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SELECTION AND TREATMENT OF FOOD PLANTS BY WHITE-HANDED GIBBONS *(HYLOBATES LAR)* IN KHAO YAI NATIONAL PARK, THAILAND

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ABSTRACT

An inventory of the food plants selected by white-handed gibbons *(Hylobates lar)* and their treatment of each species is presented, based on two field studies covering five years in Khao Yai National Park, Thailand. The inventory includes food plant identification, plant abundance at the site, months during which eaten, and an evaluation of the effects of gibbon feeding on the plant species. These effects fall into the categories of seed dispersal, seed destruction, or herbivory (consumption of nonfruit parts).

Gibbons at this 40 ha site were observed using 76 different species, from 466 individual plants. They consumed 23 different *Ficus* species and 53 other plant species. Ripe fruit was selected from a total of 61 species, either taken exclusively (35 species) or in combination with other plant parts. Beneficial seed treatment and dispersal were observed for 18 fruit species and are likely for 26 others. Both herbivory and the consumption of large quantities of flowers or unripe fruit may result in harmful effects to 69 plants from 20 of the species eaten by gibbons. Gibbons may help maintain species diversity in their forest habitats through beneficial seed dispersal, a role which needs further investigation.

INTRODUCTION

Gibbons *(Hylobates* spp.*)* occupy the primary tropical moist forests of Southeast Asia, forests noted for the high diversity and usefulness of their plants. Gibbon diets reflect the biodiversity of their regions. Since gibbons are largely frugivorous and have been ubiquitous inhabitants of the forests since the Pleistocene (CREEL & PREUSCHOFT, 1984), their impact on forest ecosytems as potential mutualists deserves continued investigation (BROCKELMAN, 1985).

A consistent dietary pattern for gibbons has emerged from previous studies of gibbons at other sites in Asia (CARPENTER, 1940; CHIVERS, *et al.*, 1980; ELLEFSON, 1974; GITTINS & RAEMAEKERS, 1980; SRIKOSAMATARA, 1984). These tropical primates exploit a wide variety of fleshy fruit species, as well as particular leafy foods, flowers, occasional unripe fruit, and insects. The proportion of each food category has been found to vary from site to site and season to season, but the reliability of the fruit species eaten at any single site is noteworthy. Such reliable plant-consumer relationships may have contributed to evolutionary adaptations in plant populations as individuals were selected to attract or avoid consumption by gibbons (HOWE, 1984).

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Hylobates lar ranges from northern Sumatra and Peninsular Malaysia, to northern Thailand, Myanmar and Western Yunnan Province, China (CREEL & PREUSCHOFT, 1984). Undoubtedly the fruits and food plants they encounter vary greatly across such a large range. The food plants of lar gibbons have been well documented at two sites at the southern end of their range, Kuala Lompat (GITTINS & RAEMAEKERS, 1980; CHIVERS, et al., 1980) and Tanjong Triang (ELLEFSON, 1974). Except for Carpenter's pioneering work in Thailand in 1937 (CARPENTER, 1940), no detailed dietary studies have been published for the northern or central portions of their range.

The diet of *H. lar* gibbons is presented here as it was assessed in 1983–84 and 1988 – 90 during two separate field studies carried out by the authors in Khao Yai National Park in Central Thailand. Particular emphasis has been placed on aspects of gibbon food selection and treatment which might affect tree regeneration, such as the phenological stage preferred and seed dispersal.

STUDY SITE

The research site is located at 14° 26' N, 101°22' E, in the Mo Singto study area of Khao Yai National Park, Thailand (Figure 1). The park, 2162 km^2 in area, is one of Thailand's largest primary tropical evergreen forests.

The site is hilly and well drained, with elevations from 720 to 870 m MSL. It receives over 3000 mm of rain each year, with a marked wet season from May through October and relatively dry conditions from November until April. Many tree species lose their leaves briefly during the dry season and replace them with flush new growth, either followed or preceded by flowering. The forest is dominated by the families Moraceae, Euphorbiaceae, Annonaceae, Myrtaceae, and Dipterocarpaceae, as well as many fruiting vines and woody climbers.

The Mo Singto area has been the site of ongoing gibbon studies since 1981, when it was used for a study of gibbon vocalization (RAEMAEKERS & RAEMAEKERS, 1984). At that time the Raemaekers succeeded in habituating one group of gibbons to scientific observers. This group, known as Gibbon Group A, has remained on its original territory and under observation by various researchers since that time (TREESUCON, 1984; WHITTINGTON, 1991; BROCKELMAN, TREESUCON & RAEMAEKERS, unpub.). Study of the food plants of this habituated group of gibbons was conducted continuously during 1983 – 84 by one author, UT, and 1988 – 90 by CW, with occasional records from the intervening years by both investigators.

The research area consists of 40 ha of forest encompassing the entire home range of Gibbon Group A plus some surrounding forest habitat used by neighboring gibbons. Group A defends a territory of approximately 30 ha but ranges in as much as 38 ha. Efforts are ongoing at this site to mark and map all food plants used by the group for further studies.

Other primates sharing the habitat include pig-tailed macaques *(Macaca nemestrina)* and the slow loris *(Nycticebus coucang)*. Other mammals include wild boar *(Sus scrofa)*, several members of the family Viverridae such as the large Indian civet *(Viverra zibetha)* and masked palm civet *(Paguma larvata)*, sambar and barking deer *(Cervus unicolor* and

Muntiacus muntjak), porcupines *(Hystrix brachyura* and *Atherurus macrourus)*, giant tree-squirrel *(Ratufa bicolor)* and other squirrels, and fruit bats of the family Pteropidae. Tigers *(Panthera tigris)*, bears *(Selenarctos thibetanus* and *Helarctos malayanus)*, and elephants *(Elephas maximus)* were also regular visitors to the study site.

METHODS

The study was based on direct observations of gibbon feeding and plant use. We Collected and identified gibbon food plant specimens, labelled the individual trees and vines used by gibbons at the site and tracked their phenology, and collected fecal samples and checked seed content and seed viability. Plant identifications were made at the Royal Thai Forest Department Herbarium. The overall effect of gibbon feeding behavior on a given plant species was evaluated based on (a) the impact on pollination and fruit-setting success via flower consumption, (b) increased opportunities for seed dispersal via the swallowing of intact seeds combined with evidence of egested seed viability, and (c) the impact on primary production capacity via herbivory.

Observations of gibbon feeding were made on several days each month, with additional time being used to locate and map food sources. Direct feeding observations were made with 7 x 35 binoculars. The manner of picking the fruit or food, the approximate rate of consumption, mastication, and seed swallowing behaviors were observed directly. Because of the density of the canopy and the height of many feeding bouts, direct observations were supplemented with indirect examination of dropped fruit and plant parts and collection and examination of gibbon feces.

Seeds were collected from feces whenever possible and tested for viability by germinating them in cups or clay pots. Controlled experiments were designed in cases where both the number of seeds collected and the timing of germination were suitable. In other cases observations were made of seeds germinating in situ from gibbon feces dropped near the research camp. Observation records of seed germination was considered roughly indicative of overall seed viability after gibbon digestion.

RESULTS

Table 1 lists the plant species selected by white-handed gibbons. *H. lar* gibbons were observed feeding from 466 individual plants of 76 different species representing 38 plant families at the study site (Table 2). Since neither every species nor every plant of a given species produces fruit each year, these numbers are probably conservative. Fig species were distinguished from one another in the field and assigned a letter, but most could not be identified. The 82 individuals of 23 diferent species makes *Ficus* the most significant plant genus in the gibbon diet.

Although the number of identified plants of each species located on the study site is listed, few plants produced fruit reliably every year. In general only 1/3 to 1/2 of the total number of known food plants were used by gibbons in a single year. Several prominent figs and other fruit trees, however, produced reliable fruit crops every year of the study. Ripe fruit accounted for the bulk of the gibbons' diet during every month of the year, but was in limited supply between November and March (Table 3). Ripe fruit was the only plant part selected from 35 food species and the major part selected from most others. Only 15 species were selected exclusively for parts other than fruit. Unripe fruit from 14 species was included in the gibbon diet, usually in small quantities.

In most cases of fruit consumption, the gibbons were very selective feeders, trying and then rejecting fruit which did not suit their taste. The partially eaten fruit was subsequently eaten by a variety of arthropod and mammalian consumers on the forest floor. Because of their high mobility, the gibbons were able to visit a food source several times during the peak season, selecting the ripest fruit each time. The gibbons may monitor fruit availability among the large pool of potential fruit sources each month, but it seems that cognition and memory of the general spatial and temporal pattern of food sources may be involved. On several occasions the gibbon group went directly to ripe fruit sources in another part of the territory not visited previously during the season.

Estimating the effect of gibbon consumption on the plants involved judgements based on the major part eaten and expected effects on plant production or reproduction. Consumption of ripe fruit, accompanied by observations of seed viability, was considered to be of probable benefit to the plant species. In the case of two species the conclusion is further supported by observations of lower viability of seeds from unconsumed fruit. Observations of seed swallowing without data on seed viability was considered to indicate possible benefit, if there was no sign of damage or depressed viability among those seeds passed. Dropping of seeds by gibbons at the fruit source, or light to moderate consumption of unripe fruit was considered to have a neutral effect. Heavy consumption of foliage, flowers, or unripe fruit was considered to be a harmful interaction. In cases where several plant parts were selected, the effects were estimated according to the major part eaten.

The results of this evaluation show that 18 plants may benefit from gibbon seed dispersal, based on observed viability of seeds after digestion. This includes 143 individual plants on the 40 ha site. An additional 26 species may possibly benefit from gibbon seed dispersal, but the seed viability could not be verified. In some cases, the benefit was decreased by consumption of flowers or unripe fruit. Taken together, these two classes constitute 320 plants, nearly 70% of the individual food sources available to the gibbons.

Moderate to heavy herbivory by gibbons caused potential harm to 69 plants at the site of 20 different species. A total of 11 species were judged to be subject to neutral, mixed, or uncertain effects from gibbon feeding.

Table 3 summarizes the changing diet of gibbons over the course of the year. The dry months of November through March show a higher proportion of foliage eaten, primarily as fresh young leaves and shoots of species like *Strombosia* sp. and *Erythrina subumbrans*. A monthly average of 8 different species of fruit including figs was available during those months.

Frugivory increased late in the dry season and into the rainy months, along with the variety and abundance of fruit available. A monthly average of 15 different species of figs and other fruit was available during April through October. The month of January appears to be one of potential food shortage for gibbons at this site. Only 8 different species of plants were used in January compared to the monthly average of 17.6 species. Crop failures in several of these species could have a strong impact on the territorial gibbons which cannot leave their territory to search for other food sources.

Table 1. Food plants eaten by gibbons *(Hylobates lar)* in Khao Yai National Park, Thailand. Codes:

Parts eaten: Lf = young leaf, Fl = flower, Sh = shoots, UFr = unripe fruit, Fr = ripe fruit.
Seed treatment: Drp = dropped under tree, Sw = swallowed, Ms = masticated, Un = uncertain
Seed viability: Vi = viable after digestion, Un = uncertain viability, Nd = not digested
Effect on plant: 1 = beneficial, 2 = possible benefit, 3 = neutral, 4 = harmful, 5 = uncertain

FAMILY/Species	Plants on site	Parts eaten	Months available	Seed treatment	Seed viability	Effect on plant
ANNONACEAE						
Polyalthia viridis Craib	10	Lf, Sh	5	Nd	Nd	4
		Fr	5, 6	Drp	Nd	4
Polyalthia debilis (Pierre) Finet & Gagnep.	7	Fr	3 – 7	Sw	Vi	1
Pseuduvaria sp.	15	Fl	3, 4	Nd	Nd	
		Fr	6 – 8	Sw, Drp	Un	1 – 2
Mitrephora sp.	2	Fl	5	Nd	Nd	
		Fr	8, 9	Drp	Nd	3 – 4
Desmos cochinchinensis Lour.	1	Fr	2, 3	Sw	Un	2
ANACARDIACEAE						
Buchanania reticulata Hance	2	Fr	3 – 5	Sw	Un	2
Choerospondias axillaris Burtt & Hill	16	UFr, Fr	8 – 10	Sw	Vi	1
AQUIFOLIACEAE						
Ilex goshiensis Hayata	6	Fl, UFr	2, 5	Nd	Nd	
		Fr	6 – 8	Sw	Un	2 – 4
ARACEAE						
Pothos sp.	3	Lf	1, 9	Nd	Nd	4
CELASTRACEAE						
Salacia verrucosa Wight	1	Fr	6	Un	Un	5
CONNANARCEAE						
Rourea mimosoides (Vahl) Planch.	2	Fr	3	Drp	Nd	3

FAMILY/Species	Plants on site	Parts eaten	Months available	Seed treatment	Seed viability	Effect on plant
CONVOLVULACEAE						
Erycibe sp.	10	Fr	5	Sw	Vi	1
DIPTEROCARPACEAE						
Dipterocarpus gracilis Bl.	2	Lf	1 – 3, 12	Nd	Nd	4
EBENACEAE						
Diospyros glandulosa Lace	2	Fr	9	Drp	Nd	3
ELAEOCARPACEAE						
Sloanea sigun Schum.	13	Fl	1, 9	Nd	Nd	4
ELAEAGNACEAE						
Elaeagnus latifolia Lim.	1	Fr	2	Un	Un	5
EUPHORBIACEAE						
Sapium baccatum Roxb.	9	Fr	6, 7	Sw	Vi	1
Baccaurea ramiflora Lour.	1	Fr	5	Sw	Vi	1
GNETACEAE						
Gnetum montanum Markgr.	12	Fr	6, 7	Sw	Un	2
GUTTIFEREAE						
Garcinia speciosa Wall.	10	Fl	8	Nd	Nd	
		Fr	9, 10	Sw	Vi	1 – 2
ICACINACEAE						
Medusanthera gracilis (King) Sleum.	1	Lf	3, 4, 8, 12	Nd	Nd	4
Platea latifolia Bl.	1	Fr	9	Un	Un	5
LAURACEAE						
Litsea cf cambodiana	4	Fr	9	Dr, Ms	Nd	4
LEGUMINOSAE						
Acacia sp.	1	Lf	7	Nd	Nd	4
Erythrina subumbrans (Hassk.) Merr.	1	Lf	11, 12	Nd	Nd	4
Mucuna macrocarpa Wall.	1	Fl	1 – 3, 12	Nd	Nd	4
Pueraria lobata (Willd.) Ohwi	2	Lf	4 – 12	Nd	Nd	4
MELIACEAE						
Sandoricum koetjape (Burm.f.) Merr.	8	Fr	7, 8	Sw	Vi	1
Walsura trichostemon Miq.	18	Fr	4, 6, 7	Sw	Vi	1

FAMILY/Species	Plants on site	Parts eaten	Months available	Seed treatment	Seed viability	Effect on plant
MELASTOMATACEAE						
Diplectria divaricata Ktze.	7	Fr	7 – 10	Sw	Vi	1
MORACEAE						
Maclura cochinchinensis (Lour.) Corner	1	Fr	8, 9	Sw	Un	2
Ficus spp. (23 sp. total)	82 total					
7 species:	24	Fr only	1 – 12	Sw	Vi	1
8 species:	21	Fr+Lf	2–7, 10–12	Sw	Vi	2
5 species:	20	Fr+UFr	2–4, 6 8–10	Sw	Un	2
2 species:	16	Fr+UFr+Lf	1–11	Sw	Un	4
1 species:	1	Lf only	5	Nd	Nd	4
MYRISTICACEAE						
Knema elegans Pierre	56	Fl	3	Nd	Nd	
		Fr	4, 5, 8	Sw	Vi	1 – 2
MYRTACEAE						
Eugenia subviridis Craib	27	Fl	4	Nd	Nd	
		Fr	6, 7	Sw	Vi	1–2
OLACACEAE						
Strombosia sp.	2	Lf	1	Nd	Nd	4
OLEACEAE						
Chionanthus ramiflora (Roxb.) Kiew	1	UNf	1	Drp	Nd	3
PODOCARPACEAE						
Podocarpus neriifolius D. Don	5	Fr	5, 6	Dr	Nd	3
RHIZOPHORACEAE						
Carallia brachiata (Lour.) Merr.	1	Fr	1	Sw	Un	2
RUBIACEAE						
Canthum sp.	3	Fr	1, 12	Sw	Un	2
Tarenna sp.	2	Fr	8, 11	Un	Un	5
Nauclea subdita Steud.	6	Fr	8–10	Sw	Un	2
Anthocephalus chinensis Rich. ex Walp.	3	Fr	8, 11, 12	Sw, Drp	Un	3
RUTACEAE						
Toddalia asiatica Lamk.	6	Fr	7–10	Sw	Vi	1

FAMILY/Species	Plants on site	Parts eaten	Months available	Seed treatment	Seed viability	Effect on plant
SAPINDACEAE						
Nephelium melliferum Gagnep.	30	Fr	4, 5	Sw	Vi	1
SAPOTACEAE						
Genera uncertain	1	UFr	4	Drp	Nd	2
SYMPLOCACEAE						
Symplocos cochinchinensis (Lour.) S. Moore	1	UFr	4	Un	Un	4
THEACEAE						
Andinandra integerrima T Anders. ex Dyer	1	Fr	10	Un	Un	5
ULMACEAE						
Girroniera nervosa Planch.	35	Lf	1, 4–6, 8–12	Nd	Nd	
		Fr	1, 2, 4, 7, 8 10, 12	Sw	Un	2–5
Aphananthe cuspidata (Bl.) Planch.	1	UFr	7–8	Nd	Nd	
		Fr	8–11	Dr	Nd	3–4
URTICACEAE						
Poikilospermum suaveolens Merr.	1	Lf	3, 4, 7, 12	Nd	Nd	4
VERBENACEAE						
Premna sp.	1	UFr	8, 10	Un	Un	4
VITIDACEAE						
Cissus sp.	7	Fr	8–10	Sw	Vi	1
Tetrastigma cf. laoticum Gagnep.	22	Sh	11, 12	Nd	Nd	
		Fr	10–12	Sw	Un	2–3
Ampelocissus cf. martinii Planch.	2	Fr	3, 4	Un	Un	2

Figure 1. Fruit and leaves of *Nephelium melliferum* Gagnep.

Figure 2. Seeds of *Nephelium melliferum* collected from gibbon feces.

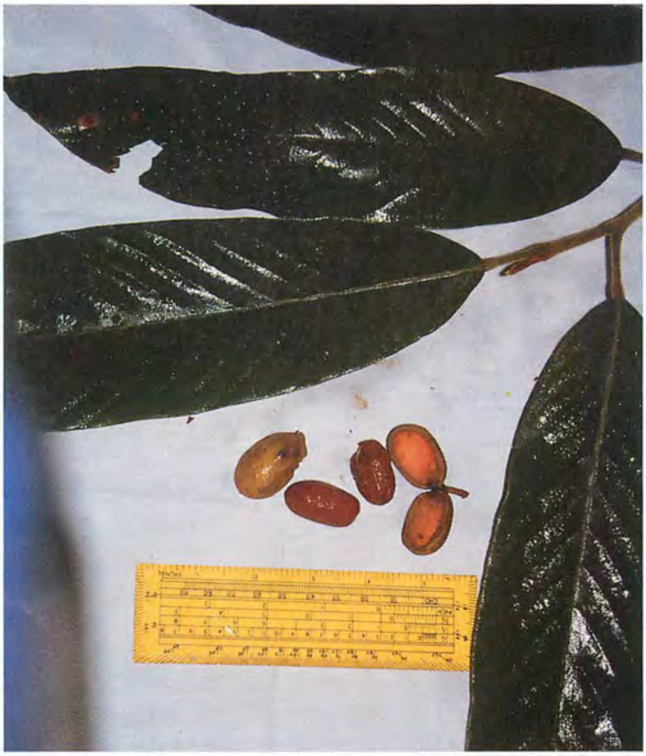

Figure 3. Leaves and seeds of *Knema elegans* Pierre.

Figure 4. Leaves and fruits of *Sapium baccatum* Roxb.

CONCLUSIONS

White-handed gibbons were found to select from a variety of the plants available on their territory but their diet was not as diverse at this site as that reported at Kuala Lompat in Malaysia (GITTINS & RAEMAEKERS, 1980). This may reflect the more limited size of the study area and a less diverse vegetation base in this more seasonal forest. The overall proportion of ripe fruit-to-foliage appears to be roughly the same at both sites, while there may be more seasonal change in the dietary proportions at the Khao Yai site.

The gibbons had a wide range of possible effects on their food plants, depending on their feeding behavior. The majority of the plants eaten by gibbons, 320 individuals from 43 species, may benefit from their interactions with gibbons through increased opportunities for seed dispersal. A minority of plants were judged to suffer detrimental effects from gibbon herbivory, which included the eating of unripe fruit of some species.

Gibbons eat a large number of ripe fruits every day, tend to swallow whole any fruit of a convenient size and shape, and leave the seeds unharmed by digestion, making them potentially beneficial dispersal agents for many, but not all, of their food plants. Further investigation of the plant species being dispersed by gibbons at this and other sites is suggested. The full assemblage of seed dispersal agents for each species should be identified and their relative contribution to fruit consumption and seed dispersal assessed. Further investigations should be made into the effects of gibbon digestion on seed germination, and whether a plant's spatial distribution and phenology show correlations with gibbon movement patterns or seasonal food shortages.

Several plant species were subject to mixed effects from gibbons eating more than one part. Figs, in particular, were often eaten at different phenological stages and the impact of this feeding pattern on the plant is difficult to assess. The relative importance of figs in gibbon diets and their diversity in Asian rainforests suggest that more detailed studies of gibbon–*Ficus* interactions should be carried out.

This study also indicates that more unripe fruit is being eaten by gibbons than previous studies have reported. the impact on plant reproduction is unknown, as are the relative nutritional and competitive merits of such a strategy. Investigations into the effects of "thinning" a potential fruit crop through flower or unripe fruit consumption followed by eating the ripe fruit might be undertaken to determine if there are any significant benefits to the consumer in the form of larger, fleshier fruit. The role of cognition, memory and active monitoring of the complex spatial and temporal pattern of food sources is also poorly understood for this species.

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