CHARACTERISTICS OF FRUITS CONSUMED BY THE WHITE-HANDED GIBBON (HYLOBATES LAR) IN KHAO YAI NATIONAL PARK, THAILAND

CHUTI-ON KANWATANAKID

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE
(ENVIRONMENTAL BIOLOGY)
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was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Environmental Biology)

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ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Prof. Dr. Warren Y. Brockelman for his guidance, invaluable advice and knowledge impartial I am also grateful to Assoc. Prof. Sompoad Srikosamatara and Dr. Paul J. Grote, my co-advisers, for invaluable discussion and kindness throughout this study. I have the deep appreciation to Assoc. Prof. Pilai Poonswad for her kindness and great suggestion.

I am grateful to Prof. Dr. Visut Baimai and Biodiversity Research Training (BRT) for granting me a fund to conduct activities in KhaoYai National Park. I would like to acknowledge to Assist. Prof. Somsri Charoenkieatkul for the invaluable suggestion and Institute of Nutrition for nutrition analysis.

I am greatly indebted to Miss Panarat Charienchai for helping me identify plant species. I would like to thank my friends at Khao Yai National park who work for our Center for Conservation Biology for collecting some plant specimens. I also thank. Udomlux Suwanvecho and Miss Piyathip Piyapan for the nice goodwill and helpfulness. I thank my friends Pimpanas Vimuktayon and Pranom Kunsakorn for their friendliness. Big thanks to all of my old friends from Prince of Songkhla University for their help and encouragement. Special thanks to Mr. Boonmee Thanomsooksun for his thoughfulness and providing many facilities.

Finally, I extend my heartily thanks and deepest gratitude my family for their kind solicitous and encouragement.

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3936823 SCEB/M: MAJOR: ENVIRONMENTAL BIOLOGY;
M.Sc. (ENVIRONMENTAL BIOLOGY)
KEY WORDS :*HYLOBATES LAR*/ SYNDROME/ FOOD SELECTION, FRUIT CHARACTERISTICS

CHUTI-ON KANWATANAKID: CHARACTERISTICS OF FRUITS CONSUMED BY THE WHITE HANDED GIBBON (*HYLOBATES LAR*) IN KHAO YAI NATIONAL PARK, THAILAND. THESIS ADVISERS: WARREN Y. BROCKELMAN Ph..D., SOMPOAD SRIKOSAMATARA Ph. D., PAUL J. GROTE Ph.D., 136p. ISBN 974-664-714-8.

Gibbons act as generalized frugivores in tropical rain forests. They play an important role in the forest ecosystem as seed dispersers. Fruit characteristics also have an important role in explaining the relationship between plants and gibbon coevolution. Feeding behavior of white-handed gibbons (*Hylobates lar*) was studied in Khao Yai National Park, Thailand. The main purpose of this research was to identify the diverse foods in the gibbons' diet and determine the fruit characteristics that influence the white-handed gibbon's choice.

The methods of study included direct observation of gibbon behavior and morphology of fruits, leaves and other plant parts. Fecal samples were also collected. Collected fruit was analyzed for nutritional value in the laboratory at the Institute for Nutrition, Mahidol University. The method of handling of fruit by gibbons was also observed in the zoo.

There were 30 families and 65 plant species collected and identified in the diet of one gibbon family. Most food diet came from trees (72%), but also from climbers (26.6%) and treelets (2.1%). The gibbons fed on 50 species of fruit with *Ficus* as the most consumed fruit. Young leaves, flowers, spadix and spathe were also observed to be consumed. Gibbons mostly consumed ripe fruit with bright colors (yellow, red, orange and purple), which was soft and juicy. Small size (less than 10 mm) and light weight (less than 10 g) and, fruits with a single well-protected seed were found more than other fruit types to be consumed by the gibbon. The nutritional value of 6 consumed types of fruits and leaves did not differ much. These observations were supported by an experiment in the zoo which revealed that gibbons chose the suitable size and weight that fit in their hands. These results indicated that the food characteristic is one of the main factors as well as other factors such as food availability and abundance determining the gibbon's choice. However, there are many factors that influence food selection of gibbons which can explain their behavior and the territorial defense hypothesis. Study of fruit characteristics should be carried out in relation to other factors which might be important in food selection. This will explain food selection of white-handed gibbons which is important for gibbon conservation in the future.

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ชุติอร กาญวัฒนะกิจ : การศึกษาลักษณะของผลไม้ที่เป็นอาหารชะนีมือขาว (*Hylobates lar*) ในอุทยานแห่งชาติเขาใหญ่ ประเทศไทย (CHARACTERISTICS OF FRUITS CONSUMED BY THE WHITE HANDED GIBBON (*HYLOBATES LAR*) IN KHAO YAI NATIONAL PARK, THAILAND.) คณะกรรมการควบคุมวิทยานิพนธ์ : วรเรณ บรอคเคลแมน, Ph.D., สมโภชน์ ศรีโกสามาตร Ph.D., พอล โกรดิ, Ph.D. 136 หน้า ISBN 974-664-714-8

ชะนีอาศัยในป่าร้อนชื้น เป็นสัตว์กินผลไม้ได้หลายชนิด ชะนีมีบทบาทสำคัญในระบบนิเวศของป่า เนื่องจากชะนีเป็นผู้กระจายเมล็ดพันธุ์พืช ดังนั้นลักษณะดึงดูดของพืชที่เป็นอาหารของชะนีมือขาว (*Hylobates lar*) จึงมีความสำคัญในการช่วยอธิบายความสัมพันธ์ของการเกิดวิวัฒนาการร่วมกันระหว่างพืชและสัตว์ ลักษณะดึงดูดของพืชที่เป็นอาหารดังกล่าวได้มีการศึกษาในอุทยานแห่งชาติเขาใหญ่ ประเทศไทย โดยมีเป้าหมายเพื่อจำแนกชนิดความหลากหลายของพืชอาหาร และลักษณะต่างๆของผลที่น่าจะมีผลต่อการเลือกกินของชะนี โดยติดตามสังเกตพฤติกรรมการกินของชะนีกลุ่มเป้าหมายโดยตรงและเก็บมูลเพื่อจำแนกชนิดเมล็ด รวมทั้งสังเกตและเก็บผลตัวอย่างเพื่อศึกษาลักษณะของผลแต่ละชนิดและวิเคราะห์หาสารอาหารในห้องปฏิบัติการ โดยความร่วมมือของสถาบันวิจัยโภชนาการ มหาวิทยาลัยมหิดล การศึกษาขนาดและสีของผลไม้ได้มีการศึกษาผลร่วมกันจากชะนีในสวนสัตว์

ผลการศึกษาพบว่ามีสามารถจำแนกพืช 65 ชนิดจาก 30 วงศ์ โดยเป็นไม้ต้น (72%) มากที่สุด รองลงมาเป็นไม้เถา (26.6%) และไม้ขนาดเล็ก (2.1%) โดยเป็นไม้ผล 50 ชนิด ซึ่งผลส่วนใหญ่เป็นผลไทร (*Ficus* sp.) นอกจากนี้พบว่าใบอ่อน ดอก และ ส่วนของช่อดอกแบบเชิงลดมีกาบ (spadix) และ กาบหุ้มช่อดอก (spathe) เป็นส่วนที่ชะนีเลือกกินเช่นกัน ชะนีเลือกกินผลไม้สุกลักษณะผลนิ่มที่มีปริมาณน้ำมาก (80.85%) และมีสีสดเช่น สีเหลือง แดง ส้ม และม่วง ขนาดผลเล็กและน้ำหนักน้อย ซึ่งเกี่ยวข้องกับลักษณะการหยิบจากการศึกษาชะนีจากสวนสัตว์ และพบว่าชะนีอาจเลือกผลที่มีขนาดและน้ำหนักที่เหมาะกับขนาดมือ ผลส่วนใหญ่มี 1 เมล็ด และเป็นเมล็ดแข็ง(well-protected seed) ซึ่งมีอาจมีผลต่อการเลือกกินผลชนิดที่มีข้อดีต่อการกระจายเมล็ด เนื่องจากเมล็ดแข็งและมีขนาดใหญ่จะมีประสิทธิภาพการงอกสูง การวิเคราะห์สารอาหารจากพืช 7 ชนิด พบว่ามีความแตกต่างกันในแต่ละชนิด ซึ่งขึ้นอยู่กับสารอาหารและสารประกอบทุติยภูมิ (Secondary Metabolites) ลักษณะดึงดูดของพืชเป็นปัจจัยหลักในการเลือกกินอาหารของชะนี นอกจากปัจจัยอื่นๆเช่น การกระจายและการออกผลของพืชแต่ละชนิดในป่า ซึ่งมีอิทธิพลต่อการเลือกอาหาร, พฤติกรรมและทฤษฎีการป้องกันอาณาเขตของชะนี การศึกษาถึงลักษณะดึงดูดของพืชอาหารจึงมีความสำคัญ และควรมีการศึกษาเพิ่มเติมร่วมกับปัจจัยอื่นที่มีผลต่อการเลือกอาหาร เพื่อผลดังกล่าวจะเป็นข้อมูลสำคัญในการอนุรักษ์ชะนีในอนาคตต่อไป

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LIST OF ABBREVIATIONS

Abbreviations	**Terms**
g	Force of gravity
cm	Centimeter
m	Micrometer
mm	Milimeter
mm^2	Square Milimeter

CHAPTER I

INTRODUCTION

The tropical rain forest ecosystem has high species diversity and complex relationships between species. In a tropical rain forest trees can be seen in flower or fruit at any time of year, but the reproductive such as vegetative activities of species and individuals, is generally not continuous (1). It is also a heterogeneous environment, with patches in time and space where reproduction and food preferences differ (2). Plants benefit from the high diversity of seed vectors, which implies that strategies of fruit production, advertisement and nutritional reward should evolve to attract the greatest variety of dispersers possible (3).

Many plants in the world depend on birds and mammals for dispersal of their seeds. The traits of fruits and their frugivores are the product of diffuse coevolution in which groups of plants interact with groups of animals (4). Coevolution between plants and their seed predators may help to explain some events of plant reproductive biology and animal feeding habits (5)

1.1 Seed dispersal and Fruit characteristics

Seed dispersal plays a potentially important role in ecology in maintaining the structure and diversity of the plant community. The relationship between a fruiting plant and its seed dispersers is a dynamic mutualism in which frugivores use fruits for food, and the plant depends on the frugivores to disseminate its seeds (6).

Seed dispersal is the transport of seeds away from parent plants. Most species of seed-bearing plants use attractive fruits to attract birds, mammals or ants that bury, regurgitate or defecate various seeds away form parent plants. Howe and Wesley

(1998) suggested that the most highly developed modification for dispersal are these adapted for consumption by fruit-eating birds and mammals, which frequently offer substantial nutritional rewards (7). Furthermore, generalized adaptations attract a variety of potential dispersal agents, reducing the likelihood that plants come to rely on specialized dispersers which evolve into destructive seed predators. As a result, the different characteristics of fruits will promote the diet selection that occurs in animals. Thus, diet selection is a main cause for adaptation in plant species which are involved with dispersal syndromes. Dispersal syndromes are constellations of scents, shapes and nutritional qualities that are associated with different means of seed dissemination by biotic and abiotic agents (6).

Primates are the single most important group of mammals in many tropical forests. Their dietary habits are extremely varied. Most commonly, they eat fruits and foliage, but many species are specialized and feed on such items as seeds, bamboo gum, nectar or small animal prey (8). Gibbons are primates which have mutualistic relationships with fruits. These develop through coevolution, and fruits adapt their morphology and physiology for attracting gibbons. Host selection criteria are one of the first priorities to study and concern the role of color in the attracting dispersal agents (9).

Many researchers have done research on seed dispersal and diet selection. Some of these seed dispersal studies on animals suggest that the main fruit colors prefered by birds are purple, black and red (10).

A study about fruit choice of the Red Howler monkey (*Alouatta seniculus*) revealed that they prefer fruits with juicy pulp and bright color (red, orange, and yellow). These fruits have generally a small number of well protected seeds (9). Preliminary studies of gibbons have been carried by some Thai and foreign researchers at Khao Yai National Park. They have found that White-handed gibbons eat a large number of ripe fruits and swallow whole any fruit of convenient size and shape, and leave the seeds unharmed by digestion (11).

Although many studies have been done about seed dispersal in mammals, information about seed dispersal syndromes in primates is very rare. Gibbons may help maintain species diversity in their home range through beneficial seed dispersal and their role still needs further investigation (11). At the present time, the populations of gibbons in the world are decreasing for many reasons, such as habitat loss, trading and hunting (12). Small and isolated gibbon populations are at risk of extinction from the interaction of random and deterministic processes. These populations will require intensive management if gibbons are to survive for 50 to 100 years (13).

The main purpose of this research was to identify the diverse foods in the diet and determine the fruit characteristics that lead to choice by white-handed gibbons (*Hylobates lar*). The discussion will address the relationship between fruit availability and selectivity of gibbons in comparison with other studies on fruit choice by birds and other primate; which determines the syndrome and the impact of certain morphological characteristics of fruit species on dispersal by gibbons. This study will provide basic information for management and gibbon conservation. Fruit characteristics has an important role that can help explain the relationship between plants and gibbons in coevolution. It can also explain food selection in the white-handed gibbon, and additional research will help us understand the gibbon's way of life in the forest for gibbon conservation in the future.

1.2 The study site

Khao Yai National Park lies between 14° 05′ and 14° 15′ N, and 101° 05′ and 101° 50′ E. It is located about 200 km northeast of Bangkok (14) and covers four provinces: Nakhon Ratchasima, Saraburi, Prachinburi and Nakhon Nayok. It consists of a mountainous area which is a part of Phanom Dongrak range which lies between 250 and 1351 m above sea level. Phanom Dongrak is the source of the Lam Takhong River which flows northeast, and it is also the source of the Nakhon Nayok River below Nang Rong falls and Salika fall. Mountainous areas in the park include Khao Laem and Khao Khieo in the central part and Khao Sam Yot in the west (15) (See Figure 1.1, 1.2).

Smitinand (1977) classified the vegetation of Khao Yai National Park into five categories (16).

1. Mixed Deciduous forest occurs along the northern slope at 400-600 m elevation. Tree species in this forest type include *Afzelia xylocarpa* (Makhaa mong), *Pterocarpus macrocarpus* (Pradu), and *Bambusa arundinacea* (Phai paa) has been found to be in the understory.

2. Dry Evergreen forest occurs along the eastern border in Nakhon Ratchasima and Prachinburi at 100-400 m elevation. Typical trees are *Dipterocarpus alatus* (Yaang naa), *D. turbinatus* (Yaang daeng), *Hopea odorata* (Takhian thong), etc.

3. Tropical Rain Forest or Seasonal evergreen forest is similar to dry Evergreen Forest but there are more Dipterocarpaceae in the higher area, (most species can be found generally) such as *Dipterocarpus gracilis* (Yaang Khon), Yaang klong and *Dipterocarpus costatus* (Yaang Pai), etc. Moreover, the fern (*Cynthea* sp. Mahaa sadam) can be found along the streams, and the ground flora is also similar to dry Evergreen Forest but it is much denser in nature.

4. Hill Evergreen Forest This type occurs from the altitude of 1,000 m upward. Dipterocapaceae are replaced by *Podocarpus neriifolius* (Phaya mai) which is a gymnosperm. The forest is denser than other types of forest in Khao Yai National Park.

5. Field and Secondary growth This area is the recent effect of man. Most area caused from the shifting cultivation many years ago and the effects of road construction. The main species in grassland is *Imperata cylindrica* (Yaa Khaa).

1.3 Mo Singto study site

The research site was located at Mo Singto, Khao Yai National Park. This site is located at 101° 22′ E., 14° 26′ N. at an elevation of 730-860 m above sea level (11). The park has a very large area of primary tropical evergreen forest. The area receives about 3,000 mm of rain a year mostly between April and September (18). The average temperature ranges from 17°C in December and January to 28°C in April and May. During the dry season (December to April) most small streams become dry (19) (See Figure 1.2).

Generally, the phenology of tropical woody plants has been shaped by both biotic and abiotic factors. Most energy of gibbons comes from fruit, especially figs, and they get protein from shoots and leaves and some insects (20).

Mo Singto is a good site for studying gibbon diet as there were many researchers followed and habituated some gibbon group. Moreover, this area has a steep upper watershed and it is not difficult to observe gibbons feeding.

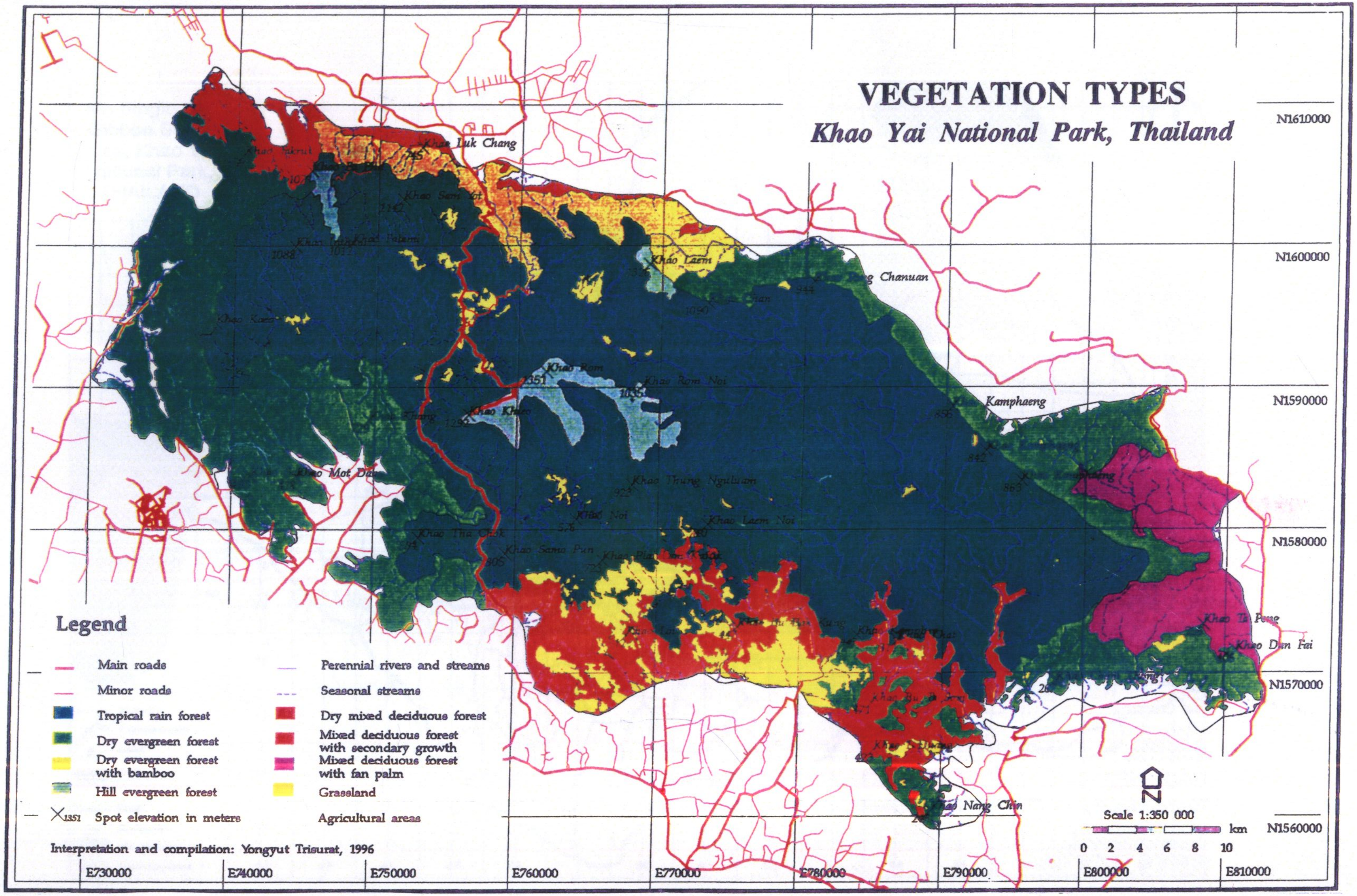


Figure 1.1 Vegetation types of Khao Yai National Park, Thailand (Trisurat et al., 1996) (17).

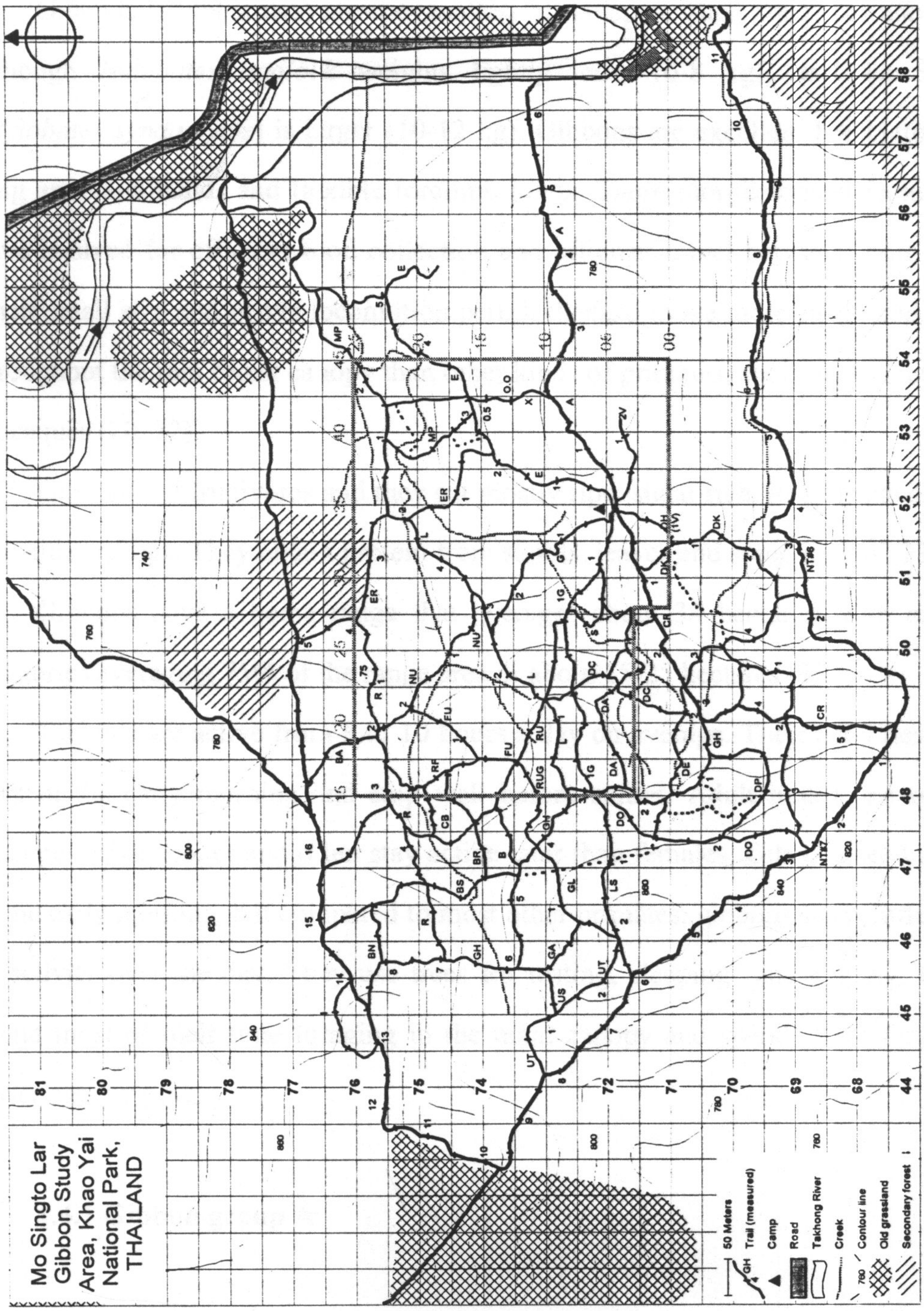


Figure 1.2 Mo Singto Study Site (15) (Flame is the area of gibbon group A)

1.4 Gibbons

Gibbons (Hylobatidae) are the smallest of the apes. Their weight is about 5 kg, although *Hylobates hoolock* weights lightly more (6-8 kg), and the Siamang (*Hylobates syndactylus*) is larger (10-12 kg). Gibbons are excellent brachiators, with long arms and hands and flexible forelimb joints. These morphological features may have evolved for efficient food collection and efficient travel between food sources. Their small size and active locomotion permit them to move more easily and directly throughout the rain forest canopy than other kinds of primates, such as orangutans and macaques (20, 22).

Gibbons are frugivores and they eat mostly ripe, sugar rich, juicy fruits and large quantities of figs. They obtain protein from shoots, leaves and some insects (23).

Gibbons have a home range that averages about 34 hectares, with exclusive territories averaging 75% of the range area or about 15-25 hectares (23).

Gibbons are active from 8 to 10 hours a day on average. Their activities usually start in the early morning and stop well before sunset. Adult males and offspring become active sooner and often stay active later than females. Gibbons feed and sing in the early morning, but compared to most other primates, gibbons show little change in activity over the day. They use trees for resting, sleeping and singing. Gibbons spend most of their time foraging in the main canopy and spend little time in the lower canopy (24).

1.4.1 Gibbon group A

A group of white-handed gibbons (*Hylobates lar*) which was named "group A" was habituated and then this gibbon group has been the subject of most gibbon research at Mo Singto. This group has been the subject of study of social behavior and feeding behavior (14, 25, 26, 27, 28, 29).

Gibbon group A's occupied home range consists of 30 ha (26). (See Figure 1.3).

My observations of this gibbon group started in June, 1997, and finished in November, 1998. There were 5 members in gibbon group A which were followed and observed (Table 1.1). Observations were made of all individuals. During September, 1997, the juvenile male "Aran" disappeared, thus his data were missing from that time onward.

Table 1.1 Members of gibbon group A

Animal	**Age-class**	**Sex**	**Color**	**Age (December 1997)**	**Name**
A0fL	adult	female	buff	>29 years	Andromeda
F1mD	adult	male	black	22 years -11months	Fearless
A3mD	subadult	male	black	10 years - 2 months	Amadeus
A4mL	juvenile	male	buff	7 years - 3 months	Aran
A5mL	juvenile	female	buff	4 years- 2 months	Akira

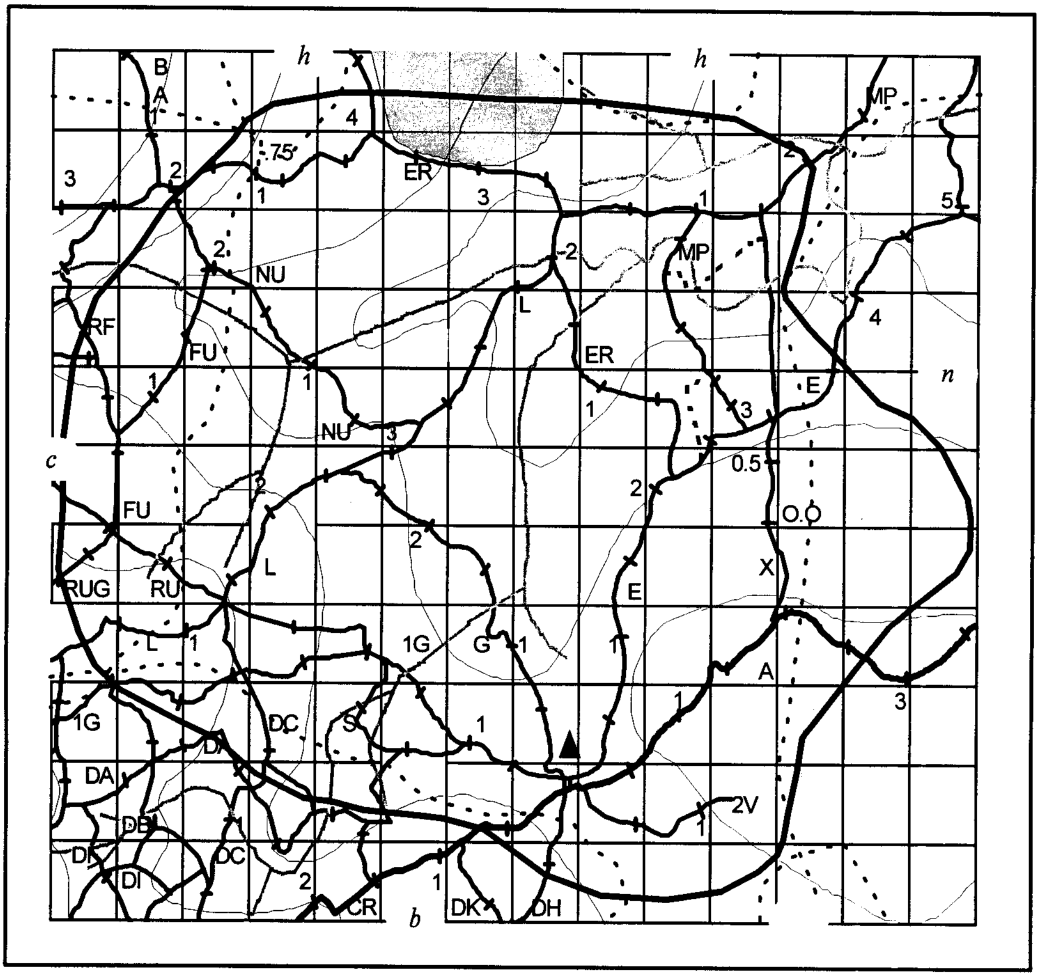


Figure 1.3 Home Range of gibbon group A (Suwanvecho, 1997)

Camp

Boundary of neighboring groups

50 meters (trails)

Territory of gibbon group A

Contour line
(topography 780-850 m.)

Creek

Secondary growth

Gibbons act as generalized frugivores in tropical rain forest. Gibbons play the important role in tropical rain forest ecosystem. Many fruit plants can disperse their offspring through seed dispersal agents such as gibbons, deer, birds even the large animals like elephants. These seed dispersers will be the helper to disperse seeds. So each plant species adapts itself to attracted its own seed dispersers. Animals also adapt their morphology to fit to plant consumed. However, there are many factors that influence food selection by seed dispersal agents in the forest. Fleming (1991) suggested the ecological patterns that deal with food selection (4).

1. Patterns in space

Latitude is a factor for successional and spatial availability of fleshy fruits. It may cause the different morphology of fruit for adaptation of their morphology.

2. Patterns in time

The temporal availability of fruits also varies latitudinally. The example of factors in this case are abundance, diversity, peak fruit abundance and food availability.

3. Morphological/Nutritional Patterns.

This part is very important for plant adaptation. Morphology and nutrition are thing that can attract to seed disperser. The term "fruit characteristics" is involved with adaptation. Fruits differ considerably in their "profitability" to frugivores and these differences should influence the food choice decisions of frugivores.

Morover, the other factors were summarized that involve food selection.

- Breeding season (19).
- Competition among frugivores
- Unpredictable location
- Palatability to each seed disperser.

etc.

Animals select the highest quality of plants consumed when there are many kinds of fruits in their territory. They will select more than staying in the scarcity area. By contrast, they will consider other important factors that reduce the cost of foraging behavior especially syndrome of food plants. Thus, Herrera (1985) (30) suggested that syndrome can maintain in a lineage of plants by a succession of different dispersal agents.

CHAPTER II
LITERATURE REVIEW

Most tropical woody plants produce new leaves and flowers in a burst (3). Seasonal variations in tropical rain forest communities are displayed by the presence of new leaves, flowers and fruits. This patterning suggests that phenological changes represent adaptation to either biotic or abiotic factors. During periods of scarcity, many mammals resort to feeding on materials that are of low nutritional value, protected by hard coverings, contain chemical deterrents, and are sparsely distributed in the environment. Thus, mammals have to spend more time searching for food (31, 32)

Gibbons are brachiators, with long arms and hands, and flexible forelimb joints. They are small in size for suspensory locomotion so they can move very easily and directly through the rain forest canopy (11). In studies of gibbon diet, fruits comprise about 60% and leaves 30% for most smaller gibbons, but monthly proportions of fruit sometimes exceed 90% or fall below 30% (23). The larger siamang (*Hylobates syndactylus*) is more folivorous, but *H. klossii* and *H. pileatus* are more frugivorous, and obtain more protein from insects instead of young leaves (23). All hylobatids have a very diverse diet of fruits and leaves which changes throughout the year and also includes some animal material such as termites and caterpillars. Mammals are believed by evolutionary ecologists to have "coevolved" with fruiting plants, to the mutual benefit of both animals and plants (3, 33).

Studies of gibbon ecology and behaviors have been carried out for more than 40 years. The first study of gibbon ecology and behavior was carried out in 1937-1938 by C. R. Carpenter in northern Thailand. He established that gibbons are frugivorous.

The second person to study gibbons was Ellefson (1974) who studied several groups of *Hylobates lar* in the forest of West Malaysia (34). He reported that gibbons ate 76 species of plants including leaves, shoots and succulent fruits. Gibbons change their food selection each month because of the fruiting season and leafing season. Chivers and Gittins & Raemaekers (24) studied Malaysian gibbons including *H. lar, H. agilis,* and Siamang (*Hylobates syndactylus*). Studies of the diets of other gibbon species have been carried out by Srikosamatara (1984) (35), Kappeler (1984) (36), Whitten (1982) (21). All studies have found that gibbons eat many kinds of fruits and leaves which change throughout the year and they also eat some animals such as termites and caterpillars (35, 21, 23).

2.1 Seed dispersal

Seed dispersal is a nonsymbiotic mutualism that depends on animal foraging behavior and plant nutritional rewards. Seed dispersal differs from pollination in the degree to which plants influence the outcome of pollen transfer and seed dissemination. The advantages to plants are escape from seed and seedling attack by pathogens, insects and rodents near parent plants, and dissemination to sites suitable for seedling growth. The advantages to animals are food for insects or vertebrates which digest edible pulp and pass or regurgitate seeds (7). Most animals that disperse seeds are vertebrates that are capable of carrying seeds long distances. Seed dispersal may increase parental plant fitness in several ways. Seed dissemination may allow plants to establish their offspring in vacant sites, a process termed colonization. In contrast, dispersal may represent escape from disproportionate seed and seedling mortality near the parent. In rare cases, animals consistently deliver seeds to special sites necessary for germination and establishment. This is termed directed dispersal (7).

Animals disperse seeds in two principal ways: by carrying away and storing fruit or seeds and, second, by ingesting seeds while eating the fruits and later voiding them undamaged. Vertebrates eat fruits and digest part of the material, but many seeds pass through the digestive system unharmed (5). The efficiency of dispersal depends on the number of seeds eaten, then the energy that went into the production of the surplus will be wasted. Conversely, if there are not enough seeds at one time of the year, then the potential dispersal agents will either starve or will eat something else (31). The inability of plants to guide dispersal agents to particular seed "targets" and the destructive habits of many frugivores favors generalized fruit adaptations (10).

The majority of plants whose seeds are dispersed by animals depend on multiple species of animals as dispersal agents. Plants advertise fruits by a ripening process in which the fruits change color, taste and odor (33). These ripe fruits can be attacked by damaging agents like fungi and bacteria, or by destructive feeders who will not disperse the seeds (5).

Physical environmental factors are the most important in determining the fruiting season (37). The relationships between animal-dispersed plants and frugivorous animals provide examples of diffuse coevolution. The evolution of adaptations to specialized frugivory has resulted in generally increased dispersal quality. Specialized frugivores begin to move seed after fruit maturation. Seeds can adapt for dispersal by animal digestion by evolving hard coats to prevent their being destroyed by dispersal agents (33). Plant species dispersed by obligate specialists that generate high-quality dispersal usually produce very nutritious flesh and provide a high reward to dispersers. In non-tropical areas, plants dispersed by opportunists predominate, dispersers shifting their diets temporarily to fruit when the availability of the most preferred resources falls below a critical threshold (38).

Considering the fleshy fruits, there are many features that are potential candidates for the action of natural selection for foraging behavior of frugivorous vertebrates. Foster and Janson (1985) (39) suggested the first pattern in space that frugivorous vertebrates will be faced with is a wider array of seed and fruit sizes in tropical habitats as compared with temperate habitats. The second one is pattern in time and the third is the morphological patterns that influence fruit choice of frugivores (4).

In a study of seed dispersal of *Guarea glabra* and its disperser, it has been found that the fruiting season of this species is adaptatively synchronized with the northward migration of opportunistically frugivorous North American birds (40).

2.2 Fruit characteristics and diet selection of birds

In birds, there are many studies which focus on diet selection and seed dispersal syndromes. Jordano (1995) (41) suggested that avian frugivores may use foraging cues based on "extrinsic" plant characteristics (type of surrounding habitat, number of neighbors, proximity of forest edges etc.) when discriminating among fruit crops. Individual seeds might face strong selection if frugivores use with-in crop foraging cues based on "intrinsic" fruit traits (color, seed and size) (41).

In Madagascar, foraging behavior was observed in flocking species by Egushi et al. (1991) (42). Birds used many foraging locations such as the air, underground, trunks, branches, twigs and leaves. Many bird species have overlapping foraging niches and this might be important in mixed species flocks for enhancing their foraging efficiency (42). Snow buntings (*Plectrophenax nivalis*) have some opportunity to choose both the size of the flock to forage and where to feed within a flock. The leading bird might have the first access to the places they think are the best patches (43).

Birds may be generalized or specialized frugivores in some habitats. Hornbills are good examples of generalized frugivores. Poonswad et al. (1988) studied the food and feeding ecology of sympatric hornbills and found that the main foods were fig fruits, non-figs fruits and animals (19). Wreathed Hornbills consumed a great quantity of fruit of *Polyalthia viridis* in the breeding season. Helmeted Hornbills (*Buceros rhinoplax*) fed mostly on one fig while Brown Hornbills consumed mostly animal food but followed with the figs and non-fig fruits. *Ficus* was the main diet in hornbills in spite of it yielding relatively low energy, as figs were available monthly. Thus, diet selection in hornbills may involve food abundance, regardless of nutritional value (19). Stiles (1980) found that generalized birds in the Eastern deciduous forest of

North America ate many kinds of fruits with large seeds and high lipid content (44). Some frugivorous birds, such as Waxwing (*Bombycilla cedrorum*) and American Robin (*Turdus migratorius*) preferred food with seeds that pass through the gut very rapidly, as this will increase the net rate energy gain from nutrient-poor food by process-limited animals (45). Specialized birds are those that consume a specific kind of fruit. Howe and Stephen (1979) suggested that competition among potential dispersers for a limited and highly nutritious food resource has led to facultative specialization by frugivore species (40). They also found that the 19 species of birds were large and taxonomically diverse. This relationship involves the syndrome, dissemination of seeds to a variety of suitable sites by birds with different habits, with the number of visitors and the richness of the disperser assemblage increasing with the size of the available crop.

Three fruit tree families of greatest importance for specialized birds are Lauraceae, Burseraceae and Palmae. Their fruits have a large size, with relatively large seeds, and have high protein and fat content (46).

Howe and Estabrook (1977) (48) suggested that specialists may require particular vitamins or minerals from certain fruits which opportunists obtain from alternate sources of food such as insects (48).

In the tropics frugivorous birds have coevolved with fruit plants. Originally, fruits may have been typically small (unspecialized frugivores being mostly medium size or small birds), with watery flesh containing mainly carbohydrate, and having small seeds. Later, some fruits then evolved to a larger size with high nutrition for pursuing generalized birds so that seedlings will have a chance to establish on the forest floor (46).

In another example, seed dispersal syndromes in Australian *Acacia* were studied by O' Dowd et al. (1986). They concluded that many dispersal agents such as birds, ants and mammals chose brightly colored arils (48). Bird syndrome species had high dispersal investments such as high aril mass, lipid content more than ant-disperser species (49).

2.3 Fruit characteristics and diet selection in primates

Most primates are omnivorous. They feed on fruits, leaves, insects and when they can get it, meat. Their locomotion behavior is a factor in choosing food. Specialized foliage-eating types have evolved in all four lines including lemurs, New World monkeys, Old World monkeys, and apes (12) (Appendix 4).

Gibbons are frugivores. Most diet fruits consumed are ripe, sugar-rich, juicy fruits and large quantities of figs (24). They eat about 60% fruit and 30% leaves but the proportion of fruit each month sometimes exceeds 90 % (23). For figs, gibbons place small figs directly into their months one or more at a time, but they bite large figs repeatedly while grasping them manually, before proceeding to the next items (50). Whitten (1982) studied the diet and feeding behavior of Kloss gibbons (*Hylobates klossii*). He found that most of their food consisted of insects and arthropods as they need high protein. Moreover, he reported that *Myristica cinnamomea* (Myristicaceae) and *Neesia pilufera* (Bombacaceae) were not eaten simply because they were too large to be swallowed (21).

In Khao Yai National Park, 76 species representing 36 families were found to be eaten by White-handed gibbons (*Hylobates lar*) (11). They eat large amounts of ripe fruit every day and tend to swallow whole any fruit of a convenient size and shape, and leave the seeds unharmed by digestion. In most cases of fruit consumption, they were very selective feeders which rejected fruit which did not suit their taste (29, 11).

The selection of food is a hierarchical process. An animal selects the feeding behavior microhabitat and then selects food items. Consequently, factors that determine the diet of animals depend not only on food quality and abundance, but also the multiple factors that determine microhabitat selection (51, 52).

Julliot (1996) studied fruit choice in Red Howler monkeys (*Alouatta seniculus*). Data was shown that they consumed essentially 52 species of fruits with juicy pulp, bright color and small numbers of well-protected seeds. Consequently they can be considered as "specialized frugivores," preferring Sapotaceae (9).

Nutrition and secondary compounds are also important factors for diet selection in primates. The diet of *Cebus apella* has been studied in extreme habitats by Glander (1981) (53). Their diet included 6 species of bromeliads (72%), *Philodendron bipinnatifidum* shoots, and immature seeds, they ate only leaves. The main nutritional requirements were protein and sugar. During critical periods, the monkeys used those environments in which these plants were most abundant (54).

Small primates like *Callithrix* and *Cebuella* have high food energy sources not used to any great extent by larger primates and other potential competitors (55). Some primates are not seed dispersers, but their food choices are interesting. Feeding behavior and morphology of primates can explain the way of choosing their main diet. There are many example of studies about feeding behavior which attempt to explain the diet choices of some primates.

The Aye-Aye (*Daubentoria madagascariensis*) is a primate with several unusual morphological characteristics (56). It feeds mostly on insect larvae and eats plants such as cultivated coconut, litchies and mango. It has specialized incisors adapted for eating hard nuts such as ramy nuts. This study does not support the idea that most insectivorous primates have a low body weight (0.06-0.2 kg.), because the aye-aye is large (3 kg).

The Samango monkey (*Cercopithecus mitis labiatus*) is an arboreal guenon species which tolerates a variety of habitats. It also has a varied diet. When food availability is low, the monkeys increase feeding time using poorer quality foods (eat more foliage) from common trees and conserve energy by moving about the home range more slowly (57).

Koenig et al. (1997) (58) suggested that the diet of the Hanuman langur (*Presbytis entellus*) depends on physical conditions, availability and the abundance of high quality food such as young leaves and fruits. The three main food plants of Hanuman langurs are *Spatholobus parviflorus* (climber), *Terminalia bellirica* (tree) and *Dillenia pentagyna* (tree). *S. parviflorus* food items (flowers, young leaves and mature leaves) contained more protein, sugar or both than did other plants (59).

2.4 Adaptability to food in primates

Sometimes the food choice of primate groups depends on their habitats and environments. Primates can adapt themselve to consume different foods that are available at different times. For example, Lion tamarins (genus *Leontopithecus*) are the largest members of the family Callitrichidae. They feed on 64 plant species in 23 families, with ripe fruit and nectar as the two plant food categories most often consumed (60). In the dry season, when ripe fruit availability was lowest, they consumed nectar from a few common plant species such as *Symphonia globulifera* (61). Another example is the Japanese monkey (*Macaca fuscata*) which is distributed from the warm temperate zone to the cool temperate zone in Japan. Agetsuma (1995) found that mature leaves and fallen seeds were the main food categories from January to April. Differences in time spent feeding were found in different habitats. Monkeys had to move for a longer time to obtain the quality of food in cool temperate areas under the poor food conditions (62).

Moreover, animals have to adapt themselves to survive for seasonal changes. For example, Howler monkeys (*Alouatta caraya*) drink water from tree holes during the wet season. In the dry season, which has lower average monthly relative humidity, they feed only on young leaves and reduce the ingestion of mature leaves that contain less water and more secondary compounds. After detoxification, secondary compounds produce water-soluble metabolites that need water to be flushed out of the Howler's body (63). In a similar fashion, Glander (1978) found that the species Howler monkey (*Alouatta palliata*) drinks water from trees during the wet season but not during the 5 month dry season (64). They drank during the less stressful wet season to maintain their water balance. During the average wet season day the howlers spent 30 min (25.3% of the feeding time) eating mature leaves and 47 min (31.2%) eating new leaves, compared to 21 min (11.5%) eating mature leaves and 104 min (56.5%) ingesting new leaves during the dry season. The mean water content of new leaves is significantly greater than that of mature leaves. Thus, the dry season diet provides significantly more water than the wet season. The explanation for this may be that mature leaves with more toxins may force Howler monkeys to drink supplementary water from the hollows of trees. One of the primary detoxification pathways (microsomal enzymes located in the liver and kidney) produces water-soluble metabolites. Thus, they drank water in wet season for flushing the toxins out of their bodies (64).

Red Colobus monkeys (*Colobus badius rufomitratus*) are entirely vegetarian and arboreal primates. They feed on fruits, leaves and flowers. Young leaves were not only the most important items in the annual diet, but also the most consistently selected. Foods such as *Ficus sycamorus* were available for long periods and used roughly in proportion to their availability. An arboreal folivore faces a problem in choosing and digesting food. The first is that leaves are low in nutritive value and contain a high proportion of structural elements such as fibre. The second is that leaves of some species contain potential toxic compounds (65).

Guillotin and Dobost (1994) studied food choice and food competition among three major primate species of French Guiana. *Ateles paniscus* was frugivorous, *Alouatta seniculus* was frugivorous-folivorous and *Cebus apella* was insectivorous. They reported that the diet of each species underwent seasonal fluctuations that are similar to and synchronous with characteristics of fruit production. Their diet was mainly of fruits that were orange-yellow, orange or varying intensities of red; green or brown were the least consumed, although they were most frequently on the ground. However, some fruit characteristics such as size separated the monkey species from each other in fruit choice (66).

Norton (1987) studied yellow baboons (*Papio cynocephalus*) over a 5 year period, and reported that they ate 4 types of food plants: herbs, vines, shrubs and trees. Selected species were recorded and identified. Frequent feeding on certain species was due in part to availability, but availability is not the whole story since many commonly available foods were little eaten (60).

2.5 Plant-frugivore coevolution

Coevolution is the simultaneous evolution of ecologically interacting populations (7). The most highly developed modification for dispersal are adaptations for consumption by fruit eating birds and animals. (7). Janson (1983) also suggested that the fruit morphology of species frequently is adapted to the general characteristics of animals that eat it (67). Plants may adapt in size, color and morphology even among species within genera, implying that natural selection has produced the divergence in fruit form associated with bird and mammal fruit-eating. Plants might evolve secondary compounds that only a few species of their insect enemies can detoxify (7). Bernays (1998) studied the role of plant secondary compounds. She found that toxins in leaves and fruits may deter feeding by seed -dispersing animals (68). Constitutive secondary compounds include phenolics such as tannins and lignins as well as alkaloids, terpenoids and saponins. Induced secondary compounds are formed or released only after damage or consumption, and include phytoelexins, phenolic glycosides, cardenolides and cyanogenic glycosides (51). But specialized plant eaters are often capable of detoxifying secondary compounds in their livers and in consequence they gain access to food supplies that are poisonous to other species (8).

Pair-wise coevolution in which two species adapt specifically to each other is not the only possible or likely outcome of ecological interaction. Diffuse coevolution occurs when two sets of species interact, each set influencing the other more or less equally (7).

Snow (1971) reported that in evolutionary aspects of fruit-eating by birds, two important evolutionary developments are attributed to differences in food supply. The strategies adopted by fruits for dispersal by birds result in the production of abundant food supplies which are easy to access and exploitable by many species of birds (69).

Moreover, body size and body morphology including gut morphology, are factors in diet selection. The Howler monkey (*Alouatta palliata*) is a moderate-sized arboreal primate (adult body mass 7-9 kg.). They have a relatively capacious hindgut and slow food passage rates which provide conditions suitable for the efficient destruction of plant cell wall material. Thus, the Howler monkey must feed on young leaves or mature leaves that have high quality to provide maximal energy and nutrition (70). In lorisoids, tarsiers, small lemuroids, New World monkeys and night monkeys, a large proportion of diet is obtained from insects for high protein (Jolly, 1972). In another case, the strong jaws and teeth of the gray-cheeked mangabey allowed them to open tough fruits that are unavailable to other monkeys in Uganda's Kibale forest. Thus, body size and morphology were factors in diet selection (21).

Carpenter (1967) studied gibbons in Thailand and he suggested that brachiation is an adaptation useful in the fruit-eating habits of gibbons. When feeding, a gibbon will swing out underneath a limb and as near to the fruit-bearing twigs as its weight will permit which is called "terminal branch feeding". The gibbon uses tongue and lips to make selection after taking the food into the mouth (71). Moreover, gibbons also use hands and eyes to make the selection before testing food (22).

CHAPTER III
METHODOLOGY

3.1 Observation of feeding behavior

The gibbon diet was studied by direct observation, and indirectly through collection of fecal samples and recording of the morphology of fruits, leaves and other parts. The methods of handling of fruit by gibbons were observed. Gibbon group A was the main target group for my research. I started following gibbons in June, 1997, and finished in November, 1998. There were five members of this gibbon group during my study. All individuals were observed until September 1997, when the juvenile male disappeared from the group. Thus, his data were lost from that time on. I followed on the gibbons for 15 days per month, for10 hours per day on good days. I also collected gibbon fecal material from defecating individuals for analysis. Observations recorded included time, date, and individual animal for each fecal stool. Each fecal sample was placed in a separate plastic bag, labeled with all the record collection information.

Collecting seeds and fruits was planned for twice each month, over the course of five days. Fruits, leaves and some kinds of termites were collected for identification and nutritional analysis in laboratory. Plant specimens of tree parts were collected from the ground from the remains of gibbons feeding.

3.2 Species identification of food plants via seed analysis

Within 24-48 hours of collection, the feces were suspended in water and washed through sieves (140 mm, 600 mm, 300 mm, 1.00 mm, 2.00 mm hole size) in order to collect seeds for species identification. Seeds were identified with the aid of reference specimens located at the herbarium of the Center for Conservation Biology.

3.3 Characteristics fruit and seed study

The adaptive hypothesis predicts particular trends of variation in fruit characters such as overall fruit size, color, structure, seed number, relative yield of pulps and nutrition (9).

3.1 Characteristics of tree fruits and seed

I plotted variation in the number of fruiting trees of each species in each month.

3.2 Fruit characteristics

Fruit of species consumed by gibbons was weighed, measured and described without regard to botanical origin of fruit parts. Average wet weight of each fruit species was obtained on the basis of sample size of the specimens as an average 1-50 items per food species (9).

The different morphological characters were:

3.2.1. Size and weight of fruits and leaves in wet and dry specimens. Weight was measured by a digital balance. A vernier caliper was used for measurement of the length of leaves and fruits. I measured the maximum length of each fruit and recorded it in the data table.

3.2.2 Kind of pulp: only water content was considered. Two classes were defined as dry pulp and juicy pulp. Arillate fruits are included in dry or juicy pulp types according to their water content. Thus, different types of arils were not distinguished, because arils can have different aspects and show different water content.

3.2.3. Color of external mature fruit. The colors recorded were yellow, orange, red, purple, green and mixed color.

3.2.4. Seed number and seed size per fruit defined as on average value.

3.2.5 Seed protection (the hardness of seed test). This morphology can be noted as:

- (n) no protection (very soft and very easy to break)
- (+) can be opened with finger nail
- (++) can be opened with a knife
- (+++) cannot be opened with a knife.

In this study, gibbons consumed fruits and seeds with different morphological characteristics. The frequency of selection of each species was defined as the relative number of seeds found in the feces. With these results, after finishing this research we can recognize types of frugivores that are specialized, associated with plants corresponding to particular syndromes, or non-specialized frugivores corresponding to several syndromes.

3.2.6 Seed Volume

The volume of each species of seeds by putting seeds in the water and measureing the displacement in volume. Seed volume per seed was calculated, and also seed volume per fruit.

3.4 General observations of feeding behavior of white-handed gibbons (*Hylobates lar*) at Dusit Zoo

Feeding behavior was also collected from Dusit Zoo which is near Mahidol University, Bangkok. Many kinds of fruit were selected by gibbons. I went to Dusit Zoo 3 times to try to observe fruit selection by captive gibbons in large cages. Every time I arrived at the zoo in the morning (6.00-7.00 a.m.) before gibbons were fed by their feeder. I tested many species that were collected from Khao Yai National Park, for example, *Ficus* sp. and *Elaeagnus latifolia.* Domestic fruits of similar size were also used to present with wild fruits, for example, orange (*Citrus suhuiensis*, Rutaceae), banana (*Musa*, Musaceae) and guava (*Psidium guajava*, Myrtaceae), divided into different sizes.

I tasted guava fruit and sliced it into five size classes. They are small pieces (minced), 2x2 cm (similar in size to *Gnetum montanum),* 3.5x2 cm (similar in size to *Ficus* sp), 3.5x3.5 cm (similar in size to *Alphonsia boniana*) and more than 3.5x3.5 cm (similar in size to *Garcinia xanthochymus*).

All of the fruits used for selection by gibbons were put in a tray. Then, those trays were moved close to the cage and the gibbons were allowed to select what they wanted to eat. Observations on fruit selection by gibbons and how they picked pieces of food by hands were recorded. These data were confirmed by photographs (Figure 4.27-4.29).

3.5 Fruit and leaf nutritional quality

Collected fruit was analyzed for nutritional quality in the laboratory. Fruits in the diet were analyzed for carbohydrate, lipid, sugar, energy content and water at the Institute for Nutrition, Mahidol University.

Eight collected plant species parts were chosen for nutritional analysis. These chosen species were available in th forest and not difficult to collect from the trees.

1. *Balakata baccatum* (Roxb.) Esser (Euphorbiaceae) (ripe)
2. *Balakata baccatum* (Roxb.) Esser (Euphorbiaceae) (unripe)
3. *Walsura robusta* Roxb. (Meliaceae)
4. *Diospyros glandulosa* Lace (Ebenaceae)
5. *Choerospondias axillaris* Burt & Hill (Anarcardiaceae)
6. Fig fruit : *Ficus* sp. (Moraceae)
7. *Polyalthia viridis* Craib (Annonaceae) (mature leaves)
8. *Polyalthia viridis* Craib (Annonaceae) (young leaves)

3.6 Data analysis

Most data obtained in this study were stored by using the Excel spread sheet program for PC. Data were analyzed at the Center for Conservation Biology, Mahidol University. Statistical programs were used for interpretation of research data. This study used the SPSS package for data analysis.

CHAPTER IV

RESULTS

4.1 Preliminary study and general observations

The observations of my research began in June, 1997, and preliminary observations were finished in May, 1997. collected data about feeding behavior of 5 white-handed gibbons after one month of preliminary observation.

Daily observation data were collected as soon as preliminary observations were finished. From the preliminary study and general observation , gibbons have many behaviors, which can be classified as singing, travelling, playing, resting, grooming and feeding. Gibbons begin feeding upon awakening and feeding alternates with other behaviors until they go to the night tree. The white-handed gibbon group A usually starts activity in the early morning before dawn. Mostly the first solo morning call is from the subadult male. When the edge of the sun emerges from the sky, it is the time for seeking food. I mostly met them at the feeding tree after hearing the solo song of the subadult. Gibbons always started feeding on the fruiting tree that they met first in the morning.

The approximate distribution of activities throughout the day is indicated in Table 4.1. They mostly fed in the early morning. I started following the gibbons as soon as I found the focal group and finished when they went to the night tree. Gibbon group A usually choose a big, tall and bushy trees which contained fruits to be their nigth trees. It was very rare that all members stayed together in the same night tree. I followed five individuals on every observation day and recorded some of their activities, such as feeding, grooming, travelling and singing. Since September 28, 1997, the juvenile male was disappearing from the group A; thus data on him is missing.

Table 4.1 Some behavior on average of the gibbons group A at Mo Singto study site, Khao Yai National Park; in each time period

	Time				
Behavior	6.00-8.00	8.00-10.00	10.00-12.00	12.00-14.00	14.00-16.00
Feeding	31%	44%	19%	4%	6%
Grooming		29%	39%	32%	
Traveling	14%	36%		43%	7%
Singing	74%			26%	

4.2 Feeding observations

Gibbons fed on many kinds of food which included both plants and insects. Gibbons used simple methods to consume food items. They used one hand to pick up food and send it into the mouth, while the other hand was used for hanging support. One hand is very convenient for picking up young leaves, flowers, shoots and small fruits. They mostly used one hand and one or two feet to hold food such as large fruits and insects. Gibbons ate insects by picking from tree bark or leaves. They used the similar technique of feeding as the to above technique on a sitting on a main branch of a tree and used two hands to open rolled leaves or tree bark.

Drinking behavior was also observed. A gibbon drank water by pushing a cupped hand into a tree hole and letting the water drip off its fingers into the mouth. Sometimes, they sucked water that was absorbed in the hand's hairs. Gibbons usually repeated this action with the same hand about 10-15 times.

4.3 Food consumption

Plant diet consumed by gibbons included fruits, leaves, flowers, shoots and some termites. Overall, 30 families and 4 unknown families of 65 plant species were collected and identified in the diet of gibbon group A (Table 4.2). The list of plant species eaten is shown in Table 4.4. Voucher specimens were collected for each species of plant fed upon by the gibbons and the specimens are stored at the Center for Conservation Biology, Mahidol university. Eleven species are unknown species. In

1997, there were more fruiting trees than year 1998 that I compared with unobserved time because of the weather and topographic conditions. There were three life forms among food species, namely trees (72%), climbers (26%) and tree lets (2%) (see Figure 4.1). The climbers was distinguished into 2 categories, woody climbers (liana) (18%) and creepers climber (climbers that climb on trees) (7%). Appendix 3 shows the list of species of each life form.

The White-handed gibbons of group A consumed a variety of plant parts eaten, including fruits, leaves, young shoots, flowers, legumes and spadix or spathe (Araceae). The part most consumed by gibbons was fruit (73.5%), followed by leaves (19.1%), young shoots (1.5%), flowers (2.8%), legumes (1.5%) and spadix/spathe (1.5%) (Table 4.3)

4.3.1 Fruits

Fruit was the major part in plant diet (73.5%) (Table 4.3 and 4.4). There were 50 species of fruit recorded by gibbon group A. Fifteen species of *Ficus* spp. were consumed. In this study,. figs were available throughout and were eaten by many kinds of animals, for example gibbons, squirrels, civets and birds. Figs and some plants species could not be identified to species, thus they are listed as unknown species and identified by the Family name. There were 6 major fruits of non-fig species eaten by the gibbons such as *Choerospondias axillaris*, *Alphonsea boniana*, *Sandoricum koetjape*, *Gnetum montanum*, *Knema laurina* and *Garcinia xanthochymus*. The list of plant species eaten by the focal gibbon group is shown in

Table 4.4. Most fruits were consumed as whole fruits (73.5%) (Table 4.3). They swallowed these whole fruit with seeds and defecated on the same or next day. The percentages and number of fruit species consumed is shown in Table 4.3.

4.3.1.1 Nature of fruits

There were many types of fruits eaten by White-handed gibbons in my collected specimens. Most fruits were drupes. Fruits were catagorized into 4 groups. Each group has various size, shape and color.

1. Need peeling

This fruit type was peeled by gibbons to remove the skin before eating. They ate only the seed and flesh and dropped the skin. Some species are small in size and some are large. The skin of some fruits have latex, hairs and hard skin. Appendix 5.1-5.3 shows examples of fruit species in whichthe skin is usually peeled skin before eating.

2. Ready to be eaten whole

Gibbons did not remove the skin before consuming this kind of fruit. They eat whole fruit with seed and flesh. Kind of fruit was usually not large and gibbons put the fruits into their mouth easily. The examples of this fruit type are shown in Appendix 5.4-5.8.

3. Seed and pulp easily separated

These fruits have various seed shapes and juicy pulp. Most fruits are common food and not the large size, such as *Polyalthia viridis*, *Elaeagnus latifolia*, *Knema laurina* and *Walsura robusta* (Appendix 5.9-5.10)

4. Husky fruit

Some fruit species posseses very hard cover or rind. gibbons had to try to effort the rind to eat the flesh and seed inside. The flesh is very juicy and contains many seeds. *Melodionus cambodiesis* and *Garcinia xanthochymus* are the example of large fruit size (Appendix 5.11).

Appendix 5.3 and Appendix 5.11 show the examples of big size and juicy fruits (>40 mm) with large and small seeds. Some fruits have many small seeds such as *Melodionus cambodiesis* but some fruits have many large seeds (such as *Garcinia xanthochymus*. Skins are not soft so sometimes gibbons had to use their hands and feets during eating fruits. Appendix 5.1, 5.2, 5.4, 5.9 and 5.10 show the example of bright color and small fruit size such as *Alphonsea boniana* and *Eberhardtia tonkinensis*. They also have the soft skin and thick flesh. Appendix 5.5 show an example of yellow-green color fruits with soft skin such as *Prunus javanicus* and *Cherospondias axillaris* but they have the well-protected seeds. Appendix 5.6, 5.7, 5.8 and 6.9 show the example of small fruit size with single seed (such as *Diploclisia glaucescens* and *Bridelia tomentosa* numerous seeds (*Ficus* sp.)

4.3.2 Leaves

Gibbons were also observed to feed on young leaves. I observed that they ate only those new leaves which were soft and fresh with purple, pink or bright green color. Thirteen species of young leaves were recorded in this study and seven were unknown. Common species that were consumed were *Polyalthia viridis*, (*Gironniera nervosa, Choerospondias axillaris* and some *Ficus* leaves.

4.3.3 Flowers

Diperocarpus gracilis flowers were also eaten by the gibbons. When their petals were new and very fresh. Petal color is pink and pale orange. Gibbons bit them and dropped the bases of some of the flowers.

4.3.4 Other parts

Gibbons also sometimes ate other parts of plants for their consumption. They were seen to eat young shoots of *Philodendron* sp., the spadix and spathe of *Rhapidophora* sp., and legumes of *Acacia pennata* (Appendix 5.12).

Sometimes gibbons looked for insects in rolled-up leaves on which to feed.

Table 4.2 Number of species in each family eaten by White-handed gibbon (*Hylobates lar*)

Number	Family	Number of species
1	Anarcardiaceae	1
2	Annonaceae	7
3	Apocynaceae	1
4	Araceae	2
5	Araliaceae	1
6	Asclepediaceae	1
7	Celastraceae	1
8	Convolvulaceae	1
9	Diperocarpaceae	1
10	Ebenaceae	1
11	Elaeagnaceae	1
12	Euphorbiaceae	3
13	Gnetaceae	2
14	Guttiferae	1
15	Icacinaceae	1
16	Lauraceae	2
17	Leguminosae-Mimosoideae	1
18	Meliaceae	1
19	Menispermaceae	2
20	Moraceae	15
21	Myristaceae	3
22	Myrtaceae	1
23	Piperaceae	1
24	Rosaceae	1
25	Rubiaceae	3
26	Rutaceae	1
27	Sapindaceae	1
28	Sapotaceae	1
29	Ulmaceae	2
30	Vitaceae	1

Note: There are four unknown families

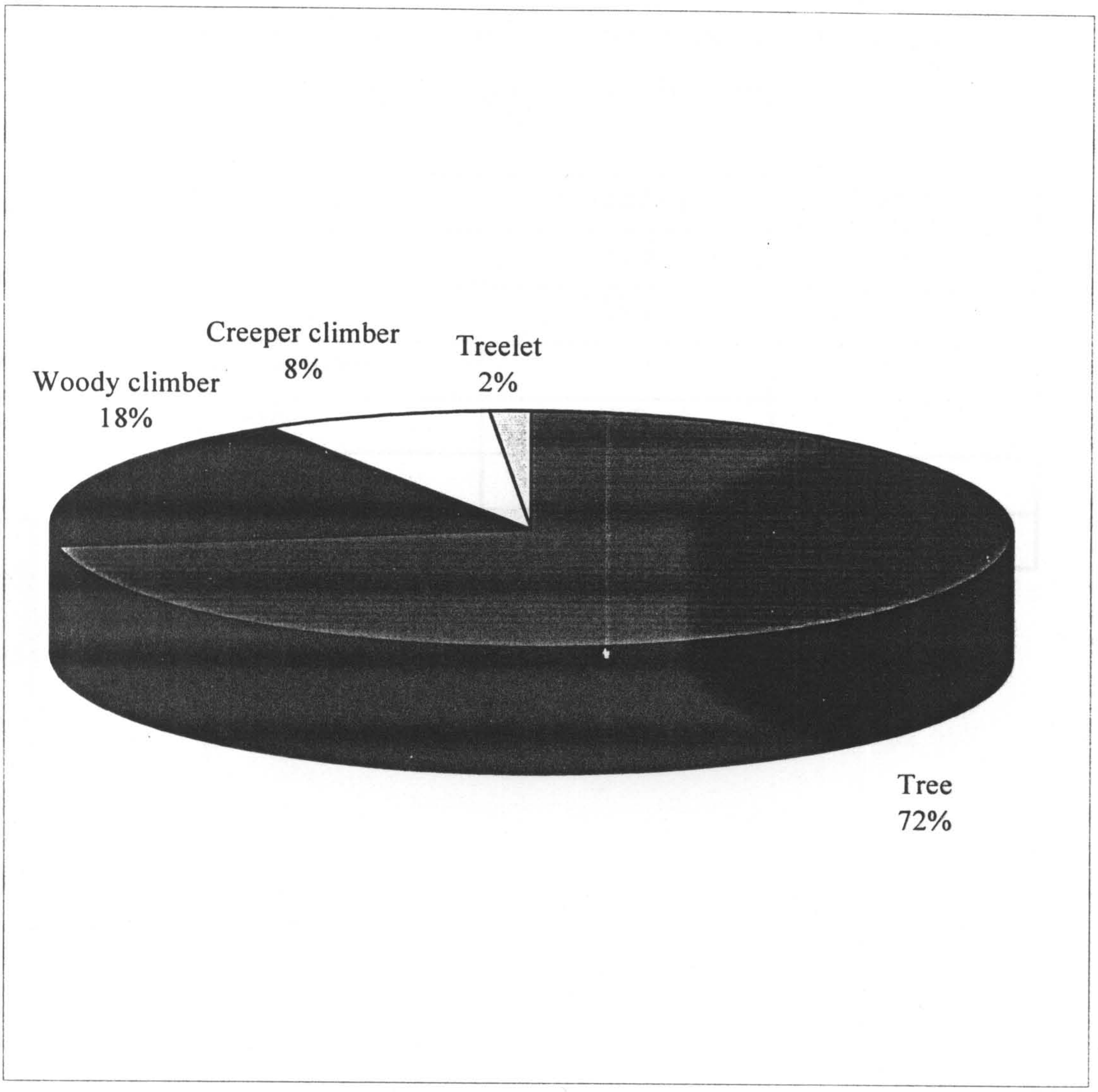


Figure 4.1 Proportion of life forms of eaten plant species of White-handed gibbon (*Hylobates lar*)

Table 4.3 Percentage of species whose plant parts are eaten by White-handed gibbon (*Hylobates lar*)

Eaten Part	Percentage	Number
Fruit	73.5	50
Leaf	19.1	13
Young shoot	1.5	1
Flower	2.8	2
Legume	1.5	1
Spadix, Spathe	1.5	1

4.4 Characteristics of fruits food (Appendix 2, 3)

Gibbons mostly consumed ripe fruits (80.9% of juicy fruits) with bright colors, such as yellow, orange and red. These ripe fruits were soft and very easy to bite and chew. From general observation, I found that they chose fruits that were not infested by insects. They dropped fruits every time that they found them infested or damaged.

Some eaten plants were tasted randomly by me. I can describe that most fruits eaten were bitter or sour. The cover of fruits could be a characteristic used to predict their taste. Mostly green covered and hard fruits had more bitter taste than the brighter colored and soft fruits because they were unripe.

The morphology of plant species eaten by gibbons are categorized in Table 4.5 From this table, the gibbons' diet has many characteristics such as color of cover, seed number, kind of pulp, and seed protection. All of these were determined for the eaten parts and these data were shown in Table 4.4.

4.4.1 Colors

I could classify the colors of eaten fruits into six groups, which are yellow-green, yellow, dark blue or purple, orange, red and brown. Yellow fruits were consumed the most (37.0 %) (Table 4.5). Sometimes gibbons dropped the external fruit parts from fruits after removing the flesh. Although gibbons chose fruits with bright color, sometimes they also bit the unripe green fruits before dropping them down.

The data of color of fruits in this study were compared with the color choice of hornbills and tested by chi-square. The list of color of identified fruit eaten by hornbills is showed in Appendix 1. There was no significant difference between the proportion of color choice of fruit consumed by hornbill and gibbons (X^2=4.18, df=4, p=0.05)

4.4.2 Size

The fruit sizes were distinguished into five groups by length. These five groups are <10.0, 10-20, 20-30, 30-40 and >40 mm Fruits of size less than 10 mm were consumed the most (Table 4.5). Table 4.5 shows the fruit size in each species. Appendix 6.1-6.9 show the example of fruits that were grouped in different size.

4.4.3 Weight

Weight was classified into five categories: <10, 10-20, 20-30, 30-40 and >40g. Fruits with weight less than 10 g were consumed more than those of other weights (Table 4.5). Table 4.5 shows the fruit weight of each species.

4.4.4 Pulp

There are only two categories of pulp in consumed fruits. Actually, I determined three classes for kind of pulp, which were fleshless (no flesh), juicy pulp, and dry pulp. In this study, only juicy and dry pulp were found in the consumed fruits. Gibbons consumed juicy fruits (54.7%) more than dry fruits (45.3%) (Table 4.5).

4.4.5 Seed number

The number of seeds in each fruit was determined by opening fruit fallen on the ground and counting its seeds. This study distinguished the number of seeds into three categories which are 1, less or equal to 10 and more than 10 seeds per fruit. Fruit species with only one seed (44.9%) were found more than those of other classes (Table 4.5).

4.4.6 Seed hardness

Each seed species was tested for seed hardness and recorded as one of four types which were no protection, can be opened with fingernail, can be opened with knife and cannot be opened with knife. There are no seeds consumed which had no protection and were soft. Seeds which could be opened with fingernail were found the most (58%). Seeds which could be opened with knife (22%) were found more than hard seeds which could not be opened by knife (20%) (Table 4.5)

Table 4.4 List of plant species eaten by White-handed gibbon group A

No	Thai Name	Species	Family	Eaten Part	Life from
1	สีเสียดเทศ	*Choerospondias axillaris* Burt&Hill	Anarcardiaceae	fruit, leaf	Tr
2	มะป่วน	*Alphonsea boniana* Fin.& Gagnep.	Annonaceae	fruit	Tr
3	สายหยุด	*Desmos chinensis* Lour.	Annonaceae	fruit, leaf	Cl
4	ยางโอน	*Polyalthia viridis* Craib	Annonaceae	fruit, leaf	Tr
5	นมวัว	*Fissistigma rubiginosum* Merr.	Annonaceae	fruit	Cl
6	กระปุกข่าง	*Melodionus cambodiesis* Pierrs ex Spire	Apocynaceae	fruit	Cl
7		*Philodendron* sp.	Araceae	young shoot	Cl
8		*Rhapidophora* sp.	Araceae	spadix, spathe	Cl
9	คอกิ่ว	*Scindapsus hederaceus* Schott	Arataceae	leaf	Cl
10		*Dischidia nummularia* R. Br.	Asclepidiaceae	leaves	Cl
11	ขอบกระด้ง	*Salacia macrophylla* Bl.	Celastraceae	fruit	Cl
12	ช้างสารสับมัน	*Erycibe elliptilimba* Merr. & Chun	Convolvulaceae	fruit	Cl
13	ยางต้น	*Dipterocarpus gracilis* Bl.	Dipterocarpaceae	flower	Tr
14	จันป่า	*Diospyros glandulosa* Lace	Ebenaceae	fruit	Tr
15	สลอดเถา	*Elaeagnus latifolia* Linn.	Elaeagnaceae	fruit	Tr
16	มะไฟป่า	*Baccaurea ramiflora* Lour.	Euphorbiaceae	fruit	Tr
17	ขนหนอน	*Bridelia tomentosa* Bl.	Euphorbiaceae	fruit	Tl
18	โพบาย	*Balakata baccatum* (Roxb.) Esser	Euphorbiaceae	fruit	Tr
19		*Beilshmiedia glauea* Lee	Lauraceae	fruit	Tr
20	มะเมื่อย	*Gnetum macrostachyum* Hook.f	Gnetaceae	fruit	Cl
21	มะเมื่อย	*Gnetum montanum* Markgraf	Gnetaceae	fruit	Cl
22	มังคุดป่า	*Garcinia xanthochymus* Hook.f.	Gutiferae	fruit	Tr
23	มันหมู	*Platea latifolia* Bl.	Icacinaceae	fruit	Tr
24		*Cinnamomum subavenium* Miq	Lauraceae	fruit	Tr
25	หนามขี้แรด	*Acacia pennata* (Linn.) Willd.	Leguminosae-Mimosoideae	legume	Cl
26	กระท้อนป่า	*Sandoricum koetjape* (Burm.f.) Merr.	Meliaceae	fruit	Tr
27	ลำไยป่า	*Walsura robusta* Roxb.	Meliaceae	fruit	Tr
28	เครือไส้ไก่	*Diploclisia glaucescens* (Bl.) Diels	Menispermaceae	fruit	Cl
29	ไทร	*Ficus hirsuta (Ficus hispida* Linn.f.*)*	Moraceae	fruit	Tr

Table 4.4 (Cont.)

No	Thai Name	Species	Family	Eaten Part	Life form
30	ไทร	*Ficus benjamina*	Moraceae	fruit	Tr
31	ไทร	*Ficus nervosa*	Moraceae	fruit	Tr
32	ไทร	*Ficus virens*	Moraceae	fruit	Tr
33	ไทร	*Ficus altissima*	Moraceae	fruit	Tr
34	ไทร	*Ficus annulata*	Moraceae	fruit	Tr
35	ไทร	*Ficus* no. 361	Moraceae	fruit	Tr
36	ไทร	*Ficus* no.373	Moraceae	fruit	Tr
37	ไทร	*Ficus* no. 379	Moraceae	fruit	Tr
38	ไทร	*Ficus* sp.07	Moraceae	fruit	Tr
39	ไทร	*Ficus* sp.09	Moraceae	fruit	Tr
40	กำลังเสือคม้า	*Knema laurina* Warb.	Myristaceae	fruit	Tr
41		*Syzygium grande* (Wight) Walp. var *grand*	Myrtaceae	fruit	Tr
42	หว้าเล็ก	*Cleistocalyx operculatus* Merr.& Perry	Myrtaceae	fruit	Tr
43		*Piper* sp.	Piperaceae	fruit	Cl
44	นูคต้น	*Prunus javanica* (Teijam.&Binn) Miq.	Rosaceae	fruit	Tr
45		*Aidia cochinchinensis* Lour.	Rubiaceae	fruit	Tr
46	กระทุ่ม	*Neolamarkia cadamba* (Roxb) Bosser.	Rubiaceae	flower	Tr
47	เถางูเห่า	*Toddalia asiatica* Lamk.	Rutaceae	fruit	Cl
48	เงาะป่า	*Nephelium melliferum* Gagnep.	Sapindaceae	fruit	Tr
49		*Eberhardtia tonkinensis* H. Lec.	Sapotaceae	fruit	Tr
50	ขี้หนอนควา	*Gironniera nervosa* Planch.	Ulmaceae	leaf	Tr
51	กรวยแหลม	*Aphananthe cuspidata* (Bl.) Planch	Ulmaceae	fruit	Tr
52	องุ่นป่า	*Tetrastigma laotica*	Vitaceae	leaf,fruit	Cl
53		Unknown 01	Annonaceae	leaf	Tr
54		Unknown 02	Annonaceae	fruit	Tr
55		Unknown 03	Unknown	fruit	Cl
56		Unknown 04	Rubiaceae	fruit	Tr
57		Unknown 05	Unknown	leaf	Tr
58		Unknown 06	Moraceae	leaf	Tr

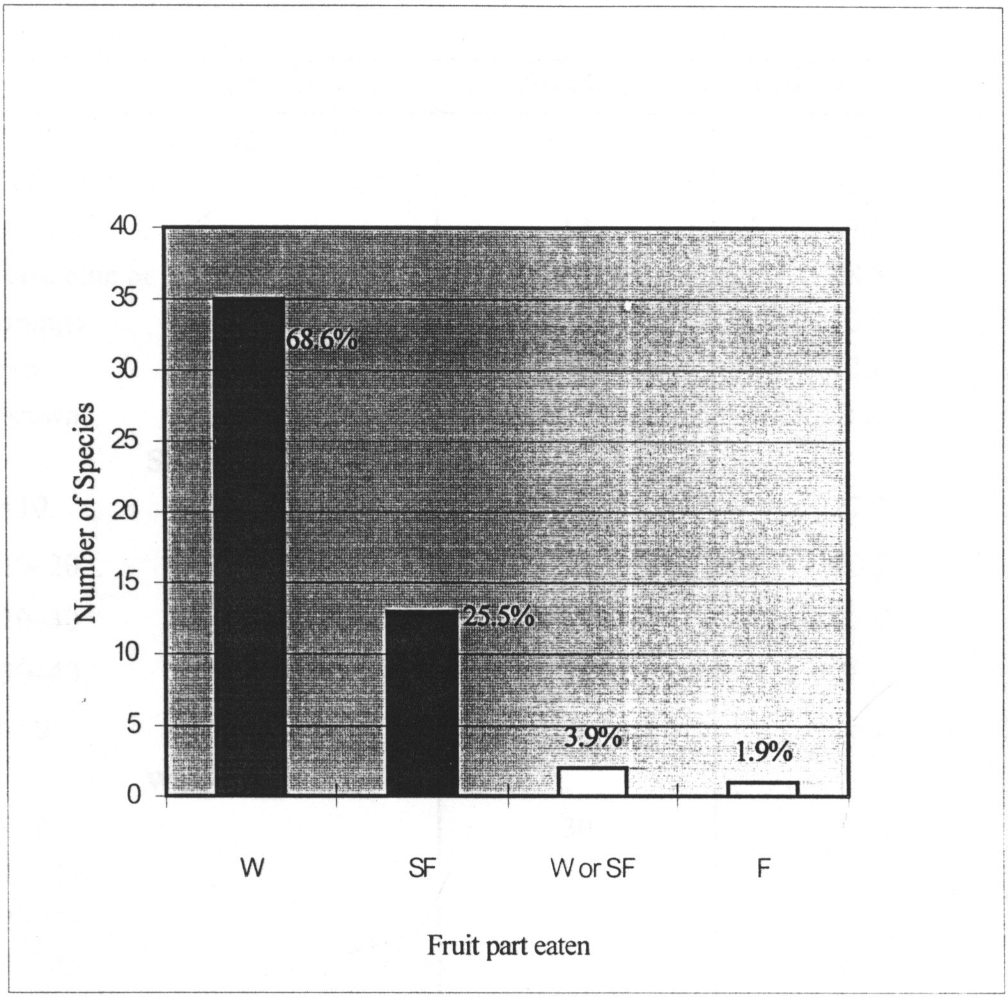
Table 4.4 (Cont.)

No	Thai Name	Species	Family	Eaten Part	Life Form
59		Unknown 07	Unknown	young leaf	Tr
60		Unknown 08	Unknown	leaf	Tr
61		Unknown 09	Araceae	shoot, leaf	Tr
62		Unknown 10	Moraceae	young leaf	Tr

Note Tr : Tree

Cl : climber

Tl : Tree let



Note: W= eat whole fruit

SF= eat seed and flesh but not rind or test

W or SF= eat whole fruits or only seed and flesh

F= eat only flesh, not seed or rind

Figure 4.2 Number of fruit species consumed by gibbons according to parts eaten

Table 4.5 Number and percentage of fruit eaten by white-handed gibbons according to fruit morphology

Characteristics	Number	Proportion (%)
colors		
yellow-green	3	6.5
yellow	17	37.0
dark blue or purple	13	28.3
orange	6	13.0
red	6	13.0
brown	1	2.2
Size (mm)		
<10	12	27.3
10–20	9	20.5
20–30	11	25.0
30–40	4	9.1
>40	8	18.2
Weight (g)		
<10	30	68.2
10–20	3	6.8
20–30	5	11.4
30–40	3	6.8
>40	3	6.8
Kind of pulp		
dry pulp	9	19.2
juicy pulp	40	80.9
Seed number		
1	21	44.7
<=10	10	21.3
>10	16	34.0
Seed hardness		
could be opened with finger nail	15	30.0
could be opened with knife	25	50.0
could not be opened with knife	10	20.0

4.5 Characteristics of non-eaten plants

Most of my data came from direct observation. When I followed gibbons, I focused on their feeding behavior. Non-eaten plant species included both fruits and leaves. Their characteristics that did not lead gibbons to choose them will be summarized for fruits and leaves.

1. Fruit

I observed that gibbons always dropped green fruits which were not soft. Most green fruits are unripe and too hard to eat. Sometimes, they bit one or two times before dropping. Some of these green fruits had sticky liquid or latex in the skin. They also dropped the non-fleshy fruits or infested fruits from the trees.

2. Leaves

Gibbons consumed a lot of young leaves of many species. I observed that a gibbon ate leaves beginning from the top branch. They were not interested in the mature leaves at all. Sometimes, they chose only the youngest leaves of a branch which had many leaf stages and dropped the branch with mature leaves or infected leaves.

4.6 Fecal examination and characteristics of seeds

The adult female usually provided larger piles of feces than other members in the same group. Numbers of collected seeds were most numerous for *Ficus* spp. There were *Ficus* seeds in most feces piles.

Collected seeds from gibbons feces were counted in each month (April 1997-July 1998) (Table 4.6). These seeds were also used to estimated the number of fruits consumed by five individuals of gibbon group A (Table 4.7 and 4.8).

There were 36 species of seeds collected from gibbon feces. Ten species were from unknown plants, which were not found in the fruit and seed collections in the Center for Conservation Biology. These unknown seeds were named unknown sp. 1–sp. 11. Table 4.7 shows fruiting season for species eaten by gibbons in the Mo Singto study site. The results show there was *Ficus* sp. available every month. Appendix 6.1-6.9 show some of the seeds collected in gibbons' feces which were grouped into size catagories. Appendix 6.1-6.3 show species which have relatively large seeds such as *Nephelium melliferum* and *Elaeagnus latifolia* (long seed). Seeds of *Elaeagnus latifolia* and *Diospyros glandulosa* are very sharp in the edge and have pointed ends. The Seed of *Platea latifolia* also is very large (Appendix 6.2b). Most seeds found in gibbon feces had lacked any fleshy mesocarp which was digested, leaving the exposed testa. Appendix 6.4-6.8 show seeds of smaller size such as *Toddalia asiatica* and *Prunus javanicus.* Appendix 6.9 show very small seeds from fig fruits and *Neolamarkia cadamba.*

Table 4.6 Cumulative overlap of fruit season among species eaten by White-handed gibbon (*Hylobates lar*).

Ficus spp.	15
Nephelium melliferum	3
Knema laurina	1
Aphananthe cuspidata	9
Aidia cochinchinensis	11
Cleistocalyx operculatus	2
Diploclisia glaucescens	5
Gnetum sp.	6
Unk. 04	2
Piper sp.	1
Garcinia xanthochymus	6
Seed Unk. 01	1
Bridelia tomentosa	2
Sandoricum koetjape	1
Seed Unk.02	1
Seed Unk. 03	1
Alphonsea boniana	9
Fissistigma rubiginosum	4
Choerospondias axillaris	5
Platea latifolia	1
Seed Unk. 05	2
Seed Unk. 04	3
Neolamarkia cadamba	4
Toddalia asiatica	9
Seed Unk. 06	1
Beilshmiedia glauca	1
Seed Unk. 08	1
Tetrastigma laotica	2
Seed Unk. 07	5
Elaeagnus latifolia	2
Desmos chinensis	3
Balakata baccatum	6
Melodionus cambodiesis	2
Diospyros glandulosa	2
Polyalthia viridis	5
Seed Unk. 09	1
Eberhardtia tonkinensis	1
Prunus javanicus	2
Gnetum macrostachyum	3
Walsura robusta	2

	F	Apr.	May	Jun	Jul.	Aug	Sept	Oct.	Nov	Dec.	Jan.	Feb.	ar.	Apr.	May	Jun.
Number of fruiting species		5	7	10	9	13	13	14	12	9	9	9	11	8	8	7
		******************************** 1997 ******************************									......	.......................1998............				

F= Fruiting periods

Gibbons ate fruits from fruiting trees more than from climbers during April 1997–December (1998) (Table 4.7). The result shows that feeding in fruiting trees started to decrease in September (1997) and increase in October (1997). Between November (1997) to May (1998) gibbons fed on climbers more than trees. After that they started to feed on fruiting trees again, starting in May (1998).

Two sample groups of eaten fruit were measured the dry weight and wet weight of each eaten part, and non–eaten part.

1. Fruits consumed whole by gibbons. There are many species such as *Bridelia tomentosa*, *Desmos chinensis*, *Ficus benjamina* and *Toddalia asiatica.*

2. Fruit in which gibbons consumed only seeds and flesh and dropped the cover. Examples of these fruit species are *Alphonsia bonina*, *Salacia macrophylla*, *Baccaurea ramiflora*, *Knema laurina*, *Walsura robusta*, *Balakata baccatum* and *Garcinia xanthochymus.*

Table 4.8 shows that the proportion by weight flesh and cover to seed is about 1:1 in the first group. And the proportion of cover and flesh to seed is also 1:1 in the second group.

Table 4.3 shows a list of plant species eaten by White-handed gibbons, with seed number and volume. The volume of most seed species is less than 1.0 cm^2 . Some seeds have large size and their seed volume is more than 2.0 cm^2 such as *Choerospondias axillaries*, *Polyalthia viridis*, *Platea latifolia*, *Sandoricum koetjape* and *Prunus javanicus*.

Table 4.7 Fruit preference of White-handed gibbon (*Hylobates lar*)

Month	Species	Individual					Number of Seed	Number of Fruit
		AF	AM	SM	JM	JF		
April (1997) (6 days/14 piles)	*Aidia cochinchinensis*	*	*	*	*	*	*	*
	Aphananthe cuspidata				102		102	102
	Nephelium melliferum	12					12	12
	Knema laurina					26	26	26
	Gnetum sp.	18	1	4	4		27	27
May (1997) (6 days/21 piles)	*Aidia cochinchinensis*	*	*	*	*	*	*	*
	Diploclisia glaucescens				1		1	1
	Nephelium melliferum	8	37	3	2	3	53	53
June(1997) (3 days/19 piles)	*Aphananthe cuspidata*	51				120	171	171
	Garcinia xanthochymus	2	4	2		6	14	3
	Aidia cochinchinensis	*	*	*	*	*	*	*
	Diploclisia glaucescens	6		2			8	8
	Alphonsia boniana	2					11	2
	Gnetum sp.	1	2				3	3
	Cleistocalyx operculatus	23		5			28	28
	Unk 01			1			1	N
	Diploclisia glaucescens	4	3				7	7
July (1997) (9 days/18 piles)	*Diploclisia glaucescens*	7	3	2	4	1	17	17
	Alphonsia boniana	1	1	5	5	2	14	2
	Unk 08	3	11	17	28	8	67	N
	Aidia cochinchinensis	*	*	*	*	*	*	*
	Gnetum sp.				24		24	24
	Piper sp.		1				1	1
	Cleistocalyx operculatus	1				1	2	2
	Fissistigma rubiginosum	7	6	4	4	2	23	7
	Diploclisia glaucescens		2				2	2
	Unk 09		2	2	1		5	N
	Unk 06	1					1	N

Table 4.7 (cont.)

July (1997) (9 days/18 piles)	Unk 08	11					11	N
	Garcinia xanthochymus	3		1	1		5	1
	Aphananthe cuspidata		1				1	1
August (1997) (9 days/45 piles)	*Choerospondias maxillaries*			1	1		2	2
	Aphananthe cuspidata	3	2				5	5
	Aidia cochinchinensis	*	*	*	*	*	*	*
	Sandoricum koetjape	204	101	142	9	8	464	121
	Garcinia xanthochymus	3	4	5	2	3	17	3
	Gnetum sp.	13	2	8	3	4	30	30
	Unk 02	11		16	1	2	30	7
	Aphonsia boniana	11	24	39	12	6	92	16
	Aidia cochinchinensis	*	*	*	*	*	*	*
	Unk 03	3	1				4	4
	Platea latifolia	1					1	1
	Neolamarkia cadamba	*	*	*	*	*	*	*
September (1997) (6 days/48 piles)	*Aphananthe cuspidata*	49	291	26	4	14	384	384
	Sandoricum koetjape	8					8	2
	Alphonsia boniana	4	14	4	7	3	32	6
	Unk 04	30					30	8
	Unk 08	1					1	*
	Garcinia xanthochymus	5	3	2	4	7	22	4
	Aidia cochinchinensis	*	*	*	*	*	*	*
	Prunus javanicus	52	14	12		5	83	83
	Choerospondias axillaris	5	4	1	1		11	11
	Neolamarkia cadamba	*	*	*	*	*	*	*
October (1997) (4 days/11 piles)	*Gnetum* sp.	4	5				9	9
	Aphananthe cuspidata	47	6	2		13	68	68
	Aphonsia boniana	12	1	11		6	30	5
	Beilshmedia glauca	4	3			15	22	22
	Platea latifolia	4					4	4

Table 4.7 (cont.)

October (1997) (4 days/11 piles)	*Garcinia xanthochymus*	17		1		17	35	6
	Neolamarkia cadamba	*	*	*		*	*	*
November (1997) (6 days/25 piles)	*Aphananthe cuspidata*	9	1	10		1	21	21
	Unk 09	11					11	N
November (1997) (6 days/25 piles)	*Fissistigma rubiginosum*	8				1	9	3
	Beilshmedia glauca	6					6	6
	Tetrastigma laotica	9	1	5		1	15	5
	Neolamarkia cadamba	*	*	*		*	*	*
	Bridelia tomentosa	12	7	3		9	31	31
	Unk 09	1					1	*
	Diospyros grandulosa	18	27	14		14	73	5
	Unk 10	1		1			2	N
	Garcinia xanthochymus	3		4		4	11	2
	Aidia cochinchinensis	*	*	*		*	*	*
	Choerospondias axillaris	4	8			7	19	19
December (1997) (7 days/15 piles)	*Aphananthe cuspidata*	5					5	5
	Unk 09	1				1	2	N
	Tetrastigma laotica		40			7	47	14
	Neolamarkia cadamba	*	*	*		*	*	*
	Diospyros grandulosa	14	19	24		13	70	5
	Melodionus cambodiesis	9	4	8		1	22	1
	Elaeagnus latifolia	6		1			7	7
	Choerospondias axillaris	3		21		2	26	26
January (1998) (6 days/17 piles)	Unk 09	7					7	N
	Desmos cochinchinensis	10		2		10	22	22
	Elaeagnus latifolia	3				2	5	5
February (1998) (2 days/5 piles)	*Polyalthia viridis*	4					4	4
	Desmos cochinchinensis	131		30		11	172	172
	Neolamarkia cadamba	*	*	*		*	*	*
	Balakata baccatum					7	7	4

Table 4.7 (cont.)

February (1998) (2 days/5 piles)	*Desmos cochinchinensis*	50					50	50
	Elaeagnus latifolia	3	60	2		11	76	76
March (1998) (3 days/15 piles)	*Choerospondias axillaris*	12		2			14	14
	Eberhardtia tonkinensis	9					9	2
	Toddalia asiatica	21					21	5
	Aidia cochinchinensis	*	*	*		*	*	*
	Unk 09		1				1	N
	Gnetum sp.			2			2	2
	Toddalia asiatica	2				5	6	1
April (1998) (2 days/14 piles)	*Toddalia asiatica*	13	11			161	185	40
	Gnetum sp.		4	13		10	27	27
May (1998) (2 days/11 piles)	*Gnetum* sp.		4	13		10	27	27
	Alphonsia boniana					3	3	1
	Balakata baccatum	4		4		1	9	5
	Walsura robusta	6		44		14	64	64
June (1998) (3 days/35 piles)	*Gnetum* sp.	3				6	9	9
	Sandoricum koetjape	5	2			4	11	3
	Alphonsia boniana	9	1	2		4	16	3
	Balakata baccatum	123	4			67	194	97
	Walsura robusta	105	49			6	160	160
	Aidia cochinchinensis	*	*	*		*	*	*
	Unk 05	1					1	N
July (1998) (3 days/18 piles)	*Alphonsia boniana*	1	1			4	6	1
	Elaeagnus latifolia					1	1	1
	Toddalia asiatica	27	3			1	31	7
	Aidia cochinchinensis	*	*	*		*		*
	Balakata baccatum	2	4	3		7	16	8
	Choerospondias axillaris	8	11			6	25	25
Total		**1331**	**810**	**526**	**220**	**683**	**3579**	**2283**

Table 4.7 (cont.)

N= No data

* = Numerous seeds

AF = Adult Female

AM = Adult Male

JM = Subadult Male

JF = Juvenile Female

SM = Subadult Male

Note1 : Gibbon JM has disappeared since 28th September 1997

Note2 : There were numerous seeds of *Ficus* sp. in every piles

Table 4.8 Species of seeds found in feces of gibbons and their frequency (number of fecal piles out of 390) (April 1997- July 1998).

Species	Frequency	Percentage
Aidia cochinchinensis	12	10.3
Alphonsia boniana	4	3.4
Aphananthe cuspidata	8	6.9
Aphonsia boniana	5	4.3
Balakata baccatum	4	3.4
Beilshmedia glauca	2	1.7
Bridelia tomentosa	1	0.9
Choerospondias axillaris	5	4.3
Cleistocalyx operculatus	2	1.7
Desmos cochinchinensis	3	2.6
Diospyros grandulosa	2	1.7
Diploclisia glaucescens	4	3.4
Eberhardtia tonkinensis	1	0.9
Elaeagnus latifolia	4	3.4
Fissistigma rubiginosum	2	1.7
Garcinia xanthochymus	6	5.2
Gnetum sp.	9	7.8
Knema laurina	1	0.9
Melodionus cambodiesis	1	0.9
Neolamarkia cadamba	6	5.2
Nephelium melliferum	2	1.7
Piper sp.	1	0.9
Platea latifolia	2	1.7
Polyalthia viridis	1	0.9
Prunus javanicus	1	0.9
Sandoricum koetjape	3	2.6
Tetrastigma laotica	2	1.7
Toddalia asiatica	3	2.6
Unk 01	1	0.9
Unk 02	1	0.9
Unk 03	1	0.9
Unk 04	1	0.9
Unk 05	1	0.9
Unk 06	1	0.9
Unk 08	4	3.4
Unk 09	6	5.2
Unk 10	1	0.9
Walsura robusta	2	1.7
Total	**116**	**100.0**

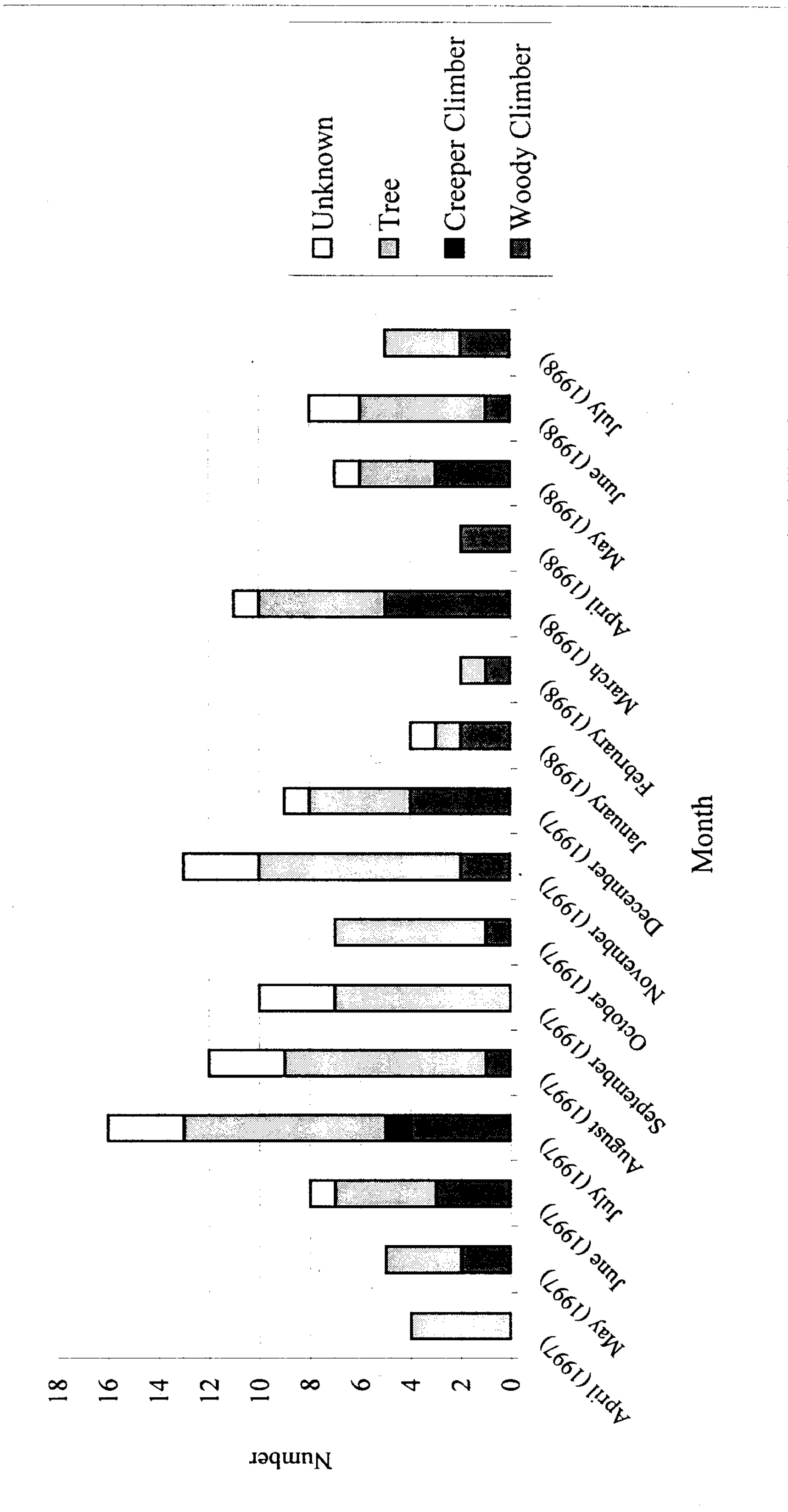


Figure 4.3 Number of fruiting plant species and their life forms collected in feces of White-handed gibbon (*Hylobates lar*) during April 1997-July 1998

Table 4.9 Weights (g) of fruit parts eaten of White-Handed gibbon (*Hylobates lar*)

Species	FCW	sd	SW	sd	FCD	sd	CW	sd	CD	sd	FW	sd	FD	sd	FSW	sd	FSD	sd
Unk03	5.82	0.82	5.80	0.90	1.69	0.32												
Bridelia tomentosa Blumb	0.16	0.02	2.75	0.06	1.10	0.04												
Desmos chinensis Lour.	2.76	0.01	2.81	0.01	2.72	0.01												
Salacia macrophylla	16.08	2.89	3.90	1.04	8.26	1.78												
Ficus Benjamina	10.65	1.40	5.04	1.02	5.15	0.89												
Alphonsea boniana Fin.& Gagnep.	8.81	1.66	4.82	0.50	4.52	0.56												
Toddalia asiatica Lamk.	0.78	0.12	0.01	0.01	0.14	0.04												
Alphonsea boniana Fin. & Gagnep.			5.59	1.17			7.91	0.78	3.78	0.46	5.32	0.66	3.33	0.42				
Baccaurea ramiflora Lour.			2.73	0.24			4.61	2.58	1.38	1.04	3.43	0.30	2.53	0.21				
Knema laurina Warb.			3.16	1.58			4.22	0.81	2.23	0.43	3.67	0.68	2.01	0.73				
Walsura robusta Roxb.			3.31	0.37			3.52	0.34	2.88	0.12	3.07	0.54	2.48	0.42				
Balakata baccatum			2.77	0.01			3.10	0.09	2.76	0.18	3.37	0.19	2.46	0.81				
Garcinia xanthochymus							45.7	8.99	8.48	2.97					17.8	4.386	5.73	1.79

FCW : Flesh and cover wet weight
CW : Cover wet weight
CD : Cover dry weight
FW : Flesh wet weight

FD : Flesh dry weigth
SW : Seed wet weight
FCD : Flesh and cover dry weight
FSW : Flesh and seed wet weight
FSD : Flesh and seed dry weight

Table 4.10 List of plant species eaten by White-handed gibbon group A with seed number and volume

No.	Thai Name	Species	Volume per seed (cc)	Seed Number Average	Seed Number SD	Seed Volume (per fruit)
1	สีเสียดเทศ	*Chorospondias axillaries* Burt&Hill	2.300	1.00	None	2.300
2	มะป่วน	*Alphonsea boniana* Fin.& Gagnep.	0.400	5.77	None	2.308
3	สายหยุด	*Desmos chinensis* Lour.	0.100	1.00	None	0.100
4	ยางโอน	*Polyalthia viridis* Craib	2.200	1.00	None	2.200
5	นมวัว	*Fissistigma rubiginosum* Merr.	0.216	1.00	None	0.216
6	กระปุกข่าง	*Melodionus cambodiesis* Pierrs ex Spire	0.007	16.33	3.51	0.120
7	ขอบกระด้ง	*Salacia macrophylla* Bl.	0.011	11.70	1.42	0.123
8	จันป่า	*Diospyros glandulosa* Lace	0.030	13.50	2.26	0.405
9	สลอดเถา	*Elaeagnus latifolia* Linn.	0.013	2.25	0.07	0.028
10	มะไฟป่า	*Baccaurea ramiflora* Lour.	0.001	1.00	None	0.001
11	ขนหนอน	*Bridelia tomentosa* Bl.	0.027	1.00	None	0.027
12	โพบาย	*Balakata baccatum* (Roxb.) Esser	0.425	2.00	None	0.850
13	มะเมื่อย	*Gnetum macrostachyum* Hook.f	0.026	1.00	None	0.026
14	มะเมื่อย	*Gnetum montanum* Markgraf	0.113	1.00	None	0.113
15	มังคุดป่า	*Garcinia xanthochymus* Hook.f.	0.440	5.56	1.30	2.446
16	มันหมู	*Platea latifolia* Bl.	2.000	1.00	None	2.000
17	กระท้อนป่า	*Sandoricum koetjape* (Burm.f.) Merr.	2.750	3.85	1.57	10.588
18	ลำไยป่า	*Walsura robusta* Roxb.	0.500	1.00	None	0.500
19	เครือไส้ไก่	*Diploclisia glaucescens* (Bl.) Diels	0.330	1.00	None	0.330
20	กำลังเลือดม้า	*Knema laurina* Warb.	1.630	1.00	None	1.630
21	หว้าเล็ก	*Cleistocalyx operculatus* Merr.& Perry	0.500	1.00	None	0.500
22		*Piper* sp.	0.160	1.00	None	0.160
23	นูดต้น	*Prunus javanica* (Teijam.&Binn) Miq.	2.000	1.00	None	2.000
24		*Aidia cochinchinensis* Lour.	*	1.00	None	*
25	เถางูเห่า	*Toddalia asiatica* Lamk.	0.100	4.66	1.07	0.466
26	เงาะป่า	*Nephelium melliferum* Gagnep.	1.700	1.00	None	1.700
27		*Eberhardtia tonkinensis* H. Lec.	0.700	3.85	1.03	2.695
28	กรวยแหลม	*Aphananthe cuspidata* (Bl.) Planch	0.300	1.00	None	0.300
29	องุ่นป่า	*Tetrastigma laotica*	0.200	3.30	1.26	0.660

31		Unknown 02	0.250	4.50	0.70	1.125
32		Unknown 03	0.510	1.00	None	0.510
33		Unknown 04	0.970	3.95	1.23	3.832
34		Unknown 05	0.990	N	N	N
35		Unknown 06	0.480	N	N	N
36		Unknown 07	0.25	N	N	N
37		Unknown 08	0.05	N	N	N
38		Unknown 09	0.96	N	N	N
39		Unknown 10	0.962	N	N	N

* = Numerous seeds

N = No data (were not found in feeding observations)

4.7 General observations of feeding behavior of gibbons at Dusit Zoo

Data on food selection by gibbons were recorded at the Dusit Zoo. I chose a cage which contained four white-handed gibbons. I found that gibbons did not choose to eat domestic guava fruits that I gave to them, even once. In contrast, they chose two species of wild fruits, which are *Ficus* sp. and *Elaeagnus latifolia* (Table 4.10). Gibbons have different methods to pick different food sizes to place into their mouths (Figure 4.37–4.29)

Table 4.11 Number and percent of fruits chosen by gibbons at Dusit zoo

	Elaeagnus latifolia (6.71±1.27mm.)			*Ficus* sp. (9.85±2.22mm.)		
	1	2	3	1	2	3
Big size	12	12	100	19	11	58
Small size	13	13	100	20	7	35

1= Number of given fruit

2= Number of chosen fruit

3= Percent of choosing

Figure 4.4 Photographs of gibbon holding fruits in the hand

a. Guava b. Orange

Figure 4.5 a-b Photograph of gibbon picking *Elaeagnus latifolia*

Figure 4.6 a-b Photograph of gibbon picking *Ficus* sp. in the hand

4.8 Nutritional analysis

Eight species were chosen for nutritional analysis, including 6 species of fruits and leaves. Young and mature leaves of *Polyalthia viridis* were chosen to compare their nutritional value. This study compared the nutritional qualities of ripe and unripe fruits of *Balakata baccatum*. Nutritional qualities in each species were found only for the eaten parts of plant species in one fruit and per gram. Table 4.12 and Table 4.13 show the nutritional quality per fruit or leaf or per gram respectively.

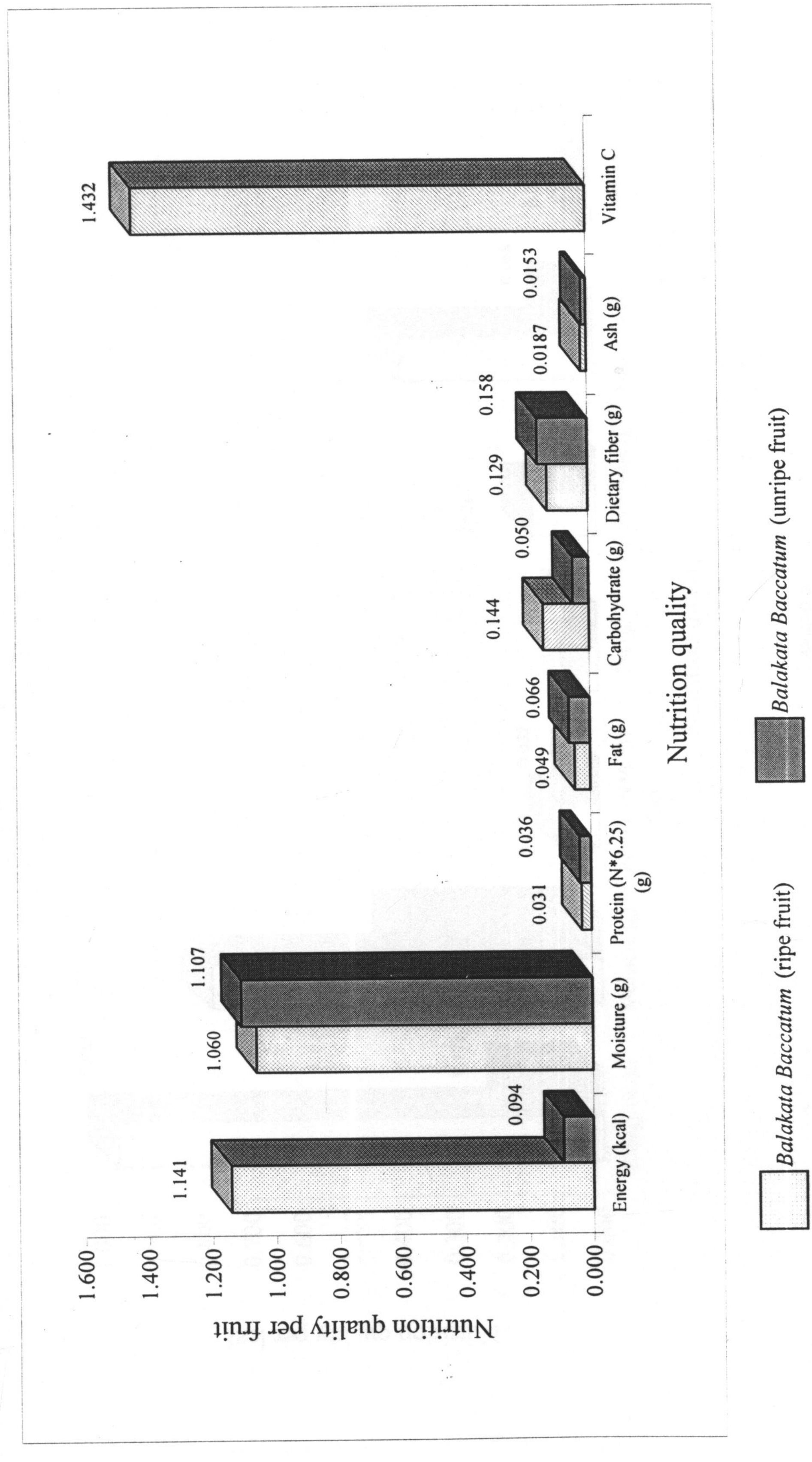
Two sample pairs were compared for nutrition quality, namely that are ripe and unripe fruits of *Balakata baccatum* and mature and young leaves of *Polyalthia viridis.* Energy (1.141 kcal) and carbohydrate (0.1449 g) in the ripe fruit were more than those of the unripe fruit (Figure 4.7). Nutritional quality in the mature leaves was higher than that of the young leaves for all classes (Figure 4.8).

Table 4.12 Nutrition quality (per fruit or leaf) of fruits and leaves eaten by White-handed gibbon (*Hylobates lar*)

Species name	Energy (kcal)	Moisture (g)	Protein(N*6.25) (g) (N*6.25)	Fat (g)	Carbohydrate (g) (exclude dietary fiber)	Dietary fiber (g)	Ash (g)	Vitamin C (g)
Balakata baccatum (ripe)	1.141	1.060	0.031	0.049	0.144	0.129	0.0187	1.432
Balakata baccatum (unripe)	0.094	1.107	0.036	0.066	0.050	0.158	0.0153	-
Walsura robusta	0.740	1.466	0.044	0.003	0.135	0.050	0.021	1.719
Diospyros glandulosa	9.334	16.212	0.091	0.039	2.179	3.050	0.137	-
Choerospondias axillaris	2.555	7.366	0.040	0.026	0.548	0.762	0.069	-
Ficus sp.	2.561	2.720	0.197	0.006	0.434	1.926	0.234	-
Polyalthia viridis (mature leave)	0.965	0.773	0.078	0.017	0.126	0.382	0.022	-
Polyalthia viridis (young leave)	0.172	0.392	0.035	0.004	0.000	0.068	0.008	-

Table 4.13 Nutrition quality (per 1 g) of fruits and leaves eaten by White-handed gibbon (*Hylobates lar*)

Species name	Energy (kcal)	Moisture (g)	Protein(N*6.25) (g) (N*6.25)	Fat (g)	Carbohydrate (g) (exclude dietary fiber)	Dietary fiber (g)	Ash (g)	Vitamin C (g)
Balakata baccatum (ripe)	0.7971	0.7404	0.0213	0.0343	0.1008	0.0901	0.0131	0.0168
Balakata baccatum (unripe)	0.6543	0.7733	0.0250	0.0463	0.0344	0.1103	0.0107	-
Walsura robusta	0.4304	0.8531	0.0254	0.0061	0.0786	0.0292	0.0121	0.0701
Diospyros glandulosa	0.4300	0.7468	0.0042	0.0018	0.1004	0.1405	0.0063	-
Choerospondias axillaris	0.2900	0.8361	0.0045	0.0629	0.0622	0.0865	0.0078	-
Ficus sp.	0.8400	0.0846	0.0647	0.0019	0.1423	0.6318	0.0766	-
Polyalthia viridis (mature leave	0.6900	0.5532	0.0561	0.0120	0.0899	0.2731	0.0157	-
Polyalthia viridis (young leave)	0.3400	0.7804	0.0686	0.0071	0.0000	0.1341	0.0116	-



Note: No data of Vitamin C of the unripe fruit

Figure 4.7 Nutrition quality (per fruit) of ripe and unripe fruit of *Balakata Baccatum*

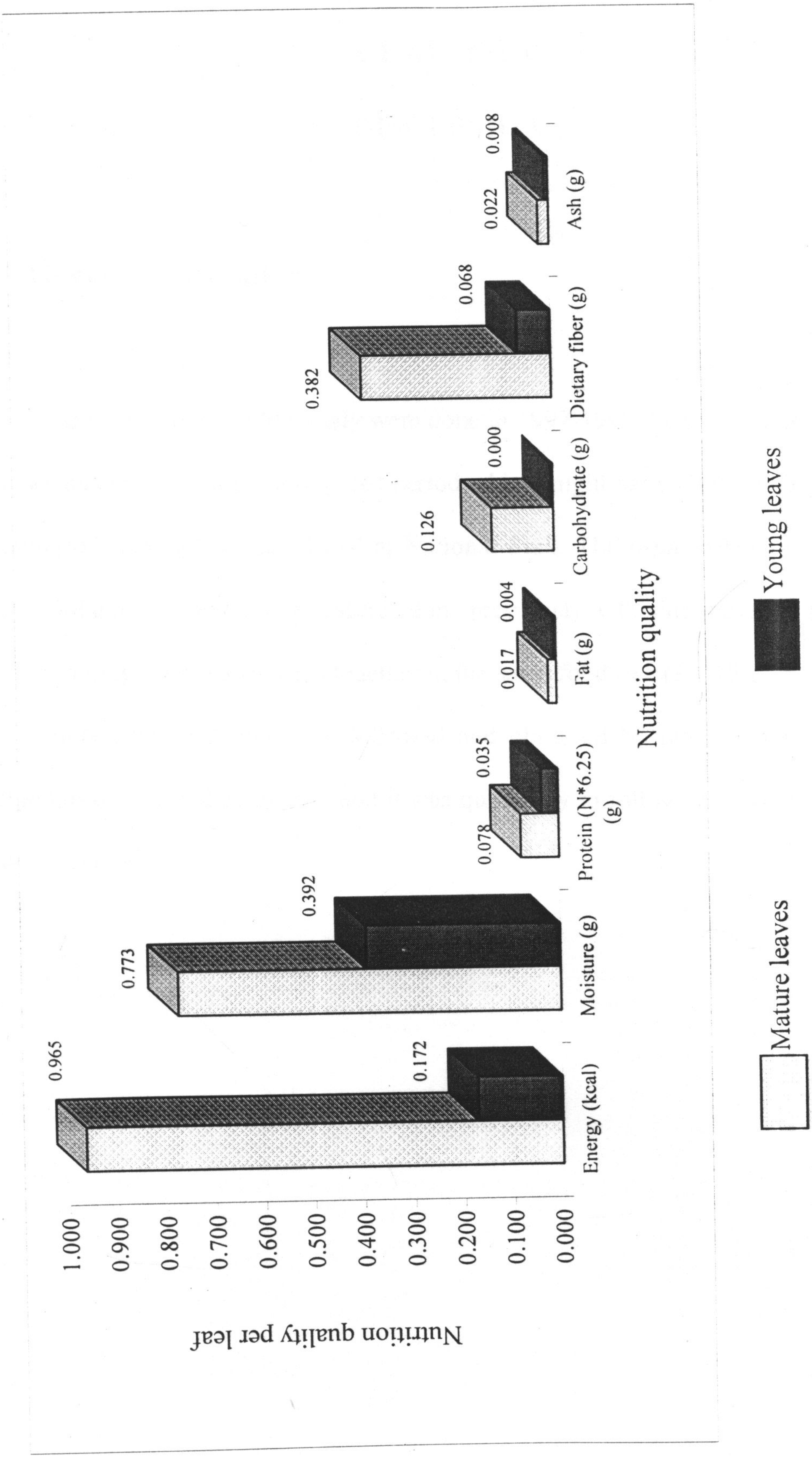


Figure 4.8 Nutrition quality (per leaf) of mature and young leaves of *Polyalthia viridis*

CHAPTER V

DISCUSSION

5.1 General observation

The observations of this study were done in 1997-1998. I observed that there was not so much precipitation during that period which might have affected blooming and fruiting of plant species at Khao Yai National Park. The usual behavior of gibbons was similar to that reported in research done previously. Gibbons started to feed in the early morning. They usually fed together in the same food tree (14, 15).

Gibbon group A has been followed and observed by many researchers. This helped to habituate the gibbons, and it was quite easy to follow the group and collect data from them.

5.2 Feeding observations and food consumption

There were 65 food species in 30 families collected in this study. Plant species consumed was not exactly the same as in the study of Whitington and Treesucon (1991) (29). Some plant species names have changed since then.

Some species consumed by gibbons whose species names were changed because of taxonomic revision are listed:

Whitington and Treesucon (1991) (29)	This study
Desmos cochinchinensis	*Desmos chinensis*
Knema elegans	*Knema laurina*
Salacia verrucosa	*Salacia macrophylla*
Baccaurea sapida	*Baccaurea ramiflora*
Garcinia speciosa	*Garcinia xanthochymus*
Nephelium lappacium	*Nephelium melliferum*
Polyalthia debilis	*Polyalthia viridis*

Some collected species that were chosen by gibbons are the same species found in other research but some are not. This point may be explained by the fact that the time period was different. There was less rainfall and more dry days during this study. This problem may have caused some species not to produce fruit and flowers. This supported by Glander (1981) (53) who noted that flower and fruiting availability was linked to rainfall with flowering being a dry season phenomenon and fruiting a wet season phenomenon. *Nephelium melliferum* is a good example for this case. There were fewer fruiting trees in Khao Yai National Park in 1998, so I could collect only a couple of fruits.

Most food items came from trees (72%) and climbers (27%) which is similar to the proportion of species consumed by the hornbills at Khao Yai National Park (72). The major foods of gibbons are fruits and leaves and the minor foods are flowers, shoots and some small animals. Fruit is expected to be a "high yield" food to compensate for the high cost of traveling. A few mature leaves were consumed by gibbons so mature leaves are expected to be the "low yield" food that requires low cost (62).

Most fruit that were collected and consumed by gibbons in this study consisted of *Ficus* spp (Family Moraceae) (Table 4.2). My observations indicate that fig fruits are the keystone species in Khao Yai National Park, which supports Bartlett (1999) (73) and Raemaekers (1979) (74). They also suggested that all small-body gibbons (subgenus *Hylobates*) can be broadly described as frugivores, for which fruit contributes more to the diet than any other food category (73). These keystone resources were consumed the most when other (more favored) fruits were unavailable.

Fruit preference of gibbons in this study were based on fruit availability in the forest. The results in Table 4.3 can be explained that most chosen fruits came from trees and climbers that were fruiting during the feeding time. There were fewer fruiting trees in 1998 so gibbons selected more fruiting climbers (Figure 4.6). But I cannot say that gibbons preferred trees over climbers. It was likely that food availability influenced food selection by gibbons.

5.3 Syndrome: Characteristics of plant species consumed

Fruits consumed by gibbons were ripe and juicy, which has been found by other researchers. One reason that gibbons chose juicy fruit is they need water from the flesh. Food preferences of hornbills are the ripest fruits with high nutritional value but these fruits are usually not juicy (19). The choice of ripe fruit of birds may be guided by softness and color. There is not much difference between the syndromes of gibbon and hornbill fruits with respect to color alone. The results are in accordance with the bird-gibbon syndromes noted by Gautier-Hion et al. (1985) (75). The proportions of colors of fruit consumed by gibbons were similar to those eaten by hornbills (X^2, df=4, œ=0.05). Poonswad (1994) (19) explained that birds did not choose juicy fruit as did gibbons because they were not be able to determine the pulp composition and nutritional richness. The hypothesis was that hornbill's preferences for fruits is chiefly determined by the abundance of food items (Sorensen, 1981 and Foster, 1990) (76). Hornbills also have to select fruits they can swallow and therefore they are more limited than gibbons. Fruits chosen by gibbons were compared with those chosen by hornbills which was studied by Poonswad, 1994 (19). The results support Glaser et al.

1978 (77) who suggested that bright external colors mostly occur in the ripe fruits which have sweet taste and are juicy for animals (Appendix 4).

The structure of fruit might influence fruit selection by gibbons. Gibbons could consume many types of fruits. Most eaten fruits were drupes which were ready to be eaten whole. A reason that gibbon chose the drupes is because most drupes contains lot of flesh.

Gibbons also fed on young leaves, shoots and flowers. Feeding on leaves may be explained by the need for energy or protein content. Whitten (1982) (21) noted that Kloss gibbons appeared to differ from other gibbons in that they did not feed on tree leaves. They ate arthropods as a major part of the diet. There is evidence from several studies that secondary plant metabolites may mediate food selection in primates. Thus; the gibbons try to avoid unusually high levels of secondary compounds in leaves. Eltayeb and Roddick (1984) (78) suggested that it is generally accepted that a primary function of secondary metabolites in green fruit (immature fruit) is defense from all types of potential consumers. It was broadly assumed that all important secondary chemicals were lost during ripening. Evolution of secondary metabolites in fleshy fruits is the result of selection for multifunctionality. Since secondary metabolites may be expensive to produce, selection pressures may lead to the economical solution of retaining chemicals that have different functions or purposes under differing sets of circumstances. Ripe fleshy fruits are evolutionarily designed to be consumed by vertebrates, and hence they are likely to be an ideal place to look for compounds that are directed toward organisms other than vertebrates (79). Secondary metabolites may serve a variety of adaptive purposes and also involve the mediation of fruit-frugivore interactions from consumption, seed predation and seed dispersal (51).

From this study, it appears that gibbons prefer feeding on young leaves which may be explained by their need for the protein in these leaves. They chose young leaves although protein content in the mature leave is higher than the young leaves. As this result, gibbons may avoided consumming dietary fiber which is high in the mature leaves. This is not similar to Waterman et al. (1980) (80), who noted that protein concentration normally appears to be highest in immature leaves.

Taste preference was not studied in this research because it has to set the special experiments for taste studied with captive gibbons. The problem was it was difficult to collect enough fruit samples in the forest. The results of taste just was studied by the observer during following gibbons in the forest. Most chosen fruits were sour and sweet which agrees with a study of taste preference of Old World monkeys (cynamolgus monkey). It showed that they accept solutions containing sucrose and reject those with bitter taste (81). Aspen et al. (1999) (82) showed that rhesus monkeys responded to sour compounds but rejected bitter tasting ones. The chimpanzee is a primate species whose sense of taste does not differ from that of humans (83). Squirrel monkeys were found to use information about sweetness to select food items with the highest sugar content and highest nutritive value available. High sugar seems advantageous for a frugivorous species to cover energy needs in times of low fruit abundance (84). It is very easy for gibbons to find and eat this kind of fruits This idea agrees with a study of taste response in primates by Glaser et al. (1978) (77). who found that only the Cercopithecidae, the Hylobatidae and Pongidae responded to the proteins monellin and thaumatin that are sweet tasting to humans. Tamarins fed on a large variety of typically small, soft and sweet fruits and foraged heavily on nectar from a few tree species during the dry season, when ripe fruits were relatively scarce (61).

Gibbons are primates as are humans. Gibbon taste may be similar to the human sense of taste according to the human concept of taste qualities (85).

Although Glander (1981) found that plant secondary compounds certainly influenced food choice in Howler monkeys, they were not the only factors influencing selectivity. several other factors such as the nutrient content of the plant material as well as its digestibility must be considered.

In this study, white-handed gibbons consumed principally ripe fruits with juicy pulp and bright colors (red, orange and yellow); these fruits had generally well-protected seeds. By contrast, immature fruits deter frugivores by being hard, bitter or sour. Gibbons preferred bright colors such as yellow, orange and red which indicate when the fruit is ripe. Dark blue color was also sometimes chosen by gibbons in this study. These results agree with those of Gautier-Hion et al. (1985) (75). They found that fruits favored by monkeys were orange, red and yellow, but bird fruits were smaller and red or purple. Colors, especially yellow, seems to be the important choice criterion for fruit eaten by gibbons; orange and red fruits are also often consumed, though green fruits were not totally avoided. The observation is similar to Julliot

(1996) (9) but it contrasts with observations of Janson (1983) (67), who considered that neotropical primates eat principally brown, green, yellow or orange fruit and avoid red fruits. He explained this behavior that primates see well in the green-yellow-orange range but have low sensitivity and poor ability to discriminate among reds. Willson and Whelan (1990) (86) also noted that it is most unlikely that the evolution of fruit colors has a single explanation and the possibility of variety must be borne in mind, such as physiological function, or constraints imposed by various costs of pigment production.

Studies of vision in gibbons are very rare. Visual of gibbons may be explained from many primates studies. Martin and Grunert (1999) (87) studied the short wavelength-sensitive (SWS or blue) cone mosaic in the primate ratina and compared New World and Old World monkeys. They found that the peak spatial density of SWS cones of marmoset was close to 10,000/mm^2 at the foveola. In macaques, the peak spatial density of SWS cones, close to 6,000/ mm^2, is at the fovea. The SWS cones in macaque are arranged in a semiregular array, but they are distributed randomly in marmosets. The results suggested that the SWS cone photorecepter system is subject to different developmental and evolutionary constraints than those that have led to the formation of the red-green photorecepter system in primate vision. Caine and Mundy (2000) (88) explained that the major advantage of trichromatic over dichromatic color vision in primates is enhanced detection of red/yellow food items such as fruit against the dapple foliage of the forest. The observed spectral changes associated with the yellowing of the lens are the result of a chronological process, including chemical or photochemical modifications, not biological aging (89). Thus; color vision of gibbon may improve fruit selection, and color vision may not be effected by the age.

The results of feeding behavior at Dusit zoo showed that gibbons chose *Elaeagnus latifolia* more than *Ficus* sp. They also did not choose the guava and orange fruits even once. This may be because color was a main reason for fruit selection of gibbons in this study.

Gibbons always select fruits that are available in the forest. Some of the results also agree with Gullotin and Dobost (1994) (90). They studied fruit choice of *Ateles paniscus* and *Alouatta seniculus* and found that these monkeys chose bright colored soft fruits (yellow-orange, orange or red) of medium size, but their fruit choice was not dependent on fruit hardness. This also supports Fleming (1991) (4), who noted that fruit size is a basic morphological parameter that influences frugivore food choice. In general, mean and maximum fruit size tends to be positively correlated with body size of frugivore (4). It also agrees with Janson (1983) (67) who found that mammal fruits to be larger than bird fruits. Gibbons may choose the fruit size that is easy to pick up and hand easily. Although they were fed in cages as captive animals, juicy wild fruits with bright colors were still selected by them.

The distribution of size classes of fruit consumed by gibbons was relatively even. This indicates a lack of strong size preference. However, they ate more species of small fruits or more by number or weight. Gibbons also preferred feeding on fruit containing one seed with good protection. This result is similar to the study of Howler monkeys by Julliot (1996) (9). She found that Howler monkeys consumed principally fruits with juicy pulp, with generally a small number of well-protected seeds. The well-protected seeds of *Ficus* spp. were found the most in every pile of gibbon's feces in this study. This may be because gibbons chose many species of fig fruit with small and well-protected seeds as there were fig fruits throughout the whole year. Next to figs, most commonly consumed fruits by gibbons were fleshy fruits with one seed.

Fruit size is an important factor in attracting consumers. It has been proposed that the evolutionary trend toward larger fruit benefits the plant by limiting its dispersers to a restricted set of specialized animals (91). Gautier-Hion et al. (1985) (75) also described that fruit size was one of the most important criteria distinguishing fruits eaten by birds and monkeys; birds mainly exploited small-size fruit (<5 g). It is different to gibbon fruit choice observed in this study. Gibbons chose many size classes of fruits, not only the large size. Size is important for large fruit and seed species to attract large animals as their weight may be a problem in seed dispersal. As the result, they need larger seed dispersal agents such as elephant, monkeys and gibbons (92).

Fruit protection is also an important morphological characteristic as regard seed dispersal because it also limits the number of potential dispersers. Some vertebrates, especially primates, can open fruits with hard and indehiscent pericarps with their teeth; so seed size, and not fruit size, limits the number of dispersers that can swallow seeds (9).

However, McKey (1975) (93) suggested that there is no relationship between fruit nutrition and fruit size that points to evolution favoring specialization by plants for reliable dispersers. Many smaller fruits contain nutritious arils or flesh and are dispersed by a wide variety of opportunistic consumers. Small seeds are often early-successional, while large seed plant are often late-successional (94) because large seeds can be dispersed by abiotic means and a variety of dispersal agents.

It is possible that there is much higher plant-disperser specificity in the case of large protected fruits. There seems to be high disperser-specificity for fruits that are difficult to open (95).

This study may indicate that although gibbons are generalized frugivores, they might be the particularly important dispersers for some plant species. These plant species cannot be eaten by birds and other frugivores, such as fruits with well-protected, large fruits with large seeds, but gibbons have the specific ability to consume these species. For example, *Platea latifolia*, *Elaeagnus latifolia*, *Sandoricum koetjape* and *Garcinia xanthochymus* are large fruits that cannot be swallowed by birds, and they might need gibbons to disperse their seeds. For *Platea latifolia* and *Elaeagnus latifolia*, these species have no cover so any animal or bird should be able to eat them, but may not be able to swallow the seeds. However, their seeds will be dropped under the trees and not dispersed as far as gibbons can disperse them.

Most fruits (except *Ficus* spp.) consumed by gibbons from this study contain one seed. Gibbons chose fruiting trees in the peak of that fruit abundance and chose fig fruits when other fruit species were rare.

The results in Table 4.7 and 4.10 shows fruit preference and each species' seed volume. This results may be explained that gibbons can swallow a lot of small seeds that contain low seed volume. Most fruits with small seed size such as *Aphananthe cuspidata, Cleistocalyx sperculatus* and *Ficus* sp. were swallowed in large number by gibbons group A.

Total seed volume per fruit may effect the types of seeds that gibbons can swallow. They might know when they should stop feeding on fruit with each seed size. Most large-seeded fruits contain a relatively high seed volume (Table 4.9). Gibbons can therefore obtain a greater volume of flesh by swallowing small seeds than by swallowing large seeds. They will stop swallowing seeds when they gain a high seed volume or their stomach are full. Net volume of seeds that gibbon can swallow may depend on the size of their stomach. Thus; relative proportion of seed volume may be factor in fruit selection of gibbons as they select fruit species that should provide the most benefit.

Gibbons prefered feeding on whole fruit which shows in Figure 4.2. Table 4.8 shows the weight (g) of parts eaten by gibbons. Results of each weight parts of some species that were consumed whole show that quantity of flesh and cover wet weight and seed wet weight are not much different from each other. It seems that gibbons consumed a lot of flesh and swallowed medium seed size. Gibbons also consumed a lot of fruits for which they had to remove the rind such as *Walsura robusta* and *Balakata baccatum.* The cover weight was more than flesh weight and seed weight. As a result, gibbons gained a lot of biomass from fruits in which they had to remove the cover, and fruits that they could eat whole.

Table 4.11, 4.12 and Figure 4.7, 4.8 show that mature leaves of *Polyalthia viridis* contains more nutritional value more than young leaves. Gibbons chose young leaves more than mature leaves to avoid the high dietary fiber.

The nutritional analysis in Tables 4.11 and 4.12 suggested that mature leaves that were not eaten have more energy, moisture, protein, fat, carbohydrate fiber, and ash than the young leaves that were eaten. These results do not agree with the study of feeding patterns in the Mantled howling monkey by Glander (1981) (53). He noted that there was no difference between mature leaves (eaten) and new leaves (non-eaten).

In another study, Koenig et al. (1998) (59) reported that Hanuman langurs (*Prebytis entellus*) consumed fruits containing protein and sugar. Gibbons may face two main problems in choosing and digesting leaves. The first is that mature leaves are generally of low nutritive value compared to fruit and contain a high proportion of structural elements such as fiber (Table 4.11, 4.12). The most important of these are cellulose and lignin which are resistant to mammalian digestive enzymes. The second is that leaves of many tree species contain toxic compounds (96). However, the values of the food selected by Howlers changes depending on availability. For example, the value of mature leaves was high when new leaves of higher value were not available, but was low when new leaves were available (53).

New leaves have less crude fiber and should have more protein than young leaves. Most herbivorous mammals can tolerate toxic compounds such as alkaloids if digested in small amounts, but these toxins require an expenditure of energy to detoxify. Digestibility of crude protein is influenced by the crude fiber content of the food because increasing crude fiber has a depressing effect on protein digestibility in nonruminants (53). Fruit selection in this study may agree with Glander (1981) (53) in that gibbons may be maximizing energy intake as evidenced by their preference of fruits and flowers. In addition, they are also maximizing their intake of water, total protein and all amino acids, maximizing digestibility of protein, and minimizing their intake of fiber, ash and plant secondary compounds. Moreover, Glander (1981) (53) explained that food containing a high proportion of fibre takes longer to ferment and must be eaten in smaller quantities. Therefore, despite gibbons' ability to tolerate cellulose, the animal must eat food in which fiber content is minimal and the concentration of other nutrition, especially protein, is maximal.

5.4 Foraging Strategies of Gibbons

This study showed that gibbons have the ability to find the ripest fruit and most nutritious plant species very efficiently. It seems that they usually move directly to the target trees which are the fruiting trees. It is supported by Brockelman (unpublished paper) (31) and Carpenter (1967) (71) that they habitually use routes of foraging through the branches toward a goal. They also easily find alternative sources of ripe fruit when fruits availability changes in the forest (Figure 4.26).

Consequently, Smith and Metcalfe (1997) (43) also added that another factor that may effect an individual's capacity to forage in the most profitable areas is competition for access to such feeding situations. Gibbons sometimes may compete for food with neighbouring groups. The food competition among gibbon groups might be a factor in food selection of gibbons.

Although gibbons have experience in finding food, there are also variables that influence their decision to select food. From a baboon study, it has been found that they have ability to remember the locations of previous search, and the inclination to follow a systematic plan when visiting other possible food sources (60). These points may also relate to gibbon foraging behavior. Gibbons defended large fruiting trees from the neighboring groups. Nevertheless, the evidence of food selection can support the resource defense hypothesis for territoriality in primates. It may explain that the reason that gibbons defend their territories and live in small groups is to insure an adequate resource supply.

5.5 Plant-primate coevolution

The coevolution between plants and animals may have occurred over a long period of time. Sometimes, gibbons ate small insects from leaves. The catching of insect food may be linked to the evolution of manual dexterity and manipulative skill (12). Fruiting trees have to adapt the morphology and physiology of fruits to attract their seed dispersal agents. This study may help explain again how fruit evolved to attract frugivores by involving an attractive "syndrome" of characters. The meaning of syndrome is quite complicated. It is the characteristic of plants that attracted to seed dispersal agents. There is not only one syndrome for all frugivore but also each frugivore always consider many characteristics of food before eating. For example, they attracted the larger generalized frugivores by producing a lot of fruits with small seeds.. For specialized frugivores, fruits may attract seed dispersers by producing highly nutritious fruits with large seeds (4).

Appendix 5.11 shows *Melodionus cambodiesis* which has a tough rind. Gibbons have to try to open it with hands, feet and mouth. It seems like this species is consumed only by gibbons so their seeds may be dispersed by only one coevolved disperser. It is difficult for other animals to eat it. Thus; gibbons may be the main seed disperser to disperse this kind of seed in the forest. Focusing on the fruit consumed by gibbons, the reason that they spend a lot of energy to eat tough fruit is interesting. Perhaps gibbons may simply know from experience and limitation which species of fruits have good flesh. The benefit gained outweight the cost of opening the fruit. Some fruit species such as *Choerospondias axillaris*, *Garcinia xanthochymus* and some *Ficus* sp. were consumed by gibbons and other animals such as deer, squirels and birds. I can indicate that gibbons may not be the main seed disperser of these fruit species in the forest. Thus; other frugivores may be important dispersal agents as well as gibbons.

This study found many of the fruits and seeds consumed by gibbons were small, such as fig fruit. Thus, Moraceae family (figs) seems to be important for gibbons in this study. This is not similar to Snow (1981) (46) who suggested that fruits of the three families of greatest importance for specialized frugivores (Lauraceae, Burseraceae, and Palmae) are consistent in being large, having a relatively large seed, and having high values for protein and fat content. This results were record from the survey in the four main tropical regions (tropical America, Africa, Southeast Asia, Australia). Moreover, *Ficus* sp (in this study) also were consumed by a variety of birds and mammals with general diets. Some fruits which have large seeds and high nutritional value were also consumed by many kinds of birds and mammals, such as *Choerospondias axillaris, Balakata baccatum* and *Diospyros glandulosa.* Fruit plants are adapted for dispersal in many ways which are based on type of frugivores (specialized or opportunistic). For example, if seeds are large, the only way to attract frugivorous birds is a coat with nutritious flesh (46).

Gibbons are primates that have special digestive adaptations that allow them to consume immature fruits protected by plant secondary compounds. Thus, this may be the reason that frugivores can consume foliage as well, because plants use similar substances to protect both their fruits and their leaves (51). However, gibbons consume only limited foliage of few species, and the leaves often pass through undigested. It is supported by the results that were found leaves of *Polyalthia viridis* in the gibbon's feces.

Evolution of secondary metabolites in fleshy fruits is the result of multifunctional selection. It may be expensive to produce. So it may serve a variety of adaptive purposes (51). Seed dispersers as such gibbons also adapt themselves by changing their behavior and physiology for feeding on selected plants. They feed on fruits which contain high nutritional value and adapt their long gut for passing through the seeds unharmed by digestion.

Small body size benefits a frugivore. Gibbons have a relatively small size so they can go to the top branches of fruiting trees.

It seems that palatability is also a factor for food selection. I observed that gibbons were always very active during their feeding time. Gibbon's ability to swing beneath branches may be considered a feeding adaptation, which allows the animal to hang like fruit swaying on terminal twigs, without the need to keep their balance on top of branches. One reason that gibbon have specific ability to swing on the tree is their light weight and size. It is supported Jolly (1972) (12) who suggested that their brachiation is also a special ability of gibbons.

Terborgh (1992) (8) noted that large mammals have slow metabolism which is needed to extract the scant nutrient content of fibrous leaf material.

Moreover, the high energy expenditure of branchiation may limit the distance that single animals can economically travel and thus lead to families inhabiting small defended areas of forest. As a result, gibbons tend to have small group size and travel only within their own territory.

From the results it can be summarized that many factors influence food choice in gibbons. The consumption of fruit was linked to the seasonal availability of trees of each species in the habitat, but some fruit species were strongly preferred. Gibbons are fairly generalized frugivores but it seems like they are specialized to some extent in their fruit preferences. Fruit plants are adapted not only for gibbons but also for other large or small vertebrates such as deer, hornbills, monkeys and elephants so plants will disperse seeds as much as possible. As this result, food plants in the forest always have variation of size, shape, color and taste in order to attract various frugivores. It seems like coevolution between plants and animals, nothing occurs "intentionally" in coevolution but the relationship between plants and animals have evolved together based on natural selection. Animals tend to select the best food for their survival. Thus, plants have to adapt their physiology and morphology to attract to their dispersal agents.

Gibbons select fruits with higher production cost; hence those with high rate of germination. These fruits with one seed usually peak in abundance in a short time. Thus, food availability also influences food selection by primates.

Herrera (1985) (24) suggested that the dispersal syndrome is not specific to a single disperser species, but is maintained in a lineage of plants by a succession of different dispersal agents Thus, the syndrome results from coevolution between taxonomically restricted groups of plants and animals (97, 67).

The selection of food is said to be a hierarchical process (97). Animals actively select the feeding microhabitat and then they select food items. Consequently, factors that determine an animal's diet depend not only on food quality, food availability and abundance, but also on the multiple factors that determine microhabitat selection such as nutrient, energy content of food and fruit morphology (98). This contrasts with my gibbon observations as gibbon go directly to the fruit tree without selecting a microhabitat, other than the forest canopy.

CHAPTER VI

CONCLUSION

White-handed gibbons (*Hylobates lar*) feed on a wide variety of plant parts including fruits (73.5%), leaves (19.1%), young shoots (1.5%), flowers (2.8%), legumes (1.5%) and spadix and spathe (1.5%). In all, 30 families and 65 plant species were collected and identified in the diet of gibbon group A at Mo Singto study site, Khao Yai National Park. Gibbons preferred consuming ripe fleshy fruits with bright color and that were juicy. Characteristics of fruit color were not much different from hornbills' fruit choice. The reason is both species eat the ripest fruit with bright color cover. *Ficus* spp. act as keystone resources in the forest. Not only gibbons and hornbills, but other animals such as deer and squirrels consume fig fruits.

Gibbons consumed principally fruits with juicy pulp as they need water from flesh. Proportions of size classes of fruit consumed by gibbons were relatively even. This indicates a lack of size preference. However, seed size is an important factor in attracting consumers as gibbons. Gibbons preferred feeding on fruit containing one seed with good protection. They ate small fruits of many more species, or more by number or weight but many highly preferred fruits that were large. This may be because gibbons chose many species of fig fruit with small and well protected seed as there were fig fruits throughout the whole year.

Nature of fruit might involves fruit selection of gibbons. Most eaten fruits were drupes which were ready to be eaten. Gibbons could consume many types of fruit. They also could consume fruits and swallow seeds that other animals such as deer, birds could not do. Taste preference was observed by observer during following gibbons in the forest. They chose most of sour and sweet fruits. This result may show that they accept solution containing sucrose and reject the bitter taste.

Total seed volume per fruit effects the types of seeds that gibbons can swallow. Gibbons could swallow a lot of small seeds that contain low seed volume.

Seed size and fruit protection are the most important morphological characteristics of fruit as regard seed dispersal because they limit the number of potential dispersers. Many such species thus rely heavily on gibbon for dispersal.

Nutritional quality is a factor which influences gibbon food selection. Gibbons need energy or protein content but avoid secondary metabolites. Therefore, they feed on young leaves and ripe fruits. They also need the higher quality of food if there is high food availability for choosing. Although secondary compounds certainly influenced food choice, they were not the only factors of gibbon selection. Fruit preference of gibbons in this study were based on fruit availability in the forest.

There were many fruit species were consumed by many animals such as bird, deer and gibbons such as *Choerospondias axillaris*, *Elaeagnus latifolia* and *Ficus* spp. Thus; this may indicate that these fruits can disperse their seeds not only by gibbons. Only one specie was consumed only by gibbon, was *Melodionus latifolia.* It is the large fruit with hard cover and contains good flesh and a lot of seeds. Thus; gibbons might be the main seed disperser for this species.

Coevolution between plant and frugivore has been discussed by many researchers for a long time. Gibbons used experience to find and select food to be consumed. It seems like the food syndrome and food choice can explain behavior and ecology of gibbons. This supports the resources defense hypothesis for territoriality in primates

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APPENDIX

Appendix 1 List of color of identified fruit eaten during the breeding season by four hornbill species in Khao Yai National Park (1981-1985). (Poonswad et al., 1996)

No.	Family	Fruit species	Color of fruit
1	Moraceae	*Ficus drupacea*	orange
2	Moraceae	*Ficus Benjamina*	dark purple
3	Moraceae	*Ficus altissima*	dark purple
4	Moraceae	*Artocarpus lakoocha*	yellow
5	Myristicaceae	*Horsfieldia glabra*	yellow
6	Myrtaceae	*Syzygium cumini*	dark purple
7	Piperaceae	*Piper ribesoides*	orange
8	Podocarpaceae	*Podocarpus polystachya*	red
9	Oleaceae	*Jasminum sp.*	black
10	Sapindaceae	*Lepisanthes rubiginosa*	red
11	Symplocaceae	*Symplocos laurina*	dark purple
12	Olacaceae	*Beilchmiedia sp*	dark purple
13	Annonaceae	*Polyalthia viridis*	black(dark purple)
14	Annonaceae	*Uvaria pierrei*	yellow
15	Burseraceae	*Canaruim subulatum*	dark purple
16	Elaeagnaceae	*Elaeagnus latifolia*	orange
17	Elaeocarpaceae	*Elaeocarpus grandiflorus*	dark purple
18	Elaeocarpaceae	*Sloanea sigun*	orange
19	Lauraceae	*Cinnamomum subavenium*	dark purple
20	Lauraceae	*Litsaea cubeba*	Black(dark purple)
21	Meliaceae	*Aglaia spectabilisaril*	orange
22	Meliaceae	*Aglaia Lawii*	orange

Appendix 2 Some Characteristics of plant species consumed by white-handed gibbon

No.	Thai name	Species	Family	Life form	Eaten Part	Seed number	Kind of pulp	Seed protection
1	ลีเลียดเทศ	*Chorospondias axillaris* Burt&Hill	Anarcardiaceae	Tr	W&SF, L	1	J	4
2	มะป่วน	*Alphonsea boniana* Fin.& Gagnep.	Annonaceae	Tr	SF	5.77±1.69	D	3
3	สายหยุด	*Desmos chinensis* Lour.	Annonaceae	Cl	W	1	D	4
4	ยางโอน	*Polyalthia viridis* Craib	Annonaceae	Tr	SF, L	1	D	3
5		*Fissistigma rubiginosum* Merr.	Annonaceae	Cl	W	3.33±0.42	D	4
6	กระปุกช่าง	*Melodionus cambodiesis* Pierrs ex spire	Apocynaceae	Cl	SF	16.33±3.51	J	2
7		*Philodendron* sp.	Araliaceae	Cl	A			
8		*Rhapidophora* sp.	Araceae	Cl	A			
9		*Scindapsus herderaceus* schott.	Araceae	Cl	L			
10		*Dischidia nummularia* R.Br.	Asclepidiaceae	Cl	L			
11		*Salacia macrophylla* Bl.	Celastraceae	Cl	SF	11.7±1.418	J	3
12		*Erycibe elliptilimba* Merr. & Chun	Convolvulaceae	Cl	W	1	J	2
13		*Dipterocarpus gracilis*						
14	จันป่า	*Diospyros gladulosa* Lace	Ebenaceae	Tr	W	13.5±2.26	J	4
15	สลอดเถา	*Elaeagnus latifolia* Linn.	Elaeagnaceae	Cl	SF	1	J	2
16	มะไฟป่า	*Baccaurea ramiflora* Lour.	Euphorbiaceae	Tr	SF	2.25±0.07	J	2
17	ขนหนอน	*Bridelia tomentosa* Blumb	Euphorbiaceae	Tr	W	1	D	2
18	โพบาย	*Balakata baccatum* (Roxb.) Esser	Euphorbiaceae	Tr	W	2	J	2
19		*Beilshmeidia glauea* Lee	Lauraceae	Tr	W	1	J	4
20		*Gnetum macrostachyum* Hook. f.	Gnetaceae	Cl	W	1	D	2
21	มะเมื่อย	*Gnetum montanum* Markgraf	Gnetaceae	Cl	W	1	D	2
22	มังคุดป่า	*Garcinia xanthochymus* Hook.f	Gutiferae	Tr	SF	5.56±1.30	J	2
23		*Platea latifolia* Bl.	Icacinaceae	Tr	W	1	J	4
24		*Cinnamomum* sp.	Lauraceae	Tr	W	1		4
25		*Acacia pentana(Linn.)* Willd						

Appendix 2.(Cont.)

No.	Thai name	Species	Family	Life form	Eaten Part	Seed number	Kind of pulp	Seed protection
26	กระท้อนป่า	*Sandoricum koetjape* (Burm.f) Merr.	Meliaceae	Tr	SF	3.85±1.57	J	3
27	ลำไยป่า	*Walsura robusta* Roxb	Meliaceae	Tr	SF	1	J	3
28	เครือไส้ไก่	*Diploclisia glacescens* (Bl.) Diels	Menispermaceae	Cl	W	1	J	2
29	ไทร	*Ficus hirsuta (Ficus hispida* Linn.f.)	Moraceae	Tr	W	Numernous	D	3
30	ไทร	*Ficus benjamina*	Moraceae	Tr	W	Numernous	J	3
31	ไทร	*Ficus nervosa*	Moraceae	Tr	W	Numernous	J	3
32	ไทร	*Ficus virens*	Moraceae	Tr	W	Numernous	J	3
33	ไทร	*Ficus attissima*	Moraceae	Tr	W	Numernous	J	3
34	ไทร	*Ficus annulata*	Moraceae	Tr	W	Numernous	J	3
35	ไทร	Ficus no. 361	Moraceae	Tr	W	Numernous	J	3
36	ไทร	Ficus no. 373	Moraceae	Tr	W	Numernous	J	3
36	ไทร	Ficus no. 379	Moraceae	Tr	W	Numernous	J	3
37	ไทร	Ficus sp. 07	Moraceae	Tr	W	Numernous	J	3
38	ไทร	Ficus no. 09	Moraceae	Tr	W	Numernous	J	3
39	กำลังเลือดม้า	*Knema laurina* Warb.	My ristaceae	Tr	SF	1	J	3
40	หว้าเล็ก	*Cleistocalyx aperculatus* Merr.& Perry	Myrtaceae	Tr	W	1	D	
41		*Syzygium grande* (Wight) Walp. var grande	Myrtaceae	Tr	W	1	D	2
42		*Piper* sp	Piperaceae	Cl	W	1	D	2
43		*Prunus javanica* (Teijam.&Binn) Miq.	Rosaceae	Tr		1	J	3
44		*Aidia cochinchiensis* Lour.	Rubiaceae	Tr	W	1	J	3
45	กระทุ่ม	*Neolamarkia cadamba* (Roxb) Bosser.	Rubiaceae	Tr	W	Numernous	J	2
46	เถางูเห่า	*Toddalia asiatica* Lamk.	Rutaceae	Cl	W	4.66±1.07	J	4
47	เงาะป่า	*Nephelium mellifurum* Gagnep.	Sapindaceae	Tr	SF	1	J	2
48		*Eberhardtia tokinensis* H. Lec.	Sapotaceae	Tr	W	3.85±1.03	J	4
49		*Aphananthe cuspidata* (Bl.) Planch	Ulmaceae	Tr	W	1	J	4
50	ขี้หนอนควาย	*Gironniera nervosa* Planch.	Ulmaceae	Tr	L		J	2

Appendix 2.(Cont.)

No.	Thai name	Species	Family	Life form	Eaten Part	Seed number	Kind of pulp	Seed protection
51	องุ่นป่า	*Tetrastigma laotica*	Vitaceae	Cl	W&SF	3.3±1.26	J	3
52		Unk01	Annonaceae	Tr	SF		J	3
53		Unk 02	Annonaceae	Tr	SF	4.5±0.70	J	3
54		Unk03		Cl	F	1	J	
55		Unk04		Tr	W	3.95±1.23	J	
56		Unk05		Tr	A		J	
57		Unk 06		Tr	L			
58		Unk 07		Tr	L			
59		Unk. 08		Tr	L			
60		Unk. 09		Tr	L			
61		Unk. 10		Tr	L			
62		Unk 11		Tr	L			

W: eat whole fruit
SF: eat seed and flesh
W&SF: eat whole ftuit, seed and flesh
F: eat only flesh

L: eat leaves
A: eat another part

Tr: Tree
Cl: Climber
Tl: Tree let

D: Dry fruit
J: Juicy fruit

1: No protection
2: Could be openned with finger nail
3: Could be openned with knife
4: Could not be openned with knife

Appendix 3 Average weight and size of plant species consumed by White-handed gibbon

No.	Thai name	Species	Family	Total.	Fresh fruit			
				Number	Everage weight (g.)	Std.	size (mm.)	Std.
1	สีเสียดเทศ	*Choerospondias axillaris* Burt&Hill (leave)	Anarcardiaceae					
2	สีเสียดเทศ	*Chorospondias axillaris* Burt&Hill (fruit)	Anarcardiaceae	100.00	8.81	1.66	22.00	3.31
3	มะป่วน	*Alphonsea boniana* Fin.& Gagnep.	Annonaceae	27.00	16.65	3.51	33.06	6.01
4	สายหยุด	*Desmos chinensis* Lour.	Annonaceae	30.00	0.19	0.02	0.83	0.07
5	ยางโอน	*Polyalthia viridis* Craib (fruit)	Annonaceae	19.00	2.00	0.06	21.11	2.69
6	ยางโอน	*Polyalthia viridis* Craib (leave)	Annonaceae	52.00	0.86	0.46	15.42	4.50
7		*Fissistigma rubiginosum* Merr.						
8	กระปุกข่าง	*Melodionus cambodiesis* Pierrs ex spire	Apocynaceae	3.00	81.00	5.12	80.80	3.08
9		*Philodendron* sp.	Araceae	12.83	24.40			
10		*Rhapidophora* sp.	Araceae					
11		*Scindapsus herderaceus* schoott.	Arataceae					
12		*Dischidia nummularia* R.Br.	Asclepidiaceae					
13		*Salacia macrophylla* Bl.	Celastraceae	10.00	24.49	4.73	35.92	6.37
14		*Erycibe elliptilimba* Merr. & Chun	Convolvulaceae	4.00	26.00	0.29	2.77	0.11
15	ยางต้น	*Dipterocapus gracilis*	Dipterocarpaceae					
16	จันป่า	*Diospyros gladulosa* Lace	Ebenaceae	24.00	21.71	3.43	31.59	1.83
17	สลอดเถา	*Elaeagnus latifolia* Linn.	Elaeagnaceae	31.00	32.30	3.71	6.71	1.27
18	มะไฟป่า	*Baccaurea ramiflora* Lour.	Euphorbiaceae	8.00	1.79	0.22	21.01	1.28
19	ขนหนอน	*Bridelia tomentosa* Blumb	Euphorbiaceae	30.00	8.83	1.10	0.12	0.06
20	โพบาย	*Balakata baccatum* (Roxb.) Esser	Euphorbiaceae	8.00	1.43	0.28	14.24	1.18

Appendix 3 (Cont.)

No.	Thai name	species	Family	Total Number	Fresh fruit Everage weight (g.)	Std.	size (mm.)	Std.
21		*Beilshmeidia glauea* Lee	Lauraceae	8.00	0.56	0.16	12.38	1.61
22		*Gnetum macrostachyum* Hook. f.	Gnetaceae					
23	มะเมื่อย	*Gnetum montanum* Markgraf	Gnetaceae	20.00	0.63	0.15	19.40	2.37
24	มังคุดป่า	*Garcinia xanthochymus* Hook.f	Gutiferae	30.00	80.01	29.93	59.50	9.22
25		*Platea latifolia* Bl.	Icacinaceae					
26		*Cinnamomum* sp.	Lauraceae					
27	หนามขี้แรด	*Acacia pennata (Linn.)* Willd						
28	กระท้อนป่า	*Sandoricum koetjape* (Burm.f) Merr.	Meliaceae	7.00	80.30	24.19	51.34	4.82
29	ลำไยป่า	*Walsura robusta* Roxb	Meliaceae	35.00	1.72	0.22	14.57	0.78
30	เครือไส้ไก่	*Diploclisia glacescens* (Bl.) Diels	menispermaceae	10.00	1.25	0.17	13.22	1.01
31		*Ficus hirsuta (Ficus hispida* Limm.f.*)*	Moraceae	28.00	10.21	0.93	44.10	3.36
32	ไทร	*Ficus benjamina*	Moraceae	6.00	0.66	0.17	8.52	2.05
33	ไทร	*Ficus nervosa*	Moraceae	30.00	0.61	0.12	0.84	0.09
34	ไทร	*Ficus virens*	Moraceae	30.00	0.39	0.18	9.14	0.97
35	ไทร	*Ficus attissima*	Moraceae	20.00	3.29	0.53	20.53	1.60
36	ไทร	*Ficus annulata*	Moraceae	30.00	7.79	1.11	34.02	2.76
37	ไทร	Ficus no. 361	Moraceae	24.00	1.49	0.16	17.80	1.52
38	ไทร	Ficus no. 373	Moraceae	19.00	0.20	0.08	9.85	2.22
39	ไทร	Ficus no. 379	Moraceae	14.00	32.71	2.88	12.45	2.37
40	ไทร	Ficus sp. 07	Moraceae	30.00	1.38	0.37	19.13	1.74

Appendix 3 (Cont.)

No.	Thai name	Species	Family	Total	Fresh fruit			
				Number	Everage weight (g.)	Std.	size (mm.)	Std.
41	ไทร	Ficus no. 09	Moraceae					
42	กำลังเสือคม้า	*Knema laurina* Warb.	My ristaceae	30.00	3.90	0.40	25.55	1.92
43	หว้าเล็ก	*Cliestocalyx aperculatus* Merr.& Perry	Myrtaceae					
44		*Syzygium grande* (Wight) Walp. var *grande*	Myrtaceae	11.00	0.21	0.05	7.37	0.40
45		*Piper* sp	Piperaceae	10.00	0.05	0.01	5.10	0.52
46		*Prunus javanica* (Teijam.&Binn) Miq.	Rosaceae	8.00	19.41	0.93	2.22	0.42
47		*Aidia cochinchinensis* Lour.	Rubiaceae	28.00	0.35	0.10	10.58	2.98
48	กระทุ่ม	*Neolamarkia cadamba* (Roxb) Bosser.	Rubiaceae	18.00	33.43	4.37	42.76	6.56
49	เถาງูเห่า	*Toddalia asiatica* Lamk.	Rutaceae	5.00	12.78	0.69	1.31	0.04
50	เงาะป่า	*Nephelium mellifurum* Gagnep.	Sapindaceae	15.00	22.49	2.10	35.93	3.42
51		*Eberhardtia tokinensis* H. Lec.	Sapotaceae	20.00	9.50	1.52	24.25	3.54
52		*Aphananthe cuspidata* (Bl.) Planch	Ulmaceae					
53	ขี้หนอนควาย	*Gironniera nervosa* Planch.	Ulmaceae	20.00	0.55	0.13	96.73	10.97
54	องุ่นป่า	*Tetrastigma laotica*	Vitaceae	20.00	3.63	1.29	20.38	1.59
55		Unk01	Annonaceae	2.00	3.12	1.89	19.75	6.01
56		Unk 02	Annonaceae	2.00	3.12	1.89	19.75	6.01
57		Unk03		3.00	5.81	1.30	24.63	1.68
58		Unk04		30.00	0.80	0.27	12.58	1.99
59		Unk05						
60		Unk 06						

Appendix 3 (Cont.)

No.	**Thai name**	**Species**	**Family**	**Total**	**Fresh fruit**			
				Number	**Everage weight (g.)**	**Std.**	**size (mm.)**	**Std.**
61		Unk 07		3.00	0.06	0.21	60.97	11.36
62		Unk. 08						
63		Unk. 09						
64		Unk. 10						

Appendix 4. Food habits in some primate species (Jolly, 1992)

Primate	Fruit	Leaves	Insects	Other
Prosimians				
Lorisiformes				
Lorisidae				
Slender loris	*		*	
Slow loris	*		*	
potto	*		*	Birds
golden potto	*		*	
bushbaby				
thicktailed	*		*	
Senegal	*		*	
needle - clawed			*	Resins
Tarsiiformes	*			
tarsier			*	
Lemuriformes				
Lemuridae				
mouse lemur	*		*	
lepilemur	*	*		
hapalemur	*	*		Bamboo
Indriidae				
indri	*	*		
sifaka	*	*		
avahi	*	*		
Daubentoniidae				
aye-aye	*		*	

Appendix 4 (Continued)

Primates	Fruits	Leaves	Insects	other
Ceboidea				
Cebidae				
night monkey	*		*	
titi	*		*	
howler	*	*		
spider	*			
cebus	*		*	
squirrel	*		*	
wooly	*		*	
Cercopithecoidea				
Cercopithecidae				
macaque	*			
mangabey	*			
baboon	*	*	*	Grass, meat
gelada	*	*	*	Grass, Bulbs
guenon	*		*	(see below+)
talapoin	*		*	
patas	*	*	*	Grass, Lizards
Colobinae				
langur	*	*		
colobus	*	*		
Hominoidea				
Hylobatidae				
gibbons	*	*	*	

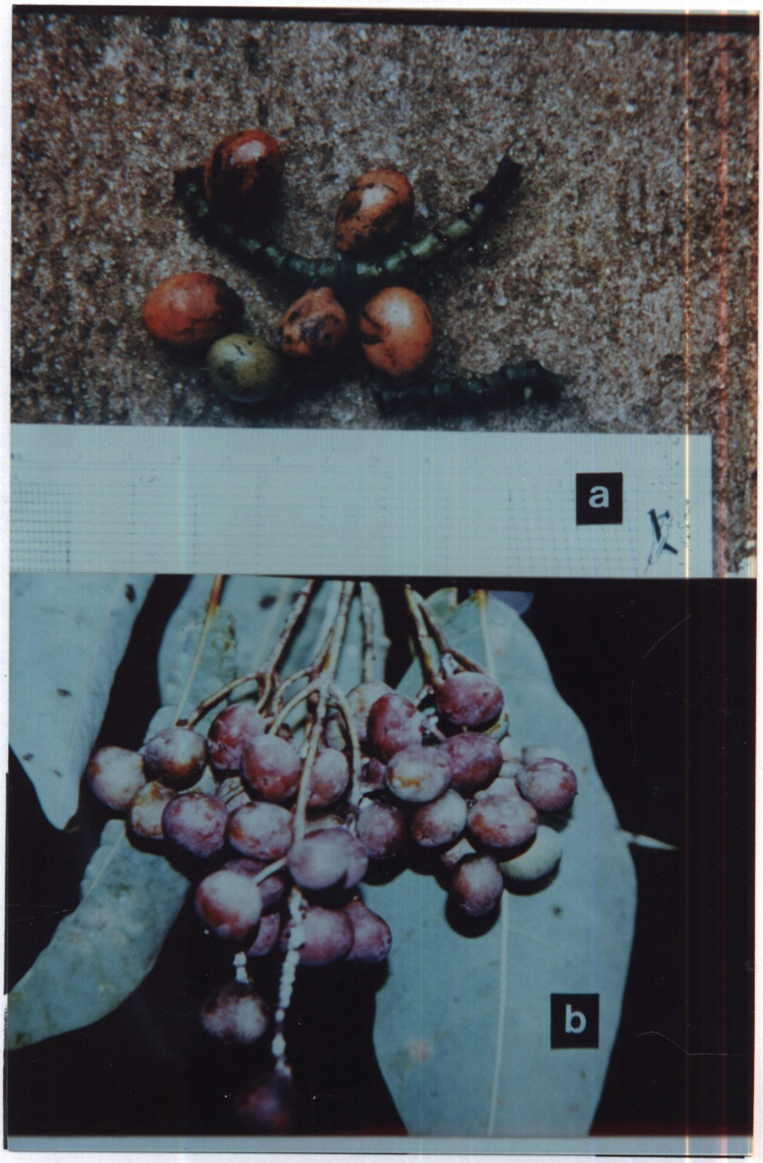
+ Vervets eat eggs and chickens, Lowe's guenons eat flowers

Appendix 4 (Continued)

Primate	Fruits	Leaves	Insects	Other
Pongidae				
orangutan	*			
Hominoidea				
gorilla	*	*		
Chimpanzee	*		*	Occasionally meat
man	*	*	*	Frequently Meat

* is a rough measure of significance data on category of food (Jolly, 1972)

Appendix 5 Photographs of fruit eaten by gibbons



Appendix 5.1 Photographs of fruit eaten by gibbons

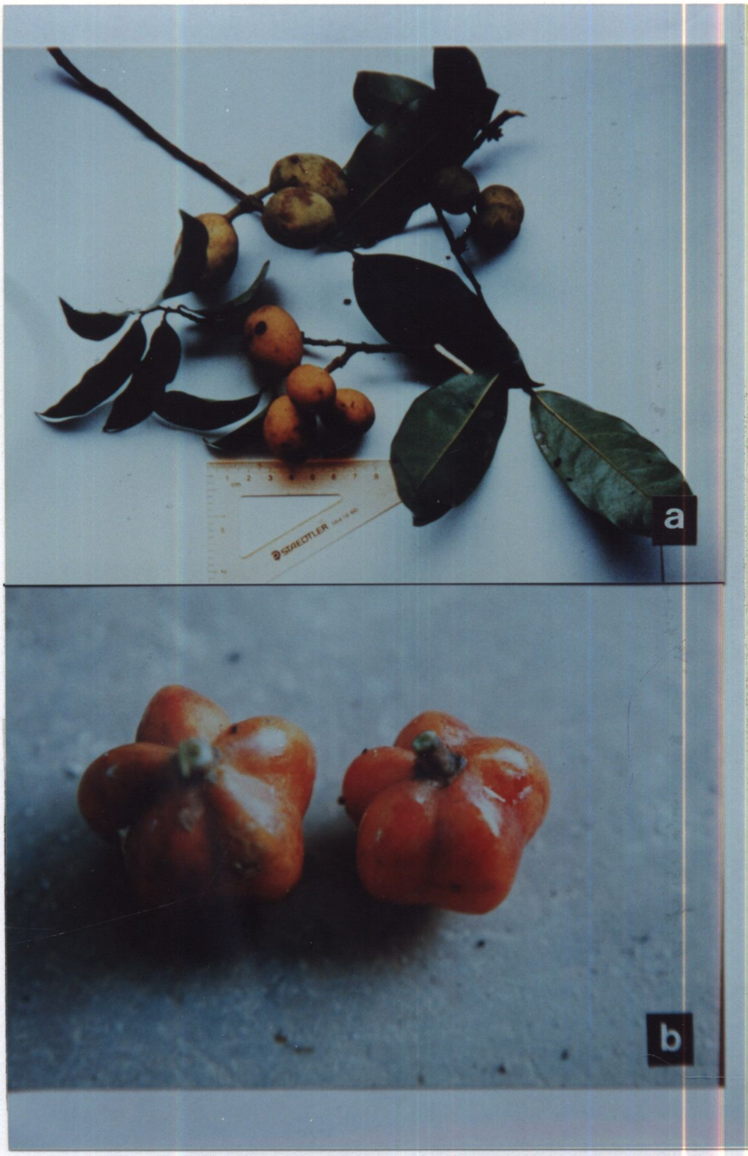
a. *Gnetum montanum* b. *Balakata baccatum*

Appendix 5.2 Photographs of fruit eaten by gibbons

a. *Ficus hirsuta* b. *Salacia macrophylla*

Appendix 5.3 Photographs of fruit eaten by gibbons

a. *Neolamarkia cadamba* b. *Sandoricum koetjape*

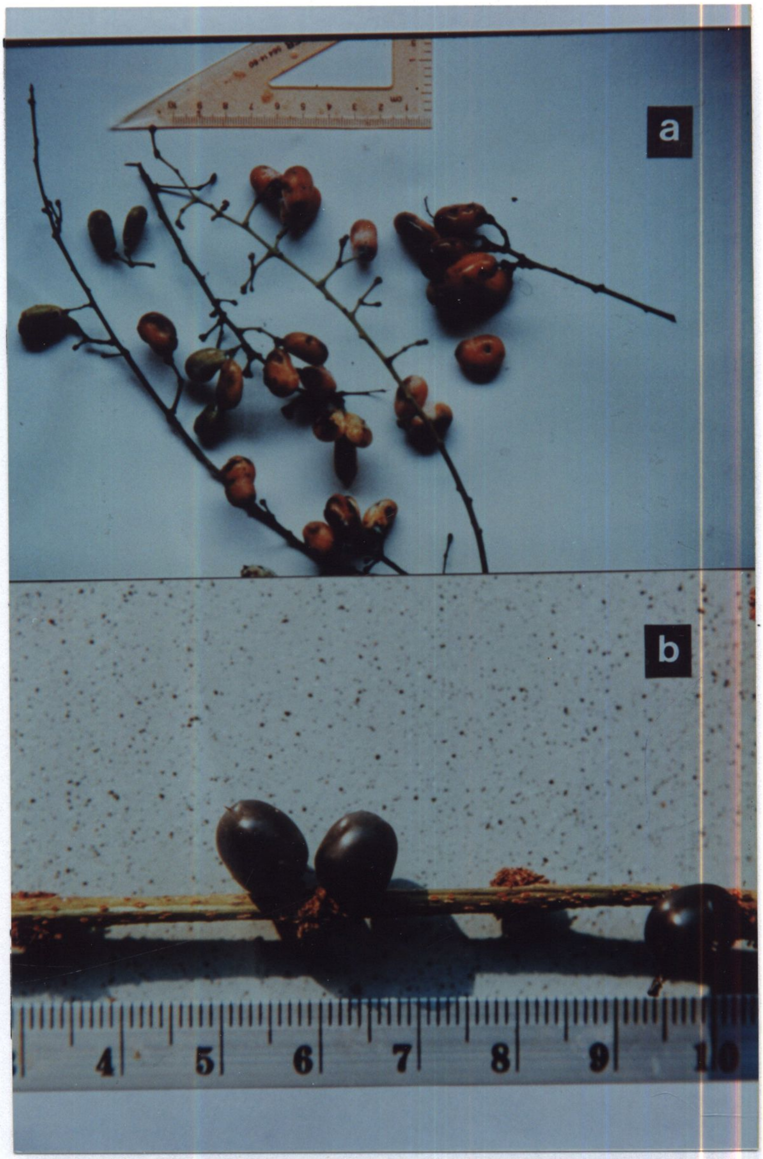


Appendix 5.4 Photographs of fruit eaten by gibbons

a. *Alphonsea boniana* b. *Eberhardtia tonkinensis*

Appendix 5.5 Photographs of fruit eaten by gibbons

a. *Prunus javanicus* b. *Choerospondias axillaris*



Appendix 5.6 Photographs of fruit eaten by gibbons

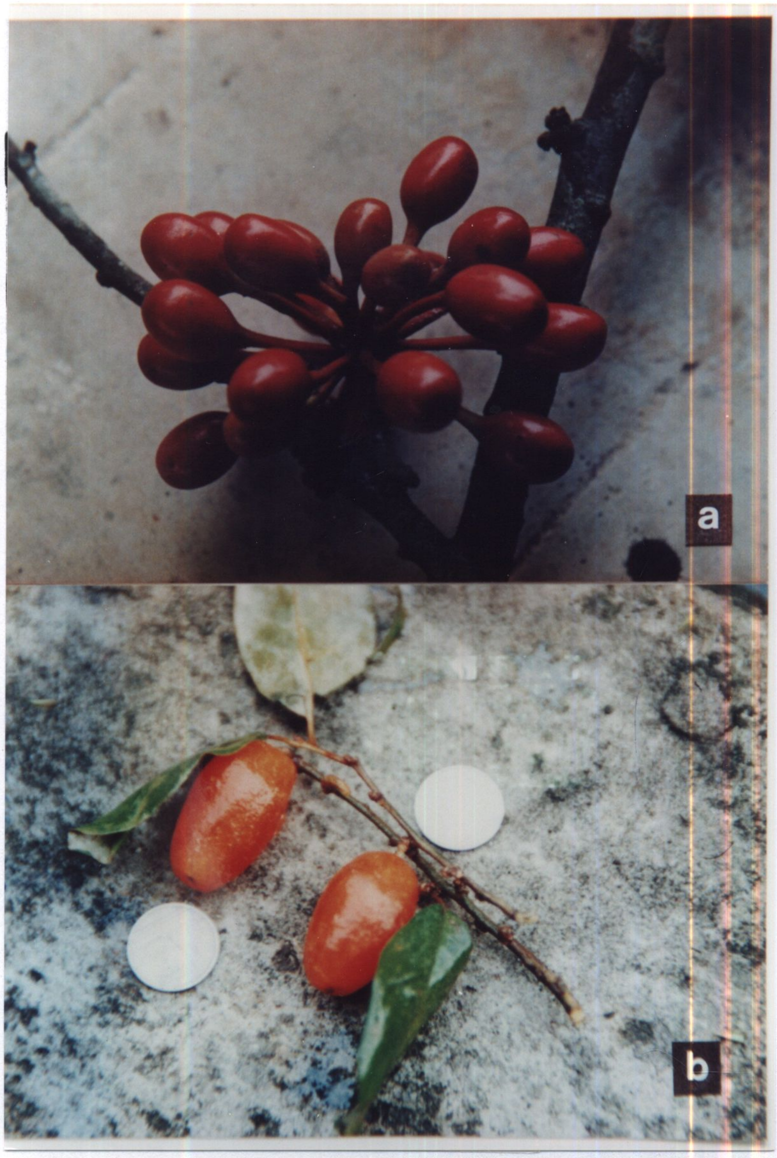
a. *Diploclisia glaucescens* b. *Bridelia tomentosa*

Appendix 5.7 Photographs of fruit eaten by gibbons

a. *Cleistocalyx operculatus* b. *Piper* sp.

Appendix 5.8 Photographs of *Ficus* spp. which were consumed by gibbons

a. *Ficus* sp. 04 b. *Ficus* sp. 12

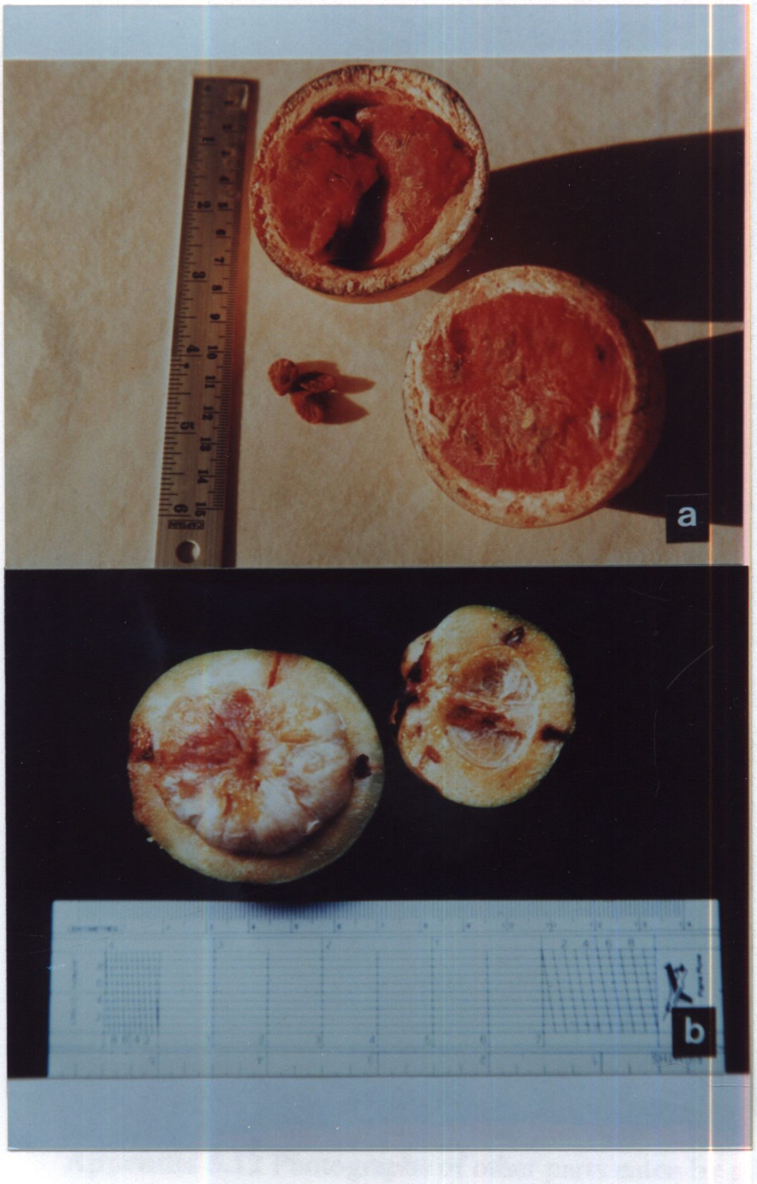


Appendix 5.9 Photographs of fruit eaten by gibbons

a. *Polyalthia viridis* b. *Elaeagnus latifolia*

Appendix 5.10 Photographs of fruit eaten by gibbons

a. *Knema laurina* b. *Walsura robusta*



Appendix 5.11 Photographs of fruit eaten by gibbons

a. *Melodionus cambodiesis* b. *Garcinia xanthochymus*

Appendix 5.12 Photographs of other parts eaten by gibbons

a. young shoot of *Philodendron*

b. leaves of *Acacia pennata*

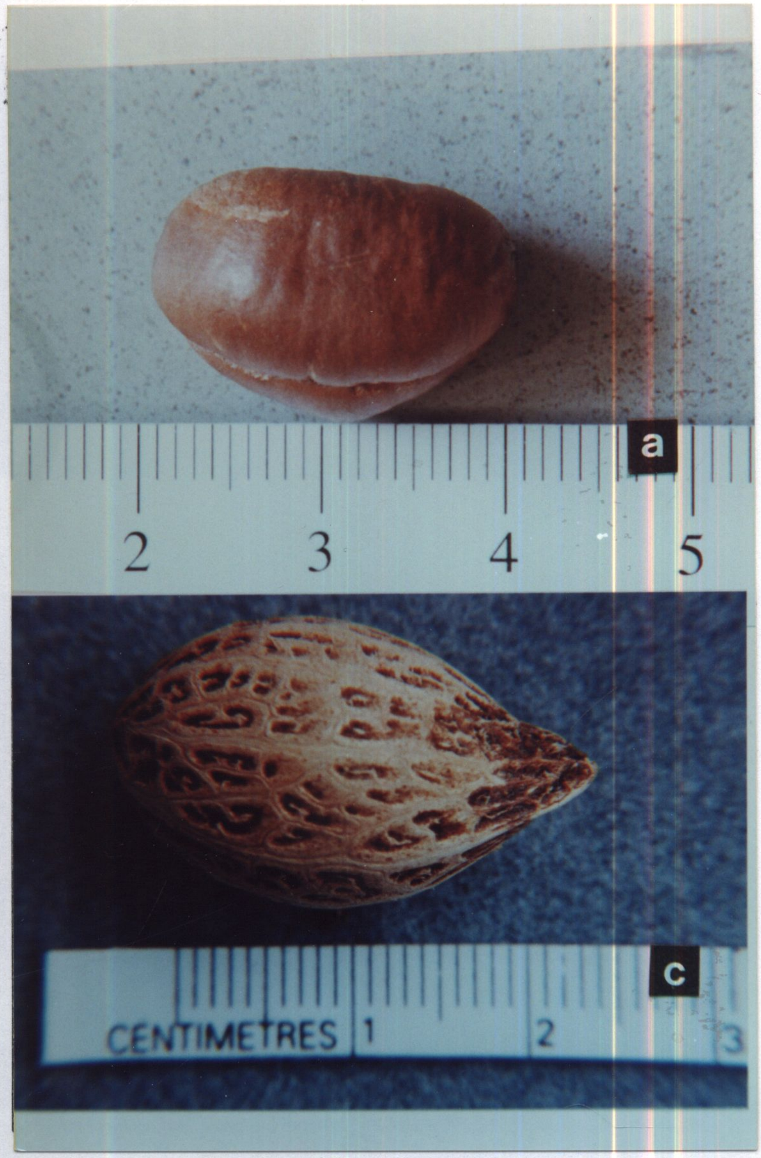
c. spadix and spathe of *Rhapidophora*

Appendix 6 Photograph of seeds collected from feces

Appendix 6.1 Photograph of seeds collected from feces

a. *Nephelium melliferum* b. *Elaeagnus latifolia*

c. *Choerospondias axillaris* d. *Sandoricum koetjape*

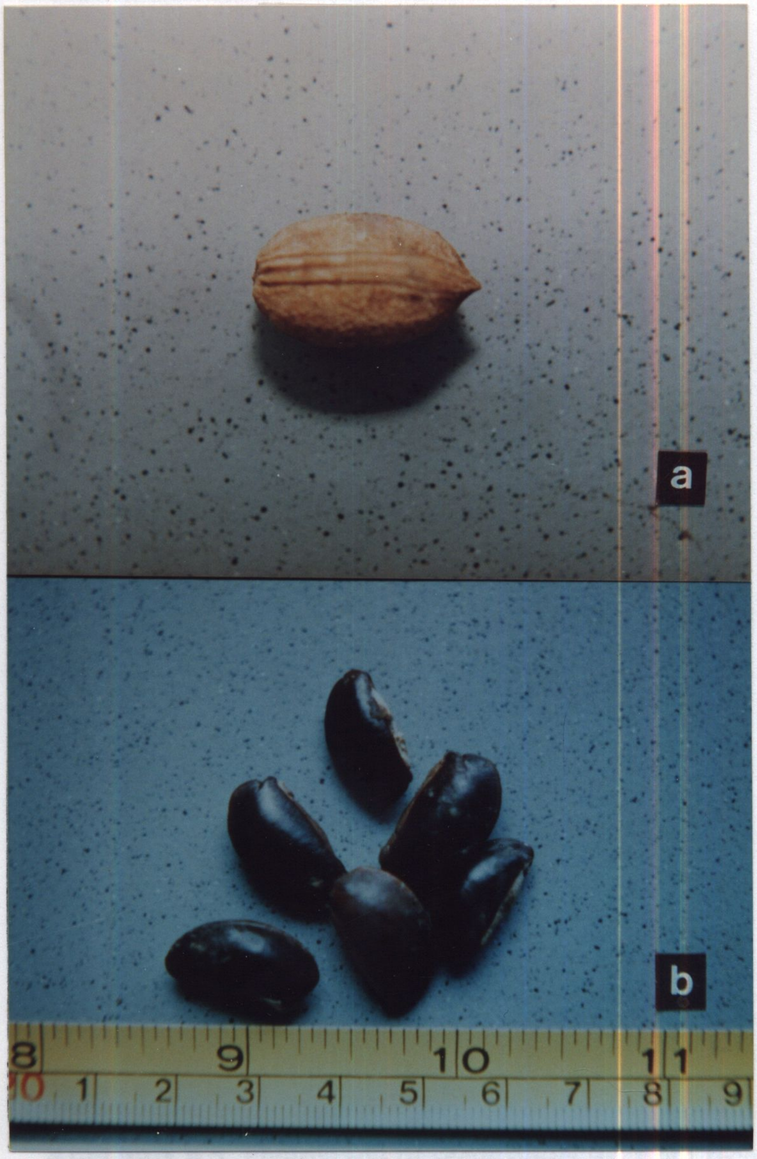


Appendix 6.2 Photograph of seeds collected from feces

a. *Polyalthia viridis* b. *Platea latifolia*

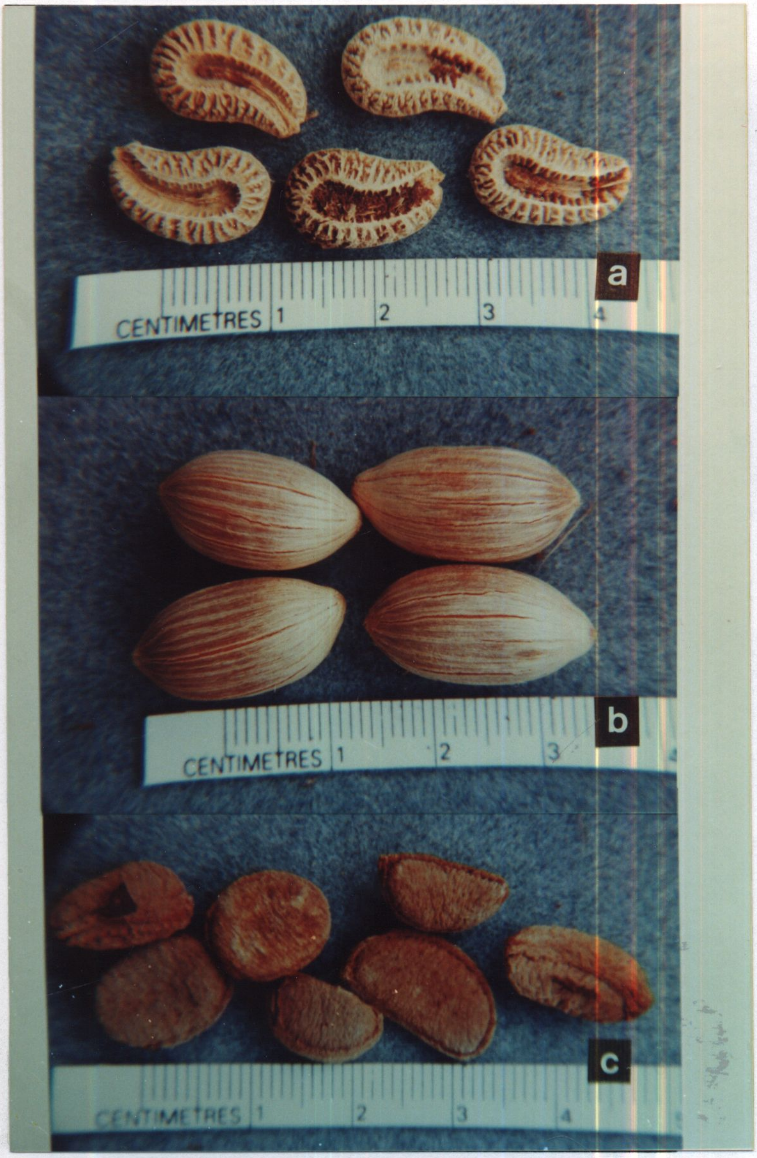
Appendix 6.3 Photograph of seeds collected from feces

a. *Knema laurina* b. *Garcinia xanthochymus*



Appendix 6.4 Photograph of seeds collected from feces

a. *Prunus javanicus* b. *Eberhardtia tonkinensis*



Appendix 6.5 Photograph of seeds collected from feces

a. *Diploclisia glaucescens*

b. *Gnetum montanum*

c. *Alphonsea boniana*

Appendix 6.6 Photograph of seeds collected from feces

a. *Diospyros glandulosa* b. *Walsura robusta*

Appendix 6.7 Photograph of seed collected from feces

a. *Toddalia asiatica* b. *Desmos chinensis*

Appendix 6.8 Photograph of seed collected from feces

a. *Baccaurea ramiflora*

b.*Cleistocalyx operculatus*

c. *Balakata baccatum*

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Appendix 6.9 Photograph of seed collected from feces

a-b *Ficus* sp. c. *Neolamarkia cadamba*

BIOGRAPHY

NAME	Miss Chuti-on Kanwatanakid
DATE OF BIRTH	16 September 1973
PLACE OF BIRTH	Nakorn Sri Thammarach, Thailand
INSTITUTIONS ATTEND	Prince of Songkhla University, 1992-1995 Bachelor of Science (Biology) Master of Science (Environmental Biology)
RESEARCH GRANT	Biodiversity Research Training (BRT) in the year 1996-1997. Grant of Graduated Studies (1998)