Feeding on non-plant food items by Western hoolock gibbon (*Hoolock hoolock*)

The distribution and quality of food resources are generally recognized as the pre-eminent factors explaining much interspecific and intraspecific variation in the behaviour of non-human primates[1]. The diet of non-human primates is characterized by large portion of plant items such as fruits, flowers and leaves and also contributes a small portion of non-plant food items[2]. Primates that live in seasonal forests often show predictable responses of feeding to fluctuating resources[3]. Generally during the dry season, when preferred food resources become a limiting factor, primates often consume non-plant food items[4]. These mainly include insects, caterpillars and larvae as well as other items like bird's eggs, soil from salt-licks, termite nests, etc. which are seldom eaten by primate species, including gibbons and contribute only a small part of their diet[4–6]. Although the quantity of these food items is usually small in size, they provide larger amounts of energy, protein and fat per unit mass than most other food items of primates, such as fruits, flowers and leaves[7]. But, while studying the ecology and feeding behaviour of western hoolock gibbon (*Hoolock hoolock*) in an isolated forest patch of Hollongapar Gibbon Wildlife Sanctuary (HGWLS), Assam, we recorded high-scale feeding evidences on non-plant food items, particularly on insects by the species during the hot pre-monsoon (March–May) and monsoon (June–September) seasons, besides the presence of ripped fruits in their major food plants. This uncommon food items consumption may form a regular part of their diet in small fragmented and isolated forest patches.

H. hoolock is distributed in the monsoon evergreen and semi-evergreen rainforests of North East India, south of the Brahmaputra[8], eastern Bangladesh, northwest Myanmar and west of the Chindwin River[9]. In NE India, gibbons are distributed in 22 protected areas, including 6 national parks and 16 wildlife sanctuaries in addition to several populations in non-protected areas[10]. Due to large-scale deforestation in primary habitats of *H. hoolock* in the entire distribution range, particularly in NE India, most of the gibbon population has become fragmented and isolated in small forest patches and the population has been declining drastically in the last two decades[11]. As a result, the western hoolock gibbon has become endangered under the IUCN category in India and critically endangered in Bangladesh[12]. It is also included in Appendix-I of CITES and listed in Schedule I of Wildlife (Protection) Act, 1972.

HGWLS is a small isolated forest patch covering an area of 20.98 sq. km and situated between 26°40″–26°45″N and 94°20″–94°25″E at an elevation of 100–120 m amsl. The sanctuary is surrounded by tea gardens, agricultural fields and small villages and is located in the south bank of the mighty Brahmaputra River system in Mariani area, Jorhat district, Assam, India. The forest type of HGWLS is 'Eastern Alluvial Secondary Semi-Evergreen Forest (1/2/2B/2S2)' under Moist Tropical Forest of India[13]. This is the only sanctuary in NE India which provides habitat for seven primate species, viz. *Trachypithecus pileatus*, *Macaca assamensis*, *Macaca arctoides*, *Macaca leonina*, *Macaca mulatta*, *Nycticebus bengalensis* and *Hoolock hoolock*[14]. Twenty-five groups of *H. hoolock* comprising 101 gibbons (mean = 4.4 ± SE 1.1 individuals per group) were reported from sanctuary[15].

We conducted a study on feeding ecology and behaviour of *H. hoolock* in two groups (group A – one adult male and one adult female; group B – one adult male, one adult female, one sub-adult male and one infant) for a period of one year from January to December 2011 in HGWLS after initial habituation of both the groups for three months. Selected groups were followed from dawn to dusk between 0600 and 1600 h for 12 days every month to collect field data on their basic feeding ecology, diet composition and behaviour via focal animal sampling[16,17]. Instantaneous sampling (every five minutes) was used to quantify activity budget and behaviour. Continuous sampling was used every time the focal animal began to feed. The total observation time was 1440 h during the one-year study period, accounting 720 h for males and females belonging to both the groups. The different behavioural activities recorded were categorized as feeding, resting, travelling, calling and social behaviour. In the present study, 'feeding' refers to catching followed by chewing and then ingestion of plant and non-plant food items and this excludes the time for foraging, as it has been included under travelling. The focal animal was rotated between the adult male and female of the group every one hour. There was no significant variation in feeding time on non-plant food items between the selected groups and also between the sexes. Therefore, data of both groups were pooled together for final analysis. We calculated the percentage of the daily feeding time on different food categories to the total feeding time for each month, according to Gupta and Kumar[18].

$$T_a = \frac{N_a \times 100}{N},$$

where T_a is the percentage time spent on activity a, N_a the number of records with activity a and N is the total number of records for the day.

It was established that hoolock gibbons are mainly frugivorous in nature and largely feed on plant items, particularly on fruits[19]. Interestingly, we observed that *H. hoolock* spent a considerable fraction of their monthly feeding time on non-plant food items (Figure 1), viz. insects, caterpillars, bird eggs (*Dicrurus macrocercus*, *Dicrurus leucophaeus, Dicrurus remifer*), etc., besides feeding on plant items which contribute 9.7% of the total average annual feeding time. During one year observation, gibbons consumed more than ten species of insects, but due to difficulty in collection of specimen, only a few of them could be identified (Table 1 and Figures 2 and 3 *a*). Non-plant food items feeding incidents were recorded throughout the year, except in January and highest consumption was recorded in July (Figure 1) during summer. Both adult male and female gibbons were observed feeding on non-plant food items. Daily time spent on feeding of non-plant food items varied from 5 to 115 min with average 29.52 ± 11.56 min and it varied significantly ($t = 11.94$, d$f = 83$, $P < 0.05$). Variation in monthly time spent on non-plant food

items was also highly significant ($F = 4.861$, $df = 11$, $P < 0.05$).

It was observed that gibbons got active in the morning at 0600 h during the pre-monsoon and monsoon period (March–September) and fed on their preferred plant foods (viz. *Ficus lepidosa*, *Artocarpus chaplasha*, *Sapium baccatum*, *Ichnocarpus frutesens*, etc.) between 0630 and 0900 h. During this period, they generally complete their duet (voice/songs of adult gibbons are known as duet). After 0900 h onwards with the increasing intensity of sunlight, gibbons were observed feeding on caterpillars and insects. Two peaks of insect feeding were recorded in a day – first between 0900 and 1100 h (forenoon) and second between 1330 and 1430 h (afternoon).

H. hoolock was observed feeding on black ant eggs and larvae by destroying the nests on the trees with its hands (Figure 4). To avoid biting by the ants, they frequently shake their hands at regular intervals while feeding on the eggs from the hives. Das[5] reported that hoolock gibbons also consume insects from the rolled dry leaves of trees, specially spiders (Arachnida) and that they collect large insects (treehoppers) by unfolding the dry leaves and eating them directly. During the study period, gibbons were found to feed on insects from the plant species like *Vatica lanceaefolia*, *Lagerstroemia speciosa*, *Ilex godjam*, *Chukrasia tabularis* and *Dysoxylum gobara*. In the month of May, caterpillars of Drury's Jewel (*Cyclosia papilionaries*) feed on the leaves of *V. lanceaefolia* (Figure 3 *b*), a medium-sized tree belonging to the family Dipterocarpaceae and found abundantly (density 227 individuals/ha)[20] inside the sanctuary. Gibbons extensively feed on caterpillars of *C. papilionaries*, even when they are at the pupal stage.

Insect feeding by hoolock gibbons in fragmented habitats of Assam does not follow any particular seasonal trend[6]. In the present study, it was recorded throughout the year, except January. This may reveal some important aspects of their feeding ecology, adaptations and availability of insects. The maximum time (29.73%) spent on insects feeding was recorded in July (Figure 1) during summer. The gibbons catch the caterpillars and insects with their long hands and consume them within seconds. Insects were the second preferred food items of gibbons after *Artocarpus chaplasha* during the monsoon season, although they have sufficient fruiting trees available in the habitat during these months. The feeding times spent on major preferred fruiting trees in July were *A. chaplasha* (47%), *Olea dioica* (6.86%), *F. lepidosa* (5.23%) along with some other food plant species. During summer, temperature reaches up to 32.4°C and relative humidity corresponds to 95% in the study area (Figure 1). These hot and humid environmental conditions generally favour the metamorphosis of large number of insects, thereby increasing the availability of the insects population during wet and warm periods. Kakati[6] has reported that overall insect feeding comprised 6% of the annual diet of gibbon in fragmented forest of Assam, which is lower than the present study (9.73%). Further,

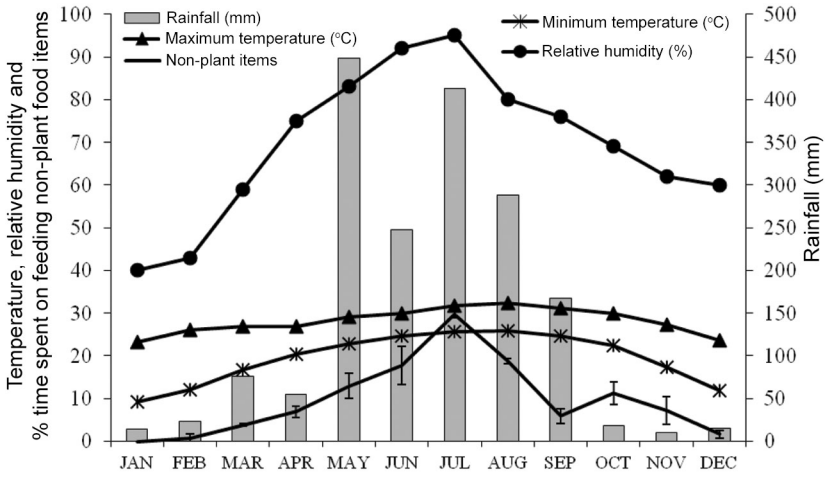

Figure 1. Relationship between climatic condition and monthly average feeding time spent (%) on non-plant food items by *Hoolock hoolock* at HGWLS, Assam.

Figure 2. A leaf insect (*Microcentum* sp.) consumed by *H. hoolock*.

Table 1. List of insects fed by *Hoolock hoolock* in HGWLS, Assam

English name	Scientific name	Family
Leaf insect	*Microcentum* sp. (Figure 1)	Tettigoniidae
Weaver's red ant	*Oecophyllas maragdina*	Formicidae
Black ant	*Lasius niger*	Formicidae
Drury's Jewel	*Cyclosia papilionaries* (Figure 2 *a*)	Zygaenidae
Muga silk worm	*Antheraea assamensis*	Saturniidae
Tasar silk worm	*Antheraea mylitta*	Saturniidae
–	*Erasmia pulchella*	Zygaenidae
Winged white termite	*Odontoterme assamensis*	Termitidae

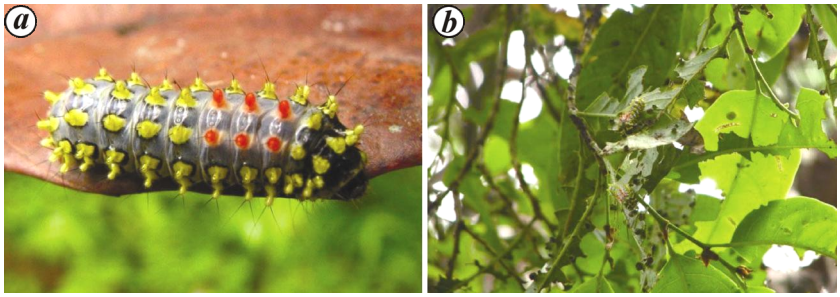

Figure 3. ***a***, A caterpillar of *Cyclosia papilionaris* (Drury's Jewel) consumed by *H. hoolook*. ***b***, A caterpillar of *C. papilionaris* feeding on leaves of *Vatica lanceaefolia*.

Figure 4. ***a***, Adult female *H. hoolock* destroying ant hive. ***b***, Adult female *H. hoolock* feeding on ant eggs.

the site-specific seasonal variation in insects feeding by gibbons was also recorded, which varied from 3.6% to 8.0% in the wet season (end March–September) and 0.9% to 13% in the dry season (October–February). Similar observation of highest insect feeding was also recorded in Hanuman langur (*Presbytis entellus*) in July, when temperature and rainfall were recorded at maximum levels[21]. It is also reported that most primate species consume a small quantity of insect matter in their diet, but the same may increase to more than 90% of the diet when insects are ample and easily captured[22] due to the influence of climatic conditions.

Hamilton and Busse[22] observed the facultative trend towards increased carnivory of chacma baboons, *Papiour sinus* in the Namib Desert, Namibia and reported that the species shifted their almost complete dietary habit to insectivory due to an outbreak of grasshoppers. It is reported that chacma baboon fed up to 72% of all time allocated to feeding on scale insects (Homoptera; Coccidae) due to enormous outbreak on mopane trees in Okavango Swamp forest, Botswana during the summer season. However, the adjacent troops of baboon, without this insect food resource in the area, sustained an exclusively vegetarian diet during the same period[23]. This evidence for food preference and a choice for animal matter gives an idea of preference for insectivory whenever insect resources are available. Shaffer[24] reported that the sakis monkey in Guyana travelled towards caterpillar host trees during the caterpillar breeding season, and tracked and exploited this foreseeable annual resource. Thus the quantity of insect matter in primate diets can be altered dramatically throughout the year due to palatable and accessible prey species which often occur seasonally[23]. In the present study, availability of insects was observed to be less during the winter season, which resulted in lowest insect feeding during this period, and no insect feeding in January (Figure 1). Insects may provide disproportionate nutritional benefits as a source of animal protein, which is higher digestible than plant protein[25]. Insects are particularly valuable because they provide certain amino acids, vitamins (such as vitamin B_{12}) and minerals, including iron (Fe) and manganese (Mn) that may be absent in plant food items[25,26]. According to micronutrient hypothesis, primates select animal foods to secure essential micronutrients, especially vitamin B_{12} (ref. 26), as this is unavailable in higher plants[27]. It has been reported that many captive primate species enter into hypovitaminosis B_{12} when maintained on vegetarian diets[28].

McGrew[29] has reviewed the primate insectivory and its potential role in early human dietary habits. The study classifies the primates into four categories based on different grades of insectivory. The consumption of insects is widespread among non-human primates, and their entomophagy depends on their body size. The smaller primates such as galagos (*Galago crassicaudatus* and *Galago senegalensis*), pottos (*Perodicticus potto*) and tarsiers (*Tarsius spectrum*) are obligate insect eaters; their diet is composed mainly of insects belonging to the orders Lepidoptera, Orthoptera and Hymenoptera respectively[30]. The diets of medium-bodied primates such as red colobus monkeys (*Procolobus tephrosceles*) and blue monkey (*Cercopithecus mitis*) consist mainly of young leaves, flowers and unripe fruit; they are also known to eat insects less frequently than small primates[19]. The diet of the large-bodied great apes also has an insectivorous component[31], besides their frugivory and folivory components. Earlier studies conducted in the same site reported that the diet of *H. hoolock* consists of about 0.1% animal prey[32], which is very low compared to that value estimated in the present study (9.7%, annual average). The present study reveals that *H. hoolock* preferred non-plant food items during the pre-monsoon and monsoon periods, even if the species is frugivorous in nature. It is reported that primates are known to prefer non-plant food items generally during the scarcity of favourable major food plants[4], but the present evidences indicate preference for insects as food, irrespective of limiting factors of plant food availability. A probable reason behind this rare observation may be the maximum outbreak of insects during the hot and humid conditions in the sanctuary resulting in high abundance of insect population and easy availability. Non-human primates are known to choose animal matter generally when it is available and frugal relative to other foods[33]. However, a scientific explanation for this rare feeding strategy of hoolock gibbon is important. Therefore, a detailed investigation of the diet by applying molecular methods to faecal samples for the detection of different non-plant food items consumed by *H. hoolock* is required.

Moreover, seasonal outbreak or availability of insect populations needs to be analysed for better understanding of feeding strategy of the species and conservation of species in this highly isolated forest fragment.

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