Habitat selection between siamang (*Symphalangus syndactylus* Raffles 1821) and agile gibbon (*Hylobates agilis* Cuvier, 1821) in Bala Forest, Hala-Bala Wildlife Sanctuary, Narathiwat, Southern Thailand

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Ecology (International Program)

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Thesis Title	Habitat selection between siamang (*Symphalangus syndactylus* Raffles 1821) and agile gibbon (*Hylobates agilis* Cuvier, 1821) in Bala Forest, Hala-Bala Wildlife Sanctuary, Narathiwat, Southern Thailand
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ชื่อวิทยานิพนธ์ การเลือกใช้ถิ่นอาศัยของชะนีดำใหญ่ (*Symphalangus syndactylus* Raffles 1821) และ ชะนีมือดำ (*Hylobates agilis* Cuvier, 1821) ในป่าบาลา เขตรักษาพันธุ์สัตว์ป่าฮาลาบาลา จังหวัดนราธิวาส

ผู้เขียน นาย สุทธิรักษ์ หนองแก้ว

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ปีการศึกษา 2553

บทคัดย่อ

วัตถุประสงค์หลักของการศึกษาในครั้งนี้คือ วิเคราะห์ปัจจัยที่จำกัดการกระจาย และการเลือกใช้ถิ่นอาศัย ประเมินคุณลักษณะ และขนาดของถิ่นอาศัยที่เหมาะสมของชะนีดำใหญ่และชะนีมือดำในป่าบาลา ผลจากการศึกษาในครั้งนี้พบชะนีดำใหญ่ 19 กลุ่ม โดยส่วนใหญ่พบการกระจายในฝั่งตะวันตกเฉียงใต้ของพื้นที่ ส่วนชะนีมือดำพบ 136 กลุ่ม พบกระจายโดยทั่วไปในพื้นที่

จากการหาความสัมพันธ์ระหว่างความหนาแน่นประชากรของชะนีกับลักษณะของถิ่นอาศัยของชะนี พบว่าความหนาแน่นประชากรของชะนีดำใหญ่แปรผันตามความสูงของพื้นที่ที่พบอย่างมีนัยสำคัญ (r = 0.810, p = 0.015) (ดังตารางที่ 3) ส่วนความหนาแน่นประชากรของชะนีมือดำไม่พบมีความสำพันธ์กับลักษณะของถิ่นอาศัยอย่างมีนัยสำคัญ

ผลจากการเปรียบเทียบค่าเฉลี่ยของลักษณะของถิ่นอาศัยระหว่างพื้นที่ที่พบและพื้นที่ที่ไม่พบชะนีดำใหญ่ สรุปว่าพื้นที่ที่พบชะนีดำใหญ่มีความสูงจากระดับน้ำทะเลมากกว่าอยู่ใกล้กับสันเขามากกว่า พื้นที่มีความลาดชันมากกว่า ทิศทางของด้านลาดชันใกล้กับทิศตะวันออกมากกว่าอยู่ใกล้กับถนนมากกว่า และห่างไกลจากหมู่บ้านมากกว่าพื้นที่ที่ไม่พบชะนีดำใหญ่อย่างมีนัยสำคัญ ($p < 0.05$) ส่วนพื้นที่ที่พบชะนีมือดำมีความสูงจากระดับน้ำทะเลต่ำกว่า อยู่ใกล้กับสันเขามากกว่า อยู่ใกล้กับถนนมากกว่า และอยู่ใกล้กับลำธารมากกว่า แต่ไกลจากหมู่บ้านและขอบป่ามากกว่าพื้นที่ที่ไม่พบชะนีมือดำอย่างมีนัยสำคัญ ($p < 0.05$)

ปัจจัยที่มีความสำคัญในการจำแนกถิ่นอาศัยที่เหมาะสมสำหรับชะนีดำใหญ่มี 3 ปัจจัยได้แก่ ความสูงจากระดับน้ำทะเล ทิศทางของด้านลาดชันใกล้กับทิศตะวันออก และระยะทางจากขอบป่า ปัจจัยเหล่านี้นำมาจำแนกพื้นที่ที่เหมาะสมกับชะนีดำใหญ่ได้ 56 ตารางกิโลเมตร ส่วนปัจจัยที่มีความสำคัญในการจำแนกถิ่นอาศัยที่เหมาะสมสำหรับชะนีมือดำมี 4 ปัจจัย ได้แก่ ความสูงจากระดับน้ำทะเล ระยะทางจากสันเขา ทิศทางของด้านลาดชันใกล้กับทิศตะวันออก และระยะทางจากลำธาร ปัจจัยเหล่านี้นำมาจำแนกพื้นที่ที่เหมาะสมกับชะนีมือดำได้ 54 ตารางกิโลเมตร

เมื่อเปรียบเทียบถิ่นอาศัยของชะนีทั้งสองชนิด พบว่าถิ่นอาศัยของชะนีดำใหญ่คือพื้นที่สันเขาหรือยอดเขาที่มีความสูงและความลาดชันมากกว่า ส่วนลักษณะถิ่นอาศัยของชะนีมือดำคือพื้นที่สันเขาหรือยอดเขาที่ต่ำกว่ามีความลาดชันน้อยกว่าอยู่ใกล้แหล่งน้ำ แต่อยู่ห่างจากขอบป่า โดยถิ่นอาศัยของชะนีทั้งสองชนิดล้วนอยู่ห่างจากหมู่บ้าน

Thesis Title Habitat selection between siamang (*Symphalangus syndactylus* Raffles 1821) and agile gibbon (*Hylobates agilis* Cuvier, 1821) in Bala Forest, Narathiwat, Southern Thailand

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Major Program Ecology

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Abstract

The aims of this study were to determine habitat attributes that siamang and agile gibbon use, analyse restricting factors of their distribution selection and estimate utilizable habitat areas for them in Bala forest. Nineteen groups of siamang were found. They distributed densely in southwest of Bala Forest. A number of 136 groups of agile gibbon were found. They have tended to ordinary distribution.

Densities of siamang in its distribution area significantly positively relate with mean altitude (r = 0.810, p = 0.015). Densities of agile gibbon were not found significantly related with characteristics of habitats. Grids with siamang have higher altitude, higher slope value, greater distance from village, but shorter distance from ridge, slope direction near east, shorter distance from road, than grids without siamang significantly. Grids with agile gibbons have lower altitude, shorter distance from ridge, shorter distance from road, shorter distance from stream but greater distance from village, and forest edge than grids without agile significantly.

Three factors (altitude, slope direction near east, and distance from edge), were used to predict suitable areas for siamang. It was about 56 km^2. Four factors (altitude, distance from ridge, slope direction near east, and distance from stream) were estimated suitable areas for agile gibbons 54 km^2.

Comparing habitat of siamang and agile gibbon, habitats of siamang were at higher altitude, ridges or top hills, and steeper slope while habitats of agile gibbon were lower ridges or top hills, lower slope value, near the stream, and more distant from forest edge. In addition, both gibbons were far from village.

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Sutthirak Nongkaew

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CHAPTER 1

INTRODUCTION

The theoretical approaches to habitat selection include optimal foraging models, in which individuals choose patches (habitats) and stay in them in order to maximize the gain of some resource (Drickamer *et al*., 2002) for survival and regeneration. Factors of habitat selection can estimate survival of species from habitat resources. The factors are important for habitat management for species conservation.

Gibbons are important seed dispersers in Southeast Asian tropical rain forests, they normally disperse seeds without destroying them. Some animals such as rodents and langurs are known to destroy and eat seeds. The siamang (*Symphalangus syndactylus* Raffles, 1821) and agile gibbon (*Hylobates agilis* Cuvier, 1821) are found sympatrically in the Malay Peninsula and also in the north of Sumatra and agile gibbons are also found in the southwest of Borneo, Kalimantun, Indonesia (Chivers, 1977; Gittins and Raemaekers, 1980). The status of siamang and agile gibbon are endangered (IUCN 2008).

In 1997 Treesucon and Tantithadapitak reported that siamang was found in Bala Forest in Narathiwat Province. Siamangs are distributed in the central and western areas of Bala Forest (Thong-aree, 2000). The population of siamangs in Thailand is small and limited in distribution. Most primate social groups restrict their activities to a limited area which provides all necessary resources (Chivers, 1974). Another gibbon which occurs in Bala Forest is the agile gibbon. The distributions of siamangs and agile gibbons in Thailand are poorly known. There is a danger of local extinction in the future if the conservation strategies do not take into account the behaviour and ecology of them.

Questions of this study are: what are the characteristic attributes of siamang and agile gibbon habitats in Bala Forest?

From literature reviews of the ecological study of siamang and agile gibbon in Malaysia that are some basic outlines for hypothesis of this study. The answers of there questions are required for successful siamang and agile gibbon conservation in Thailand.

Review of Literature

The Gibbons

The Family Hylobatidae consists of 4 genera and about 13 species (Brandon-Jones *et al*., 2004), ranging from Assam through Burma and Thailand to Indochina, Yunan, Malaya, Java, and Borneo (Lekagul and McNeely, 1977; Brandon-Jones *et al*., 2004).

Calls

Gibbons advertise their territories by characteristic loud wailing calls, heard wherever gibbons occur. At the boundary of two gibbon territories, the group will often confront each other, with aggression usually confined to a calling contest (though calls are also heard in other contexts) (Lekagul and McNeely, 1977). Although the call is species-specific, the calls of males and females are quite different (thus call can be used to identify the sex of the caller in forested habitats where visual contact may be difficult) (Lekagul and McNeely, 1977; Gittins and Raemaekers, 1980).

The siamang and agile gibbons

Description

The siamang (*Symphalangus syndactylus* Raffles (1821)) is classified in genus *Symphalangus* following Simpson (1945), Walker (1964), Simons (1972), Rumbaugh (1972) same with Brandon-Jones *et al*. (2004) but older publications classified in genus *Hylobates* such as Chaesen (1940), Ellerman and Morrison Scott (1951), Groves (1972) (Lekagul and McNeely, 1977).

Siamang, the largest living gibbon, has an adult weight of 10-12 kg, males and females being of the same size (Schultz, 1933, 1974 referred Gittins and Raemaekers, 1980). The coat of long hair is completely black in colour, except for a little whitening of the hair around the mouth. The siamang has a large throat pouch, which inflates to act as a resonator while vocalising (Gittins and Raemaekers, 1980).

The agile gibbon (*Hylobates agilis* Cuvier, 1821) is classified in genus *Hylobates* (Illiger, 1811 referred Brandon-Jones *et al*., 2004).

Agile gibbon closely resembles *Hylobates lar* but without the white hands and with much less white around the face (Lekagul and McNeely, 1977). Characteristics of the male include a white brow and white or pale brownish cheek patches, often joined under the chin (Marshall and Sugardjito, 1986). Adult females usually have separate, arched, white eyebrows and no cheek patches (Marshall and Sugardjito, 1986).

The calls of siamang and agile gibbons

The calls of siamang can be heard over about 1.5 km. but the calls of agile can be heard about 1 km. in flat terrain (Gittins and Raemaekers, 1980). The time of siamang's call is 8.00 -11.00 h in the morning but the peak of agile call 6.00 -8.00 h in the morning (Gittins and Raemaekers, 1980).

Distribution

Siamangs are found in the Malay Peninsula and the north of Sumatra, Indonesia. Agile gibbons are found the Malay Peninsula, and the north of Sumatra, (Groves, 2001; Brandon-Jones *et al*., 2004).

Sympatric

Siamang and agile gibbons occur sympatrically in peninsular Malaysia and extreme south of Thailand, and on Sumatra, Indonesia (central and south Sumatra) (O'Brien *et al*., 2004). Siamang and agile gibbon were found in Bala forest.

Distribution in Thailand

In 1997 Treesucon and Tantithadapitak first reported siamang in Bala Forest. There are two groups at a lower hill of Khao Ba Tu Ta Mong and near Khlong Ai Ka Ding. Three groups of siamangs are distributed in the central and western areas of Bala Forest (Thong-aree, 2000). The general habitat type of Bala Forest is Malayan tropical rain forest.

The agile gibbon (*Hylobates agilis* Cuvier, 1821) is distributed from Thepa River (Songkha province) to border of Thailand and Malaysia (Marshall and Sugardjito, 1986).

Status

Status of siamang and agile gibbon is Endangered (IUCN, 2008).

Habitat selection

Habitat selection is the process or behavior that an animal uses to select or choose a habitat in which to live. To live in a habitat an animal must first have access to the habitat. Once the animal has access to the habitat it must be able to tolerate the conditions of the habitat and find the resources that it needs to survive in that habitat (McClary *et al*., 2008). Habitat selection of species can be described by optimal foraging theory and ideal free distributions. Optimal foraging: this theory enables us to predict which habitat patches an animal should select and when it should leave one habitat and move to another so as to get the greatest benefit for the least cost (Drickamer *et al*., 2002). Also ideal free distributions predict how individuals distribute themselves so as to have the highest possible fitness (Fretwell and Lucus, 1970; referred Drickamer *et al*., 2002).

Canopy of tropical rainforest is available for gibbon because the physical characters of gibbons are suitable for living and feeding in closed canopies. Beside biological characteristics of habitat such as feeding plants, competition and predator animals, disturbance, disease, geography, and weather in habitat affect habitat selection of gibbons. Siamang and agile gibbons have difference characteristics of habitat selection. In peninsular Malaysia siamang usually occur in higher altitude and also at higher levels of the canopy than agile gibbons (Gittins and Raemaekers, 1980). Percent of leaf in food of siamang is more than agile so siamang travel to large sources of young leaves but agile gibbons travel to fruits sources more (Chiver, 1977; Gittins and Raemaekers, 1980).

Habitat use by siamang and agile gibbons

1. Geological attribute

1.1 Altitude

The siamang is commonly found living in hill forest, usually over 300m above sea-level (a.s.l.) (Chivers, 1977), but is rarely found an altitude above 1500 m (4920 ft) above sea-level (Caldecott, 1980; Gittins and Raemaekers, 1980).

1.2 Top hill and ridge

“Hill top” is the top convex area of the hill. “Ridge” is convex area continuous from hill. “Valley” is a concave and lower elevations area. Distance of hill top and ridge in terms of topography are factors to identify characters of siamang and agile gibbon habitats.

1.3 Slope

Slope of area is index to explain character of soil, such as erosion, and interior water.

1.4 Stream

Water seems to serve as a zoogeographic barrier to most gibbons, and rivers often mark species boundaries (i.e., the Bhramaputre (India), Salween (Myanmar), Mekong (Thailand), Mudah, Perak (Malaysia), Kapuas, and Barito rivers (Indonesia)) (Lekagul and McNeely, 1977)

2. Forest disturbance

2.1 Natural disturbance

The commonest form of natural disturbance is the death of trees and the formation of gaps (Richards, 1996). In a lowland forest in Malaya, Poore (1968) found gaps up to 600 m^2 (Richards, 1996). Natural disturbance may reduce food resources of siamang and agile gibbons.

2.2 Logging

Logging is a major cause of forest disturbance in all rain forest formations (Richards, 1996). Logging practices vary widely but in most rain forests they involve the selective extraction of only a proportion of the larger trees (Richards, 1996). The overall response of the studied primate community to selective logging appeared to be a reaction to reduced food availability and to fragmentation or other alterations of the habitat (Johns, 1986).

Bala Forest was selectively logged about 30 years ago and clear cutting occurred along roads about 15 years ago.

3. Habitat Fragmentation

Habitat fragmentation is the process whereby large, continuous areas of habitat are both reduced in area and divided into two or more fragments (Wilcove *et al.*, 1986 referred Primack, 1993)

The process of fragmentation has a number of important aspects; namely, loss of original habitat, reduction in remnant patch size and increasing isolation of remnant patches (Andren, 1994 referred Didham, 1997).

Habitat fragmentation results in a reduction of the area of the original habitat, a greater amount of edge habitat for a given area, and a reduced distance to the nearest edge (Primack, 1993). Habitat fragmentation threatens the persistence of species in more subtle ways (Primack, 1993). First, fragmentation may limit a species potential for dispersal and colonization. A second harmful aspect of habitat fragmentation is that it reduces the foraging ability of animals (Primack, 1993).

3.1 Effects from forest edge

The microenvironment at the fragment edge is different from that of the interior (Primack, 1993). The more important edge effects include microclimatic changes in light, temperature, wind, and the incidence of fire (Lovejoy *et al*. 1986; Kapos 1989; Bierregaard *et al*., 1992 referred Primack, 1993). Edge effects may be important both for the ecological characteristics of forest fragments themselves and for the local and regional environment (Kapos *et al*., 1997).

Each of these edge effects can have a significant impact on the vitality and composition of the species in the fragment (Primack, 1993). Kapos (1989) found that plants near newly created edges sometime had lower leaf relative water contents than those in the interior of a forest reserve, but found no evidence of appreciable water shortage in the relatively wet period when the study was done (Kapos *et al*., 1997).

In a recent review of edge effects in forest remnants, Murcia (1995) distinguished three types of edge effects: abiotic, direct biological, and indirect biological (Turton and Freiburger, 1997).

Direct biological effect involve changes in the distribution and abundance of species caused by altered physical condition near edges, while indirect biological effects result from changes in species interactions at or near edges (Murcia, 1995 referred Turton and Freiburger, 1997).

A swath cut through natural vegetation for a linear clearing has twice its length in edges, allowing edge effects to penetrate into the surrounding natural habitat from both sides of the clearing (Goosem, 1997). Different types of edge effects may penetrate different distances into the forest (Goosem, 1997). Laurance (1989) concluded structural damage in northern Queensland rainforests, that edge effects often penetrate 200 m. into rainforest and may be detectable up to 500 m. from the edge (Goosem, 1997).

3.2 Effects from roads

Internal fragmentation occurs when natural habitat is fragmented and wildlife populations are subdivided by linear clearings such as roads and powerlines (Goosem, 1997). Roads, highways, and powerline clearings are an integral feature of the modern landscape and, outside urban areas, are one of the most obvious anthropogenic impacts on the natural environment (Goosem, 1997). The construction and maintenance of roads and powerline clearing has a variety of effects on native fauna, including: (1) destruction or alteration of habitats, with consequent reductions in population size; (2) disturbances, edge effects, and intrusions of fauna alien to the natural habitats; (3) increased mortality due to vehicle traffic; and (4) fragmentation of habitats and wildlife populations (Andrews, 1990; Bennett, 1991 referred Goosem, 1997).

Most road verges and powerline rights-of-way are maintained as grasslands or low, weedy shrublands by cutting regrowth, spraying with herbicides, mowing, burning, or grading (Goosem, 1997). These practices have the dual effects of maintaining a structurally different plant community in the clearing and creating an unstable edge between this community and the native vegetation (Goosem, 1997). The long forest edge typical of powerline and road clearings can have hidden effects, causing changes in various habitat attributes for varying distances beyond the clearing and substantially increasing the areal extent of habitat alteration (Goosem, 1997).

Orangutans, gibbons, and other primates typically remain in forests and forage widely for fruits. Finding scattered trees with abundant fruit crops may be crucial during episodes of fruit scarcity. Clearings and roads that break up the forest canopy may prevent these primates from reaching nearby fruiting trees because the primates are unable or unwilling to descend to the ground and cross the intervening open landscape (Primack, 1993).

A road built in 1990 cuts through Bala Forest for about 13 km from Ban Bala Village to Ban Phu Khao Tong Village (Tohdam, 2001). Creating internal fragmentation patches may affect siamang and agile gibbon populations in Bala Forest.

3.3 Effects from nearest villages

Bala Forest has about 10 villages nearby. The areas in the south are near the border with Malaysia and have rubber, oil palm, and fruit garden plantations. People who are living in villages near Bala Forest collect non-timber produce such as fruits of *Archidendron bubalinum*, *Archidendron jiringa*, *Baccaurea macrophylla*, *Dialium indum*, *Dialium platysepalum*, *Elateriospermum tapos*, *Garcinia* spp., *Parkia speciosa* and *Pakia timoriana* (Tohdam, 2001). The food sources of siamang and agile gibbons include *Baccaurea* spp., *Dialium platysepalum* and *Garcinia atroviridis* (Chivers, 1974; Chivers, 1980). Only Ban Bala Village uses Bala Forest economically, collecting products with a value of 133,274 baht per year (about 1,800 baht per family) (Tohdam, 2001). Nine percent of people collect *Dialium indum* and *Dialium platysepalum* by cutting trees (usually cut branches) (Tohdam, 2001) reducing available food sources of siamang and agile gibbons.

4. Hunting

The most importance anthropogenic activities are deforestation causing fragmentation and hunting. Hunting increases their likelihood of extirpation (Bordmer *et al*., 1997 referred Cullen *et al*, 2000). Robinson (1996) and Turner and Corlett (1996) emphasize that species inhabiting fragmented areas are more vulnerable to hunting than species living in areas of continuous forest cover (Cullen *et al*, 2000).

Objectives

1). Estimated forest attributes that siamangs and agile gibbon uses in Bala forest.

2). Analysed factors restricting siamang and agile gibbon distributions and habitat selection.

3). Estimated utilizable habitat areas for siamang and agile gibbons in Bala forest.

CHAPTER 2

Research Methodology

Study sites

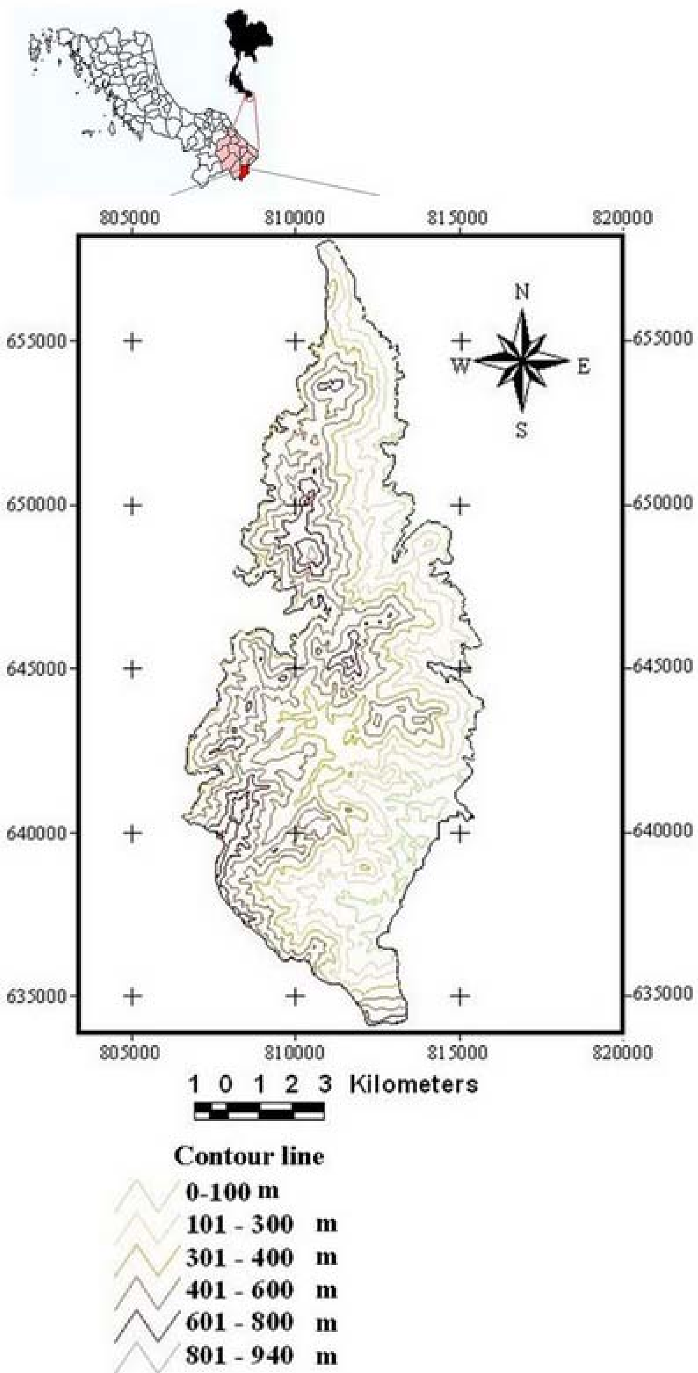

Figure 1. Topographic map of Bala Forest, Narathiwat Province.

The field study area was tropical rainforest of Bala forest. This area covered 168.16 km^2 and is a part of Hala-Bala Wildlife Sanctuary in Waeng district and Sukirin district, Narathiwat province, southern Thailand. Bala Forest altitude is 100–953 m above sea-level. This is the first order watershed of Kolok River and Saiburee River.

Bala Forest is Malayan dipterocarp forest (Niyomthum, 2000), that is classified into two subtypes which are

1. Lowland tropical forest covering altitudes below 600m above sea-level. There are numerous dipterocarps and palms in the community. Plants classified in Family Dipterocarpaceae such as *Anisoptera costata*, *Dipterocapus chartaceus*, *Shorea leprosula*, *Shorea assamica*, *Koompassia excelsa*. Plants classified in Family Palmae include *Oncosperma horrida*, *Orania sylvicola*.

2. Highland tropical forest covering altitudes 600-1,000 m above sea-level. There are genus *Shorea*, genus *Eugeissona* and genus *Johannesteijsmannia* Community, and genus *Shorea* and *Calamus castaneus* Community such as *Shorea curtisii*, *Eugissona tristis*, *Dipterocarpus grandiflorus*, and *Johannesteijsmania altifrons*.

Bala Forest is a separated fragment patch from Hala Forest by about 10 Thai villages and rubber and oil palm plantations in Malaysia around the forest area. The core area is important habitat for wildlife and protected area for sustainable use.

Method

Distribution survey

Thirteen listening areas were designed on a 1:50,000 topographic map to determine the distribution of siamang and agile gibbon in Bala Forest. Each listening area contained 4 listening posts (LPs) (Fig.2) on the top of hills or ridges, located to the nearest 100 m on the map, or more accurately using a GPS. Siamang and agile gibbon groups were located by triangulation method from their calls in the morning (Brockelman and Srikosamatara, 1993), 7.00-11.00 is the peak of time of siamang's call (Gittins and Raemaekers, 1980). 1 or 2 persons went to each LP and sat on a rock or log, listened for siamang and agile gibbon's calls in all directions (estimate its direction with a hand compass) (Appendix A Table 1, Appendix A Fig. 1). The distributions of gibbon groups were located in each listening area at 3-day intervals. There were mapped distributions of siamang and agile gibbon groups on a 1:50,000 topographic map of Bala Forest. A protractor and a ruler plotted the directions of each individual or group that called. Lines were drawn the same length as the estimated distance extending from the LP to their calls heard on the same map. Gibbon groups heard (by more than one LP) were exactly located by the intersection of the lines, a procedure called **triangulation** (Appendix A Fig. 2).

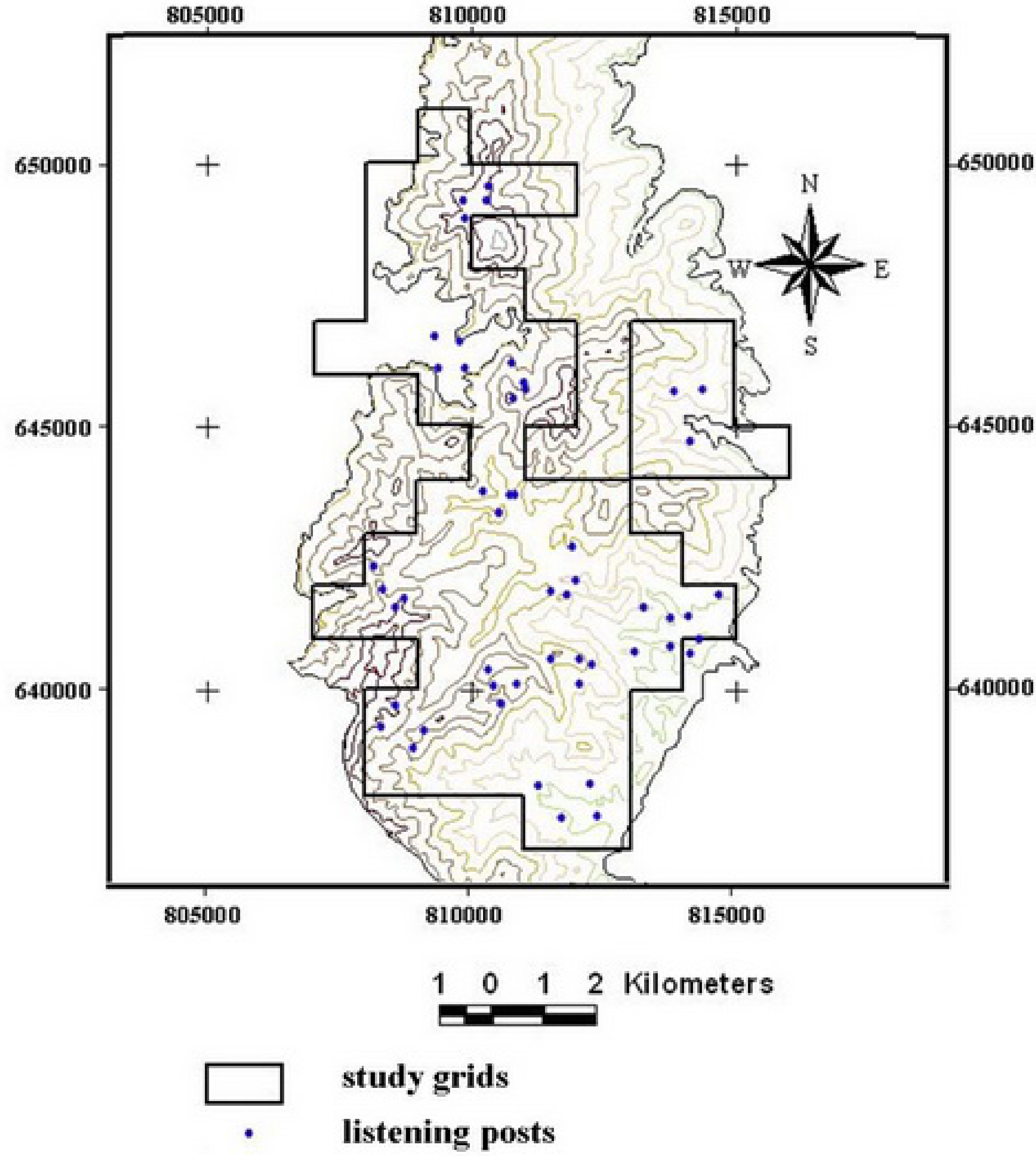

Figure 2. Distribution of listening posts in Bala Forest.

Habitat characteristic measurement

Transect lines were made east to west direction from camp or center of LPs 250 m in north direction and 250 m in south direction (Fig. 3). On each part of the line, the field team made 25 plots at 20-m intervals on eastern side and 25 plots 20-m intervals on western side of both northern baseline and southern baseline (Appendix A Fig. 5 and Appendix A Fig. 6). There were 100 plots in each Listening Area, each 5.6 m in radius (0.01 ha). Habitat characters 100 plot areas:

Altitude

Altitude of each subplot were measured by GPS or estimated on a 1:50,000 topographic map of Bala Forest.

Canopy height

Canopy height were measured with the point-intercept method requires two kinds of instruments: one that measures vertical angles to find the zenith point (90^o angle) and an optical rangefinder to measure canopy height (Brockelman, 1998) at the center of each subplot (Appendix A Fig. 7).

Canopy tree basal area

Measured basal area of canopy trees (>10 cm d.b.h. , > 20 cm dbh, >40 cm dbh, > 80 cm dbh) in each plot (Appendix A Fig. 8).

Number of trees

Counted number of trees (> 10 cm dbh, > 20 cm dbh, >40 cm dbh, > 80 cm dbh.) in each plot.

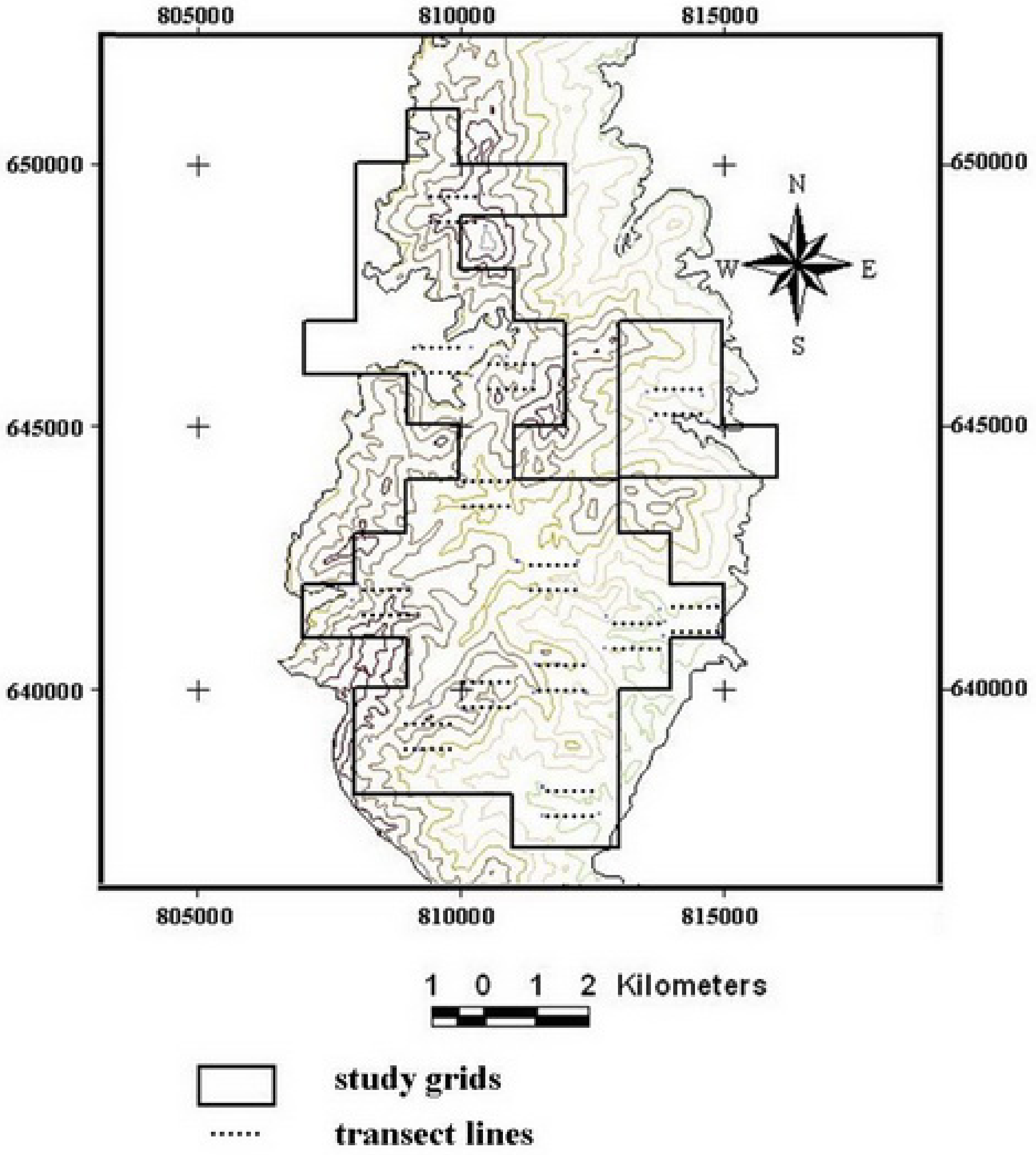

Figure 3. Distribution of transect lines in Bala Forest.

Habitat attributes

Habitat attributes of gibbons in each group in study area (60 km^2) were described are:

Altitude: measured altitude at center of gibbon group distributions (a center 3-day interval distributions) on a 1:50,000-topographic map of Bala Forest,

Distance from ridge: distance from center of gibbon group distributions to the ridge of hill which nearest,

Slope direction near east (Slope direction of habitat near the east): 1 plus with sine ($1 + \sin(\theta)$) of direction of center of gibbon group range to the lowest altitude point (value between 0 to 2),

Slope value: value of slope direction of center of gibbon group distributions to the lowest altitude point,

Distance from road: distance from center of gibbon group range to nearest road,

Distance from nearest village: distance from center of gibbon group range to the nearest village,

Distance from stream: distance from center of gibbon group range to the nearest stream,

Distance from edge: distance from center of gibbon group range to the nearest edge of Bala forest.

Analysis

Mapping distributions and density determinations

An enlarged 1:20,000 scale map of the area were made by photo-enlarging the 1:50:000 map by 250%. (On this map 1 km = 5 cm) Using a protractor and a ruler, plot the directions of each individual or group that sang, using a line the same length as the estimated distance extending from the LP. All teams at all LPs plotted their songs heard on the same map. Gibbon groups heard by more than one team were exactly located by the intersection of the lines by **triangulation**.

When all teams plotted their song locations on a map, it were possible to estimate the total number of groups heard from the map.

In order to estimate the density of groups per km^2, it is necessary to estimate the total **listening area** within which all groups are believed to be audible. This can be done by studying the topographic features on the map, as one cannot hear groups located behind hills or ridges. If the terrain is too flat to do this, one can simply include all area within 1 km of the listening posts, and estimate the density from the number of groups that are mapped within that area (Brockelman and Srikosamatara, 1993).

Density of gibbon groups was calculated based on the formula below.

$$\text{Density of gibbon groups} = \frac{\text{Number of gibbon group}}{\text{Listening Area}}$$

Correlation between densities and habitat condition

Siamang and agile gibbon densities in each LA were correlated with habitat characteristics in each LA such as mean canopy height, number of trees (> 10 cm dbh, > 20 cm dbh, > 40 cm dbh, > 80 cm dbh), basal area of trees (> 10 cm dbh, > 20 cm dbh), altitude (mean sea level). Using the Correlation Coefficient in program SPSS version 15. Test significance of Correlation Coefficient (*r*) by converting *r* to a *t* value (divide *r* by the Standard Error (S.E.) of *r*).

Habitat selection of siamang

Habitat attributes of 19 groups of siamang were compared with habitat attributes of 30 randomly selected (from 4203) 1 ha-grids without siamang. Eight characteristics of grids were tested for normal distribution by Kolmogorov-Smirnov test (program SPSS version 15.0). Means of four characteristics, which were normally distributed, were compared between grids with siamang and grids without siamang, by t-test (program SPSS version 15.0). Four characteristics, which were not normally distributed, were compared between grids with siamang and grids without siamang by Mann-Whitney *U* test.

Habitat selection of agile gibbons

Habitat attributes of 136 groups of agile gibbon were compared with habitat attributes of 150 randomly selected (from 2214) 1-ha grids without agile gibbons. Eight characteristics of their grids were tested for normal distribution by Kolmogorov-Smirnov test (program SPSS version 15.0). Mean altitude (which was normally distributed) was compared between grids with agile gibbon and grids without agile gibbon by t-test (program SPSS version 15.0). Mean of seven characteristics (which were not normally distributed) was compared between grids with agile gibbon and grids without agile gibbon by Mann-Whitney *U* test (program SPSS version 15.0).

Comparison of habitat selection between siamang and agile gibbons

Habitat attributes of 19 groups of siamang were compared with habitat attributes of 136 groups of agile gibbon. Eight characteristics of their grids were tested for normal distribution by Kolmogorov-Smirnov test (by program SPSS version 15.0). Mean distance from village, which was normally distributed, were compared by t-test (program SPSS version 15.0). Means of seven characteristics, which were not normally distributed, were compared by Mann-Whitney *U* test (by program SPSS version 15.0).

Discriminant Analysis

Discriminant Analysis was applied to determine factors influencing the presence or absence of siamang and agile gibbons in each grid. Discriminant analysis requires multivariate normal distributions and equal variance-covariance. Results of Discriminant Analysis were 3 functions for determining the factors which influenced the presence or absence of siamang, presence or absence of agile gibbons, and factors influencing the habitat selection of siamang and agile gibbons.

CHAPTER 3

Result

Thirteen listening areas were established in 2005 for siamang and agile gibbon distribution censuses in Bala Forest. Overall 19 groups of siamang and 136 groups of agile gibbons were found in 60 km^2. The siamang groups were most dense in the southwest of Bala Forest (Fig. 4), but agile groups tended to be more widely distributed (Fig. 5).

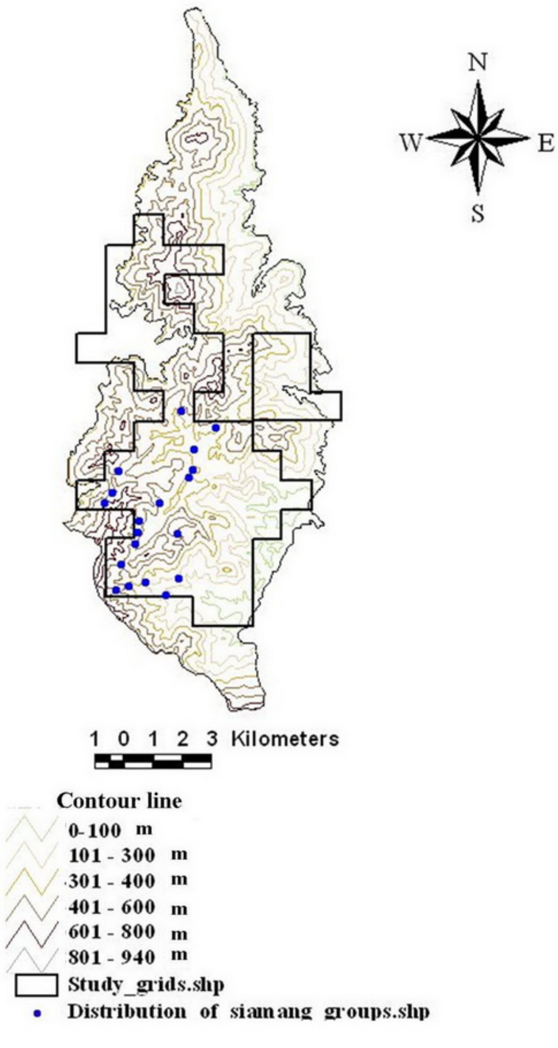

Figure 4. Distribution of siamang in study grid area. All square kilometers containing parts of listening areas are outlined.

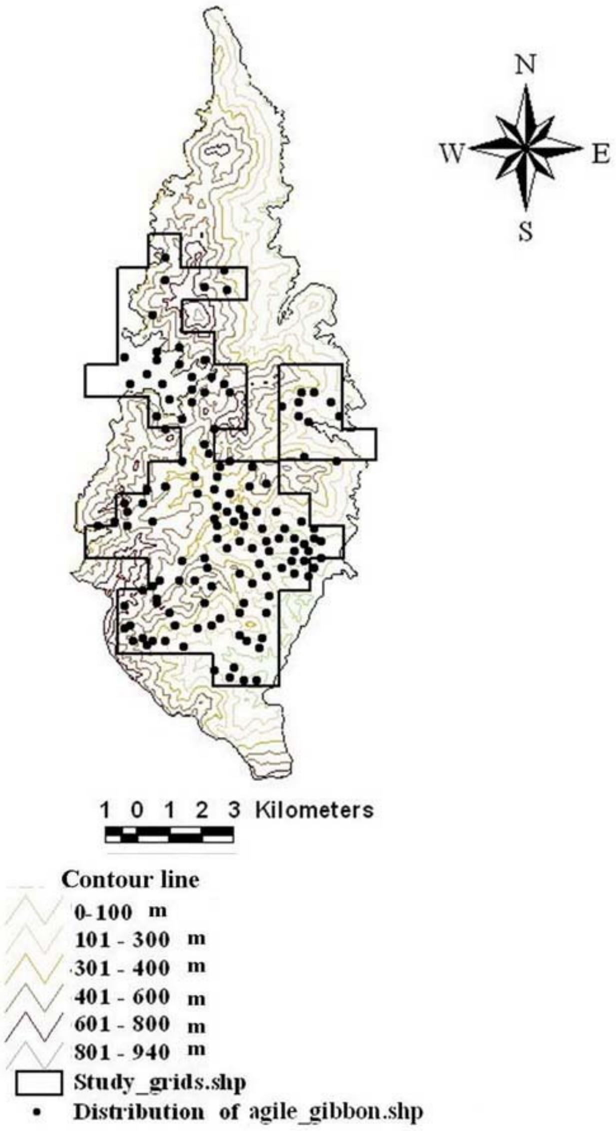

Figure 5. Distribution of agile gibbons in study grid area. All square kilometers containing parts of listening areas are outlined.

Gibbon density

The 13 sites (listening area) are listed in Table 1 along with mean altitude, date of census, area of each LA, and densities of siamang groups and agile gibbon groups in Bala forest.

Table 1. List of census listening areas, number of gibbons, and group density in each sampling area in Bala Forest.

LA	Date	Mean altitude msl (m)	Area (km^2)	Agile gibbon		Siamang	
				No. groups	Density (groups / km^2)	No. groups	Density (groups / k m^2)
1	22 April 05	424	5.8	15	2.59	3	0.52
2	4 May 05	134	7.5	21	2.8	0	0
3	9 May 05	123	5.8	16	2.76	0	0
4	6 June 05	748	7.6	8	1.05	0	0
5	10 June 05	348	7.9	16	2.03	1	0.13
6	8 July 05	583	5.4	12	2.22	0	0
7	13 July 05	372	7	22	3.14	3	0.43
8	19 July 05	642	4.9	16	3.27	7	1.43
9	10 August 05	132	6.5	13	2	2	0.31
10	16 August 05	425	5.8	11	1.9	1	0.17
11	24 August 05	636	4.3	10	2.33	3	0.7
12	7 Sept.05	231	5.2	10	1.92	0	0
13	21 Sept. 05	601	6.8	10	1.47	4	0.59
Total			80.5	180	2.24	24	0.3
Total without overlapping area			60.2	136	2.27	19	0.32

The density of siamangs group ranged from 0.00 to 1.43 groups km^{-2} (mean = 0.32 ±S.E. 0.08 groups km^{-2}). Considering only 8 Listening areas where siamang was found (LA 1, 5, 7, 8, 9, 10, 11, 13), the densities of groups ranged from 0.13 to 1.43 groups km^{-2} (mean = 0.53 ±S.E. 0.08 groups km^{-2}). Mean density of groups in distribution sites (LA 1, 5, 7, 8, 9, 10, 11, 13) of Bala Forest was 0.53 groups km^{-2} (±S.E. = 0.15).

Agile gibbons were found in all 13 sites, and densities ranged from 1.05 to 3.27 groups km^{-2}. Mean density in Bala Forest was 2.27 groups km^{-2} (±S.E. = 0.177).

Forest canopy in 1-ha plots

The distribution of height of the upper surface of the canopy was plotted in 20-m interval for each of the 13 1-ha plots (LA) in Bala Forest (Table 2). Most of the LAs had mean heights greater than 20 m, and nine LAs had mean canopy heights of 25 m or more, which is characteristic of tropical rainforest in this region (Table 3). Four LA, however, (LA 9, LA11, LA3, LA4) had mean canopy heights below 25 m. LA9 ,had mean canopy height below 20 m, and LA3 was a secondary forest which was plantation and selectively logged about 15 year ago. LA11 near the road was clear-cut about 15 years ago. LA4 (land high habitat) was covered with dense bamboo.

Table 2. Forest canopy characteristics and tree densities in 1-ha forest plots within listening areas in Bala Forest.

LA	Dominant canopy height class (m)	Mean of canopy height (m)	S.D.	Number of tree				Tree basal area	
				>10 cm dbh	> 20 cm dbh	> 40 cm dbh	> 80 cm dbh	>10 cm dbh (m^2)	> 20 cm dbh (m^2)
1	20-24	25.28	10.45	286	133	44	12	26.3	23.7
2	25-29	27.61	9.9	222	109	30	6	17	15
3	25-29	23.65	10.61	331	154	50	9	27.9	25.1
4	20-24	24.79	9.87	302	161	53	10	31.1	28.5
5	25-29	27.95	12.1	420	205	61	14	36.4	32.8
6	35-39	28.49	12.22	367	175	51	20	40.1	36.9
7	20-24	27.88	11.39	430	207	46	7	31.4	27.9
8	30-34	28.86	12.71	351	178	60	18	41.2	38.5
9	15-19	19.23	8.46	264	122	34	5	18.4	16
10	25-29, 35-39	29.46	13.88	294	135	40	17	33.9	31.2
11	0-4, 25-29	22.51	13.3	244	118	29	7	21.1	19.1
12	15-19	25.81	13.91	316	140	38	9	29.8	26.9
13	35-39	31.34	12.78	302	149	58	15	36.3	33.8

Relationship between density and forest canopy

The densities of listening areas were plotted against several forest characteristics. These characteristics include mean canopy height, basal area of trees over 10 and 20 cm dbh, number of trees over 10, 20, 40, 80 cm dbh, and mean altitude. Data for listening areas of Bala forest are shown in Table 2. It was predicted that density would be positively related to these forest characteristics but in no case was the relationship significant. The density of siamang was positively related to mean canopy height (r = 0.175) and altitude (r = 0.435) but non-significantly related with most forest characteristics (Table 3). When density of siamang was considered only where it was found (such as LA 1, 5, 7, 8, 9, 10, 11, 13) it was relate to forest characteristics. Only altitude was significantly positively related with density of siamang (r = 0.810, p = 0.015) (Table 3; Fig. 6).

The density of agile gibbons was positively related to number of trees > 10 cm dbh (*r* = 0.179), and number of trees > 20 cm dbh (*r* = 0.132). Density of agile gibbons was negatively related to number of trees > 80 cm dbh (*r* = -0.165), basal area of tree > 20 cm dbh (r = -0.154), 40 cm dbh (r = -0.192), 80 cm dbh (r = -0.192), and altitude (*r* = -0.214) (Table 3).

Relationship between altitude with siamang and agile gibbon density in listening areas were shown in Fig. 6 and Fig. 7.

Table 3. Correlation coefficient (r) of habitat characters and gibbons density.

Habitat characters	Siamang density in Bala		Agile gibbon density in Bala
	all 13 LA	only siamang's habitat	
mean of canopy height	0.175	0.024	-0.06
number of tree > 10 cm dbh	-0.096	-0.214	0.179
number of tree > 20 cm dbh	-0.017	-0.214	0.132
number of tree > 40 cm dbh	0.062	-0.071	-0.077
number of tree > 80 cm dbh	0.116	0.180	-0.165
basal area of tree > 10 cm dbh	0.158	0.071	-0.071
basal area of tree > 20 cm dbh	0.153	0.190	-0.154
basal area of tree > 40 cm dbh	0.062	0.214	-0.192
basal area of tree > 80 cm dbh	0.051	0.143	-0.192
altitude	0.435	0.810 (*)	-0.214

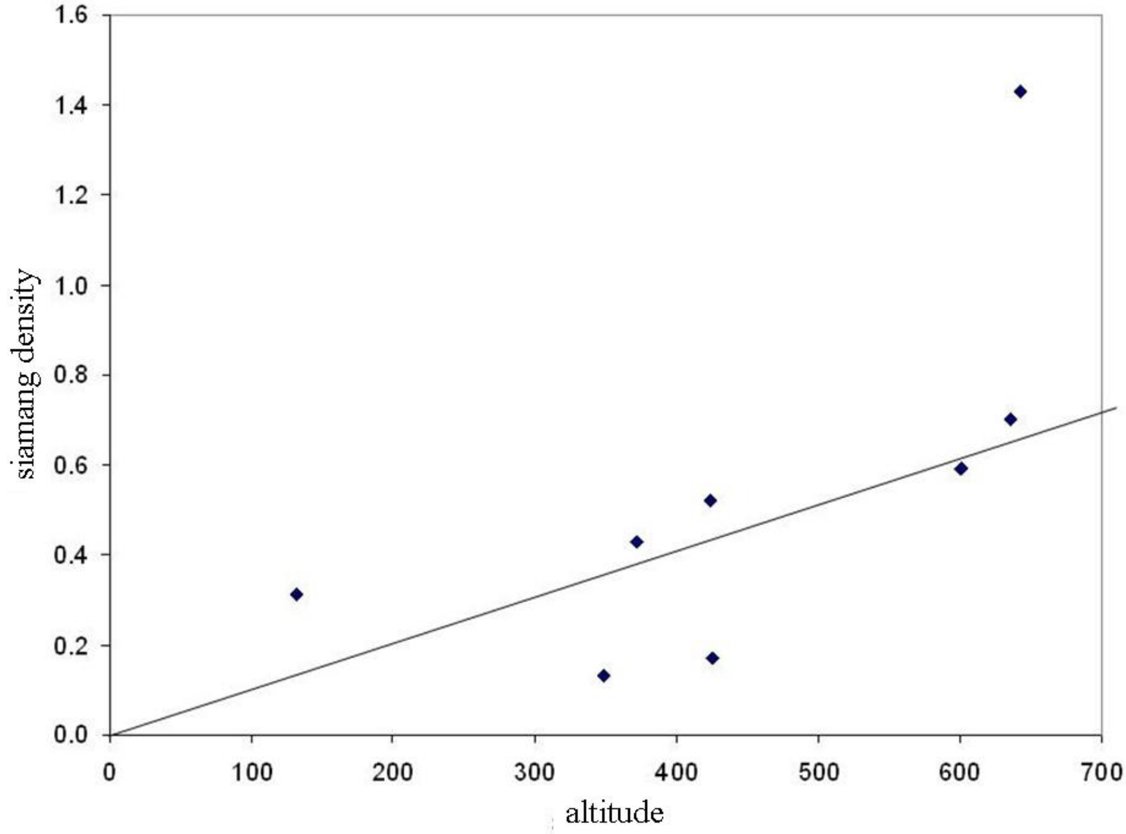

Figure 6. Relationship between altitude and siamang density in listening areas were siamang were heard.

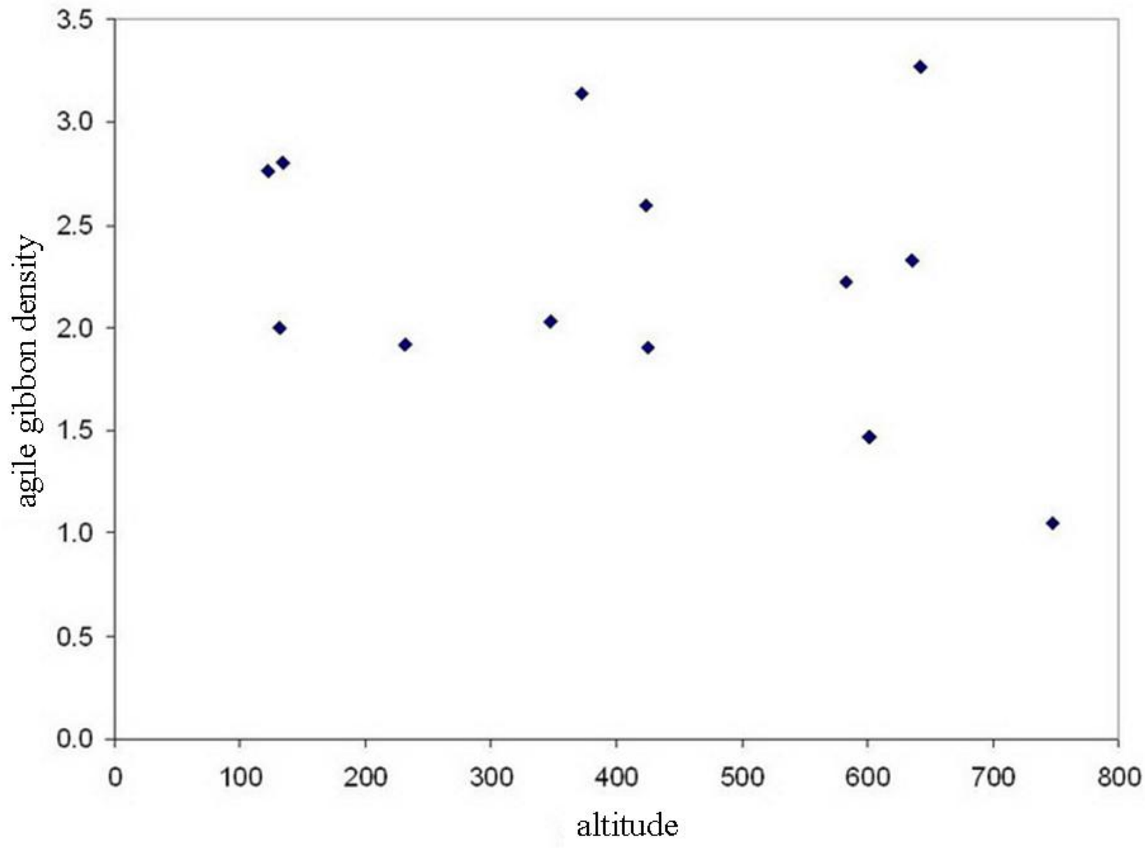

Figure 7. Relationship between altitude and agile gibbon density in listening areas were agile gibbons were heard.

Habitat selection of siamang

Nineteen grids with siamang which were categorised at 1-ha grid centers of group ranges and 30 grids without siamang (1-ha grid) selected randomly from 4203 grids without siamang, were compared with respect to mean of 8 factors (Table 4).

Table 4. Characteristics of 1-ha grids without siamang and grids with siamang.

No.	Characteristic	Mean		Kolmogorov-Smirnov test		*t*-test		Mann-Whitney test	
		Grids without siamang	Grids with siamang	Statistic	Sig.	*t*	Sig.	*U* test	Sig.
1	altitude	387 m.	478 m.	0.118	0.086	-2.488	0.016*		
2	distance from ridge	173 m.	90 m.	0.261	0.000			-2.236	0.025*
3	slope direction near east	1.1518	1.596	0.209	0.000			-2.596	0.009**
4	slope value	0.326	18.421	0.348	0.000			-5.863	0.000**
5	distance from road	3371 m.	1708 m.	0.094	0.200(*)	3.245	0.002**		
6	distance from village	3900 m.	5944 m.	0.083	0.200(*)	-5.484	0.000**		
7	distance from stream	323 m.	203.979	0.135	0.027			-1.375	0.169
8	distance from edge	1237m.	1620 m.	0.096	0.200(*)	-1.376	0.175		

* = $p < 0.05$, ** = $p < 0.01$

Mean characteristic of grids without siamang were compared with grids with siamang. It was found that 6 factors (altitude, distance from ridge, slope direction near east, slope value, distance from road, distance from village) were statistically significantly different (Table 4). Grids with siamang had higher altitude, higher slope value, greater distance from village, but shorter distance from ridge, shorter slope direction near east, shorter distance from road, than grids without siamang.

Habitat selection of agile gibbons

From listening areas (LA) in 60 km^2 (Table 1), 136 agile grids which were categorised as 1-ha grid center of group distributions and 150 grids (1-ha grid) that were randomly selected from 2214 grids without agile gibbons were compared with respect to 8 factors based on topographic maps and satellite maps of Bala Forest (Table 5).

Table 5. Characteristics of 1-ha grids without agile gibbons and grids with agile gibbons.

No.	Characteristic	Mean		Kolmogorov -Smirnov test		*t*-test		Mann-Whitney	
		Grids without agile	Grids with agile	Statistic	Sig.	*t*	Sig.	*U* test	Sig.
1	altitude	437 m.	361 m.	0.05	0.083	3.786	0.000**		
2	distance from ridge	183 m.	119 m.	0.11	0.000			-5.007	0.000**
3	slope direction near east	0.936	0.955	0.12	0.000			-0.191	0.848
4	slope value	0.366	0.368	0.092	0.000			-0.119	0.905
5	distance from road	3430 m.	2214 m.	0.103	0.000			-4.462	0.000**
6	distance from village	4255 m.	4754 m.	0.063	0.008			-2.435	0.015*
7	distance from stream	293 m.	239 m.	0.08	0.000			-2.369	0.018*
8	distance from edge	989 m.	1402 m.	0.095	0.000			-3.581	0.000**

* = $p < 0.05$, ** = $p < 0.01$

I compared mean characteristic of grids without agile with those with agile. It was found that 6 factors (altitude, distance from ridge, distance from road, distance from village, distance from stream, and distance from edge) were significantly different (Table 5). Grids with agile had lower altitude, shorter distance from ridge, shorter distance from road, shorter distance from stream but greater distance from village, and greater distance from edge than grids without agile gibbons.

Difference of habitat selection between siamang and agile gibbons

A total of 19 grids with siamang were compared with 136 grids with agile gibbons with respect to means of 8 factors (Table 6).

Table 6. Characteristics of 1-ha grids with siamang and grids with agile gibbons.

No.	Characteristic	Mean		Kolmogorov-Smirnov test		*t*-test		Mann-Whitney	
		grids with agile	grids with siamang	Statistic	Sig.	*t*	Sig.	*U* test	Sig.
1	altitude	361 m.	478 m.	0.078	0.022			-3.244	0.001**
2	distance from ridge	119 m.	90 m.	0.153	0			-1.167	0.243
5	slope direction near east	0.955	1.596	0.118	0			-3.918	0.000**
6	slope value	0.368	18.421	0.485	0			-7.075	0.000**
7	distance from road	2214 m.	1708 m.	0.107	0			-1.009	0.313
8	distance from village	4754 m.	5944 m.	0.068	0.078	-3.593	0.000**		
9	distance from stream	239 m.	204 m.	0.091	0.003			-0.567	0.57
10	distance from edge	1402 m.	1621 m.	0.076	0.03			-1.113	0.266

* = $p < 0.05$, ** = $p < 0.01$

I compared mean characteristic of grids with siamang with grids with agile gibbons. It was found that 4 factors (altitude, slope direction near east, slope value, and distance from village) were statistically significantly different (Table 6). Grids with siamang had higher altitude, slope direction near east, higher slope value, and greater distance from village than grids with agile gibbons.

Discriminant Analysis for siamang

Eight factors (altitude, distance from ridge, slope direction near east, slope value, distance from road, distance from village, distance from stream, and distance from edge) were descriptive characters of siamang habitat. Discriminant function analysis was based on 3 factors (altitude, slope direction near east, and distance from edge) although only altitude and distance from edge were found to be normally distributed and slope direction near east was not normally distributed.

The assumption of equal population covariance matrices was met since Box'M test was not significant (p = 0.211) (Table 7).

Table 7. Results of Box's Test of Equality of Covariance Matrices for grids without siamang and grids with siamang by altitude, slope direction near east, and distance from edge**.**

Box's M		9.070
F	Approx.	1.398
	df1	6.000
	df2	9729.117
	Sig.	0. 211

From the degree of correlation between discriminating variables and standardized canonical discriminant function 1 (Table 8), altitude was the most important factor in discriminating between habitat with siamang and habitat without siamang. In addition, slope direction near east, and distance from edge were fairly important.

Table 8. Pooled within-group correlations between discriminating variables and standardized canonical discriminant function.

	Correlation
	Function 1
altitude	0.776
slope direction near east	0.665
distance from edge	0. 347

Classification Function Coefficients

Occurrence of siamang in the study site of Bala Forest was classified by function coefficients of Fisher's linear discriminant function (Table 9) for measurement discriminant scores.

Table 9. Classification of Fisher's linear discriminant functions coefficients of grids without siamang and grids with siamang.

Factors	Occurrence	
	Grids without siamang	Grids with siamang
altitude	0.0284319	0.0355034
distance from edge	0.0014188	0.0018332
slope direction near east	3.1296977	4.2378445
(Constant)	-8.8718659	-14.043756

Discriminant score for grids with siamang (Table 9) is

D_1 (grids with siamang) = (-14.043756) + 0.0355034 altitude + 0.0018332 distance from edge + 4.2378445 slope direction from east

Discriminant score for grids without siamang (Table 9) is

D_2 (grids without siamang) = (-8.8718659) + 0.0284319 altitude + 0.0014188 distance from edge + 3.1296977 slope direction from east

Fisher's Linear Discriminant Function

In case of two groups discriminant, its discriminant score was $D^{\wedge} = D_1 - D_2$ from classification function (Table 9).

$D^{\wedge}$= ((-14.043756) - (-8.8718659)) + (0.0355034 - 0.0284319) altitude + (0.0018332 - 0.0014188) distance from edge + (4.2378445 - 3.1296977) slope direction near east

$D^{\wedge}$= (-5.1718901) + (0.0070715) altitude + (0.0004144) distance from edge + (1.1081468) slope direction near east

Canonical Discriminant Function

The Canonical Discriminant Function of grids without agile and grids with agile (Table 14) was D = (-4.4164602) + 0.0062132 altitude + 0.0003641 distance from edge + 0.9736576 slope direction near east. This function was similar in pattern with Fisher's linear discriminant function (Table 10). Distribution of canonical discriminant function of grids with siamang and grids without siamang are shown in Fig. 8 and Fig. 9.

Table 10. Coefficients of Canonical Discriminant Function of grids without siamang and grids with siamang.

Factors	Function 1
altitude	0.0062132
distance from edge	0.0003641
slope direction near east	0.9736576
(Constant)	-4.4164602

Canonical Discriminant Function 1

Grids without siamang

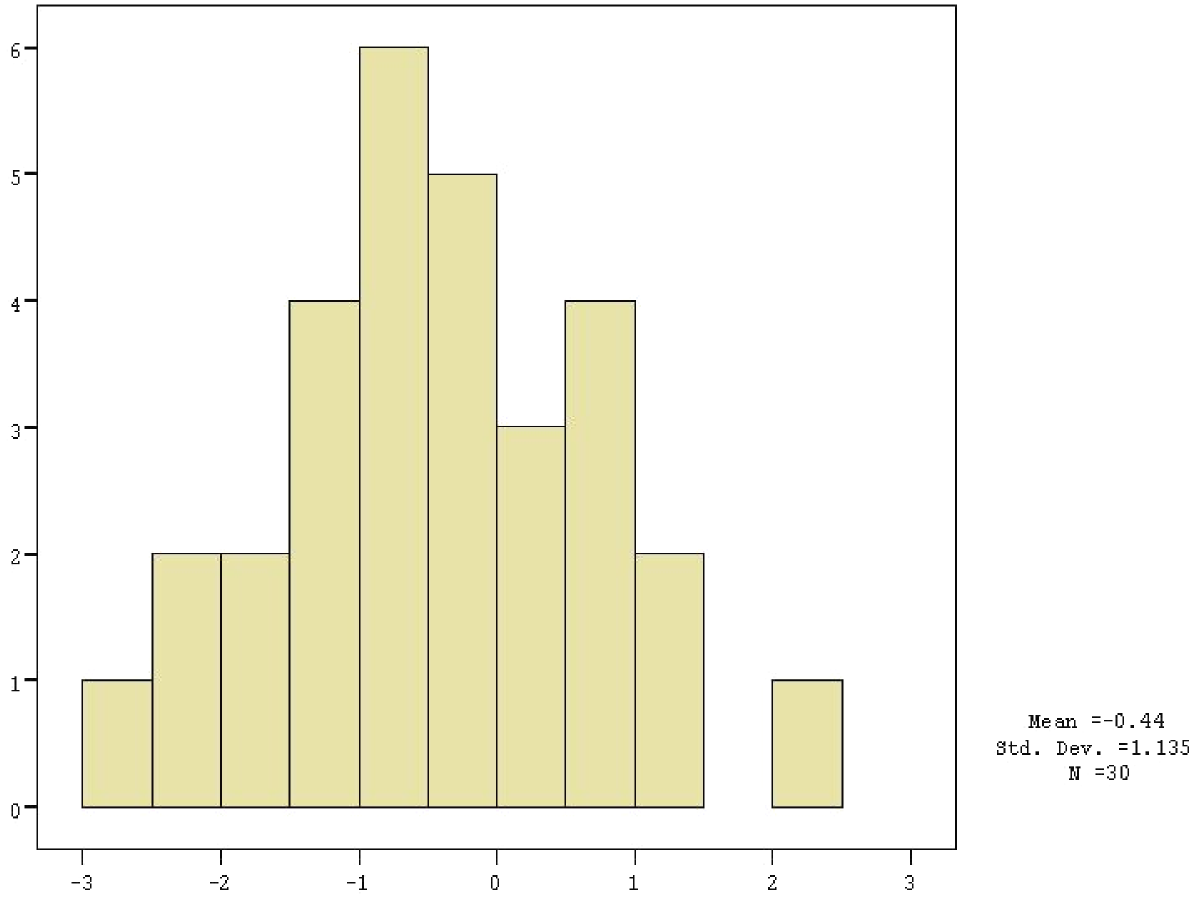

Figure 8. Distribution of canonical discriminant function scores of grids without siamang.

Canonical Discriminant Function 1

Grids with siamang

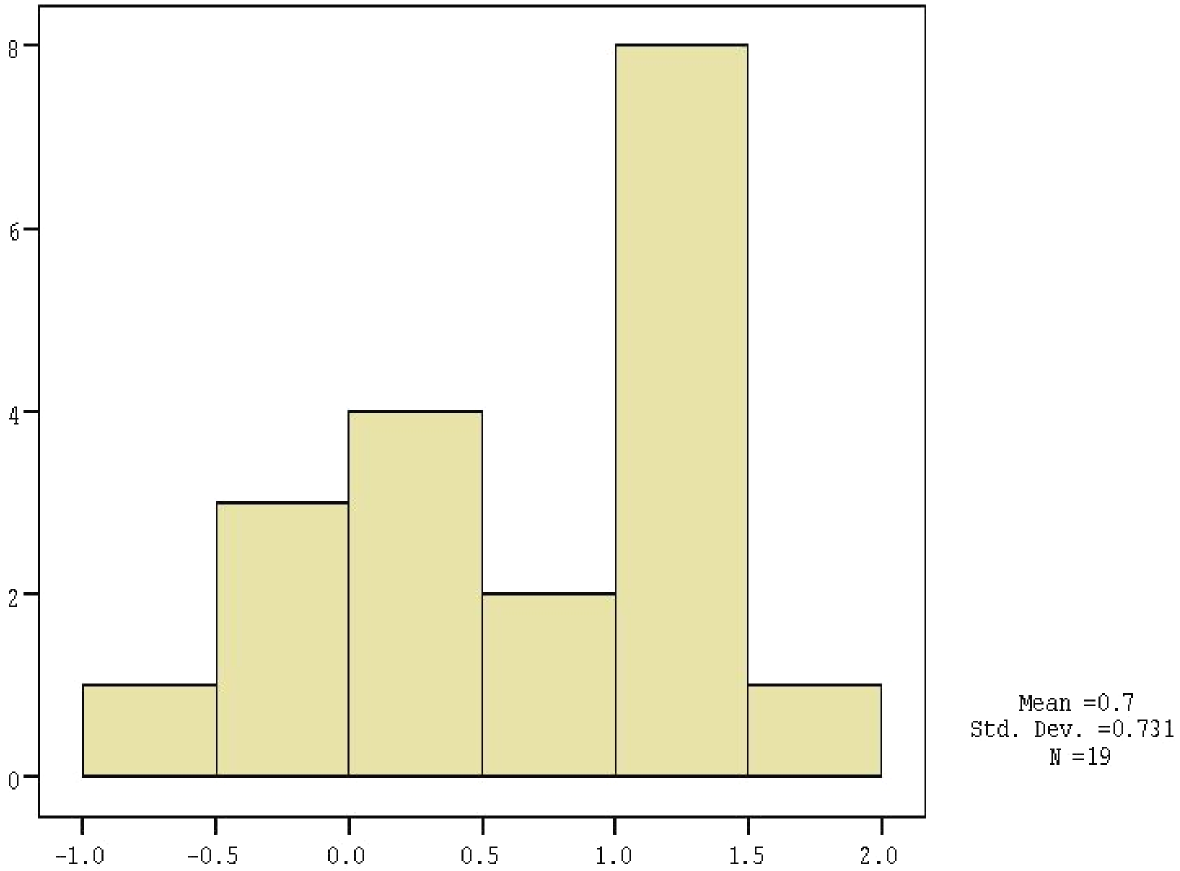

Figure 9. Distribution of canonical discriminant function scores of grids with siamang.

Discriminant Analysis for agile gibbons

Eight factors (altitude, distance from ridge, slope direction near east, slope value, distance from road, distance from village, distance from stream, and distance from edge) were descriptive characters of agile gibbon's habitat. Discriminant function analysis was based on 4 factors (altitude, distance from ridge, slope direction near east, distance from stream, and distance from edge) even though all 4 factors were not normally distributed.

Table 11. Results of Box's Test of Equality of Covariance Matrices for grids without agile and grids with agile by altitude, distance from ridge, distance from stream and distance from edge.

Box's M		19.448
F	Approx.	1.915
	df1	10.000
	df2	377283.504
	Sig.	0. 038

From degree of correlation between discriminating variables and standardized canonical discriminant function 1 (Table 12), distance from ridge and altitude were the most important factors in discriminating between habitat with agile and habitat without agile. In addition, distance from stream and slope direction near east were fairly important.

Table 12. Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions.

	Correlation
	Function 1
distance from ridge	0.878
altitude	0.601
distance from stream	0.351
slope direction near east	-0.034

Classification Function Coefficients

Occurrences of agile gibbon in study site of Bala Forest were classified by function coefficients of Fisher's linear discriminant function (Table 13) for measurement discriminant score. That was used to predict the occurrence of agile gibbons outside the study site of Bala Forest.

Table 13. Classification of Fisher's linear discriminant functions coefficients of grids without agile gibbons and grids with agile gibbons.

Factors	Occurrence	
	Grids without agile gibbons	Grids with agile gibbons
altitude	0.0163891	0.0131219
distance from ridge	0.0260000	0.0179329
slope direction near east	2.0750403	2.1206572
distance from stream	0.0092071	0.0074134
(Constant)	-8.9793024	-6.0231278

Discriminant score for grids with agile gibbon (Table 13) is

D_1 (grids with agile) = (-6.0231278) + 0.0131219 altitude + 0.0179329 distance from ridge + 2.1206572 slope direction near east + 0.0074134 distance from stream

Discriminant score for grids without agile gibbon (Table 13) is

D_2 (grids without agile) = (-8.9793024) + 0.0163891 altitude + 0.0260000 distance from ridge + 2.0750403 slope direction near east + 0.0092071 distance from stream

Fisher's Linear Discriminant Function

In case of two groups discriminant, its discriminant score was $D^{\wedge} = D_1 - D_2$ from classification function coefficients (Table13).

$D^{\wedge}$= ((-6.0231278) - (-8.9793024)) + (0.0131219 - 0.0163891) altitude + (0.0179329 - 0.0260000) distance from ridge + (2.1206572 - 2.0750403) slope direction near east + (0.0074134 - 0.009207) distance from stream

$D^{\wedge}$= (2.9561746) + (-0.0032672) altitude + (-0.0080671) distance from ridge + 0.0456169 slope direction near east + (-0.0017937) distance from stream

Canonical Discriminant Function

Canonical Discriminant Function of grids without agile and grids with agile (Table 10) was D = (-3.1949872) + 0.0035059 altitude + 0.0086566 distance from ridge + (-0.0489501) slope direction near east + 0.0019248 distance from stream. This function has a similar pattern with Fisher's linear discriminant function (Table 14). Distribution of canonical discriminant function scores of grids with agile and grids without agile are shown in Fig. 10 and Fig. 11.

Table 14. Coefficients of Canonical Discriminant Function of grids without agile gibbons and grids with agile gibbons.

Factors	Function 1
altitude	0.0035059
distance from ridge	0.0086566
slope direction near east	-0.0489501
distance from stream	0.0019248
(Constant)	-3.1949872

Canonical Discriminant Function 1

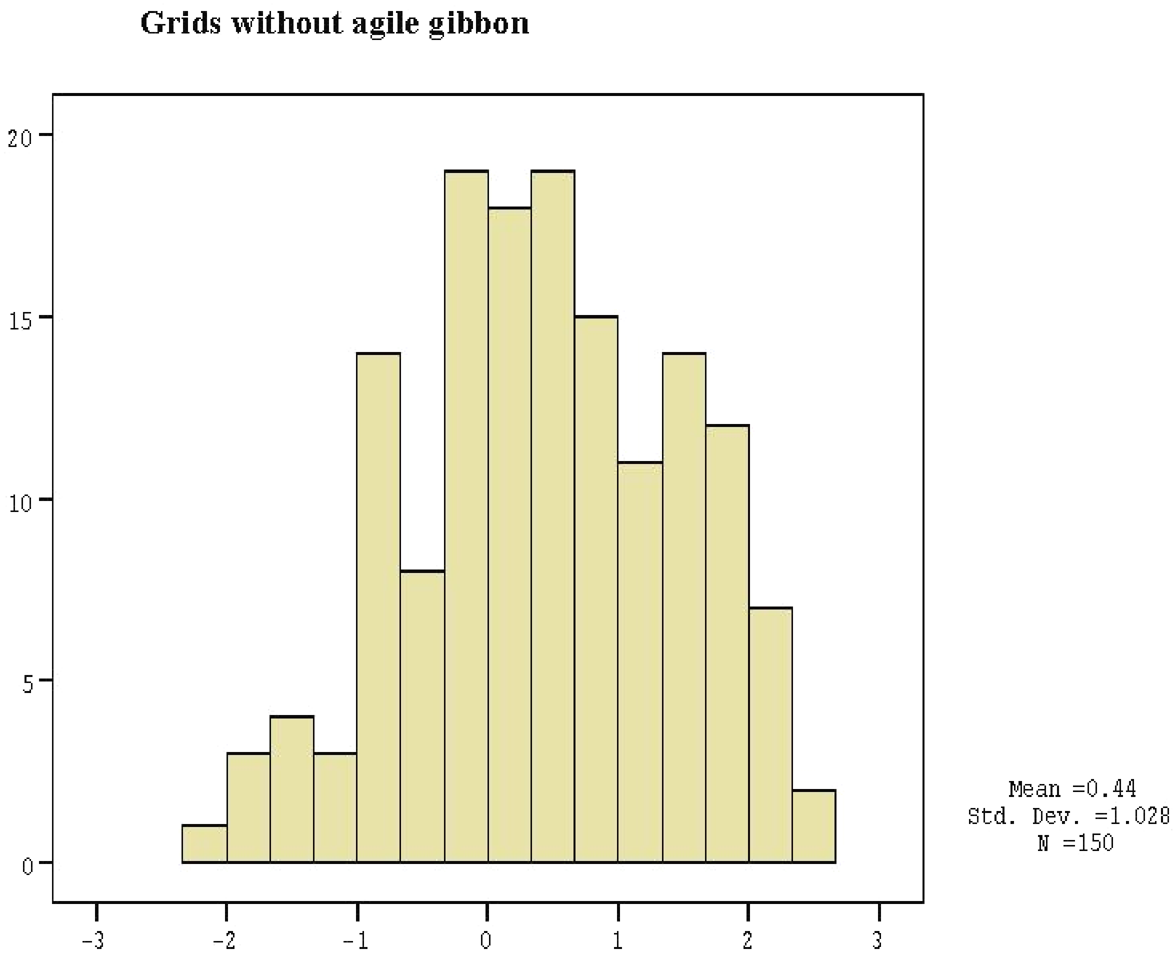

Figure 10. Distribution of canonical discriminant function scores of grids without agile.

Canonical Discriminant Function 1

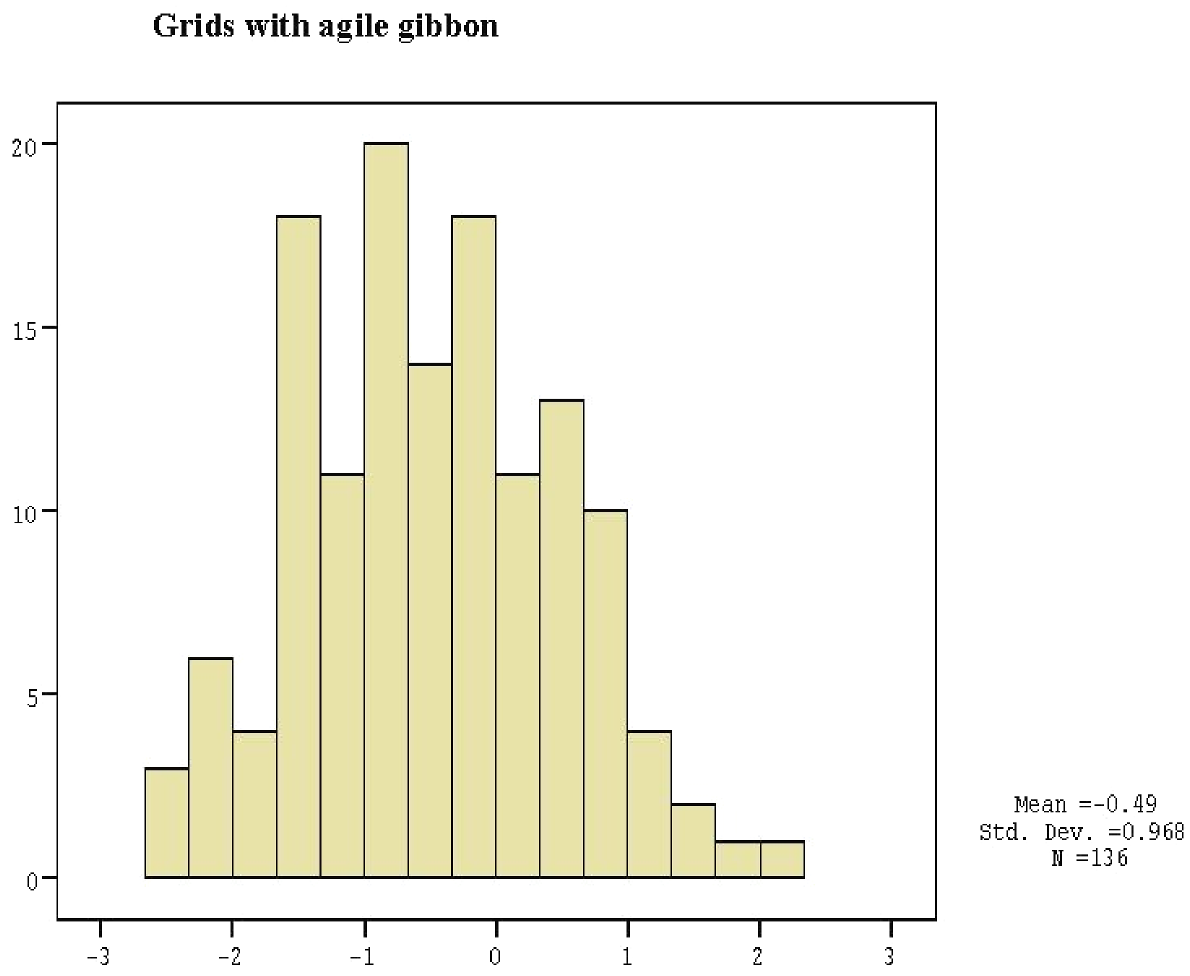

Figure 11. Distribution of canonical discriminant function scores of grids with agile.

Utilizable habitat areas of siamang

From Fisher's Linear Discriminant Function, discriminant scores ($D^{\wedge}$) were used to predict the occurrence of siamang in unstudied areas in Bala forest. The factors used for predicting the occurrence of siamang in 117 grids (1 km^2-grid), total area of Bala Forest, were altitude, slope direction near east, and distance from edge (Table 9). Total 117 discriminant scores were calculated, grids with siamang have score more than 0 that were suitable areas for siamang gibbon. If the score of grids without siamang ranged less than 0, that were unsuitable areas (Table 15).

The discriminant equation for predict occurrence of siamang in Bala forest were $D^{\wedge}$= (-5.1718901) + (0.0070715) altitude + (0.0004144) distance from edge + (1.1081468) slope direction near east.

Table 15. Available areas for siamang use classified by discriminant scores in Bala Forest.

No.	Available classified areas	Discriminant score	Area (km^2)
1	suitable areas for siamang	>0.00	56
2	unsuitable areas for siamang	<0.00	61
	area ocupied siamang in study site		15

There are 56 km^2 of areas that agile gibbon can be found (47.86 percent of all classified areas in Bala Forest) (Fig. 13). Beside areas the siamang cannot be found in 61 km^2 (52.14 percent of all classified areas in Bala Forest), there were unsuitable areas.

From degree of correlation between discriminating variables and standardized canonical discriminant function 1 (Table 8), altitude and slope direction near east were the most important factors in discriminating between habitat with siamang and habitat without siamang. These factors were plotted to describe relationship between unsuitable areas and suitable areas for siamang (Table 15) base on habitat of siamang are higher altitude and more slope direction near east (Fig. 12).

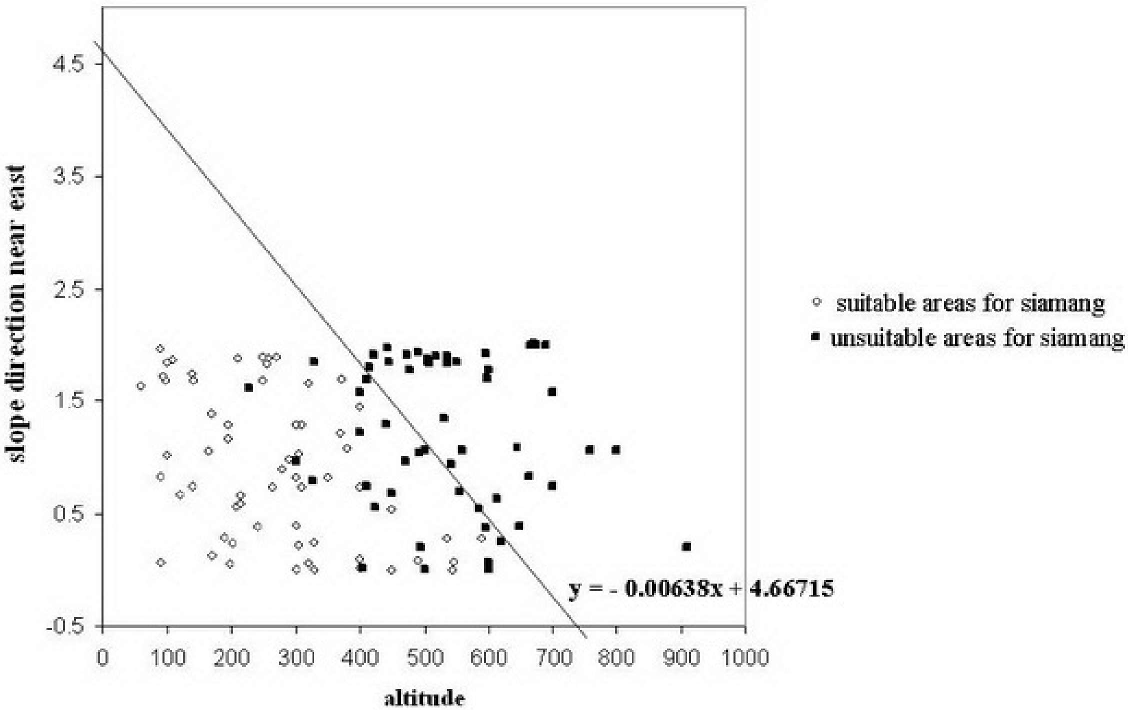

Figure 12. Distribution of altitude and slope direction near east of unsuitable areas and suitable areas of siamang and linear equation of discriminant from Table 9.

Relationship altitude (x) and slope direction near east (y) of unsuitable and suitable areas of siamang was calculated. Linear equation of discriminant of altitude (x) and slope direction near east (y) from Table 9 are shown (Fig. 12):

$D^{\wedge}$= (-5.1718901) + (0.0070715) altitude + (1.1081468) slope direction near east.

$D^{\wedge}$= 0, $0.0070715x + 1.1081468y = 5.1718901$

$$y = - 0.00638x + 4.66715$$

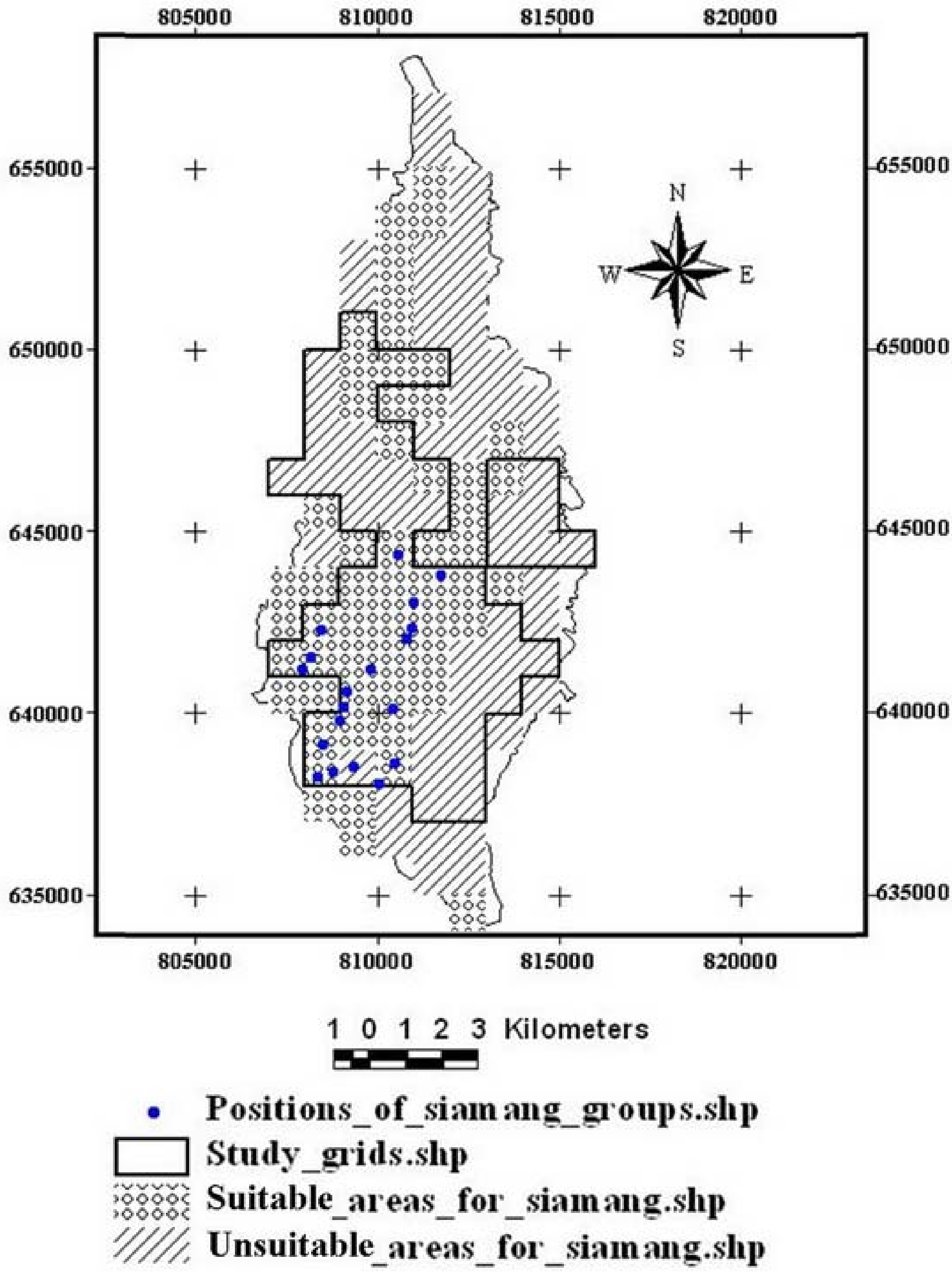

Figure 13. Map of available habitat for siamang in Bala Forest**.**

Utilizable habitat areas of agile gibbons

Fisher's Linear Discriminant Function, discriminant scores ($D^{\wedge}$) were used to predict the occurrence of agile gibbon in unstudied areas in Bala forest same pattern of siamang. All 117 grids (1 km^2-grid) of Bala Forest, total area of Bala Forest, were measured of their 4 factors (altitude, distance from ridge, slope direction near east, and distance from stream) (Table 13). A total 117 discriminant scores were calculated and grids with agile had scores more than 0, that were suitable areas for agile gibbon. If the score of grids without agile ranged less than 0, that were considered unsuitable areas (Table 16).

The discriminant equation for predicted occurrence of agile gibbon in Bala forest were $D^{\wedge}$= (2.9561746) + (-0.0032672) altitude + (-0.0080671) distance from ridge + 0.0456169 slope direction near east + (-0.0017937) distance from stream.

Table 16. Available areas for agile gibbon use classified by discriminant scores in Bala Forest.

No.	Available classified areas	Discriminant score	Area (km^2)
1	suitable areas for agile gibbon	>0.00	54
2	unsuitable areas for agile gibbon	<0.00	63
	area occupied agile gibbons in study site		50

There are 54 km^2 of areas that agile gibbon were found (46.15 percent of all classified areas in Bala Forest) (Fig. 15). Beside areas the agile cannot be found in 63 km^2 (53.84 percent of all classified areas in Bala Forest), there were unsuitable areas.

Considered degree of correlation between discriminating variables and standardized canonical discriminant function 1 (Table 12), distance from ridge and altitude were the most important factors in discriminating between habitat with agile and habitat without agile. These factors were plotted to describe relationship between unsuitable areas and suitable areas for agile gibbons (Table 16) base on habitat of agile are low altitude and shorter distant from ridge (Fig. 14).

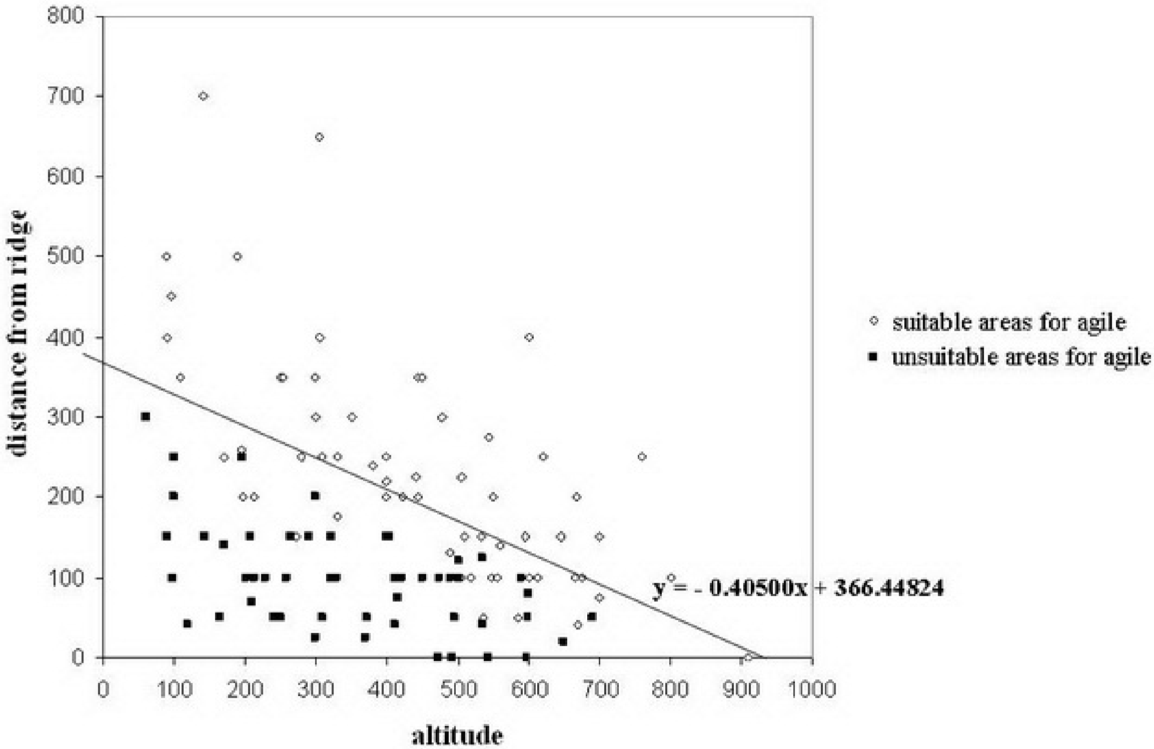

Figure. 14 Distribution of altitude and distance from ridge of unsuitable areas and suitable areas of agile gibbons and linear equation of discriminant from Table 13.

Relationship altitude (x) and distance from ridge (y) of unsuitable and suitable areas of agile gibbon. Linear equation of discriminant of altitude (x) and distance from ridge (y) from Table 13 was shown (Fig. 14):

$\hat{D}$ = (2.9561746) + (-0.0032672) altitude(x) + (-0.0080671) distance from ridge(y);

$\hat{D} = 0$, $0.0032672x + 0.0080671y = 2.9561746$

$y = -0.40500x + 366.44824$

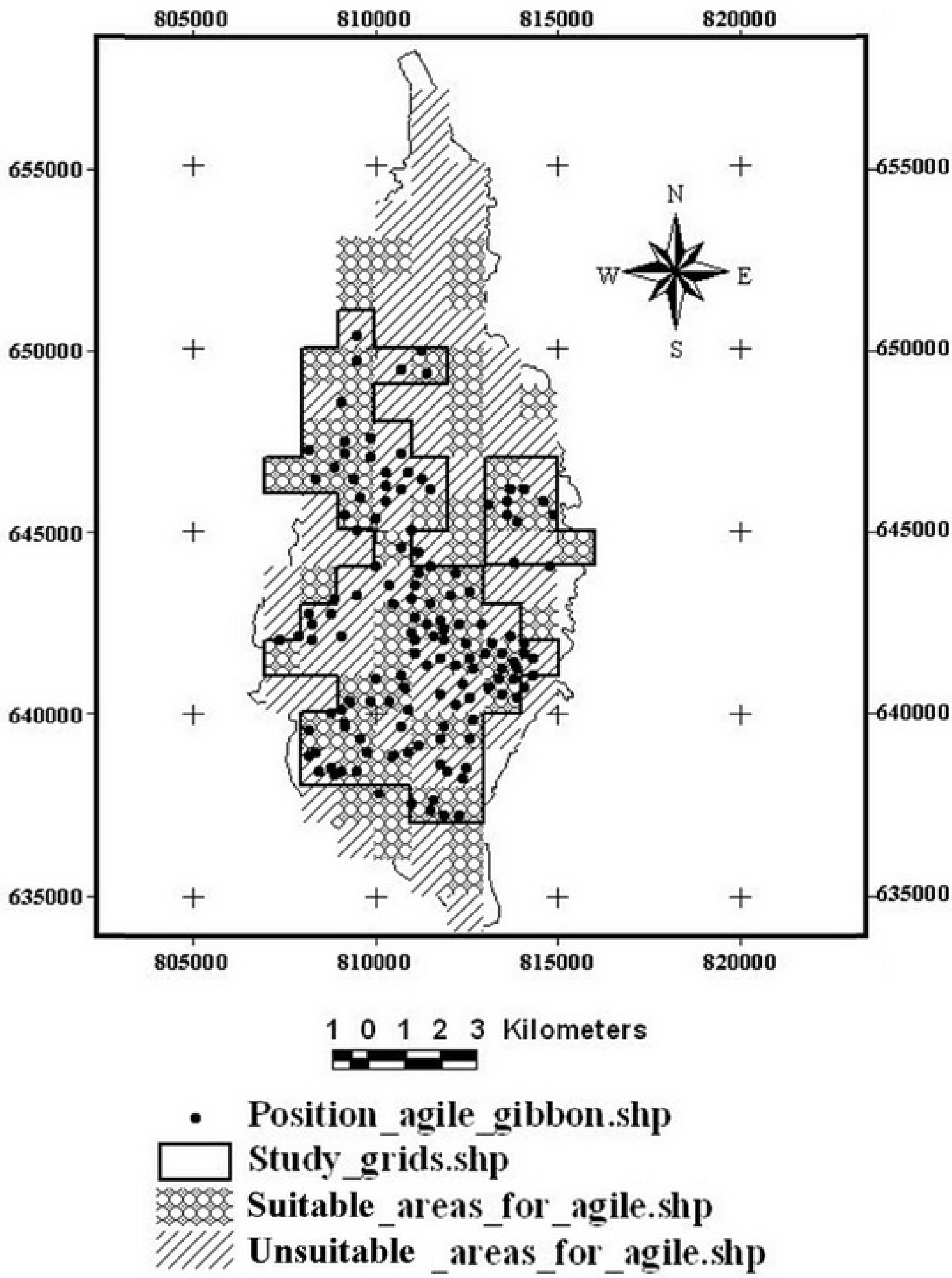

Figure 15. Map of available habitat for agile gibbons in Bala Forest.

Utilizable habitat areas between siamang and agile gibbons

From discriminant scores ($D^{\wedge}$) were used to predict the occurrence of siamang (Table 15) and agile gibbons (Table 16) in Bala forest. Occurrence of siamang and agile gibbons were considered by positions of available areas were shown in Table 21.

Table 17. Available areas for siamang use and agile gibbon use classified by discriminant score of Table 15; Fig.13 and Table 16; Fig.15.

No.	Available classified areas	Area (km^2)
1	suitable areas for siamang and agile gibbons	22
2	suitable areas for only siamang	34
3	suitable areas for only agile gibbons	32
4	unsuitable areas for gibbons	29

There are 22 km^2 of suitable areas for siamang and agile gibbons (18.8 percent of all classified areas in Bala Forest) and suitable areas for gibbons in Bala forest are 88 km^2 (75.2 percent) beside unsuitable areas for gibbons are 29 km^2 (24.8 percent) (Fig. 18).

From degree of correlation between discriminating variables and standardized canonical discriminant function 1 of siamang (Table 8) and agile gibbon (Table 12). Altitude and slope direction near east were important factors for predicted occurrence of siamang. While altitude and distance form edge were important factors for agile gibbons. These factors were plotted to describe relationship between suitable areas of siamang, suitable areas of agile gibbons, suitable areas of both and unsuitable areas of both based on habitat of siamang are higher altitude and slope direction near east than agile gibbon, and habitat of both near the ridge (Fig. 16; 17).

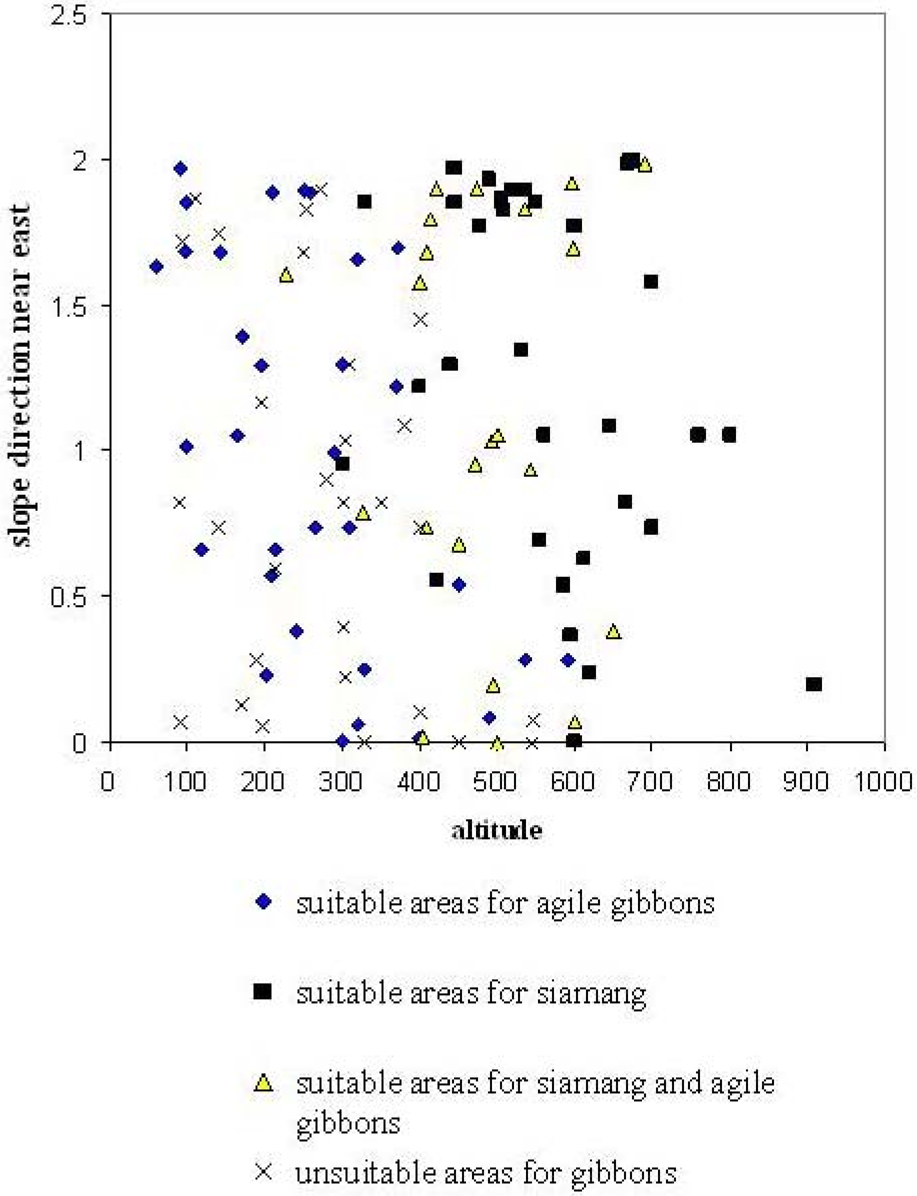

Figure 16. Distribution of altitude and slope direction near east of suitable areas of siamang, agile gibbons, suitable areas of both, and unsuitable areas of gibbons.

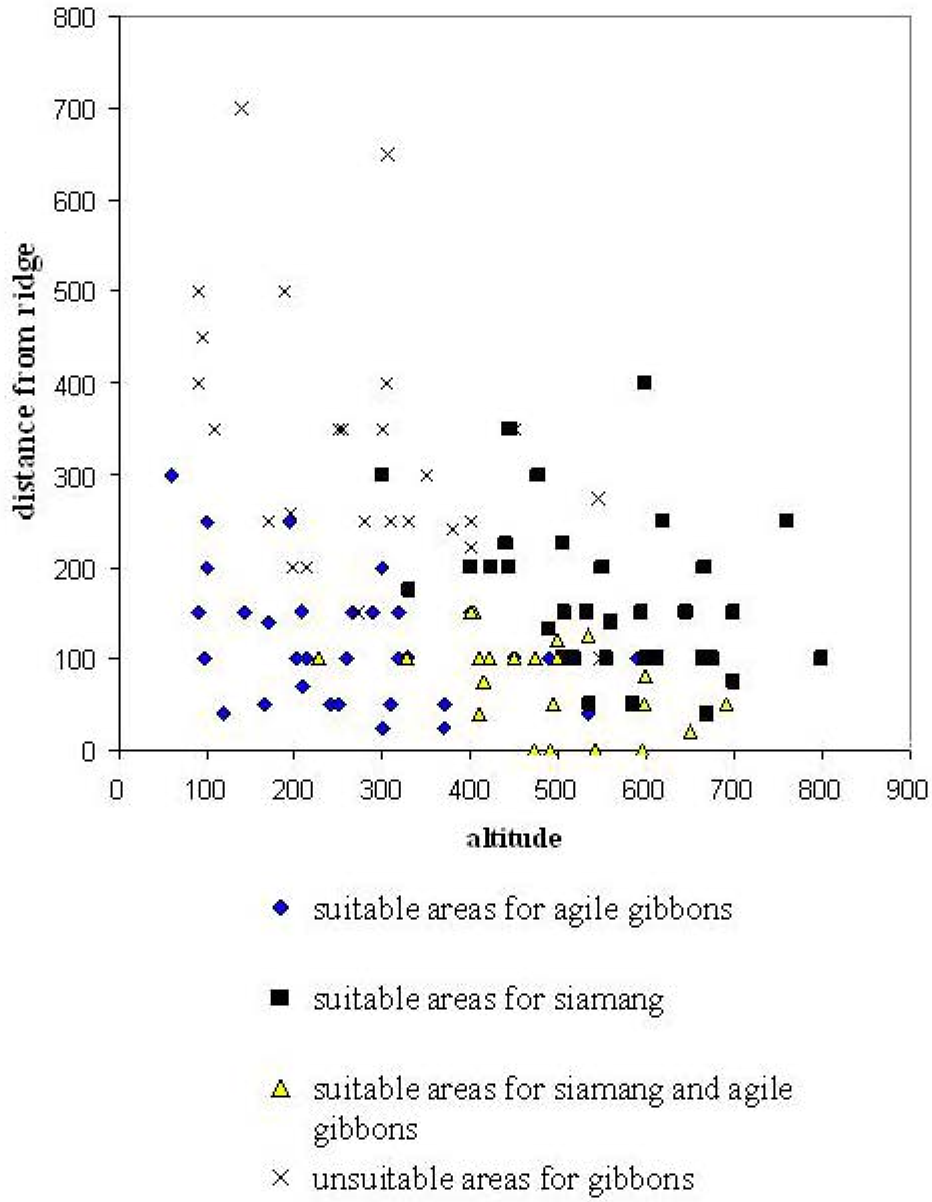

Figure 17. Distribution of altitude and distance from ridge of suitable areas of siamang, agile gibbons, suitable areas of both, and unsuitable areas of gibbons.

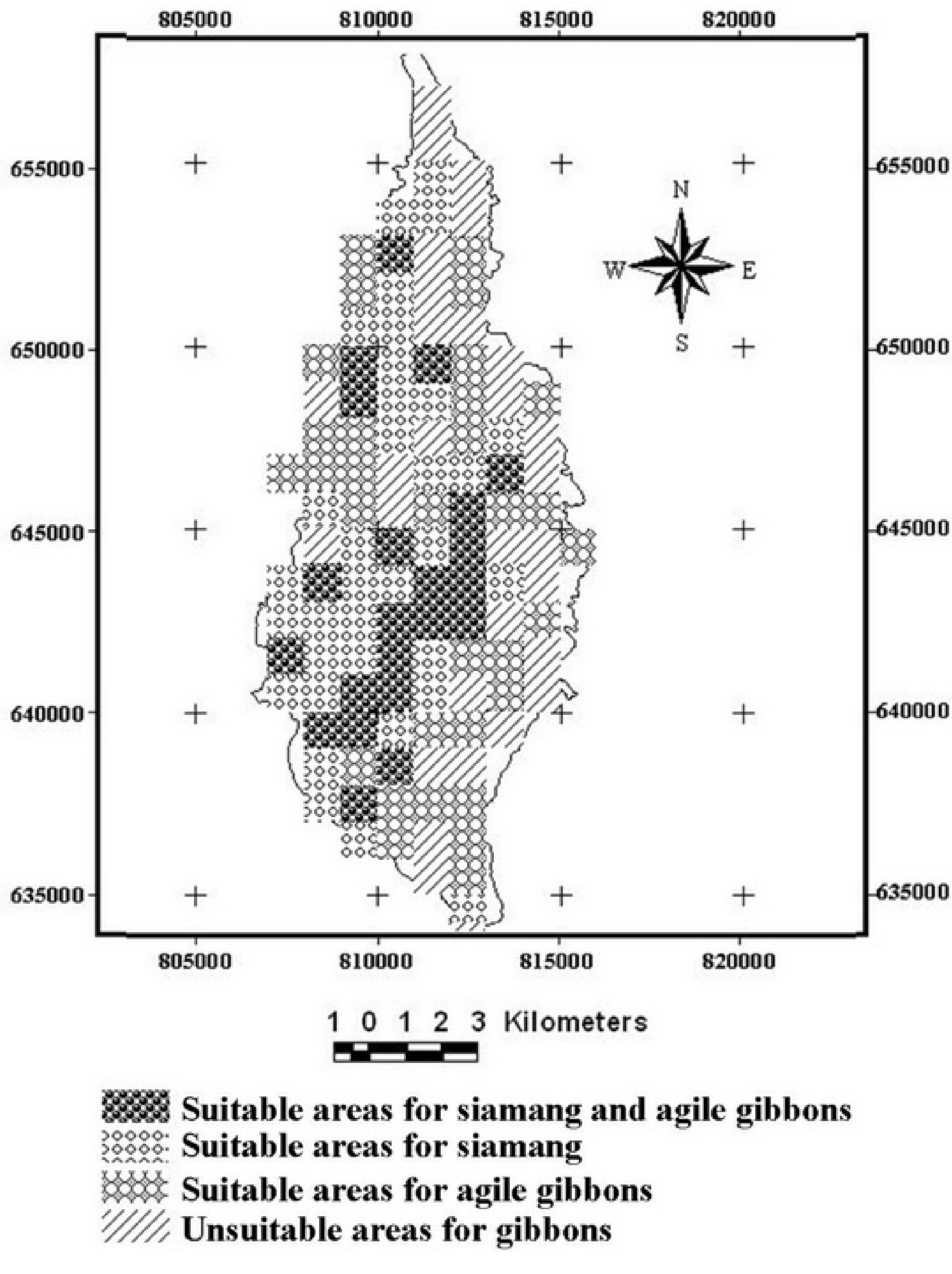

Figure 18. Map of available habitat for siamangs and agile gibbons in Bala Forest**.**

CHAPTER 4

Discussion

Siamang and agile gibbon densities

Results of gibbon census in 13 sites (60 km^2), 19 groups of siamang were found. The mean density of siamang was 0.32 groups km^{-2} (range 0 to 1.43 groups km^{-2}). Also 136 groups of agile gibbons were found, at a density of 2.26 groups km^{-2} (1.05 to 3.27 groups km^{-2}) (Table 1). The area of Bala forest is about 168 km^2 estimated population of siamang was 53 groups (range from 0 groups to 240 groups) and that of agile gibbon was 380 groups (range from 176 groups to 549 groups).

Considering only the distribution of 19 group (in 15 km^2) of siamang (Fig. 4) and 136 (in 50 km^2) of agile gibbon (Fig. 5), densities of siamang and agile gibbon were 1.27 groups km^{-2} and 2.72 groups km^{-2}. The suitable areas for siamang, about 56 km^2, and agile gibbons, about 54 km^2, (Table 15, Table 16) were analyzed. The potential population of siamang in suitable areas will be 71 groups and population of agile gibbons in potentially suitable areas will be 147 groups.

Density of siamang in this study were 0.32 groups km^{-2} (Table 1), which was lower than other sites such as in Krau Wildlife Reserve, Pahang, Malaysia (1.5 groups km^{-2}, Mackinnon and Mackinnon (1980)), Kuala Lompat (3 groups km^{-2}, Raemaekers and Chivers (1980)), Way Kampus (0.7 groups km^{-2}, Yanuar and Sugardjito (1993) referred Yanuar (2009)), Bukit Barisan Selatan National Park, Sumatra, Indonesia (2.23 groups km^{-2}, O'Brien *et al*. (2004)), West Central Sumatra (2.1, 3.2, 5.0, 5.4 groups km^{-2}, Yanuar (2009)).

Density of agile gibbons in this study was 2.26 groups km^{-2}, somewhat lower than other sites such as in Sungai Dal (4.3 groups km^{-2} Gittins and Raemaekers (1980) referred Yanuar (2009)); Gunung Paiung, West Kalimantan, Indonesia (3.4, 3.7, 3.9 groups km^{-2} Mitani (1990)); and West Central Sumatra (2.0, 3.6, 3.8 groups km^{-2} Yanuar (2009)) but more than Way Kampus (0.9 groups km^{-2} Yanuar and Sugardjito (1993) referred Yanuar (2009)) Bukit Barisan Selatan National Park, Sumatra, Indonesia (0.67 groups km^{-2}, O'Brien *et al*., 2004).

O'Brien *et al*. (2004) suggested that densities of agile gibbon tend to increase from southern to northern latitude on Sumatra, Borneo and Peninsular Malaysia but siamang decline from south to north. Densities of these gibbons agree with his suggestion because the Bala Forest is the northern-most distribution of siamang and agile gibbons.

Distribution

In 13 listening areas, agile was found in all areas, while siamang was found in 8 listening areas (LA 1, 5, 7, 8, 9, 10, 11, and 13). While densities of siamang showed a significantly positive relationship with mean altitude of habitat (r = 0.810, p = 0.015) (Table 3), densities of agile gibbon were not found significantly related with characteristics of habitats.

Nineteen groups (found in 15 km^2) of siamang in study site (60 km^2) were found in either core or near-edge areas in southwest of Bala Forest. Distribution (50 km^2) of 136 groups of agile gibbons in study site (60 km^2) tend ordinarily distribute.

Distribution of available areas for siamang and agile gibbon, were analyzed for their habitat selection. Three important factors for predicting available habitats of siamang in Bala Forest (117 km^2) were altitude, slope direction from east, and distance from edge (Table 9) while 4 important factors for available habitats of agile gibbon were altitude, distance from ridge, slope direction from east, and distance from stream (Table 13) by Fisher's discriminant function scores of gibbon use and non-use.

Distribution of suitable areas for siamang tended to be clumped in the south-west and along high ridges of Bala forest (Fig. 13) while the distribution of available areas for agile gibbon (Fig. 15) tended to have a more widespread distribution. So suitable areas of siamang tend to be distributed along higher ridges and on top of hills but available areas of agile gibbon tend to be distributed in lower areas of Bala Forest. These are similar in pattern to actual occurrences of siamang and agile gibbons.

Suitable areas for agile gibbons in Bala Forest were 54 km^2 (Table 16) and currently agile gibbons were found in 50 km^2 (Fig. 5) so it can be suspected that the current population of agile gibbons in Bala Forest is near the carrying capacity of the habitat. Since potential suitable areas of siamang in Bala forest were 56 km^2 but siamang only were currently found in 15 km^2, it can be suspected that the current population of siamang in Bala Forest is lower than its carrying capacity of habitat. From behaviour of siamang after eight years of age, it must leave family to find its mate and home range. With the density of 1.27 groups km^{-2} (19 groups in area 15 km^2), the population of siamang should potentially be 19 to 71 groups. Generally, siamang will take more than two years before weaning.

In addition, two possible factors may explain why siamang were not found naturally in other utilizable habitats (41 km^2): (1) the area is inaccessible because the dispersal ability of the organism is limited, (2) the organism fail to recognize the area as a suitable habitat (Lack, 1933 referred Drickamer *et al.*, 2002).

Table 18. Differential characters of factors between habitats with agile gibbons, habitats with siamang , and habitat without them, siamang habitats, and agile gibbon habitat (from Table 4, 5, and 6) in Bala Forest.

Factors	Agile		Siamang		Siamang and agile gibbon	
	agile habitat	habitat without agile	siamang habitat	habitat without siamang	siamang habitat	agile habitat
altitude	< (**)	>(**)	>(*)	< (*)	>(**)	< (**)
distance from ridge	< (**)	>(**)	< (*)	>(*)		
slope direction near east			>(**)	< (**)	>(**)	< (**)
slope value			>(**)	< (**)	>(**)	< (**)
distance from road	< (**)	>(**)	< (**)	>(**)		
distance from village	>(*)	< (*)	>(**)	< (**)	>(**)	< (**)
distance from stream	< (*)	>(*)				
distance from edge	>(**)	< (**)				

* = $p < 0.05$, ** = $p < 0.01$

Table 19. Important characters of factors analyzed discriminant analysis between habitats with agile gibbons, habitats with siamang , and habitat without them, siamang habitats, and agile gibbon habitat (from Table 8 and 12) in Bala Forest.

Factors for discriminant analysis	Agile gibbons		Siamang	
	agile habitat	habitat without agile	siamang habitat	habitat without siamang
altitude	##	##	##	##
distance from ridge	##	##		
slope direction near east	#	#	##	##
distance from stream	#	#		
distance from edge			#	#

= important factor, ## = more important factor

Characteristics of habitat

Of the ten factors (Table 3) that were analysed, only altitude had significantly positive relationship with densities of siamang. Eight factors (altitude, distance from ridge, slope direction from east, slope value, distance from road, distance from village, distance from stream, and distance from edge) differentiate the used habitats and non-used habitats of siamang and agile gibbon (Table 18, and Table 19).

Altitude

Mean altitude is an important factor for habitat selection of siamang and agile gibbon. Habitat with siamang was higher in altitude but habitat with agile gibbon was lower (Table 3, and Table 18). This pattern is similar to Raemaekers (1977) who found mean altitude of siamang was higher than agile and lar gibbons in both areas in Sumatra (Wilson, 1975) and Malaya (Chivers, 1974). Similarly, a census in Peninsular Malaysia Forest found that density of siamang in montane forest sites was greater than lowland forest sites and no siamang were found in swamp forest sites (Marsh and Wilson, 1981). In addition, in montane forest sites, siamang was found in the upper forest site, but not at the lower ones (Marsh and Wilson, 1981). From observations on Gunong Benong (Krau Wildlife Reserve in Pahang, Malaysia), siamang was most abundant between 700 and 1100 m elevation (Caldecott, 1980 referred Marsh and Wilson, 1981). The siamang is commonly found living in hill forest, usually over 300m above sea-level (a.s.l.) (Chivers, 1977), but is rarely found above an altitude of 1500 m above sea-level (Caldecott, 1980 referred Gittins and Raemaekers, 1980).

In contrast, O'Brien *et al.* (2004) who studied in Bukit Barisan Selatan National Park, Sumatra, found that the density of siamang peaked in elevations below 300 m (3.3 groups km^{-2}), while mid-elevation densities were lowest, but agile gibbon density peaked in mid-elevations, while lowest densities were in low-altitude, densities above 1000 m were intermediate for both species. Yanuar (2001) referred O'Brien *et al.* (2004) found a similar pattern of higher siamang densities in low-elevation (Lowland forest) while lowest densities in mid-altitude. Agile gibbons occurred at high densities in mid-elevation (Hill forest), and low densities in low-altitude in Kerinci Seblat National Park, Sumatra. Yanuar (2009) found densities of agile gibbon showed the same pattern but densities of siamang peaked in low altitude (Lowland (<450m.)) and highest elevation (montane (>1400m.).

O'Brien *et al.* (2004) suggested that siamangs are more folivorous in Malaysia than on Sumatra (Chivers and Raemaekers, 1986; Nurcahyo, 1999; Palombit, 1997 referred O'Brien *et al.* (2004). Marsh and Wilson (1981) speculated that dipterocarp forests there had lower primate densities (and community biomass) than other forest types because the dominance of dipterocarps resulted in fewer fruits. The mid-elevation forests of Bukit Barisan Selatan National Park are characterized by higher densities of dipterocarp trees (O'Brien *et al*., 2004). Siamang are more frugivorous in Sumatra, and densities of siamang in mid-elevation forests are lowest.

Distance from top hill and ridge, slope value, and distance from stream

Siamang and agile gibbons selected areas with significantly less distance from ridges, siamang selected higher slope area, and agile gibbons selected areas at less distance from streams than habitats without them. Thus higher ridge and upper-slope habitats were suitable characters of siamang habitat more than mid-slope and valley. While suitable characters of agile gibbon habitat were lower ridges and near streams.

Valencia *et al*. (2004) found that forest structure also changed from valley to ridge; the valley had smaller-stature trees, fewer individuals, less basal area, and a lower canopy. Gunatilleke *et al.* (2006) found that the canopy of forest is more compact and uniform on the ridge than in the valley.

In the Western Ecuadorian Rain Forest, the valley had higher proportions of gaps than the ridges, the proportion of gaps increases in the valleys but decreases on the upper slopes and ridges (Gale, 2000). Patterns of forest structure with lower mean tree density and basal area in valleys compared to mid-slope and upper ridge sites have been observed in the topographically heterogeneous FDP (Forest Dynamics Plot) at Yasuni, Ecuador (Valencia *et al*. 2004), in Brunei (Ashton, 1964) and in Sinharaja Forest, Sri Lanka, (Gunatilleke *et al*., 2006).

Stem density on the upper-ridge held for all life forms (shrubs to tall trees), which had more tall trees, whereas basal area in the valley was mostly in medium-sized trees (Valencia *et al*., 2004) and more secondary or disturbed species than ridge (Greig-Smith *et al*., 1967). In valleys, larger canopy gaps, lower tree density and basal area, were found than on ridges because there is a stronger tendency for trees to die in groups (Gunatilleke *et al*., 2006). Larger and more frequent openings in the moist valley sites, especially along streams of the lower elevations, support a greater cover of herbaceous vegetation (Harms *et al*.2004, Gunatilleke *et al*., 2006).

A higher canopy height is related to better developed arboreal habitat (Medley, 1993). The canopy trees of the high level provide sites for sleeping and calling and some food (Chivers, 1977). Densities and basal area of trees are rough estimate of crown mass, thus of surface area (Raemaekers *et al*., 1980) and fruit production (Chapman, 1992). As a function of their more folivorous diet, siamangs also spend more of their feeding and traveling time to eat the leaves of tall trees (Gittins and Raemaekers, 1980). Canopy closed habitat has more supports and locomotion is easier (common is brachiation (Gittins, 1979 referred Fleagle, 1980).

Slope direction

Siamang selected habitats, those have direction near east. The areas of slope direction near east get more sunlight in the morning than the areas of slope direction near west which get more sun in the afternoon. Hodges (1966) found peak of photosynthesis rates of plants at about 9.00-12.00 in the morning more than in afternoon. Therefore habitats that have slope direction near east will have available food for siamang more than in the west. In other hand suitable characteristics of habitats of siamang in Bala Forest are higher ridge and top hill. Those topographic characters of Bala Forest occurred mostly in western areas. Because the topographic character of order watershed of Kolok River is slope to east, so characteristic of habitats are slope direction near east will occurs.

Distance from edge and nearest village

Siamang and agile gibbons selected habitats that were farther from edges and villages in Bala Forest. Similar are were found in other animals such as monkeys. Density of large mammals has also been shown to increase with distance to villages (Muchaal and Ngandjui, 1999), points of hunting access (Blom et al., 2005; Laurance et al., 2006; Blake et al., 2007 referred Kuehl et al., 2009), and human population centers (Wilkie and Carpenter, 1999; Walsh *et al.*, 2003, Kuehl et al., 2009).

In this study, edge was defined as the border between Hala-Bala Wildlife Sanctuary with plantations of local people. Local people were not found hunting gibbons in Bala Forest, hence edge effects with agile and siamang may be affected of local people in villages around Bala forest who collect non-timber produce such as fruits of *Baccaurea spp., Dialium spp.,* and *Garcinia atroviridis* (Tohdam, 2001), that are food source of siamang and agile gibbons (Chivers, 1974; Chivers, 1980). For example, in only Ban Bala Village, non-timber forest product contributes economically 133,274 baht per year. People about 9 % collected it by cutting trees (usually cut branches) (Tohdam, 2001) which may reduce available food sources of siamang and agile gibbons.

This study contrasted with O’Brien *et al.* (2004) who found siamang and agile gibbons appear at the forest edge so humans in Bukit Barisan Selatan National Park, Sumatra, Indonesia were not affecting siamang and agile gibbon distribution. Therefore edges and villages were not important factors in their distribution.

Habitat selection of siamang and agile gibbons

Geographical characteristics of Bala Forest are complex hills. There are high and low of ridges and hill tops, and also slopes, valleys, and streams. In terms of ridge to valley habitats (Gale, 2000; Valencia et. al., 2004; Gunatilleke *et al*., 2006), Bala Forest was classified as ridge or hill top, upper slope, mid-slope, valley, and stream habitat (Fig. 19).

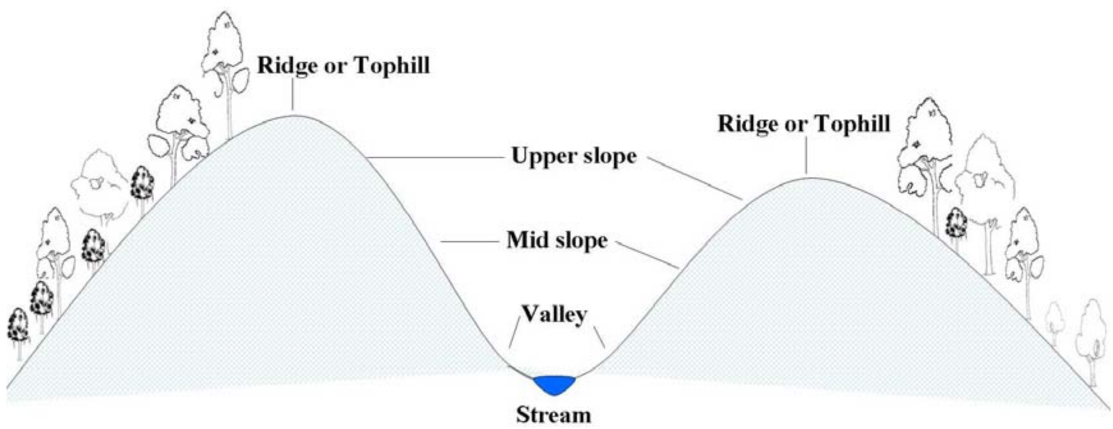

Figure 19. Characters of topographic habitat in terms of ridge to valley (Gale,2000; Valencia et. al., 2004; Gunatilleke *et al*., 2006)

Important habitats variables of siamang are higher ridge or hill top, steeper slope, greater distance from stream, and greater distance from forest edge and villages (Fig. 20). Habitats of agile gibbons are lower ridge or hill, lower slope value, near stream, and greater distance from forest edge and villages (Fig. 20).

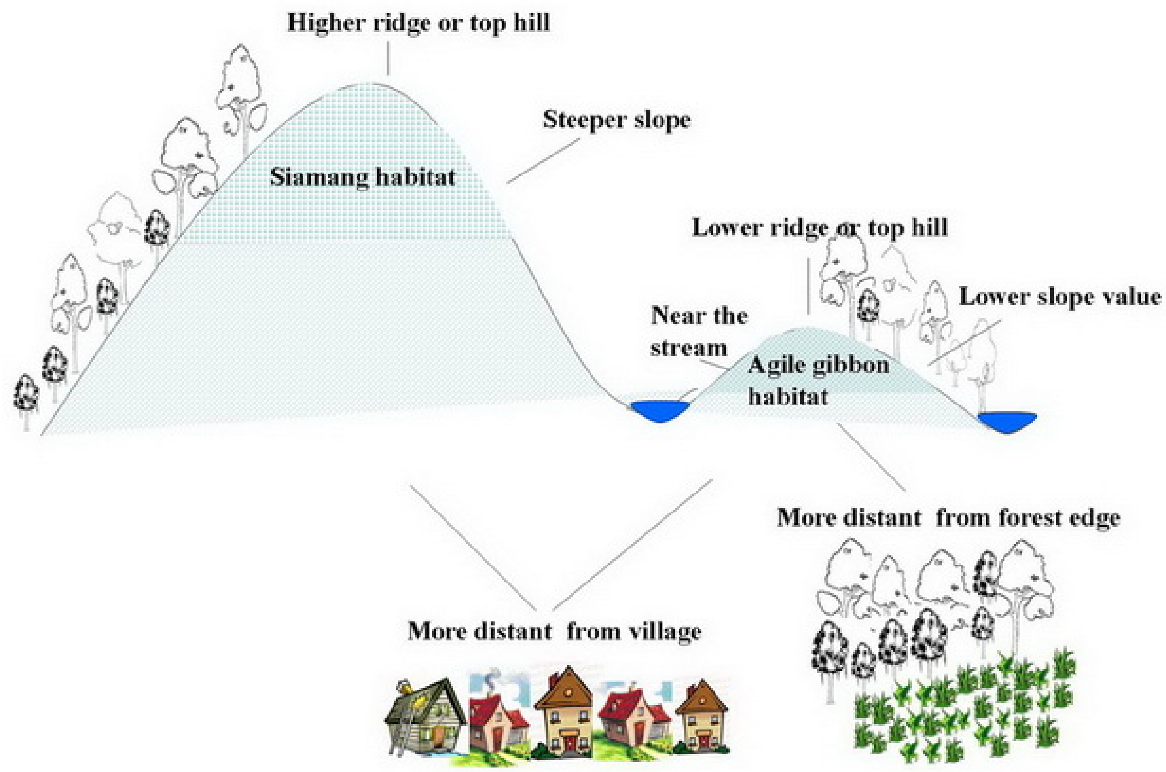

Figure 20. Characters of siamang and agile gibbon habitat.

CHAPTER 5

CONCLUSIONS

Bala Forest is only one site of siamang distribution in Thailand then population of them is very low (19 groups). The suitable conservation strategies are very important for siamang. The habitat selection of siamang are habitats that are higher ridge or top hill, steeper slope, more distance from stream, and more distance from forest edge and village. The conservation strategies for siamang is reducing disturbance in higher ridge and top hill habitat. While habitats of agile gibbon are lower ridge or top hill, lower slope value, near the stream, and more distance from forest edge and village. Therefore conservation strategies for agile gibbon is reducing disturbance in lower ridge and habitat near stream. Besides conservation strategy for gibbons is reducing disturbance especially from people in nearly village who cutting feeding plants of gibbons. Habitat selection of siamang and agile gibbon in this study focus in abiotic factors but factors of suitable habitats for habitat selection of species are biotic factors and abiotic factors (McClary *et al*. 2008). Therefore biotic factors such as feeding plants, predators, and competitor must be analyzed in next time.

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Appendix

Appendix A

Appendix A Table 1. Form for locate gibbons distributions by call**.**

Gibbon Call Data Form - Hala Bala Wildlife Sanctuary

Area………………………….... LP………….. GPS …………

Listeners ……………………………..……….. Date ………….

Time arrived at station …………. Time left at station …………….

Weather (give times of change) ……………………………………………

Direction	Est. distance (m)	Times and call types (d=duet, ms=male solo, gc=great-call)

Appendix A Table 2 Form for characters of habitats of gibbons**.**

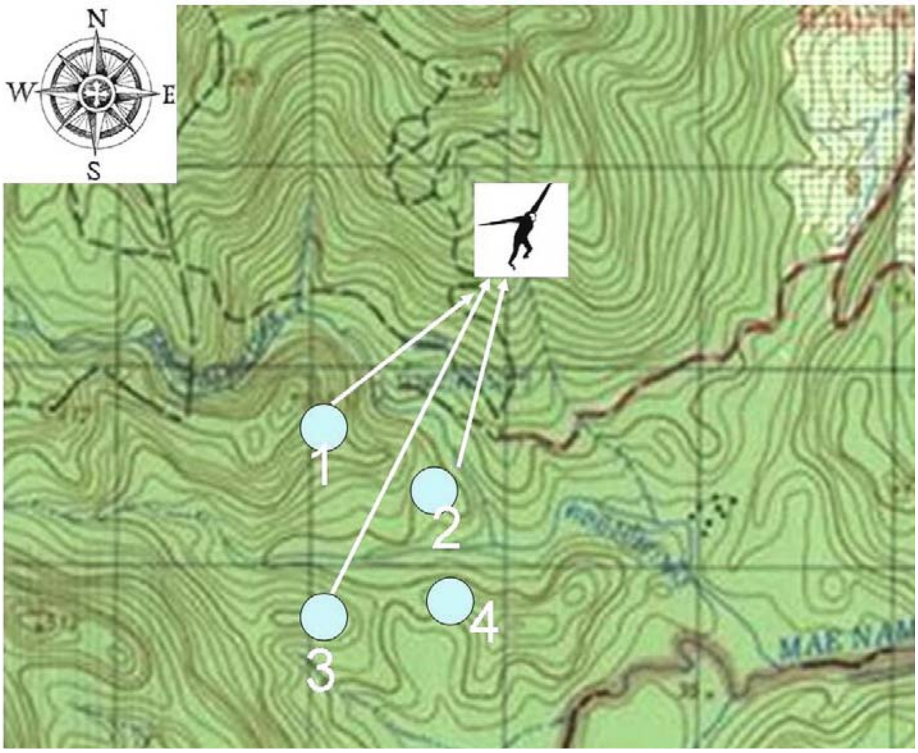
Gibbon Habitat Data Form - Hala Bala Wildlife Sanctuary

Area_____________ Location______________ UTM Start Point_____

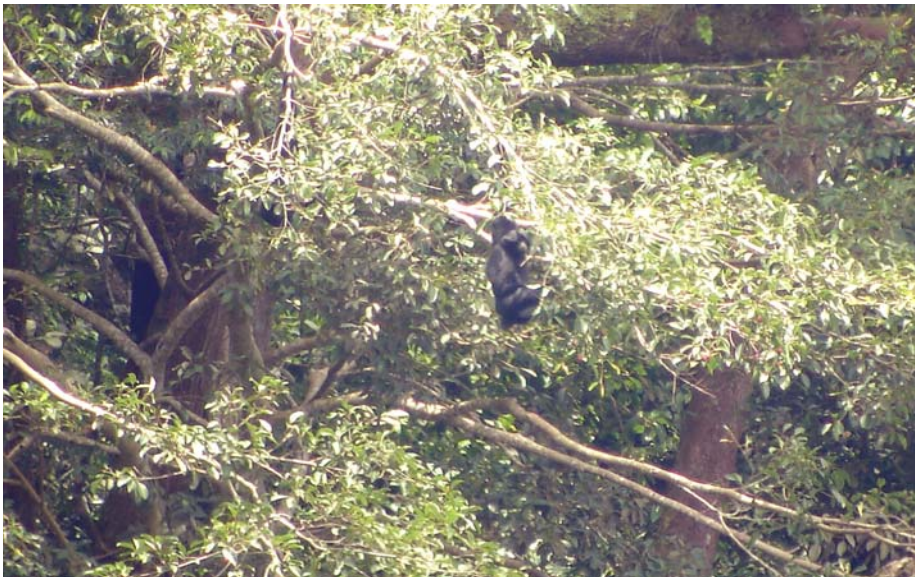
Recorder_______________ Date_____ UTM End Point_____

Line	Point	Height	DBH

Appendix A Figure 1. Estimated gibbon's call direction with a hand compass.

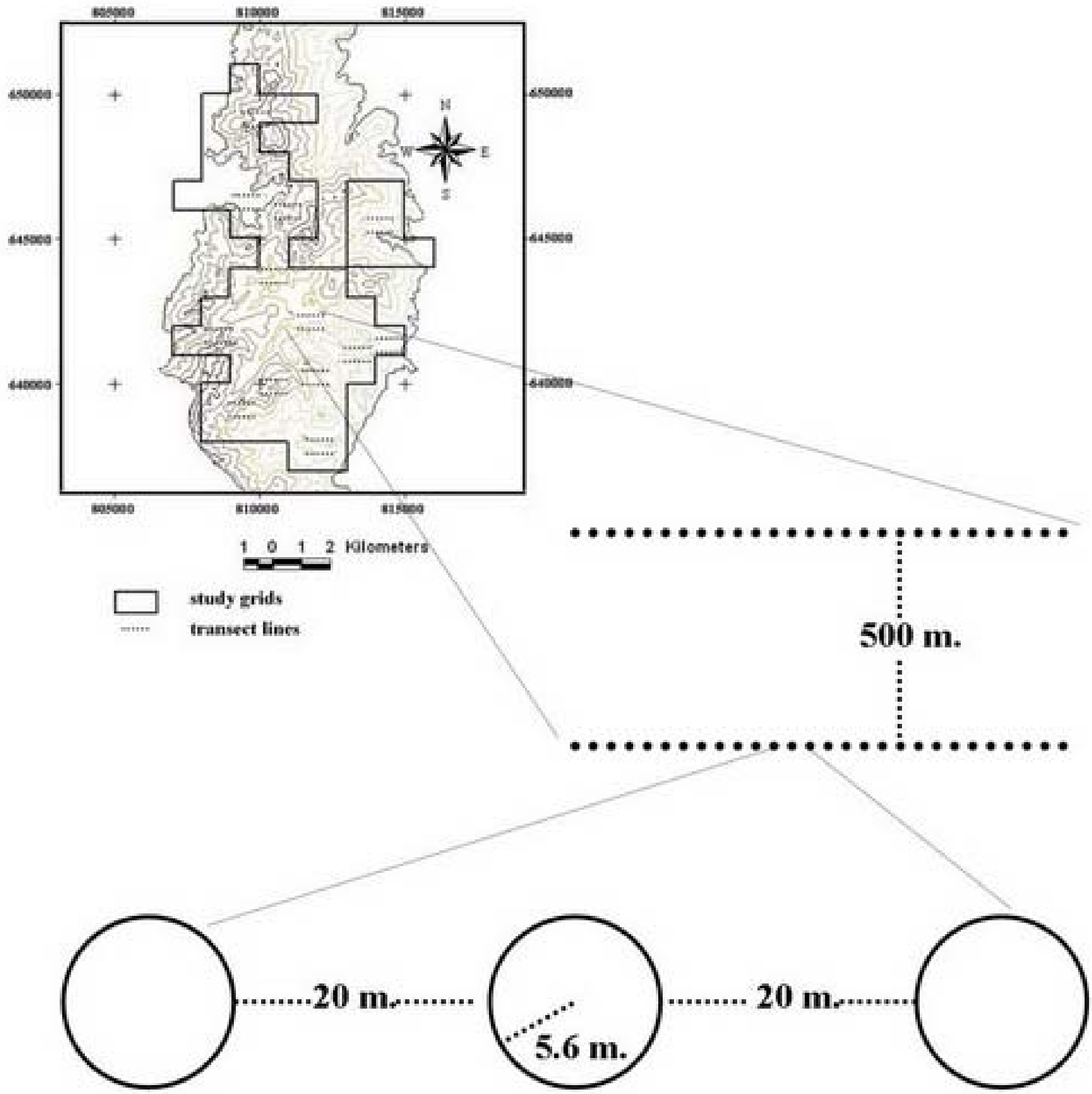


Appendix A Figure 2. Triangulation



Appendix A Figure 3. Siamang group distributed in 47N 0807500E, 0641500N of Bala Forest.

Appendix A Fig. 4 To went in location of gibbon habitat for make plots.



Appendix A Figure 5. Distribution of plots in line transects, and distribution of line transects in Bala Forest.

Appendix A Figure 6. To made plots in transect lines for measured characteristic of gibbon habitat.

Appendix A Figure 7. To measured height of canopy and canopy distance by optical rangefinder.

Appendix A Figure 8. To measured diameter of trees in plots of siamang habitat.

Appendix B

Appendix B Table 1. Mean, standard deviation, standard error of mean of factors of 1-ha grids without agile and grids with agile gibbons.

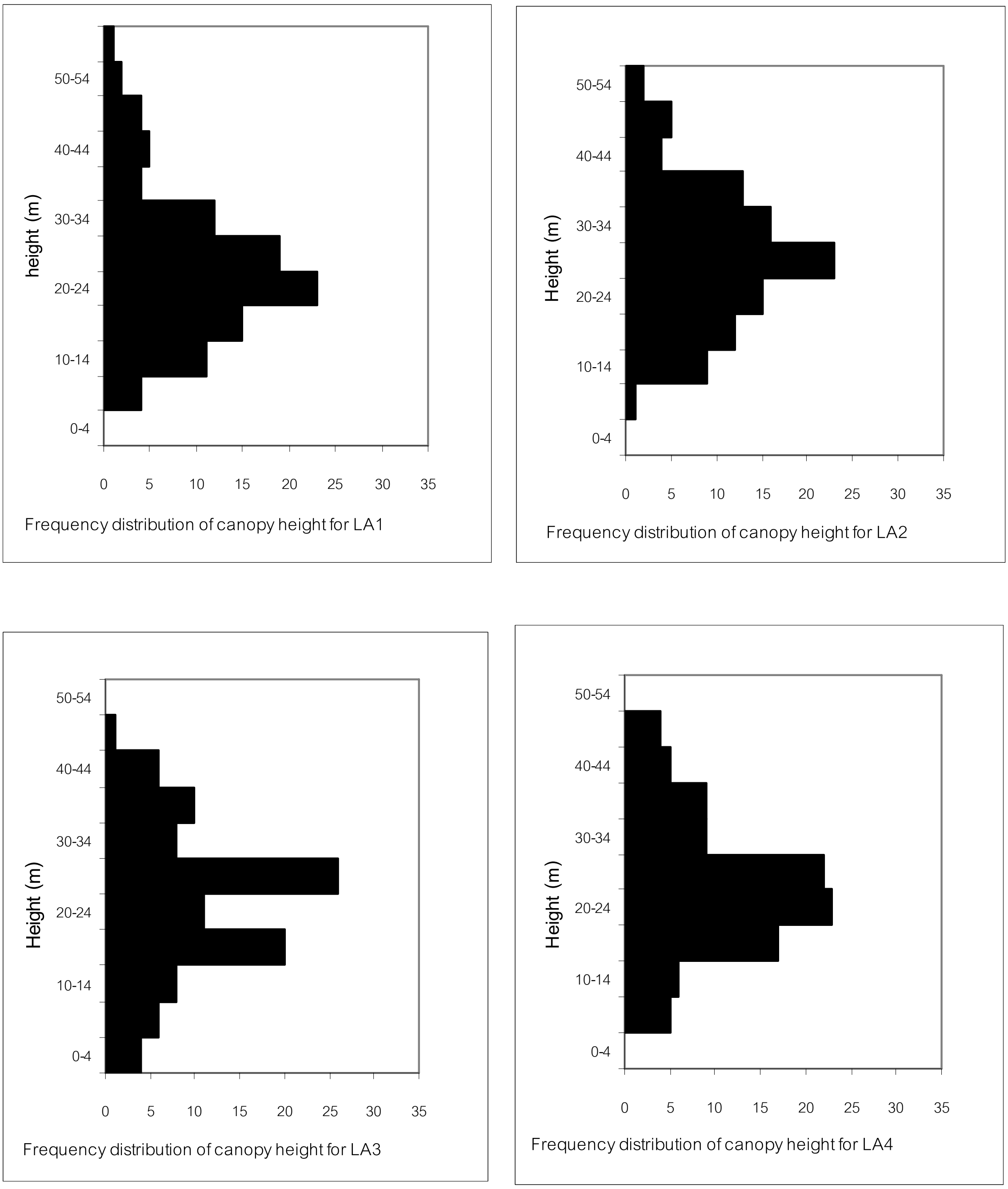
Factors of habitats	Occurrence	Mean	Std. Deviation	Std. Error of Mean
altitude	grid without agile	437.333	181.94112	14.85543
	grid with agile	360.552	158.71996	13.61012
distance from ridge	grid without agile	183.333	113.0639	9.23163
	grid with agile	118.824	86.66931	7.43183
slope direction near east	grid without agile	0.9359	0.6707	0.05476
	grid with agile	0.955	0.70734	0.06065
slope value	grid without agile	0.3658	0.15739	0.01285
	grid with agile	0.368	0.13995	0.012
distance from road	grid without agile	3430.67	2340.73063	191.11986
	grid with agile	2213.85	1752.03668	150.23591
distance from village	grid without agile	4254.61	1744.46754	142.43518
	grid with agile	4754.03	1391.80464	119.34626
distance from stream	grid without agile	292.829	191.29464	15.61914
	grid with agile	239.138	171.62538	14.71676
distance from edge	grid without agile	988.908	712.90829	58.20872
	grid with agile	1401.61	947.67807	81.26272

Appendix B Table 2. Mean, standard deviation, standard error of mean of factors of 1-ha grids without siamang and grids with siamang.

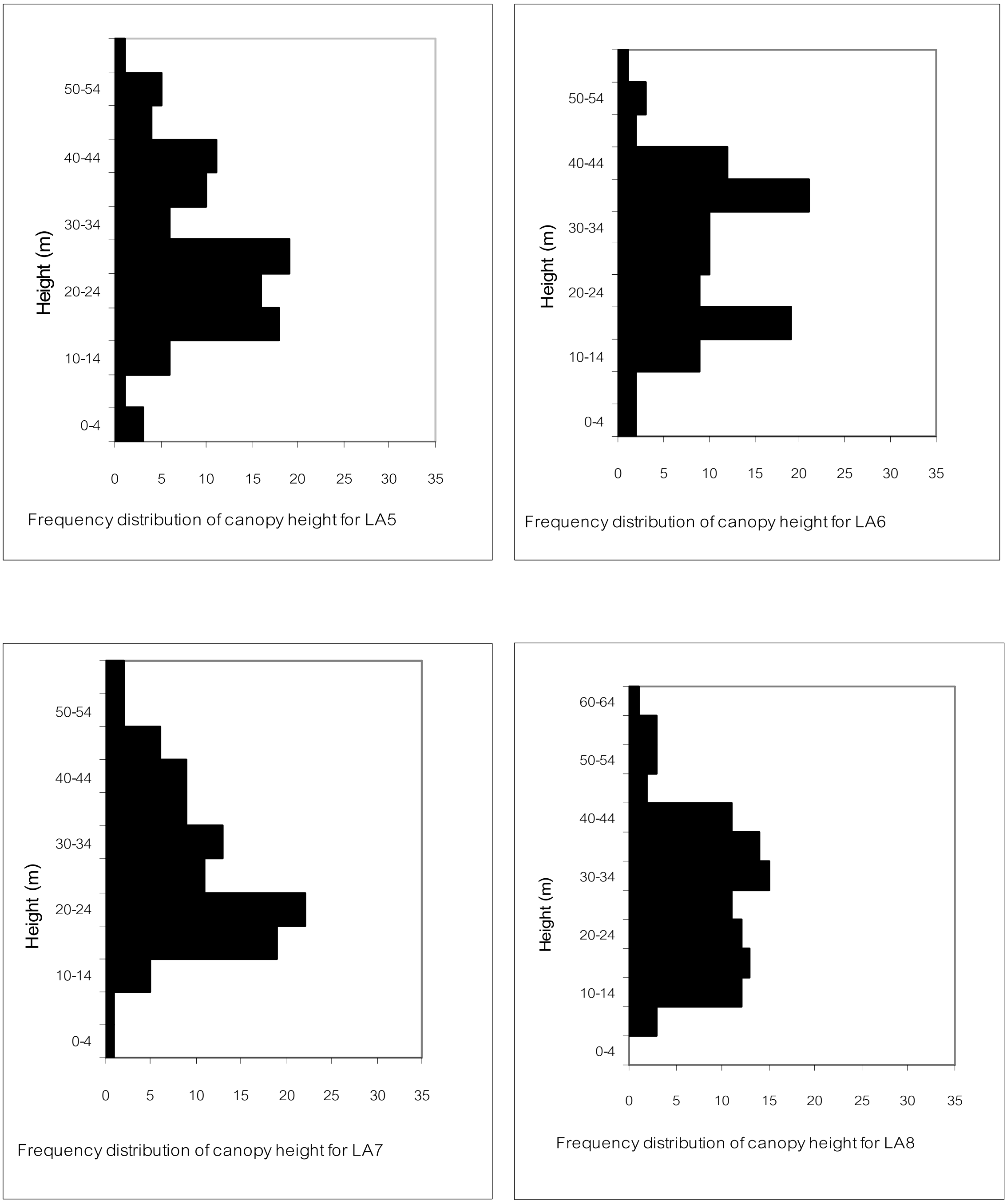
Factors of habitats	Occurrence	Mean	Std. Deviation	Std. Error of Mean
altitude	grid without siamang	386.833	130.47977	23.82224
	grid with siamang	477.895	115.14865	26.41691
distance from ridge	grid without siamang	173.333	121.32411	22.15065
	grid with siamang	89.7368	50.83944	11.66337
slope direction near east	grid without siamang	1.1518	0.7434	0.13573
	grid with siamang	1.5959	0.57194	0.13121
slope value	grid without siamang	0.326	0.14333	0.02617
	grid with siamang	18.4211	8.98342	2.06094
distance from road	grid without siamang	3370.75	1965.03946	358.76548
	grid with siamang	1707.88	1323.93819	303.73225
distance from village	grid without siamang	3900.27	1600.72393	292.25087
	grid with siamang	5944.04	1007.86299	231.21963
distance from stream	grid without siamang	322.741	239.22207	43.67578
	grid with siamang	203.979	119.28822	27.36659
distance from edge	grid without siamang	1236.53	1007.71249	183.98229
	grid with siamang	1620.83	856.95265	196.59842

Appendix B Table 3. Mean, standard deviation, standard error of mean of factors of 1-ha grids without siamang and grids with agile gibbons.

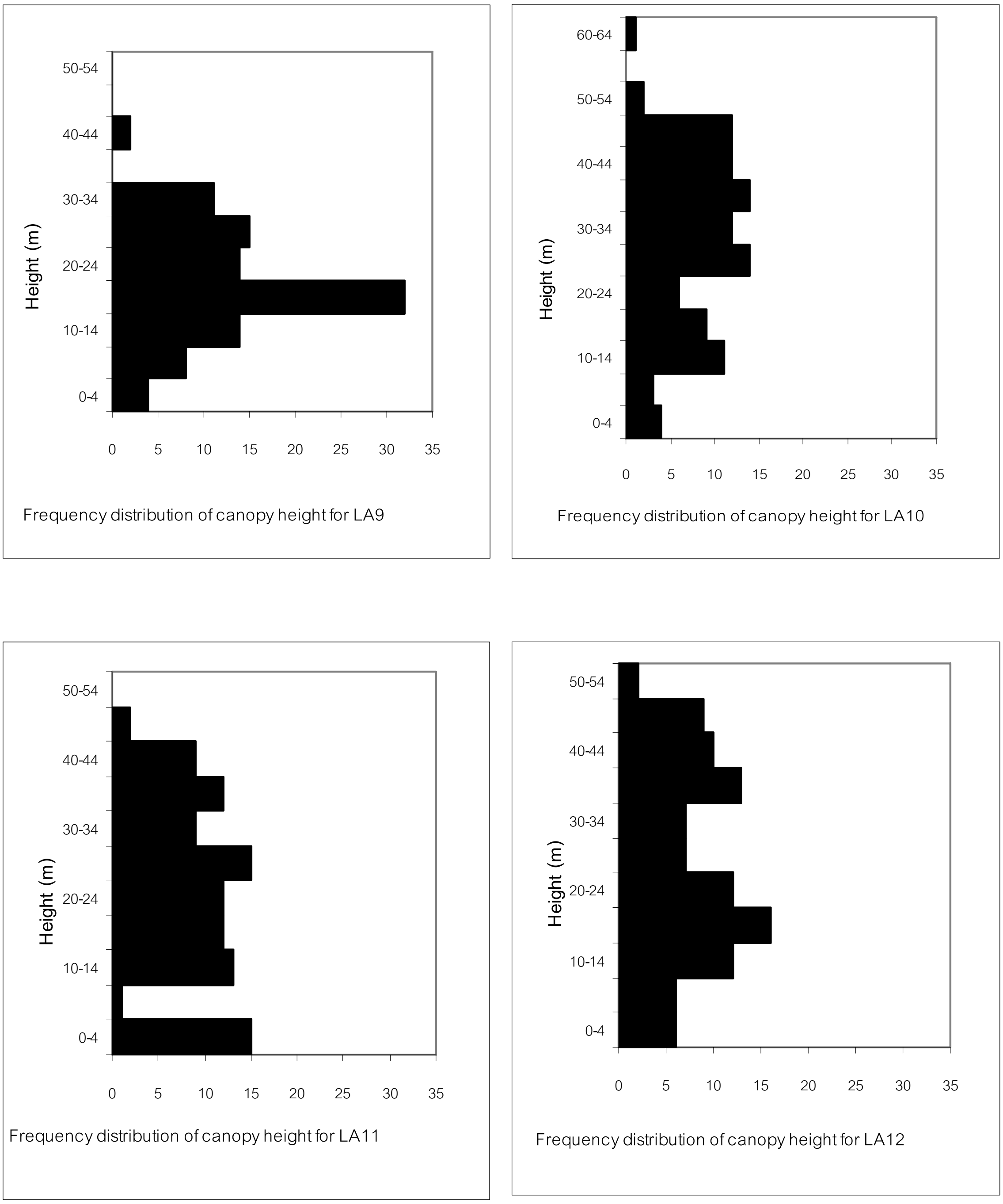
Factors of habitats	Occurrence	Mean	Std. Deviation	Std. Error of Mean
altitude	grid with agile	360.552	158.720	13.610
	grid with siamang	477.895	115.149	26.417
distance from ridge	grid with agile	118.824	86.669	7.432
	grid with siamang	89.737	50.839	11.663
slope direction near east	grid with agile	0.955	0.707	0.061
	grid with siamang	1.596	0.572	0.131
slope value	grid with agile	0.368	0.140	0.012
	grid with siamang	18.421	8.983	2.061
distance from road	grid with agile	2213.85	1752.037	150.236
	grid with siamang	1707.88	1323.939	303.732
distance from village	grid with agile	4754.03	1391.805	119.346
	grid with siamang	5944.04	1007.863	231.220
distance from stream	grid with agile	239.138	171.625	14.717
	grid with siamang	203.979	119.288	27.367
distance from edge	grid with agile	1401.61	947.678	81.263
	grid with siamang	1620.83	856.953	196.598



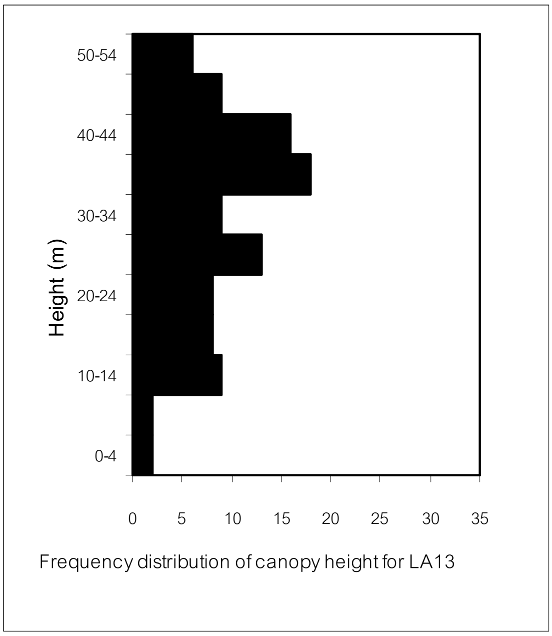
Appendix B Figure 1.1 Characters of canopy height of study site in LA 1 to LA4.



Appendix B Fig. 1.2 Characters of canopy height of study site in LA 5 to LA8



Appendix B Fig. 1.3 Characters of canopy height of study site in LA 9 to LA12



Appendix B Figure 1.4. Characters of canopy height of study site in LA 13.

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