The number of food plants, which the gibbons consumed in my research, was less than in the research of Muangkhum (2001) in Huai Kha Khaeng Wildlife Sanctuary. She found the gibbons consumed 32 species, 30 genera and 19 families of food plants in the dry evergreen forest. In addition, most of food plants were in the F. Annonaceae. This difference in the different amount of food plant species in the different places might be due to the different forest structure and different species of trees composition in the respective places. To test this idea it would be necessary to directly compare the food choice and the habitat characteristics of the different gibbon groups.

Judging from the items, which were used, the white-handed gibbons mainly ate plant parts. In my observations of G1, I saw them utilize many different plant parts namely ripe fruits, unripe fruits, young leaves, flowers, and shoots, with different percentages (Figure 13). Of the plant parts which the white-handed gibbons ate, ripe fruits made up the highest percentage with 42% (in the dry season 19% and the wet season 23%); this included fruits such as Sai (*Ficus* sp), Sai Krang (*Ficus altissima* Blume), Ma Faen (*Protium serratum* Engl.) and Po Khi Haet (*Miliusa lineata* (Craib)Aiston) (Figure 14). This was followed by unripe fruits at 16% (in the dry season 6% and the wet season 10%) from species such as Mao (*Syzygium grande* (Wight)Walp.), Kam Yan (*Styrax benzoides* Craib) (Figure 15). The third category of food items was young leaves with 22% (in the dry season 13% and the wet season 9%). Such items came from plants such as many climbers, Sai (*Ficus* sp), Ko Riap (*Quercus glabricupula* Barrett.). Flowers made up 6% from species such as Ko Riap (*Quercus glabricupula* Barrett.) and Kam Yan (*Styrax benzoides* Craib). Finally the gibbons also ate shoots with a percentage of 14% (in the dry season 6% and the wet season 8%), This category included many climbers and at least three unknown species of Sai (*Ficus* sp.).

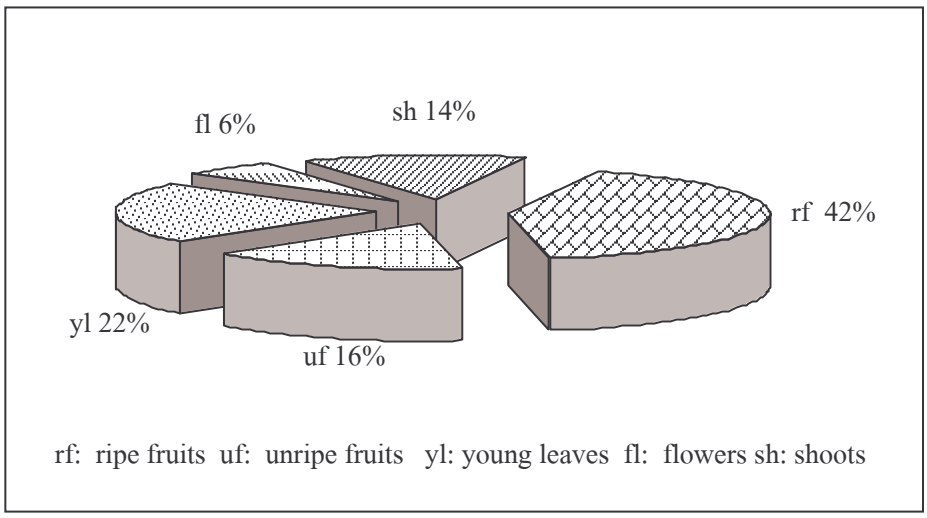

Figure 13 Percentage of plant part in the gibbon diet.

The use of the different plant parts by the gibbons clearly related to the phenology of the food plants. In the wet season most plants bear fruits and buds and, indeed, gibbons were mostly relying on fruits. As for dry season, many of the food plants are flowering, however, even though the gibbons would ate flowers, they relied more on young leaves in dry season. When comparing the percentage of plant parts in the two seasons, the white-handed gibbon consumed young leaves and flowers in the dry season more than in the wet season. In addition, the gibbons consumed ripe fruits, unripe fruits, and shoots in wet season more than in the dry season. This pattern is similar to Phayre's leaf monkeys in the same area (Koenig personal communication).

In general, these finding support the idea that white-handed gibbons are frugivorous. The parts most consumed by gibbons of this study were indeed fruits such as Ma Faen (*Protium serratum* Engl.) and Sai Yoi Bai Thu (*Ficus retusa* L. var. *retusa*) (58% ripe and unripe fruits together). However, compared to other study areas, the family G1 is at the lower end of frugivory. While in some populations the amount of fruits may be as low as 50% (Chivers, 1984; Ramaekers, 1984), in some of the more evergreen areas the percentage of fruits in the diet may be as high as 71% or even 80% (Napier and Napier, 1967; Palombit, 1997). This suggests that the seasonality as well as the primary productivity of an area affects the diet of white-handed gibbons. An additional factor, which might influence the diet, might be the number of competitors

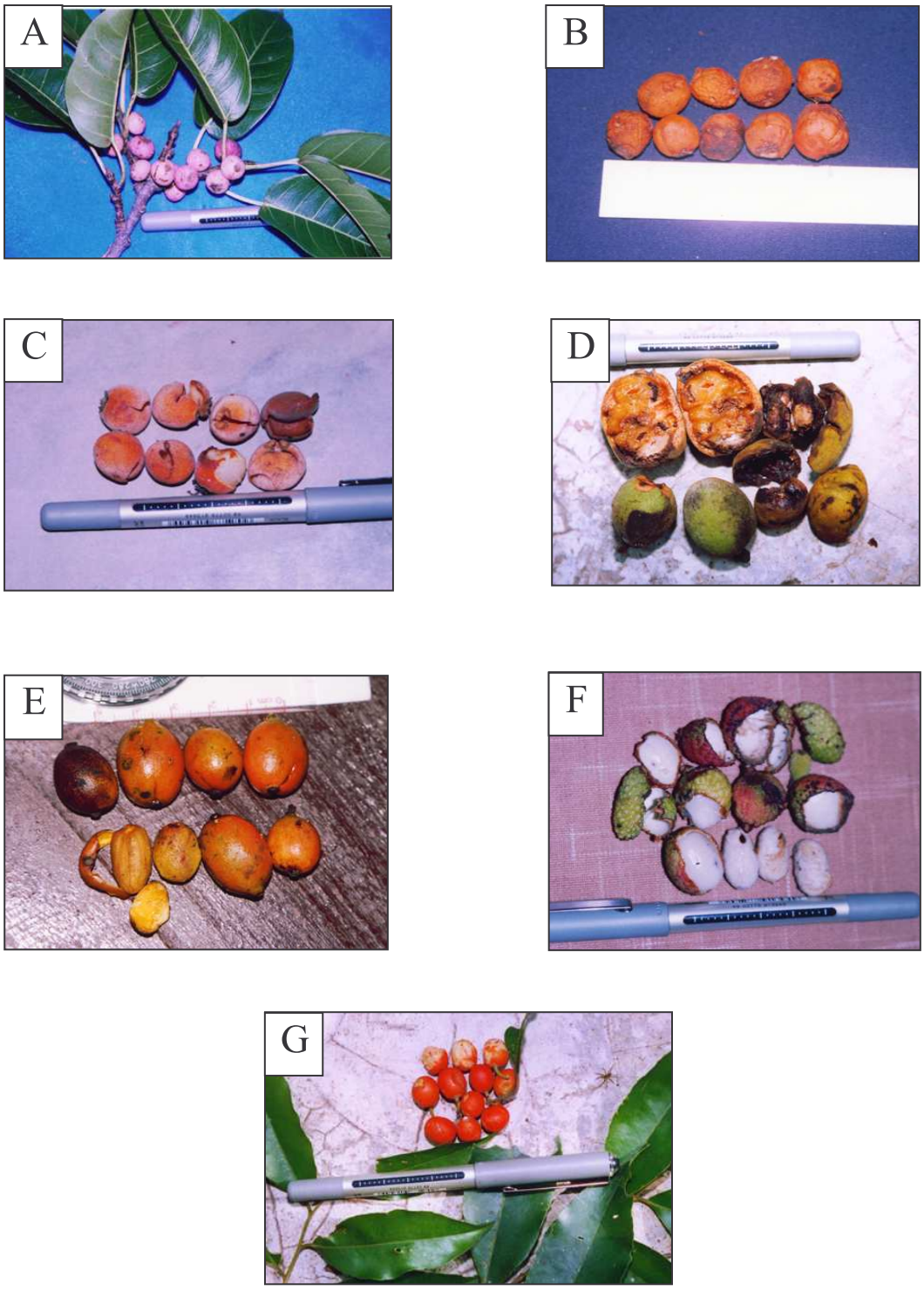

Figure 14 Some food plants of white-handed gibbons: A. *Ficus* sp., B. *Ficus altissima* Blume, C. *Protium serratum* Engl., D. *Miliusa lineata* (Craib)Aiston, E. *Garcinia succifolia* Kurz, F. *Nephelium hypoleucum* Kurz and G. *Drypetes hainanensis* Merr.

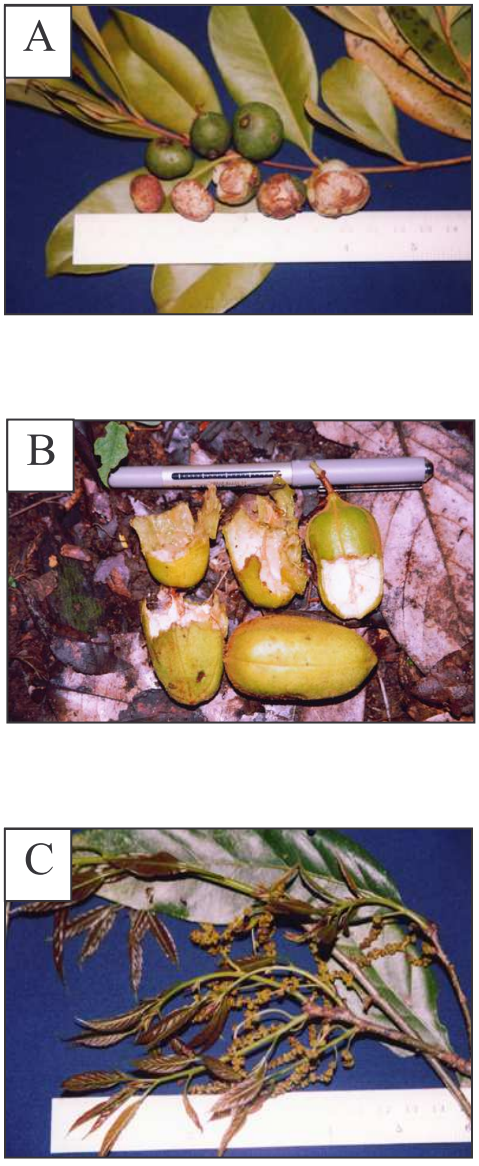

Figure 15 Some food plants of white-handed gibbons: A. *Syzygium grande* (Wight) Walp., B. *Styrax benzoides* Craib and C. *Quercus glabricupula* Barrett.

in an area. Because Phu Khieo Wildlife Sanctuary harbors an unusually high number of primates (6-7 at Huai Mai Sot Yai; Borries *et al.*, 2002) plus many birds and squirrels, gibbons may simply be forced to rely more on other parts than fruits.

1.5 Plant Community: There were three forest types in the study area namely dry evergreen forest (DEF), hill evergreen forest (HEF) and dipterocarp forest (DF). Studying the ecology and behavior of the white-handed gibbon, I found that they all concentratly used DEF and HEF. Following this finding, I established two sample plots in the forest types that the gibbons used (Figure 16). The structure of the DEF and HEF communities are shown in figure 17-18 and the plant names in table 4-5.

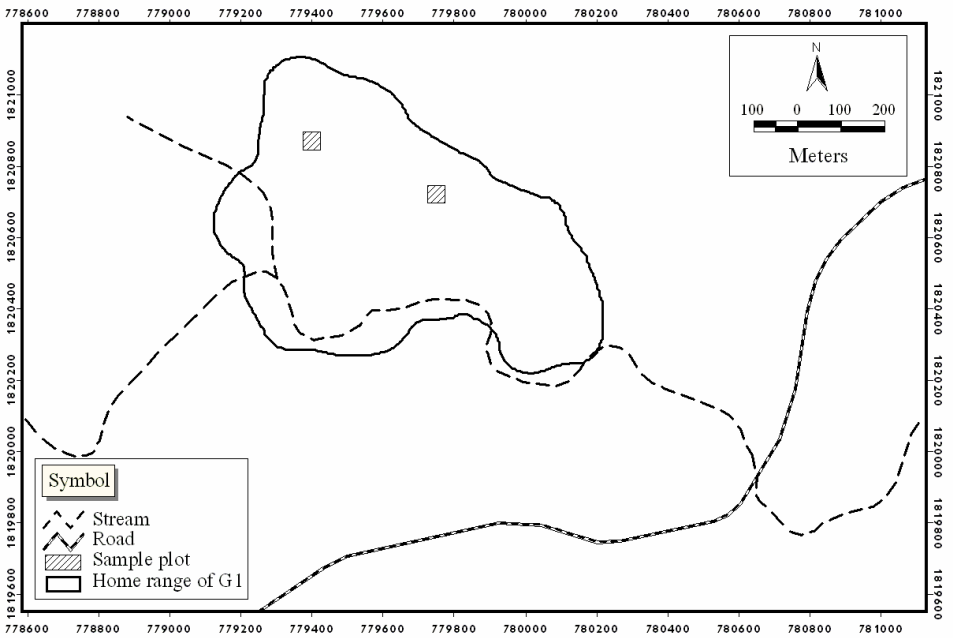

Figure 16 The locations of the sample plots in this study.

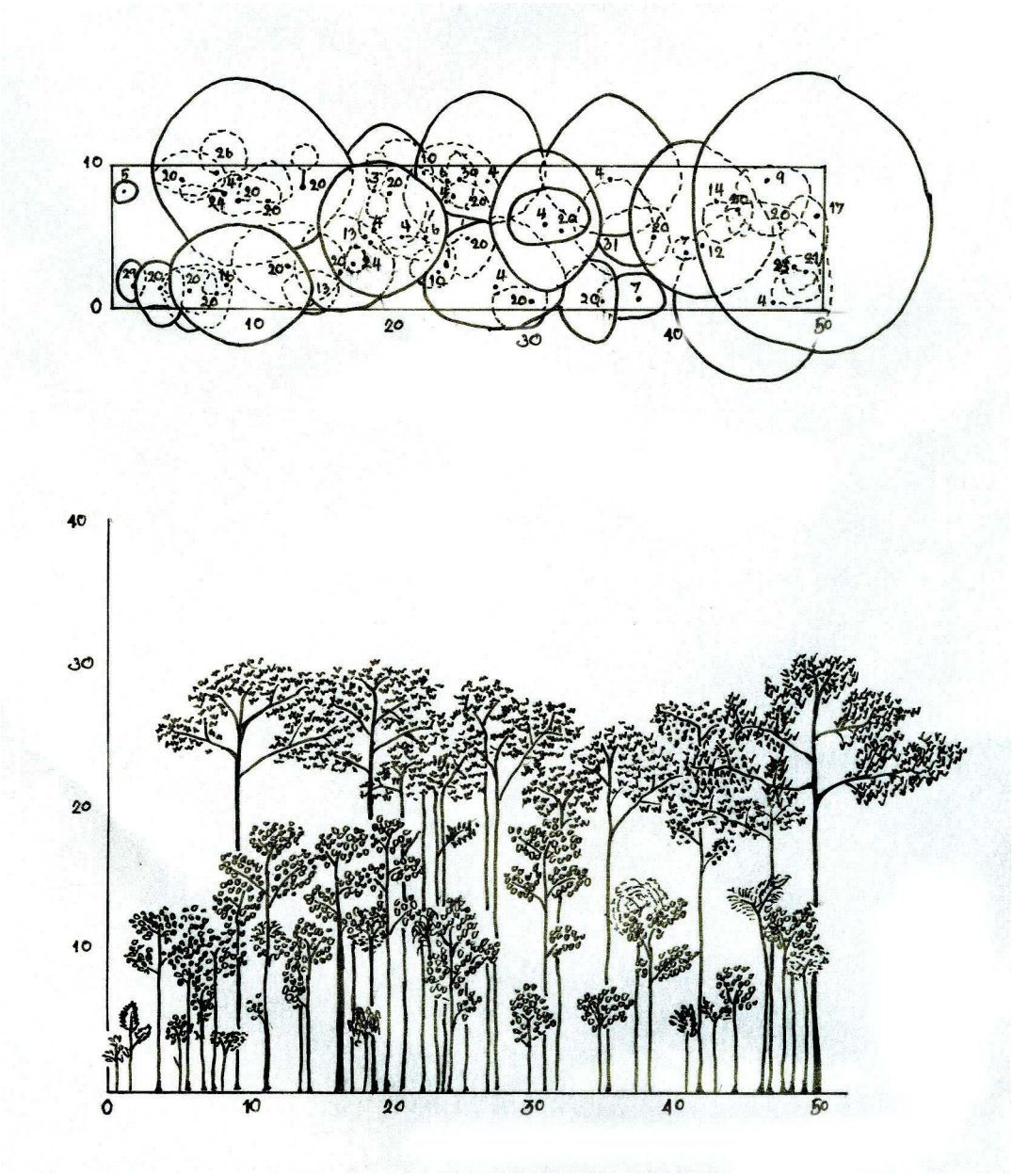

Figure 17 Profile diagram of dry evergreen forest in Huai Mai Sot Yai.

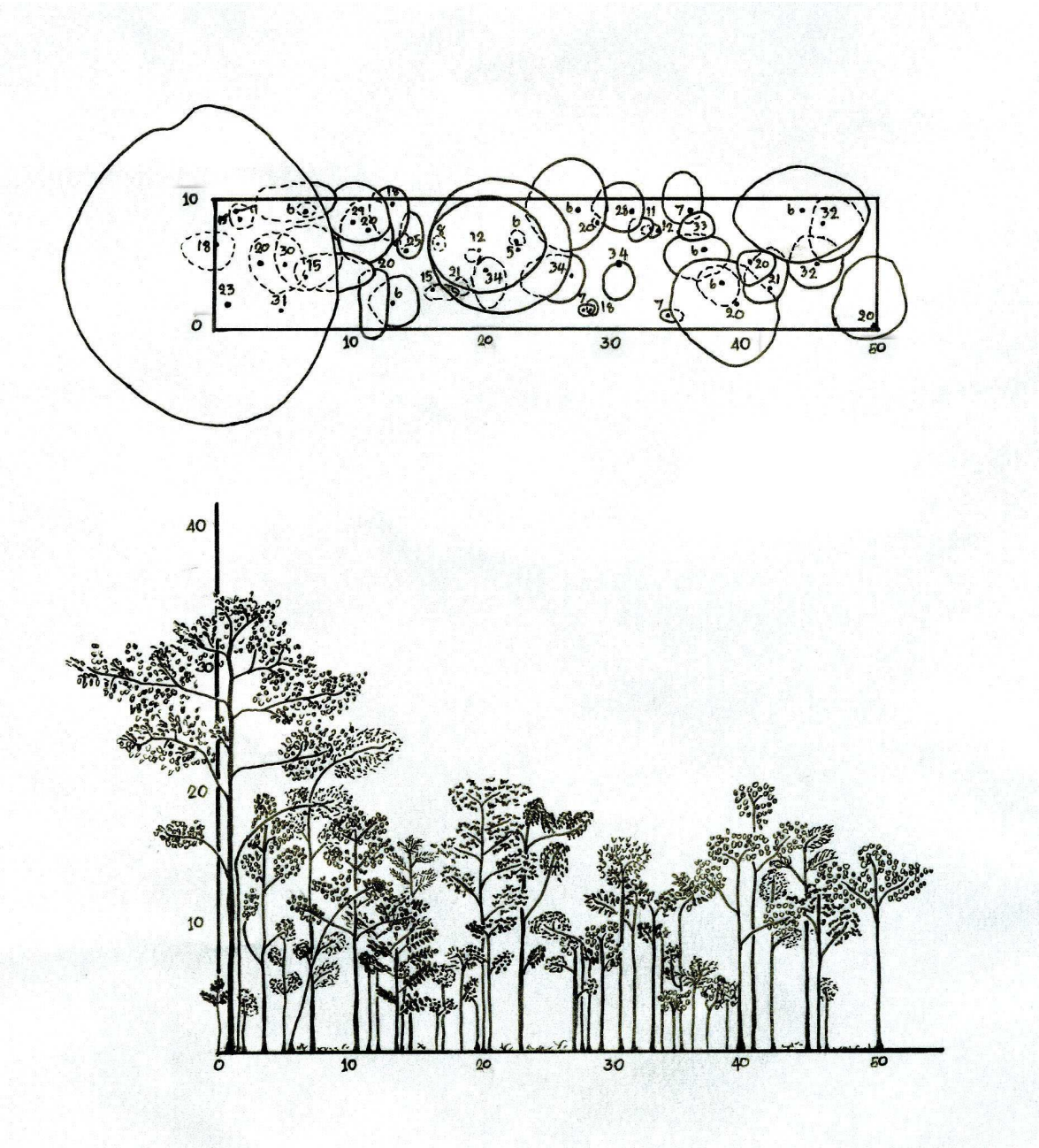

Figure 18 Profile diagram of hill evergreen forest in Huai Mai Sot Yai.

Table 4 List of trees in dry evergreen forest sample plot

ID	Scientific Name	Thai Name	Family
1	*Meiogyne hainanense* (Merr.)Ban	Sai Den	Annonaceae
2	*Mitrephora vandaeflora* Kurz	Ma Puan	
3	*Rhus succedarea* L.	Sadao Chang	Anocardiaceae
4	*Hopea ferrea* Laness.	Ta Khian Hin	Dipterocarpaceae
5	*Diospyros bejaudii* Lecomte	I Do	Ebenaceae
6	*Diospyros pilosula* (A.DC.) Hiern	Hang Nu	
7	*Diospyros rubra* Lecomte	Phaya Rak Dam	
8	*Antidesma thwaitesianum* Mull.Arg.	Mao Luang	Euphorbiaceae
9	*Aporosa nigricans* Hook.f.	Krom Khao	
10	*Quercus franchetii* Skan	Ko Pha	Fagaceae
11	*Garcinia thorelii* Pierre	Mada Khi Non	Guttiferae
12	*Dalbergia* sp.	-	Leguminosae-Papilionoideae
13	*Lagerstroemia duperreana* Pierre ex Gagnep.	Ta Baek Plueok Bang	Lythraceae
14	*Aglaia silvestris* (M.Roem.)Merr.	Chan Chamot	Meliaceae
15	*Dysaxykum hynanensis* var. *larberimum*	Lan Ngo	
16	*Walsura villosa* Wall.	Khi Ai	
17	*Ficus glabella* Blume var.*concinna* Miq.	Sai Krang	Moraceae
18	*Chionanthus microstigma* (Gagnep.)P.S.Green	Fin Ton	Oleaceae
19	*Chionanthus sutepensis* (Kurr) P.S.Green	Khao San Su Thep	
20	*Eriobotrya bengalensis* (Roxb.) Hook.f.forma *bengalensis*	Ta Krao Nam	Rosaceae
21	*Canthium glabrum* Blume	Khang Ten	Rubiaceae
22	*Canthium parvifolium* Roxb.	Nam Ma Khet	
23	*Canthium umbellatum* Wight	Wa Khi Kwang	
24	*Catunaregam longispina* (Roxb.ex Link) Tirveng	Khet Nam	
25	*Ixonanthes javanica* (Blume) DC.	Khem	
26	*Aeronychia pedunculata* (L.) Miq.	Kra Uam	Rutaceae
27	*Citrus maxima* (Burm.f.) Merr.	Som O Phi	
28	*Murraya paniculata* (L.) Jack	Kaeo	
29	*Dimocarpus longan* Lour. subsp.*longan* var.*longan*	Lam Yai Pa	Sapindaceae
30	*Celtis tetrandra* Roxb.	Mahat	Ulmaceae
31	*Ulmus lancaefolia* Roxb.ex.Wall.	Lop Lip	

Table 5 List of trees in hill evergreen forest sample plot

ID	Scientific Name	Thai Name	Family
1	*Meiogyne hainanense* (Merr.)Ban	Sai Den	Annonaceae
2	*Mitrephora vandaeflora* Kurz	Ma Puan	
3	*Xylopia malayana* Hook.f.&Thomsan	Krai	
4	*Radermachera* sp.	-	Bignoniaceae
5	*Diospyros bejaudii* Lecomte	I Do	Ebenaceae
6	*Diospyros pilosula* (A.DC.) Hiern	Hang Nu	
7	*Diospyros rubra* Lecomte	Phaya Rak Dam	
8	*Baccaurea ramiflora* Lour	Mafai	Euphorbiaceae
9	*Drypetes hainanensis* Merr.	Song Kra Dong Hin	
10	*Macaranga gigantea* (Rchb.f.&Zoll.) Mull.Arg.	Tao Luang	
11	*Mallotus philippensis* Mull.Arg.	Kham Saet	
12	*Quercus glabricupula* Barrett.	Ko Riap	Fagaceae
13	*Flacourtia rukam* Zoll.&Moritzi	Ta Khop Thai	Flacourtiaceae
14	*Garcinia thorelii* Pierre	Mada Khi Non	Guttiferae
15	*Apodytes dimidiata* E.Mey.ex Arn.	Mak Fak Dong	Icacinaceae
16	*Vitex quinata* (Lour.) F.N.Williams	Pha Sian Doi	Labiatae
17	*Neocinnamomum caudatum* Kosterm.	Chuang Hom	Lauraceae
18	*Phoebe paniculata* (Nees) Nees	Sa Thip	
19	*Michellia rajaniana* Craib	Champi Luang	Magnoliaceae
20	*Aglaia silvestris* (M.Roem.) Merr.	Chan Chamot	Meliaceae
21	*Chukrasia tabularis* A.Juss.	Yom Hin	
22	*Dysoxylum alliaceam* (Blume) Blume	Ta Suea	
23	*Ficus retus* L. var. *retusa*	Sai Yoi Bai Thu	Moraceae
24	*Ardisia* sp.	-	Myrsinaceae
25	*Syzygium claviflorum* (Roxb.)A.M.Cowan&Cowan	Wa Hin	Myrtaceae
26	*Chionanthus microstigma* (Gagnep.) P.S.Green	Fin Ton	Oleaceae
27	*Chionanthus sutepensis* (Kurr) P.S.Green	Khao San Su Thep	

Table 5 (Continued)

ID	Scientific Name	Thai Name	Family
28	*Stranvaesia nussia* (D.Don) Decne. var.*oblanceolata* Rehder&Wilson	Kritsana	Rosaceae
29	*Tarennoidea wallichii* (Hook.f.) Tirveng.&Sastre	Lek Ki	Rubiaceae
30	*Harpullia arborea* (Blanco) Radlk.	Hom Klai Dong	Sapindaceae
31	*Mischocarpus pentapetalus* (Roxb.) Radlk.	Pha-Bang	
32	*Pterospermum cinnamomeum* Kurz	Tong Tao	Sterculiaceae
33	*Pterospermum diversifolium* Blume	Lam Pang	
34	*Symplocos cochinchinensis laurina* (Retz.) Noot.	Mueat Luang	Symploeaceae
35	*Ulmus lancaefolia* Roxb.ex.Wall.	Lop Lip	Ulmaceae

1.5.1 Dry evergreen forest: The sample plot at Huai Mai Sot Yai area contained 31 species, 27 genera, 17 families of trees (see table 4). The common families found were F. Rubiaceae, especially Khang Ten (*Canthium glabrum* Blume), Nam Ma Khet (*Canthium parvifolium* Roxb.), and Wa Khi Kwang (*Canthium umbellatum* Wight). The second most frequently were F. Ebenaceae, Meliaceae and Rutaceae such as I Do (*Diospyros bejaudii* Lecomte), Khi Ai (*Walsura villosa* Wall.), and Som O Phi (*Citrus* sp.). The most common tree found within the sample plot is Ta Krao Nam (*Eriobotrya bengalensis* (Roxb.) Hook.f. forma *bengalensis*). The second most frequent were Ta Khian Hin (*Hopea ferrea* Laness.), Khlet Nam (*Catunaregam longispina* (Roxb.ex Link) Tirveng), and Wa Khi Kwang (*Canthium umbellatum* Wight).

Furthermore, comparing the inventory of the sample plots with the feeding behaviour of the gibbons I found that 6 species, 6 genera and 6 families of white-handed gibbon's food plants were present in the DEF sample plot namely Ma Puan (*Mitrephora vandaeflora* Kurz), Sai Krang (*Ficus glabella* Blume var.*concinna* Miq.), Lup Lip (*Ulmus lancaefolia* Roxb.ex.Wall.), Ta Khian

Hin (*Hopea ferrea* Laness.), Laen Ngo (*Dysoxylum hynanensis* var. *larberimum*) and Wa Khi Kwang (*Canthium umbellatum* Wight).

1.5.2 Hill evergreen forest: The sample plot in the study area contained 35 species, 31 genera and 22 families of trees (see table 5). The most common trees were the member of F. Euphorbiaceae such as Mafai (*Baccaurea ramiflora* Lour), Song Kradong Hin (*Drypetes hainanensis* Merr.), and Tao Luang (*Macaranga gigantea* (Rchb.f.&Zoll.) Mull. Arg.). The second most common trees are in F. Annonaceae, Ebennaceae and Meliaceae such as Sai Den (*Meiogyne hainanense* (Merr.) Ban), Phaya Rak Dam (*Diospyros rubra* Lecomte) and Yom Hin (*Chukrasia tabularis* A. Juss.). The most common tree in the sample plot was Hang Nu (*Diospyros pilosula* (A. DC.) Hiern) and the second most common are Mak Fak Dong (*Apodytes dimidiata* E. Mey. ex Arn.) and Chan chamot (*Aglaia silvestris* (M. Roem.) Merr.).

Comparing the inventory to the gibbon's ecology, in HEF sample plot there were 5 species, 5 genera and 5 families which were identified as the white-handed gibbon’s food plants such as Ma Puan (*Mitrephora vandaeflora* Kurz), Sai Yoi Bai Thu (*Ficus retus* L. var. *retusa*), Ko Riap (*Quercus glabricupula* Barrett.), Song Kradong Hin (*Drypetes hainanensis* Merr.) and Lob Lip (*Ulmus lancaefolia* Roxb.ex.Wall.).

Altogether, there were 10 species, 7 genera and 6 families of trees in both sample plots such as Fin Ton (*Chionanthus microstigma* (Gagnep.) P.S. Green), Khao San Su Thep (*Chionanthus sutepensis* (Kurr) P.S. Green), and Mada Khi Non (*Garcinia thorelii* Pierre). And, there were 2 species of white-handed gibbon’s food plants on both sample plots, namely Ma Puan (*Mitrephora vandaeflora* Kurz) and Lop Lip (*Ulmus lancaefolia* Roxb. ex. Wall.).

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2. Population Density

The density of white-handed gibbon groups in Huai Mai Sot Yai area was 2.51 families per km^2. There were 25 groups in Huai Mai Sot Yai area recorded with the auditory method and 26 gibbons' locations from transect surveyed in this study. The total study area was approximately 22 km^2 comprising of hill evergreen forest and dry evergreen forest (20.3 km^2). The mean number of individuals in a family group was 3.33 individuals (see above). When computing from the number of members in each family upon contact, the density of white-handed gibbons in Mai Sot Yai was 8.36 individuals per km^2.

Within the Mai Sot Yai area, primate densities were previously studied by Borries *et al.* (2002). They suggested that the density of the white-handed gibbon from line transect method was 2.6 groups per km^2 and 10 to 12 individuals per km^2, which is a little bit higher than my results despite the different methodology used by the two studies. The research of Borries *et al.* (2002) collected data via a line transect method, in which it is often difficult to see gibbons. In contrast, my research collected data by an auditory method, which is suggested to be more suitable to study gibbons (Brockelman, 2003; Srikosamatara, 1980). In addition to the very similar densities, the mean group size in this study was 3.33 individuals. This result corresponds very well to the results from research by Borries *et al.* (2002) in Phu Khieo Wildlife Sanctuary and to research by Bhumpakphan (1988) in Huai Kha Khaeng Wildlife Sanctuary. The result is also broadly similar to other areas with ca. 4 individuals per family (Borries *et al.,* 2002; Reichard, 2003). However, it contrasts rather strongly with the high density area of Khao Yai National Park with ca. 5 families per (Brockelman, 2003).

That this is indeed a population of low density is further supported by the results from the home range size of ca. 60 ha. In general, the results from the home range study and the population density match quite well. The density of white-handed gibbons was approximately 2.5 families per km^2. Assuming no overlap between home ranges of different families, it means that one family would use an area of 40 ha. This corresponds almost exactly to the 41 ha of the core area (overlapping dry season and wet season range) and the territory (excluding the overlap with

the neighbours' home ranges) of G1's family. Together with the data from Borries *et al.* (2002) this confirms the low density status of this area.

3. Habitat suitability map

3.1 Significant habitat factors: The relationship of potential habitat factors (independent variables) and gibbon location (dependent variable, n = 194) was defined by using GIS and logistic regression function model (forward stepwise method: LR). The results of this analysis are shown in table 6.

Table 6 Relative factors of the distribution of white-handed gibbon

Variable*	B	S.E.	Wald	df	Sig	R	Exp(B)
LU			15.5929	2	0.0004	0.2184	
LU 112	3.0794	1.3365	5.3092	1	0.0212	0.1167	21.7463
LU 113	0.5904	1.3931	0.1796	1	0.6717	0.000	1.8048
Distance to road	-0.0016	0.0005	10.0878	1	0.0015	-0.1824	0.9984
Distance to stream	-0.007	0.0015	21.5076	1	$3.52e^{-06}$	-0.2833	0.993
Percentage of slope	-0.3543	0.0765	21.4286	1	$3.68e^{-07}$	-0.2827	0.7017
DEM	0.0563	0.0107	27.8356	1	$1.32e^{-07}$	0.326	1.0579
Constant	-40.2298	7.8738	26.1052	1	$3.23e^{-07}$		

* LU. Land use, LU 112. Dry evergreen forest and LU 113. Hill evergreen forest.

When considering the relative factors of distribution of the white-handed gibbons throughout the whole year, the factors that influenced to the detection of gibbons and the habitat utilization by the gibbons were elevation (DEM), slope, the proximity to streams and the road and forest types. The relationship between the dependent factor (gibbon / Z) and those independent factors can be written in a multiple linear regression model as follow:

$$Z = -40.2298 + 0.0563(DEM) - 0.3543(Slope) - 0.007(Stream) - 0.0016(Road) + 0.5904(LU\ 113) + 3.0794(LU\ 112) \qquad (R^2 = 0.65)$$

This model used specific factors for Huai Mai Sot Yai area in that period only. This multiple linear regression model could explain 65 percent ($R^2 = 0.65$) of the relationship between distribution of the white-handed gibbons and their environmental factors in Huai Mai Sot Yai area. Each environmental factor had a different relation to the distribution of white-handed gibbons:

DEM: The DEM or digital elevation model takes into account the elevation of an area from mean sea level. The model showed that the probability of finding white-handed gibbons was higher in the high altitude areas. Because gibbons are arboreal mammals, it might be expected that DEM does not directly affect the distribution of gibbons. The gibbons move through the connectivity of the crown canopies. In addition, the study area is rather small and the different levels of elevation are not very high making it unlikely to expect an effect of altitude. However, in the analysis the DEM was part of the model. This may indicate that DEM is important, because it affects the growth of trees, which might be food plants of white-handed gibbons. However, the areas of higher elevation in the study area are often drier and more seasonal suggesting that gibbons should (if ever) avoid such areas. The impact of the DEM seems therefore related to other factors than food. One possible explanation is the nature of the data. Parts of the data are derived from the auditory method. Because gibbon's singing is often done at very high tree crowns or elevated points of their home range, is likely that these results reflect the preferred points of singing of the gibbons.

Percentage of slope: The model shows the probability to find white-handed gibbons was higher in flat areas or less steep areas. Slope might not affect the distribution of white-handed gibbons directly, because as an arboreal mammal their locomotion is not necessarily depending on the slope. However, it might affect the growth of food plants and hence foraging behavior. It is possible that most food plants are distributed in less steep areas, therefore gibbons might tend to forage in these particular areas.

Distance to stream: The model shows that the probability of finding white-handed gibbons was higher in the proximity of streams. Streams may be related to the distribution of white-handed gibbons in the form of distance to a water source. Even though in my study of the ecology of the white-handed gibbons at Huai Mai Sot Yai, the gibbons did not come down to streams to directly drink water, the distance to a water source may still be an important factor for two reasons. Often the gibbons were resting on trees near streams. This is a pattern that has also been observed in Phayre's leaf monkeys at Huai Mai Sot Yai (Koenig, personal communication). It is possible that such places are cooler particularly during the dry and hot season in spring. In addition, such areas may, because of the proximity to the water, have many food plants (i.e. Sai Yoi Bai Thu and Song Kradong Hin) and more abundant food.

Distance to road: The model showed that the probability of the white-handed gibbons was higher near roads. As shown through the relation model, gibbon distribution was affected by the road but this does not mean that a forest with many roads would be a suitable habitat for white-handed gibbons. Because the study area was rather small and containing the road to the southeast. In addition, there might be an additive effect, because the area of road was so flat and it has less slope that might potentially affect the gibbon’s distribution.

Vegetative covers or forest types: The model showed that the probability of white-handed gibbons was high in dry evergreen forest and hill evergreen forest. The two forest types were the strongest relative factor of the white-handed gibbon’s distribution. In my direct observations of the ecology of the white-handed gibbon at Huai Mai Sot Yai, they often moved to a particular food site, so that the distribution of gibbons likely follows the distribution of food sites. The study of the structure of the plant communities in the study area showed that food plants of the white-handed gibbons can be mostly found in dry evergreen forest (DEF) and hill evergreen forest (HEF), but there were none in the deciduous dipterocarp forest (DDF). Besides, the structure of DDF in Huai Mai Sot Yai study area was more open and lacked of connectivity canopies. This conformed to the relative model, which included DEF and HEF in the model.

To input relative value to logistic regression function model and to be analyzed by GIS,

$$P(x) = \frac{e^Z}{1+e^Z}$$

Table 7 Probability zoning of the white-handed gibbons in Huai Mai Sot Yai area

Probability scores	Levels	Area (km^2)	Percentage of area
0 - 0.1	less probable	9.76	44.43
0.1 - 0.6	moderate probable	5.99	27.26
0.6 - 1.0	most probable	6.22	28.31

The probability scores in table 7 are based on a classification based on natural breaks from the histogram of the distribution of the data (Appendix figure 1). These results from the zoning values of the probabilities of the gibbon's distribution at Huai Mai Sot Yai were classified into three probabilities namely mostly, moderate and less (Figure 19). From the study area, totally 22 km^2, the most probable zone covered 6.22 km^2, the moderate probability zone was 5.99 km^2 and the less probability zone was 9.76 km^2.

3.2 Verification: The percentage of accuracy of the probability distribution map was 78.79% for the whole year. In order to find this measure of accuracy, I overlaid 33 gibbons coordinates, which I had randomly selected from the field data (20% of all field data), on the probability distribution map. 26 of these 33 points were located in the most and medium probability distribution areas of the map.

In this study the number of observational points data was rather small. Therefore, I did not divide the data further into the dry season and the wet season. But if the number of available data would be suitable, it might be possible to explain the differences in habitat use of the white-handed gibbons in different seasons. In any case, this study is the first to analyze the gibbon's habitat suitability by a logistic regression function. This kind of study in itself is an important step

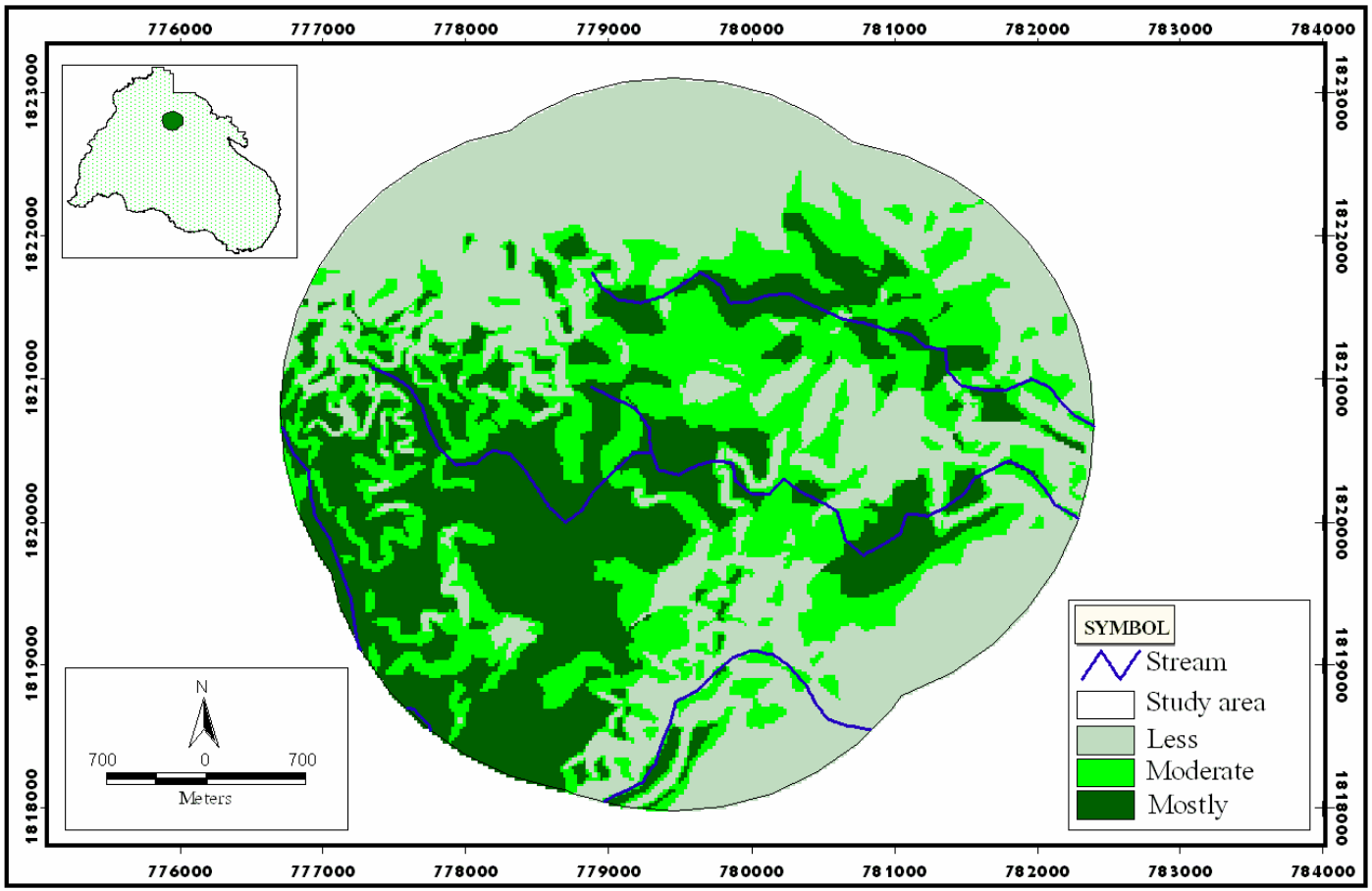

Figure 19 Probability distribution map of white-handed gibbons in Huai Mai Sot Yai.

for the study of white-handed gibbons in Thailand. Such a study can give important hints for the distribution of gibbons and the suitability of their habitat.

In any case this study is only a first step. It is very likely that not all factors important for the gibbons' distribution have been properly identified and incorporated. The factors presented here make for the most part intuitive sense. However, additional factors may be of equal or higher importance. For example, in the study of the gibbon's ecology it was shown that crown cover's density and the distribution of food plants may be important factors. But this study did not collect data on both of these factors, which might have affected the model. Incorporation of these factors could make the model more accurate and specific for the white-handed gibbons.

3.3 Estimation of population density from habitat suitability: Using the data derived from the habitat suitability, the white-handed gibbon's densities were 21.57 families in the study area. This translates into the densities or 1 family/km^2 or 3.33 individuals/km^2. For this analysis I used the data from the size of most probable zone in the habitat suitability analysis (6.22 km^2), the white-handed gibbon's home range (28.82 ha, 50% Kernel method) and the mean of the number of individuals in a family (3.33 individuals/family).

This density was lower than the white-handed gibbon density derived from the auditory method (2.51 families per km^2 and 8.19 individuals per km^2). Two possible explanations for this difference come to mind immediately. The analysis of the gibbon density from habitat suitability mapping incorporated the size of the gibbon's home range, while the auditory method does not. Similarly the auditory method treats all areas in the study site equally without taking into account that some areas might be less suitable. In both cases, the auditory method would overestimate the true density of gibbons. On the other hand, the area of the most probable zone, which was used in the analysis, was smaller than the area, which was used for the analysis via the auditory method. In addition, the most probable zone of the habitat suitability map does not represent a homogeneous area but is fragmented and smaller than a white-handed gibbon's entire home range. Thus, the density estimate via the habitat suitability map is likely to underestimate the true population density.

CONCLUSIONS

1. Ecology and Behavior

1.1 Family structure: During one-year study, the number of individuals in the G1's family varied between 3 to 5 individuals. There were 3 individuals that were observed all through out the year. They were composed of buff adult male, a black adult female and a black small juvenile. Two black sub-adults (male and female) were either expelled (female) or emigrated/ were lost (male) from the natal group. In addition, one black infant was born in this family during the course of the study. The size of the family and the demographic events observed in the course of the study match previous observations at other places, even though an actual expulsion of sub-adults has rarely been observed.

1.2 Behavior: The most common of the adults' behaviors were locomotion (28.53%) and feeding (25.32%). Similarly, most of the juveniles' behaviors were locomotion (35.04%) and feeding (33.96%). Furthermore, interesting behaviors of the adults' were vocalization behavior (9.00%) and aggression behavior (1.54%), which were more common in adults than in juveniles'. In addition, juveniles were playing quite often. In general, the activities of the gibbons is similar in other areas, but the study group showed an unusually high amount of traveling, which is probably due to their large home range and low food tree density.

1.3 Home Range: The home range of G1's family for over the whole year was 59.71 and 28.83 ha (95 and 50% Kernel method). The home range in dry season was bigger in size than the home range in the wet season. The overlapping seasonal home range of both seasons (core area) measured about 41 ha. There were 5 additional gibbon families, of which four had overlapping home ranges with G1's home range. Measuring G1's home range without the overlap of the neighbours' home ranges (G1's territory) revealed a figure of 41 ha. Regardless of the actual measure, the home range of this family is one of the largest ever measured for white-handed gibbons. It is likely that this large home range is the consequence of low food tree density and the strong seasonality of the habitat.

1.4 Food: White-handed gibbons were observed throughout the year at Huai Mai Sot Yai eating altogether 25 species, 22 genera and 16 families of plants and many types of climbers. They consumed more different food plants in the wet season than during dry season. The composition of the diet in terms of plant parts were as follows: ripe fruit 42%, unripe fruit 16%, young leaves 22%, flowers 6% and shoots 14%. In addition to many plants, white-handed gibbons ate small insects, which they picked up from leaves and branches. The diet matches the general diet of frugivorous gibbons in other areas. However, as expected for a rather seasonal environment the amount of fruits is lower than in the diet of gibbons in more evergreen forests.

1.5 Plant Community: The sample plot in the dry evergreen forest (DEF) contained 31 species, 27 genera and 18 families of trees. There were 6 species, 6 genera and 6 families of white-handed gibbon's food plants in the DEF sample plot. Furthermore, a hill evergreen forest (HEF) sample plot contained 35 species, 31 genera and 22 families of trees. In the HEF sample plot, there were 5 species, 5 genera and 5 families of white-handed gibbon's food plants. Moreover, comparing across plots there were 10 species, 7 genera and 6 families of trees, which occurred on both sample plots. In addition, there were 2 species of white-handed gibbon's food plants on both sample plots namely Ma Puan (*Mitrephora vandaeflora* Kurz) and Lop Lip (*Ulmus lancaefolia* Roxb.ex.Wall.).

2. Population Density

The density of white-handed gibbon groups at Huai Mai Sot Yai was estimated to be 2.51 families per km^2. The mean number of individuals in a family was 3.33. Thus, the density of white-handed gibbon in Mai Sot Yai is 8.36 individuals per km^2. These density values were similar to the density value by other researchers in similar environments (Borries *et.al*., 2002; Bhumpakphan, 1988), however, very much lower than in other areas such as Khao Yai National Park (Brockelman *et al.,* 1998). In addition, the density of gibbons (2.51 families per km^2) was matching very well with the size of the territory of white-handed gibbons in Huai Mai Sot Yai area. With a size of 41 ha for a territory approximately 2.5 groups should be present per km^2.

3. Habitat suitability map

The relative factors of distribution and selection of the areas used by white-handed gibbons were high elevation (DEM), lower slope, the distance to streams, the distance to the road and forest type. The model showed that the probability for white-handed gibbons was high for high altitude and flat areas, near streams and roads and in dry evergreen and hill evergreen forest. This multiple linear regression model could explain 65 percent (R^2 = 0.65) of the relationship between distribution of the white-handed gibbons and their environmental factors in Huai Mai Sot Yai area. The study area (22 km^2) entailed a most probable zone of 28.31% (6.22 km^2), a moderate probability zone of 27.26% (5.99 km^2) and a least probability zone of 44.43% (9.76 km^2). This probability distribution map had an accuracy of 78.79%. To predict the occurrence and distribution of white-handed gibbons more precisely, in the future factors such as crown cover and food tree distribution should be taken into account.

RECOMMENDATIONS

Gibbon's ecology and GIS technique

1. In this study one focal family of semi-habituated white-handed gibbon family was selected for direct observations through out the year. I selected a gibbon family, namely G1 which was found in the same study area of Dr. Andreas Koenig's research (Behavioral Ecology of Macaque and Langur Monkeys). In other words, this family was already used to observers in the forest. During my research, the gibbon family became even more habituated and direct observation became much easier. Therefore, for the study or direct observation of the ecology of gibbons or other primates, it is essential to start habituation early before the data collection.

2. The analysis of home ranges of wild animals can be done by several methods. This study used the Kernel method in order to determine the gibbon's home range. The benefit of this method is that it can define smooth boundaries and can fix the cover of percentage of data. If other methods will be used to analyze the home ranges of white-handed gibbons, one could compare each home range using different methods.

3. The plant community was studied using by sample plots (10 x 50 m^2) in two forest types (dry evergreen forest and hill evergreen forest), which were used by gibbons. In addition, another sample plot in deciduous dipterocarp forest, which was not used by gibbon, was selected to compare the structure of the plant community. The current analysis could already point out some differences between these plots and the use by the gibbons. When comparing all sample plot's structure, e.g. crown cover density, temperature and tree species in those forest, it is likely that one could explain the selection of the area used by white-handed gibbons in forest even better.

4. The population density in this research was studied at Huai Mai Sot Yai area, which covers a comparatively small area of the whole sanctuary. The main data for the analysis of population density was collected by the auditory method, which is a popular method for studying

gibbon density. This method is also useful for larger areas, however more listening posts should be added.

5. The white-handed gibbon is a small forest dwellers living almost entirely arboreal and with almost fixed home ranges. Thus, it is likely that the habitat factors may be different from those mammals, which are terrestrial. This analysis did a first step incorporating some seemingly important factors. But other environmental factors that directly related to gibbons such as density of crown cover and distribution of gibbon's food plants were not included in this analysis. Consequently, in future studies one should plan and find methods for measuring both factors and to incorporate these measures in the analysis of habitat suitability. In addition, several protected areas in Thailand have evidence of illegal hunting, which could be added as additional environmental factors in the analysis.

Future work

1. The white-handed gibbon is only one from 4 species of the gibbon, which is distributed range covered all over Thailand (Lekagul and McNeely, 1977). The distribution of gibbons should be surveyed in order to know the status of white-handed gibbon populations to support the protection of white-handed gibbon and other 11 species primates i.e. pileated gibbons, slow loris and rhesus macaque.

2. This study surveyed only a small portion of the area, which should be extended to a broader survey of white-handed gibbon in many representative areas in Phu Khieo Wildlife Sanctuary. This should be combined with the analysis of habitat suitability, in order to clearly explain the relation between environmental factors and the distribution of the white-handed gibbons. The results of such a survey and analysis could lead to a useful plan for the management of white-handed gibbons in Phu Khieo Wildlife Sanctuary.

3. The application of GIS for habitat analysis of wildlife is useful in planning and managing wildlife in each protected area. Therefore, we can apply use the results of such analysis

in planning and managing of protected areas in order to conform to the demand of particular wildlife in each protected area for more efficient management. For example, the results of such an analysis could be such that it pinpoints keystone resources i.e. saltlicks and water sources are so important to particular wildlife, this in turn could lead to the suitable management of these resources and to increase well protection overall saltlick and water area.

4. White-handed gibbons of this study were semi-habituated and studied only for one year. In order to know more about the dynamics of family structure, pair formation and social behaviors of white-handed gibbons it is necessary to habituate more families and to study many white-handed gibbon's families over the long term. The long term study of white-handed gibbons at Mo Singto in Khao Yai National Park (Brockelman *et al*., 1998) is an example. But it is clearly desirable that white-handed gibbon's studies will be conducted at other places in order to compare to see how difference of its ecology in particular area where has different environment factors.