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The day range and home range of the Eastern Hoolock Gibbon *Hoolock leuconedys* (Mammalia: Primates: Hylobatidae) in Lower Dibang Valley District in Arunachal Pradesh, India

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Abstract: This paper presents the findings of a study conducted on the Eastern Hoolock Gibbon *Hoolock leuconedys* in Mehao Wildlife Sanctuary and outside to the south of the park, Arunachal Pradesh, India investigating the daily path length (DPL) and home range used by the species in two forest areas with different disturbance gradients. The four habituated groups of *H. leuconedys* in fragmented and contiguous forest areas, two groups in each of the forest types, showed considerable variation in their DPL ranging from 6.59m to 1019.01m with a mean distance of 192.75m (SE = ±26.48) in 73 full day observations. Although the mean DPL was recorded with very little variation across the seasons in both the forest types, it was significantly different from fragmented forest. Similarly, the home range size also varied among the groups and was estimated as the maximum for Group D (24.62ha) followed by Group E (16.28ha) in contiguous forest and Group B (2.49ha) and Group A (1.09ha) in fragmented forest. Also, there was a distinct seasonal pattern of home range used by all the study groups with largest seasonal home range in monsoon and pre-monsoon season in fragmented and contiguous forest respectively. The DPL and home range of *H. leuconedys* in Arunachal Pradesh has been highly affected by forest fragmentation and/or canopy discontinuity which makes the species vulnerable to hunting, predation by feral dogs and hawks and ultimately local extinction. Thus, the findings of the present research evoke the question of long term survival of the species in fragmented forests.

Keywords: Contiguous forest, fragmented forest, Mehao Wildlife Sanctuary, movement pattern.

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Author Details: Dr. Kuladip Sarma has completed his doctoral research on ecology of eastern hoolock gibbon from Department of Forestry, NERIST and currently pursuing his post-doctoral research from University of Gauhati. He is interested on ecoloical conservation of threatened mammals of northeastern India. Dr. Awadhesh Kumar, an Associate Professor, Department of Forestry, NERIST has been working on primates and other threatened mammals of northeastern India. His interest lies in ecological processes related to wildlife and forest management under the umbrella of forestry research.

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INTRODUCTION

Movement patterns in primate groups are restricted to a limited area and they are highly influenced by the distribution of resources in time and space (Milton 1980; Sigg & Stolba 1981). The patchy distribution of fruits and their abundance in any forest at a given time has a major impact on the ranging behaviour of frugivorous primates. Also, the degree of frugivory, behavioural and dietary plasticity and the ability to utilize the matrix habitat are the key features which decide whether primates can live in forest fragments (Estrada & Coates-Estrada 1996; Lovejoy et al. 1996; Tutin & White 1999; Onderdonk & Chapman 2000; Marsh 2003). Essentially, the range requirement of a particular primate species influences the survival rate in forests of different disturbance gradients. For example, primates with small home ranges may survive better in fragments than those with large range requirements; on the contrary home range dispersion pattern of a species might be altered in a fragment (Kakati 2004). Other factors cited as potential determinants of ranging behaviour in primates include rainfall (Olupot et al. 1997), group size (Ostro et al. 1999), reproductive condition (Overdorff 1993), water availability (Chapman 1988), locations of sleeping sites (Harrison 1983), intergroup relationships (Kinnaird 1992), and parasite avoidance (Hausfater & Meade 1982).

The genus *Hoolock* comprises two distinct species, the Eastern Hoolock Gibbon *Hoolock leuconedys* and the Western Hoolock Gibbon *Hoolock hoolock* which have been separated based on differences in fur coloration (Mootnick & Groves 2005; Geissmann 2007). *Hoolock leuconedys* was earlier known to be distributed east of the Chindwin River to the Salween River in Myanmar and southwestern Yunnan Province in China at an altitudinal range of 1067m to 1219m (Groves 1971) until it was reported from Arunachal Pradesh, India by Das et al. (2006). *Hoolock leuconedys* has been reported to occur in India between the Lohit River in the north and the high altitude mountain of Dafa bum in the south (Das et al. 2006). The species, however, was reported from the lower Dibang Valley (Chetry et al. 2008) and Mehao Wildlife Sanctuary (Chetry et al. 2010). Recently, the species was also found to occur in Sadiya Division, the easternmost part of Assam, south of Dibang-Brahmaputra River system (Chetry & Chetry 2010).

The Hoolock Gibbon is a territorial species with a group occupying a home range area of 22–35 ha in size on average, and defending a major part of it (77–95 %) as an exclusive territory (Tilson 1979; Gittins & Akonda 1982; Ahsan 1994; Alfred & Sati 1990; Feeroz & Islam 1992). Das (2002) and Kakati (2004) have studied the home range of *Hoolock hoolock* in different disturbance gradients with special reference to northeastern India. Kakati (1997, 2004) has addressed the impact of fragmentation on range use of *H. hoolock* in various forest fragments of Assam. Further, Kakati (1997) stated that gibbon groups in a small fragment occupy small home ranges (4.8ha and 7.1ha) resulting chiefly from the groups being unable to access several pockets of trees due to the discontinuous canopy. Other studies reported were merely on the comparison of the home range size of two or more groups in the same habitat (Ahsan 2004). While among the other gibbon species of Southeast Asia, Lar Gibbon is the most studied (Raemaekers 1979; Bartlett 1999, 2009) followed by Kloss's Gibbon (e.g., Whitten 1982) and others (e.g., Ganas & Robbins 2005; Zhou et al. 2007; Kim et al. 2011). A few studies were carried out on the genus *Hoolock* to document its ranging pattern in Bangladesh, China and India (Feeroz & Islam 1992; Ahsan 2001; Kakati 1997, 2004; Das 2002; Fan et al. 2013), although the range use pattern of *H. leuconedys* has not been studied in India earlier. This study, therefore, emphasizes the ranging behaviour of *H. leuconedys* in two habitats of different disturbance gradients and different sizes.

Study Sites and Study Groups

The present study was conducted in Mehao Wildlife Sanctuary (MWS) near the southern boundary and outside the sanctuary at Horupahar and Delo area in Lower Dibang Valley District of Arunachal Pradesh (Fig. 1). MWS covers an area of 282km^2 whereas the lower reaches of the sanctuary which is an Unclassified State Forest covers c. 500km^2 area including Horupahar and Delo. Four social groups of Eastern Hoolock Gibbon were selected for the study, two in MWS which has a contiguous forest and two in Horupahar and Delo areas which are characterized by fragmented forests. The fragmented forest areas are located outside MWS and are 5-7 km away from the southern boundary of MWS. These sites are unclassified forests and lie between 27^{0}58'30"–28^{0}03'38"N & 95^{0}50'30"–95^{0}58'18"E and altitude ranges from 145–390 m (Fig. 1). The major forest types recorded in the area are low hills and plains semi-evergreen forest, Assam alluvial plains semi-evergreen forest 2B/CIa and sub Himalayan light alluvial evergreen forest 2B/CI/ISI (Kaul & Haridasan 1987; Champion & Seth 1968).

Field work was carried out from October 2010 to March 2013. A preliminary population census and

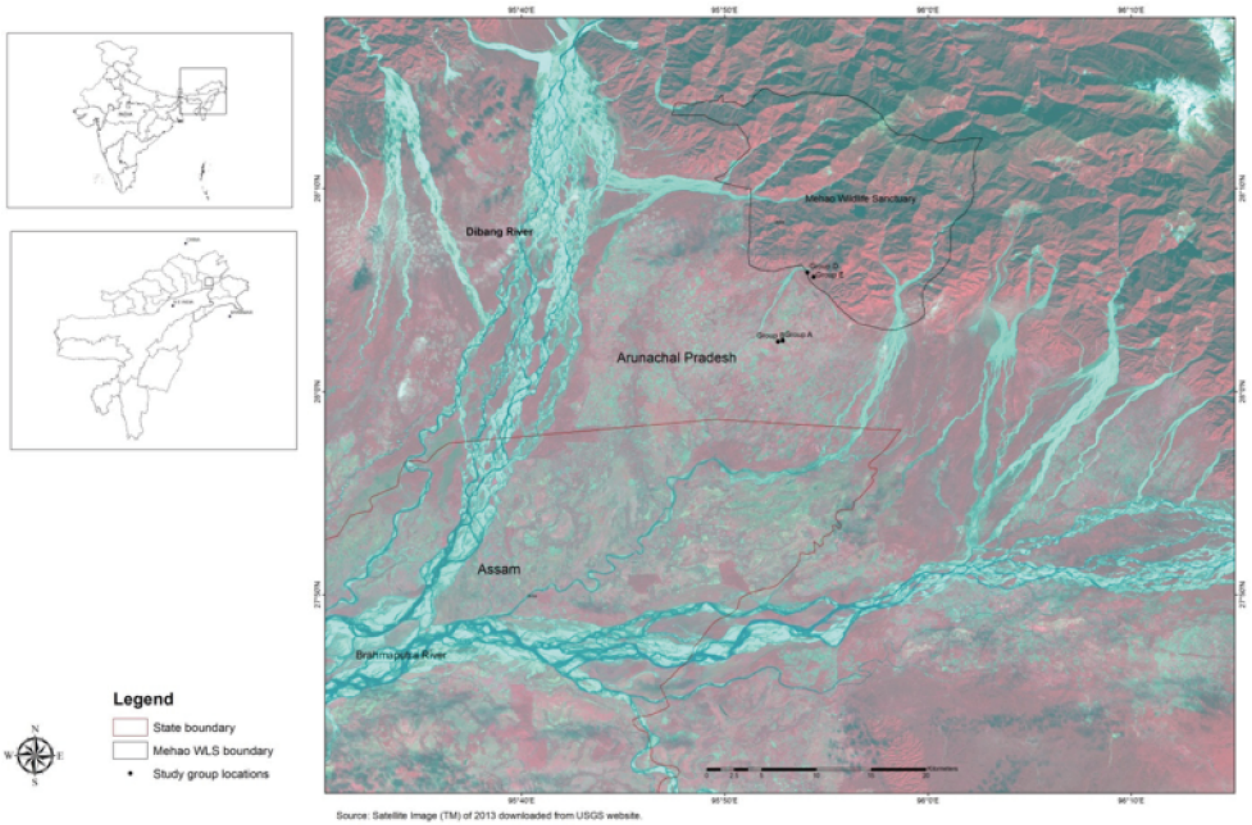

Figure 1. Map of the study area showing the locations of study groups.

distribution survey commenced prior to the selection of gibbon groups for behavioural observations (e.g., Sarma et.al. 2015). Four Eastern Hoolock Gibbon social groups, viz., Group A and Group B in fragmented forest patches and Group D and Group E in contiguous forest patches with the home range in the study area were habituated and selected for intensive study (Images 1–6). The detailed age-sex composition of the study groups is presented in Table 1. The intensive study was conducted between January 2012 and February 2013.

METHODS

The locations of the focal animals during travel and feeding were taken with a hand held Garmin e-Trex 30 global positioning system (GPS), set to the WGS 84 grid system. During the location sample, the tree occupied by the focal animal was marked by flagging tape and subsequently relocated and mapped relative to the trail system using 30m measuring tape and compass. The location sample of the known feeding and lodging trees were also combined with the 30 minutes location samples and the home range size was calculated using the home range module of ArcGis 9.3 by drawing a minimum convex polygon around the cumulative day ranges of each social group. Same location samples in a given day were discarded and not used in the analysis. Groups in contiguous forests were followed for 11 months each (31 full days) as it was difficult to find gibbons because of the large home range and a low frequency of calling (Zhang et al. 2014). However, the two study groups in fragmented forests were followed for a consecutive 12 months (42 full days) as the topography was quite accessible. The sample size was comparable to most gibbon studies regarding ranging patterns (Gittins 1982; Whitten 1982; Islam & Feeroz 1992; Ahsan 2001; McConkey & Chivers 2007; Bartlett 2009; Fan & Jiang 2008; Kim et al. 2011) and other primate studies (Kaplin 2001; Zhou et al. 2007). The locations and duration of all group encounters and vocalizations were recorded in field notebooks.

Data Analysis

The Daily Path Length (DPL) was calculated from full-day observations (N = 73) as the sum of the straight-line distances (in meters) between consecutive GPS points via Arc Map 9.3. Later, the home range size was

Image 1. Fragmented habitat.

Image 2. Fragmented habitat surrounded by agriculture field.

Image 3. Adult male gibbon walking on branch during dispersal.

Image 4. Adult female gibbon resting during mid-day.

Image 5. Adult female on dispersal mode.

Image 6. Adult male and female resting together during mid-day.

calculated in Arc Map 9.3. using an extension tool home range by drawing minimum convex polygon around the cumulative day ranges of each study group. The total home range is defined here as the area included within a minimum convex polygon encompassing all locations recorded in each seasons (seasonal home range size)

Table 1. Group structure of the selected study groups of *H. leuconedys*.

Forest quality	Group ID	Total no. of individuals	Age/sex composition					
			Adult Male	Adult Female	Sub-adult Male	Sub-adult Female	Juvenile	Infant
Contiguous	Group-D	2	1	1	-	-	-	-
	Group-E	3	1	1	-	-	-	1
Fragmented	Group-A	3	1	1	-	-	-	1
	Group-B	3	1	1	-	-	-	1
Total		**11**	**4**	**4**	-	-	-	**3**

and throughout the study (total home range size) (e.g., Kaplin 2001; Zhang et al. 2014). Home range and DPL were analysed in four seasons, viz., Winter (December–February), Pre-monsoon (March–May), Monsoon (June–September) and Retreating monsoon (October–November) following Borthakur (1986). All statistical analyses were performed using SPSS 16.0 for Windows.

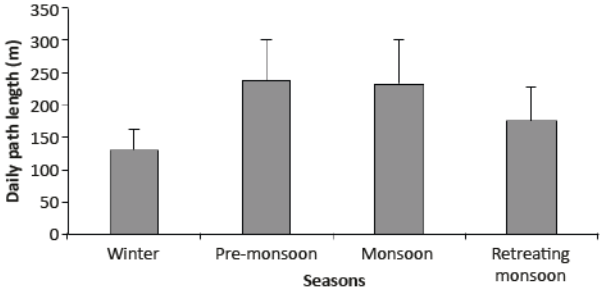

Figure 2. Total daily path length across different seasons of the year.

RESULTS

Daily path length

The daily path length (DPL) of the four study groups varied from 6.59m to 1019.01m with a mean distance of 192.75m (SE = ±26.48) (Table 2). However, DPL was significantly different among the four groups (F = 49.79; df = 3; p<0.01) and it was much smaller in fragmented forests (mean = 37.42; SE = ±3.86) in comparison to that of contiguous forests (mean = 410.21; SE = ±36.01). Although, the mean DPL was recorded with very little variation across the seasons in both the forest types (Table 3), it was significantly different in fragmented forest (F = 3.54; df = 3; p<0.05). The mean DPL of the four study groups was found to be the highest in the pre-monsoon season (237.82; SE = ±61.58) followed by the monsoon (231.60; SE = ±66.51) and the retreating monsoon seasons (175.21; SE = ±50.90). The lowest DPL was recorded in the winter season (130.95; SE = ±28.93) (Fig 2).

Table 2. Mean of daily path length (DPL) with minimum and maximum values of four study groups in fragmented and contiguous forests.

Groups*	Mean DPL (m) ± SE	Minimum	Maximum
Fragmented forest			
Group A	36.09±5.85	6.59	96.64
Group B	38.75±5.15	7.36	115.46
Average	37.42±3.86	6.98	106.05
Contiguous forest			
Group D	440.67±65.03	169.27	1019.01
Group E	375.40±21.14	266.19	531.32
Average	410.21±36.01	217.73	775.17
Total	192.75±26.48	6.59	1019.01

*ANOVA; F = 49.79; df = 3; p < 0.01

Home range size

The Home range size greatly varied among the groups and the estimated maximum size was for Group D (24.62ha) followed by Group E (16.28ha) in contiguous forests and Group B (2.49ha) and Group A (1.09ha) in fragmented forests (Figs. 3a &3b). Both the home range size and DPL were found to be higher in contiguous forests in overall estimates in a year (Fig 4). The home range estimated seasonally was found to be the highest during the monsoon season by both groups in fragmented forests (0.58ha for group A and 1.59ha for group B), whereas in contiguous forests, the home range in the pre-monsoon season was found to be the highest for both the groups D and E (11.78ha and 9.53ha respectively) (Table 4). The seasonal home range was found to be significantly different among the groups (Chi square = 11.41; df = 3; p<0.05).

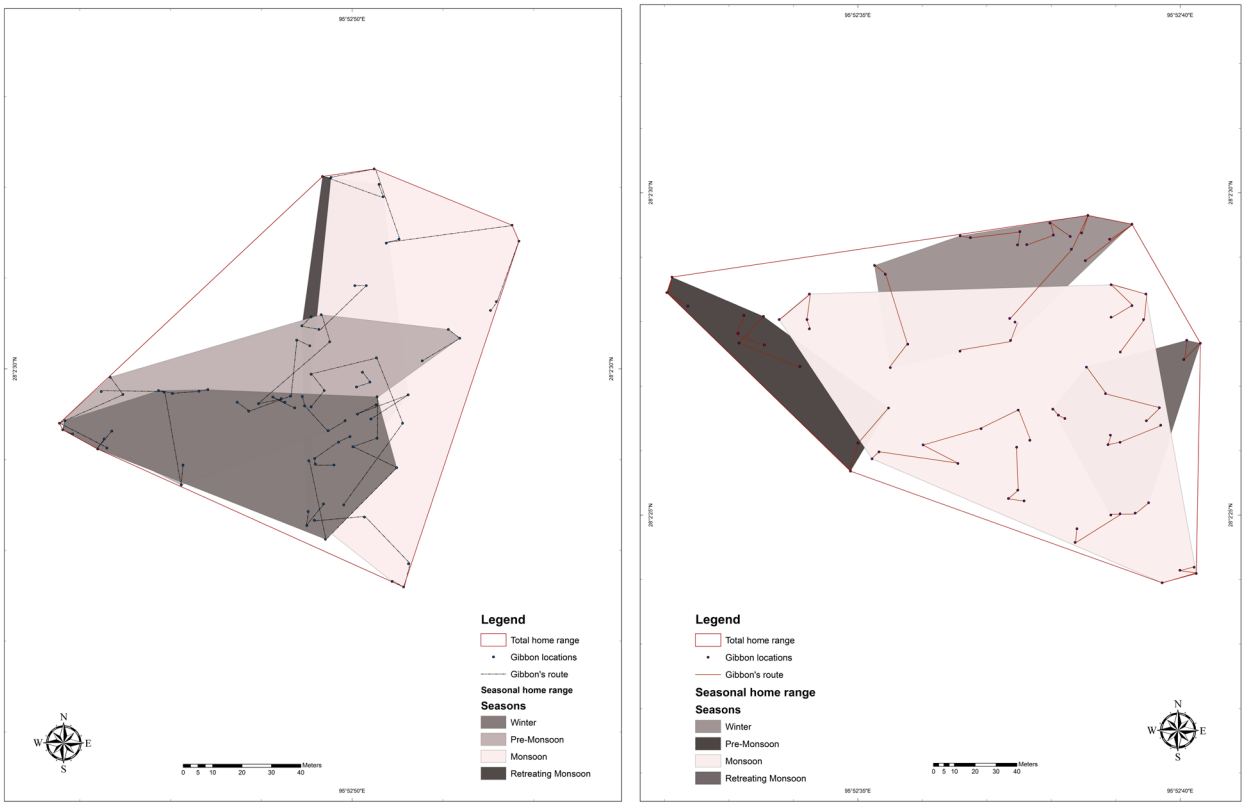

Figure 3a. Home range of Group A (left) and Group B (right) showing seasonal pattern in different shades.

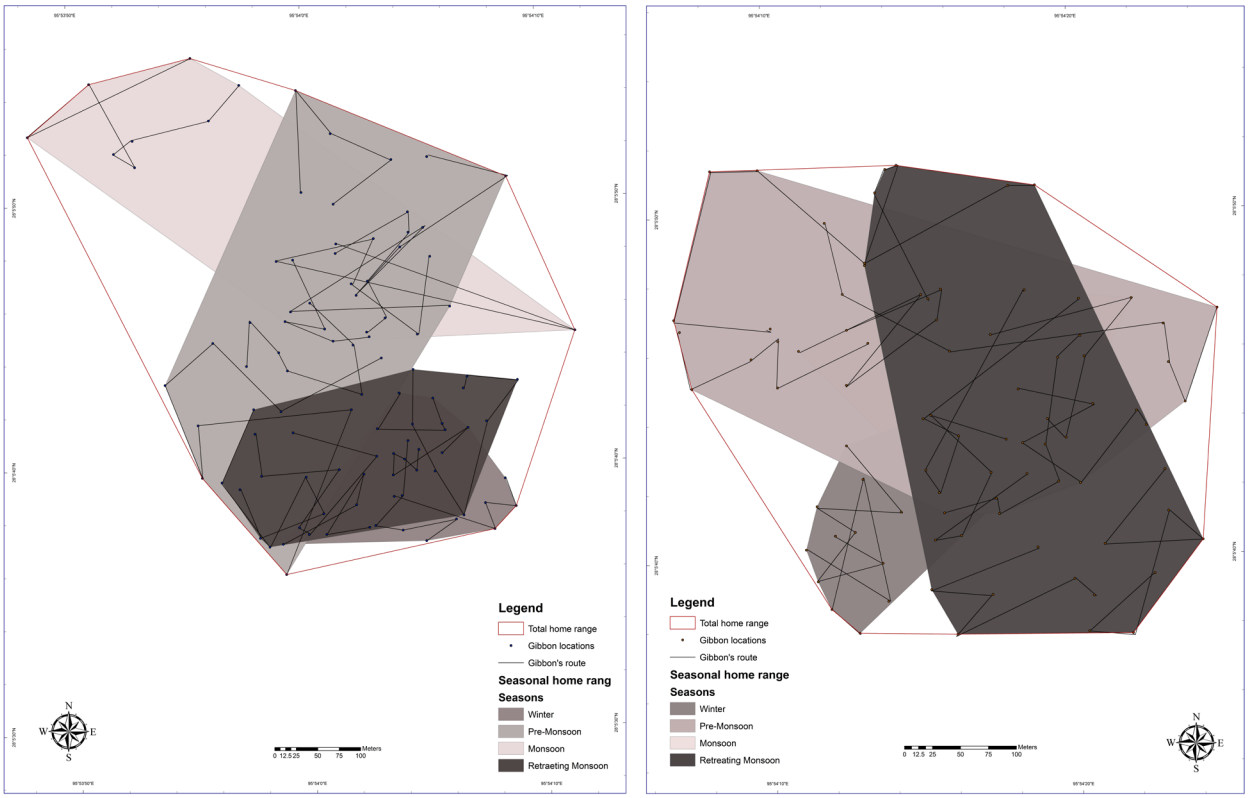

Figure 3b. Home range of Group D (left) and Group E (right) showing seasonal pattern in different shades.

Table 3. Mean daily path length (DPL) in fragmented and contiguous forests across the seasons of the year.

Season	Mean DPL±SE	Minimum	Maximum
Fragmented forest			
Winter	34.84±7.74	6.59	96.64
Pre-Monsoon	35.32±4.46	18.29	58.52
Monsoon	56.11±9.97	24.91	115.46
Retreating Monsoon	23.91±4.10	7.36	47.66
Overall mean	37.42±3.86	6.59	115.46
Contiguous forest			
Winter	275.10±24.32	169.27	362.03
Pre-Monsoon	462.81±77.25	266.19	883.56
Monsoon	482.30±103.08	239.44	1019.01
Retreating Monsoon	427.36±18.06	348.39	467.31
Overall mean	410.21±36.01	169.27	1019.01

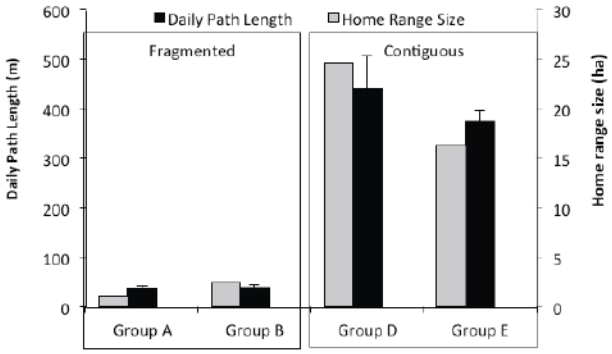

Figure 4. Daily path length and home range size of four study groups.

Table 4. Seasonal home range, estimated by minimum convex polygon method, used by *H. leuconedys* groups and their percentage contribution to total home range.

Seasons	Group A		Group B		Group D		Group E	
	Home Range (ha)	% Contribution to total home range	Home Range (ha)	% Contribution to total home range	Home Range (ha)	% Contribution to total home range	Home Range (ha)	% Contribution to total home range
Winter	0.31	28.70	0.44	17.79	2.84	11.53	2.15	13.23
Pre-monsoon	0.36	33.06	0.26	10.53	11.78	47.84	9.53	58.53
Monsoon	0.58	53.47	1.59	63.81	9.35	37.99	3.29	20.24
Retreating monsoon	0.26	23.59	0.30	12.09	4.95	20.09	8.40	51.59

DISCUSSION

The results of the present study have shown that the daily path length of the groups in fragmented forests is much shorter than that in contiguous forests. The reason may be distantly located forest patches which make dispersal of the gibbon more troublesome in fragmented forests in particular. Severe canopy loss in the fragmented forests in Lower Dibang Valley district had been reported by Sarma et al. (2015). Similar results have also been reported for *H. hoolock* in other distribution ranges (Kakati 2004). She reported a minimum of 654 m day range in smaller fragments and a maximum of 1513m in large fragments. Furthermore, she stated that low fruit abundance in those disturbed habitats caused the shorter day range. A similar observation was also reported by Fan et al. (2013) on *H. leuconedys* in China who stated that *H. leuconedys* in such situations might switch their diet from fruit to leaves. Thus, besides canopy loss, food abundance, distribution and dietary preferences might also have a correlation with shorter DPL like in the case of many other primates (Janson & Goldsmith 1995; O'Brien & Kinnaird 1997; Olupot et al. 1997; Ganas & Robbins 2005), though some other studies have discarded this hypothesis (e.g., Gautier-Hion et al. 1988; Buzzard, 2006).

Several other articles on frugivorous primate species including gibbons have emphasized on fruit availability (*Cercocebus albigena:* Olupot et al. 1997; *Ateles chamek*: Wallace 2006; *Nomascus concolor*: Fan & Jiang 2008; *Hylobates lar*: Bartlett 2009), both on the spatial and temporal scales as an important determinant of change in DPL (Kaplin 2001). Moreover, other factors like territorial defense, resource monitoring and even insect prey abundance may also have a profound effect on the ranging pattern (e.g., DiFiore 2003; Buzzard 2006). Therefore, it will not be conclusive to state that canopy discontinuity was the only cause of shorter DPL in the study groups. A more systematic study integrating all the above mentioned factors is of utmost necessity to understand the matter clearly. Furthermore, the mean DPL calculated for both fragmented and contiguous

forests in the present study was much shorter (192.75m) than other studies carried out on the genus Hoolock in lowland forests as well as montane forests of china (Zhang et al. 2014).

It was also noted that the DPL was found to be the highest during the monsoon season in both fragmented and contiguous forests. This result may not have been affected by the availability of food resources alone. The fragmented as well as the contiguous forest patches are located nearby human habitation and experiences a high degree of anthropogenic pressure (Sarma 2015). However, in the present study it was observed that human activities were minimal during the monsoon season and that might have allowed the study groups to access more area for foraging. The shortest DPL observed during the winter season is in conformation with ranging patterns reported for White-handed Gibbons in KhaoYai National Park (Bartlett 1999). On the contrary, other studies carried out on *H. hoolock* argued that the winter season holds the longest DPL of the species (Das 2002).

The quality and productivity of the habitat often determines the home range size (Laundre & Keller 1984) and thus home range is guided by feeding habits (Ellefson 1974) as well as local anthropogenic factors (Das 2002). Further, Sarma et al. (2015) stated that gibbons were also found to survive on a single tree surrounded by agriculture fields and mostly in forest patches having more than seven tree individuals. In the present study, gibbons were mostly observed to feed on fig species which are abundant in the study area.

The ranging pattern may be affected by the habitat quality because primates have less foraging options in fragmented habitats (Poulsen et al. 2001) which essentially influence animal movement (Morales et al. 2010). Generally, gibbon home ranges average approximately 34ha with some as large as 50ha (Chivers 1984). In this context, the home range size of the two study groups is very small (1.09ha for Group A and 2.49ha for Group B) in fragmented forests, however, this finding is comparable with those of other studies of *H.*

Table 5. Summary of information on Hoolock Gibbon daily path length and home range size. Numbers indicate mean values (and range of values). Also cited in Geissmann et al. 2013.

Study sites	Sample size		Daily path length (DPL) (m)	Home range (ha)	Source
	No. of groups observed	Study duration			
Western Hoolock Gibbon (*H. hoolock*)					
Chunati WS, Bangladesh	1	24 months	-	25.7	Ahsan 2001
Rajkandi, Bangladesh	-	5 months	-	23.0	Gittins & Tilson 1984
West Bhanugach, Bangladesh	2	2 months	-	10.6 (3.2–18)	Gittins 1980 cited in Gittins & Tilson 1984
West Bhanugach, Bangladesh	1	12 months	1200 (600–1600)	35 (30–35)	Feeroz & Islam 1992; Islam & Feeroz 1992
West Bhanugach, Bangladesh	2	24 months	1367[a] (278–3375)	63.4 (40.7–86)	Ahsan 2001
Northeastern India	-	-	-	15-30	Alfred & Sati 1986, 1990a; Alfred 1992
Tripura, India	6	-	-	300 (300–400)	Mukherjee 1982 cited in Alfred & Sati 1992
Tripura, India	2	1976–1983	600 (300–1000)		Mukherjee 1986
West Garo Hills, Meghalaya, India	42 (survey)	-	-	31 (14–55)	Alfred & Sati 1990b
Hollongapar, Assam, India	7	2 months	-	22 (18–30)	Tilson 1979
Hollongapar, Assam, India	3	3 months	1136 (973–1421)	41.8 (23.5–58)	Sankaran 2009
Eastern Assam, India	6	12 months	1116 (654–1513)	25.7 (13.0–47.8)	Kakati 2004
Borajan RF, Assam	2	6 months	380.7 (130–1000)	8 (5.4–10.5)	Kakati 1997
Eastern Hoolock Gibbon (*H. leuconedys*)					
Lohit District, Arunachal Pradesh, India	-	-	100-200	100-200	Mukherjee et al. 1992
Nangkang Nature Park, Yunan, China	1	-		ca.100	Fan 2008
Nangkang Nature Park, Yunan, China	2[a]	14 months	1162 (345–2606)	88.1	Zhang et al. 2014
Fragmented forest around Mehao WS, Arunachal Pradesh, India	2	11 months	37.4 (6.98–106.05)	1.09–2.49	Present study
Mehao WS, Arunachal Pradesh, India	2	12 months	410.21 (217.73–775.17)	16.28–24.62	Present study

hoolock in isolated forest patches in NE India where the home range was recorded between 3–10.5 ha (Gittins & Tilson, 1984; Kakati 1997; Kakati et al. 2009; Thampy et.al. 2009) (Table 5). The groups in contiguous forest have a comparatively stable home range which is within the range of other studied gibbon species including *H. hoolock* (e.g., Tilson 1979; Alfred & Sati 1986; Alfred 1992; Ahsan 2001; Kakati 2004; Barlett 2007). The recent study on *H. leuconedys* had claimed a higher home range in the Montane forests of China due to patchily distributed food resources than for most lowland gibbons (Zhang et al. 2014). Many researchers have also pointed out the effect of group size on the home range. The present study could not draw a clear conclusion regarding such affects as the study groups were almost of the same size ranging from 2–3 individuals in each group (Table 1).

There is a distinct seasonal pattern of home range used by all of the study groups with the highest contribution during the monsoon and pre-monsoon seasons in fragmented and contiguous forests respectively (Table 4). The reason for fragmented forests' groups preferring the monsoon season were very clear and thought to be the same DPL that is due to the minimal human interference in their range. Zhang et al. (2014) had reported the largest monthly home range in the month of May for *H. leuconedys* in China. However, the results for the other seasons of his study did not conform with those of the present study. The reasons might be different in different forest types which influence monthly and seasonal home range. As fruit availability was more in the pre-monsoon season, groups of gibbons in contiguous forests move to greater extent to explore more patches.

In conclusion, the home range and daily path length of *H. leuconedys* in the Lower Dibang Valley, Arunachal Pradesh has been highly affected by forest fragmentation or canopy discontinuity which makes habitat specialists' species (gibbons) more vulnerable and they become more accessible to hunting and predation by domestic dogs (Panor 2011). Thus, forest fragmentation ultimately is leading the population towards local extinction. These findings evoke the question of the long term survival of the gibbons in fragmented forests or unclassified state forest of Lower Dibang Valley District.

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