Effects of tsaoko (*Fructus tsaoko*) cultivating on tree diversity and canopy structure in the habitats of eastern hoolock gibbon (*Hoolock leuconedys*)

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Abstract: In this study, the quadrat method was used to study the effects of tsaoko (*Fructus tsaoko*) plantation on tree diversity and canopy structure of two natural habitats of eastern hoolock gibbon (*Hoolock leuconedys*): Nankang (characterized by extensive tsaoko plantation) and Banchang (relatively well reserved and without tsaoko plantation). Totally, 102 tree species from 25 families and 16 woody liana species from 10 families were recorded in Nankang, whereas 108 tree species from 30 families and 17 woody liana species from 12 families were recorded in Banchang. Although the tree species between two habitats is different, both habitats are characterized by enriched food resources for eastern hoolock gibbons, sharing similar dominant plant families. Due to tsaoko plantation, tree density proportion and diversity of forest layer Ⅰ (>20 m) in Nankang were both significantly decreased, but the tree density of layerⅡ (10−20 m) increased. Likewise, in conjunction with these behavioral observations, we also address potential impacts of tsaoko plantation on the behavior of eastern hoolock gibbon.

Keywords: Eastern hoolock gibbon (*Hoolock leuconedys*); Habitat; Tree diversity; Canopy structure; *Fructus tsaoko* plantation; Mt. Gaoligong

Habitats are essential to animal survival. They provide shelter for protection and food resources for sustenance and reproduction. Currently, deforestation and fragmentation are two of the primary threats to species conservation, which then often result in changes to plant composition and distribution (Saunders et al, 1991; Benítez-Malvido & Martínez-Ramos, 2003; Laurance et al, 2006), reducing food resources (Das et al, 2009; Boyle & Smith, 2010; Wang et al, 2000), and influencing animal behavior and species diversity (Feeraz et al, 2003).

Different species, such as arboreal primates, have developed various strategies to respond to environmental alterations. For example, the bearded saki monkey (*Chiropotes satanas chiropotes*) moves less and rests more (Boyle & Smith, 2010), while the western hoolock gibbon (*Hoolock hoolock*) spends more time resting and less time feeding, while increasing its alternative food consumption (Das, 2002; Das et al, 2009). The howler monkey (*Alouatta palliate*) has also been seen to broaden its diet choices (Cristóbal-Azkarate & Arroyo-Rodríguez, 2007). The black crested gibbon (*Nomascus concolor*) in Mt. Wuliang meanwhile avoids areas with high human disturbance, while also increasing feeding and movement and decreasing rest (Fan & Jiang, 2010). The François's

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languor (*Trachypithecus francoisi*), in small populations in Fusui, Guangxi Province, appear to choose mountain tops with relatively low human disturbance or deforestation to feed (Zhou et al, 2010).

Habitat degradation also affects the quality and quantity of sleeping sites, and subsequently impacts the animal's choice of sleeping sites (Wang et al, 2011). Francois's languors living in places with high disturbance and food scarcity, for example, use proximity to food instead of predator avoidance as the determining factor in choosing a sleeping site as compared to others living in better preserved habitats (Wang et al, 2011).

Habitat degradation has increased deforested areas which many monkeys are loath to cross (Das et al, 2009; Fan et al, 2011). Hoolock gibbons must walk on the ground or jump over big gaps in India's severely deforested Borajan area, thereby increasing their chance of dropping their young (Das et al, 2009). However, some reports claimed that habitat degradation benefited certain primate populations. Plumptre & Reynolds (1994) found that population densities of blue monkey (also names diademed monkey) (*Cercopithecus mitis*), red-tailed monkey (*C. ascanius*), and mantled guereza (*Colobus guereza*) in selectively logged Budongo forest reserves, Uganda, were even higher than the ones in well preserved habitats.

The eastern hoolock gibbon (*H. leuconedys*) is a primate from the Hylobatidae (gibbon) family, *Hoolock* genus. The species is found in extreme eastern corner of Assam, India, Myanmar east of the Chindwin River, and in southwest portion Yunnan in China (Das et al, 2006). Updated surveys of hoolock gibbon in China showed that they were only distributed in 17 forest patches around the towns of Baoshan, Tengchong and Yingjiang, with less than 200 individuals in total (Fan et al, 2011). Commercial logging, illegal hunting and farmland expansion are the main factors in its declining population in China (Fan et al, 2011). Due to the small population size and narrow distribution area, eastern hoolock gibbon has been listed as "EN" or endangered in IUCN and is a Grade I National Protected Species in China. Moreover, because eastern hoolock gibbons mainly inhabit Myanmar, little is actually known about this species due to a lack of observational studies in the area and the remoteness of some of these regions. Lan et al (1999) and Zhang et al (2011) analyzed their vocalizations. Bai et al (2007, 2008, 2011), Zhang et al (2008a, b) and Wu et al (2009, 2010) reported their habitat utilization, diet and food choice, time budget and daily food consumption based on short time research. Fan et al (2013) and Zhang et al (2014) studied the seasonal variation in diet and time budget, and the ranging pattern of an eastern hoolock gibbon population in Nankang based on a 14-month observation period.

The eastern hoolock gibbon is a typical diurnal and arboreal primate that lives together in monogamous pairs that stake out territory. Like other gibbons, they brachiate through the trees with their long arms, as it is the most efficient form of movement (Feeroz & Islam, 1992; Islam & Feeroz, 1992; Fan et al, 2013). Similarly, because of their unique moving pattern, eastern hoolock gibbons spend most of their lives in the crown canopy. They obtain approximately 49.1% of their diet from fruit and the rest from leaves and flowers (Fan et al, 2013). In Mt. Gaoligong, which has a high altitude and high latitude, one group's home range size was 93 hm^2 (Zhang et al, 2014).

Fructus tsaoko (*Amomum tsaoko*), also named tsaoko, is a perennial shade tolerance herb of Zingiberaceae family, *Amomum* genus, and grows in high altitude areas that are cool in summer and warm in winter, in enriched soil and under forest shading ranging from 50% to 60% (Dai et al, 2004; Qin et al, 2008). To reach the moisture, ventilation and shading requirements of tsaoko cultures, farmers remove trees, shrubs and weed (Dai et al, 2004). Since the 1980s, as an economically important cash crop, tsaoko has been planted in a large-scale area and has become the primary household income of local residents in the Mt. Gaoligong Reserve. As a result, the impact of tsaoko cultivating on habitats of eastern hoolock gibbons below 2300 m a.s.l. has become increasingly obvious. In Nankang and Houqiao, Mt. Gaoligong, the habitat degradation caused by tsaoko plantations was responsible for more than 50% of the decrease of eastern hoolock gibbon populations. For example, in one population in Nankang, 3 infants were born during the past 8 years, with the first 2 resulting in death (Fan et al, 2011).

In this study, to investigate the impact of tsaoko plantations on the eastern hoolock gibbon and offer a theoretical basis for species conservation, we analyzed the differences in tree species diversity and canopy structure of their two habitats, Nankang and Banchang (with and without tsaoko plantations, respectively). We further discussed the potential influence of tsaoko plantations on the behaviors of the eastern hoolock gibbon.

MATERIALS AND METHODS

Study site

We collected data at two areas of Mt. Gaoligong National Nature Reserve: Banchang (precinct of Baihualing management station, N25°12′, E98°46′), and Nankang (precinct of Nankang management station, N25°49′, E98°46′). Three eastern hoolock gibbon groups in Banchang and two groups (one family group and one solitary female) in Nankang were recorded. The vegetation type of Banchang and Nankang are both mid-montane evergreen broad-leaved forests, and the latter is characterized by large-scale tsaoko plantation.

Quadrats setting and data collection

In the habitats of eastern hoolock gibbons in Banchang and Nankang, quadrats (20 m×20 m) were set along the contour lines 100 m apart using systematic sampling methods and taking 100 m contour lines as transect lines. Due to topographic factors in Banchang, 50 quadrats were set along 6 lines with altitude ranging from 2,000 m to 2,400 m, and length ranging from 200 m to 1,000 m. In Nankang, 33 quadrats were set along 4 lines with altitude ranging from 2,000 m to 2,300 m, with lengths ranging from 200 m to 1,100 m. According to the height of trees inside the quadrats, the forest was categorized as 3 sub-layers, layer Ⅰ (height>20 m), layer Ⅱ (10<height≤20 m) and layer Ⅲ (height≤10 m).

An altitude logger and GPS were used to record quadrat locations. Based on our field observations, eastern hoolock gibbons rarely use trees with diameter-at-breast-height (dbh) smaller than 10 cm, so we only measured trees with dbh≥10 cm, and these trees with dbh≥10 cm were identified at the species level. Circumference-at-breast-height (dbh=circumference-at-breast-height/3.14) was measured with ring ruler and height was determined by hand-hold laser altimeter. In Banchang, among the 1 286 labeled trees, 10 had a dbh of <10 cm, having with broken or fallen treetops or were dead due to natural reasons, and 6 were lacking data. So, data was collected for 1 270 trees. In Nankang, 1 010 trees were labeled. Meanwhile, name and abundance of edible woody liana species were recorded by the aid of keys provided by Wu et al (2009) and Fan et al (2013) in Nankang, and the behavioral data of eastern hoolock gibbons in Banchang was recorded from June, 2012 to June, 2013. Unidentified specimens were brought back to laboratory for further analysis.

Data processing

Basal coverage and abundance of edible woody liana (Sun et al, 2007)

$$\text{Basal coverage} = \sum_{i=1}^{n} Ai \quad (1)$$

n: number of trees in quadrat, Ai: cross sectional area at breast height of the ith labled tree in quadrat.

Average abundance of edible woody liana= abundance of edible woody liana/ the total number of quadrats.

α diversity, Jaccard index and importance value

α diversity, Jaccard index and importance value were calculated according to the protocols of Survey Plan for Plant Species Diversity of China's Mountains (PKU-PSD) (Fang et al, 2004).

Shannon-Wiener index: $H = -\sum_{i=1}^{s} Pi \ln Pi$

Pi=total area-at-breast-height of the ith tree species/total area-at-breast-height of all the tree species in one quadrant.

Pielou index: $E=H/\ln S$

S (abundance index): total tree species in quadrant.

Jaccard index (similarity index of species diversity): $cj=c/(a+b-c)$, in which a and b: number of tree species in habitat a and b, respectively; c: common tree species of habitat a and b, respectively.

Importance value of a family or species (V)=(relative abundance of a family or species + relative frequency of a family or species+relative dominance of area-at-breast-height of a family or species)/3.

Relative abundance (%)=100%×total number of one tree species in quadrat/total numbers of all tree species in quadrat.

Relative frequency (%)=100%×occurrence frequency of one tree species in quadrats/sum of occurrence frequency of all species;

Relative dominance of area-at-breast-height (%)= 100%×total area-at-breast-height of one tree species/ total area-at-breast-height of all tree species.

We used t-tests to assess the height, dbh, crown diameter, abundance and basal coverage of the trees in two habitats. 2×2 Chi-square test was used to evaluate the density differences of trees and edible woody liana between two habitats. Mann-Whitney test was used to determine the diversity among the forest layers. All statistics were completed using Excel and SPSS 16.0.

RESULTS

Characteristics and diversities of trees in habitats

The height (t=–4.438, df=2 278, P<0.001), dbh (t=–6.432, df=2 278, P<0.001) and basal coverage (45.36 m^2/hm^2, t=4.494, df=81, P<0.001) of trees in Banchang were significantly higher than those in Nankang. However, no difference was found in crown diameters (t=–0.447, df=2278, P=0.655) (Table 1).

Forest layer Ⅱ (10–20 m) was the most important component of habitat vegetation (45.0% and 59.8% in Banchang and Nankang, respectively), and the percentage of layer Ⅱ in Nankang was significantly higher than that in Banchang (Mann-Whitney Test: Z=–4.078, $n_{Banchang}$= 50, $n_{Nankang}$ =33, P<0.001) (Figure 1). Layer Ⅲ (<10 m) was the second major component (41.9% and 37.3% in Banchang and Nankang, respectively), and no difference was found between two habitats (Mann-Whitney Test: Z=–0.656, $n_{Banchang}$=50, $n_{Nankang}$=33, P=0.512) (Figure 1). Although layer Ⅰ (>20 m) was only a small part of habitat forest, its percentage in Banchang was significantly higher than in Nankang (Mann-Whitney Test: Z=–5.620, $n_{Banchang}$=50, $n_{Nankang}$=33, P<0.001) (13.1% and 2.9% in Banchang and Nankang, respectively) (Figure 1)

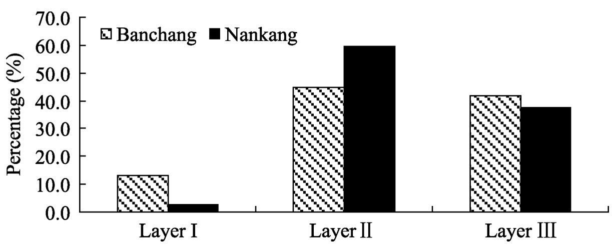

Figure 1 Percentage of forest layers in the habitats of eastern hoolock gibbon at two sites. Sites included Nankang (with tsaoko plantation) and Banchang (without tsaoko plantation)

There was no difference between tree density of forest layer Ⅲ between the two habitats (266 and 286 individual/hm^2 in Banchang and Nankang, respectively) (*Chi*-square test: χ^2=0.362, df=1, P=0.547). Tree density of layer Ⅰ in Banchang was significantly higher than in Nankang (84 and 22 individual/ha in Banchang and Nankang, respectively) (*Chi*-square test: χ^2=19.828, df=1, P<0.001), whereas, the tree density of layer Ⅱ in Nankang was significantly higher than in Banchang (285 and 457 individual/ha in Banchang and Nankang, respectively) (*Chi*-square test: χ^2=20.207, df=1, P<0.001). t-test showed that the average heights of both layer Ⅰ (25.1 and 22.5 m in Banchang and Nankang, respectively)(t-test: t=8.120, df=908, P<0.001) and layer Ⅱ (13.9 and 13.3 m in Banchang and Nankang, respectively)(t-test: t=–4.735, df=1171, P<0.001) in Banchang were significantly higher than in Nankang, whereas, the average height of layer Ⅲ in Banchang (7.3 m) was shorter than in Nankang (8.2 m, t-test: t=–2.969, df=195, P=0.003).

The Jaccard index of family, genus and species of trees in the two habitats was 0.719, 0.514 and 0.346, respectively. The abundance index of trees in Banchang (H=3.631) was slightly higher than in Nankang (H=3.550), but without significant difference (t-test: t=–0.104, df=208, P=0.914). Evenness index showed no significant difference between the two habitats either (E=0.775 and 0.768 in Banchang and Nankang, respectively) (t-test: t=–1.951, df=80, P=0.055). Among different forest layers, both the highest diversity index and evenness index were found in layer Ⅱ in Banchang, whereas, in Nankang, the highest diversity and highest evenness were found in layer Ⅲ and layer I, respectively (Table 2).

Table 1 Characteristics of tree composition in the habitats of eastern hoolock gibbons at two sites
Nankang (NK, with tsaoko plantation) and Banchang (BC, without tsaoko plantation)

	Maximum value		Minimum value		Mean		*SD*	
	BC	NK	BC	NK	BC	NK	BC	NK
Number of trees in quardat (idi.)	56	56	5	15	25	31	12	9
Height (m)	39.8	28.3	1.5	1.4	12.6	11.6	6.4	3.7
Crown diameter (m)	20.0	11.0	1.0	1.0	4.6	4.9	2.8	1.8
DBH (cm)	88.4	53.2	4.8	4.8	14.3	11.7	11.3	7.2

Table 2 Diversity and Evenness index of different forest layers in the habitats of eastern hoolock gibbons at two sites.
Nankang (NK, with tsaoko plantation) and Banchang (BC, without tsaoko plantation)

	Species number (*S*)		Diversity index (*H*)		Evenness index (*E*)	
	BC	NK	BC	NK	BC	NK
Layer Ⅰ	44	16	2.879	2.500	0.761	0.902
Layer Ⅱ	87	77	3.678	3.356	0.821	0.770
Layer Ⅲ	85	79	3.643	3.632	0.820	0.831

Although the lowest diversity of both habitats occurred in layer I, layer I in Banchang was still much more diversified than in Nankang (*t*-test, t=–4.210, df=58, P<0.001). In layer I of Banchang, 44 tree species were recorded, but in Nankang, only 16 were recorded (Table 2). The diversity of layer Ⅱ and layer Ⅲ between two habitats showed no significant difference (Table 2).

Difference in dominant species in two habitats

Tree species belonging to 23 families were found in both habitats, with Tiliaceae, Flacourtiaceae, Meliaceae, Celastraceae, Tetracentraceae, Oleaceae, and Caprifoliaceae in Banchang only, whereas, Daphniphyllaceae, and Rutaceae in Nankang only (Table 3). Except Rosaceae, Juglandaceae in Banchang and Moraceae, Aceraceae in Nankang, the rests of the top 10 dominant families (shadowed areas in Table 3) in the two habitats were the same. Among the identified tree species, 54 were distributed in both habitats, 55 were only found in Banchang and 48 were only found in Nankang. There were 32 and 33 species could provide food to eastern hoolock gibbons in Banchang and Nankang, respectively. Among the top 20 dominant species in the quadrats of the two habitats, 9 were common (shadowed areas in Table 4).

Difference in edible woody lianas in two habitats

A total of 13 families of edible woody lianas were found in the quadrats of both habitats. Among them, 12 families and 17 genus were distributed in Banchang and 10 families and 16 genus in Nankang. 11 species were found in both habitats (Table 5). Neither the density (202 and 192 individuals/ha in Banchang and Nankang, respectively) (*Chi*-square test: χ^2=0.103, df=1, P=0.748) nor average abundance (8.08 and 7.67 in Banchang and Nankang, respectively) (*t*-test: t=–0.112, df=32, P=0.904) of edible woody lianas between two habitats was of any significant difference.

DISCUSSION

Effect of tsaoko plantations on forest layer structure and diversity

This study was conducted within Mt. Gaoligong National Nature Reserve, and the vegetation types of both habitats are mid-montane evergreen broad-leaved forests. So, the diversity and evenness index of the tree species in quadrats were similar, and because of the closed flora of seed plants (Chen, 2008; Li et al, 2008), the similarity index of both families (0.719) and genus (0.514) in two habitats were high. However, due to the differences in local precipitation, thermal energy reallocation and human disturbances, the similarity index of tree species (0.346) in the two habitats was relatively low (Chen, 2008; Li et al, 2008).

Tsaoko cultivation had impacts on vegetation diversities (Dai et al, 2004; Guo et al, 2010), in specific, it caused degradation of fine vertical partitioning of forest strata and the decease or loss of tree and shrub species on

Table 3 Importance value of tree families in the habitats of eastern hoolock gibbons, Nankang (NK, with tsaoko plantation) and Banchang (BC, without tsaoko plantation)

Families	Importance values in BC (v1)	Importance values in NK (v2)
Fagaceae	17.56	23.27
Lauraceae	15.87	13.77
Magnoliaceae	11.59	15.07
Theaceae	10.93	8.9
Ericaceae	5.44	8.76
Rosaceae	4.51	1.58
Araliaceae	4.2	3.82
Elaeocarpaceae	3.81	7.82
Aquifoliaceae	3.26	2.69
Juglandaceae	2.62	0.11
Moraceae	2.48	3.47
Euphorbiaceae	2.26	0.98
Hamamelidaceae	1.98	0.11
Betulaceae	1.96	0.16
Proteaceae	1.55	1.31
Staphyleaceae	1.38	0.61
Symplocaceae	1.16	0.99
Myrsinaceae	1.02	1.13
Aceraceae	0.89	2.35
Tiliaceae	0.88	–
Rubiaceae	0.58	0.34
Nyssaceae	0.37	0.97
Flacourtiaceae	0.36	–
Meliaceae	0.36	0.08
Celastraceae	0.24	–
Styracaceae	0.22	0.14
Santalaceae	0.21	0.11
Oleaceae	0.11	–
Caprifoliaceae	0.11	–
Tetracentraceae	0.11	–
Rutaceae	–	0.8
Daphniphyllaceae	–	0.15

Families in shadow areas were top 10 dominant families in each habitat; –: absent in the quardats.

Table 4 Top 20 dominant tree species in the habitats of eastern hoolock gibbons, Nankang (NK, with tsaoko plantation) and Banchang (BC, without tsaoko plantation)

Species in BC	Importance values in BC (v1)	Species in NK	Importance values in NK (v1)
Phoebe yunnanensi	6.48	*Castanopsis hystrix*	11.33
Castanopsis hystrix	6.41	*Alcimandra cathcartii*	6.61
Michelia floribunda	6.40	*Elaeocarpus boreali-yunnanensis*	5.41
Lithocarpus fenestratus	5.24	*Eurya pseudocerasifera*	4.42
Laurocerasus undulata	4.04	*Rhododendron delavayi* var.	4.36
Schima wallichii	3.42	*Lithocarpus hancei*	4.12
Lithocarpus hypoglaucus	3.30	*Michelia doltsopa*	4.02
Eurya pseudocerasifera	2.92	*Schefflera minutistellata*	3.36
Vaccinium duclouxii var.*pubipes*	2.67	*Ficus neriifolia*	3.35
Elaeocarpus boreali-yunnanensis	2.63	*Manglietia insignis*	2.91
Manglietia insignis	2.34	*Neolitsea lunglingensis*	2.90
Exbucklandia populnea	2.27	*Lithocarpus fenestratus*	2.71
Ficus neriifolia	2.05	*Vaccinium duclouxii* var. *pubipes*	2.51
Lithocarpus variolosus	1.93	*Beilschmiedia yunnanensis*	2.41
Juglans cathayensis var. cathayensis	1.87	*Elaeocarpus duclouxii*	2.06
Camellia caudata	1.83	*Lyonia ovalifolia*	0.60
Schefflera hoi	1.76	*Cinnamomum pauciflorum*	1.75
Ilex delavayi	1.47	*Lithocarpus variolosus*	1.58
Elaeocarpus duclouxii	1.54	*Lindera foveolata*	1.39
Alnus nepalensis	1.38	*Acer pubipetiolatum*	1.35

Species in shadow areas were common top dominant species in two habitats.

middle level or ground level. As a result of this degradation, alongside reduced community stability and species diversity, the entire ecosystem had become quite fragile (Dai et al, 2004). In this investigation, the degraded forest vertical layer structures were primarily seen in Nankang. To open closed canopies, trees in layer I in the tsaoko plantation areas have been largely logged. Therefore, the density, proportion, average height, diversity and species abundance in layer I in Nankang were all lower than in Banchang. On the other hand, because of the massive clearance of trees in layer I, better illumination conditions provided for the growth and regeneration of trees in layer Ⅱ and layer Ⅲ. Therefore, in Nankang, the trees in layer Ⅱ were shorter than in Banchang, but their density was higher, whereas due to the increased shadow of layer Ⅱ, the regeneration of trees in layer Ⅲ in Nankang was hindered and showed no difference either in proportion or density with the trees in Banchang.

Implications of tsaoko plantation on the behaviors of eastern hoolock gibbons

Providing enough food to animals is the most basic and important function of habitats. Gibbons feed on leaves, flowers, and especially fruit (51%−89%) (Bartlett, 2007). Habitats degradation could result in the migration and loss of gibbon populations (Eudey, 1990; Marshall, 1990). Deforestation and fragmentation are the main threats to eastern hoolock gibbons' survival and reproduction. Fan et al (2013) reported that tree species, such as *Castanopsis hystrix*, *Lindera foveolata*, *Elaeocarpus duclouxii*, *Nyssa javanica*, *Ficus neriifolia*, *Eurya pseudocerasifera* and *Schefflera minutistellata*, and woody lianas, such as *Embelia floribunda*, *Rhaphidophora decursiva*, *Embelia procumbens* and *Cayratia japonica* were the main food species of eastern hoolock gibbons in Nankang. These species were distributed in both Banchang and Nankang. According to the importance values of tree species, some of the 9 common dominant species (the species with the top 20 importance values) in both habitats were also the important components of the diet of eastern hoolock gibbons (e.g. *Ficus neriifolia*).

Moreover, the average abundance of woody lianas in the two habitats was comparable (Table 5). Some reports claimed that herbivorous primates in disturbed habitats could fully explore the woody lianas resources to meet their food requirements (*Alouatta fusca*: Chiarello, 1994; *Trachypithecus francoisi*: Li et al, 2009).

Table 5 Species composition and average abundance of edible woody lianas in the habitats of eastern hoolock gibbons, Nankang (NK, with tsaoko plantation) and Banchang (BC, without tsaoko plantation)

Species	Families	Average abundance of edible woody lianas	
		BC	NK
Smilax mairei	Liliaceae	0.02	−
Smilax bockii	Liliaceae	0.04	0.09
Smilax lunglingensis	Liliaceae	−	0.27
Pterolobium punctatum	Leguminosae	0.44	−
Cyclea polypetala	Menispermaceae	0.06	0.42
Stephania japonica	Menispermaceae	0.02	0.15
Melodinus khasianus	Apocynaceae	0.08	0.51
Actinidia venosa	Actinidiaceae	0.10	−
Schisandra micrantha	Magnoliaceae	−	0.12
Schisandra propinqua	Magnoliaceae	−	0.06
Sargentodoxa cuneata	Lardizabalaceae	0.26	−
Cayratia japonica	Vitaceae	0.90	2.39
Tetrastigma sp.	Vitaceae	−	0.03
Tetrastigma planicaule	Vitaceae	1.2	−
Tetrastigma delavayi	Vitaceae	0.30	−
Rubus xanthoneurus	Rosaceae	0.12	0.39
Ficus sarmentosa	Moraceae	0.14	0.03
Rhaphidophora decursiva	Araceae	3.08	1.91
Toddalia asiatica	Rutaceae	0.02	0.09
Embelia procumbens	Myrsinaceae	0.74	1.00
Embelia floribunda	Myrsinaceae	0.50	0.18

−: Absent in quardats.

Based on those observations the Nankang habitat might still be capable of providing food to eastern hoolock gibbons and supporting populations despite the influence of tsaoko plantation.

Like other gibbons (Tenaza & Tilson, 1985; Reichard, 1998; Fan & Jiang, 2010; Phoonjampa et al, 2010; Fei et al, 2012), eastern hoolock gibbons prefer to sleep on large trees in forest layer Ⅰ to avoid predation (unpublished data). Due to tsaoko plantations, large trees in layer Ⅰ had been isolated because of the large clearance in Nankang. This could result in the decreased quantity of suitable trees for gibbons to sleep in, and increase their chance of being exposed to predators.

Moreover, like the other gibbons (Feeroz & Islam, 1992; Islam & Feeroz, 1992; Fan et al, 2009), most of the activities of eastern hoolock gibbons happen in canopies (unpublished data). But in Nankang, because of deforestation, the top canopies were patched and fragmented, which made it difficult and energy consuming for eastern hoolock gibbons to move in the top layer of trees. Meanwhile, the chance of infants falling increased significantly. During our field survey in Nankang, we had witnessed a 3-year-old gibbon fall from the canopy while moving; fortunately, it was not wounded. In Nankang, although layer Ⅰ has been destroyed, layer Ⅱ and layer Ⅲ were still relatively intact and the canopy was continuous, allowing it to support the movement and feeding behaviors of gibbons.

Habitats vegetation protection

Although Nankang Station has bolstered its management practices since 2007, there was still a lack of control of the commercial-driven tsaoko plantations. Indeed, the plantation area is expanding every year, increasing both the frequency and density of human disturbance. Based on this study, tsaoko plantations have had a significant impact on the forest structure of the Nankang habitat and therefore, a potential negative effect on the movement and sleep patterns of gibbons. Accordingly, to conserve both eastern hoolock gibbons and other arboreal species, we have suggested several new initiatives, including controlling tsaoko plantation expansion or even decreasing plantation area, and restricting cultivation activities.

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