ECOLOGY AND APPLICATION OF GIS FOR ANALYSIS OF THE WHITE-HANDED GIBBON (*Hylobates lar*) HABITAT AT PHU KHIEO WILDLIFE SANCTUARY, CHAIYAPHUM PROVINCE

INTRODUCTION

In the past, wildlife research mainly focused on the biology and ecology of individual species or the overall species diversity within a given area. Likewise, studies on white-handed gibbons in the wild and in captivity have to focus on their biology and ecology, especially some important behavioral characteristics, the relationships within a family or interspecific relationship with other primates, the size of home ranges, the types of food. However, given the current situation of habitat loss and habitat destruction the main scientific questions should be: "How large are the remaining wildlife populations?"; "Where is the wildlife still existing?"; and "Why do they live in particular areas?". Together with certain census and observation techniques, the Geography Information System (GIS) is a tool that might help to answer these questions. At present, GIS is often used as a tool in with various descriptive works, e.g. forest management, watershed management, and wildlife study. However, GIS can also be used to study the distribution of wildlife and to predict the risk of encroachment or poaching. Such wildlife studies were predominantly conducted on terrestrial mammals such as the elephant, tapir, gaur, banteng, sambar deer and many others.

Given a considerable lack of comparable studies of arboreal mammals, this study applied GIS for habitat analysis of the white-handed gibbons. Gibbons belong to a member of primates with dewelling and on trees canopies. This simple fact changes the environmental factors compared to other terrestrial mammals making such a study worthwhile. Thus, this study are focused on these three objactives:

1. To study the ecology and behavior of white-handed gibbons in terms of the family structure, home range and types of food.

2. To estimate the white-handed gibbon population density.

3. To apply GIS for the analysis of a white-handed gibbon's suitability map in the Huai Mai Sot Yai study area, Phu Khieo Wildlife Sanctuary.

Based on previous research on white-handed gibbons and the characteristics of the habitat in which this study was conducted (see study area) the following predictions can be made: i) Ecology and behavior: The previous studies have found little variation, the family structure should be similar to other areas. The study area is very seasonal, the gibbons should feed less on fruits and more on leaves than gibbons from less seasonal areas. The habitat has probably less food trees and the home range should be rather large. ii) Population density: Because of seasonality, few food trees, many different primate species and many other food competitors (e.g. hornbills, squirrels), the density of white-handed gibbons should be rather low. iii) GIS application: The gibbons should preferentially use areas with high tree species diversity and food production (near streams, in valleys etc.) and avoid areas with low food production or high disturbance (dry dipterocarp forest, road). The habitat suitability analysis should accurately predict the distribution of gibbons found during census. The population density calculated from the habitat suitability analysis should match the population density from the field census data.

LITERATURE REVIEW

Biology and Ecology of White-handed Gibbons

1. Taxonomy

The family Hylobatidae consists of 4 genera and 12 species (Lekagul and McNeely, 1977; Brandon-Jones *et al*., 2004). There are 4 species of gibbons found in Thailand namely white-handed gibbons (*Hylobates lar* (Linnaeus, 1771)), pileated gibbons (*H. pileated* Gray, 1861), agile gibbons (*H. agilis* Cuvier, 1821) and siamangs (*Symphalangus syndactylus* (Raffles, 1821)) (Treesucon and Tantithadapitak, 1977; Thong-aree, 2000; Parr, 2003). Taxonomically the species of white-handed gibbons has many synonyms; *Homo lar* Linnaeus, 1771; *Simia longimana* Schreber, 1774; *Pithecus variegates* Geoffroy, 1821; *Hylobates entelloidae* Geoffroy, 1842. The classification of the white-handed gibbon by Ankel-Simons (1983) and Brandon-Jones *et al*. (2004) is shown as follows:

Order Primates
Suborder Anthropoidae
Infraorder Catarrhini
Superfamily Hominoidae
Family Hylobatidae
Genus *Hylobates*
Species *Hylobates lar*

2. Distribution

All *Hylobates* species occur in Southeast Asian rain or deciduous forest both on the continent and on many islands (Ankel-Simon, 1983). *H. lar* is found in the Malay Peninsula (Chivers, 1972), Thailand (Borries *et al*., 2002), north Sumatra (Palombit, 1997), Tenasserim,

Burma east of the Salween River, North Laos west of the Mekong River and southwestern Yunnan (Lekagul and McNeely, 1977).

3. General Characteristics

Ankel-Simon (1983) points out that as in all the hominoids an external tail is absent in all *Hylobates* species. White-handed gibbons are dimorphic in color, with some individuals chocolate to nearly black and other individuals whitish to very light brown; the coloration is not related to age or sex, and the same color is maintained throughout the life of the animal (Brockelman 2004). In both color phases, the fur of back hands and feet are white and the naked black face is circled with a border of white hairs (Lekagul and McNeely, 1977).

4. Family Structure and Population Density

H. lar lives in monogamous family groups that consist of an adult pair and their offspring varying from 0-4 individuals. Female produces approximately one young every 2 years or 2.5 years. Bhumpakphan (1988) classified the offsprings into 4 categories; infant (0-2.5 years old), younger juvenile (25.-4.5 years old), older juvenile (4.5-6.5 years old) and sub-adult (6.5-8.5 years old; see also Brockelman *et al.,* 1998; Reichard, 2003). Infants still cling to her mother's body, while younger juvenile move on their own. Brokelman *et al.* (1998) suggested the age at birth of first offspring average 12.9 years for the males and was 9.75 years for female. The life span of the gibbon is about 30 years (Srikosamatara, 1980).

Population density of white-handed gibbons may vary widely. Borries *et al.* (2002) suggested that the density of white-handed gibbon at Phu Khieo Willdlife Sanctuary was 10 to 12 individuals per km^2 and 2.6 groups per km^2. In contrast, at Khao Yai National Park (NP) the density may be as high as 5 groups per km^2 (Brockelman *et al.* 1998). The mean group's size was estimated to range between three to four individuals at Phu Khieo Wildlife Sanctuary (WS) (Borries *et al.* 2002). Equally, Bhumpakphan (1988) suggested the mean group size was 3.3 individuals per group (range 2 to 6 individuals, n = 33) and groups with three individuals were

most common (30.5%). This is not very different from other areas such as Khao Yai NP, where an average group consists of approximately 4 individuals (n = 107; Reichard, 2003).

5. General Ecology

White-handed gibbons inhabit a wide range of various forest types with the only requirement being that there should be enough water and tall trees (Lekagul and McNeely, 1977). We can find white-handed gibbons in wealthy forest if there is continuous crown cover. The examples of forest types are dry evergreen forest, rain evergreen forest, hill evergreen forest and deciduous forest or mixed deciduous forest, which is not too dry (Bhumpakphan, 1988; Brockelman, 1975).

White-handed gibbons spend most of the day in tall trees, often sunning themselves on an exposed branch in the early morning, during the hotter parts of the day they are usually found at the lower, cooler levels. When alarmed, they may brachiate away at high speed or hide curled up in a ball among thick vegetation, in which situation they are quite difficult to spot (Lekagul and McNeely, 1977).

6. Home Range and Territory

Lekagul and McNeely (1977) suggested that gibbons in optimal habitats do not seem to expand to fill all suitable territory in the area, leaving some "in reserve". An exception can be seen, however in Khao Yai NP, where almost no vacant spaces are available (Brockelman *et al.,* 1998; Reichard, 2003). In addition the gibbons advertise their territories by characteristic loud wailing calls, heard wherever gibbons occur. Gibbons use these distance signals to locate the position of their neighbours so that they may then interact at the territorial boundary in an elaborate way (Ellefson, 1974).

Typically, the female begins the call and is joined by the male toward the end; the call of the male may continue after the great call of the female has ended, and each sex may call on its

own (Brockelman, 1975; Lekagul and McNeely, 1977; Bhumpakphan, 1988). Brockelman *et al*. (1974) said that the amount of morning vocalization in females seems related to the necessity for defending a territory. The territorial defense is a predominantly male activity. Ellefson (1968) suggested each gibbon-family live on a territory of between 15 and 50 ha. In addition, Chivers (1972) said white-handed gibbon's territories were 20 – 44 ha. Moreover, Muangkhum (2001) observed the home range of white-handed gibbons was 11.48 ha and 15.88 ha in dry evergreen forest of white-handed gibbons in mixed deciduous forest at Huai Kha Khaeng WS. And Reichard (2003) found that the average home range was 24 ha in the evergreen forest at Khao Yai NP. In contrast, Yimkao (2005) said that the home range of white-handed gibbons was 40 to 61 ha in deciduous forest at Mae Hong Son.

7. General Behavior

Gibbons are primates, which have many interesting behaviors or activities. Punnadee and Damiana (2004) investigated the behavior or activity period of white-handed gibbons at Khao Phra Theaw Non-hunting Area. They found the following subdivision of activities: Feed 37.9%, Rest 28%, Travel 22.4%, Social activity 5.7%, Calls 2.9% and Other behavior 3.1%. Additionally, the white-handed gibbons at Khao Yai NP divided their behavior in the following way (Bartlett, 1999): Feed 32%, Rest 27%, Travel 24%, Social activity 11% and Calls 4%.

7.1 Feeding: White-handed gibbons are foraging most of the day. Their feeding behavior usually consists of bouts ranging in duration from 5 minutes to 1.5 hour. The most commonly seen gibbon feeding pattern involves hanging from a terminal branch by one hand and arm, and picking or drawing the pieces of food with the other hand and bringing them to the mouth. Sometimes, one or both feet are utilized to steady or bend in the terminal branch being eaten. Feeding behavior includes plucking, putting into the mouth, chewing, shifting postures, movement around food source, looking for the next bit of food to pick, and resting for brief intervals. This basic feeding posture varies considerably depending on the character of the food source and the types of food being eaten (Ellefson, 1974; Muangkhum, 2001).

7.2 Drinking: Gibbons drink from bowls formed in the crotches of large trees, or where a large branch had broken from a tree trunk. At these drinking spots a gibbon dips a hand into the water and moves the hand quickly to its mouth by flexing the wrist and elbow and supinating. Water is taken from the dense hair on the back of the hand or phalanges with the lips and tongue (Ellefson, 1974). White-handed gibbons used their hand to drink 8-10 times per min. and spent 1-5 min. for one times. They drank 1-3 times per day in dry season but 1 times per day in wet season (Muangkhum, 2001).

7.3 Vocalization: One of the most distinctive and interesting features of gibbons is their vocal behavior, which all species of gibbons have. They have loud, far reaching melodic vocalizations that are correlated with establishing a territory as their own (Ankel-Simon, 1983). The vocalizations are clearly a substitute for fighting as a secondary means of inter-group social control. In addition the group call aids the defence of the boundaries of territory. Bhumpakphan (1988) reported that *H. lar* began calling when sunrise or enough lighted at 05:30 h but in rainy season they began calling at 06:00 h and 07:30 - 08:00 h in winter at Huai Kha Khaeng WS.

Brockelman *et al*. (1974) categorized the vocalization of white-handed gibbons into 3 types;

1) a very regular series of calls by the female; increasing and then decreasing in pitch and volume, of about 15 – 20 sec. in duration. (great call).

2) several hoots by the male immediately following the great call. Given around dawn by territorial males or by sub-adult males trying to attract potential mates (Brockelman, 2003).

3) hoots by both male and female, before or between repetitions of these rituals or duet call.

7.4 Grooming: Grooming is the cleaning of the body surface by licking, nibbling, picking with the fingers, or other kinds of manipulation. Gibbons pick off biting insects, clean insect webs from their fur, or clean the exudates of fruit husk from their hands. When the action is directed toward one’s own body, it is called self-grooming (autogrooming); when directed at

another individual, it is referred to as allogrooming. Apart from a hygienic function, it appears to function at least to some extent as a group bonding device (Ellefson, 1974; Srikosamatara, 1980).

7.5 Locomotion: Gibbons are extremely acrobatic and agile. They spend most of their life on the trees. They move by swinging gracefully from branches and vines; this is called "brachiation". When they brachiate, they use four fingers of their hands like a hook (but not the thumb). They swing from branch to branch (horizontally or vertically), with legs flexed under body; using arms alternately and keeping the hand bent in hook shape, and movements appear effortless. They are able to change direction even during fastest bounding by slightly touching a branch. Gibbons can also leap acrobatically across large gaps in the tree canopy from branch to branch. Brachiation comprises 90% of locomotor activity.

When on the ground or walking on larger tree branches, gibbons frequently progress bipedally, balancing the upright body with their long arms (Ankel-Simon, 1983).

8. Foods

White-handed gibbons are frugivorous. The parts most consumed by gibbons were fruits (80%) and other (20%) namely young leaves, flowers, insects, nestlings and eggs etc. (Napier and Napier, 1967). On average the gibbon diet contains at least 50% fruits (Chivers, 1984; Ramaekers, 1984). Fruit consumption usually varies with season and might drop to only 49 % (Chivers, 1984) or as high as 71 % of the diet (Palombit, 1997). Furthermore, at Khao Yai NP, the most food of white-handed gibbons came from trees (72%), but also from climber (26.6%) and sapling (2.1%) (Kanwatanakid, 2000). Moreover, Bhumpakphan (1988) suggested the most food came from trees 79.2%, shrubby trees 5.7% and climber 26.6% at Huay Kha Khaeng WS.

At Huay Kha Kaeng WS, there were 46 plant species, 45 genera, 23 families in the diet of white-handed gibbons in evergreen forest as discerned by direct observation and literature review; for instance fruits of Ficus (*Ficus* sp.), young leaves of Mamuang Pa (*Mangifera quadrifida* Jack), flower of Hom Klai Dong (*Harpullia arborea* (Blanco) Radlk. and fruits,

young leaves and flowers of Kuam (*Acer oblonggum* Wall. ex DC. (Muangkhum, 2001). At the evergreen forests in northern Sumatra white-handed gibbons used 57 species (Palombit, 1997).

9. Population Status and Threatened

Based on actual census work, Brockelman (1994) estimated the density of white-handed gibbons in many protected area in Thailand. He found that in the north at Doi Chiang Dao WS hill tribes had hunted out gibbon. In the northeast at Phu Luang WS the density was very low (1 group per km^2). In the west of Thailand at Kaeng Kha Chan NP the density of gibbons was 2.5 groups per km^2 in the core area. Finally, in the south of Thailand at Khlong Saeng WS the density was less than 2 groups per km^2.

Being large arboreal mammals, gibbons have few enemies and predators. The main predators are Leopard or Panther (*Panthera pardus* Linnaeus, 1758), Clouded Leopard (*Pardofelis nebulosa* Griffith, 1821), Crested Serpent-Eagle (*Spironis cheela* Latham, 1790) and Reticulated Python (*Phython reticulates* Schneider, 1801) (Lekagul and McNeely, 1977; Bhumpakphan, 1988; Muangkhum, 2001). Furthermore Srikosamatara (1980) found that the six pileated gibbons in Khao Soi Dao WS to be shot to death by "mai hom" (*Aquillaria crassna* Pierr ex Lecomte) collectors in January, March and July, 1979. In the past, gibbons were very threatened by hunters. Although at present, the hunting pressures are lower still the remains of gibbons are sometimes listed in the illegal hunting filing. White-handed gibbons are listed as vulnerable species in Thailand (Office of Environmental Policy and Planning, 1977) and lower risk (near threatened) at a global scale (IUCN, 2004).

Geographic Information System (GIS)

A Geographic Information System (GIS) is an efficient tool system designed for the collection of diverse data within databases. It is an organized collection of computer hardware, software, geographic data and personnel capable of input, storage, manipulation analysis and display of geographically-referenced information. GIS is useful in management planning and land-use decisions on a landscape scale (Nuanchawee and Wongpan, 1993).

1. The Components of GIS

The GIS has three components: computer hardware, sets of application software modules, and a proper organizational context (Burrough, 1986).

1.1 Computer Hardware: The computer hardware is the electric structure to support computer software. The general hardware components are a central processing unit (CPU), a disk drive storage unit, input devices, and display devices.

1.2 Computer Software: The software package for a geographical information system consists of five basic technical modules. These basic modules are sub-systems for data input and verification, data storage and database management, data output and presentation, data transformation, and interaction with the user.

1.3 GIS data: Geographical data are referenced to locations on the earth's surface by using a standard system of coordinates. There are two primary types of data that are used in GIS: spatial data and attribute data. Attribute data are linked in the GIS to spatial data that define the location. Spatial data are grouped into two different types: vector and raster. Vector representation - three main geographical entities points, lines and areas. Raster representation – set of cells located by coordinates.

2. Analysis Techniques

With GIS one can analyze events and predict various phenomenons by many different techniques. The type of analysis techniques includes overlay analysis, modeling, buffering and network analysis (Russell, 1992).

2.1 Overlay analysis: The ability to analyze spatial data separates true geographic information system from spatial database. Overlay analysis could create a new layer of information from two or more existing layers. In addition, this output can be combined with other information from the same or another data layer.

2.2 Modeling: In this technique, the user tries to simulate complex phenomena using a combination of spatial and nonspatial information. For example, in the predictive modeling statistical techniques (usually regression analysis) are used to build a model that will use spatial information to make predictions.

2.3 Buffering: Buffering is a technique by which a boundary of known width is drawn around a point or a linear feature. A linear buffer could delineate an area around a stream where logging is prohibited or around a utility line where digging is restricted.

2.4 Network analysis: In network or corridor analysis, a linear path is identified that represents the flow of some object through the area. Network analysis is especially useful in hydrology, transportation, and other disciplines that study the flow of an object.

3. Application of GIS for Wildlife Habitat Mapping

At present, many scientists are interested in GIS and are applying this technology for the analysis of wildlife habitats. Such analyses include for example GIS for the analysis of large mammal habitats in Taboh-Huai Yai WS (Chumsangsri, 2002), habitat utilization of the Malayan tapir (*Tapirus indicus*) in Khlong Saeng WS, Changwat Surat Thani (Thunhikorn, 2003), and the

application of GIS for the analysis of the elephant (*Elephas maximus* Linnaeus, 1758) distribution at Phu Khieo WS, Chaiyaphum Province (Vinitpornsawan, 2003). All research used logistic regression analysis to define wildlife habitat suitability. These techniques show the relationship between environmental factors and habitats of different wildlife.

Study area

The study site (Mai Sot Yai, 16°27′ N, 101°38′ E) is located at 600-800 m above mean sea level and comprises an area of about 3,000-4,000 ha of dry evergreen forest interspersed with patches of dry dipterocarp forest. The borders are set by the river Phrom to the east, a plateau mountain (Phu Khieo Noi) to the south and a rugged mountainous area to the west and north. The areas to the south, west, and north are dominated by hill evergreen forest. The area east of the river Phrom consists of dry evergreen forest, but due to earlier use, it is mainly a regenerating forest of low canopy height (less than 10 m.) with islands of primary forest stands. The whole area is bisected northeast to southwest) by a road that ends at the headquarters in the center of the sanctuary (Borries *et al.*, 2002).

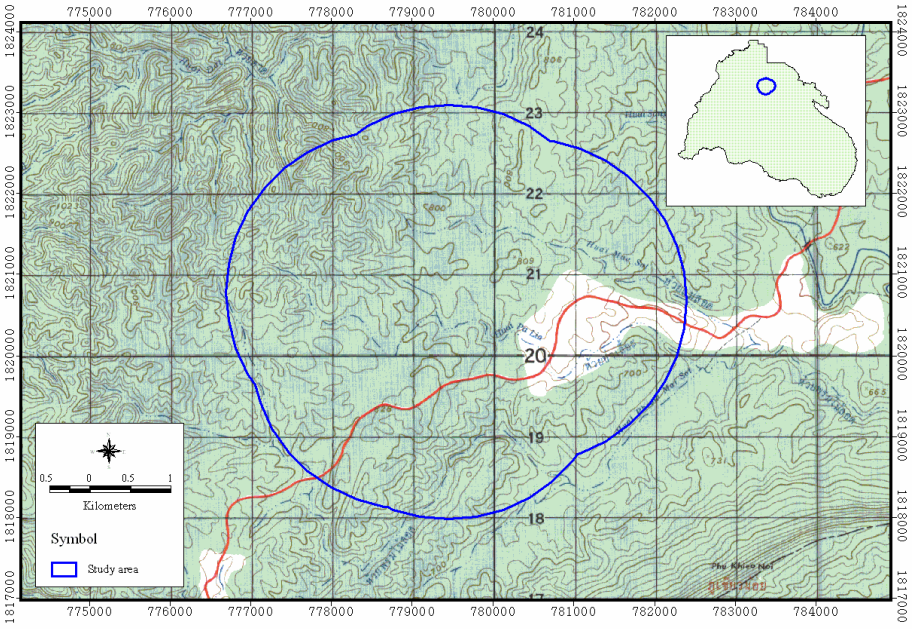

Figure 1 The topographic map of the study area at the Huai Mai Sot Yai.

1. Site history

Phu Khieo WS was established in 1972 by the Thai government following a revolutionary committee's notice. The area covers approximately 1560 km^2. It is located in Chaiyaphum Province. Due to a forest concession these areas had been encroached for agriculture and wildlife hunting. Subsistence farming by local peoples were scotter located at Thung Ka Mung, Boung Mon and Salaphrom. In 1972, all of the 40 families from Thung Ka Mung and 100 families from Saraphrom were translocated to other sites. Some of them were translocated to the new resettlement sit sat Thung Lui Lai Subdistrict in Khonsan District, Chaiyaphum Province. In 1979, the government included some more area into Phu Khieo WS, which lead to the migration 304 families of privates at Ban Nong Rai Kai, Ban Phromsong, Ban Pha Poung and Ban Somtoei into Dong Larn National Reserved Forest Development Project at KhonKhaen Province (Horata and Kreetiyutanond, 1997).

2. Location and Surrounding Area

Phu Khieo WS is located at Latitude between 16°5´N to 16°35´N and Longitude 101°20´ E to 101°55´ E. The sanctuary extends to Thung Lui Lai Subdistrict, Khonsarn District, Ban Yang, Ban Kha, Ban Boa, Kud Lao Kasetsomboon District, Nang Dad, HnongWang, Hnong Boa Dange, Tham Woa Dange Subdistrict, Hnong Boa Dange District, Chaiyaphum Province. The area is connected with neighboring area as follows (Figure 2);

To the north is the Juraphon Hydro Electric Dam and Nam Nao NP, Khonsarn District Chaiyaphum Province and Muang District, Phetchaboon Province;

To the south is Taboa-Hui Yai WS, Tham Woa Dange, Nang Dad, Hnong Wang Subdistrict, Hnong Boa Dange District, Chaiyaphum Province;

To the east is Pha Poung WS Kua Lao, Ban Yang, Ban Boa, Hnong Kha Subdistrict Kasetsomboon District, Chaiyaphum Province;

To the west is Taboa-Hui Yai WS and Tard Mog NP, Muang District, Petchaboon Province (Horata and Kreetiyutanond, 1997).

3. Topography

Phu Khieo WS covers altitudes from 250-1,310 meters above mean sea level (MSL). The west and north side includes steep mountains and slope complexes, which are a part of the Petchaboon range. They mostly have steep slopes at the high altitude with rock outcrop soil. To the east and the south is a cliff with the center of the area being a big plain and some part of this area was a lake. The center of this area is occupied by dense vegetation and there are perennial creeks and streams.

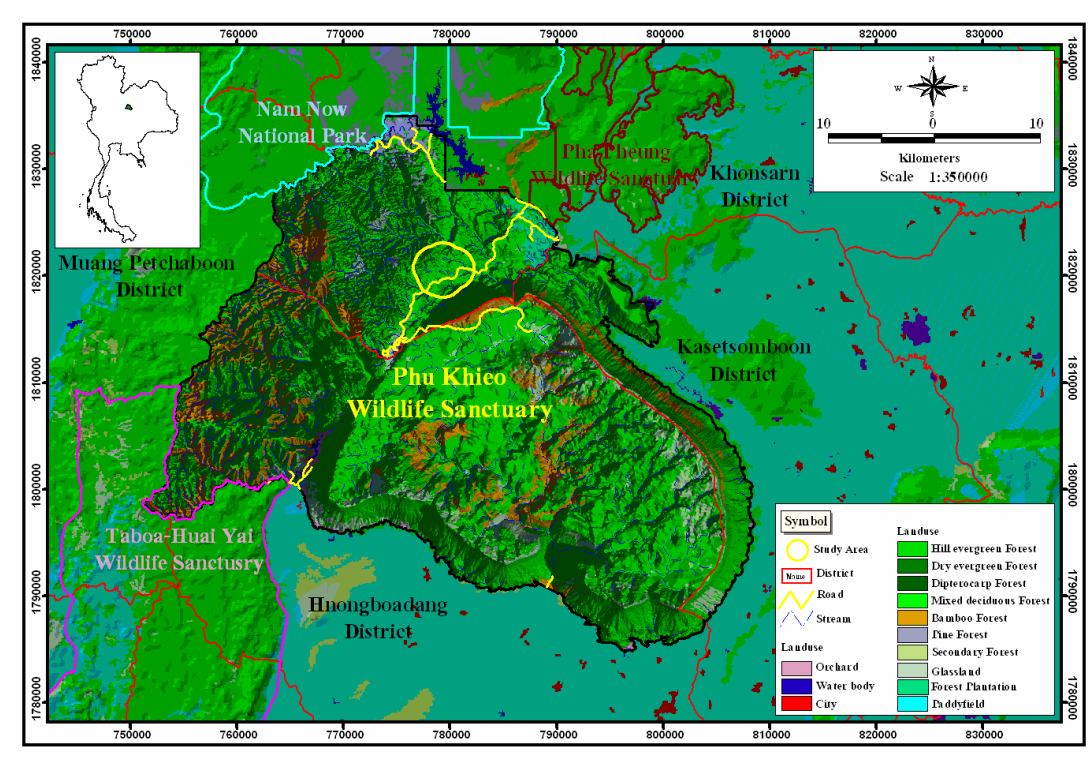

Figure 2 Phu Khieo Wildlife Sanctuary and Study Area.

4. Climate

The climate of the Phu Khieo WS is classified as Tropical Savannah Climate: AW. Data from the upper plain of this area and the foothills show some variation in precipitation. The amount of mean annual rainfall was 1,100 mm and at Thung Ka Mung 1,500 mm. The minimum mean air temperature is 17°C, while the maximum mean temp is 27°C. The mean relative

humidity is 90%. The dry season lasts from November to March and the wet season lasts from April to October (Figure 3).

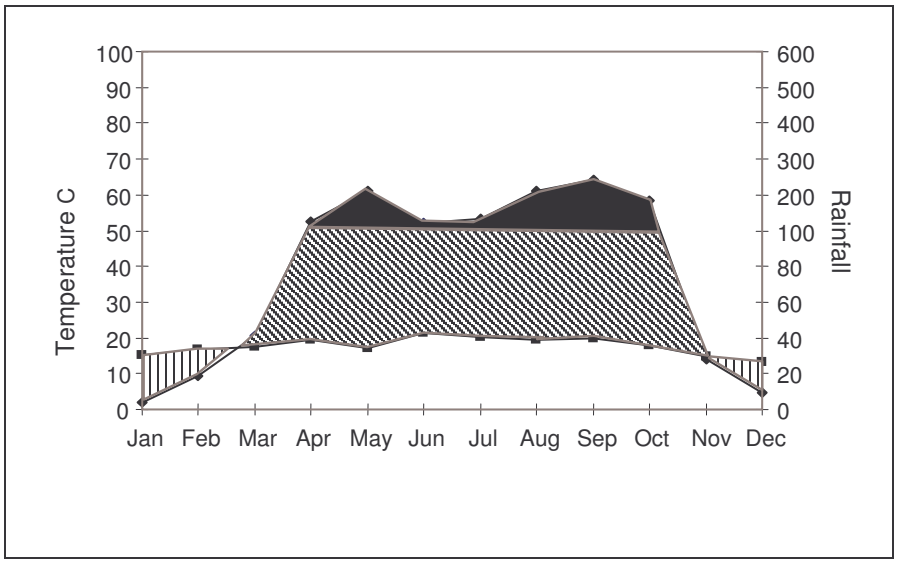

Figure 3 Average monthly rainfall and temperature in Phu Khieo Wildlife Sanctuary (1992 - 2002).

Source: Thung Ka Maung Climatological, Phu Khieo Wildlife Sanctuary (2002).

5. Vegetative Type

Phu Khieo WS includes several plant communities, which can be classified into 8 types (Horata and Kreetiyutanond, 1997)

5.1 Hill Evergreen Forest: This vegetation prevails at more than 800 m MSL. Mean temperature is less than 24° C and humidity much more than 90 percent. The dominant plant species are *Quercus auricoma, Lithocarpus dealbatus, Aquilaria crassna, Cacrydium elatum* and *Cimocarpus longan*

5.2 Dry Evergreen Forest: This forest type prevails at less than 800 m MSL. The temperature is higher than in the Hill Evergreen Forest, but it has less of humidity especially in

the dry season. The dominant plant species that can be found in this vegetation are *Lagerstroemia calyculata, Afzelia xylocarpa, Hopea ferrea, Memecylon geddesianum* and *Dendrocalamus strectus.*

5.3 Moist Evergreen Forest: This vegetation prevails at the riverside of ravines and more than 600 m MSL. Compared to the other vegetation types it has much more humidity. Some areas are flooded during the wet season. The important plant species are similar to the Hill Evergreen Forest and are comprised by *Baccaurea sapida, Livistona speciosa, Arenga pinnata, Dracontomelon mangiferum, Altingia siamensis* and several species of rattans.

5.4 Dipterocarp Forest: This vegetation type can be subdivided into 2 types. The details are as follows:

5.4.1 Deciduous Dipterocarp Forest: It prevails at the slope of mountains. This type is characterized by a long time of dry season and hot weather. It includes the dominant plant species *Shorea obtusa, S. siamensis, Phyllanthus embrica* and *Phoenix acaulis.*

5.4.2 Mixed Deciduous Dipterocarp Forest with Pine: It prevails at about 700-900 m MSL. The temperature is less than 25^{0}C throughout the year and it has comparatively high humidity. Areas have an intermediate slope and good drainage. The dominant plant species are *Pinus kesiya, Dipterocarpus obtusifolius, Phyllanthus embrica* and *Quercus kerrii.*

5.5 Mixed Deciduous Forest: This type prevails in the area of the north-east hill side, which is not more than 600 m MSL. Generally it looks similar to Dipterocarp Forest but does not have any “Dipterocarpaceae”. Often these areas contain bamboo. The dominant plant species are *Vitex peduncularis, Schleichera oleosa, Dalbergia nigrescens, Terminalia bellerica* and *Gigantochloa albociliata.*

5.6 Pine Forest: It prevails in the more upper parts of the area or the connected zone with Nam Nao NP. The pine species that can be found in this forest is *Pinus kesiya.* There are few pine-forests remaining in Phu Khieo WS.

5.7 Bamboo Forest: It prevails in wide areas of the west of the mountains. It alternates with hill evergreen forest at more than 35% of slope. Generally, the bamboo species which dominates this type is *Gigantochloa albocilliata.*

5.8 Grassland: It can subdivide into 2 types, namely natural grassland and man-made grassland.

5.8.1 Natural grassland: It prevails at hill sides with rock outcrop soil and strong winds. It is combined with small shrubs and the dominant plant species are *Imperata cylindrica, Osbeckia* sp., *Ericocaulon* sp. and *Rhododendron lyi.*

5.8.2 Man-made grassland: It prevails in areas with previous agriculture area such as Thung Ka Maung, Bung Pan and Bung Ka. The dominant plant species are *Imperrata cylindrica, Arundinaria pusilla* and *Cyperus* sp.

6. Wildlife Resource

Phu Khieo WS has a diverse array of animal species adjoining with Nam Nao NP, Tard Morg NP, Thabao-Huai Yai WS and Pha Poung WS. Such a larger area is considered as an optimum habitat for wildlife (Faculty of Forestry, 1989; Sanguenyat, 1997). In this sanctuary, there are five faunal types of wildlife which are mentioned by Horata and Kreetiyutanond (1997), their are as follows:

There are at least 57 species, 47 genera, 25 families of mammals such as *Elephas maximus* Linnaeus, 1758, *Panthera tigris* Linnaeus, 1758, *Macaca nemestrina* Linnaeus, 1758, *Hylobates lar* (Linnaeus, 1771), and *Ursus thibetanus* Cuvier, 1823.

There are at least 356 species, 205 genera, and 61 families of birds. Interesting birds species are *Anorrhinus tickelli* Blyth, 1855, *Buceros bicornis* Linnaeus, 1758, *Anthracoceros albirostris* Shaw & Nodder, 1807 and *Upupa epops* Linnaeus, 1758.

There are at least 28 species, 21 genera, 12 families of reptiles such as *Bungarus candidus* Linnaeus, 1758, *Ophiophagus hannah* Cantor, 1836, *Trimeresurus albolabris* Gray, 1842, *Indotestudo elongata* Blyth, 1853 and *Calotes emma* Gray, 1845.

There are at least 15 species, 8 genera and 6 families of amphibians such as *Bufo melanostictus* Schneider, 1799, *B. macrotis* Boulerger, 1887, *Phrynoglossus martensi* Peter, 1867, *Rana nigrovittata* Blyth, 1855 and *R. pileata* Boulenger, 1916.

In addition, so far 26 species, 20 genera, 11 families of fishes were found. Example of fish species are *Neolissochilus blanci* Pellegrin, 1758, *Cyprinus carpio* Linnaeus, 1758, *Barbodes altus* Gunther, 1868, *Hampala macrolepidota* Kuhl & Van Hasseltin, 1823 and *Labeo rohita* Hamilton, 1822.

Many of the species found at Phu Khieo WS are listed as endangered species such as *Dicerorhinus sumatrensis* (Fischer, 1814), *Panthera tigris* Linnaeus, 1758, *Elephas maximus* Linnaeus, 1758, *Cairina scutulata* (S.Muller, 1842).