed.

Being a territorial species, the daily requirement of energy is high which is fulfilled by consuming fruits with high energy content. Gibbons prefer ripe fruits over the unripe ones which also indicate the need for high energy food. The high sugar content also provides energy in morning calling bouts which is an important activity of the day.

Scatter plots were generated to further understand the relationship between various other fractions of plants analyzed. Scatter plots show how much one variable is affected by another. Proximate analysis revealed that the Western hoolock gibbons selected plants with a higher protein-to-fibre ratio.

Perception towards conservation among local communities and threat analysis

To understand the perception of local communities towards conservation of biodiversity and Western hoolock gibbons in particular, a perception study was conducted by interacting with local community and village headmen living in the fringe areas of Western hoolock gibbon habitats. Through interaction the sentiments of local communities and how they perceive conservation initiatives was understood. It was found that local communities responded positively towards conservation when they did not experience any conflict with wild animals. The findings indicate that biodiversity conservation depends on educational level of participants and their understanding of ecosystem services. Although local communities agreed that forest must be conserved but they also reiterated the need for alternative livelihood options. Interaction with the local communities was helpful in analyzing the threats towards Western hoolock gibbons.

Via community interaction it was noted that the anthropogenic presence such as timber felling, fuelwood collection, slash and burn cultivation, tea estate expansion, livestock grazing and non-timber forest product collection were major threats to the habitats of Western hoolock gibbons. The present study noted the evidences of hunting and trapping of deer, turtle, monkeys and birds. Local villagers also believe in the medicinal properties of primate bones which are either used as amulets or powered and consumed in small amounts. However, no direct evidence of hunting or killing of Western hoolock gibbons was recorded in this study. Based on the observations of the present study, the following specific threats to Western hoolock gibbons conservation in the Cachar district were identified.

I) Habitat destruction and horticulture: Expansion of tea estates and agriculture are two primary reasons for shrinkage of habitats of Western hoolock gibbons in Cachar district. Tree lopping and felling for timber collection resulted in poor habitat quality. Slash and burn or shifting (*jhum*) cultivation for agriculture has been recorded in Bhubankhal village woodlot. Apart from agriculture, cultivation of betel vine for betel leaves (*pan jhum*) was recorded in Anandakhal village woodlot.

II) Expansion of tea estates: Cachar district has a vibrant tea industry with 56 tea estates most of which were established during the colonial period after clearing large tracts of forests thereby entrapping several animal species including Western hoolock gibbons. As observed in the present study, isolation of Western hoolock gibbons in small forest fragments inside two study sites namely Silcoorie and Rosekandy tea estates have left the gibbons in vulnerable position where they are experiencing a slow and steady extirpation. Four other tea estates included in the present study have plans for future expansion implying further fragmentation of habitats of Western hoolock gibbons.

III) Harvesting of non timber forest products: Extraction of non timber forest products was noted from forest patches where Western hoolock gibbons were present. This acts as a major threat as it hampers the habitat quality. Local communities residing in Raraipunjee, Bhubankhal and Anandakhal village woodlots depend upon forest products like cane and bamboo for their livelihood. They weave cane and bamboo into open storage baskets, lidded baskets, winnowing fans, fish traps, sleeping mats, etc. which are in turn sold in nearby weekly markets.

DISCUSSION

Across its distribution, Western hoolock gibbon experiences fragmented habitats in Cachar district of Assam, India. It is very important to understand the fundamental link between this species and its habitat for formulation of effective conservation plans (Das *et al.*, 2005, Ray *et al.*, 2015). The habitat of Western hoolock gibbons in Cachar district includes forest patches inside tea estates, village woodlots near forest fringes and small tree cladded areas which are in contrast to the reported habitats of Western hoolock gibbons in other parts of India that are tropical and subtropical evergreen, tropical wet evergreen, tropical semi-evergreen, tropical moist deciduous, and sub-tropical hill forests (Kumar *et al.*, 2009). The forests of Cachar district have historically been ill-utilized and misappropriated especially during the British colonial rule and hardly any management strategy was adopted by the Indian government since then in order to maintain these forests as functional ecosystems. The Forest Report of Cachar district provides an historical insight where these forests once were one of the main sources of timber in Sylhet district and other parts of erstwhile undivided Bengal prior to the partition of India and erstwhile East Pakistan (now Bangladesh) in 1947. Selective felling of trees caused irreparable damage where all aspects of silviculture and regeneration were overlooked. Accompanied by increased anthropogenic pressure the populations of Western hoolock gibbons have borne the brunt of continuous habitat destruction in Cachar district over the past several decades.

The status and distribution of Western hoolock gibbons in the entire Cachar district is not conclusive. For effective conservation and management of threatened and endangered species, specific knowledge about their ecology, actual distribution and group size are important and absence of such information acts as a barrier in forming well-organized strategies. In the present study, 28 Western hoolock gibbon individuals from 5 locations in Cachar district were reported. One solitary male was recorded from a very small tree cladded area in Silcoorie tea estate. A study conducted inside Inner-line Reserve Forest of Cachar district earlier recorded 10 families with 33 individuals of Western hoolock gibbons which provided data for only one of the protected areas of Cachar district (Islam *et al.*, 2013a, b).

In this study, the male and female Western hoolock gibbons were recorded making territorial calls early in the dusk hours which demonstrated their expected calling activity. The highest number of groups was recorded from Rosekandy tea estate where nearly 20 km area was covered by the forest fragment. The forest patches in Bhubankhal and Anandakhal village woodlots were undulating and remained inundated during the monsoon season. During rainy season, Western hoolock gibbons avoided the forest patch and moved towards interior areas of Sonai reserve forest in Cachar district. Apart from Western hoolock gibbons, some other primate species were also documented during the study period. Phayre's leaf monkey (*Trachypithecus phayrei*) was recorded from Ecoforest of Assam University campus and Silcoorie tea estate. Rhesus macaque (*Macaca mulatta*) was recorded from all the study sites. It was also observed that the village woodlots adjacent to forested areas acted as the boundary for Western hoolock gibbon groups. In Bhubankhal village woodlot, a Himalayan mango tree (*Mangifera sylvatica*) was regularly visited by a Western hoolock gibbon group. This solitary tree was an important fruit tree as a number of feeding bouts were recorded. During the study period itself the mango tree was cut down for construction activity and after this incident, the Western hoolock gibbon group stopped visiting the site.

In our study, the mean group size of Western hoolock gibbon troops in Cachar district was found to be 2.8 ± 1.1. This mean group size is comparable to the mean group size of 2.5 which was reported from small fragmented forests of eastern Assam (Kakati *et al.*, 2009). Mean group size of Western hoolock gibbons in Cachar district has been found to be smaller when compared with average mean group size from the entire state of Assam which is 3.2 (Das *et al.*, 2009). Similar to the present study, Kumar *et al.* (2009) reported a mean group size of 2.5 individuals for 20 groups from Arunachal Pradesh. A considerably small mean group size of 2.1 for 34 groups in Tripura was also reported (Gupta, 1994). Mean group size of 3 to 3.2 for 6 to 10 groups (Mukherjee, 1982) and 3 for 42 groups (Alfred and Sati, 1990) were reported from Meghalaya. Studies from large forests reported a higher mean group size of 3.1 for 8 groups and 3 for 14 groups (Choudhury, 1990, Choudhury, 1991) in Assam and 2.9 for 13 groups in Bangladesh (Feeroz and Islam, 1992). The reported mean group size from large forests and protected areas are higher because of the contiguous tropical forests with fewer disturbances. A study spanning 8 years in northeast India documented fewer numbers of immature individuals in comparison to adults where Western hoolock gibbons were surviving in a sub-optimal habitat. Habitat loss resulting in poor forest quality and hunting were identified as prime threats (Srivastava and Mohnot, 2001). Thus, the mean group size in Cachar district indicates sub-optimal habitat for gibbons in most of the sites studied.

Proximate analysis also revealed that the Western hoolock gibbons selected plants which have a higher protein-to-fibre ratio and a significant correlation was noted. It has been observed that higher protein content in plant correlates to higher crude fibre content in plants. Moreover, a significant interaction between different plant fractions was observed. As this species is a frugivore, the fibre from leaves is generally avoided due to high secondary metabolites. This shows that correlation between these two analysis fractions influences food selection and feeding pattern.

The fruit eating primates therefore, have to solve the challenge of locating ripe fruit crops that are often sparsely distributed in the tropical forest both in space and time. Moreover, searching for rare fruit trees is likely to be insufficient because detection distances for fruit crops are probably short. But in the studied fragmented forest patch, Western hoolock gibbons ate a mixed 'frugi-foli' diet which shows that fruit consumption is not satiating the nutritional demands of the body.

Over the course of evolution, extinctions are generally viewed as an expected biological phenomenon with available data of both mass and local extinction with reference to time. But in recent times extinction is believed to progress at an alarming rate (Blaustein *et al.*, 1994). Western hoolock gibbons have now become dependent on human interventions for survival after experiencing a serious decline in preceding decades (Walker and Molur, 2007). The protected and the unprotected areas of Cachar district need to be declared as priority landscape areas for Western hoolock gibbon conservation. One of the key elements which may help in the long-term conservation is to replicate models for the reduction in dependency of local inhabitants for timber and non-timber forest products. Villagers living in the fringe areas of forests are generally poor and depend directly on forest resources for their livelihood. Timber and non-timber forest products have also been reported as a critical threat inside Inner Line Reserve Forest of Cachar district which borders the present study site (Islam *et al.*, 2013a). Furthermore, due to loss of fruiting and roosting trees, the forest patches of Cachar district have become relatively unviable in terms of habitat quality (Das *et al.*, 2009).

In conclusion, Western hoolock gibbons as well as a number of other primate species were recorded in fragmented habitats particularly in tea estates with low density and group size. Such population reduction in primates may have genetic consequences such as increased genetic drift which may ultimately lead to decreased genetic diversity and inbreeding depression (Molur, 2005, Osada, 2015). In this regard, immediate identification and translocation of Western hoolock gibbons from the fragmented areas such as tea estates to a viable habitat may provide a major impetus to their survival and conservation in Cachar district.

CONCLUSION

Lack of empathy among the local inhabitants and low awareness regarding the ecosystem services provided by wild animals are major impediments for Western hoolock gibbon conservation across its geographical range including all the study sites in Cachar district of Assam, India. The involvement of local communities in this regard is extremely crucial. The Government of India has played a leading role in defining the United Nations Sustainable Development Goals (SDGs) which are universal goals with local implications and intervention possibilities. The 15th goal of this framework aims to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". To fulfill these SDGs, the Government of India has involved the village councils (*gram panchayats*) to develop *Gram Panchayat* Development Plans which are in accordance with universal SDGs.

The present study recommends preparation of a Local Biodiversity Conservation Plan along with *Gram Panchayat* Development Plans highlighting the conservation strategies of local biodiversity within the jurisdiction of respective village councils. Involvement of village councils is expected to ensure participation of local villagers and awareness at the community level. Formulation of Local Biodiversity Conservation Plan is also likely to create awareness among villagers particularly in areas where dependency on local villagers on extracted bio-resources from forests is very high. This is the case in Cachar district in the study sites Rosekandy tea estate, Bhubankhal and Anandakhal village woodlots. Formulation of new conservation plans as mentioned above is very likely to help create awareness on the scale of biodiversity loss and also conduct assessments not only among forest fringe villages but also tea estates labourers, such as in Rosekandy and Silcoorie wherein a number of wild fauna including Phayre's leaf monkey and pig tailed macaque have been reported. Such awareness on biodiversity loss will encourage the local communities to demarcate remaining forest patches as reserve forests or sacred groves. The plan should aim at providing a chance to local villagers to assess and manage the biodiversity around them and find local solutions. The outcome of such plan will help formulate a Biodiversity Register for each village council which will further assist in identification of endangered biota and raise much needed awareness. The Local Biodiversity Conservation Plan also envisages on generating alternate livelihoods for labour engagement. Rural communities living in fringe forests such as Raraipunjee, Bhubankhal and Anandakhal village woodlots are entirely dependent upon bio-resource extraction for their livelihood and can be involved in skill training programmes such as India's *Pradhan Mantri Kaushal Vikas Yojana* as well as linking the community to National Skill Development Agency. Youths from tribal communities from some study sites, for example, Raraipunjee, Bhubankhal and Anandakhal village woodlots may also be trained as nature guides thereby creating employment in eco-tourism.

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2

Two sentences in the Statistical Analysis section werw misleading, correct form is:
Pearson's correlation coefficient was used to analyze the relationship between the five fractions of plants consumed by Western hoolock gibbons. The Two way ANOVA was used to assess the relation and interaction between different plant contents. Scatter plots were created using statistical package MS-Excel.