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Thirteen years observation on diet composition of Hainan gibbons (*Nomascushainanus*)

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Abstract. Researches on diets and feeding behavior of endangered species are critical to understand ecological adaptations and develop conservation strategies. To document the diet of the Hainan gibbon (*Nomascus hainanus*) we conducted a long-term dietary composition survey in Bawangling National Nature Reserve, Hainan Island, China from 2002 to 2014. Transects and quadrants were established to monitor plant phenology and to count tree species. Tracking survey and scan-sampling method were used to record the feeding species and feeding time of Hainan Gibbon. Our results showed that Hainan gibbons' habitat vegetation structure is tropical montane evergreen forest dominated by Lauraceae species while Dipterocarpaceae, Leguminosae and *Ficus*are rare. Hainan gibbons consume 133 plant species across 83 genera and 51 families. Hainan gibbons consumed more Lauraceae and Myrtaceae plant species than other plant species, whereas their consumption of leguminous species was little and with no Dipterocarpaceae compared to other gibbons. Furthermore, we classified the food plants as different feeding parts and confirmed that this gibbon species is a main fruits eater particularly during the wet season (114 species,64.8% feeding time), meanwhile we also observed five species of animal foods. Most fruit plant species is supra-annuals fruiting in the habitat of Hainan Gibbon. It seems this gibbon species also has diversified its dietary composition by including leaves, buds and flowers based on their natural availability. Food resources may be a major factor limiting the population growth of Hainan gibbons, they are the most important factor to restore and improve the current habitat for the conservation of this species.

Key words: gibbon, *Nomascus hainanus*, diet composition, feeding behavior, habitat.

Introduction

The Hainan gibbon (*Nomascus hainanus*) is one of the world's most endangered primates and categorized as "critically endangered" in IUCN Red Data List (Geissmann et al. 2004). Studies have shown that Hainan gibbon population growth is slow and the sex ratio of infants is male-skewed (Zhou and Zhang 2003, Deng et al. 2015). Increasing human population and accelerated habitat loss threaten this species badly (Lee 2010). Suitable natural forest was mainly replaced by secondary forest or artificial forest below 760 m above sea level, or degraded by logging, grazing and planting pines in Bawangling (Zhang et al. 2010). Only four groups of Hainan gibbons inhabit in Bawangling National Nature Reserve (BNNR), Hainan Island, China (Bryant et al. 2016). Without effective protection measures, Hainan gibbons will soon go extinct (Wu et al. 2004, Zhou et al. 2005). Knowledge of an animal's diet is important to evaluate wildlife habitat quality (Cui et al. 2007).

Much more data about gibbons' feeding behavior are now available (*Hylobates lar*: Raemaekers 1978; *H. klossii*: Whitten 1982; *H. moloch*: Kappeler1984, Kim et al. 2011; *H. agilis*: Gittins 1982; *H. mulleri*: McConkey et al. 2002; *Nomascus concolor*: Hu et al. 1990; *Symphalangus syndactylus*: Palombit 1997; *Hoolock hoolock*: Islam & Feeroz 1992, Zhang et al. 2008, Wu et al. 2009; and *N. concolor*: Fan et al. 2009, Fan & Jiang 2010). Gibbons are frugivorous (McConkey et al. 2002). Xu (1984) reported that Hainan gibbons mainly feed on mature fruits, young leaves and buds, but did not identify the plant species consumed. Liu and Tan (1990) collected a diet survey of one group of the Hainan gibbon, reported 40 feeding plant species, and Lin et al (2006) had an incomplete diet of plant species, both cannot provide enough information to evaluate foraging strategies of these rare gibbons.

In this writing, we reported dietary data based on 13 years of field observation, including detailed information on plant species composition, food items consumed by and the availability of food resources for Hainan gibbons. The results might supply basal data for exploring Hainan gibbons feeding species selection and allocation. Understanding diet also expands our understanding of aspects of their behavioral ecology and adaptation for survival, and their evolutionary adaptations

Materials and methods

Study area

We conducted this study in Bawangling National Nature Reserve (BNNR) (Fig. 1) in China (19°02´–19°08´N, 109°02´–109°13´E). Altitude range from 650–1,437 m, annual average temperature is 21.3 °C, annual precipitation is 1,657 mm. The area has a tropical monsoon climate with obvious wet season (June to November) and dry seasons (December to May) (Long et al. 2011). Vegetation consists primarily of tropical montane evergreen forest species, where the species diversity decreases with the increase in altitude (Yu et al. 2001). Dominant plant families include Lauraceae, Rubiaceae, Fagaceae and Euphorbiaceae; a dominant genus is *Symplocos* (Long et al. 2011). The lowland forest and part of the high-altitude rainforests in BNNR faced logging and road building from the 1950s to 1990s (Zang et al. 2004).

Methods

We observed Hainan gibbons over 68 months during the following periods: August 2002–September 2003, December 2003–November 2004, April 2005–August 2008, October 2009 –June 2013 and September 2013–August 2014. We followed two groups (Group A: 1 adult male, 2 adult females, 2 adolescents, 1 juvenile and 1 infant; Group B: 1 adult male, 2 adult females, 1 juvenile and 1 infant) before 2011. Group C formed newly in August 2011 by 5 individuals, including 1 adult male, 2 adult females and 2 infants (Deng et al. 2017). We observed Group C from August 2011 to July 2014. Total field observation days of all groups were up to 584, and accumulated 3400 hours.

Before the investigation, the Hainan gibbon was habituated for a month, then observed them from 30 meters away, without affecting its normal activities. To analyze the differences of food species

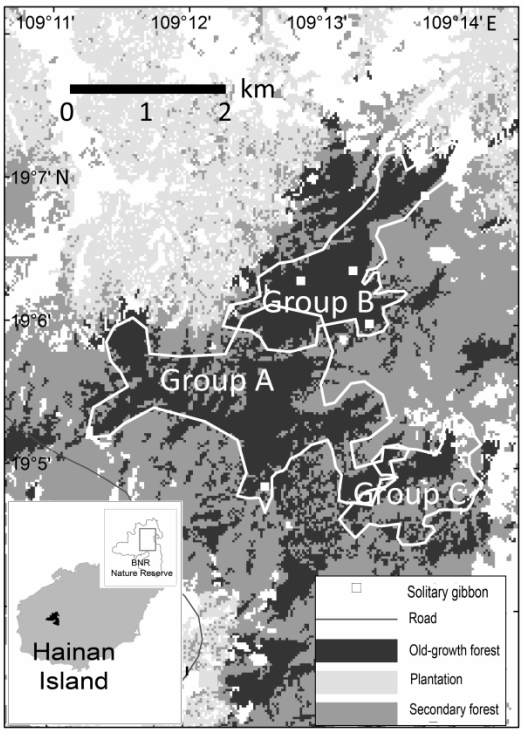

Figure 1. The distribution of the Hainan gibbon *Nomascus hainanus* in Bawangling National Nature Reserve, Hainan, China (cite: Deng et al. 2017).

utilized by Hainan gibbon, we adopted the scan-sampling method to record food species in all groups every 5 minutes. We also collected fresh droppings of Hainan gibbons and put into plastic automatic sealing bags. The droppings were used to identify the food remains in the laboratory to confirm the plants that were consumed especially drupes. Since gibbons cannot digest those drupes' cores, we judge the species of the drupes by their nutlets in fecal samples. Plants were considered as diet items if any one of the following three criteria were met:(1) one individual gibbon consumed the same plant more than twice, or feeding time is greater than 5 s (Struhsaker 1975); (2) the plants were found to be partially consumed after a gibbon left a site; and (3) the plants items were found in gibbon fecal samples.

We established two transects in Hainan gibbon habitat at an altitude of 600–1,200 m, length of each transect was 4 km, the transect width was 20m. The staffs of the nature reserve helped to record phenological information twice a month from 2004 to 2014. We set up 85 quadrants (30×30m) in whole habitat of Hainan gibbon by using the minimum area sampling method. At the elevation 600-1,200 m of the habitat, every 100m toward different slope direction (East, West, South and North) and in different topography (Bridge and Valley), surveys to the arbors and vines whose diameter at breast height (DBH) are larger than 10 cm in each quadrant were carried out. We tagged 3,249 sample trees (dbh >10 cm, height >10 m) across 58 families and 293 species. Blanquet methods were used to calculate the abundance of food species (Subcommittee on Conservation of Natural Populations, 1982). The categories used were: very abundant (VA): > 100 trees (>10 cm in dbh) per ha; abundant (A): 10-100 trees per ha; common (C): 1-10 trees per ha; uncommon (U): 0.1-1 tree per ha; rare (R): < 1 tree per 10 ha; and very rare (VR): < 1 tree per 50 ha.

Data collection and analysis

We began monitoring gibbons from daybreak. A telescope (Olympus, EXWPI) and digital camera (Panasonic, DMC, FZ30GK) were used to observe and record plants eaten by Hainan gibbons. Every day we arrived at monitoring points before sunrise to locate gibbons based on their morning great calls (Deng et al, 2014). We recorded each food species, the part eaten, and the duration of a feeding bout. We calculated the abundance of food species and monitored fruit tree species monthly and recorded their budding, flowering and fruiting times. Hainan gibbon move to one place, and we defined a feeding bout as the individuals of a group from the first begin feeding to the end of the last one to gather the food. We marked each tree on which gibbons fed and collected a relevant specimen (leaf, flower or fruit) for preservation and later for identification after the individuals leaving the trees. The plant species were identified according to the monograph "Flora of Hainan" (Chen et al. 1964). Each food item was classified as fruit, fresh leaf, shoot, flower, or animal food. We calculated the feeding plant species and feeding time of food intake per month. We used single-factor analysis of variance to test for differencesof food availability among months. We set the significance level to $\alpha = 0.05$.

Results

Dietary composition of Hainan gibbons

Hainan gibbons consumed 133plant species (Table 1). We identified 131 of these species across 51 families and 83 genera. Of the plant species eaten, 81.1% were trees, 15.9% were lianas, and 3.0% were herbs. Hainan gibbon spent 64.8% of feeding time on fruits, followed by on leaves (28.8%), buds (5.5%), flowers (0.6%) and animals feed (0.3%). The Hainan gibbon consumed fruits from 14 *Ficus* species, whereas it only accounts for 7.2% of the feeding time. The most commonly used part of a plant was ripe fruit in general. Five kinds of animal feed were eaten including young birds, bird eggs, spiders, termites and pupae. Because the Hainan gibbon captured the animal feeds in the higher canopy of the trees, it was hard to observe them clearly, therefore we can't identify what their species are, and just described simply as "moths' pupae", or "bird eggs".

Seasonal variation in the amount of time spent feeding on different food types was detected in Hainan Gibbon (Fig. 2). A greater proportion of fruits were eaten mostly in the wet season. The proportion of leaves, bud and flowers in the diet accounted for the larger proportion in dry season, especially in January accounted for about 50%. According to our record the animal feed was consumed only in September and December. Hainan gibbon spent more time in feeding when they eat more leaves during the dry season (Fig. 3).

Hainan gibbons fed on multiple plant species, but the total proportion per species was low (<3%). Only six species' feeding proportion were more than 3.0%, including *Gironniera subaequalis* (12.0%), *Schefflera octophylla* (6.4%), *Endospermum chinense* (5.0%), *Artocarpus styracifolius* (4.2%), *Canthium dicoccum* (3.2%) and *Xanthophyllum hainanense* (3.0%).

The dominant plant families were Moraceae, Annonaceae, Lauraceae, and Myrtaceae, with more than 7 species (Table 1). Hainan gibbons feed on two kinds of Leguminosae plants, *Derris trifoliata* and *Millettiapachyloba*, consuming their tender leaves in the dry season when other food is scarce. Plant family and species such as Moraceae, *Pouteria hainanense*, *Canarium album*, and *Gnetum montanum*are the major food sources of Hainan gibbon, but during the dry season they bear only a few fruits.

Table 1. Plant species consumed by Hainan gibbons at BawanglingNational Nature Reserve.

Family	Species	Life form	Part(s) eaten	Fruit type	Fruit Time	Abundance
Aceraceae	*Acer fabri* Hance	T	Fr	Drupe	9,10	R
Actindaceae	*Actindia latifolia*	V	Fr	Berry	8,9	C
Anacardiaceae	*Choerospondias axillaris*	T	Fr	Drupe	7,8,9,10	U
	Spondias lakonensis	T	Fr	Drupe	7,8,9,10	U
Annonaceae	*Desmos chinensis*	T	Fr	Berry	6-3(Next year)	R
	Fissistigma maclurei	T	Fr	Berry	9,10	R
	Fissistigma oldhamii var. longistipitatum	T	Fr	Berry	5,6	C
	Fissistigma polyanthum	T	Fr	Berry	8,9	R
	Fissistigma tungfangense	T	Fr	Berry	6,7	R
	Oncodostigma hainanense	T	Fr	Berry	4,5.6	C
	Polyalthia laui	T	Fr	Berry	3,4,5.6	C
	Polyalthia laui	T	Fr	Berry	10,11,12,1	C
	Polyalthia suberosa	T	Fr	Berry	4,5,6	A
	Uvaria microcarpa	T	Fr	Berry	11,12,1	U
Apocynaceae	*Alyxia hainanensis*	V	L	Drupe	3,4,5	C
	Melodinus suaveolens	V	Fr	Berry	All the year	A
Aquifoliaceae	*Ilex angulata*	T	Fr	Drupe	7,8,9,10	R
	Ilex goshiensis	T	Fr	Drupe	1,2	C
	Ilex kobuskiana	T	Fr	Drupe	1,2	A
Araceae	*Pothos repens*	V	L	Berry	Uncertain	VA
Ariaceae	*Schefflera octophylla*	T	Fr、L	Berry	1,2,3,4	A
Aspleniaceae	*Neottopteris nidus*	E	L		Uncertain	U
Boraginaceae	*Ehretia longiflora*	T	Fr	Drupe	8,9	U
Bursraceae	*Canarium album*	T	Fr	Drupe	8,9,10,11	A
	Canarium pimela	T	Fr	Drupe	9,10,11	R
Capparidaceae	*Capparis zeylanica*	V	Fr	Berry	11,12	U
	Stixis suaveolens	V	Fr	Drupe	7,8	U
Convolvulaceae	*Erycibe obtusifolia*	V	Fr	Berry	1,2	C
Dichapetalacea	*Dichapetalum longipetalum*	T	Fr	Drupe	Uncertain	U
Dilleniaceae	*Dillenia turbinate*	T	Fr	Berry	5,6,7	C
Ebenaceae	*Diospyroscathayensis*	T	Fr	Berry	4,5,6	C
	Diospyros nitida	T	Fr	Berry	1,2	U
	Diospyros maclurei	T	Fr	Berry	2,3	U
	Diospyros susarticulata	T	Fr	Berry	2,3	U
Elaeocarpaceae	*Elaeocarpus apiculatus*	T	Fr	Drupe	10,11,12	C
	Elaeocarpus dubius	T	Fr	Drupe	6,7,8	C
	Elaeocarpus ganitritrus	T	Fr	Drupe	1、2	C
	Elaeocarpus sphaericus	T	Fr	Drupe	Uncertain	R
	Elaeocarpus howii	T	Fr	Drupe	6,7	U
	Elaeocarpus sylvestris	T	Fr	Drupe	10,11	C
Euphorblaceae	*Antidesma montanum*	T	Fr、L	Drupe	1,2	C
	Baccaurea ramiflora	T	Fr	Berry	5,6,7	C
	Endospermum chinense	T	Fr、L	Drupe	4,5,6	C
	Bischoffia javanica Hance	T	Fr	Berry	10,11,12,1	A
	Bridelia insulana.	T	Fr	Drupe	7,8,9	C
Fagaceae	*Castanopsis hystrix*	T	L	Drupe	8,9,10,11	VA
Flacourtiaceae	*Flacourtia rukam.*	T	Fr	Berry	10,11,12	U
Gesneriaceae	*Aeschynanthus moningeriae*	E	Fl		9,10,11,12	C
Gnetaceae	*Gnetum montanum*	V	Fr	Drupe	8,9,10,11,12	A
	Gnetum parvifolium	V	Fr	Drupe	9,10,11	C
Guttiferae	*Garcinia multiflora*	T	Fr	Berry	7,8,9,10,11,12	C
	Garcinia oblongifolia	T	Fr	Berry	8,9,10,11,12	C
Icacinaceae	*Apodytes dimidiata*	T	Fr	Drupe	Uncertain	R
Lauraceae	*Beilschmiedia intermedia*	T	Fr	Drupe	1,2	A
	Cryptocarya densiflora	T	Fr	Drupe	1,2,3	U
	Crypocarya maclurei	T	Fr	Drupe	1,2,3	VA
	Crypocarya metcalfiana	T	Fr	Drupe	1,2,3	C
	Litsea baviensis	T	Fr	Drupe	9,10,11,12,1,2,3	C
	Litsea monopetala	T	Fr	Drupe	Uncertain	C
	Lindera kwangtungensis		Fr	Drupe	7,8,9,10	U
	Machilus odoratissima	T	Fr	Drupe	8,9,10	C
	Machilus chinensis	T	Fr	Drupe	3,4,5	C
	*Phoebe*sp.	T	L		Uncertain	VR
Leguminosae	*Derris trifoliata*	V	L	Berry	1,2,3	VA
	Millettia pachyloba	V	L	Berry	1	A
Loranthaceae	*Dendrophthoe pentandra*	T	Fr	Berry	Uncertain	U
	Macrosolen cochinchinensis	T	Fr	Drupe	7,8	U
	Viscum articulatum	T	Fr	Drupe	Uncertain	U

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Table 1 (continued)

Family	Species	Life form	Part(s) eaten	Fruit type	Fruit Time	Abundance
Magnoliaceae	*Illicium temstroemioides*	T	Fr		7,8,9,10	U
Menispermaceae	*Albertisia laurifolia*	E	Fr	Berry	1,2	C
Meliaceae	*Aglaia roxburghiana*	T	L	Drupe	3,4,5	A
	Walsura robusta	T	Fr	Drupe	5,6	U
Moraceae	*Artocarpus nitidus*	T	Fr	Drupe	7,8	VR
	Artocarpus styracifolius	T	Fr	Drupe	9,10	C
	Artocarpus tonkinensis	T	Fr	Drupe	8,9,10	U
	Ficus altissima	T	Fr	Drupe	Uncertain	R
	Ficus benjamina	T	Fr	Drupe	7,8	U
	Ficus esquiroliana	T	Fr	Drupe	Uncertain	U
	Ficus graberrima	T	Fr	Drupe	Uncertain	C
	Ficus harmandi	T	Fr	Drupe	Uncertain	U
	Ficus hateropleura	T	Fr	Drupe	4,5	U
	Ficus langkokensis	T	Fr	Drupe	Uncertain	U
	Ficus microcarpa	T	Fr	Drupe	10,11	U
	Ficus nervosa	T	Fr	Drupe	7,8,9	U
	Ficus sagittata	T	Fr	Drupe	Uncertain	VR
	Ficus tinctoria	T	Fr	Drupe	5,6	C
	Ficus variegata	T	Fr	Drupe	Uncertain	U
	Ficus virens	T	Fr	Berry	7,8	C
	Ficus virgata	T	Fr、L	Berry	All the year	C
Myrtaceae	*Acmena acuminatissima*	T	Fr	Berry	12,1	C
	Cleistocalyx conspersipunctatus	T	Fr	Berry	9,10	C
	Cleistocalyx operculatus	T	Fr	Drupe	10,11,12	C
	Syzygium brachyantherum	T	Fr	Drupe	11,12	U
	Syzygium championii	T	Fr	Drupe	11,12	C
	Syzygium chunianum	T	Fr	Drupe	11,12,1,2,3,4	C
	Syzygium hainanense	T	Fr		10,11,12	U
Nyssaceae	*Nyssa javanica*	T	Fr		7,8	VR
Orchidaceae	*Dendrobium aurantiacum var. denneanum*	E	Fl	Berry	6	U
	Dendrobium hainanensis	E	Fl	Berry	6	A
Palmae	*Calamus egregius*	V	Fr	Berry	7	U
	Calamus tetradactylus	V	Fr	Berry	5,6	U
	Caryota ochlandra	T	Fr		Uncertain	C
	Daemonorops margaritae	V	Fr		10,11,12,1,2	VA
Podocarpaceae	*Dacrycarpus imbricatus*	T	Fr	Drupe	2,3,4	C
	Dacrydium pierrei	T	Fr	Drupe	1,2,3	C
	Podocarpus neriifolius	T	Fr	Drupe	5,6	C
Polyalaceae	*Xanthophyllum hainanense*	T	L		12,1,2,3,4,5	A
Proteaceae	*Helicia hainanensis*	T	Fr	Drupe	9,10,11,12	C
	Helicia kwangtungensis	T	Fr	Drupe	8,9,10,11	C
Rhamnaceae	*Ziziphus fungii*	T	Fr	Drupe	4,5	R
Rosaceae	*Pygeum topengii*	T	Fr	Drupe	4	U
Rubiaceae	*Canthium dicoccum*	T	L		1,2,3,4	C
	Mussaenda hainanensis	T	L		1,2,3	A
	Pertusadina hainanensi	T	L		Uncertain	U
	Psychotria rubra	T	Fr	Drupe	7,8,9	A
Rutaceae	*Acronychia oligophlebia*	T	Fr	Berry	8,9,10,11,12	R
	Acronychia pedunculata	T	Fr	Berry	7,8,9	C
Sapindaceae	*Aphania oligophylla*	T	Fr	Drupe	5,6	C
	Litchi chinensis Sonn. var. euspontanea	T	Fr	Berry	6	C
	Nephelium topengii	T	Fr	Berry	5,6	C
Sapotaceae	*Pouteria annamensis*	T	Fr	Berry	7,8,9,10	U
Sarcospermaceae	*Sarcosperma laurinum*	T	Fr	Drupe	3,4	C
Schizandraceae	*Kadsura coccinea*	V	Fr	Berry	8,9,10,11,12	U
Theaceae	*Adinandra hainanensis*	T	Fr	Berry	6,7	C
Tiliaceae	*Microcos chungii.*	T	Fr	Drupe	8,9,10,11,12	U
	Microcos paniculata	T	Fr	Drupe	10,11,12	U
Urticaceae	*Oreocnide rubescens*	T	Fl		1	C
Ulmaceae	*Gironniera cuspidata*	T	Fr	Drupe	8,9	U
	Gironniera subaequalis planch	T	Fr	Drupe	7,8,9,10,11,12	A
Vttaceae	*Tetrastigma cauliflorum*	V	Fr	Berry	6,7,8,9,10,11,12	C
	Tetrastigma planicaule	V	Fr	Berry	10,11	C
Undefined	SP1	E	Fr		9,10,11	U
Undefined	SP2	E	*L*			U

Note: Life form: T, tree, V, vine, E, epiphyte; Part(s) eaten: L, leaves, Fr, fruit, Fl, flowers;
Abundant: very abundant, VA, abundant, A, common, C, uncommon, U, rare, R, very rare, VR.

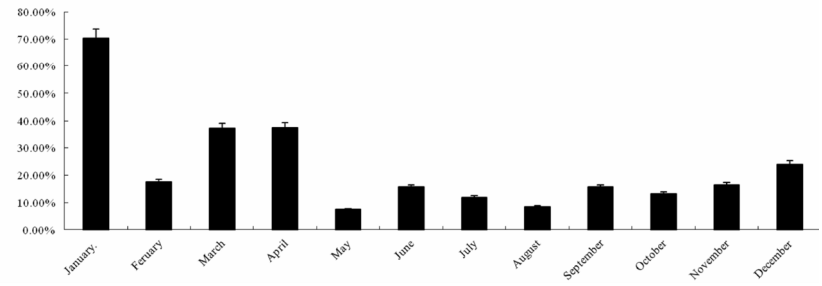

Figure 3. The percentage of Hainan gibbon feeding time to all activity time per month at Bawangling National Nature Reserve.

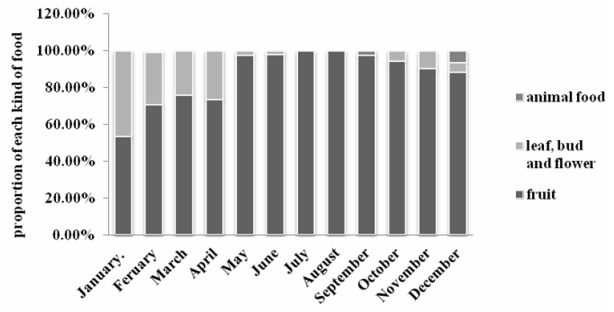

Figure 2. The food composition of Hainan gibbon at Bawangling National Nature Reserve.

Table 2. Plant species that can be used by Hainan gibbons per year at Bawangling National Nature Reserve.

Family	Species	Feeding part
Anacardiaceae	*Choerospondias axillaria*	Fr
Annonaceae	*Oncodostigma hainanense*	Fr
	Pouteria hainanense	Fr
	Polyalthia laui	Fr
Apocynaceae	*Melodinus suaveolens*	Fr
Ariaceae	*Schefflera octophylla*	Fr, L
Bursraceae	*Canarium album*	Fr
Elaeocarpaceae	*Elaeocarpus apiculatus*	Fr
	Elaeocarpus sylvestris	Fr
Euphorblaceae	*Baccaurea ramiflora*	Fr
	Bischoffia javanica	Fr
	Endospermum chinense	Fr, L
Guttiferae	*Garcinia multiflora*	Fr
	Garcinia oblongifolia	Fr
Lauraceae	*Litsea baviensis*	Fr
	Machilus chinensis	Fr
Moraceae	*Artocarpus styracifolius*	Fr
	Ficus esquiroliana	Fr
	Ficus harmandi	Fr
	Ficus tinctoria	Fr
	Ficus variegata	Fr
	Ficus virens	Fr, L
Myrtaceae	*Acmena acuminatissima*	Fr
Myrtaceae	*Acmena acuminatissima*	Fr
Papilionaceae	*Derris trifoliata*	L
Polyalaceae	*Xanthophyllum hainanense*	L
Proteaceae	*Helicia kwangtungensis*	Fr
Rubiaceae	*Mussaenda hainanensis*	L
	Nephelium lappaceum	Fr
Tiliaceae	*Microcos paniculata*	Fr
Ulmaceae	*Gironniera subaequalis planch*	Fr
Vttaceae	*Tetrastigma cauliflorum*	Fr

Availability of food resources

We recorded 1484 (individuals?) trees in the habitat of Hainan Gibbon, of which *Ficus* comprised of 597 plants. There, only a few large trees bear fruit every year. These include *Bischoffia javanica* (15 trees), *Nephelium lappaceum* (28 trees), *Pouteria hainanense* (26 trees), and *Ficus virens*, *F. variegatae, Endospermum chinense*and *Choerospondias axillaria* (<30 trees in the whole habitat). There were only 15 species with fruiting rates greater than 50% across all tagged tree species. The greatest rate was for *Polyalthia laui* at 76.67%, followed by *F. altiscima* (75%), *F. tinctoria* (73.91%), *F.virgata* (71.14%), *F. glaberrima* (66.67%), *Spondias lakonensis* (63.64%), *Microcos paniculata* (62.67%), *Psychotria rubra* (62.50%), *F. variegata* (58.33%), *Pouteria hainanense* (58.33%), *Nephelium topengii* (57.75%), *Litsea baviensis* (50%), *Syzygium hainanense* (50%), *Elaeocarpus apiculatus* (50%) and *Bridelia insulana* (50%).

Our results show that the availability of food resources changes each year. The number of species eaten per year was 58±7.3. There were only 32 food species repeatedly used by Hainan gibbons each year, and for 18.7% of species leaves were eaten (Table 2). There are few fig species available as foods (Fig. 4). Food availability is different among months ($t=2.53$, $P=0.03$) and the food shortage season happens in dry season. For this season, there are less precipitation, makes *Ficus* fruit and non-figs become scarce and less available during this period. Hainan Gibbons eat more tender leaves and increase their feeding time (Fig. 3) to live through this period.

Discussion

Dietary differences between Hainan gibbons and other gibbons

Our long-term survey identified 133 plant species belonging to 83 genera from 51 families which were eaten by Hainan gibbons. Compared with previous reports (40 species, Liu & Tan 1990; 82 species, Lin et al. 2006), our investigation resulted in longer list and more expanded dietary composition of this rare gibbons. Furthermore, we classified the food plants into different feeding parts to evaluate its abundant rank and confirmed this gibbon as a main fruit eater, although Hainan gibbons was found eating some kinds of animal items in the wild. It seems that this gibbon also diversifies its dietary components by including leaves, buds and flowers based on natural availability or a survival feeding strategy (habitat may have been degraded, Zang et al. 2004, Zhang et al. 2010). This is not similar with West Black crested gibbon *Nomascus concolor* who feeds on leaves and fruits half in half (44.1% fruits: 55.9%leaves, Fan 2009), and same as the other gibbon species lived in the tropical rain forests of southeast Asia, except the *concolor* gibbon.

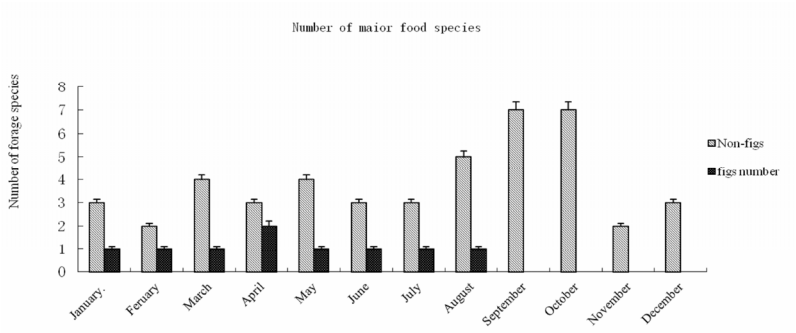

Figure 4. Number of major foraging species of the figs and non-figs fruits utilized by the Hainan gibbon per month at Bawangling National Nature Reserve.

Table 3. Comparison of dietary compositionfor different gibbon species.

Gibbon species	*N. hainanus* (This study)	*H. kloss* (Whitten 1982)	*H. agile* (Gittins 1982)	*N. leucogenys* (Hu 1990)	*N. concolor* (Fan 2009)
Ficus (ratio)	14(7.2)	9(23)	8(17)	5	3(18.6)
Dipterocarps	0	7	3	0	0
Leguminosae	2	3	1	0	0
Lauraceae	10	2	1	0	2
Elaeocarpaceae	6	0	1	2	1
Study area	Banwangling	Paitan	Sungai Dal	Mengla	Wuliang Mountains
Study time	13 years	Two years	Two years	Four years	14 months
Altitude	680-1280m	-	150-875m	1244m	1900-2800m
Habitat type	Montane evergreen forest	Tropical rainforest	Tropical rainforest	Tropical rain forest and monsoon forest	Montane evergreen forest
Home range	548- 987ha*	31ha	29ha	540ha	150ha

Note: * Bryant et al. 2017 report the homerange is 149 ha.

We found that the area at different latitudes where gibbons inhabit also influence its food and plant availability and further cause difference. For example, Hainan gibbons (which lives in 18°53́–19°20́) consumed Annonaceae, Myrtaceae and Rubiaceae, while White-cheeked gibbons (*H. leucogenys,* 21°08´–22°00´N, Hu 1990) can feed on Alangiaceae and Myrsinaceae. Moraceae and Burseraceae were eaten by both animals because those trees are available at both sites. Moraceae, Annonaceae, Myrtaceae, and Euphorbiaceae contributed to the main part of diet of Hainan and other gibbons (*Hylobateslar*, *H. klossii*, *H. moloch*, *H. agile*, *H. mulleri* and*S. syndactylus*, Mather 1992). Hainan gibbons fed more species of Elaeocarpaceae and Lauraceae than other gibbons (0–2 species, Whitten 1982, Gittins 1982, Hu et al. 1990, Fan et al. 2009) (Table 3). Other gibbon's feed a lot on Leguminosae and Dipterocarpaceae, while Hainan gibbons only eat two Leguminosae plants and did not eat Dipterocarpaceae at all (Table 1). Why Hainan gibbons did not eat Diperocarpaceae species in BNNR? The possible reason is that *Vatiea mangachampoi blauco* and *Hopea hainanensis* only grow below 400m above sea level in this area and the gibbons move about above this elevation too much and cannot use them as food.

The home range area (548-987 ha) of Hainan gibbon was larger than other gibbon species. Bryant et al. (2017) reported that the home range (149 ha) of Hainan gibbon was similar to other gibbons', but this research finished in short time, just in 93 days of dry season and 3 months of wet season (2010–2011); and the observation time and the following time were very short, just 24 days and mean following observation time 2.16±1.73 hrs. It might not reflect the accurate movement distances of Hainan gibbons in different seasons. Our result of larger home range area was based on the 29 months field survey continuously, and the mean observation time was 5.85±1.12 hrs.

The current habitat vegetation of Hainan gibbon is the tropical mountain evergreen broad leaf forest, and is not similar to the other gibbon species lived in lowland tropical rain forests of Southeast Asia, but more similar to the west black-crested gibbons' (*N. concolor*), which distributed in Yunnan Province of China. There is no regular phenology of plants in the habitat of Hainan Gibbon. Most fruit plant species are supra-annuals fruiting within 3 to 7 years in BNNR. For example, *Nyssa javanica* fruited in 2002, 2007 and 2014; and *N. lappaceum* and *Dendrobenthamia angustata* fruited in 2004, 2007, 2011 and 2014. That means, there is the difference among the food compositions in different years in the life of Hainan gibbon. It might indicate that the current habitat is not suitable for this primate species, because of the dominant families appear in the habitat vegetation, such as Fagaceae (Important Value: 19.6%) and Lauraceae (Important Value: 26.4%) (Zhou, 2008).There are some species of these two families eaten by Hainan gibbon, similar to the western black-crested gibbon, and do not appear in the dietary compositions of other gibbon species, which lived in the lowland tropical rain forests of Southeast Asia. There is not any *Ficus* species which occupy the top ten of the important value among the vegetation analysis (Zhou, 2008), meanwhile, the habitat also lacks of the Leguminosae species. So, we think that the vegetation and the food resource may be the limited factors on the population recovery for this critically endangered species. It is very important to recover the lowland forest for the conservation action of Hainan gibbon, and this study give the comprehensive data on the plants selection for the lowland forest recovery in BNNR.

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