การเลือกใช้พื้นที่ และการประเมินความชุกชุมของไก่ฟ้าพญาลอ
ในสถานีวิจัยสิ่งแวดล้อมสะแกราช

นางสาวศรันย์ภัทร์ สุวรรณรัตน์

มหาวิทยาลัยเทคโนโลยีสุรนารี

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาชีววิทยาสิ่งแวดล้อม
มหาวิทยาลัยเทคโนโลยีสุรนารี
ปีการศึกษา 2556

HABITAT SELECTION AND ABUNDANCE ESTIMATES OF SIAMESE FIREBACK *LOPHURA DIARDI* AT SAKAERAT ENVIRONMENTAL RESEARCH STATION

Saranphat Suwanrat

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Environmental Biology

Suranaree University of Technology

Academic Year 2013

HABITAT SELECTION AND ABUNDANCE ESTIMATES OF SIAMESE FIREBACK *LOPHURA DIARDI* AT SAKAERAT ENVIRONMENTAL RESEARCHSTATION

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

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ศรันย์ภัทร์ สุวรรณรัตน์ : การเลือกใช้พื้นที่ และการประเมินความชุกชุมของไก่ฟ้าพญาลอในสถานีวิจัยสิ่งแวดล้อมสะแกราช (HABITAT SELECTION AND ABUNDANCE ESTIMATES OF SIAMESE FIREBACK LOPHURA DIARDI AT SAKAERAT ENVIRONMENTAL RESEARCH STATION) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.พงศ์เทพ สุวรรณวารี, 171 หน้า.

ไก่ฟ้าพญาลอ (*Lophura diardi*) เป็นไก่ฟ้าที่มีความสวยงามและเป็นชนิดพันธุ์ที่มีสถานภาพถูกคุกคาม การศึกษานี้มีวัตถุประสงค์เพื่อตรวจสอบขนาดถิ่นที่อยู่อาศัย การใช้พื้นที่อยู่อาศัย พฤติกรรมการเกาะนอน การเลือกใช้พื้นที่เกาะนอน นิเวศวิทยาการสืบพันธุ์ และการเลือกใช้พื้นที่ทำรังของไก่ฟ้าพญาลอที่อาศัยอยู่ในพื้นที่ป่าที่ราบต่ำในสถานีวิจัยสิ่งแวดล้อมสะแกราช จังหวัดนครราชสีมา ในปี พ.ศ. 2553-2555 ผลการศึกษาจากการใช้วิทยุติดตามตัวไก่ฟ้าเพศเมีย จำนวน 8 ตัว จาก 8 กลุ่ม เป็นเวลา 2 ถึง 27 เดือน พบว่า ไก่ฟ้าพญาลอมีขนาดถิ่นที่อยู่อาศัยเฉลี่ยในรอบปี 31.4 เฮกแตร์ โดยขนาดอาณาเขตในช่วงนอกฤดูผสมพันธุ์จะมีขนาดใหญ่ที่สุด (26.3 เฮกแตร์) รองลงมา คือ ช่วงฤดูผสมพันธุ์ (21.7 เฮกแตร์) และช่วงที่เลี้ยงลูกตามลำพัง (9.7 เฮกแตร์) ตามลำดับ จากการศึกษาสังคมพืช 480 แปลง (แปลงวงกลมรัศมี 10 เมตร) พบว่า ในช่วงที่เลี้ยงลูกตัวเมียจะจำกัดการเคลื่อนไหวของตัวเองเพื่อหลีกเลี่ยงการสูญเสียลูก จึงส่งผลทำให้ถิ่นที่อยู่อาศัยมีขนาดเล็กลง และเลือกเลี้ยงลูกในบริเวณที่มีการปกคลุมของพืชที่ระดับความสูง <0.5 เมตร และมีจำนวนต้นไม้ที่มีความสูง >3 - 5 เมตร ค่อนข้างหนาแน่น สำหรับการเลือกใช้พื้นที่เกาะนอน พบว่า ไก่ฟ้าพญาลอเลือกเกาะนอนบริเวณพื้นที่ที่มีความลาดชันสูง แต่มีการปกคลุมของเรือนยอดที่ระดับความสูง >5 เมตร ค่อนข้างต่ำ คาดว่าเพื่อให้สะดวกในการบินหนีเมื่อถูกผู้ล่าจู่โจม

ในช่วงฤดูผสมพันธุ์ ไก่ฟ้าพญาลอจะเริ่มวางไข่ตั้งแต่เดือนเมษายนถึงต้นเดือนสิงหาคม จากการติดตามเก็บข้อมูลรังจำนวน 18 รัง พบจำนวนไข่เฉลี่ย 6.4 ± 0.3 ฟองต่อครอก (4 - 8 ฟองต่อครอก) ระยะเวลากกไข่นาน 23 - 24 วัน ไข่จึงจะฟักเป็นตัว และพบว่ามีเพียง 2 รังเท่านั้นที่รอดพ้นจากการโดนล่า ทั้งนี้การล่าและทำลายรังจากสัตว์ผู้ล่าถือเป็นสาเหตุหลักที่ทำให้การทำรังล้มเหลว โดยส่วนใหญ่ไก่ฟ้าพญาลอจะเลือกทำรังในรากพูพอนของต้นไม้ขนาดใหญ่ที่มีเส้นผ่านศูนย์กลางระดับอกเฉลี่ย 185.4 ± 23.9 เซนติเมตร (63.5 – 359.0 เซนติเมตร) และเป็นพื้นที่ที่มีการปกคลุมของพืชที่ระดับความสูง <0.5 เมตร ค่อนข้างหนาแน่น, มีความลาดชันของพื้นที่สูง, มีพื้นที่หน้าตัดของต้นไม้ขนาดใหญ่มาก และเป็นพื้นที่ที่รังจะมีโอกาสถูกล่าหรือทำลายโดยสัตว์ผู้ล่าต่ำ

การประเมินความหนาแน่นของประชากรไก่ฟ้าพญาลอโดยใช้ข้อมูลที่ได้จากการติดตั้งกล้องดักถ่ายภาพสัตว์ (5.6 ตัวต่อตารางกิโลเมตร) พบว่า มีความแม่นยำมากกว่าค่าที่ประเมินได้จาก

distance sampling (40.3 ตัวต่อตารางกิโลเมตร) เนื่องจากมีช่วงความเชื่อมั่นที่แคบกว่า และมีความถูกต้องมากกว่าเมื่อเปรียบเทียบกับค่าที่ได้จากการติดตามสัญญาณวิทยุ (16.7 ตัวต่อตารางกิโลเมตร) การศึกษานี้ได้แสดงให้เห็นถึงประสิทธิภาพของการใช้กล้องดักถ่ายภาพสัตว์เพื่อประเมินความหนาแน่นของประชากรไก่ฟ้าพญาลอซึ่งเป็นสัตว์ที่พบเห็นได้ยาก และสนับสนุนให้นำเทคนิคนี้ไปประยุกต์ใช้ในการสำรวจและติดตามประชากรไก่ฟ้าชนิดอื่นๆ ที่อาศัยอยู่ในภูมิภาคเอเชียตะวันออกเฉียงใต้ รวมถึงนกชนิดอื่นที่หากินตามพื้นดินและมีพฤติกรรมหลบๆ ซ่อนๆ

มหาวิทยาลัยเทคโนโลยีสุรนารี

สาขาวิชาชีววิทยา ลายมือชื่อนักศึกษา______________________________

ปีการศึกษา 2556 ลายมือชื่ออาจารย์ที่ปรึกษา________________________

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม_____________________

SARANPHAT SUWANRAT : HABITAT SELECTION AND ABUNDANCE ESTIMATES OF SIAMESE FIREBACK *LOPHURA DIARDI* AT SAKAERAT ENVIRONMENTAL RESEARCH STATION. THESIS ADVISOR : ASST. PROF. PONGTHEP SUWANWAREE, Ph.D. 171 PP.

GALLIFORMES/ RADIOTELEMETRY/ CAMERA TRAP/ DISTANCE SAMPLING/REPRODUCTIVE ECOLOGY

Siamese Fireback (*Lopuhra diardi*) is a distinctive and threatened galliform species restricted to lowland forest habitat. The aims of this study were to investigate the home range, habitat use, roosting behavior, roost-site selection, reproductive ecology and nest-site selection of lowland Siamese Fireback in Sakaerat Environmental Research Station, Nakhon Ratchsima, during 2010 – 2012. Eight female Siamese Firebacks from eight different groups were caught, fitted with radio-transmitters and followed for 2 – 27 months. The results showed that the average annual home range size was 31.4 ± 2.5 ha (n = 7). Non-breeding home range size was highest (26.3 ± 4.1 ha, n = 7), followed by breeding (21.7 ± 2.4 ha, n = 8) and chick rearing alone (9.7 ± 0.4 ha, n = 2) periods, respectively. From 480 habitat study plots (each a 10-m radius circular plot), females avoided loss of a brood by restricting their movements to the smallest home ranges and selected areas with dense ground cover (<0.5 m height) and higher density of understory trees (>3 – 5 m in height). In addition, Siamese Firebacks selected areas on steeper slopes with less canopy cover for roosting (n = 52), presumably to facilitate escape-flushing when a predator attacked.

During three breeding seasons, Siamese Fireback laid eggs from April to early August. From 18 nests monitored, the mean clutch size was 6.4 ± 0.3 eggs, ranging from four to eight eggs. The incubation period was 23 – 24 days and only 2 nests survived. Predation was the main cause of nest failure. Siamese Fireback appeared to prefer to nest in the buttresses of large trees, average diameter at breast high (DBH) of 185.4 ± 23.9 cm, (n = 15), ranging from 63.5 to 359.0 cm, and areas with dense vegetation coverage below 50 cm, on steeper slopes, near large basal areas of trees DBH >10 m and with low predation pressure (n = 21).

Estimates of density based on camera trapping produced relatively precise density estimates in breeding season (5.6 birds km^{-2}) with narrower confidence intervals than those of overestimates derived from distance sampling (40.3 birds km^{-2}), and relatively accurate in comparison with radiotelemetry (16.7 birds km^{-2}). This study has demonstrated the effectiveness of camera traps for estimating density of naturally unmarked Siamese Firebacks and encouraged the use of this technique to survey and monitor Southeast-Asian pheasants, including secretive terrestrial birds.

School of Biology	Student's Signature __________________________
Academic Year 2013	Advisor's Signature __________________________
	Co-advisor's Signature _______________________

ACKNOWLEDGEMENT

This study was conducted by the permission of Thailand Institute of Scientific and Technological Research (TISTR), Ministry of Science and Technology (Mr. Taksin Artchawakom, the superintendent of Sakaerat Environmental Research Station (SERS)). I thank for TISTR allowing me to undertake this study in SERS.

I would like to express sincere gratitude to Asst. Prof. Dr. Pongthep Suwanwaree, my advisor for his generous help and guidance throughout the period of study. Asst. Prof. Dr. Tommaso Savini, my thesis co-advisor, is thanked for his kindness, encouragement, valuable guidance, comment and correction of the manuscript of this thesis. I am grateful to Assoc. Prof. Dr. George A. Gale, Prof. John P. Carroll and Dr. Dusit Ngoprasert for their valuable advice and guidance in the various stages of the study.

This study would never been possible without the help and assistance of numerous colleagues. I am grateful for the help of Mr. Niti Sukumal, Mr. Tiwa Ong-in, Mr. Suwijuk Sukhapan, Mr. Peerapan Jan-udom and the staff at SERS for much assistance with field work and Mr. Wanlop Chutipong, Mrs. Naruemon Tantipisanuh, Dr. Erin Roche and Dr. Chris Sutherland for helping with data analysis. I also thank members of the Conservation Ecology Program at King Mongkut's University of Technology Thonburi for their hospitality and support during my stay.

This study was supported by the TRF/BIOTEC Special Program for Biodiversity Research and Training grant (BRT T_353035), the Human Resource

Development Science Project (Science Achievement Scholarship of Thailand) and Suranaree University of Technology.

Finally, I most gratefully acknowledge my parents, my grandmother and my brother for all their support of everything during my live and throughout the period of this study.

Saranphat Suwanrat

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LIST OF ABBREVIATIONS

asl.	=	above sea level
AIC	=	Akaike's Information Criterion
AIC_c	=	the lowest second order of Akaike Information Criterion
AUC	=	area under the receiver operating characteristic curve
ca.	=	Circa (Latin word) which meaning "about"
CHPs	=	Characteristic hull polygons
CI	=	Confidence interval
DBH	=	Diameter at breast height
DDF	=	Dry dipterocarp forest
DEF	=	Dry evergreen forest
OFP	=	Old forest plantation
OFP	=	Old forest plantation
GPS	=	Global Positioning System
ha	=	hectare
IUCN	=	International Union for Conservation of Nature
km	=	kilometer
m	=	meter
MCMC	=	Markov chain Monte Carlo
MCP	=	Minimum convex polygon
mm	=	millimeter

LIST OF ABBREVIATIONS (Continued)

RAI	=	Relative abundance index
SE	=	Standard error
SERS	=	Sakaerat Environmental Research Station
TISTR	=	Thailand Institute of Scientific and Technological Research
UNESCO	=	United Nations Educational, Scientific, and Cultural Organization

CHAPTER I

INTRODUCTION

1.1 Background and Problem

The Siamese Fireback, *Lophura diardi* is found in mainland Southeast Asia: distributed from eastern Myanmar through northeastern and southeastern Thailand, Laos, Cambodia, and central and southern Vietnam (Madge and McGowan, 2002; BirdLife International, 2012). It mainly occurs in lowland evergreen, semi-evergreen forests, including bamboo and secondary forests from plains to 800 m elevations and possibly up to 1,150 m (BirdLife International, 2012). Although its total population size has not been recently estimated, it is suspected to number 20,000 – 50,000 individuals (BirdLife International, 2012). In Thailand, its population is estimated at 5,000 individuals (Madge and McGowan, 2002; BirdLife International, 2012). Siamese Fireback is listed as "Least Concern" because it is more resilient to the threats of habitat alternation and hunting pressure than once thought, thus the rate of population decline is not suspected to be as rapid as was indicated. Although, recent evidence suggests that Siamese Fireback may be able to tolerate a higher level of hunting pressure, habitat loss and hunting are ongoing threats of the species (BirdLife International, 2012).

Siamese Fireback is secretive, relatively cryptic, not particularly vocal, and prefers dense forest habitat, making most traditional bird survey methods is difficult to implement. Although, there are recent studies in captive propagation (Boonsanong and Ruknonped, 2000a; 2000b; 2002a; 2002b) and genetics (Randi et al., 2001), there is still limited information about the ecology not only of Siamese Fireback but also other *Lophura* species in the wild. Specially, Siamese Fireback has recently expanded its range into the sub-montane habitat of Silver Pheasant (*L. nycthemera*) in Khao Yai National Park (Round and Gale, 2008). A previous study revealed that the areas of overlap between the Siamese Fireback and the Silver Pheasant within Khao Yai National Park showed small-scale patterns of habitat partitioning by topography, with the Silver Pheasant preferring steeper slopes and the Siamese Fireback flatter areas (Sukumal and Savini, 2009). Recent study on a sub-montane population of Siamese Fireback found that it tends to use topographically flat areas similar to topography found in lower elevation habitats, with the exception of nest sites, which were placed on steeper slopes (Sukumal et al., 2010). Although there are few studies on Siamese Fireback in Thailand, the information is limited because of small sample size and all studies undertaken only at high elevation in Khao Yai National Park. Moreover, no quantitative data exists of Siamese Fireback in its natural lowland habitats.

The Siamese Fireback is designated as the national bird of Thailand by Thai Royal Forest Department in 1985 (Khobkhet, 2000). In addition, the species is also selected as a symbol of Sakaerat Environmental Research Station (SERS), Nakhon Ratchasima because it is commonly found along the roadsides, forest edges, fire breaks and natural trails, particularly during the early morning and late afternoon. SERS is a small, well-protected lowland area, with three dominant habitat types, dry evergreen forest, dry dipterocarp forest and old forest plantation, elevation ranging from 240 m to 760 m above sea level (asl). The species mainly inhabit in dry evergreen forest but it can also be found in the forest plantation. Despite it is widespread in SERS, no Siamese Fireback study has ever been conducted in this area before. Thus, this is an opportunity to investigate lowland populations of Siamese Fireback in various aspects of its ecology. Moreover, information obtained from Siamese Fireback can be used and applied to other *Lophura* species whose information is still limited.

1.2 Objectives

The objectives of this study were:

1) To investigate the ranging behavior of Siamese Fireback and its patterns of habitat use in lowland forest and determine features of the forest influencing patterns of habitat use.

2) To examine roosting behavior and determine the ecological features of the habitat influencing roost-site selection.

3) To study breeding ecology of Siamese Fireback, and determine ecological features of the habitat influencing nest-site selection.

4) To estimate the abundance and density of the Siamese Fireback using camera traps and distance sampling, and compare the abundance estimates derived from the two methods to estimate based on territory mapping of radio-tagged Siamese Firebacks.

1.3 Study Scope

This study is focusing on a resident Siamese Fireback population in Sakaerat Environmental Research Station, Nakhon Ratchasima, a small and well-protected lowland area. The study area is of approximately 3 km^2 dominated by dry evergreen forest, located beside the 3 – 6 km mark of the main road, with elevation ranging between 350 – 580 m. Because of limiting number of radio-transmitters, capture attempts and radio-tracking were focused on female Siamese Fireback with the vulnerable information on reproductive ecology, and one individual for a group. All radio-collared birds were followed as long as possible until the radio fell off the bird or the bird was predated. By following the radio-collared birds, the size of their home range, patterns of habitat use, breeding ecology, habitat characteristics for their range, roost and nest sites were investigated. In addition, camera traps and distance sampling techniques were conducted to estimate abundance and density of Siamese Fireback covering a large-scale of the study area (39.50 km^2, 29.16 km^2 in dry evergreen forest and 10.34 km^2 in forest plantation). To evaluate the effectiveness of using camera traps and distance sampling for density estimates, the density estimates of Siamese Fireback in dry evergreen forest derived from those two techniques were used to compare to the estimates based on territory mapping of radio-collared birds.

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1.4 Expected Benefits

This study was carried out to increase the knowledge of life history, provide fundamental information on lowland populations of Siamese Fireback in this region, and advice to the SERS for application in management, maintenance and protection of the species in the future. Furthermore, the knowledge and information from this study could be used or applied for study of tropical Asian galliforms, specifically for *Lophura* species of which information is still limited.

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CHAPTER II

LITERATURE REVIEW

2.1 Galliformes

The Galliformes (pheasants, partridges, grouse and their relatives) is often considered among the more threatened of avian orders with 26% of the circa (ca.) 300 species globally red listed (IUCN, 2013). Habitat degradation and loss are seen as the biggest problems facing the threatened birds generally. Galliformes may be at additional risk through pressure of exploitation, typically for food (Brickle et al., 2008). Despite the threats facing the birds, little is known about the basic biology of most species.

Pheasants (subfamily Phasianinae), a group of birds in the order Galliformes, comprise of 16 genera and 51 species (IUCN, 2013). Of which, 21 species are of global conservation concern; 1 Critically Endangered, 4 Endangered, and 16 Vulnerable species (IUCN, 2013). The pheasants are Asian in their distributions, with the single exception of Congo Peafowl (*Afropavo congensis*), which is endemic to the Democratic Republic of Congo in central Africa (Crowe et al., 1986). Several species have been introduced by humans into various parts of Europe and North America for sport-hunting purposes. Within Asia, pheasants are found in eastern parts of Java, throughout the equatorial forests of the Thai-Malay peninsula, and in northeastern China. Pheasant taxa also occur throughout the Himalayan chain and extend as far east as Taiwan (Mikado Pheasant, Swinhoe's Pheasant) and Japan (Copper Pheasant, Ring-necked Pheasant) (Fuller and Garson, 2000).

Most pheasant habitats are found from sea level up to 2,745 m elevation (Johnsgard, 1999). Some species live in lowland tropical rainforest (e.g. Crested fireback *Lophura ignita*), montane tropical forest (e.g. Silver pheasant *Lophura nycthemera*) and temperate coniferous forest (e.g. Western tragopan *Tragopan melanocephalus*). Some species are found in more open habitat, such as subalpine scrub (e.g. Blood pheasant *Ithaginis ceuentus*), alpine meadows (e.g. Chinese monal *Lophophorus lhuysii*) and grassland (e.g. Cheer pheasant *Catreus wallichii*) (Fuller and Garson, 2000).

2.2 Gallopheasants

Gallopheasants (*Lophura* spp.) are chicken-like pheasants which generally show sexual dimorphism. This genus comprises of 11 species. Most of gallopheasants are distributed on the mainland of South East Asia. Six of those species are of global conservation concern; 1 Critically Endangered, 1 Endangered, and 4 Vulnerable species (IUCN, 2013; Table 2.1). The populations of these species are considered to be in decline throughout their geographic distribution due to habitat loss and hunting. Some *Lophura* species are endemic and restricted in some area. Salvadori's Pheasant and Aceh Pheasant are endemic to Sumatra, Indonesia. Edwards's Pheasant and Vietnamese Pheasant are lowland endemic birds of Vietnam while Swinhoe's Pheasant is endemic and restricted in Taiwan. Imperial Pheasant *L. imperialis* was not included in the *Lophura* species list because Hennach et al. (2003) revealed that Imperial Pheasant is a hybrid between Silver Pheasant and Edwards's Pheasant.

Despite the threats facing the birds, little is known about the basic biology of *Lophura* species, particularly Edwards’s Pheasant even though its status was up listed to critically endangered in 2012 (BirdLife International, 2012a).

Table 2.1 Distribution and status of *Lophura* species (IUCN, 2013).

Species	Common name	Status	Distribution
L. bulweri	Bulwer's Pheasant	Vulnerable	Malaysia (Sabah and Sarawak), Indonesia (Kalimantan) and Brunei
L. diardi	Siamese Fireback	Least Concern	Thailand, Laos, Cambodia, Vietnam
L. edwardsi	Edwards's Pheasant	Critically Endangered	central Vietnam
L. erythrophthalma	Crestless Fireback	Vulnerable	Peninsular and East Malaysia, Indonesia (Sumatra and Kalimantan) and Brunei
L. hatinhensis	Vietnamese Pheasant	Endangered	central Vietnam
L. hoogerwerfi	Aceh Pheasant	Vulnerable	Indonesia (Sumatra)
L. ignita	Crested Fireback	Near Threatened	Myanmar (Tenasserim), peninsular Thailand, Peninsular and East Malaysia, Indonesia (Kalimantan, Sumatra and Bangka), Brunei
L. inornata	Salvadori's Pheasant	Vulnerable	Indonesia (Sumatra)
L. leucomelanos	Kalij Pheasant	Least Concern	Bangladesh, Bhutan, China, India, Myanmar, Nepal, Pakistan, Thailand
L. nycthemera	Silver Pheasant	Least Concern	Cambodia, China, Laos, Myanmar, Thailand, Vietnam
L. swinhoii	Swinhoe's Pheasant	Near Threatened	central Taiwan

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2.3 *Lophura* in Thailand

Four *Lophura* species are found in Thailand (IUCN, 2013; Table 2.1). They are Siamese Fireback, Crested Fireback, Kalij Pheasant and Silver Pheasant. Kalij Pheasant has two subspecies *L. leucomelanos lineate* and *L. leucomelanos crawfurdii* which are only found in western Thailand. While the two subspecies of Silver Pheasant, *L. nycthemera jonesi* and *L. nycthemera lewisi*, are separately found. *L. n. jonesi* is found throughout the north and north-east, while *L. n. lewisi* is only found in south-east of Thailand (Lekagul and Round, 1991). The Kalij Pheasant and Silver Pheasant are considered to be allopatric or parapatric species, as their ranges are partially overlapping in the north-west of Thailand (Lekagul and Round, 1991; Randi et al., 2001). Siamese Fireback, a lowland species, is now found ranging into sub-montane forest habitat of the Silver Pheasant in Khao Yai National Park (Round and Gale, 2008). Although, the two pheasants are sympatric in their ranges, they maintain a substantial difference in the microhabitat use, with Silver Pheasant occurring mainly on ridges and Siamese Fireback in flatter and lower-lying areas (Sukumal et al., 2010). The Crested Fireback is the allopatric sister species of Siamese Fireback (Randi et al., 2001). Crested Fireback inhabits similar lowland forest habitat, but its range is distributed to the south of Isthmus of Kra while Siamese Fireback is found up to the north (Randi et al., 2001).

2.4 Siamese Fireback *Lophura diardi*

2.4.1 Description

Lekagul and Round (1991) and Johnsgard (1999) described the Siamese fireback *Lophura diardi* as a medium-sized pheasant, approximately 80 cm long. The male has a grey plumage with an extensive red facial skin, crimson legs and feet, ornamental black crest feathers, reddish brown iris and long curved blackish tail (Figure 2.1). There is a small area of maroon on lower back that is less extensive than in the other fireback. The female lacks an obvious crest, but has upper wing surfaces and elongated central tail feathers that are back with distinctive broad, broken, buffy white barring (Figure 2.2). The name “fireback” refers to the golden-yellow patch on lower back (Figure 2.1), a feature shared with other firebacks.

Figure 2.1 Male Siamese Fireback and the golden-yellow patch on lower back.

Figure 2.2 Female Siamese Fireback.

2.4.2 Distribution and Population

Siamese Fireback is found in mainland Southeast Asia: Cambodia, Laos, Vietnam, and some parts of Myanmar and Thailand (BirdLife International, 2012b; Figure 2.3). It is widespread in central and southern Laos and Vietnam, localized in north Annam and north Laos. In Cambodia, it is not uncommon in larger tracts of evergreen and semi-evergreen forest north of Tonle Sap Lake, and east of Mekong River but much less frequently recorded in the superficially suitable-looking Cardamon mountains in south-west (Brickle et al., 2008). In Thailand, it is uncommon to locally common resident, principally found in the north-east and south-east (BirdLife International, 2012a). Although, its global population size has not been recently estimated, it is suspected to number 20,000-50,000 individuals (BirdLife International, 2012b).

Figure 2.3 Global distribution of Siamese Fireback.

(From: BirdLife International, 2012b)

2.4.3 Habitats

Siamese Fireback is a lowland resident of evergreen, semi-evergreen and bamboo forest, secondary growth, scrub, and area of old cultivation, chiefly found below 500 m asl., but occasionally up to 800 m, and perhaps even 1,150 m (Johnsgard, 1999). It is most commonly encountered along the roads that have been cut through the jungle and seems able to tolerate considerable degradation of its forest habitat, such as moderate logging and cultivated fields in small clearings (Delacour, 1977).

2.4.4 Reproductive Biology

Khobkhet (2000) noted that Siamese Fireback bred during April to June while Boonsanong and Ruknongped (2002a) reported the breeding season of Siamese Fireback starting from March to June in captivity (at the Phu Khieo breeding center, Chaiyaphum Province, Northeastern Thailand). However, these months coincide with the late dry season to the early wet season.

Little information is available on the breeding behavior of this shy bird in the wild. The Siamese fireback is reported to be monogamous in captivity (Delacour, 1977). Perhaps this is also the case in the wild, although there is no information on this point. Wing-whirring is considered to be a major male sexual display, but it is equally probable that lateral display, which would expose the highly colorful rump patches, is also an important part of courtship (Johnsgard, 1999).

Nests have been found locating on the ground in a hollow at the base of a tree (Johnsgard, 1999). Clutches seem to contain between four and eight eggs, and are incubated for 24 to 25 days in captivity. The chicks are precocial and foraging with their mothers after hatching (Johnsgard, 1999). However, nothing is known about growth and development of the young under the natural conditions.

2.4.5 Threats and Status

This species is threatened by continuing extensive lowland forest destruction within its range and by hunting and snaring for food and trade (BirdLife International, 2012b). Siamese Fireback is listed as Least Concern as it is more resilient to the threats of habitat alternation and hunting pressure than once thought, thus the rate of population decline is not suspected to be as rapid as was indicated. As habitat loss and hunting are ongoing threats, recent evidence suggests that the species may be able to tolerate a higher level of hunting pressure (BirdLife International, 2012b).

2.5 Relevant Researches of Siamese Fireback

Despite the Siamese Fireback is slowly going to be in endangered status, only few studies have been done in Thailand. Most studies are in captive propagation (Boonsanong and Ruknonped, 2000a; 2000b; 2002a; 2002b) but only a few is in its natural range. There are particularly restricted in only Khoa Yai National Park.

Praditsup (2004) studied the social behavior and ecology of Siamese Fireback at the forest bordering of an approximately 2 km length of road leading to Khao Khiew Mountain in Khoa Yai National Park. This study reported that flock-size of Siamese Fireback varied from 1 to 10 individuals with larger mixed-sex flock during the non-breeding season (November to January) and smaller flocks or pairs in breeding season (March to June). Wing-whirring in the Siamese Fireback could be related to dominance hierarchy, territorial advertisement, flocking signals and possibly mate attraction. In addition, Siamese Firebacks did not show harem polygyny in this study because pairs were often found during the breeding season.

Round and Gale (2008) reported a range change for Siamese Fireback in higher elevation up to 800 m where previously Silver Pheasant was mostly observed in the Mo Singto Long Term Biodiversity Plot, Khao Yai National Park. The most possible reason was climate change observed during the past 100 years, whereby the average temperature has increased about 6˚C and consequently increasing evapotranspiration, which is higher in the lowland than in montane and upper sub-montane areas. This change in microhabitat may be a primary cause leading to an increase in the number of Siamese Fireback relative to the resident Silver Pheasant.

Sukumal and Savini (2009) found a distinct difference in habitat use and elevation between Siamese Fireback and Silver Pheasant in the Mo Singto Long Term Biodiversity Plot, Khao Yai National Park. Although Siamese Firebacks were observed at higher elevation, they prefer level area while Silver Pheasants were found mainly on slope. Furthermore, the topographical separation between Siamese Fireback and Silver Pheasant occurred at roughly 15 degree, physically separating the two species.

Additional study in the same area above, Savini and Sukumal (2009) showed the preliminary results on breeding behavior of Siamese Fireback and Silver Pheasant. The results showed differences between mating strategies of the two species. Siamese Fireback showed a high reproductive skew, with a dominant male was always in closer proximity to females when the other males were presented, while Silver pheasants showed a lower skew, with all males in a group sharing almost equal proximity to females. However, they were not yet able to explain why this difference in mating system occurred. Moreover, these observations were undertaken from only one breeding season (2007).

Sukumal et al. (2010) studied a sub-montane population of Siamese Fireback in the Mo Singto Long Term Biodiversity Plot, Khao Yai National Park and revealed that the preference of nesting habitat was on the ground in a hollow tree and on steeper slopes (>10 degrees) area. The study reported that sub-montane Siamese Fireback selected area with greater under-story cover during the mating season and moved to areas with higher ground vegetation density while rearing young chicks.

However, these conclusions are based on a very small sample size (only two females) from one location.

Although there are few studies on Siamese Fireback in Thailand, the information is limited because of small sample size and all studies were undertaken only at high elevation in Khao Yai National Park. Moreover, no quantitative data exists of all *Lophura* species in tropical region.

2.6 Sakaerat Environmental Research Station

2.6.1 Location and History

The Sakaerat Environmental Research Station (SERS) is situated in the Korat Plateau, approximately at 14°30´N and 101°55´E about 60 km east of Nakhon Ratchasima and 300 km northeast of Bangkok (Figure 2.4). The SERS covers an area of 78.09 km^2 mainly in six sub-districts of Nakhon Ratchasima Province in northeast Thailand, namely Ta Khob, Lam Nang Kaew, Phu Luang, Udomsap, Wang Mee and Wang Ngam Khiew (Trisurat and Duengkae, 2011). Its altitude ranges from 250 – 762 m asl and approximately 35% of the research station is situated in altitudes between 300 – 400 m asl (TISTR, 2002). It was formerly administered by the National Research Council of Thailand, but now is under the Thailand Institute of Scientific and Technological Research (TISTR).

The SERS is surrounded by extensive agricultural areas and human settlements. Long-term monitoring has shown that the natural forest has diminished due to encroachment and illegal logging (Maninan et al., 1976). Originally, there were 15 villages situated inside the SERS but all settlements were relocated to a land reform plot in 1983 (Khernark, 1991). In 1982, the Royal Forest Department started to rehabilitate degraded forest and abandoned settlements inside the SERS, thus forest cover has increased since then. An assessment in 1995 indicated that the percentage of forest inside the SERS was approximately 63.15% (Ongsomwang, 1986) and increased to 72.62% in 2002 (Trisurat, 2009).

2.6.2 Vegetation

SERS has two major natural forest types: dry evergreen forest (46.82 km^2, 60.0%) (TISTR, 2012a; Figure 2.4) dominated by tree species such as *Hopea ferrea*, *Hopea odorata* and *Hydnocarpus ilicifolia* (Figure 2.5), and dry dipterocarp forest (14.51 km^2, 18.6%) dominated by common dipterocarpus trees such as *Shorea siamensis*, *Shorea obtusa* and *Dipterocarpus intricatus*, and two large patches of more than 20 year old forest plantation of mixed acacia and eucalyptus (14.46 km^2, 18.5%), and several small patches of bamboo forest (1.12 km^2, 1.4%), grassland (0.93 km^2, 1.2%) and the office and operational building (0.25 km^2, 0.3%).

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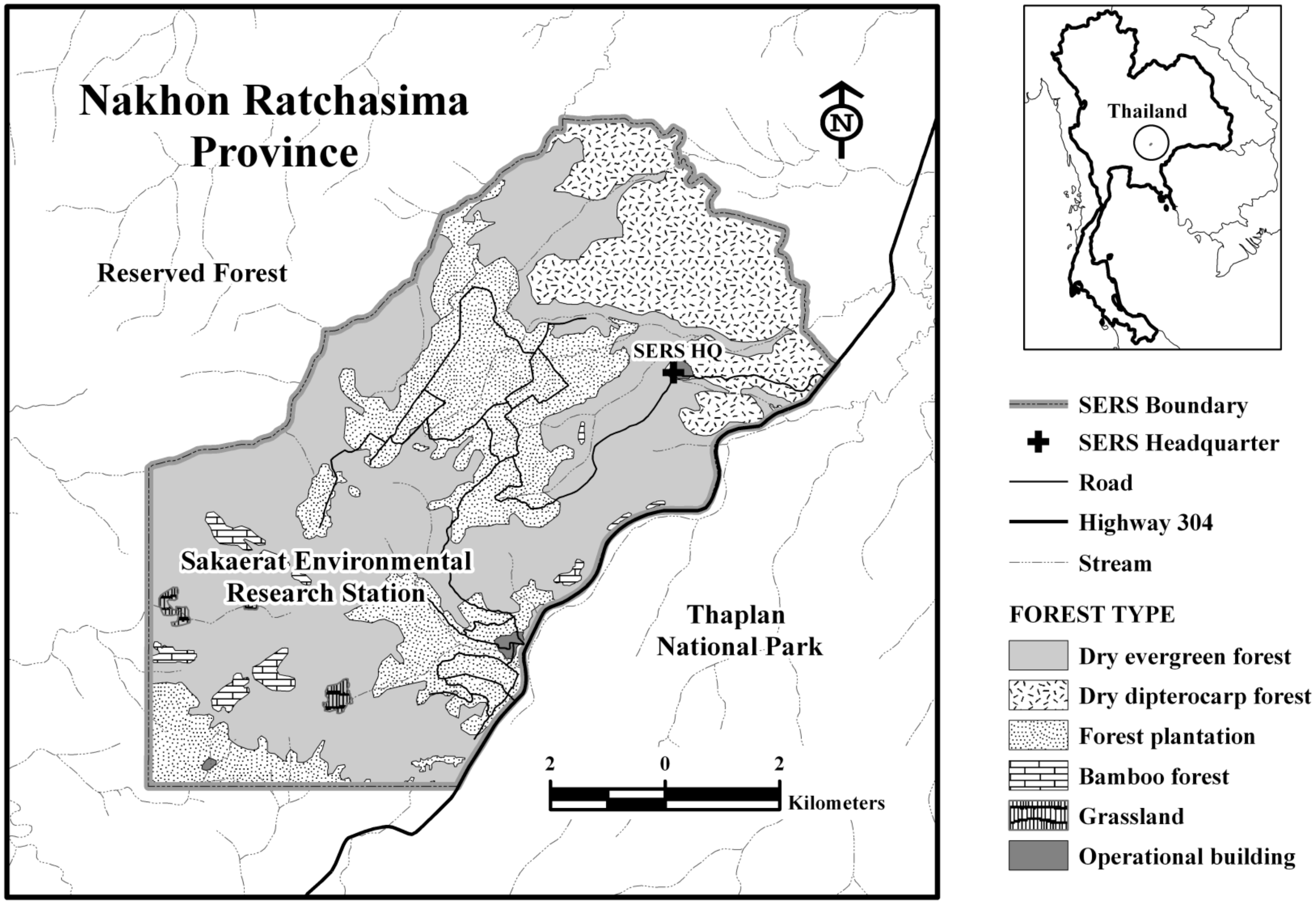

Figure 2.4 Location of Sakaerat Environmental Research Station (SERS), Nakhon Ratchasima.

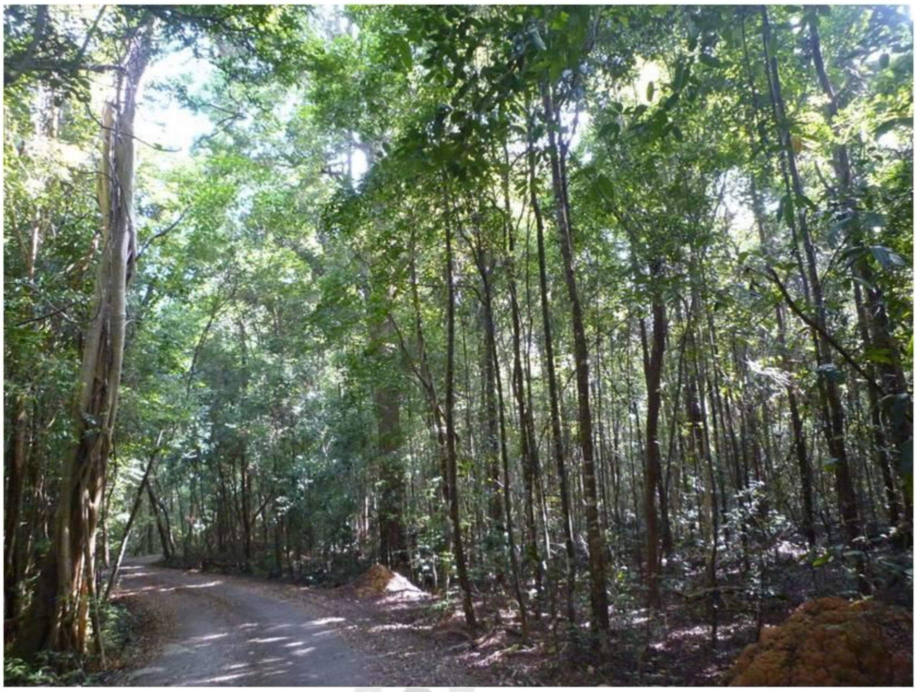

Figure 2.5 Dry evergreen forest in Sakaerat Environmental Research Station.

2.6.3 Wildlife

The natural vegetation at the SERS supports a high faunal diversity. At least 385 wildlife species were recorded in the SERS (TISTR, 2002). Some of which are regular inhabitants of the SERS, while others pass through on migratory routes or move between SERS and the adjacent Thaplan National Park. There are approximately 230 bird species which have been reported at the SERS. The Siamese Fireback, the symbol of the SERS, is common sight along the roadsides, forest edges, fire breaks and natural trails in dry evergreen forest (Angkapreechaset and Kritanuch, 2003). Nearly 80 species of mammals are known from the SERS. This includes the Serow (*Naemorhedus sumatraensis*), one of 15 Thailand's protected species. Numerous lizards and snakes in habit in the SERS forest, just fewer than 90 species.

In addition, at least 26 amphibian species has been confirmed from the SERS waterways (TISTR, 2002).

2.6.4 Climate

The climate at SERS is tropical with no occurrence of frost. The winters are cool and dry, while the summers are hot and humid. Daily maximum and minimum temperature, the relative humidity and rainfall were obtained from five meteorological stations in the SERS. The data were daily collected every morning and used as references to the study area. The average monthly temperature, relative humidity and rainfall at the SERS in 2010, 2011 and 2012 are shown in Figures 2.6, 2.7 and 2.8, respectively (TISTR, 2012b).

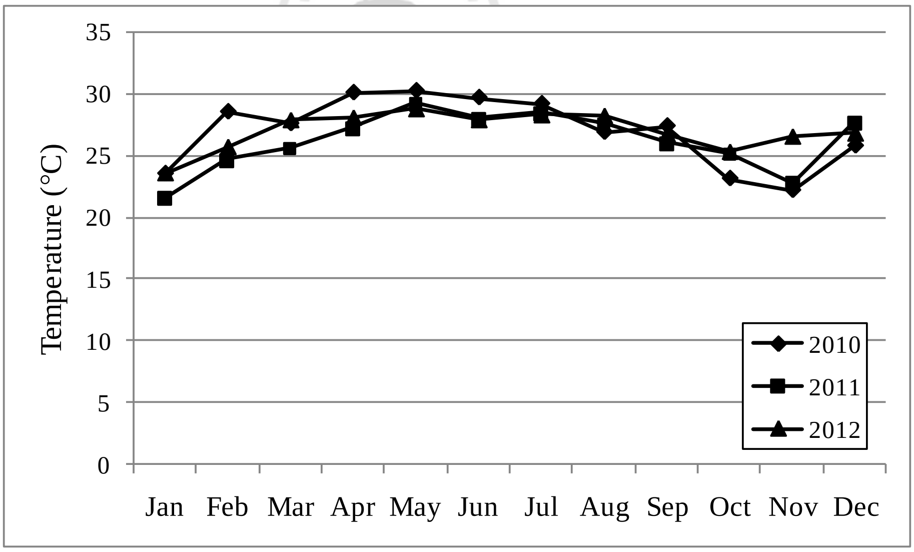

Figure 2.6 The average monthly temperature at the SERS during 2010 – 2012.

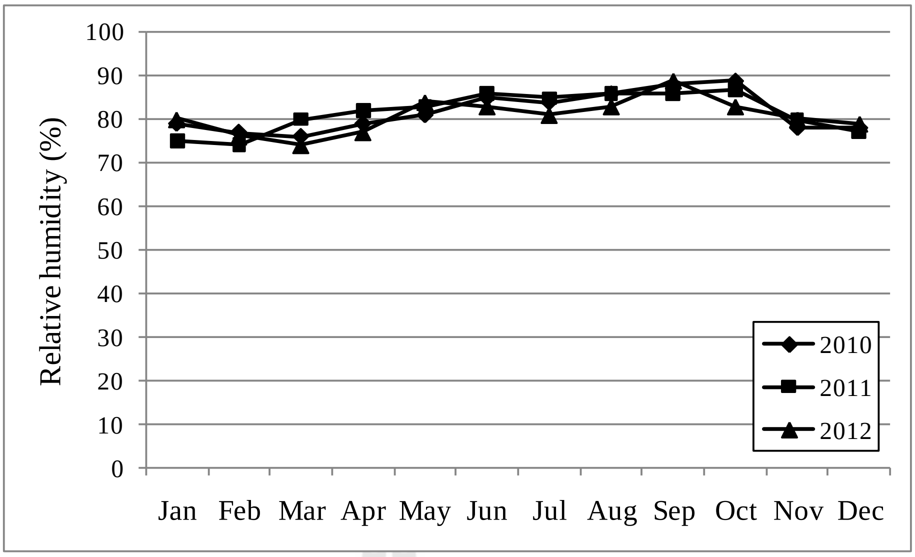

Figure 2.7 The average monthly relative humidity at the SERS during 2010 – 2012.

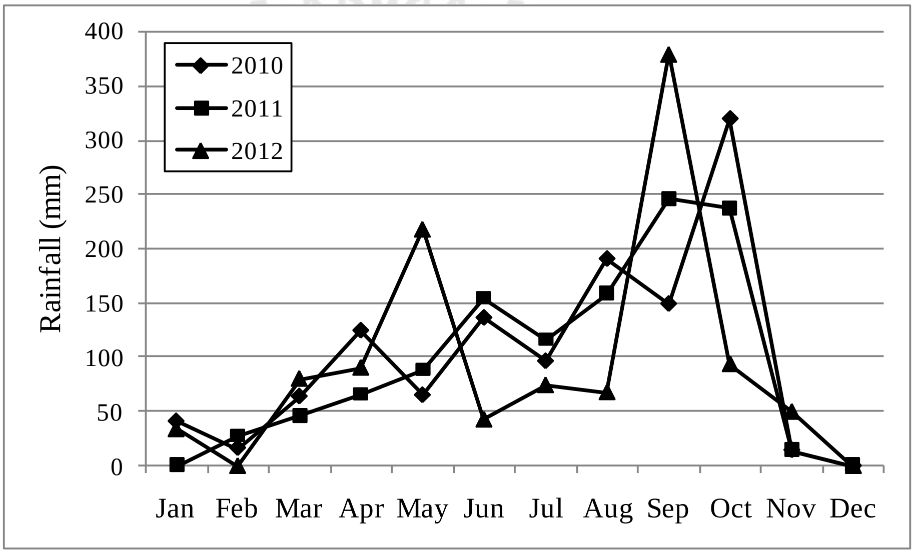

Figure 2.8 The average monthly rainfall at the SERS during 2010 – 2012.

During the three years period (2010 – 2012), average annual precipitation is 1,169 mm with a dry season from November to April (Average yearly rainfall 223 mm) and a wet season from May to mid-October (Average rainfall 945 mm), with rainfall peaks in May and September. Average annual temperature is 26.7°C (range 21.6 to 30.3 °C) and average relative humidity is 81.4% (range 74 to 89%).

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CHAPTER III

HOME RANGE, HABITAT USE AND ROOST-SITE SELECTION OF SIAMESE FIREBACK

3.1 Abstract

Siamese Fireback (*Lopuhra diardi*) is a distinctive and threatened galliform species restricted to lowland forest habitat (<800 m elevation). However, populations have been reported in an expanded range into higher elevations, up to 800 m in Khao Yai National Park. Most information available on Siamese Fireback is from a population that recently migrated to sub-montane forest habitat and no quantitative data exists in its natural lowland forest habitat. This study was conducted to investigate ranging behavior, habitat use and roost-site selection of Siamese Firebak at Sakaerat Environmenral Research Station, a small and well-protected lowland forest in Northeast Thailand. The results showed that the Siamese Firebacks in this study area had smaller home range size than previously reported for a sub-montane population. Siamese Fireback showed a distinct preference for areas that were considered to be the secondary forest patches during the different periods of the female year cycle and during different seasons. Specifically, females selected areas with dense ground cover and higher density of understory sapling when they were alone with their young chicks. In addition, Siamese Firebacks selected areas on steeper slopes with less canopy cover for roosting, presumably to avoid predation.

The study suggests that the seasonal variations in home range size and patterns of habitat use are related to food availability still need to be investigated. These results could be referable information for other places where the management for this species is needed.

3.2 Introduction

Animal ranging patterns are influenced by several factors such as resource availability and distribution, habitat structure, predation, territoriality, hunting pressure and seasonality (Osborn, 2004; Edelman and Koprowski, 2006). Home ranges can be defined as the area habitually traversed by an individual or group of animals during normal activities over a given period (Burth, 1943; Jewell, 1966). Within a home range, a smaller area can be defined as the core area that is used most intensely and is often associated with the presence of important resources (Kaufman, 1962). Larger home range may be costly in terms of time and energy allocated to travel, while also increasing encounter rates with predators and competitors (Powell, 2000; Yoder et al., 2004). Consequently, animals should attempt to use the smallest adequate home range, and that home range size will be positively correlated with resource needed for particular groups (Badyaev et al., 1996). At the same time, home range size should typically be inversely related to resource availability, habitat quality and ultimately to an individual’s fitness (Whitaker et al., 2007).

A habitat refers to particularly set of physical environmental factors that a species use for its survival and reproduction (Block and Brennan, 1993). Moreover, habitat can influence the distribution of available resources such as food, shelter or barrier against predators (Lima, 1993). High quality habitat, with plenty of food resources, adequately camouflaged nest-sites and little human disturbance is important to ensure the maximum reproduction and survival of birds (Block and Brennan, 1993; Riley et al., 1998). For endangered birds, studying the relationship between their habitat preference and habitat structure is helpful to predict their habitat suitability, assess their habitat quality and further improve their habitat conditions for the conservation and management of their populations (Morris, 2003)

Night roosts play a crucial role in bird biology because of the large amount of time birds spend roosting during the night when asleep (Woltmann, 2004). Birds that are active in the day cannot be aware of potential dangerous situations during the night time because of poor visibility (Chamberlain et al., 2000). A suitable roosting habitat not only retains a desirable temperature for birds, but also protects them from predation (Cody, 1985). Roosting behavior and roost selection are likely to be important determinants of individual fitness (Cody, 1985; Elmore et al., 2004; Fisher et al., 2004). Therefore, identifying micro-habitat variables associated with roost-site selection will undoubtedly aid in the understanding of bird-habitat relationships.

Siamese Fireback (*Lophura diardi*) is currently listed as least concern (BirdLife Internation, 2012) restricted to lowland and foothill forest habitat of South-East Asia. Populations are considered to be in decline throughout the geographic distribution due to habitat loss and hunting pressure, with a global population estimated at 20,000 – 50,000 individuals (BirdLife Internation, 2012). In the past twenty years, populations were reported in an expanded range into higher elevations, up to 800 m, where previously Silver Pheasant (*Lophura nycthemera*) was more typically found in Khao Yai National Park, Thailand (Round and Gale, 2008). Sukumal and Savini (2009) indicated that the two pheasants maintain a substantial difference in microhabitat use with Silver Pheasants habitation occurring mainly on the ridges and Siamese Firebacks in flatter areas (Sukumal and Savini, 2009; Sukumal et al., 2010). However, these conclusions are based on a very small sample size. Ranging behavior of Siamese Fireback remains unclear because of the limited number of studies undertaken in their natural range. Consequently, it is expected that this study will provide quantitative data regarding ranging behavior, habitat use and roost-site selection of Siamese Firebacks in their main lowland forest habitat. This will increase understanding of bird-habitat relationships and, hopefully for the future, be able to predict the driving force for Siamese Fireback in Khao Yai National Park to expand its range into higher elevation forests.

In this study, the home ranges of Siamese Fireback were calculated by using two methods, 95% minimum convex polygon (MCP) and the integrating the characteristic hull polygons (CHPs) with spatial statistical criteria for defining home range and core area and by using locations collected from radio-collared birds. Second, the study was conducted to determine which habitat variables influence patterns of habitat use by females during different periods of the reproductive cycle and during different seasons, and to investigate which habitat variables influence roost-site selection of Siamese Fireback. Based on the preceding explanations, the following hypotheses and predictions were tested concerning (1) selected habitat by female Siamese Fireback: If selection of habitat is a consequence of predation avoidance, females should select areas with dense understory stems, particularly when the female is alone or in a group with chicks. (2) Roosting habitat of Siamese Fireback: If selection of roosting site is a consequence of predation avoidance, Siamese Fireback should select areas with steeper slopes to facilitate escape-flushing down-slope.

3.3 Methods

3.3.1 Study Area

The study was conducted at Sakaerat Environmental Research Station (SERS, Figure 3.1), classified as a UNESCO Biosphere Reserve since 1967. The reserve, covering 78.09 km^2, is located in north-eastern Thailand (14°30´N and 101°55´E) on the edge of Thailand's Khorat Plateau at an elevation of 280 – 762 m above sea level. SERS has two major natural forest types: dry evergreen forest (46.82 km^2) dominated by tree species such as *Hopea ferrea*, *Hopea odorata* and *Hydnocarpus ilicifolia*, and dry dipterocarp forest (14.51 km^2) dominated by common dipterocarpus trees such as *Shorea siamensis*, *Shorea obtusa* and *Dipterocarpus intricatus*, and two large patches of more than 20 year old forest plantation of mixed acacia and eucalyptus (14.46 km^2), and several small patches of bamboo forest (1.12 km^2), grassland (0.93 km^2) and the office and operational buildings (0.25 km^2) (TISTR, 2012a). The study area is approximately 3 km^2 dominated by dry evergreen forest, located beside the 3 – 6 km mark of the main road, with elevation ranging between 350 – 580 m. Average annual precipitation is 1,169 mm with a dry season from November to April (average rain fall 223 mm) and a wet season from May to mid-October (average rainfall 945 mm), with rainfall peaks in May and September. Average annual temperature is 26.7°C (range 21.6 to 30.3 °C) and average relative humidity is 81.4% (range 74 to 89%) (TISTR, 2012b).

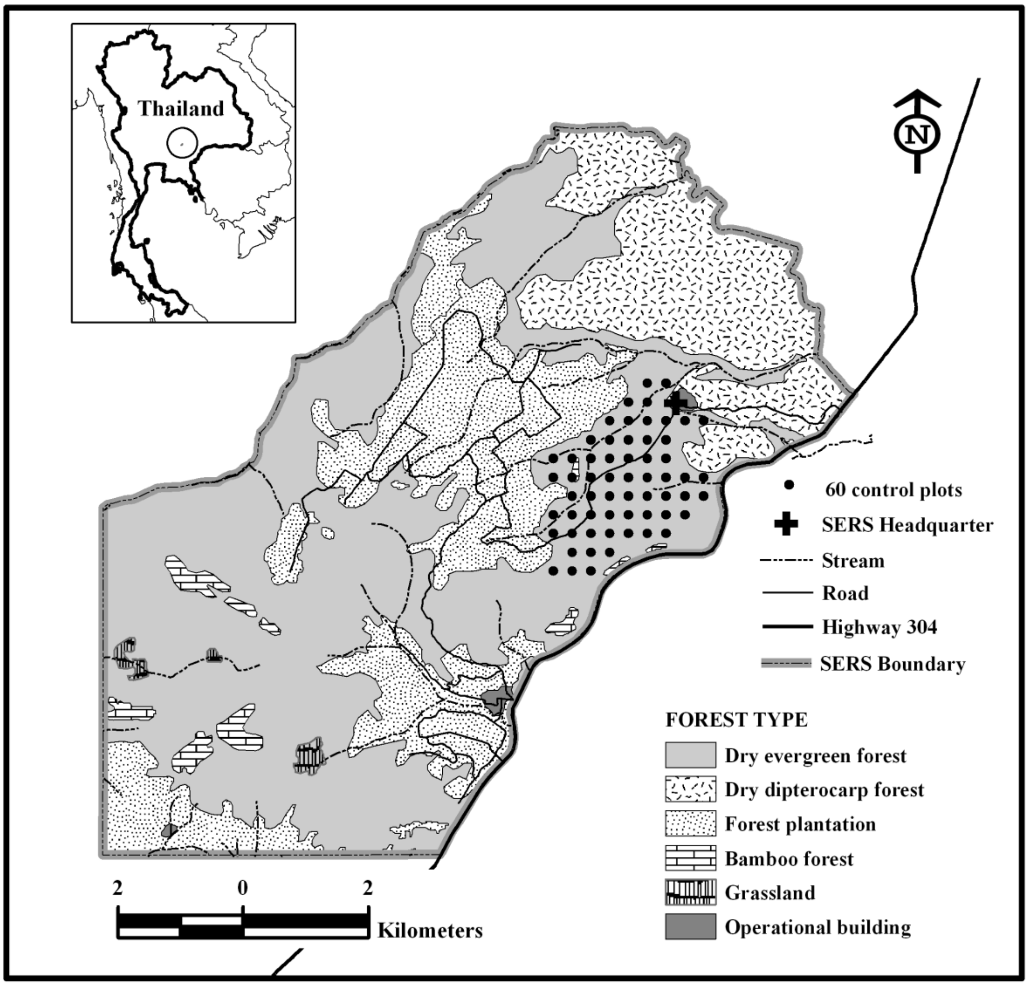

Figure 3.1 Location of Sakaerat Environmental Research Station, Nakhon Ratchasima, Thailand, including the locations of 60 control sites.

3.3.2 Capture and Radio-tracking

Siamese Firebacks were caught using mist nets (Keyes and Grue, 1982) and modified traditional leg snare traps, made from bamboo and soft polyester string (Figure 3.2) during the three trapping periods: February to April 2010, December 2010 to February 2011, and November to December 2011. All birds caught were ringed with the Thai Royal Forest Department metal ring (11A size), and color-ring with two-color combination on the left leg and one color-ring and the metal ring on the right leg, to allow individual recognition in the field. Some of those captured birds were fitted with a 15 g necklace-type radio-transmitter (model RI-2B, Holohil System Ltd.) with a life span of approximately 24 months (Figure 3.3 and 3.4).

Figure 3.2 Siamese Fireback were captured using mist nets (left) and leg snare traps (right).

Figure 3.3 Captured Siamese Fireback fitted with a 15 g necklace-type radio-transmitter (left), and banded with metal and color rings (right).

Figure 3.4 Radio-tagged Siamese Fireback: male (left) and female (right).

Animal locations started a few days after birds were caught and continued as long as the transmitter worked, the bird died or the radio-tag fell off the birds. Each radio-tagged bird was tracked every two days using homing method and ATS R410 receivers with a three-element hand-held Yagi antenna (Figure 3.5). When the birds were found, their first position was recorded by geographic coordinates using a Garmin 60CSx (GPS; ± 8 m accuracy) including group size and group composition.

Figure 3.5 Radio-tagged Siamese Firebacks were located using ATS R410 receivers with a three-element hand-held Yagi antenna.

3.3.3 Reproductive Cycle of Female Siamese Fireback

Based on known reproductive data on Siamese Fireback reported by Sukumal et al. (2010), and by the data of this study on radio-collared birds, the year cycle of female was divided into 4 periods for individuals with nests that successfully hatched, consisting of: (a) associating in a group with other adults during the breeding period, from February to April (hereafter period 1), (b) nesting/incubation, ranging approximately from April to June, during which time the female left her group, looked for a place to nest and incubate (period 2), (c) alone with chicks (or chicks rearing), the initial period after hatching when females travel alone with their chicks, ranging from one to three months (period 3), and (d) associating again in group of adults along with her chicks (non-breeding season) from August to February (period 4).

For the females with nests that failed, the year cycle was divided into two periods comprising of (a) breeding season starting from March to June, and (b) non-breeding season starting from July to February.

3.3.4 Habitat Measurements

The habitat characteristics were recorded using 5-m and 10-m radius circular plots with the same center points (Martin et al., 1997, Sukumal et al., 2010). The plots were established by centering them on the sites where individual birds were first located after homing. Thirty locations were randomly selected for each period of the reproductive cycle to represent features of habitat for each period. However, there was little movement during period 2 (incubation); no measurement was taken for this period. Circular plots were set by stretching strings (10-m in length) into four directions from the center. Three lines (5-m in length) were stretched to separate each quarter into four pieces. The strings were marked by ribbons every 1 m interval (Figure 3.6). For a 5-m radius circular plot, information on slope degree measured with a clinometer, distance to nearest stream performed using ArcGIS 9.3, number of climbers and number of understory trees with a diameter at breast height (DBH) ≤10 cm, which were categorized into 4 classes based on their height: 0.5 – 1, >1 – 3, >3 – 5 and >5 m were collected. The percentage of vegetation cover for each height category and ground covered by vegetation that is below 0.5 m in height were estimated. For a 10-m radius circular plot, only the DBH of trees with DBH >10 cm was measured in order to estimate basal area.

To estimate the availability of habitats, 60 control plots were systematically chosen over known home ranges and taken the same measurements as those at the bird radio locations. The control plots were located 300 m apart (Figure 3.1), which is considered to be the approximate width of a home range (30 ha) of Siamese Fireback derived from a sub-montane population (Sukumal et al., 2010). Information obtained from those 60 control plots were used not only for habitat use but also for roosting and nesting.

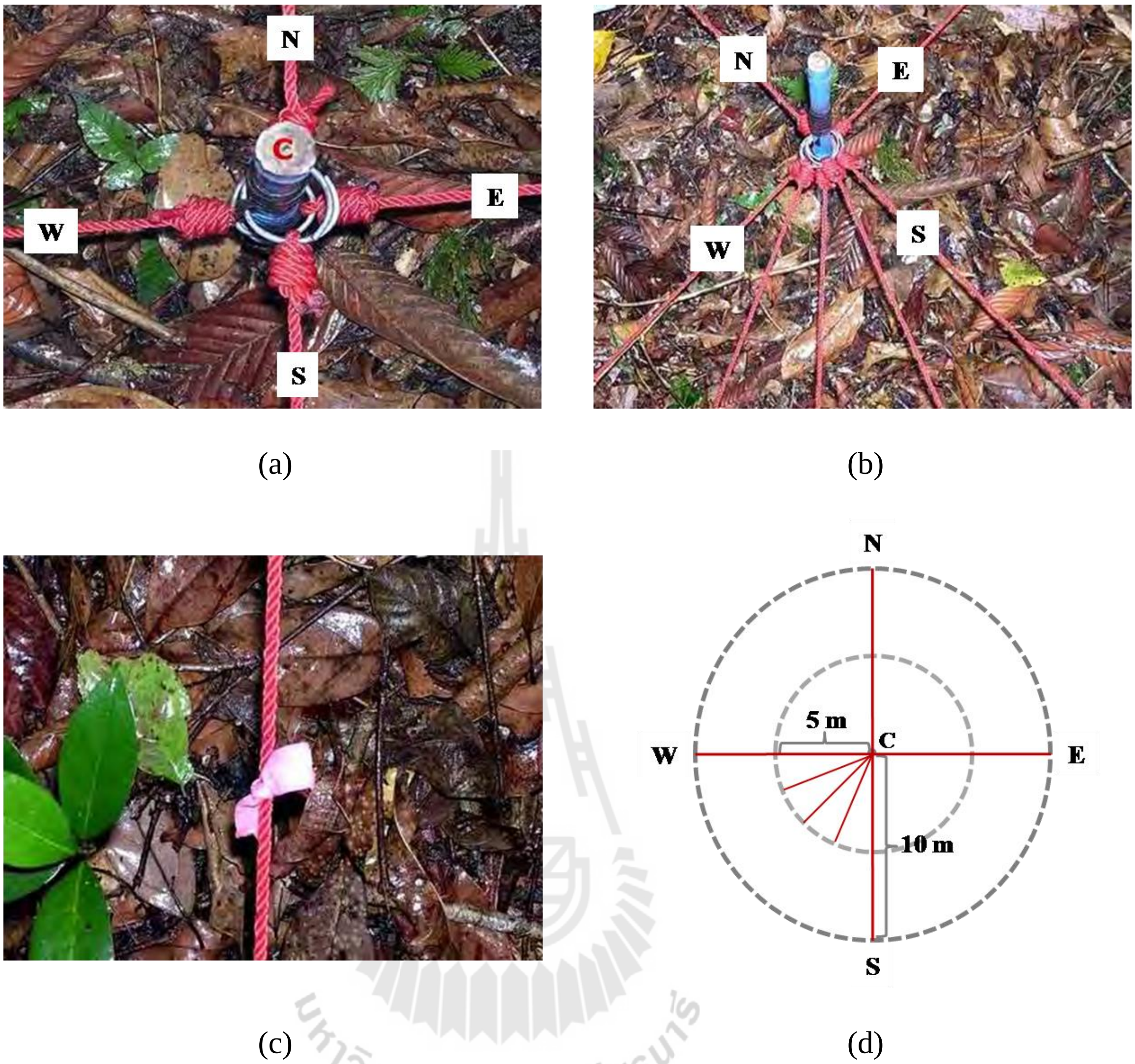

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Figure 3.6 Circular plots setting for measurement of habitat variables: (a) four 10-m strings stretching 4 directions, (b) three 5-m strings separating each quarter into 4 pieces, (c) ribbons marking every 1 m interval, and (d) 5-m and 10-m radius circular plots with the same center points.

3.3.5 Roost Sites

The radio-collared birds were followed to locate the roosting trees by homing in the early morning before sunrise (before 0600 hr). Each tree was located by geographic coordinates using a Garmin 60CSx (GPS; ± 8m accuracy). For each roosting tree the following variables were collected: plant species, DBH, perch height, roosting tree height, distance from roost point to the tree trunk, and the percentage of vegetation cover above and under roost point. Habitat characteristics surrounding the roosting trees were measured using 5-m and 10-m radius circular plots centered on the roosting tree. The same 60 control plots were used to assess the availability of habitats for roosting (see above).

3.3.6 Data Analysis

3.3.6.1 Home Range Analysis

The home ranges of Siamese Fireback were calculated using two methods. First, the simplicity of 95% minimum convex polygon (MCP) was used. MCP has been the most widely used home range estimator; the use of this method allows comparison to previous studies. The analyses were conducted in Arcview GIS 3.2a with the Animal Movement Extension (Hooge and Eichenlaub, 2000). Second, the recently developed method by Domínguez et al (in revision), which integrates the characteristic hull polygons (CHPs) with a spatial statistical criteria (here after CHPs Hot Spot) was used to define the boundaries of a home range and a core area. CHPs are built by applying Delaunay triangulation, the construction of triangles connecting neighboring points from a set of animal location points. The small triangles represent areas of higher ranging activity while large triangles represent unused or less frequently visited areas (Downs and Horner, 2009). The triangles from the home range and the core area were selected using “Hot Spot Analysis with Rendering” spatial statistics tool in ArcGIS 9.3 (Environmental Systems Research Institute, 2009). This analysis provides a z score with a *p*-value for each triangle representing its clustering intensity. For statistically significant positive z-score, the larger the score is, the more intense the clustering of large perimeter triangles is. Conversely, for statistically significant negative z-score, the smaller the score is, the more intense the clustering of small perimeter triangles is. Accordingly, long perimeter triangles that were significantly clustered (z-score >2) were eliminated and the remaining triangles formed the home range (z-score <2). The short perimeter triangles inside the home range, classified as significantly clustered, defined the core area (z-score <–2) (Figure 3.7).

The home range sizes for each period of female year cycle including the total home range size were estimated using those two methods. All radio-locations in a given period were used to create home range for both 95% MCP and CHPs Hot Spot methods. Because females showed little movement during incubation, the home range size during period 2 was not estimated.

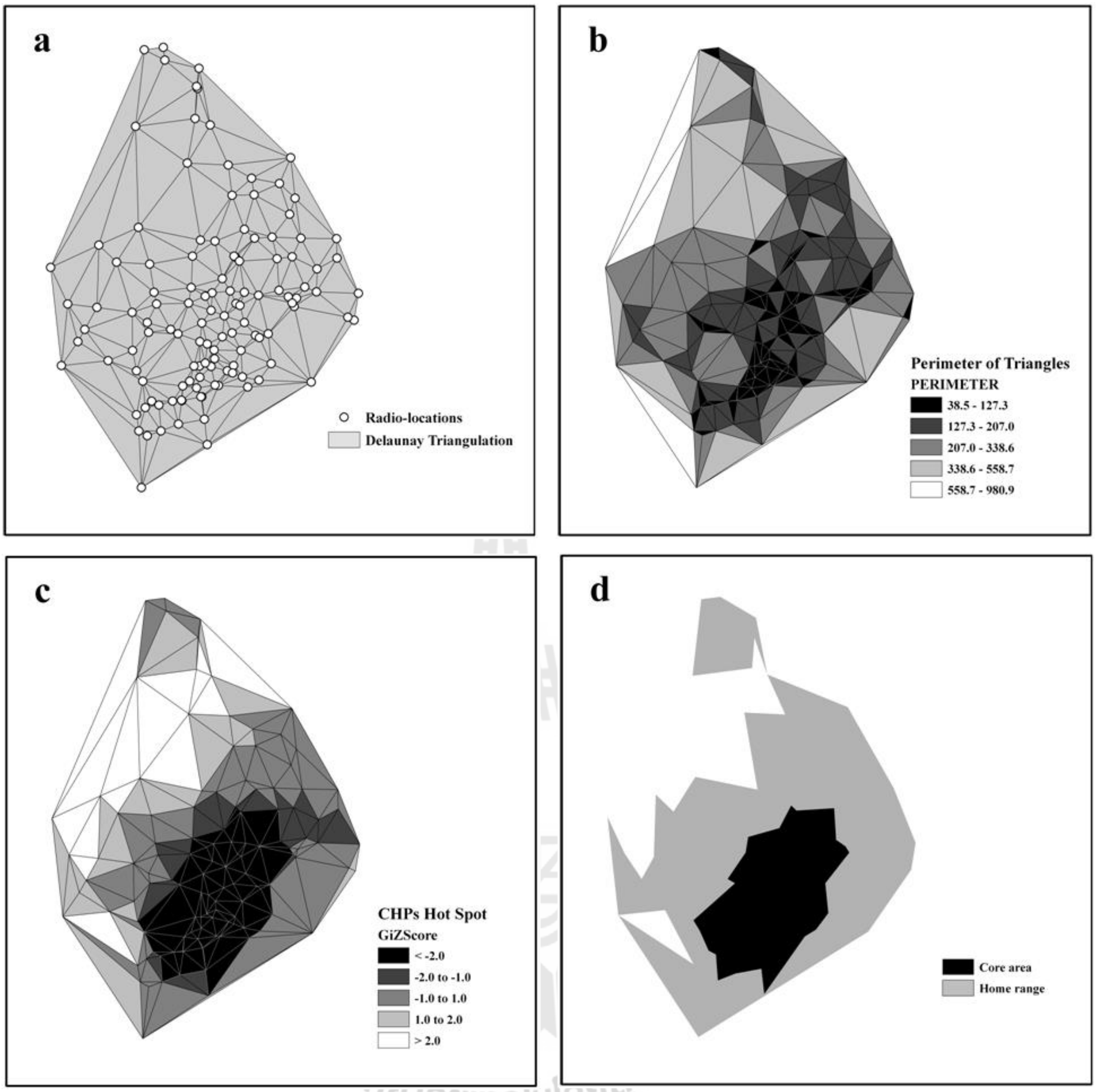

Figure 3.7 Home range and core area delineation using the CHPs Hot Spot method: (a) A set of points are plotted and Delaunay triangulation run, (b) Delaunay triangles are classified based on their perimeter size (m), (c) CHPs are generated using the Hot Spot analysis, and (d) home range (grey) correspond to triangles with z-value ≤2 and core area (black) to values <-2.

The differences in home range size between breeding and non-breeding seasons were tested using the analysis of variance (one way ANOVA). The normality of distributions of different home ranges was tested with the Shapiro-Wilk test. The Bartlett test was used to determine the homogeneity of variance of different samples. As the home range data met assumptions of normality and the variance was homogeneity, a significance level of 0.05 was used to detect differences in total home range size estimates between 95% MCP and CHPs Hot Spot methods. The statistical tests were performed using the R program 2.13.0 (R Development Core Team, 2011) and values given are mean ± SE.

3.3.6.2 Comparison of Habitat Characteristics

The habitat data did not meet the assumption of normality, therefore the non-parametric Kruskal-Wallis tests was used to compare habitat variables between selected and control sites. First, the significant differences in habitat variables between selected by females during three periods (1, 3 and 4, see above) of the reproductive cycle and control area were examined. Second, the differences in habitat variables between selected by females during breeding and non-breeding, and control area were examined. All statistical values given are mean ± SE.

3.3.6.3 Patterns of Habitat Use

Multinomial logistic regression was used to model habitat selection of Siamese Fireback. First, the regression was used to assess patterns of habitat use by females during different reproductive periods. The presence/absence of females in each reproductive period (1, 3 and 4) was entered as the dependant variable to identify which habitat features significantly influenced habitat use. The regression was then used to assess the pattern of habitat use by females during different breeding and non-breeding seasons. Here the presence/absence of females in each season (breeding and non-breeding season) was used as the dependant variable. All habitat variables were used as the independent variables. All explanatory variables were transformed by dividing the value by twice the standard deviation (Gelman, 2008) before building the models. Specifically, vegetation covers were previously transformed with the arcsine transformation (Sokal and Rohlf, 1995) and then divided the value by twice the standard deviation. For highly correlated (*r* >0.4) variables, one was selected at a time to a fitted regression model. A constant model (intercept only) was first fitted the model and then added habitat variables one at a time based upon their relative correlation with the dependent variable until the step at which all habitat variables were not included in the model. The selected model was determined using Akaike's Information Criterion corrected for small samples (AIC_c, Burnham and Anderson, 2002), whereby the lowest AIC_c value was considered to be the best fitted model. All models were fitted in R program 2.13.0 using the function "multinom" in the "nnet" package (Venables and Ripley, 2002).

3.3.6.4 Roost-site Selection Analysis

The non-parametric Mann–Whitney *U*-test was used for comparisons of habitat variables between the roosting sites and control sites. Then the binary logistic regression was used to identify which variables influenced roost-site selection. All variables were standardized by dividing the value by twice the standard deviation prior to regression analysis. The same criteria were used for the forward selection procedure as the multinomial stepwise regression model (see above). Similarly, the selected model was determined using AIC_c. When no single model is overwhelmingly supported by the data (model uncertainty, ΔAIC_c <2), then model averaging can be used (Johnson and Omland, 2004). The 85% confidence intervals were used to identify variables with significant influence on roost-site selection when model uncertainty occurred. This interval renders model selection and parameter-evaluation criteria more congruent than the narrower interval (95%) widths (Arnold, 2010). Overlapping with zero 85% confidence interval indicates a weak effect or no effect. Analyses were performed using R program 2.13.0 with MASS package (Venables and Ripley, 2002) and AICcmodavg package (Mazerolle, 2012) to create a model selection table based on the AIC_c

3.4 Results

A total of 20 Siamese Firebacks (5 males, 15 females) were caught and banded with a metal ring and color rings. Of these, 18 birds (3 males, 15 females) were fitted with a necklace radio-transmitter. The radio of five birds (2 males, 3 females), however, failed after a few days or a week after tracking. Unfortunately, five birds (1 male, 4 females) were killed by a predator. There was no indication that the birds were injured by the snares or mist nets, and no bird died as a result of capture stress. Thus only eight females, each bird representing a distinct group (hereafter group A, B, C, D, E, F, G and H, Figure 3.8), were followed for 2 – 27 months.

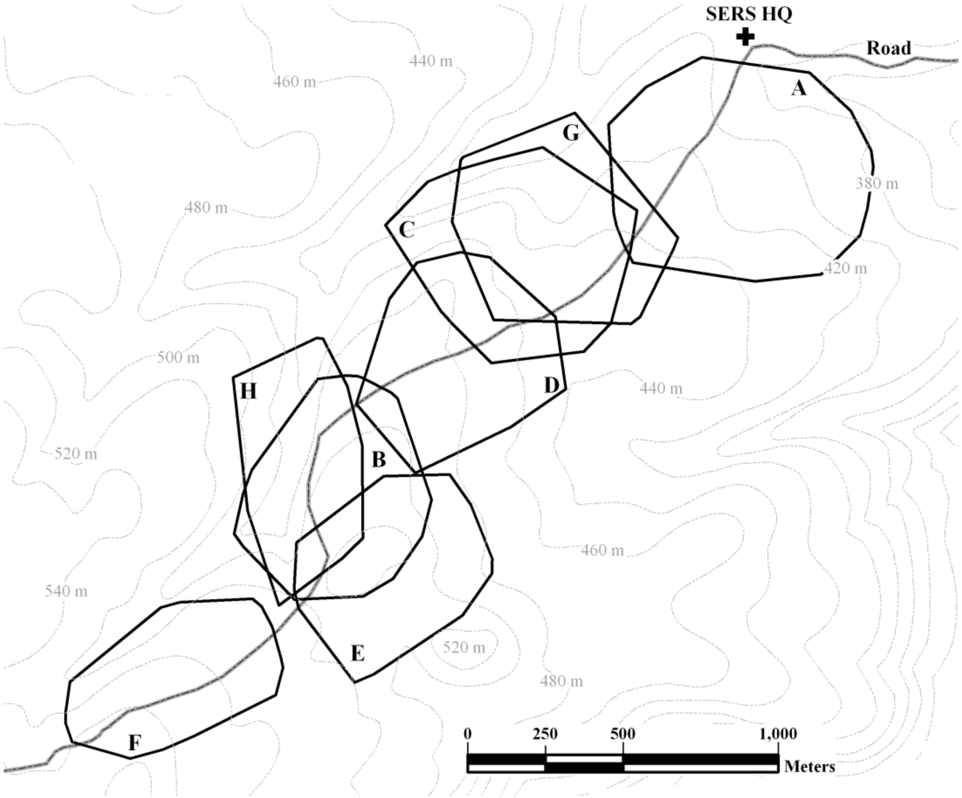

Figure 3.8 95% MCP home ranges of Siamese Firebacks from 2010 – 2012.

3.4.1 Home Range Size Patterns

Mean annual home range size for eight radio-collar females using the 95% MCP method was 31.4 ± 2.5 (SE) ha; 21.7 ± 2.2 ha during breeding season and 26.3 ± 4.1 ha during non-breeding season. Using the CHPs Hot Spot method, mean annual home range size for eight radio-collar females was 27.3 ± 1.6 (SE) ha; 19.2 ± 1.8 ha during breeding season and 22.0 ± 2.7 ha during non-breeding season. Siamese Fireback showed a variation in home range size during different seasons (Table 3.1, Figure 3.9). Mean annual core area for eight radio-collar females using the CHPs Hot Spot method was 6.3 ± 0.7 (SE) ha; 3.3 ± 0.7 ha during breeding season and 3.4 ± 0.9

ha during non-breeding season (Table 3.1). Estimated home range size during breeding season was slightly smaller than those estimated during non-breeding season. However, there was no significant difference during different seasons with either the 95% MCP method ($F_{1,13} = 1.05$, $p = 0.32$) or the CHPs Hot Spot method ($F_{1,13} = 0.76$, $p = 0.40$). Based on the estimated annual home ranges, the 95% MCP method likely estimated a larger size than the estimation using the CHPs Hot Spot method (Table 3.1), and there was no significant difference in home range size estimated ($F_{1,10} = 1.42$, $p = 0.26$).

The two females (group A and C) had successfully hatched nests in 2011. These females showed a variation in home range size during different reproductive periods (Table 3.1, Figure 3.10a). The 95% MCP analysis indicated that home range size decreased when females left the group after breeding season and started to range alone with their young chicks (9.7 ± 0.4 ha, $n = 2$), but increased again when females rejoined the group with their grown chicks (non-breeding season). Both females showed the same pattern in home range variations between the different periods (Figure 3.10b). A similar pattern was observed using CHPs Hot Spot for the overall home ranges (Table 3.1).

Table 3.1 Summary of number of radio-locations and home range size (ha) estimated using 95% MCP and CHPs Hot Spot method of eight female Siamese Firebacks, each bird representing a distinct group, during the three years study period from 2010 – 2012.

Groups	Year	No. of radio-locations				95% MCP method (ha)				CHPs Hot Spot method (ha)							
		Breeding	Chick rearing	Non-breeding	Total	Breeding	Chick rearing	Non-breeding	Annual	Breeding		Nesting		Non-breeding		Annual	
										HR[a]	CA[b]	HR	CA	HR	CA	HR	CA
A	2010	35	-	56	91	19.4	-	39.0	44.0	22.8	1.8	-	-	34.3	7.1	35.2	7.3
	2011	39	31	92	162	19.8	10.2	31.8	38.3	15.8	0.0	8.5	1.2	29.0	6.1	34.8	9.2
	2012	72	-	-	-	28.8	-	-	-	19.3	4.0	-	-	-	-	-	-
B	2010	108	-	-	-	33.6	-	-	-	36.1	6.0	-	-	-	-	-	-
	2011	44	-	110	154	14.6	-	25.2	29.2	14.1	2.1	-	-	22.6	2.4	25.8	3.1
	2012	49	-	64	113	11.9	-	20.1	23.7	9.9	0.8	-	-	15.8	2.6	21.2	3.4
C	2011	33	36	77	146	14.7	8.8	42.5	38.5	15.7	1.3	8.4	0.9	28.1	4.6	28.4	8.3
D	2011	35	-	-	-	31.9	-	-	-	17.9	2.7	-	-	-	-	-	-
E	2011	50	-	71	121	18.5	-	24.4	31.8	17.6	4.8	-	-	22.9	2.0	26.8	6.5
	2012	78	-	45	123	18.4	-	18.2	22.1	17.5	2.6	-	-	18.6	2.0	22.3	4.2
F	2011	44	-	104	148	16.0	-	21.4	24.7	17.3	0.9	-	-	15.7	2.0	21.6	5.6
	2012	67	-	45	112	15.0	-	25.1	27.8	12.2	2.6	-	-	26.2	1.9	24.7	4.6
G	2011	-	-	37	-	-	-	30.2	-	-	-	-	-	24.2	6.4	-	-
	2012	47	-	-	84*	20.7	-	-	25.7	16.9	5.9	-	-	-	-	26.3	6.1
H	2011	-	-	30	-	-	-	9.0	-	-	-	-	-	9.1	0.1	-	-
	2012	51	-	-	81*	29.8	-	-	35.0	31.4	6.4	-	-	-	-	29.9	7.6

[a] HR = Home range estimated, [b] CA = Core area estimated, *All radio-locations combined from 2011 and 2012 to estimate annual home ranges.

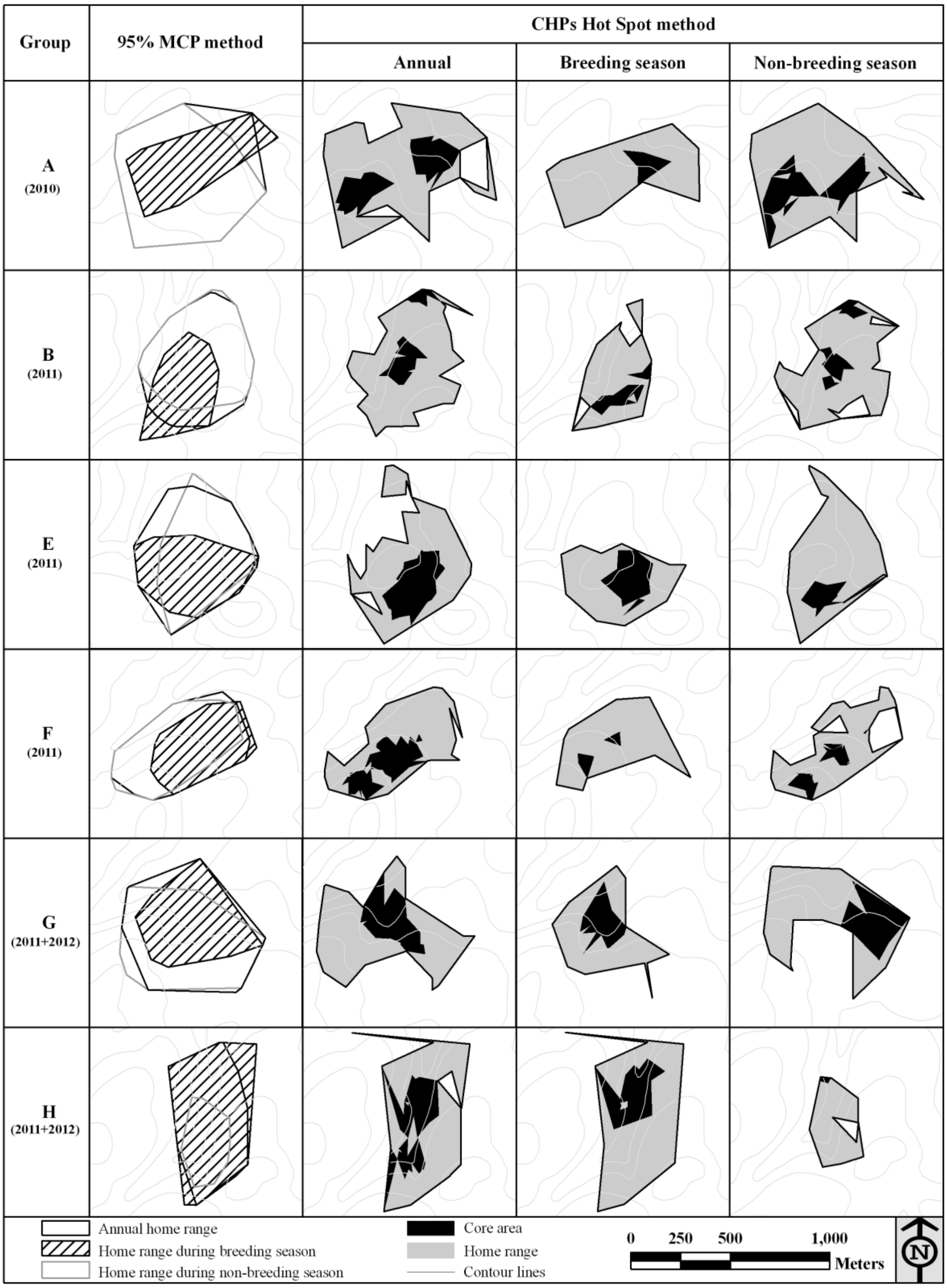

Figure 3.9 Home range of different six groups of Siamese Fireback, estimated using 95% MCP and CHPs Hot Spot methods showing seasonal variation in home range size.

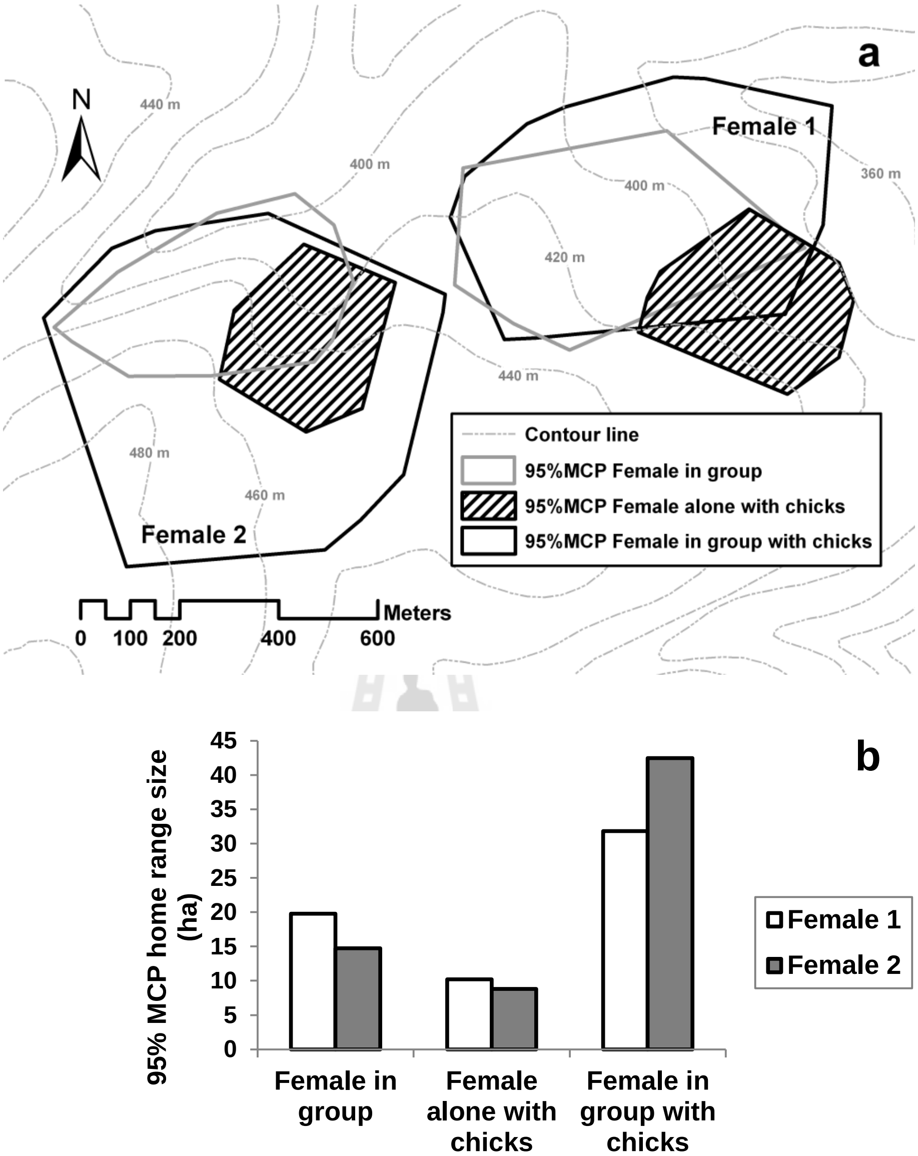

Figure 3.10 The variation in home rage size during different reproductive periods of the two female Siamese Firebacks: (a) ranging size estimated using 95% MCP for Female 1 (group A) and Female 2 (group C); (b) 95% MCP home range size compared in different periods of year cycle between the two females.

3.4.2 Comparison of Habitat Characteristics

3.4.2.1 Sites Selected During Different Reproductive Periods of Females vs. Control Sites

A comparison of habitat characteristics between sites selected by females during different reproductive periods and control sites indicated that habitat use by females was significantly correlated with understory vegetation. Females selected the area associated with less understory coverage at height >0.5 – 1 m and >1 – 3 m, higher density of understory trees at height >3 – 5 m, and in areas with a small basal area of large trees during mating, when they were alone with chicks, and when they were in group with their chicks than those in the control site. However, females selected areas with greater distance to water, heavier ground covered by vegetation at height <0.5 m and higher density of understory stems at height >1 – 3 m when they were alone with their young chicks (Table 3.2).

3.4.2.2 Sites Selected During Different Seasons vs. Control Sites

A comparison of habitat characteristics between sites selected by female Siamese Fireback during different seasons was significantly correlated with understory vegetation. Siamese Fireback selected the area with less understory coverage at height >0.5 – 1 m and >1 – 3 m, and higher density of understory stems at height >3 – 5 m during breeding and non-breeding seasons than those in the control site. However, Siamese Fireback selected the area with higher density of woody climber and small basal area of large trees during non-breeding season (Table 3.3).

Table 3.2 Comparison of habitat variables between ranging sites for each different period of female year cycle and control sites. Significant results are highlighted in italic.

Habitat variables	In group mating (n = 60)			Alone with chicks (n = 60)			In group with chicks (n = 60)			Control sites (n = 60)			Kruskal-Wallis *H*-test	
	Mean	±	SE	Mean	±	SE	Mean	±	SE	Mean	±	SE	χ^2	*p*-value
Slope (degree)	8.2	±	0.5	8.3	±	0.4	9.0	±	0.5	7.3	±	0.4	5.25	0.15
Distance to water (m)	246.8	±	17.0	354.9	±	13.9	265.4	±	19.3	312.7	±	30.6	19.84	*<0.001*
Tree coverage: height <0.5 m (%)	10.54	±	0.67	13.88	±	1.00	9.60	±	0.59	11.73	±	0.67	13.51	*0.004*
Tree coverage: height 0.5 – 1 m (%)	7.73	±	0.33	9.04	±	0.33	7.52	±	0.27	11.85	±	0.57	41.26	*<0.001*
Tree coverage: height 1 – 3 m (%)	10.87	±	0.45	12.48	±	0.53	11.74	±	0.63	17.25	±	0.80	40.29	*<0.001*
Tree coverage: height 3 – 5 m (%)	11.62	±	0.56	11.49	±	0.44	11.81	±	0.46	13.16	±	0.69	3.78	0.28
Tree coverage: height >5 m (%)	79.91	±	0.81	78.74	±	0.82	79.68	±	0.92	78.97	±	0.79	1.71	0.63
Tree density: height 0.5 – 1 m (stems)	76.0	±	2.5	77.2	±	3.5	73.4	±	2.8	80.8	±	3.4	3.19	0.36
Tree density: height 1 – 3 m (stems)	72.0	±	2.6	86.6	±	3.6	73.9	±	2.9	82.4	±	3.6	12.54	*0.006*
Tree density: height 3 – 5 m (stems)	22.2	±	1.1	26.5	±	1.5	25.5	±	1.2	13.6	±	0.7	61.99	*<0.001*
Tree density: height >5 m (stems)	14.0	±	0.6	12.6	±	0.7	13.7	±	0.6	14.1	±	0.6	4.76	0.19
Number of woody climbers (stems)	10.7	±	0.8	12.7	±	0.8	11.7	±	0.7	12.3	±	0.9	3.77	0.29
Basal area[a] (m^2)	0.56	±	0.02	0.52	±	0.02	0.54	±	0.02	0.75	±	0.04	25.30	*<0.001*

[a] Basal area = basal area of trees with DBH >10 cm recorded with in a 10-m radius circular plot.

Table 3.3 Comparison of habitat variables between ranging sites for each season, during breeding and non-breeding seasons, of Siamese Fireback and control sites. Significant results are highlighted in italics.

Habitat variables	Breeding season (n = 150)			Non-breeding season (n = 150)			Control sites (n = 60)			Kruskal-Wallis H-test	
	Mean	±	SE	Mean	±	SE	Mean	±	SE	χ^2	p-value
Slope (degree)	7.3	±	0.2	8.0	±	0.3	7.3	±	0.4	2.07	0.35
Distance to water (m)	240.1	±	11.9	239.3	±	13.0	312.7	±	30.6	2.49	0.29
Tree coverage: height <0.5 m (%)	10.21	±	0.37	10.66	±	0.44	11.73	±	0.67	4.37	0.11
Tree coverage: height 0.5 – 1 m (%)	8.88	±	0.27	9.06	±	0.30	11.85	±	0.57	20.61	*<0.001*
Tree coverage: height 1 – 3 m (%)	13.76	±	0.48	13.63	±	0.43	17.25	±	0.80	17.22	*<0.001*
Tree coverage: height 3 – 5 m (%)	12.31	±	0.49	12.04	±	0.43	13.16	±	0.69	2.67	0.26
Tree coverage: height >5 m (%)	77.59	±	0.71	79.07	±	0.61	78.97	±	0.79	2.39	0.30
Tree density: height 0.5 – 1 m (stems)	77.0	±	2.0	84.2	±	2.2	80.8	±	3.4	5.15	0.08
Tree density: height 1 – 3 m (stems)	75.5	±	2.1	79.8	±	2.0	82.4	±	3.6	3.75	0.15
Tree density: height 3 – 5 m (stems)	21.1	±	0.8	20.7	±	0.7	13.6	±	0.7	30.93	*<0.001*
Tree density: height >5 m (stems)	13.6	±	0.4	13.9	±	0.4	14.1	±	0.6	0.78	0.68
Number of woody climbers (stems)	12.2	±	0.5	14.4	±	0.6	12.3	±	0.9	7.93	*0.02*
Basal area[a] (m^2)	0.75	±	0.03	0.63	±	0.03	0.75	±	0.04	10.83	*0.004*

[a] Basal area = basal area of trees with DBH >10 cm recorded with in a 10-m radius circular plot.

3.4.3 Patterns of Habitat Use

3.4.3.1 During Different Reproductive Periods

A candidate set of 16 regression models (Table 5 APPENDIX C) were fitted to explain habitat use by female Siamese Firebacks during different reproductive periods. Model selection indicated that the best model included the habitat variables of understory coverage at height >1 – 3 m, tree density at height >3 – 5 m, and basal area of large trees and had highest support (AIC_{weight} = 0.97, Table 3.4). Based on AIC weight, the best model had 48.5 times more support than the second best model and 97 times more than the third best model (Table 3.4). Estimated beta coefficient for understory coverage at height >1 – 3 m and basal area of large trees were negative, suggesting that female preferred to use areas with less understory coverage and small basal area of large trees while the beta coefficient for tree density at height >3 – 5 m was positive, suggesting that females preferred to use areas with higher density of understory stems at height >3 – 5 m (Table 3.5).

3.4.3.2 During Different Seasons

A candidate set of 18 regression models (Table 6 APPENDIX C) were fitted to explain habitat use of Siamese Fireback during different seasons. Model selection indicated that the best model included the habitat variables of understory coverage at height >1 – 3 m, tree density at height >3 – 5 m, number of climbers, and distance to water and had highest support (AIC_{weight} = 0.97, Table 3.4). Based on AIC weight, the best model had 48.5 times more support than the second best model and 97 times more than the third best model (Table 3.4). Estimated beta coefficient for understory coverage at height >1 – 3 m and distance to water were negative, suggesting that females preferred to use areas with less understory coverage and closer to the water source while the beta coefficient for tree density at height >3 – 5 m and number of climbers were positive, suggesting that female preferred to use areas with higher density of understory stems at height >3 – 5 m and climbers (Table 3.6).

Table 3.4 The confident set of multinomial logistic regression models explaining patterns of habitat use by Siamese Fireback. (Habitat variables: Cover2 is tree coverage at height <1 – 3 m, Stem 3 and Stem 4 are tree density at height 3 – 5 m and >5 m respectively. BA is basal area of trees with DBH >10 cm, Climber is number of woody climbers, Water is distance to water).

Model	LL	K	△AIC	w_i
During different reproductive periods (16 models tested)				
Cover2 + Stem3 + BA	–255.23	12	0.00	0.97
Cover2 + Stem3 + Stem4	–259.19	12	7.92	0.02
Cover2 + Stem3	–263.76	9	10.47	0.01
During different seasons (18 models tested)				
Cover2 + Stem3 + Climber + Water	–324.91	10	0.00	0.97
Cover2 + Stem3 + Climber + BA	–328.92	10	8.01	0.02
Cover2 + Stem3 + Climber	–331.32	8	8.61	0.01

Note: LL is log-likelihood: K is number of parameters in the model: △AICc is difference in AICc (model score) value, model with △AICc value 0 has most support, values between 0 and 2 have substantial support, values greater than 2 have less support: w_i = Akaike model weights.

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Table 3.5 Results of multinomial logistic regression showing the influence of variables on habitat use by female Siamese Fireback during different periods of the reproductive cycle.

Variables in three phases of female year cycle	Coefficient	SE	*p*-value
Female in group (mating) (n = 60)			
Tree coverage: height >1 – 3 m	–3.62	0.64	*<0.001*
Tree density: height >3 – 5 m	3.88	0.80	*<0.001*
Basal area of large trees (DBH >10 cm)	–1.66	0.53	*0.002*
Female alone with chicks (n = 60)			
Tree coverage: height >1 – 3 m	–3.04	0.63	*<0.001*
Tree density: height >3 – 5 m	4.68	0.81	*<0.001*
Basal area of large trees (DBH >10 cm)	–1.87	0.57	*0.001*
Female in group with chicks (n = 60)			
Tree coverage: height >1 – 3 m	–3.45	0.64	*<0.001*
Tree density: height >3 – 5 m	4.59	0.81	*<0.001*
Basal area of large trees (DBH >10 cm)	–1.73	0.56	*0.002*

Table 3.6 Results of multinomial logistic regression showing the influence of variables on habitat use by Siamese Fireback during different seasons (breeding and non-breeding seasons). Significant results (α <0.01) are highlighted in italics.

Variables in two phases of seasons	Coefficient	SE	*p*-value
Breeding season (*n* = 150)			
Tree coverage: height >1 – 3 m	–1.62	0.36	*<0.001*
Tree density: height >3 – 5 m	2.56	0.46	*<0.001*
Number of climber stems	0.79	0.37	*0.003*
Distance to water	–1.03	0.33	*0.002*
Non-breeding season (*n* = 150)			
Tree coverage: height >1 – 3 m	–1.89	0.37	*<0.001*
Tree density: height >3 – 5 m	2.61	0.47	*<0.001*
Number of climber stems	1.62	0.38	*<0.001*
Distance to water	–1.16	0.34	*<0.001*

3.4.4 Roost Sites

3.4.4.1 Roosting Behavior

Siamese Firebacks forage on the ground with their group members during the day and fly up to elevate tree during the night, at varying heights from mid-story to canopy (Figure 3.11). There was no individuals roosted on the same tree; however, they roosted in the vicinity. Siamese Firebacks went to their roosting site before sunset. As the bird approached the roosting tree, it looked around for a moment before flying up to branches. It flew up to the roosting tree and walked a short distance on the branch or moved then from one branch to another to reach its favored perch. After that, the bird sat, looked around, contracted its neck and finally roosted. In the morning, the bird dropped to the ground directly, stretched its legs, walked a short distance along the branch or moved down to the lower branch and then flew down to the ground.

3.4.4.2 Characteristics of Roosting Sites

A total of 52 different roosting sites were used by five radio-tagged birds: one male and four females from different four groups were located with the total effort of 66 tracking days. Some of those were repeatedly used more than once (10.3%). Most were roosting trees (*n* = 49), while others were climbers (*n* = 3). The mean tree height was 8.2 ± 0.3 m with the average DBH of 9.1 ± 0.7 cm. The mean perch height was 5.6 ± 0.2 m and the mean distance from roost point to the nearest tree trunk was 2.7 ± 0.2 m. The mean vegetation cover above and under roost point were 77.32 ± 1.49 % and 23.85 ± 1.79 %, respectively (Table 3.7).

Figure 3.11 Radio-tagged female Siamese Fireback roosting on branch of tree.

Tables 3.7 Characteristics of roosting tree.

Variables	Mean ± SE	Range
Tree height (m)	8.2 ± 0.3	4.0 – 15.0
DBH (cm)	9.1 ± 0.7	2.9 – 23.6
Perch height (m)	5.6 ± 0.2	3.3 – 9.0
Distance from roost point to the nearest tree trunk (m)	2.7 ± 0.2	0.8 –5.8
Vegetation cover (%) above roost point	77.32 ± 1.49	50.00 – 95.00
Vegetation cover (%) under roost point	23.85 ± 1.79	7.50 – 60.00

3.4.4.3 Comparison of Habitat Characteristics Between Roost vs. Control Sites

The habitat variables between roosts (n = 52) and control sites (n = 60) were compared. Siamese Fireback appeared to prefer to roost in the areas associated with steeper slopes and in the areas associated with small basal areas of large trees. Percentage cover of trees at height >3 – 5 m at roost sites was significantly higher than those in control sites while percentage cover of trees at height >5 m at roost sites was significant less than those in control sites (Table 3.8).

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Table 3.8 Comparison of habitat variables between Siamese Fireback's roosting and control sites. Significant results are highlighted in italics.

Habitat variables	Roost sites (n = 52)			Control sites (n = 60)			Mann–Whitney U-test	
	Mean	±	SE	Mean	±	SE	W	p-value
Slope (degree)	10.9	±	0.7	7.3	±	0.4	926.5	*<0.001*
Distance to water (m)	230.8	±	20.0	312.7	±	30.6	1770.0	0.22
Tree coverage: height <0.5 m (%)	11.70	±	0.69	11.73	±	0.67	1546.5	0.94
Tree coverage: height 0.5 – 1 m (%)	10.49	±	0.51	11.85	±	0.57	1840.5	0.10
Tree coverage: height 1 – 3 m (%)	17.03	±	0.81	17.25	±	0.80	1586.0	0.88
Tree coverage: height 3 – 5 m (%)	15.45	±	0.78	13.16	±	0.69	1218.5	*0.047*
Tree coverage: height >5 m (%)	69.35	±	1.46	78.97	±	0.79	2443.5	*<0.001*
Tree density: height 0.5 – 1 m (stems)	75.1	±	3.1	80.8	±	3.4	1787.5	0.19
Tree density: height 1 – 3 m (stems)	81.5	±	3.5	82.4	±	3.6	1584.0	0.89
Tree density: height 3 – 5 m (stems)	15.2	±	1.0	13.6	±	0.7	1407.5	0.37
Tree density: height >5 m (stems)	14.6	±	0.6	14.1	±	0.6	1443.0	0.49
Number of woody climbers (stems)	14.4	±	0.9	12.3	±	0.9	1294.5	0.12
Basal area[a] (m^2)	0.58	±	0.03	0.75	±	0.04	2082.0	*0.002*

[a] Basal area = basal area of trees with DBH >10 cm recorded within a 10-m radius circular plot.

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3.4.4.4 Roost-site Selection

A candidate set of 16 regression models (Table 7 APPENDIX C) were fitted to explain roost-site selection of Siamese Fireback. Model selection indicated that the best model had the highest support while the second best model had reasonable support (ΔAIC_c = 0.96; Table 3.9). Based on AIC weights, the best model had 1.6 times more support than the second best model. Model averaging was estimated for the coefficients of those variables in the confidence set. The estimated coefficient for degree of slope was a significantly positive, whereas the estimate for tree coverage at >5 m height and basal area of large trees was a significantly negative influence on roost-site selection of Siamese Firebacks (Table 3.10).

Table 3.9 The confident set of multiple logistic regression models explaining roost site selection of Siamese Fireback (Habitat variables: Slope is degree of slope area, Cover4 is tree coverage at height >5 m, BA is basal area of trees with DBH >10 cm).

Model	LL	K	$\triangle AIC_c$	w_i
16 models tested				
Slope + Cover4 + BA	–52.49	4	0.00	0.62
Slope + Cover4	–54.04	3	0.96	0.38

Note: LL is log-likelihood: K is number of parameters in the model: $\triangle$AICc is difference in AICc (model score) value, model with $\triangle$AICc value 0 has most support, values between 0 and 2 have substantial support, values greater than 2 have less support; w_i = Akaike model weights.

Table 3.10 Results of binary logistic regression showing the influence of variables on roost-site selection of Siamese Fireback. Estimates of coefficients derived from model averaging and unconditional SE and its 85% confidence interval.

	Estimated coefficient	Uncond. SE	Lower 85% CI	Upper 85%CI
Model averaging				
Slope	2.00*	0.58	1.17	2.83
Tree coverage: height <5 m	–2.69*	0.69	–3.68	–1.69
Basal area	–0.93*	0.55	–1.71	–0.14

* Estimated coefficients of variables that suggest significant effects on nest-site selection of Siamese Fireback. Overlap with zero indicates a weak effect or no effect.

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3.5 Discussion

This study investigated the ranging behavior and habitat use of Siamese Fireback in their main lowland forest habitat in order to make a comparison to a population which has recently shown a range expansion into sub-montane forest habitats (Sukumal et al., 2010). Although the variation in home range size showed a similar pattern with those observed in a sub-montane population, the results showed smaller home range size perhaps as a consequence of living in a suitable lowland habitat. However, there was no significant difference in home range size between breeding and non-breeding seasons. In addition, Siamese Firebacks significantly preferred secondary forest patches which typically have a dense shrubs layer (at >3 – 5 m in height) and sparse sapling cover (at >1 – 3 m in height) during period three of their reproductive cycle and during different seasons. Otherwise, variables influencing roost-site selection by Siamese Firebacks included sloping terrain, sparse canopy cover and smaller basal area of large trees.

3.5.1 Home Range

Home range size of two observed females significantly declined when they were alone with chicks (period 3) and then expanded again when the females and their chicks returned to their group (period 4). These patterns have been observed for sub-montane Siamese Firebacks (Sukumal et al., 2010). The reduction in home range size during period 3 is correlated with the limited mobility of young chicks (Klinger and Riegner, 2008). In addition, Siamese Fireback had variations in home range size between breeding and non-breeding seasons. Breeding season is usually correlated to rainfall pattern and food availability (Stutchbury and Morton, 2001). Thus, it is likely to link the home range size during breeding season with food availability. However, no measurement was conducted to collect data on food abundance between seasons. Although breeding home ranges tend to be smaller than non-breeding home ranges, there was no significant difference in size between seasons. This could be a reason that Siamese Firebacks are not considered to be a territorial bird (Johnsgard, 1999); it is not necessary to spend time defending its range. Specifically, Siamese Firebacks are not considered to be an exploded lek, like Great Argus (*Argusianus argus*), of which the males concentrated their activities around the dancing ground leading to small home range size during breeding season (Winarni et al., 2009).

In this study, Siamese Firebacks exhibited smaller annual home ranges (31.4 ± 2.5 ha, n = 7) compared to a sub-montane population in Khao Yai (57.5 ± 6.3 ha, n = 4; Sukumal, unpublished data). Factors that may have influenced home range size between the different regions may be topography, forest habitat types, and population densities. Topography may be of particular importance since previous studies reported that Siamese Firebacks tend to cluster in topographically flatter and wetter areas, which might force them to increased their range size because those areas are patchily distributed at sub-montane elevations in the Mo Singto area (Sukumal, personal observation), while the area in this study had somewhat flat topography.

Although average annual home range estimated using 95% MCP was larger than those estimated using CHPs Hot Spot method, no significant difference was found in home range size estimated. Although, the estimates of home range using 95% MCP allows for comparison to previous studies, but MCPs often include large areas never truly used by animals and do not provide information about space use within the polygon (Powell, 2000). The use of CHPs Hot Spot method showed a limitation because the effect of sample size on its accuracy is not known. The study suggests that using a small number of locations did not guarantee seeing a distinct pattern of animal ranging.

3.5.2 Habitat Use

Siamese Firebacks showed a distinct preference for areas that were considered to be secondary forest patches in the study area during the different periods of female year cycle and during different seasons. Female Siamese Firebacks appeared to prefer areas with dense ground cover and higher density of understory sapling when they were alone with their young chicks. Similar patterns have been observed for female Siamese Firebacks in sub-montane forest habitat (Sukumal ea al., 2010). Many studies, including of Galliformes, indicated that birds tend to use densely vegetated area while raising chicks because of high mortality of young chicks in the first few weeks of life (Lima, 1993; Riley et al., 1998; Peh et al., 2005; Iamsiri and Gale, 2008; Ong-in, 2011). In addition, the regression analysis indicated female Siamese Firebacks mostly used the area with dense shrubs layer (at >3 – 5 m in height) and sparse sapling cover (at >1 – 3 m in height), including small basal area of large tress (Table 3.5). Within known home ranges, these characteristics are considered to be the patches of *Streblus ilicifolius,* spiny shrubs of 3 – 5 m tall and thicken. However, these conclusions are based on a very small sample (only two females). Using this habitat might be a consequence of a large proportion of *S. ilicifolius* patches occurring in their ranges, so females adopted a way to use those habitats for their safety strategy. The study suggests that using patches of *S. ilicifolius* seems likely to provide females with a good shelter from canopy-dwelling raptors and probably increases the likelihood of detecting predators if they approach at ground level.

Siamese Firebacks appeared to prefer areas with not only dense shrubs layer and sparse sapling cover but also areas with higher climber density and closer distance to water during different seasons. During breeding season, Siamese Firebacks tend to use a loud whistling call including the typical *Lophura* wing-whirring display (Johnsgard, 1999), which might force them to increase their risk of being detected by predators. Use of areas with higher climber density might reduce predation risk (Cody, 1985), whereas use of areas with open understory cover might facilitate their escape-flushing when predators attack. Similar patterns have been observed for Sichuan Pertridge (*Arborophila rufipectus*), of which male partridges rang mostly in evergreen broadleaf forest habitats, which have a dense and tall canopy of vegetation cover and an open understory during breeding season (Liao et al., 2008). Therefore, the means for easy escape is one of the important factors affecting habitat selection by Siamese Firebacks. The patterns of habitat use of Siamese Firebacks appear to be strongly influenced by vegetation characteristics during non-breeding season. Using areas closer to water indicated that drinking water is necessary for Siamese Firebacks. In addition, the preference for sites closer to water might reflect the bird's preference for denser high bushes (Lu and Zheng, 2003) or the bird's predominant foraging mode involves searching for food in the damp leaf litter layer on forest floor (Mackinnon et al., 2000). However, the diet of Siamese Firebacks foraging in the leaf litter is poorly described. The topic clearly deserves further study.

3.5.3 Roost-site Selection

Siamese Firebacks mostly used understory trees (average DBH of 9.1 ± 0.7 cm and average tree height of 8.2 ± 0.3 m) for roosting. Using those trees, birds can be aware of potential dangerous situations that make them exposed to dangers during night time because of poor visibility. Higher perch branches (average 5.6 ± 0.2 m) and larger distance from perch to tree trunk (average 2.7 ± 0.2 m) greatly decreases attacks from nocturnal predators (such as *Paradoxurus hermaphroditus*, *Viverra zibetha*, *V. megaspila* and *Prionailurus bengalensis*).

Based on regression models, roosting habitat was significantly correlated with steep terrain, less tree coverage at height >5 m, and small basal area of large trees. The preference of steeper slopes for roosting is considered to be one of the more common characteristics for avian roosting (Cody, 1985). The steeper the slope, the more chances for birds to escape by gliding when predators attack. This fact was confirmed by the study of roost-site selection in other Gallifomes (Cong and Zeng, 2008; Li et al., 2010; Xu et al., 2010). There was no evidence to support why the birds select the area associated with less tree coverage at height >5 m for roosting. There were two possible reasons to explain the pattern of using this habitat based on the behavioral observations. First, Siamese Firebacks have two strategies to escape predator attacks or from being suddenly disturbed: by gliding in a downslope direction or flushing through the open canopy. Selecting this habitat can facilitate escape-flushing in response to any dangerous situation. Second, using the area with less canopy cover is not a consequence of site selected for roosting but for foraging. This can be interpreted that the birds spend time during late afternoon in the area with less canopy cover. Longer periods of light penetration to the forest floor may help birds maximize their foraging profitability (Smith and Dallman, 1996). In addition, Siamese Fireback significantly preferred the secondary forest patches, the areas with small basal area of large trees for roosting. This can be confirmed by the mean DBH of roosting trees (9.1 ± 0.7: range 2.9 – 23.6 cm). The study suggests that the characteristics of secondary forest provide the most suitable habitat for roosting.

3.6 Conclusion

This study provided quantitative data regarding ranging behavior and patterns of habitat selection, including roost-site selection of Siamese Fireback in the original lowland habitat. Overall, the results showed that home range size of Siamese Fireback seems likely to be a seasonal variation; however, there was no significant difference between seasons. Female Siamese Firebacks distinctly preferred the secondary forest patches that have a high density of understory stems (at >3 – 5 m height) during different periods of the reproductive cycle. In addition, Siamese Fireback appeared to prefer to roost on steeper slopes with less canopy cover. These results could be referable information for other places where the management for this species is needed, for example in Vietnam and Laos where the loss of suitable habitat and hunting pressure is high (BirdLife Internation, 2012).

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CHAPTER IV

REPRODUCTIVE ECOLOGY AND NEST-SITE SELECTION OF SIAMESE FIREBACK

4.1 Abstract

Breeding success in birds is strongly affected by the selection of suitable nesting sites which has the ability to directly affect population dynamics within a given population. Nest-sites are generally selected to reduce the risk of nest predation; however, current habitat degradation has often forced birds to select suboptimal nesting sites. The objectives of this study were to provide information on the reproductive biology of Siamese Fireback (*Lophura diardi*) at Sakaerat Environmental Research Station and to identify habitat characteristics that influence nest site selection. A total of 21 nest-sites were found during the three year study period (2010 – 2012). Egg laying occurred from April to early August and the average clutch size was 6.4 ± 0.3 SE eggs (range 4 – 8). Incubation lasted 23 – 24 days and daily nest survival was estimated at 0.90 ± 0.02 SE (95% CI = 0.85 – 0.94), giving an estimated overall nest success of 0.08 ± 0.04 SE. Predation was the main cause of nest failure. Siamese Fireback appeared to prefer to nest in the buttresses of large trees (62.5%), which presumably have the potential to serve shelters from potential predators. Analyses indicated that Siamese Fireback significantly preferred to place nests in an area associated with dense vegetation coverage below 50 cm, on steeper

slopes, near large basal areas of trees DBH >10 m and with low predation pressure. This can be interpreted as a strategy to make the nest less conspicuous to predators and facilitate flying out of the nest when predators attack. Primary forest provides large mature trees and a complex structure of understory coverage that is important for optimal nesting sites and nest survival of Siamese Fireback.

4.2 Introduction

Nest-site selection is an important factor for species survival and reproductive success in birds (Clark and Nudds, 1991; Badyacv, 1995). Although there are several factors affecting nesting success such as the health of the female, food available, inflection, and weather, however predation appears to be the main cause of nest failure in several bird species (Descamps et al., 2005; Donehower et al., 2007; Pierce and Pobprasert, 2013). Birds choose nest sites non-randomly with respect to vegetation characteristics (Martin and Roper, 1988; Holway, 1991; Knopf and Sedgwick, 1992), and some may preferentially select nest sites with lower predation risk (Martin, 1992; Siepielski et al., 2001). Thus, vegetation structure is usually considered to be important for nest site selection of many birds (Bentzen et al., 2009; Kolada et al., 2009; Pobprasert and Gale, 2010; Wang et al., 2011; Yi-qun and Nai-fa, 2011). According to the nest concealment hypothesis, predation risk decreases in relation to high vegetation density around the nest site as vegetation density has been suggested to conceal the nest and interfere with visual, auditory, or chemical detection by predators (Martin, 1993).

However, beside vegetation density, ground structure affects nest site selection as it might play a role in predator avoidance. Ground-nesting birds often place their nests beside objects or clumps of vegetation (Lloyd et al., 2000). Suggested advantages of this pattern are protection from both nest predators and environmental conditions (Hockey, 1982; With and Webb, 1993). Many species, particularly within the order Galliformes, are precocial ground-nesting species which are particularly vulnerable to predation during nesting and brood-rearing (Hill and Robertson, 1988; Riley and Schulz, 2001; Draycott et al., 2008). Several studies have shown that predation is the principal cause of nesting mortality in Galliformes (Tapper et al., 1996; Jimenez and Conover, 2001; Draycott et al., 2008; Pierce and Pobprasert, 2013).

Siamese Fireback, *Lophura diardi* is a lowland species that nests on the ground (Johnsgard, 1999). This species was listed as Least Concern (IUCN, 2013). Although the population is considered to be undergoing a slow to moderate decline as a result of lowland habitat alteration and degradation including hunting (BirdLife Internation, 2012), however the numbers of Siamese Fireback recorded at higher elevations (>800 m) in Khao Yai National Park, Thailand has increased significantly during the past twenty years (Round and Gale, 2008). The species has been reported to be polygenous in the wild with the presence of solitary male floater and multi-male groups (Savini and Sukumal, 2009). A recent study of a sub-montane population of Siamese Fireback revealed that the preference of nesting habitat was on the ground in a hollow tree and on steeper slopes (>10 degrees) areas and the study groups showed a 45% nest success (Sukumal et al., 2010).

Although there have been few studies on ranging behavior and breeding ecology of Siamese Firebacks, their nest-site selection remains unclear because of small sample size and the limited number of studies undertaken in their natural range.

Moreover, no quantitative data exists of the breeding ecology of all *Lophura* species in tropical region. Therefore, identifying micro-habitat variables associated with nest-site selection and nest survival is important to understand bird-habitat relationships not only for Siamese Fireback but also for other *Lophura* species.

This study aimed to provide basic information on the breeding ecology of this poorly known species, including nesting period, clutch size, incubation period and nest success in its main lowland forest habitat, and to examine the relationship between micro-habitat characteristics and nest site selection, focusing on determining the ecological features of the habitat that influence nest-site selection. Moreover, the study aimed to determine how predation pressure influencing nest-site selection. If selection of nesting site is a consequence of predation avoidance, Siamese Firebacks should select the areas associated with (1) a higher degree of slope to facilitate flying out of the nest when predators attack, and (2) a higher nest concealment to make the nest less conspicuous to predators.

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4.3 Methods

4.3.1 Study Area

The study was conducted at Sakaerat Environmental Research Station (SERS), classified as a UNESCO Biosphere Reserve since 1967. The reserve, covering 78.09 km^2, is located in north-eastern Thailand (14°30´N and 101°55´E; Figure 4.1) on the edge of Thailand's Khorat Plateau at an elevation of 280 – 762 m above sea level. SERS has two major natural forest types: dry evergreen forest (46.82 km^2) dominated by tree species such as *Hopea ferrea*, *Hopea odorata* and *Hydnocarpus ilicifolia*, and dry dipterocarp forest (14.51 km^2) dominated by common dipterocarpus trees such as *Shorea siamensis*, *Shorea obtusa* and *Dipterocarpus intricatus*, and two large patches of more than 20 year old forest plantation of mixed acacia and eucalyptus (14.46 km^2), and several small patches of bamboo forest (1.12 km^2), grassland (0.93 km^2) and the office and operational building (0.25 km^2) (TISTR, 2012a) The study area is of approximately 3 km^2 dominated by dry evergreen forest, located beside the 3 – 6 km mark of the main road, with elevation ranging between 350 – 580 m. Average annual precipitation is 1,169 mm with a dry season from November to April (average rain fall 223 mm) and a wet season from May to mid-October (average rainfall 945 mm), with rainfall peaks in May and September. Average annual temperature is 26.7°C (range 21.6 to 30.3 °C) and average relative humidity is 81.4% (range 74 to 89%) (TISTR, 2012b).

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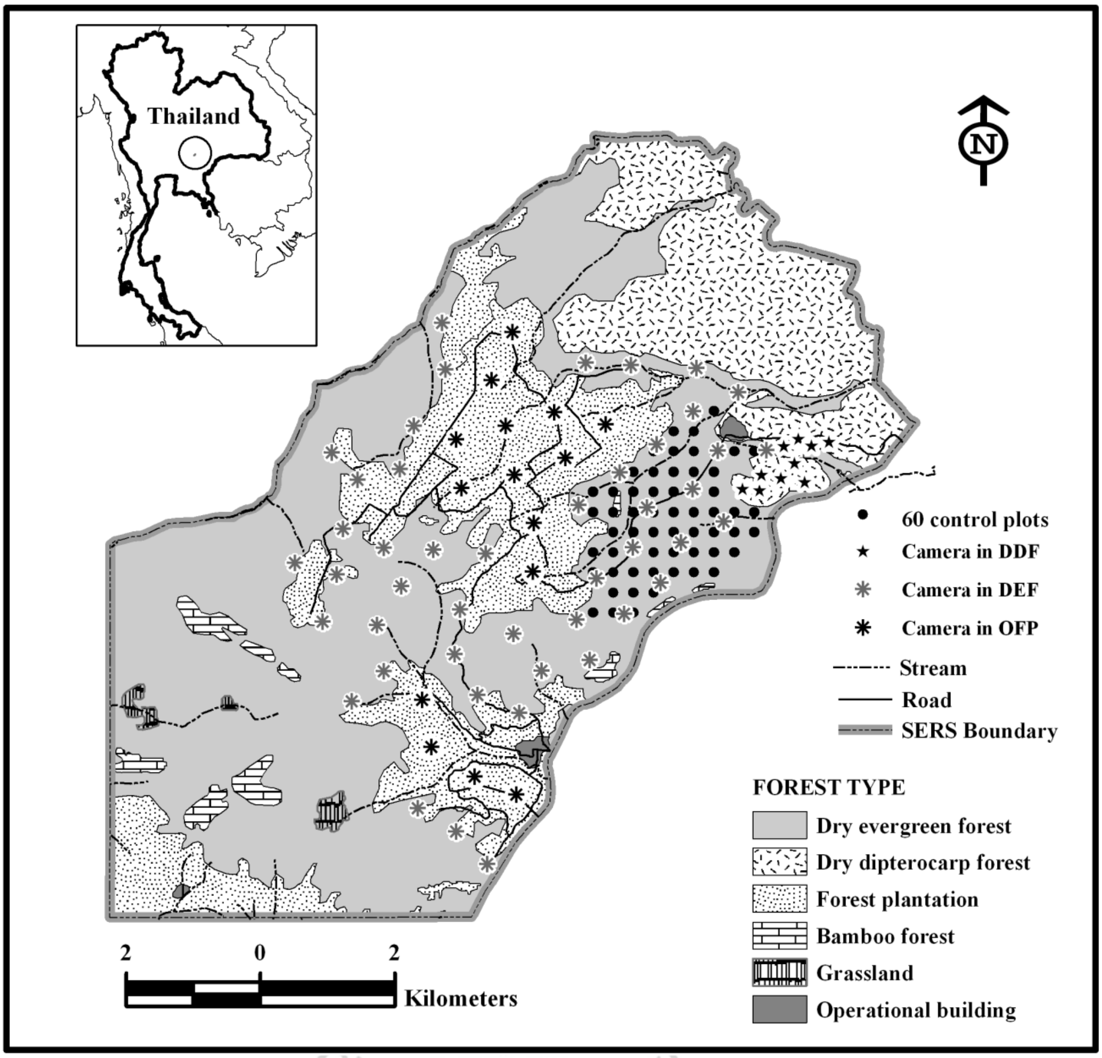

Figure 4.1 Location of Sakaerat Environmental Research Station, Nakhon Ratchasima including the locations of control plots and the camera traps.

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4.3.2 Nest Finding

During three breeding seasons (2010 – 2012), the nests of Siamese Fireback were searched within eight home ranges defined by following radio-collared and searched at the base of tree buttresses where they are known to nest (Sukumal et al., 2010). A few nests were found opportunistically while doing other field work. Eight females, belonging to eight different groups, had previously been captured using mist nets or modified traditional leg snare traps and fitted with a 15 g necklace-type radio-transmitter (in detail see previous chapter). Nests were located by tracking the birds to their nests using ATS R410 receivers with a three-element hand-held Yagi antenna.

4.3.3 Nest Monitoring

Once a nest was located, the position was recorded using a Garmin 60CSx (GPS; ± 8 m accuracy). On subsequent visits, nests were checked from ~10 m to avoid accidentally flushing the female. Each nest was checked every two to three days during the incubation stage to determine if it was still active or had failed. Successful nests were defined to have the presence of large eggshell fragments in a nest (Lu and Zheng, 2003), indicating at least one egg had hatched or by the presence of chick(s) with a female bird, while unsuccessful nests were indicated by a deserted clutch, missing clutch or small eggshells scattered around the nest during the incubation period. Bird remains or large feathers at the nest site were taken to indicate that the incubating bird had been killed or injured by predators. The nesting period was defined as the time when the first nest was found until the last active nest failed or hatched, and the incubation period as the time when the female started incubating until the hatching of the first egg.

4.3.4 Habitat Measurements

For each nest site, the following variables were recorded: type of background (i.e. in tree buttress, under bushes, under the rocky outcrops), nest tree species and their diameter at breast height (DBH). Habitat characteristics surrounding the nesting trees were measured within 5-m and 10-m radius circular plots centered on the nesting site following Martin et al. (1997) and Sukumal et al. (2010). For a 5-m radius circular plot, information on slope degree measured with a clinometer, distance to nearest stream performed using ArcGIS 9.3, number of climbers and number of understory trees with a diameter at breast height (DBH) ≤10 cm, which were categorized into 4 classes based on their height: 0.5 – 1, >1 – 3, >3 – 5 and >5 m were collected. The percentage of vegetation cover for each height category and ground covered by vegetation that is below 0.5 m in height were estimated. For a 10-m radius circular plot, only the DBH of trees with DBH >10 cm was measured in order to estimate basal area. The habitat measurements at nest sites were taken after hatching or failing.

To estimate the availability of nesting habitats, 60 control plots were systematically chosen over known home ranges and the same measurements were taken as those at nest-sites. The control plots were located 300 m apart (Figure 4.1), which is considered to be the approximate width of a home range of Siamese Fireback.

4.3.5 Predator Abundance

The automatic camera traps were placed throughout the study area in order to estimate the abundance of Siamese Fireback at a larger scale (in detail see next chapter). From camera trap pictures, all small carnivores and nest predators based on Pierce and Pobprasert (2013) were listed as the potential predators of Siamese Fireback. Camera traps were conducted during two breeding seasons (February – May) in 2010 and 2011. In 2010, cameras were installed at 46 locations in dry evergreen forest (DEF) and 10 locations in dry dipterocarp forest (DDF), while in 2011 camera were re-installed in 46 locations in DEF and installed 15 locations in forest plantation (FP) (Figure 4.1). The systems were programmed to run for 24 hr per day and to take nine consecutive pictures per detection. Each camera trap was set at least 700 m apart, and these were left in place for 14 days (except for a month in DDF) and then retrieved. The independent events were defined as consecutive photographs of individuals taken more than 30 minutes apart based on O' Brien et al. (2003). As previous studies showed a strong correlation between abundance estimates and relative abundance estimates (O' Brien et al., 2003; Rowcliffe et al., 2008; Rovero and Marshall, 2009) but see Sollmann et al. (2013). In this study, the relative abundance index (RAI) was interpreted as an index of frequency used area by potentials predators, meaning that the more predator photos at any particular camera locations indicate a higher probability of predators detecting the nests in the area. The numbers of independent photographs of a species were used as an index of species frequency and calculated the RAI by dividing the number of independent photos with the total trap-nights in each different year. RAI was standardized to the number of photographs per 100 trap-nights.

The pooled photographs of all predator species divided by the total trap-nights for each camera trap location were used as a predation pressure because of higher incidence of avian predators leading to low reproductive outcome (Eggers et al., 2006; Sparkman et al., 2013). The surface of predation pressure across the whole study area was interpolated by "Kriging" interpolation tool in the ArcGIS version 9.3 (Environmental Systems Research Institute, 2009) to generate predation pressure surface from camera trap locations for each year. Two interpolated surfaces were then averaged to create the final surface used to determine predation pressure surrounding the nest and control sites.

4.3.6 Data Analysis

4.3.6.1 Clutch Size Analysis

Average clutch size was calculated for each study year and for the study overall using information from all active nests (n = 18). Because of small sample size in 2010 (n = 2), the significant difference in clutch size between 2011 and 2012 was tested using a non-parametric Mann–Whitney *U*-test. Nests found by following the radio-collared females (n = 16) were used to calculate the average clutch size per nest-attempted. All the values given are mean ± standard errors (SE).

4.3.6.2 Nest Survival Analysis

Nest survival was modeled to estimate the daily survival rate (DSR) of Siamese Fireback nests in R Program 2.13.0 (R Development Core Team, 2011), using package RMark (Laake and Rexstad, 2008). Nests found after hatching or failure were excluded from this analysis (n = 3 nests), because the fate of those nests were not exactly known. Due to small sample of successful nests, there was no sufficient statistical power to model the effect of nest survival from other covariates. So, only the constant model was reported by assuming that all nests in the sample under consideration have the same daily survival rate for every day. Encounter histories were constructed following Rotella (2005), which required the following data for each nest: (1) the day the nest was found, (2) the last day the nest was checked when still active, (3) the last day that the nest was checked, and (4) the fate of nest (success or failed). Days were standardized so that the earliest date across all years when a nest was first found was coded as day 1, with subsequent dates numbered sequentially relative to the first day (Rotella, 2005). To calculate overall nest success, the estimated daily survival rate was raised to a power equal to duration in days of incubation period. The standard error of nest success was calculated following Powell (2007).

4.3.6.3 Nest-site Selection Analysis

A non-parametric Mann–Whitney *U*-test was used for comparisons of habitat variables and predation pressure between the nests and control sites because the data are not normally distributed. The statistical tests are two-tailed and values given are mean ± SE. Binary logistic regression was used to determine the variables influencing nest-site selection. Variables were transformed prior to analysis and vegetation cover was arcsine transformed (Sokal and Rohlf, 1995), while continuous variables were standardized by dividing the value by twice the standard deviation (Gelman, 2008). For variables which highly correlated (r >0.4), were selected only one variable at a time to a fitted regression model. A set of models was developed to test the hypotheses that may explain the selection of nest sites based on hypotheses of nesting in the area with a higher degree of slope (Sukumal et al., 2010), higher nest concealment (Martin, 1993) and lower predation risk (Bekoff et al., 1989; Martin, 1998; Latif et al., 2012). Model selections were compared with the lowest second order of Akaike Information Criterion (AIC_c) value (Akaike, 1973). Akaike model weights (w_i), were calculated as the weight of evidence in favor of model i among the model being compared.

When no single model is overwhelmingly supported by the data (i.e. w_{best} <0.9), then model averaging can be used (Johnson and Omland, 2004). The model classification accuracy was evaluated using the area under the receiver operating characteristic curve, AUC (Hosmer and Lemeshow, 2000). An optimal threshold cut-off value was chosen for classification based on the receiver operating characteristic curve using the minimized difference between the proportion of presences correctly predicted (sensitivity) and the proportion of absences correctly predicted (specificity) (Fielding and Bell, 1997). The 85% confidence intervals were used to identify variables with significant influence on nest-site selection when model uncertainty occurred. This interval renders model selection and parameter-evaluation criteria more congruent than the narrower interval (95%) widths (Arnold, 2010). All statistical analyses were performed using the R Program 2.13.0 (R Development Core Team, 2011) with MASS package (Venables and Ripley, 2002), AICcmodavg package (Mazerolle, 2012) and PresenceAbsence package (Freeman and Moisen, 2008).

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4.4 Results

4.4.1 Nesting Period, Clutch Size and Incubation

A total of 21 nest sites were found during three breeding seasons (Figure 4.2), 3 nests in 2010, 11 nests in 2011 and 7 nests in 2012. Eighteen of these were active nests consisting of 16 nests found by following eight radio-collared females and two nests found opportunistically, while the other three nests were found after they had failed or hatched judging from the presence of eggshell fragments. Considering the 18 active nests, the nesting period of Siamese Fireback in 2010 started on April 29 (when the first nest was found) and ended on May 5 (when the last active nest was predated, $n = 2$); in 2011 it started on April 1 and ended on August 1 ($n = 10$), and in 2012 it started on April 5 and ended on July 25 ($n = 6$). Thus, the results indicated that the laying period of Siamese Fireback occurred from April to early August.

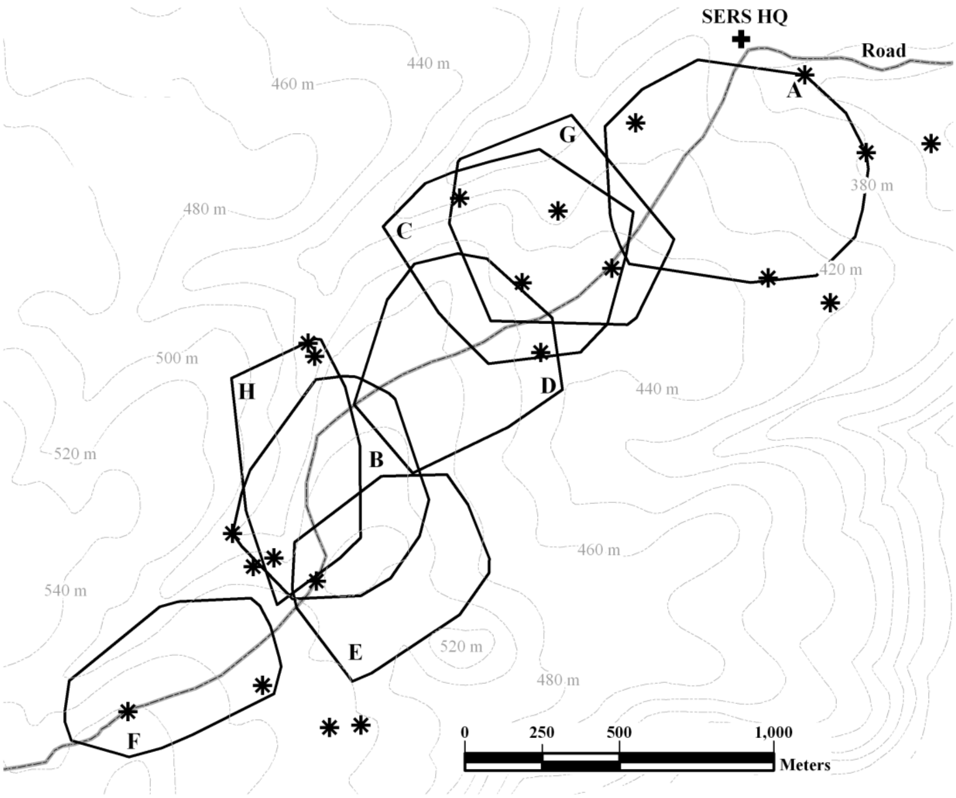

Figure 4.2 A total of 21 nest sites (black asterisk) found during three breeding seasons, polygons are 95% MCP home range of eight radio-collared Siamese Firebacks.

The mean clutch size was 6.4 ± 0.3 eggs ($n = 18$ nests, pooled data from three breeding seasons) ranging from four to eight eggs (Figure 4.3). The clutch size was similar among years with an average of 6.5 ± 0.5 eggs ($n = 2$ nests, max = 7, min = 6), 6.6 ± 0.3 eggs (n = 10 nests, max = 8, min = 5), and 6.0 ± 0.7 eggs (n = 6 nests, max = 8, min = 4) in 2010, 2011 and 2012 respectively. However, there was no significant difference in clutch size between 2011 and 2012 (Mann–Whitney *U*-test, W = 38.5, p = 0.36). In 2011, two radio-tagged females re-nested after their first nest failed. One relaying was successful while the other failed. In 2012, only one radio-tagged female re-nested, making a total of three attempts. Unfortunately, both nest and hen were predated during incubation in the last attempt. The average size of the first clutch (6.6 ± 0.3 eggs, n = 12 nests) was similar to the second clutch (6.0 ± 0.6 eggs, n = 3 nests), while the clutch size of the third attempt was 4 eggs (n = 1 nest). The average period between nest failure and re-nesting was 35.5 ± 3.8 days, ranging from 25 to 43 days. The incubation period, calculated from two successful nests, was 23 – 24 days.

Figure 4.3 The maximum clutch size of Siamese Fireback found eight eggs.

4.4.2 Nesting Success

Only 18 active nests were used to analyze nest success as their fate was accurately known. The estimated daily nest survival rate was 0.90 ± 0.02 (95% CI = 0.85 – 0.94). Overall, nest success was 0.08 ± 0.04 with only two out of the 18 nests monitored hatched. Nest failure was due to predation on the nest or on the hen. Although this study did not attempt to identify the nest predators of Siamese Fireback, there was evidence of failure at one nest as a result of Reticulated Python (*Python reticulatus*). The python was found at the nest site with two intact eggs remaining (Figure 4.4). It was believed that the adult female had already been predated while incubating judging from the python's distended body shape.

Figure 4.4 Reticulated Python (~2.0 m in length) coiled at the nest site of Siamese Fireback with two intact eggs remaining.

4.4.3 Predator Abundance

Camera traps were active for a total of 1965 trap-nights (1157 trap-nights in 2010 and 808 trap-nights in 2011) and they photographed 116 independent detections (45 detections in 2010 and 71 detections in 2011) of 10 potential predators including Asian Golden Jackal *Canis aureus*, Common Palm Civet *Paradoxurus hermaphroditus*, Hog Badger *Arctonyx collaris,* Large Indian Civet *Viverra zibetha*, Large-spotted Civet *V. megaspila*, Small Indian Civet *Viverricula indica*, Leopard Cat *Prionailurus bengalensis*, Small Asian Mongoose *Herpestes javanicus*, Pig-tailed Macaque *Macaca nemestrina* and Bengal Monitor Lizard *Varanus bengalensis* (Table 4.1). The most likely potential predators detected in 2010 were Common Palm Civet, Asian Golden Jackal and Pig-tailed Macaque with RAI values of 1.73, 0.78 and 0.61 photos/100 trap-nights, respectively, whereas in 2011 they were Common Palm Civet, Leopard Cat and Pig-tailed Macaque with RAI values of 6.19, 0.87 and 0.87 photos/100 trap-nights, respectively. Although the average RAI across the potential predators in 2010 (0.49 ± 0.20 photos/100 trap nights) was less than those in 2011 (1.26 ± 0.83 photos/100 trap nights), there was no significant difference between years (Mann–Whitney *U*-test, W = 19, p = 0.32).

Table 4.1 Number of independent photos, the relative abundance index value (RAI, photos/100 trap-nights) and average RAI across species of potential predators of Siamese Firebacks in SERS.

Potential predators	2010 (1157 trap-nights)		2011 (808 trap-nights)	
	# photos	RAI	# photos	RAI
Asian Golden Jackal, *Canis aureus*	9	0.78	-	-
Hog Badger, *Arctonyx collaris*	1	0.09	1	0.12
Common Palm Civet, *Paradoxurus hermaphrodites*	20	1.73	50	6.19
Large Indian Civet, *Viverra zibetha*	-	-	3	0.37
Large-spotted Civet, *Viverra megaspila*	1	0.09	-	-
Small Indian Civet, *Viverricula indica*	2	0.17	-	-
Leopard Cat, *Prionailurus bengalensis*	4	0.35	7	0.87
Small Asian Mongoose, *Herpestes javanicus*	-	-	2	0.25
Pig-tailed Macaque, *Macaca nemestrina*	7	0.61	7	0.87
Monitor Lizard, *Varanus bengalensis*	1	0.09	1	0.12
Average across species	0.49 ± 0.20		1.26 ± 0.83	

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4.4.4 Nest-site Selection

All nest-sites had a structure on one side of the nest such as tree trunks, rocky walls or dense bushes. From the 16 nest-sites of the eight radio-tagged females, 10 nests (62.5%) were located in the buttresses of large trees (Figure 4.5), four nests (25%) were placed on the ground with dense bushes or grasses (Figure 4.6), one nest (6.25%) was located in a clump of *Rattan* sp., and another nest (6.25%) was located between rocks. All nests found by chance were in the buttresses of large trees as a result of particular effort on searching at such sites. The average diameter at breast height (DBH) of nest trees (in genera *Hopea*, *Irvingia*, *Parkia*, and *Ficus*) was 185.4 ± 23.9 cm (n = 15 trees), ranging from 63.5 to 359.0 cm.

Figure 4.5 Female Siamese Fireback incubated her eggs in the buttresses of *Irvingia malayana* with diameter at breast height of 280.0 cm.

Figure 4.6 Nest was placed on the ground with dense bushes.

A comparison of habitat variables between nest (*n* = 21 locations) and control sites (*n* = 60 locations) indicated that nesting habitat significantly correlated with understory vegetation (Table 4.2). Percentage cover of small trees (height <0.5 m and 0.5 – 1 m) at nest sites were significantly higher than those in control sites (Figure 4.7), but densities of understory samplings (height 1 – 3 m) were significantly less than those in control sites (Figure 4.8). Nests were significantly placed in areas with higher degree of slope when compared with those at control sites (Figure 4.9). In addition, predation pressure surrounding nest sites was significantly lower than those surrounding control sites (Figure 4.10).

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Table 4.2 Comparison of habitat variables and predation pressure between Siamese Fireback's nesting and control sites.

Habitat variables	Nest sites (n = 21)			Control sites (n = 60)			Mann-Whitney U-test	
	Mean	±	SE	Mean	±	SE	W	p-value
Slope (degree)	10.9	±	1.5	7.3	±	0.4	443.0	*0.043*
Tree coverage: height <0.5 m (%)	33.91	±	4.31	11.73	±	0.67	161.0	*<0.001*
Tree coverage: height 0.5 – 1 m (%)	25.82	±	3.46	11.85	±	0.57	241.0	*<0.001*
Tree coverage: height 1 – 3 m (%)	20.33	±	2.13	17.25	±	0.80	493.5	0.14
Tree coverage: height 3 – 5 m (%)	17.80	±	2.75	13.16	±	0.69	537.0	0.32
Tree coverage: height >5 m (%)	76.59	±	2.45	78.97	±	0.79	658.5	0.76
Tree density: height 0.5 – 1 m (stems)	63.1	±	7.9	80.8	±	3.4	822.0	0.39
Tree density: height 1 – 3 m (stems)	58.2	±	7.6	82.4	±	3.6	900.5	*0.004*
Tree density: height 3 – 5 m (stems)	12.5	±	1.6	13.6	±	0.7	713.5	0.37
Tree density: height >5 m (stems)	13.1	±	1.2	14.1	±	0.6	687.0	0.54
Number of woody climbers (stems)	12.6	±	2.2	12.3	±	0.9	637.5	0.94
Basal area[a] (m^2)	1.04	±	0.16	0.75	±	0.04	485.5	0.12
Predation pressure[b] (photo/100 trap-nights)	10.93	±	0.64	15.87	±	0.98	962.5	*<0.001*

[a] Basal area = basal area of trees with DBH >10 cm recorded with in a 10-m radius circular plot.

[b] Predation pressure = interpolated values of number photos of all potential predators per 100 trap-nights.

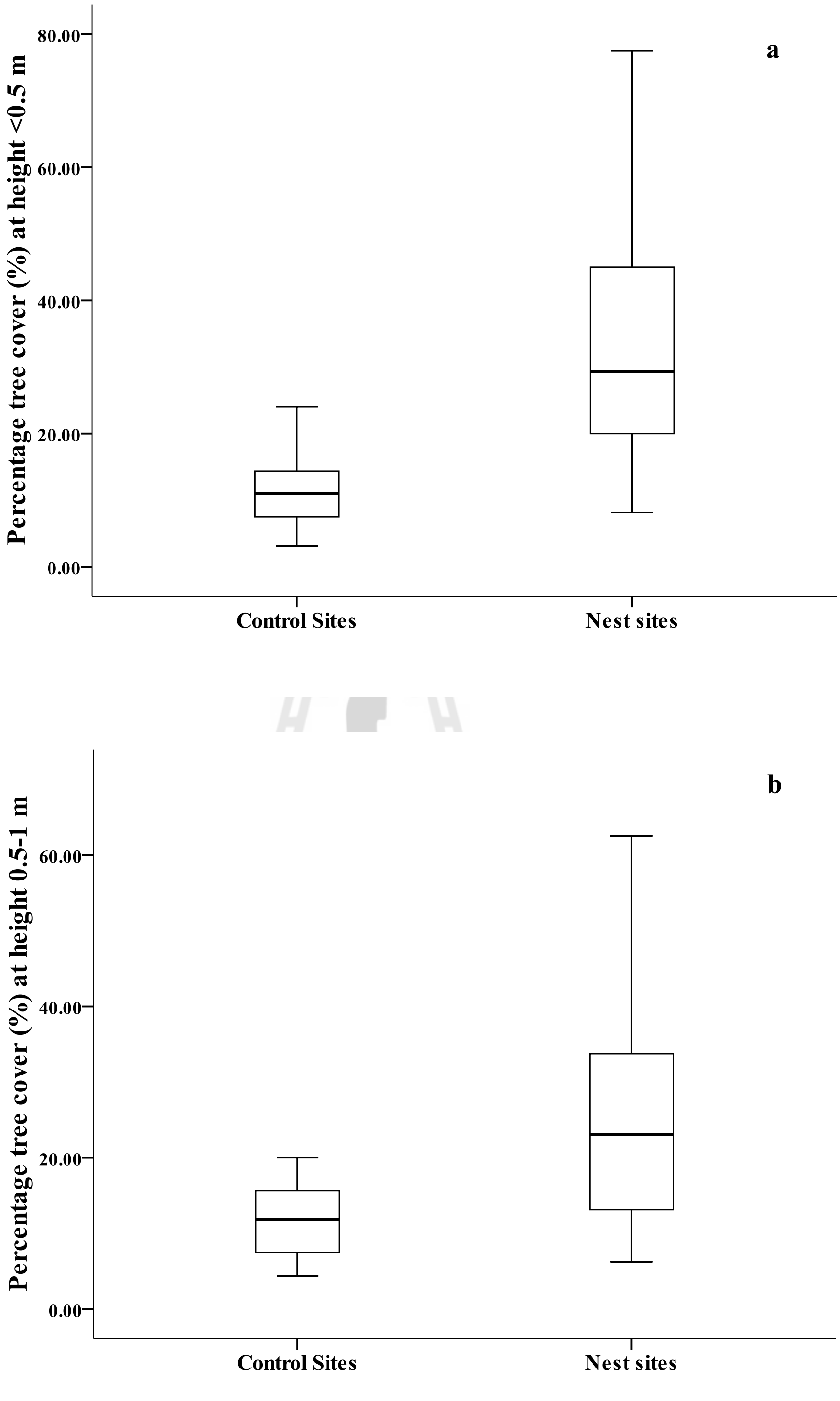

Figure 4.7 Comparisons of percentage tree cover at (a) height <0.5 m, and (b) height >0.5 – 1 m between nest and control sites.

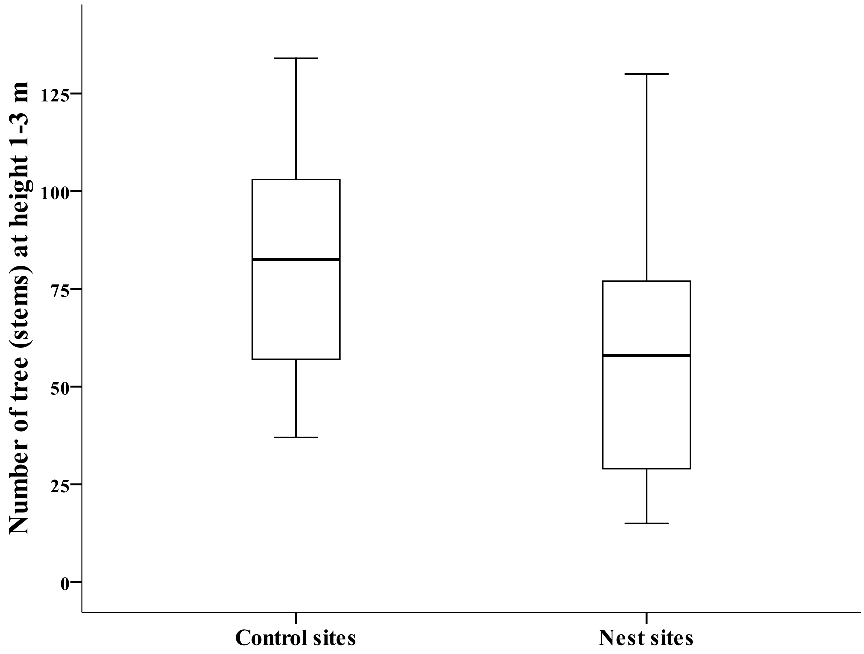

Figure 4.8 A comparison of number of trees at height 1 – 3 m between nest and control sites.

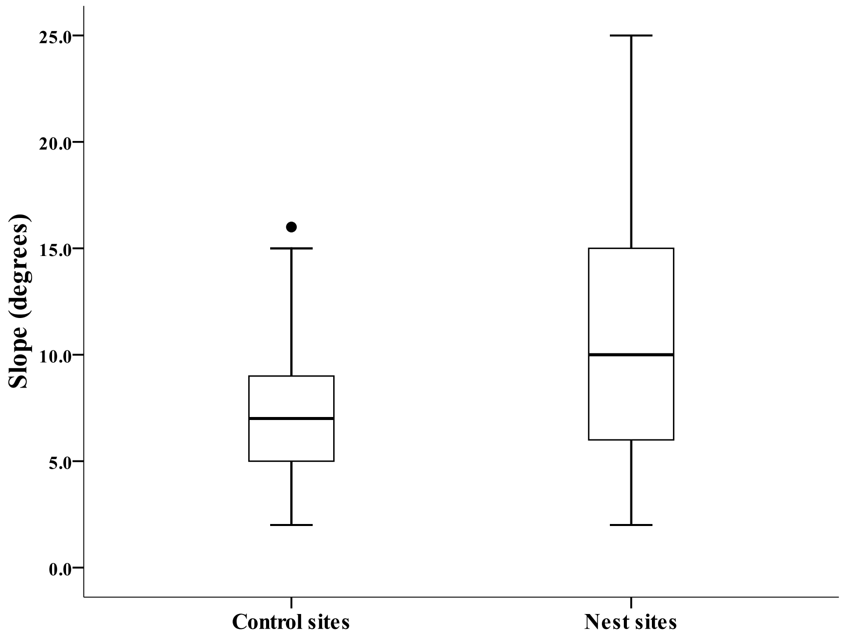

Figure 4.9 A comparison of slope between nest and control sites.

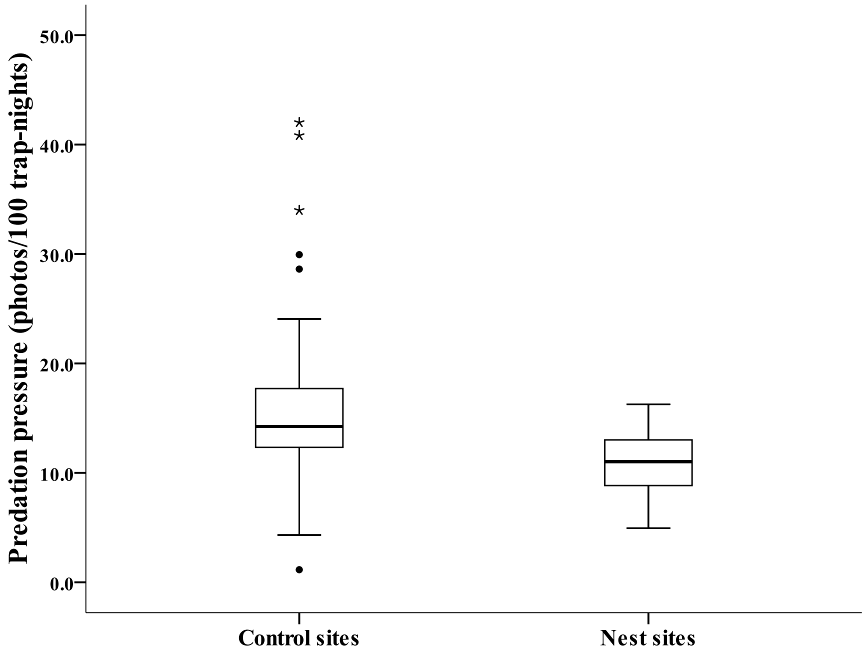

Figure 4.10 A comparison of predation pressure between nest and control sites.

A candidate set of 14 regression models (Table 8 APPENDIX C) were fitted to explain nest-site selection of Siamese Fireback. Model selection indicated that the first best model had highest support (Table 4.3). Based on AIC weights, the first best model had 4.1 times more support than the second best model. The first best model included tree coverage at <0.5 m height, degree of slope, basal area of trees with DBH >10 cm and predation pressure which correctly predicted nest sites selection in 94.52% of these cases while the second best model including all these variables except predation pressure showed relatively high percentage of classification (AUC = 91.90%). Model averaging was estimated for the coefficients of those variables in the confidence set (Table 4.3) based on accumulated 96% model weight. Estimated coefficients for tree coverage at <0.5 m height, degree of slope and basal area of large trees was significantly positive, whereas the estimated for predation pressure was a significantly negative influence on nest site selection of Siamese Firebacks (Table 4.4).

Table 4.3 The confident set of multiple logistic regression models explaining nest site selection of Siamese Fireback. Cover0 is tree coverage at height <0.5 m, BA is basal area of trees with DBH >10 cm, Slope is degree of slope, and Prd is predation pressure.

Model	LL	K	$\triangle AIC_c$	w_i	AUC
(14 models tested)					
Cover0 + BA + Slope + Prd	-16.33	5	0.00	0.77	94.52
Cover0 + BA + Slope	-18.81	4	2.81	0.19	91.90

Note: LL is log-likelihood: K is number of parameters in the model: △AICc is difference in AICc (model score) value, model with △AICc value 0 has most support, value between 0 and 2 have substantial support, value greater than 2 have less support: w_i = Akaike model weights: AUC = area under the receiver operating characteristic curve.

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Table 4.4 Estimates of coefficients derived from model averaging (averaged across all models that contain such variables) and unconditional SE and its 85% confidence interval.

Variables	Estimated coefficient	Uncond. SE	Lower 85%	Upper 85%
Tree coverage at height <0.5 m	5.54*	1.62	3.21	7.87
Basal area of large trees	2.55*	1.45	0.47	4.64
Degree of slope	3.27*	1.20	1.54	5.00
Predation pressure	-2.79*	1.34	-4.71	-0.86

* Estimated coefficients of variables that suggest significant effects on nest-site selection of Siamese Fireback. Overlap with zero indicates a weak effect or no effect.

4.5 Discussion

This study investigated the breeding biology of the Siamese Firebacks in their main lowland forest habitat. Although much of found is similar to previous studies, this study provides the largest dataset of nest outcomes for *Lophura* sp. available in their natural forest habitat. In addition, this study quantified nest survival rate of the Siamese Firebacks which is the first time attempted for a *Lophura* sp. and found that nesting success during incubation period is particularly low, indicating high nest predation in the study area. Moreover, this study attempted to determine nesting habitat for lowland population in order to make a comparison to the population which have recently shown a range expansion into sub-montane forest habitats and preferred nesting on steep terrain (Sukumal et al., 2010). Although the study area was relatively flat and less steep terrain, the results found that not only steeper slope, but also higher percentage of tree coverage below 50 cm, higher basal area of large tree (DBH>10 cm) and low predation pressure were significant factors that influence nest-site selection of Siamese Firebacks.

4.5.1 Nesting Biology and Success

In this study, the nesting period of Siamese Fireback occurred from April to early August. This period covered the nesting period for known lowland populations (Johnsgard, 1999; Madge and McGowan, 2002) and is longer than what reported for a sub-montane population (Sukumal et al., 2010). Siamese Fireback started to lay eggs approximately one month early before the beginning of rainfall (in May). The response could be interpreted as an adaptation to the variability in the onset of the rainy season as rain increases insect food abundance (Lowman, 1982; Nummellin, 1989; Leigh et al., 1996; Anu et al., 2009). So, nesting during rainy seasons can guarantee sufficient food, both in abundance and quality for the birds (Hau, 2001).

The average clutch size of 6.4 ± 0.3 eggs was similar to previous reports (Madge and McGowan, 2002; Sukumal et al., 2010). Small sample size and small variation in clutch size among years limited explanations. Birds may have response to better conditions by laying eggs earlier and by laying a larger number of eggs per clutch, which was observed in the Scaly-breasted Partridge (*Arborophila chloropus*) (Ong-in, 2011). Evolved clutch size is presumably largely a reflection of the average amounts of food available to the female around the time of nesting (Lack, 1968).

Reported incubation periods of Siamese Fireback lay between 24 and 25 days in captivity (Madge and McGowan, 2002), and 23.5 days in the wild (Sukumal et al., 2010); period of lowland Siamese Fireback from complete clutch to hatch was similar estimated at 23.5 days. However, this result was based on a very small sample (only two successful nests). Generally, incubation periods among pheasants range in length from 18 to 29 days, with the longer ones typical of such genera as *Argusianus*, *Pavo*, *Lophophorus*, and *Crossoptilon*, whereas periods of less than 23 days occur in such as *Pucrasia*, *Chrysolophus* and *Polyplectron*, but in all cases only the female incubated (Delacour, 1977; Johnsgard, 1999). The differences in clutch size and incubation period among species may be a result of the differences in relative female energy investment, as species which large female show longer incubation periods (Johnsgard, 1999).

The estimate of nest success was approximately 8%. Due to the small sample of successful nests (n = 2 nests), this study suggests that the estimate should be treated with caution. Nest success in this study area was apparently low compared with those of a sub-montane population (5 of the eleven nests hatched, Sukumal et al., 2010). These can be attributed that the bird's nest success varies with different habitat types. Several studies have shown that predation is the main cause of nesting failure in Galliformes (Tapper et al., 1996; Jimenez and Conover, 2001; Draycott et al., 2008). For pheasants, the extended nesting period (egg laying and incubation) might pose a great risk to egg and hens due to their longer exposure to predators (Lu and Zheng, 2003; Draycott et al., 2008). Moreover, high predation rates could be the result of higher densities of potential predators (Reynold and Tapper, 1993).

According to the camera trapping data, there was a diverse suite of potential predators. The most frequently detected predators were Common Palm Civets (60.3%) and Pig-tailed Macaques (12.1%). A previous study observed that Pig-tailed Macaque plays an important role as a nest predator in evergreen forest at Khao Yai National Park (Pierce and Pobprasert, 2013), which is considered to be the same as the forest complex of SERS. Because of a small and isolated area of the SERS, this can predict that usually large ranging predators, such as macaque and civets, might re-use the same part of their home range with higher intensity with the consequence of increasing their predator pressure on the nesting bird community. However, not only mammal species were potential predators of Siamese Firebacks but also other animals such as nocturnal snakes, raptors and non-raptorial birds, squirrels and tree shrews can be their nest predators (Ong-in, 2011; Pierce and Pobprasert, 2013). Practically, those animals could not be detected by camera-trapping. This study reported an evidence of the predation of a Siamese Fireback during incubation by Reticulated Python *Python reticulates* (Figure 4.4), which was similarly observed for female Silver Pheasant at

Khao Yai National Park (Sukumal, 2009). These reports of predation by reptiles on pheasants are rare (Lind and Welsh 1990; Bezy and Enderson, 2003).

4.5.2 Nest-site Selection

Regression models indicated that Siamese Firebacks preferred to place nests in areas with dense vegetation coverage below 50 cm, on steeper slopes, with large basal area of tree DBH>10 cm and low predation pressure (Tables 4.3 and 4.4). Preference for dense vegetation coverage at nest sites may be a response to predation risk, similar to other bird species that select nesting places in areas with higher nest concealment in order to reduce predation risk (Martin, 1993). Vegetation concealment seems to represent important aspects of nest-site selection in ground-nesting birds, particularly pheasants such as White-eared Pheasant (*Crossoptilon crossoptilon*) in southwestern Sichuan Province, China (Nan et al., 2006), Blue-eared Pheasant (*Crossoptilon auritum*) in southern Gansu Province, China (Yi-qun and Nai-fa, 2011), and Hume's Pheasant (*Syrmaticus humiae*) in the Doi Chiang Dao Wildlife Sanctury, Northern Thailand (Iamsiri and Gale, 2008). This can be interpreted as a strategy to make the nest less conspicuous to predators by blocking the view of raptors and mammals at a distance.

Siamese Firebacks showed high preference for steeper slopes for nest-site selection. Locating nests on steeper slopes can be interpreted as a strategy to make a nest less accessible to predators and facilitate flying out of the nest when predators attack (Lima, 1993; Sukumal and Savini, 2009). Selection of this pattern is commonly found among the Galliformes, including sub-montane Siamese Fireback (Sukumal et al., 2010), Silver Pheasant (Sukumal and Savini, 2009), Blue-eared Pheasant (Yi-qun and Nai-fa, 2011), and White-eared Pheasant (Wang et al., 2005).

As suggested by Ong-in (2011), high preference of steeper slope for nest site selection of Scaly-breasted Partridge not only provides a good position to observe predators, but also provides good drainage.

In addition, Siamese Firebacks also selected nest habitat patches with trees with larger basal area and DBH>10 cm, which are considered to be the characteristics of primary forest (Bhat et al., 2000). They prefer to place their nests in the buttresses of large trees (DBH ranging from 63.5 to 359 cm). Similar behavior has been observed for Siamese Firebacks in sub-montane forest habitat (Sukumal et al., 2010). The selection the base of tree trunk as a background object for nesting had also been reported for other galliform species such as the Scaly-breasted Partridge (*Arborophila choloropus*) in Khao Yai National Park, Thailand (Ong-in, 2011), Tinetan eared Pheasant (*Crossoptilon harmani*) in Lhasa, Tibet (Lu and Zheng, 2003), and Chinese Grouse (*Bonasa sewerzowi*) in Lianhuashan, China (Sun et al., 2007). Although nesting between tree buttresses can serve as better shelters from potential predators by limiting their detection range, the disadvantages of locating nests within the buttress of large tree is that escape flights may be limited when birds face large predators.

Moreover, the models suggested a negative response to predation pressure (Table 4.4). Siamese Firebacks selected the area associated with low predation pressure surrounding the nest-site. Previous studies on nest predators of Southeast Asian evergreen forest birds indicated that predation was the main cause of nest failure, accounting for 91.7% of nest failures (Pierce and Pobprasert, 2013). Natural selection should favor birds that choose habitats that reduce the negative effects of nest predation given the importance of reproductive success to fitness

(Martin, 1993). Increased nest predation reduces avian recruitment, limits population growth and can make some populations non-sustainable (Cowardin et al., 1985).

Interestingly, one of radio-collared female nested twice (2011 and 2012) in dry dipterocarp forest, fairly close to the edge of the evergreen forest, but outside her yearly home range. This seems to be the case in area of fairly high nesting densities which has been reported in previous Ring-necked Pheasant (*Phasianus colchicus*) studies but failed to explain the direct relationship to the placement of a nest and its distance from the edge of the habitat (Strode, 1941; Nelson et al., 1960).

4.6 Conclusion

Although the results seem to be similar to previous studies, this study provided a larger dataset of nest outcome for Siamese Firebacks in their natural lowland forest habitat. Results confirm that Siamese Fireback significantly prefers to nest in areas associated with higher percentage of ground cover, steep slopes, higher basal area of large trees and low predation pressure. According to low nest success, further studies are needed to investigate the main causes of nest failure and the main nest predators.

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CHAPTHER V

ABUNDANCE AND DENSITY ESTIMATES OF SIAMESE FIREBACK

5.1 Abstract

Most tropical Asian Galliformes are secretive and difficult to survey. Consequently, reliable estimates of abundance are lacking for many species and their conservation status remains largely unconfirmed. The objectives of this study were to compare estimates of density and habitat preference from camera trapping, distance sampling and telemetry studies using data collected on the Siamese Fireback (*Lophura diardi*), in a lowland forest of northeastern Thailand. Camera trap data were used to analyze both count based and presence/absence based methods and found that the repeated count model performed better. Density was poorly estimated using distance sampling, likely due to small sample size, the lack of visibility in dense vegetation and the bird's extreme sensitivity to observers. Estimates of density based on camera trapping data had narrower confidence intervals than those obtained using distance sampling. Based on the beta-binomial mixture model, which accounts for the group living nature of Siamese Fireback, estimated density was higher in dry evergreen forest (5.6 birds km^{-2}), than in old forest plantations (0.2 birds km^{-2}), perhaps because dense forest habitats provide birds with more resources and refuge from predation. The results suggest that the beta-binomial mixture model is a suitable

model for estimating density using data collected from camera trapping cryptic terrestrial bird species in the tropical forest that lack unique markings such as the Siamese Fireback. However, the application of this technique requires that the effective sampling area is known and thus requires some knowledge of the animal home range size.

5.2 Introduction

Animal abundance provides the most critical information for defining the status of a species and thus for conservation assessments and practical management (Conroy and Carroll, 2001). A large number of techniques exist for assessing population abundance and density, including quadrant or plot sampling technique (Jaeger and Inger, 1994), distance sampling (Buckland et al., 2001; Thomas et al., 2012), photographic mark-recapture methods (Karanth and Nichols, 2002; Karanth et al., 2004; O'Brien and Kinnaird, 2008) and repeated presence-absence surveys (Royle and Nichols, 2003). However, each of these techniques includes assumptions that can be difficult to meet for cryptic terrestrial birds such as some Galliformes. For example, distance sampling requires that the surveyed species should be detected by visual or auditory means (Buckland et al., 2001; Thomas et al., 2012), while photographic mark-recapture is based on the identification of individuals using unique markings (Karanth and Nichols, 2002).

Of the 300 Galliformes species worldwide, 26% are classified as "threatened", largely due to habitat loss and degradation, hunting and human disturbance (IUCN, 2013). In tropical Asia, there are 180 species of Galliformes (Madge and McGowan, 2002) of which 21 are of global conservation concern, 1 critically endangered, 4 endangered, and 16 vulnerable species (IUCN, 2013). Despite the threats facing tropical pheasants (Phasianidae), little is known about the basic biology of most species. Moreover, many species are secretive and hard to observe, making most traditional bird survey methodology difficult to implement. As a result, reliable estimates of abundance are lacking for species that might be in serious peril. For example, after a detailed survey, the status of the endangered Edward's Pheasant (*Lophura edwardsi*) was changed from endangered to critically endangered in 2012 (BirdLife International, 2012a).

The Siamese Fireback (*Lophura diardi*) is a pheasant restricted to lowland and foothill forest habitats (< 800 m elevation) of Southeast Asia. Although not currently endangered, its population is estimated to be fewer than 5,000 individuals in Thailand, and in decline throughout its range due to poaching and habitat loss and degradation (Round, 1988; Madge and McGowan, 2002; BirdLife International, 2012b). While some information on the habitat requirement, behavioral ecology and the mating system of this species exist (Johnsgard, 1999; Savini and Sukumal, 2009; Sukumal and Savini, 2009), information about density and habitat selection is restricted to a sub-montane habitat (Round and Gale, 2008; Sukumal et al., 2010). There has been no effort to estimate population density, or to assess the efficacy of available sampling methods, in their main lowland habitat. In northeastern Thailand, Siamese Firebacks are relatively abundant in some protected areas providing an excellent candidate species for investigating the efficacy of various survey techniques that could be applied to tropical Asian galliforms.

This study focused on a resident Siamese Fireback population in Sakaerat Environmental Research Station, Nakhon Ratchasima. A suite of models were used to apply to data collected using telemetry, distance sampling and camera trapping, and compare estimates of Siamese Fireback abundance, density and habitat preference. The objectives of this study were to (1) estimate the abundance and density of the Siamese Fireback; (2) compare the effectiveness of camera traps and distance sampling; (3) compare camera trap and distance sampling derived estimates of abundance and density to estimates based on territory mapping of radio-tagged Siamese Firebacks, and (4) assess habitat preference of Siamese Fireback between undisturbed tropical dry forest and disturbed forest plantation.

5.3 Methods

5.3.1 Study Area

The study was conducted at Sakaerat Environmental Research Station (SERS; Figure 5.1), classified as a UNESCO biosphere reserve since 1967. The reserve, covering 78.09 km^2, is located in northeastern Thailand (14˚ 30′N, 101˚ 55′ E) on the edge of Thailand's Korat Plateau at an elevation of 280 – 762 m. SERS has two major natural forest types: dry evergreen forest (46.82 km^2) and dipterocarp forest (14.51 km^2), and two large patches of more than 20 year old forest plantation (14.46 km^2), the rest of the reserve is made up of mixed acacia (*Acacia* spp.) and eucalyptus (*Eucalyptus* spp.), and several small patches of bamboo forest (1.12 km^2), grassland (0.93 km^2) and the office and operational building (0.25 km^2) (TISTR, 2012a). Average annual precipitation is 1,071 mm with a dry season from November to April (average rainfall of 210 mm) and a wet season from May to October (average rainfall of 860 mm). Average annual temperature is 26.1°C (ranging from a low average of 19.3 to a high of 32.8°C) and the average relative humidity is 82.2% (range of 74 to 87%) (TISTR, 2012b).

5.3.2 Study Species

Siamese Firebacks live in groups with a dominant male (and/or subordinate) that monopolizes all females in the group during both the breeding and non-breeding seasons. The social unit is reportedly composed of floaters, solitary males excluded by a stable group, or in a few cases, by a pair of floaters (Savini and Sukumal, 2009). A relatively high number of solitary males were observed during January and February (Savini and Sukumal, 2009), which is the period that animals travel long distances to look for breeding opportunities. The breeding season is February until July, with mating occurring in February to April and nesting in April to July. Females do not nest synchronously (Savini and Sukumal, 2009).

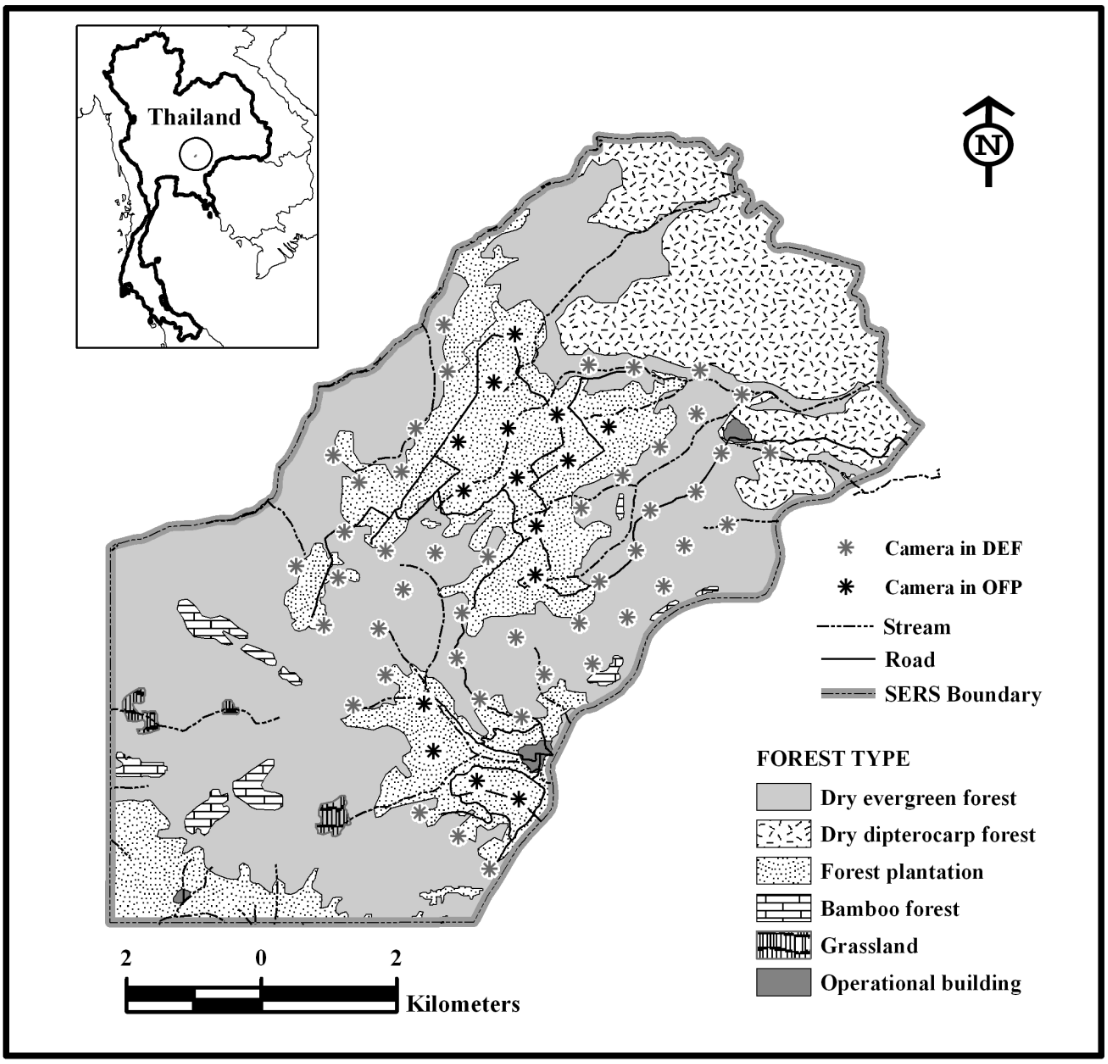

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Figure 5.1 The location of the Sakaeret Environmental Research Station in Nakhon Ratchasima including the 61 camera trap locations and line transects (all 200 m long) each intersecting a camera trap location.

5.3.3 Camera Trapping

Camera trap surveys were conducted during the 2011 breeding season (February to May) when birds were more active. Camera-traps were mounted on trees at a height of 45 cm (Figure 5.2) at 61 camera locations at two sites; 46 in dry evergreen forest (DEF) and 15 in old forest plantation (OFP) (Figure 5.1). Assuming that an individual would need to come into direct contact with a camera, and using the 30 ha home range size reported by Sukumal et al. (2010) in a study of a sub-montane population of Siamese Fireback, cameras were placed 700 m apart (i.e. approximately the diameter of a circular home range of 30 ha which is 618 m). Such trap spacing allows for some local variation in home range size while avoiding violation of the assumption that animals should not be detected in more than one site. Passive infrared camera traps (Stealth Cam, TX, USA) with the date and time stamp on each photograph were used in this study. Cameras were programmed to run continuously (24 hr a day) for 14 days and to take nine consecutive pictures beginning one minute after being triggered. Each trap was baited with rice once at the same time to maximize capture. Each photo was identified to Siamese Fireback, recorded the time and date of the photograph, and counted the number of individuals in each photo. To avoid double counting of individuals making multiple passes of the cameras, and thus the potential to overestimate abundance, only photographs taken in a one hour window (between 0630 and 0730 hours were used); it was considered to be the highest Siamese Fireback activity period. The 14 camera trapping days were used as replicate occasions which yielded both repeated count data, the number of Siamese Fireback individuals detected in each day, or repeated presence-absence data, whether or not at least one Siamese Fireback individual was detected in each day. Whereas the habitat types, dry evergreen forest (DEF) and old forest plantation (OFP) were used as a site- (camera-) specific covariate to test the effect of forest types on abundance.

Figure 5.2 Camera trap setting on trees at a height of 45 cm.

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To estimate Siamese Fireback abundance from camera trapping data, two types of model for estimating abundance: the Royle-Nichols model using repeated presence-absence data (Royle and Nichols, 2003), and the binomial mixture model using replicated count data (Royle, 2004) were fitted. These models assume that the probability of detecting an animal at a site is a function of the number of animals at that site. The binomial mixture model assumes that the probability of detecting N individuals at a site represents a binomial trial of the number of animals actually at that site. This assumption means that the detection of one bird at a site is independent of the detection of any other birds (Royle, 2004). However, Siamese Firebacks are gregarious, violating this assumption because the detection of one group member is likely to be related to the detection of other group members. To account for this non-independence in detection, a beta-binomial mixture model (Martin et al., 2011) was fitted to the repeated count data.

The Royle-Nichols model was fitted using the "unmarked" package (Fiske and Chandler, 2011) implemented in program R version 3.0.1 (R Development Core Team, 2011). Each of the candidate models were ranked using Akaike Information Criterion (AIC; Akaike, 1973) and model fit was assessed using parametric bootstrap of the chi-square goodness-of-fit statistic (1,000 iterations). The binomial and beta-binomial mixture models were fitted using JAGS program version 3.3 (Plummer, 2003) run from R via the "R2jags" package (Su and Yajima, 2012). The posterior parameter estimates are based on a Markov chain Monte Carlo (MCMC) analysis with three separate chains if 50,000 iterations (the first 5,000 were discarded as a "burn in"). Model convergence was assessed using the Rhat value, where a value close to 1 indicated convergence (Gelman and Hill, 2007). Goodness-of-fit was evaluated for both models using Bayesian *p*-value based on chi-squared discrepancy (Gelman et al., 2004), where a Bayesian *p*-value close to 0.5 indicates that a model appears to fit the data.

To convert estimates of Siamese Fireback abundance to density, the estimated (habitat specific) population size (N) was divided by the effective sampling area of the camera traps. As animals could not move more than the diameter distance of an average home range (d), the effective sampling area was calculated as being a circular buffer around each camera with a radius equal to the diameter of the average home range (or a diameter of 2*d*) . Using the "Proximity" analysis tool in the ArcGIS version 9.3 (Environmental Systems Research Institute, 2009) habitat (forest) specific buffer polygons were created, removing any overlap, allowing habitat specific densities to be calculated. Average home range size was estimated using data collected from radio-collared birds from a concurrent telemetry study of birds in the study area (see Telemetry section below).

5.3.4 Distance Sampling

Distance sampling was also conducted between February and July 2011. Sixty-one line transects, all 200 m long and each intersecting a camera trap location, were established (Figure 5.1). A pair of observers walked the transects at an average speed of 20 m min^{-1} between 0700 to 1000 and 1400 to 1700 hours, corresponded to the peak period of activity each day. The transects were walked at the same time as the camera traps were set; 4 – 5 times site^{-1} in DEF and 9 – 11 times site^{-1} in OFP for a total of 73.8 km (43.8 km in DEF and 30.0 km in OFP). For each group visually encountered while walking the transect, the number of individuals in the group and the perpendicular distance of the group from the transect were recorded.

The average group size and animal density were estimated using program DISTANCE version 6.0 (Thomas et al., 2009). AIC was used to select between the four commonly used key detection functions: uniform, half-normal, hazard-rate and negative exponential (Buckland et al., 2001). Density was firstly estimated based on data pooled across habitat types (DEF and OFP) and then estimated habitat specific density.

5.3.5 Telemetry

Siamese Firebacks were caught using mist nets (Keyes and Grue, 1982) and modified traditional leg snares made from bamboo and soft polyester string (Schemnitz et al., 2009) between April 2010 and February 2011 (n = 6) and then again in November 2011 and December 2011 (n = 2), a period that overlapped with both the camera trapping and distance sampling surveys. All birds caught were banded with a unique combination of two or three colored and one metal band (11A size, Thai Royal Forest Department). Each captured bird was fitted with a 15 g necklace-type radio-transmitter (model RI-2B, Holohil System Ltd.) with a life span of approximately 24 months. Birds were tracked by telemetry every two days using ATS R410 receivers and three-element Yagi antennae. When the birds were found, their first location, and the size and composition of the group were recorded. Based on 95% minimum convex polygons (MCP; Mohr, 1947) around these points, home range sizes and home range overlap were estimated using the Animal Movement Extension in Arcview 3.2a (Hooge and Eichenlaub, 1997).

Group density was calculated by dividing the number of groups (each collared animal representing a distinct group) by the effective area, determined by circumscribing the combined area of the 95% MCP home ranges of all radio-tagged individuals. The total number of groups in the area was defined as the proportion of tracking success for the radio-tagged bird present in each group (Garshelis, 2011). Group density was then multiplied by the average group size observed during breeding season to obtain bird density. The associated 95% confidence interval was computed by the mean ± 1.96 × SE. In this case, the size of population is known so the standard error was calculated using the finite population correction factor:

$$SE = \sqrt{\frac{S^2}{n}\frac{(A-a)}{A}}$$

where S^2 is the variance in the number of individuals in the group, n is the number of radio-tagged birds (groups), A is the total area (100% MCP estimated using pooled radiolocations from all radio-tagged birds combined); a is the sampling area (the pooled areas combined from the individual home range).

5.4 Results

5.4.1 Camera Trapping

Siamese Firebacks were detected in 16 of the 61 camera locations (15 in DEF and 1 in OFP), given 49 independent events of Siamese Firebacks (48 events in DEF and 1 event in OFP) with a total sampling effort of 808 trap-nights (average13.3 ± 0.2 (SE) nights location^{-1}). Based on telemetry data, the average home range size of Siamese Fireback during breeding season was 20.8 ± 2.4 (SE) ha (see Telemetry results below). The diameter of a circular home range of this size is 514.4 m giving a total effective sampling area of 39.50 km^2, 29.16 km^2 in DEF and 10.34 km^2 in OFP.

Using the Royle-Nichols model, a model with habitat specific fireback abundance received most support (88% of the model weight based on AIC). The bootstrapped chi-square goodness-of fit test indicated that the model adequately explains these data (p = 0.58). The binomial and beta-binomial mixture models were fitted to the count data to estimate habitat specific abundance. Comparing the Bayesian p-values (0.00 vs. 0.53) and the lack of fit ratio (2.93 vs. 0.98) of the beta-binomial mixture model and the binomial mixture model respectively suggests the beta-binomial model provides a better fitting model to the data. The estimated detection probability based on repeated presence-absence data (Royle-Nichols model) was higher than those estimates based on replicated count data (binomial and beta-binomial mixture model), while the estimated site abundance was lower (Table 5.1). The estimates of habitat specific abundance indicated Siamese Fireback in DEF show a high abundance in comparison with those in OFP (Table 5.1 and Figure 5.3).

Utilizing the mean estimated habitat specific abundance and confidence interval derived from the model estimates using Royle-Nichols model, binomial and beta-binomial mixture model multiplied by 46 camera locations in DEF, and the effective sampling area in DEF equal to 29.16 km^2, the density estimates were 0.77 birds km^{-2} (95% CI: 0.39 – 1.25) for Royle-Nichols model, 3.00 birds km^{-2} (95% CI: 2.27 – 3.86) for binomial mixture model, and 5.60 birds km^{-2} (95% CI: 3.12 – 8.68) for beta-binomial mixture model (Table 5.1 and Figure 5.3).

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Table 5.1 Estimated probabilities of detecting an animal (p) and mean site abundance (λ) with their lower and upper 95% confidence interval (CI) from the Royle-Nichols model (presence-absence based model), binomial mixture model and beta-binomial mixture model (count based models).

Model	Detection probability (p)		Site abundance (λ, birds site^{-1})				Density (birds km^{-2})			
			DEF		OFP		DEF		OFP	
	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI
Royle-Nichols model	0.16 ± 0.03	0.11 – 0.23	0.49 ± 0.13	0.25 – 0.73	0.07 ± 0.07	0.01 – 0.40	0.77 ± 0.22	0.39 – 1.25	0.10 ± 0.10	0.01 – 0.58
Binomial mixture model	0.14 ± 0.02	0.11 – 0.17	1.90 ± 0.04	1.44 – 2.45	0.08 ± 0.02	0.00 – 0.29	3.00 ± 0.06	2.27 – 3.86	0.12 ± 0.03	0.00 – 0.42
Beta-binomial mixture model	0.06 ± 0.01	0.04 – 0.09	3.55 ± 0.13	1.98 – 5.50	0.14 ± 0.04	0.01 – 0.53	5.60 ± 0.20	3.12 – 8.68	0.20 ± 0.06	0.01 – 0.77

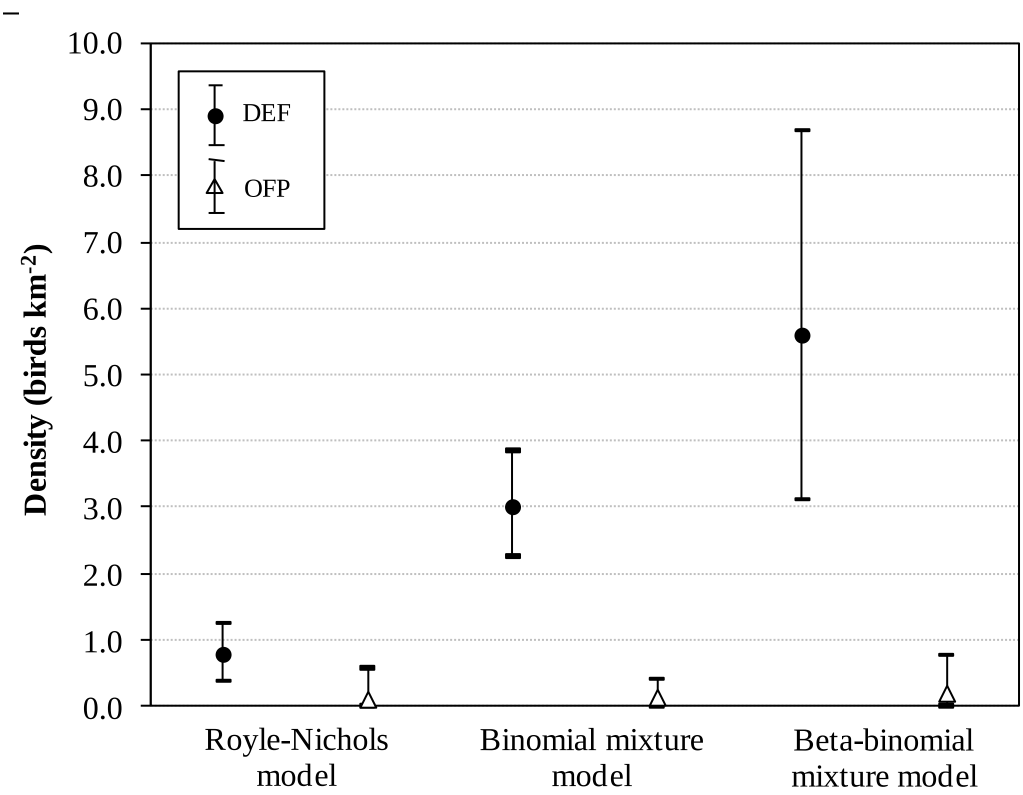

Figure 5.3 Density estimates (± 95% CI) of Siamese Firebacks in dry evergreen forest (DEF) and old forest plantation (OFP) based on camera trapping data using the Royle-Nichols, binomial and beta-binomial mixture models.

5.4.2 Distance Sampling

A total of 31 detections; 23 detections in DEF sites and 8 detections in OFP sites were recorded. Using pooled data (combining the detections from DEF and OFP), the hazard distribution with a cosine adjustment term produced the best model fit based on AIC. Siamese Firebacks were detected with the probability of 0.67, and the effective strip width was 21.6 m. The average group size of 2.1 birds group^{-1}, the encounter rate was 4 groups every 10 km of transect walked and the estimated population density of birds in the total area was 21.5 birds km^{-2} (Table 5.2).

Using only data from DEF sites, the uniform distribution with a cosine adjustment term produced the best detection function fitting our data based on AIC. Siamese Firebacks were detected with the probability of 0.56 and the effective strip width was 17.9 m. The average group size was 2.1 birds $group^{-1}$, the encounter rate was 5 groups every 10 km of transect walked and the estimated density of birds in DEF was 40.3 birds km^{-2} (Table 5.2).

Using only data from OFP sites, I only fitted the detection function with three different key functions because the uniform distribution was considered unreliable due to small sample size and so it was excluded from this analysis. The results showed that the negative exponential distribution with a cosine adjustment term produced the best model fit based on AIC. Siamese Firebacks were detected with the probability of 0.99 which can be considered unreasonable and most likely the result of a small sample size (n = 8). The effective strip width was 24.3 m. The average group size was 2.1 birds $group^{-1}$, the encounter rate was 3 groups every 10 km of transect walked and the estimated density of birds in OFP was 11.7 birds km^{-2} (Table 5.2).

Table 5.2 Estimated group density and animal density with the 95% confidence interval (CI) and their coefficient of variation (CV) for the pooled data, DEF only and OFP only using distance sampling. (*P* is detection probability, and ESW is the effective strip half-width).

Name	Effort (km)	Number of detection	*P*	ESW (m)	Encounter rate (groups/km)	Average group size (birds/group)	Animal density (birds km^{-2})		
							Estimate	95% CI	% CV
Pooled data	73.8	31	0.67	21.6	0.42	2.1	21.5	13.4 – 34.4	24
DEF only	43.8	23	0.56	17.9	0.53	2.1	40.3	25.4 – 64.1	24
OFP only	30	8	0.99	24.3	0.27	2.1	11.7	2.6 – 52.2	79

5.4.3 Telemetry

Birds were located on average in 86.0 ± 1.7% of tracking attempts (range 78.4 – 91.5%). The average home range size during breeding season was 20.8 ± 2.4 (SE) ha. Group sizes during these periods were found ranging from two to five birds with the average group size of 3.4 ± 0.4 (SE) birds group^{-1} (Table 5.3 and Figure 5.4).

On average, every group was surrounded by five neighboring groups. The average overlap area between two neighboring groups was 3.15 ± 1.46 (SE) ha (range 0.02 to 12.09 ha) and among three neighboring groups was 1.10 ± 1.08 (SE) ha (range 0.02 to 2.18 ha) (Figure 5.4). Circumscribing the combined area of the home ranges yields an area of 140 ha. Each group was present at 89.7, 91.5, 90.9, 85.7, 86.5, 78.4, 80.0 and 85.0% of tracking attempts, respectively (Table 5.3) within this 140 ha area; this yields a mean of 0.897 + 0.915 + 0.909 + 0.857 + 0.865 + 0.784 + 0.800 + 0.850 = 6.88 groups 140 ha or 4.9 groups km^{-2} (95% CI = 4.4 – 5.4). Using an average group size, the average animal density was 16.7 birds km^{-2} (95% CI = 15.1 – 18.3).

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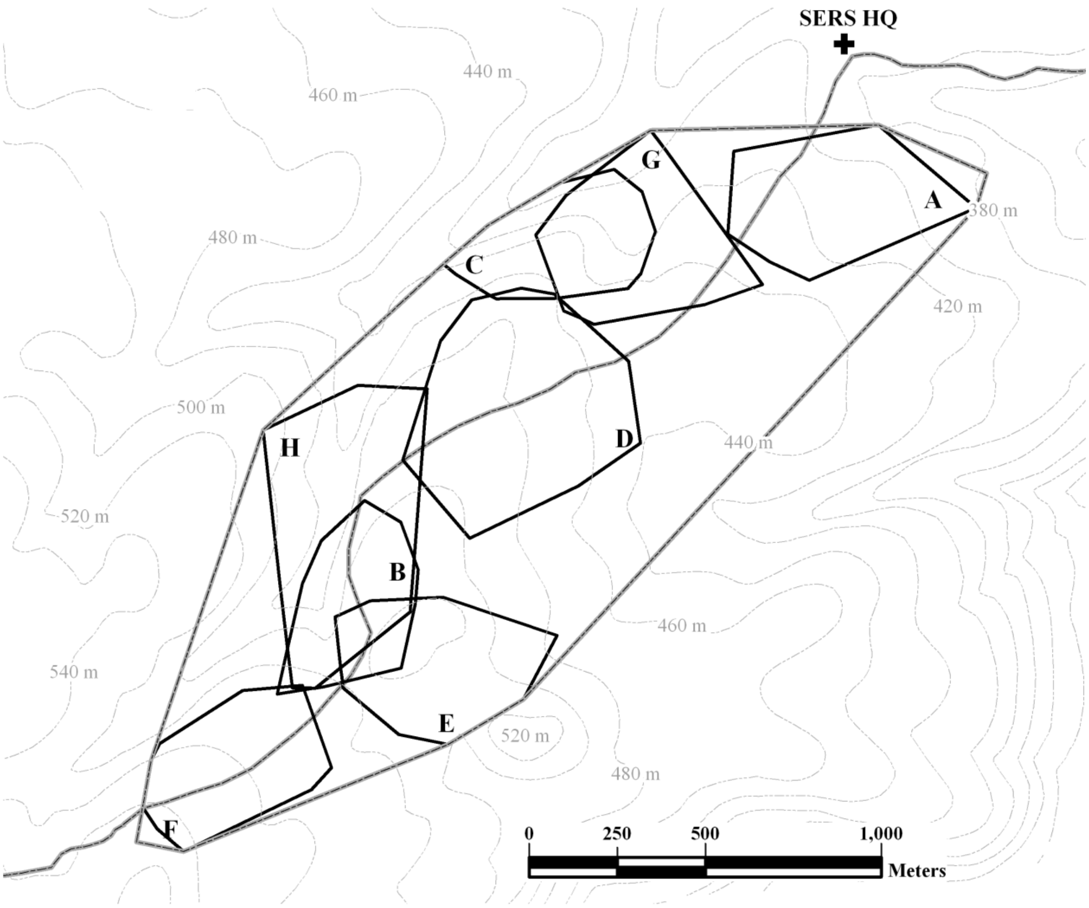

Figure 5.4 Calculated 95% minimum convex polygons (MCP) based on telemetry during breeding season are shown for the eight Simaese Fireback groups (solid black line polygons) and the total study area,100% MCP estimated using pooled radiolocations from all radio-tagged birds combined (broken gray line polygon).

Table 5.3 Means (± SE) of the number of radiolocations, percentage of radio-tracking success, 95% minimum convex polygon (MCP) home range size (ha) and group size of Siamese Firebacks during breeding season in Sakaerat Environmental Research Station.

Groups	Year	Number of radio-location	Percentage of radio-tracking success (%)	95% MCP home range (ha)	Group size (individuals)
A	2011	39	89.7	19.8	4
B	2011	44	86.5	14.6	5
C	2011	33	90.9	14.7	4
D	2011	35	85.7	31.9	2
E	2011	50	80	18.5	2
F	2011	44	85	16	4
G	2012	47	91.5	20.7	3
H	2012	51	78.4	29.8	3
	Average	42.9 ± 2.4	86.0 ± 1.7	20.8 ± 2.4	3.4 ± 0.4

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5.5 Discussion

The effectiveness of three ecological monitoring techniques was evaluated for estimating the abundance of tropical forest Galliformes. Using telemetry, distance sampling methods and analysis of camera trap data using the Royle-Nichols, binomial and beta-binomial mixture models, this study provides the first estimates of density for a population of Siamese Firebacks in dry evergreen forest (DEF), their natural habitat (Johnsgard, 1999). Moreover, all methods estimate higher Fireback density in DEF habitat than in old forest plantation habitat (OFP). Using the beta-binomial mixture model can be able to account for both imperfect and non-independent detection of elusive and gregarious animals. Although converting estimates of abundance derived from camera trapping data requires a definition of the effective sampling area, it can be able to calculate using direct estimates of home ranges of the radio-collared birds. Direct estimates of density using distance sampling methods were poorly estimated, most likely due to small sample size, lack of visibility in (preferred) dense vegetation and the bird's extreme sensitivity to observers. Given the ability to incorporate knowledge of the species behavior (elusiveness and gregariousness), the availability of estimated home ranges from tracked individuals in the study area, and the precision of abundance estimates, this study suggests that analyzing camera trapping data using beta binomial mixture models is an appropriate method for estimating density of Siamese Firebacks.

Comparing estimates of Siamese Fireback density based on two different data collection techniques, camera trapping and distance sampling, is non-trivial because in distance sampling, the effective area sampled (strip width), is estimated and therefore, density directly computed (Buckland et al., 2001). To estimate density using camera trap, density is entirely determined by the definition of the effective sampling area (Royle et al., 2013). However, the concurrent telemetry study of 8 individuals from within the study area allowed for the estimation of average Siamese Fireback home range sizes and therefore provided a reasonable measure of the effective sampling area, i.e. a circular buffer with a radius equal to the diameter of the average home range. Estimates of density based on camera trapping data (RN, binomial and beta-binomial mixture models) were all lower that derived from distance sampling, they always more precise (i.e. had narrower confidence intervals, Figure 5.5).

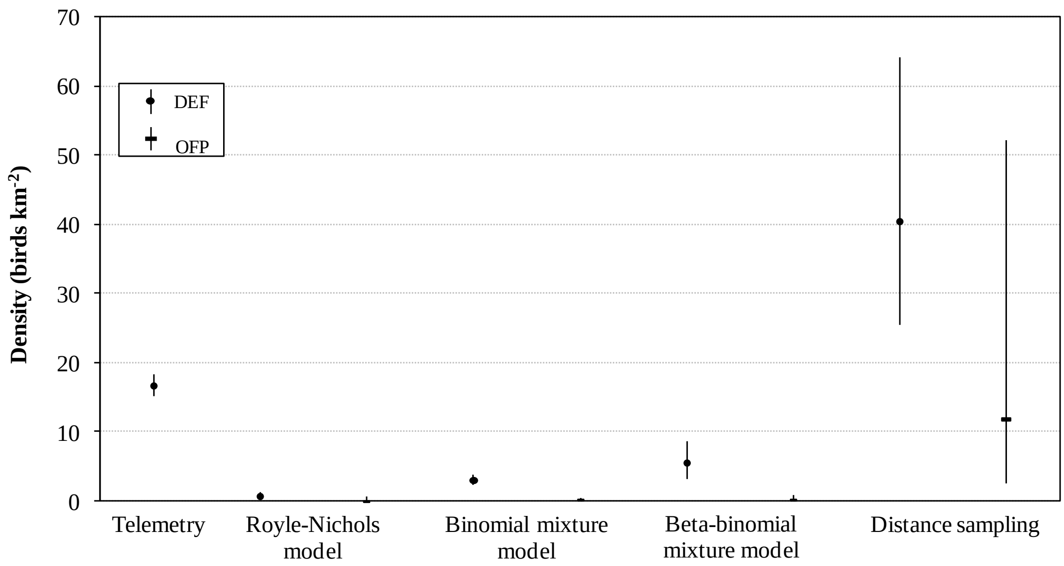

Figure 5.5 A comparison of density estimates (± 95% CI) of Siamese Firebacks in dry evergreen forest (DEF) and old forest plantation (OFP) based on telemetry data, camera trapping and distance sampling.

The performance of density estimation in using distance sampling depends largely on the behavior of the target species (Gale et al., 2009) as well as survey specific factors such as the time of survey, weather, bird activity and their susceptibility to being counted (Bibby et al., 2000). The imprecision in density estimates from distance sampling data relative to the analysis of camera trap data is therefore unsurprising given that Siamese Firebacks are cryptic, not particularly vocal, and prefer dense forest habitat, all contributing to small sample sizes. Such limitations have been discussed in other studies that suggest distance sampling will underestimate population size for some tropical forest birds when compared with densities derived from territory mapping of color banded birds (Gale et al., 2009), and in dune-dwelling lizards where the assumption of perfect detection of individuals on the transect line was violated (Smolinsky and Fitzgerald, 2010). An additional limitation when using distance sampling to estimate the density of secretive, group living and ground dwelling birds is that, although larger groups are easier to detect and group size may be accurately estimated close to the line, group sizes are poorly estimated at larger distances (Buckland et al., 2008) which is likely to have led to the underestimation of not only group size, but also the perpendicular distance from the observer to the center of a group (e.g. Brugiere and Fleury, 2000). This study is consistent with these suggestion and confirms the need to consider carefully both the study design and species behavior prior to carrying out distance sampling.

Using data collected from camera traps, the Royle Nichols model, the binomial mixture model and the beta-binomial mixture model were used to compare for estimating density (Figure 5.5), all of which used the same effective sampling area as the unit to convert abundance to density (effective area sampled = 39.50 km^2). Density estimates from each of the models are broadly comparable; first, the Royle-Nichols does not utilize data on group size as it is based on presence-absence data and thus produces lower estimates of abundance (and hence density) compared to the binomial N-mixture models. Secondly, in addition to the retention of information about group size when applying the N-mixture models (they are count based models), Siamese Firebacks are known to be gregarious and it is encouraging that the beta-binomial form of the N-mixture model to account for non-independent detections (Martin et al. 2011) provides a better fit to the data based on the derived Bayesian *p*-values. This study suggests that camera trapping data analyzed using beta-binomial mixture models is a suitable alternative to distance sampling, especially for monitoring cryptic, ground dwelling and gregarious species such as tropical Asian galliforms.

The use of camera traps and associated abundance models does however require careful consideration regarding violation of model assumptions and the need to define the effective sampling area when converting estimates of abundance to density. The use of the beta-binomial model here reflected directly the knowledge of the gregarious behavior of Simaese Firebacks (see above). However, an additional concern is that the presence of transient individuals can result in the violation of the assumption that animals should not be detected in more than one site (Sutherland et al., 2013) because these floaters can be detected at consecutive camera trap sites resulting in an overestimate of abundance. The mating strategy observed in this species; dominant males stay in close proximity to females while subordinate males move as isolated floaters (Savini and Sukumal, 2009). This may explain the observation of a relatively high frequency of solitary males and male groups ('floaters') in this study. This is consistent with a previous study of a sub-motane population of Siamese Firebacks in which high numbers of solitary males were observed during January and February (Savini and Sukumal, 2009). When transients are suspected in the population, the recommendation is to restrict the sampling window to one hour as I did (i.e. 0630 – 0730) to at least minimize the potential for double counting of large ranging individuals although there may still be bias induced by the presence of floaters. Ideally, observations of a larger number of unique individuals than the number telemetered could be used to estimate movement patterns and density directly using spatially explicit models as suggested by Borchers and Efford (2008) although when individuals lack unique identifying features/marks this can be difficult. In summary, an approach to estimating density using camera trapping data and the beta-binomial model offers a conservative approach for monitoring.

Estimates of Siamese Fireback density was higher in DEF than in OFP regardless of methodology used. The results suggest that Siamese Firebacks prefer habitats with dense understory vegetation, most likely because of higher food availability but also as a strategy to reduce predation risk. Many species, including Galliformes, tend to use areas with dense understory vegetation which provides good shelter when raising chicks as the mortality of young chicks is high in the first few weeks (Lima, 1993; Peh et al., 2005). Such patterns of habitat preference are shown by male Sichuan Hill Partridges (*Arborophila rufipectus*) in southern China (Liao et al., 2008) and Hume's Pheasant (*Syrmaticus humiae*) in northern Thailand (Iamsiri and Gale, 2008). Many studies, however, suggest that plantation forests can have a relatively high biodiversity value (Duran and Kattan, 2005). For example, coffee plantations can play an important role as refuges and breeding habitats for a variety of bird species in the Western Ghats, India (Shahabuddin, 1997); Peh et al. (2006) mentioned that rubber tree plantations can act as corridors that increase the connectivity between forest remnants for forest species persisting in agricultural landscapes; and Round et al. (2006) suggested that if the undergrowth beneath forest orchards was allowed to grow, the population of some understory birds might increase. Anecdotal observations of Siamese Firebacks in this study area during the past few years have indicated a potential range expansion from their natural habitat (DEF) to plantation habitat. However, despite the reforestation program having been started in 1982, estimates of density in OFP habitats was markedly lower than in DEF suggesting that OFP is sub-optimal habitat.

5.6 Conclusion

This study demonstrated the value of camera traps for surveying Galliformes. Specifically, data collected using cameras can be used to obtain relatively precise density estimates compared to distance sampling methods. However, care must be taken when using the camera trapping methods to estimate the density of a species in which individuals are not identifiable. It is particularly important to obtain information on home range size in order to determine the appropriate effective area sampled by the cameras. In order to avoid biases in estimates of abundance and density, camera trapping studies need to be designed and applied with a practical knowledge of species' biology and behavior in mind. Camera traps have the potential to obtain improved accuracy in species identification, cause little environmental disturbance, can be used to monitor nocturnal and diurnal species and offer the possibility of studying activity patterns, habitat use and importantly, they require very little operational training is required.

5.7 References

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CHAPTHER VI

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study focused on a resident Siamese Fireback population in Sakaerat Environmental Research Station, Nakhon Ratchasima, and highlights the general lack of detailed information on ecology and biology of Siamese Fireback inhabiting its original lowland habitat. These results could be reference information for other places where the management for this species is needed, for example in Vietnam and Laos where the loss of suitable habitat and hunting pressure are high.

6.1.1 Home Range Size Patterns of Siamese Fireback

Siamese Fireback females showed a variation in home range size during reproductive periods of the year cycle and between breeding and non-breeding seasons. Home range size of two observed females significantly declined when they were alone with chicks and then expanded again when the females and their chicks returned to their group. Although there was no significant difference in size between seasons, home ranges of Siamese Fireback during breeding season were smaller than those during non-breeding season.

6.1.2 Patterns of Habitat Use of Siamese Fireback

Siamese Fireback showed a distinct preference for areas that were considered to be the secondary forest patches during the different periods of the female year cycle and between breeding and non-breeding seasons. Habitat use of female Siamese Firebacks showed a similar pattern among periods that significantly used areas with less understory coverage (1 – 3 m in height) but higher density of understory stems at height >3 – 5 m, and areas with small basal areas of large trees. Specifically, females selected areas with dense ground cover and higher density of understory sapling when they were alone with their young chicks. Siamese Firebacks significantly used the area with less understory coverage at height >1 – 3 m, higher densities of understory stems at height >3 – 5 m and climber stems, and closer distance to water between breeding and non-breeding seasons.

6.1.3 Roost-site Selection of Siamese Fireback

Siamese Firebacks forage on the ground with their group members during the day and fly up to elevated trees during the night, at varying heights from mid-story to canopy (average perch height 5.6 ± 0.2 m; range 3.3 – 9.0 m). In most cases, Siamese Fireback roosted on the branches of trees while a few on climbers. Although no individuals roosted on the same tree, they roosted in the same vicinity. Siamese Fireback significantly preferred the secondary forest patches, the areas with small basal areas of large trees for roosting. In addition, Siamese Firebacks selected areas on steeper slopes with less canopy cover for roosting, presumably to facilitate escape-flushing in response to any dangerous situations.

6.1.4 Reproductive Ecology of Siamese Fireback

Siamese Fireback started laying eggs from April to early August. The average clutch size was 6.4 ± 0.3 eggs (maximum = 8, minimum = 4). Incubation lasted 23 – 24 days. The daily nest survival was estimated at 0.90 ± 0.02 (95% CI = 0.85 – 0.94), giving an estimated overall nest success of 0.08 ± 0.04. In this study, predation was considered to be the main cause of nest failure.

6.1.5 Nest-site Selection of Siamese Fireback

Siamese Fireback appeared to prefer to nest in the buttresses of large trees, which presumably have the potential to serve shelters from potential predators. Moreover, Siamese Fireback significantly preferred to place nests in areas associated with dense vegetation coverage below 50 cm, on steeper slopes, near large basal areas of trees DBH >10 m and with low predation pressure. Siamese Fireback significantly preferred to place nests in an area associated with dense vegetation coverage below 50 cm, on steeper slopes, near large basal areas of trees DBH >10 m and with low predation pressure. This can be interpreted as a strategy to make the nest less conspicuous to predators and facilitate flying out of the nest when predators attack.

6.1.6 Density Estimates of Siamese Fireback

Estimates of density based on camera trapping data obtained relatively precise density estimates with narrower confidence intervals than those derived from distance sampling. Based on the beta-binomial mixture model, estimated densities were 5.6 birds km^{-2} (95% CI: 3.12 – 8.68) in DEF and 0.2 birds km^{-2} (95% CI: 0.01 – 0.77) in OFP. Whereas, estimates of densities based on distance sampling were 40.3 birds km^{-2} (95% CI: 25.4 – 64.1) in DEF and 11.7 birds km^{-2} (95% CI: 2.6 – 52.2) in OFP. The imprecision in density estimates from distance sampling data is unsurprising, and give an overestimation density, because Siamese Firebacks are cryptic, not particularly vocal, and prefer dense forest habitat, all contributing to small sample sizes. Estimated densities from data collected from camera traps provided an underestimation in comparison to telemetry-based density estimate (16.7 birds km^{-2} in DEF). An approach to estimating density using camera trapping data and the beta-binomial mixture model offers a conservative approach for monitoring.

6.1.7 Habitat Preference of Siamese Fireback

Estimates of Siamese Fireback density were higher in DEF than those in OFP, regardless of methods used. The results suggest that Siamese Firebacks prefer habitats with dense understory vegetation, most likely because of higher food availability but also as a strategy to reduce predation risk. Although observations of Siamese Firebacks in this study area during the past few years have indicated a potential range expansion from their natural habitat (DEF) to plantation habitat, the estimates of density in OFP habitats was markedly lower than in DEF, suggesting that OFP is sub-optimal habitat.

6.2 Recommendation

This study provided information on ecology and biology of Siamese Fireback in its original lowland habitat which is useful for understanding of the species and for future study of other *Lophura* species. This study suggests that:

- Study on food abundance could be conducted to test whether the seasonal variations in home range size and patterns of habitat use are related to food availability.

- Because of low nest success, further studies need to investigate the main causes of nest failure and the main nest predators of Siamese Fireback, in order to add understanding of the nest behavior and reproductive strategies of the species, by video recording.

- The study confirms the need to consider carefully both the study design and species behavior prior to carrying out distance sampling.

- Although this study indicated that the camera trapping method showed potential use for monitoring cryptic ground birds, the use of this technique in associated abundance models requires careful consideration regarding violation of model assumptions and the need to define the effective sampling area when converting estimates of abundance to density.

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APPENDICES

APPENDIX A

SIAMESE FIREBACKS CAUGHT

Table 1 Information of all Siamese Firebacks caught by mist nets and leg snare traps during the three trapping periods: January to April 2010 (n = 3), November 2010 to April 2011 (n = 14), and November to December 2011(n = 3).

No.	Captured day	Location		Time	Sex	Alumenium no.	Ring Colour		Weight (g)	Radio-ID	Method	Last day Active	Status	Group
		X	Y				Left leg	Right leg						
1	27-Jan-10	814903	1604691	18.00	M	11A01751	L. Blue/Alu.	Yellow/Green	-	150050	Mist net	4-Aug-10	Radio-failed	B
2	29-Jan-10	815786	1605179	6.45	F	11A01752	D. Green/Alu.	White/White	-	150090	Mist net	7-Feb-10	Radio-failed	
3	19-Apr-10	816092	1605600	18.05	F	11A01753	White/Alu.	L. Blue/L. Blue	1,260	150071	Mist net	13-Jul-12	Predated	A
4	18-Nov-10	815786	1605179	17.30	M	11A01754	Yellow/Alu.	Yellow/Yellow	1,580	150871	Mist net	26-Dec-11	Radio-failed	
5	16-Dec-10	814086	1603642	16.50	F	-	-	-	1,080	150810	Leg-snare trap	15-Dec-12	Activated	F
6	16-Dec-10	814086	1603642	16.50	F	-	-	-	880	150031	Leg-snare trap	22-Dec-10	Radio-failed	
7	20-Dec-10	814903	1604691	16.10	M	-	-	-	1,580	-	Mist net	-	-	
8	23-Dec-10	814903	1604691	16.50	M	-	-	-	1,480	150327	Mist net	15-Apr-12	Predated	
9	22-Jan-11	814903	1604691	15.30	F	-	-	-	1,110	150191	Leg-snare trap	15-Dec-12	Activated	E
10	3-Feb-11	815786	1605179	17.50	F	11A01755	-/Alu.	Ping/Ping	1,110	150771	Mist net	25-Feb-11	Radio-failed	
11	4-Feb-11	814903	1604691	17.30	F	11A01756	-/Alu.	Red/White	1,110	150162	Leg-snare trap	15-Dec-12	Activated	B
12	5-Feb-11	814903	1604691	7.15	F	11A01757	-/Alu.	Yellow/L. Blue	1,105	150370	Leg-snare trap	7-Mar-11	Predated	
13	12-Feb-11	814903	1604691	16.50	F	11A01758	-/Alu.	D. Blue/White	1,160	150709	Leg-snare trap	3-Apr-11	Predated	
14	20-Feb-11	815786	1605179	15.20	F	11A01759	-/Alu.	D. Green/Yellow	1,220	150781	Leg-snare trap	29-Dec-11	Radio-failed	C
15	26-Feb-11	815786	1605179	17.20	M	11A01771	-/Alu.	-	1,400	-	Leg-snare trap	-	-	
16	8-Apr-11	815786	1605179	16.15	F	11A01772	-/Alu.	-	1,080	150050*	Leg-snare trap	1-May-11	Predated	
17	12-Apr-11	814903	1604691	17.00	F	11A01773	-/Alu.	-	1,200	150090*	Leg-snare trap	20-Jul-12	Radio-failed	D
18	26-Nov-11	815786	1605179	16.3	F	11A01774	Yellow/Alu.	Red/D. Blue	-	150370	Leg-snare trap	20-Dec-11	Predated	
19	26-Nov-11	815786	1605179	17.10	F	11A01775	Green/Alu.	White/D. Blue	-	150771*	Leg-snare trap	1-May-12	Predated	G
20	29-Nov-11	814903	1604691	16.15	F	11A01776	D. Blue/Alu.	D. Blue/D. Blue	-	150031*	Leg-snare trap	15-Oct-12	Predated	H

D. = dark, L. = light, Alu. = alumenium ring, * reused radio-transmitters.

APPENDIX B

ROOSTING AND NESTING SITES

Table 2 A total of 52 roosting sites used by five radio-tagged Siamese Firebacks: one male and four females.

Bird ID	Sex	No	Date	Time	Location X	Location Y	Roosting type	Tree DBH (cm)	Tree height (m)	Perch height (m)	Dist. from Trunk (m)	% cover at roosting point under	% cover at roosting point above
150050	M	1	25-Mar-10	6.15	814711	1604334	Tree	4.46	5.5	5	0.9	32.5	80.0
		2	27-Mar-10	6.14	814741	1604343	Tree	7.80	7.5	6	1.5	15.0	70.0
		3	28-Mar-10	6.19	814824	1604687	Tree	14.33	9	6	2.6	30.0	80.0
		4	31-Mar-10	6.11	814716	1604336	Climber	-	-	9	2.9	15.0	80.0
		5	6-Apr-10	6.07	814827	1604690	Tree	7.32	10	4	2.6	20.0	82.5
		6	7-Apr-10	6.09	814971	1604800	Tree	15.61	8	5.5	5.1	40.0	82.5
		7	9-Apr-10	6.08	814871	1604493	Tree	7.01	7	4.2	4.2	15.0	85.0
		8	14-Apr-10	6.02	814912	1604630	Tree	6.05	8	7	3.5	35.0	65.0
		9	15-Apr-10	6.07	814888	1604713	Tree	16.88	8	4	2.7	15.0	82.5
		10	17-Apr-10	6.05	814912	1604630	Tree	5.73	10	8	4.0	15.0	85.0
		11	19-Apr-10	5.59	814840	1604693	Tree	8.92	8	7	3.5	20.0	65.0
		12	14-May-10	5.52	814869	1604223	Tree	8.60	10	8.5	1.5	20.0	85.0
		13	15-May-10	6.18	814830	1604461	Tree	7.96	7.5	4.7	2.6	17.5	95.0
		14	16-May-10	5.57	814764	1604219	Tree	18.47	15	6	2.7	20.0	92.5
		15	19-May-10	5.58	814900	1604580	Tree	14.01	10	8.5	4.7	10.0	90.0
		16	25-May-10	5.56	814771	1604181	Tree	13.69	12	6	0.8	12.5	75.0
		17	26-May-10	5.59	814767	1604157	Tree	3.50	6	3.7	1.1	10.0	90.0
		18	27-May-10	6.01	814758	1604227	Tree	7.01	7	4.5	1.5	15.0	85.0
		19	1-Jun-10	6.03	814811	1604802	Tree	7.64	9	6.3	1.4	20.0	95.0
		20	2-Jun-10	5.55	815034	1604647	Tree	6.69	8	5	1.6	20.0	70.0
		21	3-Jun-10	6.05	814722	1604586	Tree	10.83	6.5	4.5	1.5	25.0	80.0
150071	F	1	30-Apr-10	6.14	815752	1605461	Tree	14.97	10	6.2	4.0	25.0	75.0
		2	13-May-10	6.06	815791	1605334	Tree	15.76	12	7.5	2.0	10.0	50.0
		3	15-May-10	5.49	815997	1605293	Tree	15.92	10	4.5	1.7	7.5	65.0
		4	8-Jul-10	6.05	815742	1605266	Tree	7.64	5	4.5	2.6	30.0	65.0
		5	9-Jul-10	6.05	815997	1605293	Tree	16.24	12	5	1.8	15.0	55.5
		6	16-Jul-10	6.15	815788	1605341	Tree	8.92	10	4.2	3.6	35.0	50.0
		7	19-Jul-10	6.12	815934	1605228	Tree	7.96	8	6	4.5	10.0	77.5
		8	6-Aug-10	6.11	816086	1605337	Tree	4.14	5	4	2.0	35.0	75.0
		9	22-Aug-10	6.07	815920	1605334	Tree	23.57	9.5	8	5.8	30.0	80.0
		10	23-Aug-10	6.15	815780	1605436	Tree	12.42	7.5	7	2.7	35.0	75.0
		11	24-Aug-10	6.11	815867	1605198	Tree	15.29	10	3.8	3.4	25.0	75.0
		12	25-Aug-10	6.07	815700	1605394	Tree	7.32	6	4.5	2.1	35.0	72.5
		13	21-Sep-10	6.05	816215	1605592	Tree	8.28	10	6.2	4.3	35.0	85.0

Table 2 (Continued).

Bird ID	Sex	No	Date	Time	Location		Roosting type	Tree DBH (cm)	Tree height (m)	Perch height (m)	Dist. from Trunk (m)	% cover at roosting point	
					X	Y						under	above
150162	F	1	28-Aug-12	6.00	814714	1604598	Tree	6.05	7.5	6.3	2.4	50.0	92.5
		2	7-Sep-12	6.12	814920	1604633	Tree	9.39	9	8	1.5	15.0	80.0
		3	19-Oct-12	12.30	814968	1604589	Tree	3.82	5.5	5.25	1.6	30.0	85.0
		4	21-Oct-12	6.10	814808	1604624	Climber	-	-	6.5	5.3	15.0	65.0
		5	2-Nov-12	6.10	814842	1604597	Tree	4.78	8	6.5	1.1	20.0	75.0
		6	3-Nov-12	6.20	814799	1604508	Tree	13.38	8	6	2.7	30.0	65.0
150191	F	1	1-Sep-12	6.07	815113	1604392	Tree	3.50	5	4.4	2.7	45.0	85.0
		2	25-Oct-12	6.15	815036	1604237	Climber	-	-	8.5	2.4	10.0	75.0
		3	26-Oct-12	6.20	814942	1604341	Tree	7.01	8	3.5	3.3	15.0	90.0
		4	4-Nov-12	6.20	815063	1604289	Tree	3.98	5.5	4	1.1	35.0	95.0
		5	7-Nov-12	6.22	815011	1604316	Tree	6.37	10	8	2.6	20.0	82.5
		6	9-Nov-12	6.15	814894	1604333	Tree	6.37	10	5.7	2.8	10.0	75.0
150810	F	1	25-Aug-12	5.55	814451	1603916	Tree	7.96	8	5.7	1.5	15.0	60.0
		2	15-Nov-12	6.15	813944	1603623	Tree	7.01	7.5	5	2.7	60.0	75.0
		3	16-Nov-12	6.15	814100	1603581	Tree	5.41	4	3.5	5.0	55.0	75.0
		4	17-Nov-12	6.12	814175	1603585	Tree	4.46	6	4.5	4.6	10.0	80.0
		5	30-Nov-12	6.11	813915	1603675	Tree	3.82	5.5	3.7	1.5	10.0	70.0
		6	2-Dec-12	6.15	813999	1603585	Tree	2.87	4.2	3.3	2.1	45.0	80.0

Table 3 A total of 21 nesting sites of Siamese Firebacks found during three breeding seasons, 2010 – 2012.

Year	NestID	Nest finding	Day found	Location		Altitude (m)	Clutch size (eggs)	Nest fate	Nest background	Nesting tree	
				x	y					Species	DBH (cm)
2010	N1	By chance	29-Apr-10	815246	1605360	361	6	Failed	in buttresses	*Hopea ferrea*	280
	N2	Bird ID-150071	5-May-10	816365	1605759	439	7^{st}	Failed	in buttresses	Unknown	134
	N3	By chance (after hatched)	1-Jun-10	814170	1603695	560	-	-	in buttresses	*Irvingia malayana*	307
2011	N4	Bird ID-150709	1-Apr-11	814754	1604889	454	8^{st}	Failed	between the rocks	-	-
	N5	By chance	3-Apr-11	814775	1604847	451	8	Failed	in buttresses	Unknown	63.5
	N6	Bird ID-150781	6-Apr-11	815565	1605318	420	6^{st}	Success	on the ground with dense bushes	-	-
	N7	By chance (after failed)	7-Apr-11	814925	1603652	485	-	-	in buttresses	Unknown	149
	N8	Bird ID-150071	20-Apr-11	816564	1605507	373	6^{st}	Failed	on the ground with dense grasses	-	-
	N9	Bird ID-150090	30-Apr-11	815508	1604859	457	5^{st}	Failed	in buttresses	*Hopea ferrea*	147.5
	N10	Bird ID-150810	3-May-11	814606	1603780	520	8^{st}	Failed	in buttresses	Unknown	324
	N11	Bird ID-150162	10-May-11	814644	1604194	511	6^{st}	Failed	in buttresses	Unknown	63.5
	N12	Bird ID-150071	11-Jun-11	816447	1605020	426	6^{nd}	Success	in buttresses	*Irvingia malayana*	259
	N13	Bird ID-150810	23-Jun-11	814824	1603644	528	7^{nd}	Failed	on the ground with dense bushes	-	-
	N14	Bird ID-150050	29-Jul-11	815739	1605132	440	6^{st}	Failed	on the ground with dense bushes	-	-
2012	N15	Bird ID-150810	5-Apr-12	814576	1604165	480	8^{st}	Failed	in buttresses	Unknown	99
	N16	Bird ID-150162	30-Apr-12	814509	1604273	481	6^{st}	Failed	in buttresses	Unknown	172
	N17	Bird ID-150071	1-May-12	815816	1605603	416	8^{st}	Failed	In a clump of Rattan sp.	-	-
	N18	Bird ID-150771	1-May-12	815448	1605085	442	5^{st}	Failed	in buttresses	*Parkia sumatrana*	170
	N19	Bird ID-150071	29-May-12	816246	1605101	427	5^{nd}	Failed	in buttresses	*Irvingia malayana*	122
	N20	Bird ID-150071	13-Jul-12	816774	1605536	366	4^{rd}	Failed	in buttresses	*Ficus* sp.	359
	N21	By chance (after hatched)	27-Aug-11	814781	1604118	531	-	-	in buttresses	*Hopea ferrea*	132

st = the first clutch, nd = the second clutch, and rd = the third clutch.

Table 4 Eighteen nests monitoring using for nest survival model.

No	ID	DateFound[a]	LastActive[b]	LastChecked[c]	Fate[d]
1	N1	29	34	35	1
2	N2	35	40	42	1
3	N4	1	5	7	1
4	N5	3	12	15	1
5	N6	6	29	29	0
6	N8	20	34	36	1
7	N9	30	34	36	1
8	N10	33	40	42	1
9	N11	40	44	46	1
10	N12	72	93	93	0
11	N13	84	90	91	1
12	N14	120	122	123	1
13	N15	5	15	17	1
14	N16	30	34	36	1
15	N17	31	34	35	1
16	N18	31	34	35	1
17	N19	59	66	68	1
18	N20	104	114	116	1

Note: Four pieces of information are required for each nest: (a) the day of the nesting period on which the nest was found; (b) the last day the nest was checked when alive; (c) the last day the nest was checked; and (d) the fate of the nest (0 = successful, 1 = depredated). The day presented above refer to standardized days within the study's nesting period.

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APPENDIX C

REGRESSION MODELS

Table 5 Candidate set of 16 regression models were fitted to explain habitat used by female Siamese Firebacks during different reproductive periods.

	Variables	*K*	AICc	ΔAICc	w_i	Cum.w_i	LL
1	Stem3 + Cover2 + BA	12	535.83	0.00	0.98	0.98	-255.23
2	Stem3 + Cover2 + Stem4	12	543.75	7.92	0.02	0.99	-259.19
3	Stem3 + Cover2	9	546.30	10.47	0.01	1.00	-263.76
4	Stem3 + Cover1	9	570.95	35.12	0.00	1.00	-276.09
5	Stem3	6	603.12	67.29	0.00	1.00	-295.38
6	Cover1	6	619.68	83.84	0.00	1.00	-303.66
7	Cover2	6	627.10	91.27	0.00	1.00	-307.37
8	BA	6	640.96	105.13	0.00	1.00	-314.30
9	Cover0	6	660.77	124.94	0.00	1.00	-324.21
10	Water	6	661.75	125.91	0.00	1.00	-324.69
11	Stem2	6	664.04	128.21	0.00	1.00	-325.84
12	Slope	6	671.51	135.68	0.00	1.00	-329.58
13	Constant	3	671.52	135.69	0.00	1.00	-332.71
14	Cover3	6	673.41	137.58	0.00	1.00	-330.52
15	Climber	6	673.67	137.83	0.00	1.00	-330.65
16	Stem4	6	674.17	138.34	0.00	1.00	-330.91

Note: LL is log-likelihood: K is number of parameters in the model: △AICc is difference in AICc (model score) value, model with △AICc value 0 has most support, values between 0 and 2 have substantial support, values greater than 2 have less support; w_i = Akaike model weights. Habitat variables: Slope is degree of slope area, Water is distance to nearest water, Cover 0 – 4 are tree coverage at height <0.5, >0.5 – 1, >1 – 3, >3 – 5, >5 m respectively, Stem 1 – 4 are tree density at height >0.5 – 1, >1 – 3, >3 – 5, >5 m respectively, Climber is number of climber, BA is basal area of trees with DBH >10 cm.

Table 6 Candidate set of 18 regression models were fitted to explain habitat use of Siamese Fireback between breeding and non-breeding seasons.

	Variables	K	AICc	ΔAICc	w_i	Cum.w_i	LL
1	Stem3 + Cover2 + Climber + Water	10	670.45	0.00	0.97	0.97	-324.91
2	Stem3 + Cover2 + Climber + BA	10	678.46	8.01	0.02	0.99	-328.92
3	Stem3 + Cover2 + Climber	8	679.06	8.61	0.01	1.00	-331.32
4	Stem3 + Cover2 + BA	8	688.99	18.54	0.00	1.00	-336.29
5	Stem3 + Cover2	6	695.75	25.30	0.00	1.00	-341.76
6	Stem3 + Cover1 + Water	8	699.89	29.44	0.00	1.00	-341.74
7	Stem3	4	713.79	43.34	0.00	1.00	-352.84
8	Cover1	4	722.63	52.18	0.00	1.00	-357.26
9	Cover2	4	730.37	59.92	0.00	1.00	-361.13
10	Climber	4	737.99	67.54	0.00	1.00	-364.94
11	BA	4	739.11	68.65	0.00	1.00	-365.50
12	Water	4	739.74	69.29	0.00	1.00	-365.81
13	Stem1	4	742.37	71.92	0.00	1.00	-367.13
14	Constant	2	744.33	73.87	0.00	1.00	-370.15
15	Slope	4	744.40	73.94	0.00	1.00	-368.14
16	Stem2	4	744.56	74.11	0.00	1.00	-368.22
17	Cover0	4	744.64	74.19	0.00	1.00	-368.26
18	Cover4	4	745.82	75.37	0.00	1.00	-368.85

Note: LL is log-likelihood: K is number of parameters in the model: △AICc is difference in AICc (model score) value, model with △AICc value 0 has most support, values between 0 and 2 have substantial support, values greater than 2 have less support; w_i = Akaike model weights. Habitat variables: Slope is degree of slope area, Water is distance to nearest water, Cover 0 – 4 are tree coverage at height <0.5, >0.5 – 1, >1 – 3, >3 – 5, >5 m respectively, Stem 1 – 4 are tree density at height >0.5 – 1, >1 – 3, >3 – 5, >5 m respectively, Climber is number of climber, BA is basal area of trees with DBH >10 cm.

Table 7 Candidate set of 16 regression models were fitted to explain roost-site selection of Siamese Fireback.

	Vaiables	*K*	AICc	ΔAICc	w_i	Cum.w_i	LL
1	Slope + Cover4 + BA	4	113.35	0.00	0.62	0.62	-52.49
2	Slope + Cover4	3	114.31	0.96	0.38	1.00	-54.04
3	Cover4	2	127.31	13.96	0.00	1.00	-61.60
4	Slope	2	140.11	26.76	0.00	1.00	-68.00
5	BA	2	146.75	33.40	0.00	1.00	-71.32
6	Cover3	2	153.73	40.38	0.00	1.00	-74.81
7	Water	2	154.08	40.73	0.00	1.00	-74.99
8	Climber	2	156.00	42.65	0.00	1.00	-75.94
9	Cover1	2	156.21	42.86	0.00	1.00	-76.05
10	Constant	1	156.73	43.38	0.00	1.00	-77.35
11	Stem3	2	157.04	43.70	0.00	1.00	-76.47
12	Stem1	2	157.33	43.99	0.00	1.00	-76.61
13	Stem4	2	158.57	45.23	0.00	1.00	-77.23
14	Stem2	2	158.77	45.42	0.00	1.00	-77.33
15	Cover2	2	158.78	45.43	0.00	1.00	-77.34
16	Cover0	2	158.80	45.46	0.00	1.00	-77.35

Note: LL is log-likelihood: K is number of parameters in the model: △AICc is difference in AICc (model score) value, model with △AICc value 0 has most support, values between 0 and 2 have substantial support, values greater than 2 have less support; w_i = Akaike model weights. Habitat variables: Slope is degree of slope area, Water is distance to nearest water, Cover 0 – 4 are tree coverage at height <0.5, >0.5 – 1, >1 – 3, >3 – 5, >5 m respectively, Stem 1 – 4 are tree density at height >0.5 – 1, >1 – 3, >3 – 5, >5 m respectively, Climber is number of climber, BA is basal area of trees with DBH >10 cm and Prd is predation pressure.

Table 8 Candidate set of 14 regression models were fitted to explain nest-site selection of Siamese Fireback.

	Vaiables	K	AICc	ΔAICc	w_i	Cum.w_i	LL
1	Cover0 + BA + Slope + Prd	5	43.45	0.00	0.77	0.77	-16.33
2	Cover0 + Basal + Slope	4	46.26	2.81	0.19	0.95	-18.87
3	Cover0 + Slope	3	50.25	6.80	0.03	0.98	-21.97
4	Cover0 + Basal + Prd	4	52.53	9.08	0.01	0.99	-22.00
5	Cover0 + Basal	3	53.22	9.77	0.01	0.99	-23.45
6	Cover0 + Prd	3	54.15	10.70	0.00	1.00	-23.92
7	Cover0	2	56.38	12.93	0.00	1.00	-26.11
8	Cover0 + Cover4	3	57.83	14.38	0.00	1.00	-25.76
9	Cover0 + Stem2	3	58.51	15.06	0.00	1.00	-26.10
10	Cover0 + Cover2 + Cover4	4	59.79	16.34	0.00	1.00	-25.63
11	Cover1	2	68.74	25.29	0.00	1.00	-32.29
12	Cover1 + Cover4	3	70.10	26.65	0.00	1.00	-31.89
13	Cover1 + Cover3	3	70.76	27.31	0.00	1.00	-32.22
14	Prd	2	85.99	42.54	0.00	1.00	-40.92

Note: LL is log-likelihood: K is number of parameters in the model: △AICc is difference in AICc (model score) value, model with △AICc value 0 has most support, values between 0 and 2 have substantial support, values greater than 2 have less support; w_i = Akaike model weights. Habitat variables: Slope is degree of slope area, Water is distance to nearest water, Cover 0 – 4 are tree coverage at height <0.5, >0.5 – 1, >1 – 3, >3 – 5, >5 m respectively, Stem 1 – 4 are tree density at height >0.5 – 1, >1 – 3, >3 – 5, >5 m respectively, Climber is number of climber, BA is basal area of trees with DBH >10 cm and Prd is predation pressure.

APPENDIX D

DISTRIBUTION OF SIAMESE FIREBACKS DETECTED BY CAMERA TRAPS

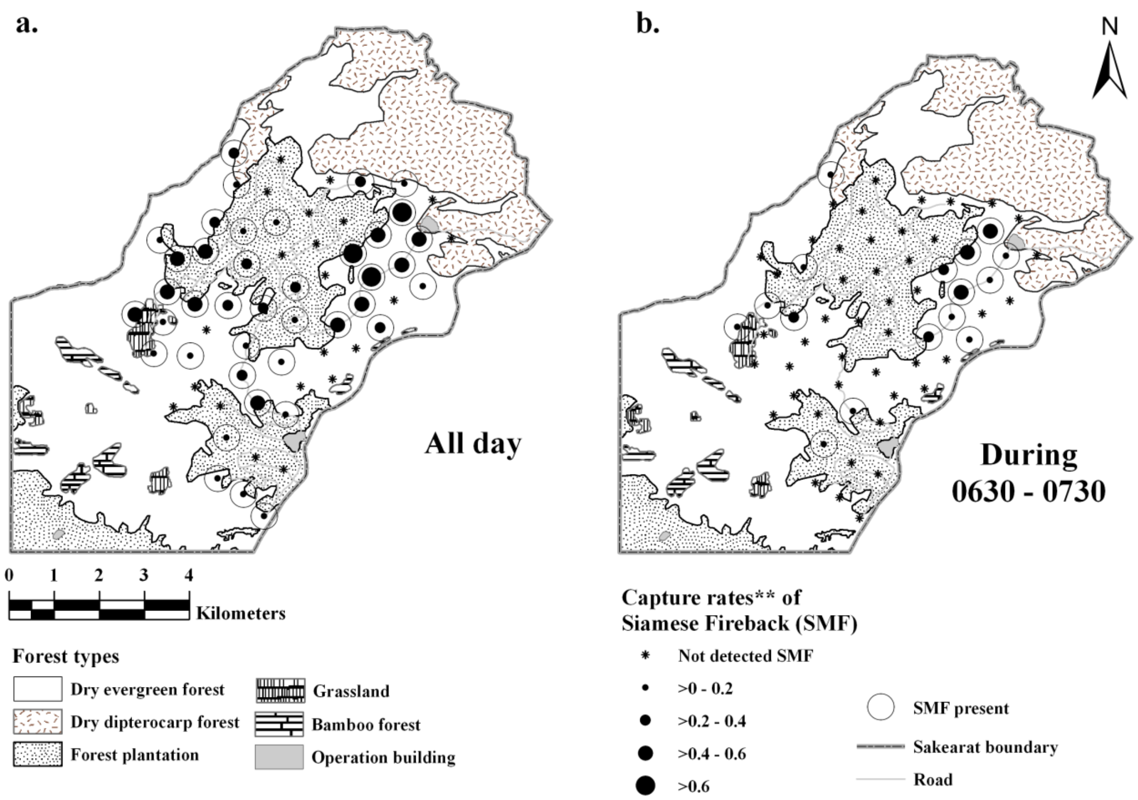

Figure 1 Distribution of Siamese Fireback detected by camera traps: (a) based on a total number of Siamese Fireback detected all day, and (b) based on the number of Siamese Fireback detected in a one hour window between 0630 and 0730.

(**Capture rates = number of days found Siamese Fireback/total trap-days)

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