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TITLE: Ecology of Rehabilitated Hog Deer (*Axis porcinus* Zimmermann,1780) in Phu Khieo Wildlife Sanctuary, Chaiyaphum Province

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THESIS

ECOLOGY OF REHABILITATED HOG DEER
(*Axis porcinus* Zimmermann, 1780)
IN PHU KHIEO WILDLIFE SANCTUARY,
CHAIYAPHUM PROVINCE

KHANCHAI PRASANAI

A Thesis Submitted in Partial Fulfillment of
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Khanchai Prasanai 2012: Ecology of Rehabilitated Hog Deer (*Axis porcinus* Zimmermann, 1780) in Phu Khieo Wildlife Sanctuary, Chaiyaphum Province. Doctor of Philosophy (Forestry), Major Field: Forestry, Faculty of Forestry. Thesis Advisor: Assistant Professor Ronglarp Sukmasuang, Ph.D. 246 pages.

This study focused on the field study of existing hog deer introduced into Thung Ka Mung (TKM) of Phu Khieo Wildlife Sanctuary, Chaiyaphum Province during 1983 to 1992 and 8 newly released hog deer (3 stags and 5 hinds), which were released in November 2007 to rehabilitate the existing population. The purposes of this study were to 1) study population characteristics of the released hog deer, 2) investigate the newly released hog deer's adaptabilities and determine forage species, carrying capacity, inter-specific relationship and probability of species geographic distribution, genetic diversity and 3) analyze the population viability and evaluate the appropriate initial population size.

The result showed that the population density of hog deer in TKM was 2.03-2.04 individuals/ha (SD = 1.25). The total population determined by total counting in October 2009 was 127 individuals. The average group size was 9.57 individuals. The hog deer preferred forming a group (91.5%) than being solitary (8.5%). Breeding season of hog deer is between May and October with the highest peak occurred during July and September. The potential predators observed by camera trap and direct sighting were Asian wild dogs, Burmese pythons, Asiatic jackals, leopard cats and clouded leopards. The mortality rate of the existing hog deer in TKM during the study period was 18.1%.

The newly released hog deer showed substantial improvement in their physical condition six months after being released. Three female hog deer gave birth to four fawns, but only two fawns (a female and a male) survived. Most observed behaviors of the existing population comprised feeding, lying, walking, and running, and ruminating, which occupied almost 98% of the observed time, were similar between males and females in both wet and dry seasons. The newly released male, which is the only male survived, showed a better adaptability to the new habitat than the females. The distribution range of the first year was larger than the second year for every newly released hog deer. Hog deer foraged at least 56 forage species, most of which were grasses. Phek in Thai name, *Vietnamosasa pusilla* alone comprised 21.07% of the hog deer's diet. The carrying capacities of TKM grassland was 272 individuals estimated by forage availability in dry season. The habitat sharing was found among 4 ungulate species. They were composed of sambar deer, barking deer, wild boar, and elephant. The species geographic probability distribution study indicated that the saltlick has high effect for ungulates in TKM.

Genetic analysis from fecal pellet group samples from both groups showed 4 different haplotypes. The population viability analysis has indicated the sustainability of the population after more than 50 years from the initial year. The population does not exhibit sensitivity to an increase or decrease in carrying capacity. The probability of survival of the population is sensitive to mortality rate and initial population size and sex ratio. The probability of survival of more than 90% can be achieved from the initial population of 10 (5:5), 9 (3:6), and 8 (2:6) for male:female ratios of 1:1, 1:2, and 1:3 respectively.

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Khanchai Prasanai

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ECOLOGY OF REHABILITATED HOG DEER (*Axis porcinus* Zimmermann, 1780) IN PHU KHIEO WILDLIFE SANCTUARY, CHAIYAPHUM PROVINCE

INTRODUCTION

Wildlife population restoration is one of strategies that can be used to restore the threatened species' population size. Before 1983, hog deer was one of the species that disappeared from the records of sighting in the wild in Thailand. However, it is suspected that the hog deer is not yet extinct from the wild in Thailand. There should be at least some natural populations in some protected areas such as Huai Kha Khaeng Wildlife Sanctuary as reported by Lekagul and McNeely (1988) and Faculty of Forestry (1989a). Nevertheless, if not yet extinct, hog deer is an endangered species (Nabhitabhata and Chan-ard, 2005; IUCN, 2012). It was categorized as the Thai National reserved species by the Wild Animal Reservation and Protection Act B.E. 2503 (A.D. 1960). It has been designated as a protected species according to the Wild Animal Reservation and Protection Act of 1992.

Anyhow, due to its very high reproductive potential, the hog deer can be successfully bred and raised in captivity in many wildlife breeding centers in both private and governmental sectors. Early studies reveal that hog deer has a high possibility to survive when released to the natural condition due to their ability to adapt to the new environment (Achapet, 1997). Thus this species is suitable for reintroducing to the wild in its suitable habitat site to promote wildlife conservation issue. In general wildlife conservation, which is the preservation, protection, or restoration of wildlife and their environment, especially in relation to endangered and vulnerable species, should consist of (1) monitoring (2) proper wildlife planning and (3) development of adequate numbers of human resources and wildlife specialists to implement the strategies (Ruangpanit, 1990). Rehabilitated of animals into the wild is

the way to restore rare or even extinct species to an appropriate habitat through natural reproduction (Achapet, 1997; Rabinowit, 1999; IUCN, 2011).

In Thailand, hog deer introduction programs were launched in Thung Ka Mung (TKM) of Phu Khieo Wildlife Sanctuary (PKWS), Chaiyaphum Province in 1983, 1987, and 1992. Total of 20 bred animals were marked and released in TKM, which is man-made grassland habitat and covers the area of approximately 1.5 km^2. In November 2007, eight hog deer (3 males and 5 females) were released to improve population size and genetic diversity of the hog deer in TKM. Anyhow the specific genetic data such as different haplotypes, which can indicate the genetic diversity, were missing and there were no report on haplotype data of the release hog deer in TKM. The other introduction program of 4 hog deer was reported to launch in Khao Chi-on Non-hunting Area, Chon Buri Province during 1993. A research on home range and habitat preference were conducted and a guideline for future hog deer reintroduction program was suggested.

Anyhow the simple statistics data gained from ecological study, such as population size and habitat area, are not enough to understand the ability of a species to persist, which is of course one of the most important objectives of every wildlife conservation project. Therefore it is crucial to have a sense of the spatial and temporal relationship between habitat and demographic factors. However there are several factors which can affect the sustainability of a species but not all those factors are of equal importance. Population viability analysis (PVA) is a process of identification of all factors that may cause a species to go extinct and help to find out which deterministic factors have the most impact on a species (Lacy, 1993; Miller and Lacy, 1999).

Nowadays genetics becomes a part of wildlife conservation management. Though the hog deer could be successfully bred in captivity and rehabilitation sites in Thailand, their genetic diversity information is still scarce. This genetic information is important for sustainable population management, thus the application of molecular techniques to analyze DNA of introduced animals has become an important tool.

Therefore genetic diversity analysis should be included in the wildlife conservation program. Thus ecological study included the animal's adaptability and also number of initial population size that involve with proper genetic management, sex ratio, carrying capacity of habitat catastrophes, dispersal of the released animal to promote the conserving endangered species by introduction program should be investigate intensively. The results and strategies gain from this study could be used to manage the introduction program not only this species but also other species.

OBJECTIVES

The objectives of the research were as follows:

1. To study population characteristics of the released hog deer, namely: density, age structure, sex ratio, recruitment rate, mortality rate and genetic diversity.

2. To investigate the newly released hog deer's adaptabilities in terms of physical conditions, reproduction, behavior, and habitat used, as well as to determine forage species, carrying capacity, inter-specific relationship and probability distribution.

3. To evaluate the appropriate initial population size based on the above data.

LITERATURE REVIEW

Biology and Ecology

General Morphology and Genetic Characteristics

The hog deer is a small deer which has seasonal pelage differences. The general body color ranges from brown to dark brown in winter and grayish in summer, while the under parts are lighter. The coat is rather short and close, with some of the hair tipped white, making the animal look speckled. Young fawns are spotted, and sometimes spots are still clearly seen in adults of both sexes, but normally the spots disappear completely by adulthood. The spots are arranged in two rows on the flanks and thighs. In comparison to females, males show a dark longitudinal stripe on the forehead and the hock and the area above the knees are rather dark. The throat of both sexes is white and the insides of the ears are filled with long white hairs. The upper surface of the tail is brown while the undersurface is white, fading away inside the hind legs. The dentition of the hog deer lacks the upper canines which are variably present in other Cervids. For this reason, the animal has often been placed with a separate genus *Axis* (Lekagul and McNeely, 1988).

Lian *et al*. (2009) developed nine novel microsatellite markers using enrichment methods, and found that the polymorphic microsatellite loci showed allele numbers of 2-3 with an average of 2.22 in a group of 26 individuals and observed and expected heterozygosity ranging from 0.044 to 0.619 (average 0.397) and 0.194 to 0.632 (average 0.433), respectively. The percentage of average base composition of cytochrome *b* gene with A, C, G and T were 32.91%, 25.51%, 12.44% and 29.08%, respectively Ouithavon (2009). The percentage of average base composition of control region gene with A, C, G and T were 28.46%, 28.46%, 15.85% and 32.09%, respectively Ouithavon (2009). The percentage of average base composition of intron1 of protein kinase C, iota gene (PRKCI) with A, C, G and T were 33.82%, 11.57%, 16.67% and 38.96%, respectively Ouithavon (2009). From the study of Ouithavon (2009), the author found that all phylogenetic analyses inferred from each

molecular marker, consisting of cytochrome *b* gene, control region, mitochondrial DNA and PRKCI intron1, including combined data of all molecular markers used in this study, yielded congruent topology of the tree in which all hog deer were clustered, sisterly in the same clade of spotted deer (*Axis axis*) with moderately up to absolutely bootstrap supported. Therefore, hog deer by now would be named *Axis porcinus*, not *Cervus porcinus* according to the traditional classification of Lekagul and McNeely (1988).

Taxonomy

Hog deer are called "Nuer Sai" or "Tamanae" in Thai (Wildlife Conservation Division, Royal Forest Department, 1978; Wattanarom, 1983; Lekagul and McNeely, 1988). The English term "hog deer" is the common name for this animal (Lekagul and McNeely, 1988; Cobet and Hill, 1992). The taxonomical name is *Axis porcinus* (Whitehead, 1972) with the Synoname of *Cervus porcinus.* Taxonomic arrangement of this species cited after Ellerman and Morrison-Scott (1966) and Cobet and Hill (1992) are as follows:

Class Mammalia
Order Artiodactyla
Family Cervidae
Genus *Axis*
Species *Axis porcinus*

According to the report by Whitehead (1972), the hog deer was assigned to two sub-species of the *Axis* Genus as follows:

1. *Axis porcinus porcinus* found in Nepal, India, Sri Lanka and Myanmar.

2. *Axis porcinus annamiticus* found in Thailand, Laos, Cambodia and Vietnam.

From Grubb (1993) the difference between genus *Cervus* and *Axis*: genus *Axis*, the antlers are carried on pedicles and are three-tined, upper canine teeth are absent, foot glands are presence and retain a full spotted adult pelage but genus *Cervus*, the antlers shape like *Axis*, but are at least three-tined, upper canine teeth are presence, no foot glands, unspotted adult pattern and prominent rump patch. From the difference between genus *Cervus* and *Axis* and genetic information, hog deer by now would be named *Axis porcinus*, not *Cervus porcinus* according to the traditional classification of Lekagul and McNeely (1988).

Distribution

Hog deer can be divided into two geographical subspecies: Typical form *C. p. porcinus* found in Pakistan, Eastern India, Bangladesh and Nepal. They are not indigenous to the Indian peninsula but have been introduced to Sri Lanka (formerly Ceylon), possibly by the Dutch or Portuguese, including Australia and United Stated. The Southeast Asia subspecies *C. p. annamiticus* can be found in Burma, Thailand and Indochina. It is larger than the typical form and lacks spots in the summer pelage (Lekagul and McNeely, 1988; Maxwell *et al.*, 2007).

Hog deer was commonly found in the central plains in Thailand, in early of last century. However, the expansion of rice farming due to economic growth caused encroachment on the prime habitat of hog deer causing a severe reduction in the population. A few sightings of hog deer were reported from the open deciduous forests along the Tenasserim mountain range, but these reports have not been confirmed (Lekagul and McNeely, 1988). Additional sightings of hog deer in Thailand include sightings in Thung Yai Naresuan Wildlife Sanctuary, Kanchanburi and Tak Provinces (Faculty of Forestry, 1989b), in Huai Kha Khaeng Wildlife Sanctuary, Uthaithani and Tak Provinces (Faculty of Forestry, 1989a), Khao Soi Dao Wildlife Sanctuary, Chanthaburi Province and Khao Anghranai Wildlife Sanctuary, Chachoengsao Province (Forestry Research Center, 1995). However, all these sightings lack definitive confirmation such as photographs, or bones and carcasses.

Population Characteristics

1. Size and social behavior

Length of head and body: 1,400-1,500 mm; shoulder height: 650-720 mm; tail: 175-210 mm; ear 160-180 mm; hind foot: 290-310 mm; weight: 70-110 kg (Lekagul and McNeely, 1988).

Under undisturbed conditions, the hog deer is gregarious, forming rather large groups of several dozen individuals. Family groups have also been reported. In recent times, however, it seems that the hog deer has become nocturnal and solitary, forming a pair or more only during the rut, when two or three individuals may be seen together (Lekagul and McNeely, 1988).

In Royal Chitwan National Park, Nepal, the average group size was 1.8. The basic social group consisted of an adult female and her juvenile offspring. Group sizes were largest during January and August-September and smallest during May and December (Dhungel and O'Gara, 1991). Social groupings varied throughout the year and between the sexes. 65.8% of adult deer were alone and 34.2% were found in groups including their fawns younger than 8 months. Adult females were frequently seen with adult males during September and October (their peak rutting season). Adult females associated with their fawns during the hot season (their peak fawning period) until the fawn was about 8 months old (Dhungel, 1985). Aggregation of up to 20 animals occurred 10-12 days after new fresh shoots of grasses appeared where fire had burned the grassland. The group size was 1.9 during the breeding season and 1.5 during the non-breeding season. Group size did not vary significantly during breeding seasons, but the largest group seen during the fawning season (20 animals) was much larger than that seen during the non-breeding season (3 animals). Pairs, including a young fawn, were observed during the fawning season. The ratio of adult males to females is characteristic of a polygamous species.

Burning of grasslands to increase the growth of these grasses for the hog deer was conducted in TKM in 1999 (Kumsuk and Kreetiyutanont, 1999b). At that time there were at least 75 hog deer in that area and they fed on the buds of the new growth of grass after the controlled burning (Kumsuk and Kreetiyutanont, 1999a; Kumsuk *et al.*, 1999). In Gorumara National Park in India the largest herd of hog deer (14 individuals) was created through the controlled burning of grasslands (Bhowmik and Chakarborty, 2001). In Sub-Himalayan West Bengal in India, the herds of hog deer ranging from 8 to 42 individuals were observed in grasslands with marshes which contained the preferred hog deer foods including young and tender grass, bamboo shoots, and leaves. These habitats also provided appropriate shelter from predators (Bhowmik *et al*., 1999). The study by Kuntaro (2002) found that among the hog deer released into the TKM of PKWS, the social organization of the hog deer was such that 41.71% were solitary while 58.29% were found in groups. The average group size was 3.35 individuals. In the rainy season the average herd size increased to 4.08 individuals, while in the dry season the average group size decreased to 2.6. The study by Aemsang (2008) found that among the hog deer released into Khao Chi-on Non-hunting Area, the social organization of the hog deer was such that 31.22% were loners while 62.78% were in groups.

2. Age structure and sex ratio

The age structure of hog deer can be characterized by three levels; adults (>24 months), yearling (13-24 months) and fawn (1-12 months) (Dhungel, 1985). According to Taylor (1971), female fawns generally weigh <15 kg and male fawns <25 kg and fawns are easily recognized by their small size. Male fawns usually do not have antlers, or their antlers are just beginning to grow. Yearling females weigh 15-24 kg, and males generally weigh 25-29 kg. Adult females average 31 kg, and adult males weigh an average 44 kg and have branched antlers. The sex ratio of adult males to adult females and yearlings to fawns was 33:57 and 5:2, respectively. Sex ratios favoring females are characteristic of a polygamous species. The sex ratio of males to females was 52:100, and females to fawns were 100:22 (Dhungel, 1985; Dhungel and O'Gara, 1991). Male to female to fawn ratios found by other

researchers were 51 to 100 to 24 (Seidensticker, 1976). The study by Kuntaro (2002) found that the ratio of adult to yearling to fawn of the reintroduced hog deer at TKM, PKWS was 87.52 to 2.54 to 9.94, respectively. The sex ratio of males to females was 50.53:100, while the ratio of females to fawns was 100:16.25. The study by Aemsang (2008) found that the ratio of adult to yearling to fawn of the reintroduced hog deer at Khao Chi-on Non-hunting Area was 83.7 to 14.3 to 1.9, respectively. The sex ratio of males to females was 48.31:100. In Axis deer (*Axis axis*) was study by Mishra (1982) found the ratio of adult to yearling to fawn was 59 to 100 to 55.

3. Population density

The fecal pellet-group counts method (Bennett *et al*., 1940) to estimate the population density of hog deer. One of the most important factors in this method is the effect of plot shape and size, in general the smaller the area and the more accurate its delineation, the smaller the error. Circular plots which were different sizes of radius to obtain the area in different unit (Smith, 1974; Ngampongsai, 1977; Dhungel, 1985; Mandujano and Gallina, 1995; Sukmasuang, 2001). Smith (1974) found that 9.308 m^2 (0.001 acres) circular plots had the highest density fecal pellet-group result, whereas 40.469 m^2 (0.01 acres) circular plots gave the lowest fecal pellet-group density, therefore he concluded that using of smaller plots combined with a large number of plots is more accurate than using a low number of larger plots. Ngampongsai (1977) used 4.65 m^2 circular plots to study the population density of Sambar deer in Khao-Yai National Park, Thailand. Dhungel (1985) and Mandujano and Gallina (1995) used circular plots of 9.30 m^2 (radius of 1.72 m) to study population density of hog deer in Royal Chitwan National Park, Nepal and the population density of white-tailed deer in Mexico respectively. In 2001 Sukmasuang used circular plots of 12.57 m^2 to study the population density of barking deer in Huai Kha Khaeng Wildlife Sanctuary, Thailand and he recommended that this size of circular plot can be used for both accuracy and convenience in field work. Therefore in the present study, circular plots of 2 m radius were used for collecting the fecal pellet of hog deer following the line plot system. Each plot covered an area of 12.57 m^2.

In the flood plains with grassland, savannah, and along gallery forest, the population densities of the hog deer groups in Royal Chitwan National Park, Nepal studied by Dhungel (1985) were 15.5, 16.5 and 0.13 per km^2, respectively. At the Gorumara National Park, the preserved territory of Himalayan West Bengal in India, censuses of the hog deer population recorded a low population density (51 to 100 individuals) or very low (<50 individuals). At these low levels, there is the risk of sudden and rapid genetic loss, and inbreeding. Kuntaro (2002) found that the average ecological density using pellet-group counts in TKM was only 1.02 individuals per ha. Aemsang (2008) found that the average ecological density using fecal pellet-group counts in Khao Chi-on Non-hunting Area was only 0.55 individuals per ha. Sukmasuang (2001) using the fecal pellet group count method to estimate the population of common barking deer (*Muntiacus muntijak*) in Huai Kha Khaeng Wildlife Sanctuary, reported that the population density was 0.158 individuals per hectare or 15.80 individuals per km^2.

Threatening Factors

In the past, the hog deer was hunted until near extinction. Also, its natural habitat was greatly reduced in the same time (Humphrey and Bain, 1990). Recently, there have still not been any confirmed sightings of hog deer in the wild. Important predators of the hog deer in natural condition were tiger (*Panthera tigris*) (Schaller, 1967; Dhungel and O'Gara, 1991), leopard (*Panthera pardus*) (Dhungel and O'Gara, 1991), snakes (of the constrictor species) such as pythons, and crocodiles (Kurt, 1988). In PKWS, Chaiyaphum Province, Asian wild dog (*Cuon alpinus*) is the most potential predator of hog deer (Kuntaro, 2002).

General Behavior and Reproduction

In Royal Chitwan National Park, Nepal, the breeding season extends from July through November and peaks in September to October (Dhungel, 1985). Generally the rut is in September and October, and the fawns are born after a gestation of 7- 8 months (Lydekker, 1898; Schaller, 1967; Dhungel, 1985). Both males and females

attained sexual maturity within about 15 months. The female shows indications of estrus by holding her tail horizontally and standing still when approached from the rear by a male. Although no maximum time was determined for the length of the estrus, several females indicated willingness to breed for at least 15-20 hours (Dhungel and O'Gara, 1991). Litter size was usually 1. The peak fawning season was March through April, but females gave birth from the end of January through April. Most fawns were born at the beginning of the dry season when natural fire promotes the growth of young, tender grasses and increases the availability of nutritious forage. In Nepal, recruitment rates were 15.8% (Seidensticker, 1976) and 13.1% (Dhungel, 1985) and Mishra (1982) found recruitment rate in Axis deer (*Axis axis*) in Nepal was 34.5%.

The fawn has a "hider relationship" with its mother. Fawns typically are not seen with their mothers for 12 to 20 days after birth; they prefer to spend the day in a hiding place (Miller, 1975; Dhungel and O'Gara, 1991). Fawns accompany their mothers between 4-5 weeks after the date of parturition (Dhungel and O'Gara, 1991). A mother calls with a "squeal" as it approaches the hiding place and the fawn then responded with a soft squeak (Miller, 1975). Fawns become interested in other food and water when they reach 2-3 weeks old. The young animal wean at an age of 2-3 months or when they reach a weight of 8-9 kg (Intarapanich, 1973). Senses of smell and hearing of hog deer are acute. Females can distinguish their young by smell.

Hog deer generally prefer to travel along trails and small paths in grassland habitats (Dhungel, 1985). They seldom jump over a bush or high grass like other deer, but usually run through underbrush with the head held low to the ground, rather like a hog. This is a distinct field characteristic of the hog deer (Lekagul and McNeely, 1988). They are usually active, feeding and moving, during mornings and evenings. Generally, bedding is observed between 10:00 am and 4:00 pm inside the enclosure during cool and hot seasons (Dhungel, 1985). They are sedentary animals in the grassland habitat where food, water and hiding cover, are sufficient, but individual movements vary extensively (Dhungel and O'Gara, 1991). Sunquist

(1981) noted that hog deer in Royal Chitwan National Park, Nepal may be active and feeding during 10:00-11:00 am.

Hog deer inside the enclosure in Royal Chitwan National Park, Nepal spent 32% of the morning and evening hours (06:00-09:00 am and 4:00-7:00 pm) grazing, 15% standing and walking around while feeding, 2% defecating and urinating, and 36% in other activities including bedding, grooming, drinking and butting. Bedding was included in "other" activities because only a few animals were bedding during these hours (Dhungel and O'Gara, 1991). Chamnankit (1974) noted that captive hog deer in Bangkok Zoo spent 53.03% of the time lying, 21.89% walking, 9.07% feeding, 8.52% ruminating, 6.86% standing, and 0.73% running. On average, the hog deer was observed drinking 2 times per day, defecating 4.6 times per day, and urinating 3.1 times per day.

Feeding Behavior and Forage Species

The hog deer is more a grazer than browser, feeding mainly on high grasses found along natural river banks (Lekagul and McNeely, 1988). The captive herd at Khao Khieo Wildlife Sanctuary was feeding 80% on grass and 20% on fob and leaves (Miller, 1975). They grazed during morning and evening and were occasionally observed grazing on moonlit nights during the hot season. Morning grazing started as early as 05:00 am and ended when the hog deer were bedding by 10:00 am on hot days, chewing their cuds until about 4:00 pm and feeding again until 8:00 am (Dhungel and O'Gara, 1991). The least time for grazing is spent during June, July and August and the most time during September. This peak may be related to the end of the rainy season when the grasses, ferns and other food species attain their maximum growth and are not tender and succulent. Therefore, hog deer must spend more time selecting plant parts to fulfill their food demands during September. They are solitary grazers. They normally start to ruminate after one hour of grazing, and while doing this they always bed under the shade of dense brush or trees (Dhungel, 1985).

Miller (1975) noted that the hog deer in semi-natural habitat at Khao Khieo Wildlife Sanctuary feed on *Bridelia tomentosa, Imperata cylindrica, Eupatorium odoratum, Cerewia elastostomoides, Streblus asper, Pennistum pupeum, Wrightia jabannia, Mecopus nudians, Desmodium pulchellum, Dalbergia discolor, Dalbergia foliacea, Polyathia obtuse, Indigofera spp., Allophylus montanus, Cassia pumita, Alibizzia lebbekoides, Cyrits caccuma accrescens, Saparia palldefusa, Brachiaria distachyn, Cassia fistula, Globba spp.*

At Khao Khieo Open Zoo, the available diet of hog deer includes grass (80%), and leaves (20%). Common plants that are consumed include *Imperata cylindrica* and *Pennisetum purpureum*. In Sub-Himalayan West Bengal in India, hog deer consume young grass, bamboo shoots, and assorted leaves. Between the dry seasons (April to June) when there are limited grass growths, hog deer resort to eating young leaves off trees. Preferred plant species include *Saccharum longisetosum* var. narayan SW *S. longisetosum* var. hookeri, *S. arundinaceum*, *S. bengalense, S. narenga, S. spontaneum, Alpinia malaccensis*, *A. nigra*, *Phragmites karka*, *Arundo donax* and *Imperata cylindrica* (Bhowmik *et al.*, 1999).

A study by Kuntaro (2002) showed that in TKM area of PKWS the released hog deer fed on 29 plants species. The study also found that forage species consumed by the released hog deer consisted of 55.17% herb, 34.48% grass, 0.35% tree and herbaceous climber. The hog deer fed on leaves, flowers and fruits such as *Phyllanthus emblica*, *Rhynchospora corymbosa*, *Kyllinga brevifolia*, *Eleusine indica* and *Setaria parviflora*.

A study by Aemsang (2008) showed that in Khao Chi-on Non-hunting Area the released hog deer fed on 22 plants species consisted of 18.18% herb, 22.73% grass, 59.09% tree and herbaceous climber. The main forage species are *Imperata cylindrica, Setaria parviflora, Chrysopogon aciculatus and Zoysia japonica.*

Habitat Preference

Originally, the hog deer was typically found on alluvial plains or on plains along the sides of rivers, particularly near marshes with tall grasses (Lekagul and McNeely, 1988). They inhabit swampy meadows, low-lying marshes, open forest, reed beds and grasslands bordering streams. They do not penetrate closed forest (Schaller, 1967; Miller, 1975; Lekagul and McNeely, 1988). Although their ancestral habitat has been lost, hog deer readily adapted to the bamboo-imperata grass habitat following slash and burn agriculture on the lowlands of Thailand (Miller, 1975). With protection of water resources and protection from poaching, the potential for reintroduction of hog deer in the wild in Thailand is highly possible (Humphrey and Bain, 1990).

Dhungel (1985) also studied hog deer in Royal Chitwan National Park, Nepal and found that they used grassland habitats 98.5% of the time, riverine forests 1.4%, and sal forest only 0.2%. They utilize small pockets (3x3 m) of short (10 cm) grass for feeding bouts. These pockets are surrounded by taller (3-4 m) grasses where the deer rest and hide. They are adapted to a small niche where they can find the food and cover necessary for survival. Hog deer were most frequently seen in the tall grasslands at the end of the cool season and during the hot season.

The major factors influencing the home range are the seasonal distribution and availability of food, water and hiding cover, in the grasslands. The estimated mean home range size was 60 ha for females and 80 ha for males in Royal Chitwan National Park, Nepal. Home ranges of both sexes overlap extensively. Home range shape was dictated by food and water (Dhungel and O'Gara, 1991). The size of home range was not significantly different between males and females. Ranges of the male were slightly larger during the wet season than in the cool and the hot seasons, probably due to rutting males traveling to find estrous females during September, which is the peak of the rutting season. The smaller home range size during the cool and hot seasons might have been related to the availability of food and water. If food is widely distributed, an animal has to make extensive seasonal movement involving

uneconomical energy expenditure (Dhungel, 1985). According to the study by Achapet (1994), it was found that the average hog deer home range size was 159.70 ha with slight differences between the sexes (153.16 ha for females and 166.24 ha for males). These large territories showed that settlement areas are not optimal for obtaining food. Walking trails of the animals are normally narrow and heavily traveled. They use spaces of about one to three meters in high grass for rest and sleep (Dhungel, 1985; Achapet, 1994). The hog deer sleep in small groups, distributed throughout their habitat.

The habitat use of hog deer is variable and is shifting in different country settings. For example, in Vietnam and Laos, hog deer are found in the low lands, with wet marshes and tall grass cover (Whitehead, 1972). In contrast, in India and Sri Lanka, hog deer congregate near tall grass meadows and water sources and groves/thickets (Prater, 1971). In the protected areas of Sub-Himalayan West Bengal in India, hog deer are mainly found in open grasslands with a great variety of food species. They can also be found in areas of dense scrubs because these areas provide more secure shelter at night (Bhowmik *et al.*, 1999). In the Royal Chitwan National Park, Nepal, hog deer are found in meadows with plentiful food supplies, cover, and usable water (Dhungel, 1985; Dhungel and O'Gara, 1991). In Myanmar, the hog deer (*A. p. porcinus*) is found in tall grasslands but not in dense forest or the foothills of the mountains (U Tun Yin, 1967; Whitehead, 1972). One exception is that they can be found in mangrove forests (Prater, 1971). In Thailand, hog deer have been found in low-lying grasslands near water sources or marshes with tall grass in the Central, Northern and Northeastern Regions (Miller, 1975; Lekagul and McNeely, 1988; Bain and Humphrey, 1982; Lekagul and Nabhitabhata, 1990). Hog deer are not found in the South of Thailand where no large meadowlands can be found. Hog deer were spotted hiding in Bang Pu, Bang Bo behind Pom Phra Chulachomklao of Smut Prakarn Province and near the seashore in the Central Region and Chanthaburi Province (Lekagul and McNeely, 1988).

Achapet (1994) studied the habitat preferences of hog deer raised in captivity, and released them into Khao Chi-on Non-hunting Area in Chonburi Province. This

location has the characteristics of a natural forest with an area of 327.53 ha (or approximately 2,047.06 rai), surrounded by a 2-meter height fence. The hog deer preferred the areas of cultivated forest and areas of human habitation near or in grasslands. The hog deer were not found in the deeper dry forested areas, secondary forests, or flat, open areas. Kuntaro (2002) studied hog deer that were introduced in to TKM area of PKWS. Initially, the hog deer remained near the area of introduction but were able to reproduce successfully in the wild. Over time, with increased numbers, they spread out to a wider area covering 462 ha. The hog deer settled in a variety of habitats including grassland, mixed pine-deciduous dipterocarp forest, saltlick area, water resource, roadways, and areas of human development (such as buildings, barracks, lawns, sports fields, etc.). The most common habitat is grassland (40.19%) followed by mixed pine-deciduous dipterocarp forest (28.97%).

Wildlife Restoration

Wildlife Habitat Restoration

The importance of habitat for each species of wildlife does not depend on that species alone; all inter-related species play a role in preservation of the entire habitat in ways that are impossible to fully document. Certain proxy variables need to be used to describe these inter-relationships between species and the overlapping habitats. From such an analysis, the ecological density can be determined which reflects the needs and balances of the ecosystem. It is possible to determine what each species derives from its share of the habitat. By identifying the gaps or shortages, it is possible to adjust some of the variables so that the habitat can accommodate the desired number of individuals that are being reintroduced. The following lists some of the guidelines in this process (Bhumpakphan, 2000):

1. To create the appropriate interface between different species in a habitat it is preferable to link habitats that have variable compositions. For example, grasslands and different kinds of forests, and forests with large ponds or swamps of standing water will have a large variety of complementary species. Alternatively, if a habitat is

reduced in size or complexity due to external factors, this might not provide enough diversity for some of the species to thrive. This in turn may lead to migration of certain wildlife species outside of the habitat to new ones with unanticipated consequences. This dynamic needs to be kept in mind.

2. The restoration of the habitat for food consumption and utilization by a given species of wildlife, for example, the modification of the grasslands to make them more attractive to herbivores will result in an increase in the number of herbivores. This will in turn have an impact on the carnivores which share the habitat. Other modifications to the habitat include adjustments to the water sources of the wildlife, or creation of small, new water sources, spread widely over a species' range. Some modifications include the selective cultivation of certain wild plants that are important sources of food of the wildlife species of interest, such as planting of *Eugenia* spp. and *Ficus spp.* In some cases, artificial clearings are created to increase the area for foraging by herbivores.

Wildlife Population Restoration

There are a number of strategies that can be used to restore the size of the population of threatened species. The IUCN guidelines for re-introduction of animals to the wild (1987) provide a narrow definition of "reintroduction" as derived from "translocation" and which covers the translocation of living organisms including introductions, reintroductions, and restocking of populations of wildlife. Specifically, "translocation" is defined as moving a living thing (flora or fauna) to a new habitat to live independently (of human intervention). The three types of translocation are described in greater detail below:

1. "Introduction" of plants or animals, either deliberately or accidentally, results in an increased number of that species of plant or animal from that in its original habitat. When this is done deliberately, introduction is done to return the number of a species to its original level as supported by its natural habitat, whether the introduction occurs in the original or a new habitat. Of particular importance when introducing any

species is the need to ensure minimal disruption to other inter-related species. At the same time, the introduction of the animals or plants can confer benefits such as increasing the diversity of the habitat. It can be concluded that, so far, the introduction of the hog deer into the PKWS of Chaiyaphum Province has been successful in this regard (Khobkhet, 1992; Kuntaro, 2002).

Several species of cervids were introduced at different times in Australia, mostly by acclimatization societies. These introductions have had variable success, and some failed altogether. The earliest introduction was of Chital (*Cervus axis*). These were brought to Australia first in 1800-1803 (Deer Advisory Council of Victoria, 1979), but the first introduction, in New South Wales, did not survive. The present population in Queensland derives from later introductions. Hog deer were introduced in a herd mixed origin, some individuals from Calcutta and others from Colombo, to Cape Liptrap in 1866 and Gembrook in 1870. The former release was successful and has spread in south-eastern Victoria; the latter release did not survive (Bentley, 1978)

2. "Reintroduction" of animals or plants is the deliberate introduction of the species into the original habitat in which no individuals can be found, or in which the species has become extinct, whether by man-made or natural causes. In reintroduction, a number of individuals of a plant or animal species are released into the ecosystem to help return the habitat to original levels of diversity. Reintroduction is usually applied to areas in which extinctions have occurred which are not the result of habitat destruction but from other causes such as over hunting and poaching. In particular, it is important to assess the site for the reintroduction carefully to determine if there have been significant changes in size and/or composition (from the original state) that will affect the viability of the animals or plants to be re-introduced. Measuring the success of reintroduction projects cannot be accomplished in a year or two, but must be assessed over the long term.

Captive breeding and reintroduction may be viewed as a process involving six stages (Figure 1)

- Decline of the wild population and its genetic consequences

- Founding a captive population
- Growing the captive populations to a secure size
- Managing the captive population over generations
- Selecting individuals for reintroduction
- Managing the reintroduction (probably fragmented) in the wild

Genetic issues of importance in the first stage are the rate of decline of the wild population, the size to which it declines, and the resulting loss of genetic diversity and inbreeding that it has suffered prior to captive breeding.

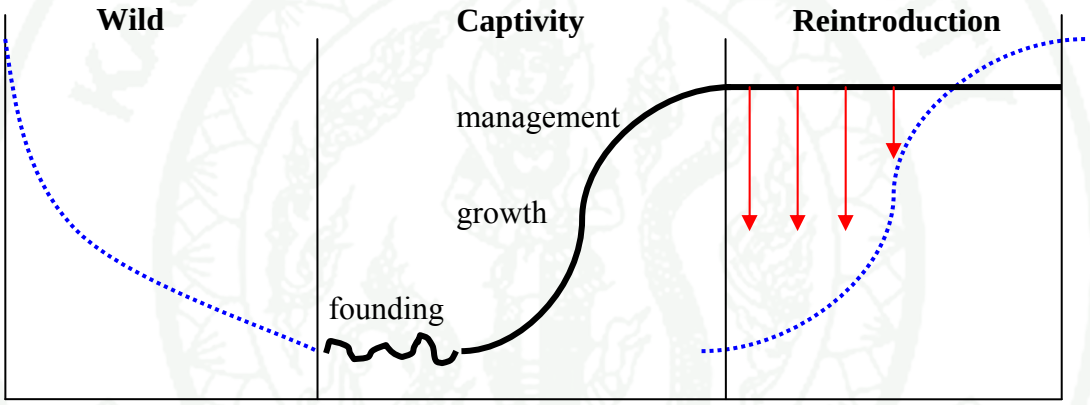


Figure 1 Captive breeding and reintroduction as components of a six-stage process.

Source: Frankham *et al*. (2002)

There was an example of reintroduction of Eld's deer in Thailand. Two *Cervus eldii thamin* were shipped from the USA to cross breed with the single remaining individual of *Cervus eldii siamensis*. The breeding in captivity was successful and many offspring were produced. Also England's wildfowl trust and Wetland program bred the white-winged duck (*Cairina scuturata*) in captivity and worked with Thai counterparts to continue the breeding process, initially with three local birds of the same species found in Yod Dome Wildlife Sanctuary, Ubon Ratchathani, Thailand. In collaboration with Khao Soi Dao Wildlife Breeding Center, Chanthaburi Province and Chong Khlam Bon Wildlife Breeding Center, Prachinburi

Province a total of 500 offspring were born, raised and prepared for reintroduction into the areas where this species once was found in abundance but those numbers had severely declined. There were enough individuals left over from the controlled breeding so that a number of individuals could be shared with Malaysia (Bhumpakphan, 2000).

Reintroduction of wildlife is an important strategy for wildlife preservation with the specific objective being to allow the reintroduced species to resume its natural lifecycle and survival practices (Achapet, 1997). The benefits of this reintroduction are to prevent extinction of the species, to prepare the habitat for future reintroduction of species, and to return the characteristics of the affected species to the most natural state possible (Noothong, 1991).

Reintroduction of species into the wild is of special interest for its potential to rapidly increase the numbers of threatened species. There is a risk of creating an imbalance if the numbers of reintroduced species achieves greater than optimal population size. Ex situ conservation can play a role to more precisely control the numbers of a species that are being prepared for reintroduction. In addition, in locations where a species has gone extinct or is near extinction, the only viable option for returning that species to its original population size is through ex-situ conservation through breeding in captivity.

The species of animals that are reintroduced might be animals that have been captured in the wild, animals that were reared as pets and then given up by their owners, animals from government institutions or institutions under royal patronage such as Wildlife Breeding Center, Department of National Park, Wildlife and Plant Conservation. From reports dated 2004, the number of animals that have been produced through the Wildlife Breeding Center totaled 10,042 individuals, including white-winged duck, silver pheasant, green peafowl, grey peacock-pheasant, among others. A total number of 3,059 individuals of mammal are kept including pig-tailed macaque, crab-eating macaque, white-handed gibbon, barking deer, sambar deer, lesser mouse deer, hog deer, and others. A total number of 873 individuals of reptiles

are kept such as different types of turtles and pythons, among others. In addition to increasing the number of offspring of threatened species, other animals are treated for illness, or protected or rescued from harsh conditions (Craven, 1982). In other cases, the wildlife authorities have transferred threatened species from one habitat to another to help them thrive (Bauer, 1988; Manen *et al*., 2000).

Projects to reintroduce wildlife require detailed, long term efforts and lengthy preparation phases to determine the size and nature of the target habitat. If the original habitat has changed significantly in terms of flora and fauna composition, or has been otherwise degraded from its natural state, then reintroduction efforts will be difficult. The cost of the preparation of the reintroduced animals and the target habitat are difficult factors. Only animals which can be bred in captivity and easily re-adapt to wild conditions are suitable candidates for re-introduction projects (Bauer, 1988; Khobkhet, 1989).

The reintroduction to the wild of animals of certain species will continue to be necessary as long as there is demand for these animals as pets, food, or medicines, and as poachers respond to this demand. There are also cases, mostly in the USA, of breeding and releasing large numbers of certain species of animal to be used as hunting game. Same cases in Thailand such as reintroduction of Eld's deer and hog deer in Sublungka Wildlife Sanctuary, Lopburi Province and Weing Lor Wildlife Sanctury, Pha Yao Province (Amata-achachai *et al*., 2009) and reintroduction of Eld's deer in Phu Khieo Wildlife Sanctuary, Chaiyaphum Province (IUCN, 2012) and Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province (Buranapim, 2009). Other countries have been successful in breeding certain species for reintroduction to the wild; mostly these are wild birds (Craven, 1982), and some of mammals such as golden lion tamarin, Arabian sand gazelle, muriqui and long-furred woolly mouse opossum.

3. "Restocking" refers to the movement of plants or animals to areas where they already exist, but where the population size is less than optimal. This process can be referred to as a form of habitat rehabilitation. In Thailand, some species of

pheasant, peacock, and jungle fowl have been restocked in Khao Kitkut, Chanthaburi Province. In addition, four individuals of the elongated tortoise (*Indotestudo elongta*) were experimentally introduced to a habitat with nine remaining wild turtles in Huai Kha Khaeng Wildlife Sanctuary, Uthaithani Province. The turtles, which had been bred in captivity, had a greater range of movement than the wild turtles, with a survival rate of 75% (Tharapoom, 1996).

Probability distribution

Predictive modeling of species geographic distribution based on the environmental conditions of sites of known occurrence constitutes an important technique in analytical biology, with applications in conservation and reserve planning, ecology, evolution, epidemiology, invasive-species management and other fields (Yom-Tov and Kadmon, 1998; Corsi *et al*., 1999; Peterson *et al*., 1999; Welk *et al*., 2002; Peterson and Shaw, 2003). Sometimes both presence and absence occurrence data are available for the development of models, in which case general-purpose statistical methods can be used (Corsi *et al*., 1999; Guisan and Zimmerman, 2000; Elith, 2002). However, while vast stores of presence-only data exist, absence data are rarely available, especially for poorly sampled tropical regions where modeling potentially has the most value for conservation (Soberon, 1999; Ponder *et al*., 2001; Anderson *et al*., 2002). In addition, even when absence data are available, they may be of questionable value in many situations (Anderson *et al*., 2003). Modeling techniques that require only presence data are therefore extremely valuable (Graham *et al*., 2004).

Maxent is a general-purpose method for making predictions or inferences from incomplete information. The idea of maxent is to estimate a target probability distribution by finding the probability distribution of maximum entropy, subject to a set of constraints that represent our incomplete information about the target distribution. The information available about the target distribution often presents itself as a set of real-valued variables, called “features”, and the constraints are that the expected value of each feature should match its empirical average. When maxent

is applied to presence-only species distribution modeling, the pixels of the study area make up the space on which the maxent probability distribution is defined, pixels with known species occurrence records constitute the sample points, and the features are climatic variables, elevation, soil category, vegetation type or other environmental variables , and function thereof (Phillips *et al*., 2006). Maxent offers many advantages, and a few drawbacks; the advantages include the following: (1) It requires only presence data, together with environmental information for the whole study area. (2) It can utilize both continuous and categorical data, and can incorporate interactions between different variables. (3) Efficient deterministic algorithms have been developed that are guaranteed to converge to the optimal (maximum entropy) probability distribution. (4) The maxent probability distribution has a concise mathematical definition, and is therefore amenable to analysis. For example, as with generalized linear model (GLM) and generalized additive model (GAM), in the absence of interactions between variables, additivity of the model makes it possible to interpret how each environmental variable relates to suitability (Dudik *et al*., 2004; Phillips *et al*., 2004). (5) Over-fitting can be avoided by using l_1-regularization. (6) Because dependence of the occurrence localities is explicit, there is the potential to address the issue of sampling bias formally, as in Zadrozny (2004). (7) The output is continuous, allowing fine distribution to be made between the modeled suitability of difference areas. If binary predictions are desired, this allows great flexibility in the choice of threshold. If the application is conservation planning, the fine distinctions in predicted relative environmental suitability can be valuable to reserve planning algorithms. (8) Maxent could also be applied to species presence/absence data by using a conditional model (as in Berger *et al*., 1996), as opposed to the unconditional model used here. (9) Maxent is a generative approach, rather than discriminative, which can be an inherent advantage when the amount of training data is limited. (10) Maximum entropy modeling is an active area of research in statistics and machine learning, and progress in the field as a whole can be readily applied here. (11) As a general-purpose and machine learning, and flexible statistical method. Some drawbacks of the method are: (1) It is not as mature a statistical method as GLM or GAM, so there are fewer guidelines for its use in general, and fewer methods for estimating the amount of error in a prediction. Our use of an “unconditional” model

is rare in machine learning. (2) The amount of regularization requires further study (Phillips *et al*., 2004), as does its effectiveness in avoiding over-fitting compared with other variable selection methods. (3) It uses an exponential model for probabilities, which is not inherently bounded above and can give very large predicted values for environmental conditions outside the range predicted values for environment conditions outside the range present in the study area. Extra care is therefore needed when extrapolating to another study area or to future or past climatic conditions. (4) Special-purpose software is required, as maxent is not available in standard statistical packages (Phillips *et al*., 2006).

Population Viability Analysis and Minimum Viable Population

Ecosystem approaches to natural resource management are often thought to represent a shift away from single species management. The ecosystem management paradigm, however, does not exclude research and management for individual species population viability. Rather, ecosystem management reinforces the need to view individual species within the context of the ecosystems that sustain them. This means looking at species population in relationship to genetic and ecological level of biological organization, understanding the role of species in ecosystem processes, and scaling management actions to ecological rather than political boundaries. Population viability analysis is a valuable and sometime indispensable tool in ecosystem management.

Population viability analysis (PVA) often uses models that simulate the future of the species based on parameters on the ecology and demography of its populations. PVAs are also used to explore different scenarios for population trends among species, and use the results to adjust wildlife management strategies using quantitative analysis (Morris and Doak, 2002). A direct benefit of PVA is its ability to analyze the effects of reintroduction of animals to the wild, especially for a threatened species (Bustamante, 1996). The PVA tool can be used as a modeling device for dynamic long term projections which can be adjusted as new input data become available in order to create more accurate projections (Boyce, 1992). PVA estimates the

probability of extinction by using only a small number of parameters; however, its predictions have been validated to be accurate for populations with simple structure and in constant habitats (Broom *et al*., 2000). PVA is speculative and predictive in a probabilistic sense (Shaffer, 1990). It is currently the most useful tool to address species conservation goals (Lindenmayer *et al*., 1993)

A part of the PVA process is to assess the current status of a species to help with wildlife management decisions such as those which have been used with the reintroduction program such as golden lion tamarin (*Leontopithecus rosalia*) (Seal *et al*., 1990; Kierulff, 1993), black lion tamarin (*L. chrysopygus*) (Seal *et al*., 1990; Valladares-Pa dua *et al*., 1994), golden-headed lion tamarin (*L. chrysomelas*) (Seal *et al*., 1990) and black-faced lion tamarin (*L. caissara*) (Seal *et al*., 1990), muriqui (*Brachyteles arachnoides*) (Strier, 1994, 2000; Rylands *et al*., 1998), long-furred woolly mouse opossum (*Micoureus paraguayanus*) (Brito and Fernandez, 2000, 2002; Brito, 2002; Brito and Grelle, 2004) and spiny rat (*Trinomys eliasi*) (Brito and Figueiredo, 2003).

An important question regarding the reintroduction of animals to the wild is the optimal number of individuals to be released. The analytical method called the minimum viable population (MVP) analysis attempts to determine the minimum number of a species that is needed for sustained survival. MVP analysis is a critically important tool for wildlife management (Shaffer, 1981; Belovsky, 1987). Brito and Fernandez (2006) used MVP analysis to determine the minimum number of long-furred woolly mouse opossum (*Micoureus paraguayanus*) that could survive as a group in the Atlantic Forest.

Various computer programs are used in conjunction with PVA such as Spgpc, Gapps, Popdyn, Ramas, and Vortex. Vortex is the most widely used of these programs (Lacy, 2000). The Vortex program creates a simulation, using a large number of variables, and introduces events that have an impact on population forces (Miller and Lacy, 1999). Vortex is used for planning the reintroduction of a species back into the wild (Bustamante, 1998).

Lacy (1993) said that Population Viability Analysis (PVA) is the estimation of extinction probabilities by analyses that incorporate identifiable threats to population survival into models of the extinction process. Extrinsic forces, such as habitat loss, over-harvesting, and competition or predation by introduced species, often lead to population decline. Although the traditional methods of wildlife ecology can reveal such deterministic trends, random fluctuations that increase as populations become smaller can lead to extinction even of populations that have, on average, positive population growth when below carrying capacity. Computer simulation modeling provides a tool for exploring the viability of populations subjected to many complex, interacting, deterministic and random processes. Vortex models population processes as discrete, sequential events, with probabilistic outcomes. Vortex simulates birth and death processes and the transmission of genes through the generations by generating random numbers to determine whether each animal lives or dies, to determine the number of progeny produced by each female each year, and to determine which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Fecundity is assumed to be independent of age after an animal reaches reproductive age. Mortality rates are specified for each pre-reproductive age-sex class and for reproductive-age animals. Inbreeding depression is modeled as a decrease in viability in inbred animals.

The user has the option of modeling density dependence in reproductive rates. As a simple model of density dependence in survival, a carrying capacity is imposed by a probabilistic truncation of each age class if the population size exceeds the specified carrying capacity. Vortex can model linear trends in the carrying capacity from binomial distributions. Catastrophes are modeled as sporadic random events that reduce survival and reproduction for one year. Vortex also allows the user to supplement or harvest the population, and multiple subpopulations can be tracked, with user-specified migration among the units.

Vortex outputs summary statistics on population growth rates, the probability of population extinction, the time to extinction, and the mean size and genetic variation in extant populations. Vortex necessarily makes many assumptions. The

model it incorporates is most applicable the interacting effects of many of the deterministic and stochastic processes that have an impact on the viability of small populations, providing opportunity for more complete analysis than is possible by other techniques. PVA by simulation modeling is an important tool for identifying populations at risk of extinction, determining the urgency of action, and evaluating options for management. This program is not only for modeling mammalian and avian populations, but also for modeling some reptiles, amphibians, fish, invertebrates and even plants. PVA combines the specification and quantification of the threats to wildlife populations with detailed mathematical model of population dynamics in order to evaluate the risk of population extinction under a variety of alternative future scenarios and furthermore the Population and Habitat Viability Assessment (PHVA) was interested to management the population. In contrast to this traditional approach, the PHVA process uses PVA methodologies and PHVA prospects of political and social changes required for effective collaboration in the management and conservation of habitat fragments and their species components.

Guo *et al*. (2002) studies PVA on giant pandas (*Ailuropoda melanoleuca*) in the Yele Nature Reserve. They found that the number of giant pandas will slowly increase with no inbreeding and no environmental catastrophes (floods, fries, disease, etc.). However, when the model includes an inbreeding rate or a 1.67% probability of an environment catastrophe, the population becomes extinct in 90 years and 60 years, respectively. The low viability projections of this isolated panda population require strategies for restoring habitat quality of the Yele Nature Reserve.

Kohlmann *et al*. (2005) studies PVA on the Island Fox (*Urocyon littoralis*) in Sanata Catalina Island, California. They found the population to be susceptible to catastrophic events; a 50% increase in mortality every 20 years was sufficient to elevate the extinction risk above 5%. Current management activities entail the transplanting of 12 juvenile foxes annually, which may reduce the viability to reduce the risk of extinction due to demographic stochasticity. Releases of translocated and captive bred animals affect the speed of recovery on the eastern half of Catalina Island, but not the probability of extinction, which is near zero under current

conditions. They conducted a sensitivity analysis for demographic parameters by incrementally varying survival, fecundity and density-dependence parameters, while holding all other parameters constant. Sensitive analyses identified mortality and mean litter size as the most sensitive parameters, while the implementation of density-dependence and environmental variation of model parameters did not seem to affect population performance. They conclude that the population of island foxes on Sanata Catalina is currently at a critically low population level, but recovery of the species appears possible.

Brito and Fonseca (2006) used Vortex for Evaluation of MVA on the long-furred woolly mouse opossum (*Micoureus paraguayanus*) in Atlantic Forest. They found that the populations of 100 and 2000 individuals were necessary to achieve demographic and genetic stability, respectively, within a time frame of 100 years. The model was sensitive to changes in inbreeding depression, mortality and reproduction. The minimum area of suitable habitat estimated to contain genetically viable populations reached 1300 ha. Fortunately, there are still quite a number of forest remnants equal to or larger than this.

Barrio (2007) studies PVA on the Taruka (*Hippocamelus antisensis*) in southern Peru. This study found that the population exhibited a high sensitivity to changes in first-year mortality, immigration and fragmentation of the population. Taruka population size and survival probabilities did not exhibit sensitivity to changes in the carrying capacity of the area or to changes in environmental variation. Although the results of this study are open to alternative interpretation, the conservation and management of taruka in Aymara-Lupaca Reserved Zone may be helped by the findings of the viability analysis. Population variability analysis is a cost-effective tool in identifying factors that might affect the survival of taruka in southern Peru.

MATERIALS AND METHODS

Materials

1. Topographic maps of study area 1:50,000
2. Liquid-filled precision hand compasses
3. GPS receivers (Garmin 60csx)
4. Sets of cameras
5. Binocular
6. Camera trap (Bushnell Trail scout)
7. Time watching sets
8. 20 and 50 meter tapes
9. 20 and 50 kg. Spring weight balances
10. Waterproof marking pens
11. Aluminum labels
12. Data tables
13. Computer
14. ArcView GIS program version 3.3
15. Pellet Tube Sampling
16. Centrifuge machine, DENVILLE 260D

(DENVILLE Scientific. Inc, USA)

17. Dry Bath Incubator (Major Science Inc, Taiwan)
18. Gel documentation machine (Alphadigidoc™, EEC)
19. Gel electrophoresis Gelmate 200 (TOYOBO®, Japan)
20. U.V. Electronic U.V. Transilluminator (Alphadigidoc™, EEC)
21. PCR machine, PTC-200 (Peltier Thermal Cycler machine, USA)
22. Chromas LITE analysis program version 2.01
23. BioEdit Sequence Alignment Editor version 7.0.9.0

Methods

1. Population characteristics

A wildlife population is a group of a single species that live naturally together in the wild (Kutintara, 1994). The single species has intra-specific relationship and can breed naturally within a certain time. Each wildlife population has specific characteristics that can be described as birth rate, death rate, growth potential, density, age, and sex structure, dispersion, migration and genetic composition.

In order to understand the population characteristics of hog deer, this study investigated the population density, size and structure, breeding season, case of death and genetic diversity. The detail of each study method is as follows:

1.1 The density studied by the fecal pellet-group counts method

Population density is the number of individuals per unit area. Population density of a species is useful for understanding its natural history and interaction with the environment (Sinclair *et al.*, 2006). In this study, the fecal pellet-group counts method according to Bennett *et al*. (1940) was used to estimate the population density of hog deer. The details are as follows:

1.1.1 Placement of preliminary sample plots:

In this study, a line plot system was used to site temporary plots where they were likely to be visited by hog deer. The sample plots were placed at 20 m intervals and were circular in shape, with a 2 m radius and an area of 12.57 m^2 for both accuracy and convenience in fieldwork (Sukmasuang, 2001). Next, by observing the number of pellet group deposits in each plot, it was possible to calculate the optimal number of plots for the study. The number of sample plots needed was determined from a preliminary survey. This method was successfully applied to the study of sambar deer (*Cervus unicolor*) in Khao Yai National Park by Ngampongsai

(1977), using equation developed from Grieb (1958):

$$N = \frac{(t_{0.05})^2 \times S^2}{(0.20 \times \overline{X})^2}$$

Where:

N = number of plots needed
S^2 = variance of preliminary data
$\overline{X}$ = mean of preliminary data
0.20 = selected risk of error
$t_{0.05}$ = tubular value of "t" for the selected level of probability

Using the line plot system, 183 temporary plots were established to help in the determination of the optimal number of plots for the study (N). The result suggested that 170 plots were required ($\overline{X}$ = 2.5355, S^2 = 11.3710, $t_{0.05}$ = 1.96), but to ensure a more precise result and to compensate for some swamp plots that might be flooded, 183 plots were used in this study.

1.1.2 Placement of permanent plots:

After determining the optimal number of plots, a line plot system was used to locate the plots. Lines of plots were 100 m apart with the plots placed every 20 m along the line. Circular permanent plots with a 2 m radius and an area of 12.57 m^2 were established. The permanent plots were distributed throughout the grasslands and some portions of mixed pine-deciduous dipterocarp forest. The center point of each plot was marked with a bamboo plug, having a height approximately 20 cm above the surface of the plot.

1.1.3 Data collection:

Only deposit pellet-groups that fell within a 2 m radius of the plot were considered. The counting of pellet groups began 30 days after establishment of

the permanent plots (Kuntaro, 2002). All plots were checked every 30 days. The number of pellet groups found in a plot was counted and recorded, and then all pellet groups were cleared. When a pellet-group is scattered on the border of a plot it is counted as 1 group if more than 50% is inside the plot. If less than or equal to 50% is inside the plot the group is not recorded (Dhungle, 1985). Data collected during February 2008 to January 2010.

1.1.4 Defecation rate of hog deer:

Though the defecation rates are vary, the average number of pellet-groups defecated per individual per day can be used to estimate the actual or relative numbers of animals in a given area. This study used the defecation rate of hog deer in captivity, which is 12.10 times/individual/day, to estimate the density of hog deer per hectare (Kuntaro, 2002).

1.1.5 Calculating the population density of the hog deer: The following equation was used:

$$\text{Population/hectare} = \frac{\text{Number of pellet - groups/hectare}}{\text{Period of time (days) x rate of pellet deposit / individual/ day}}$$

1.2 The total number studied by total count method

Understanding animal abundance, distribution and movement patterns is an important aspect of wildlife management. Measuring abundance of animal populations essentially means census. Most census methods require complex statistical treatment of the data. No doubt some simple techniques, with a minimum of statistical treatment, can yield useful results if undertaken with a clear understanding of assumptions and limitations (Miththapala, 2011). In a total counting method, the entire area under surveillance is searched, and all hog deer sighted are counted. A disadvantage of this method is that it cannot account for errors (such as double counting), especially when the census is spread over several days. This

method would not be preferred for large areas where there are different terrains and habitats.

In this study, the yearly total count method as described by Sinclair *et al.* (2006) was performed 3 times (March, April 2009 after controlled burning in TKM area, and October 2009 which is the breeding season). By separating the census area where the hog deer were observed into 5 zones, the hog deer in all zones were counted concurrently in the early morning. The animals sighted within the entire distribution range represented the minimum number in the population.

1.3 Population structure

1.3.1 Sex and age structure: Population structure of hog deer was investigated by direct sighting (Appendix Figure 1). With sightings involving family groups, observed deer were divided into three age classes in the same as Dhungel and O'Gara (1991), namely adults (>24 months), juveniles (13-24 months), and fawns (1-12 months). Otherwise, male hog deer were divided into adults with hard antlers, adults with shed antlers and juvenile males. Data observation during January 2008 to December 2008 and data analysis were made to determine the percentage of each age and sex ratios in sightings of herds (two or more individuals) or solo animals (only one individual) and average herd size.

1.3.2 Recruitment rate: the method for the annual recruitment rate estimation by Dhungel (1985) was applied to study the hog deer in this area. The formula is (number of (juvenile + fawn) x 100) / total numbers of adult hog deer.

1.4 Cause of death

1.4.1 Direct observation: To investigate threats, the cause of death for any deer carcass found was identified and recorded for 15 days per month during November 2007 to December 2008.

1.4.2 Camera trap: Four sets of camera trap were used around the area more than 10 days per month for 8 months (January 2009 to September 2009) to investigate predator and scavenger species, which threaten the hog deer. Relative abundance (RA) was calculated by the following equation:

RA = (Trap success) x 100/ (trap night)

Where,

Trap success = Total number of each species detected by photos

Trap night = Total number of nights

1.5 Genetic diversity analysis

1.5.1 Sample collection: In total, 35 pellets group were collected from three sites of TKM, PKWS by suspended in storage buffer (DETs: 20% DMSO, 250 mM EDTA, 100 mM Tris, pH 7.5 and NaCl to saturation (Seutin *et al*, 1991).

1.5.2 DNA extraction: Pellet samples were extracted with a modified protocol from Boom *et al.*, 1990.

1) A sample (1.5 ml.) of the pellet was centrifuged in preservative for 15 min. at maximum speed. Then, the supernatant was discarded.

2) Lysis buffer L1 was added to a volume to 1.5 ml. The sample was then vibrated using a vortex and incubated the sample overnight at 56 ^{o}C.

3) The sample was centrifuged at 5,000 rpm to precipitate the pellet debris for 1 min. Then pipette 750 µl. of the supernatant into a new tube containing 250 µl. fresh L1 buffer and 50 µl. silica suspension.

4) The sample was vibrated with a vortex briefly and incubated at room temperature for 1 hour with shaking.

5) Following centrifuging for 1 min. at maximum speed, the supernatant was discarded.

6) The silica was washed with 1 ml. of wash buffer (L2), vibrated with a vortex to mix well and centrifuged for 1 min at 10,000 rpm. The supernatant was discarded and the process was repeated once.

7) Step 5.2.6 was repeated with 1 ml. of 70% ethanol. Pellets were dried at 56 ^{o}C for 30 min.

8) Then, 60 µl. of TE buffer was added and the sample incubated at 56 ^{o}C for 10 min.

9) After centrifuging for 1 min. at 10,000 rpm, the supernatant was transferred to a new tube by pipette and kept at -20 ^{o}C.

1.5.3 mtDNA d-loop amplification and sequencing: This process involved amplifying 405-bp segment of mtDNA, containing the d-loop, using published primers; Fw (5'-ATRATRTTCCGRCCAYTCAGCCA-3') and Re (5'-CCTGAAGAAAGAACCA GATGC-3') (W. Wajjwalku, pers. comm.). After the initial denaturation at 95 ^{o}C for 15 min, all DNA samples were run for 40 cycles with denaturation at 94 ^{o}C for 30 sec, then primer annealing at 54 ^{o}C for 1 min and primer extension at 72 ^{o}C for 1 min, followed by a final extension at 60 ^{o}C for 30 min. The sequence of the polymerase chain reaction (PCR) product (Appendix Figure 17) was determined by automated DNA sequence analysis (ABI Prism, Applied Biosystems).

1.5.4 Identify number of haplotypes: All sequences outputs were compared with GenBank database by BLASTn program (http://blast.ncbi.nlm. nih.gov/blast.cgi) for making sure those are correct sequences. After checking for correct sequences, each base character of all sequences was edited by eye on Chromas LITE analysis program Version 2.01 and then compared all sequences with BioEdit Sequence Alignment Editor version 7.0.9.0.

2. To investigate the adaptability:

Adaptability of a species to its new habitat is important to their survival. It is including physical condition, behavior, habitat use and preference. In this study the adaptabilities of the hog deer was investigated by direct observation. The details of each aspect are as follows:

2.1 Physical Condition

In this study the physical condition, according to Riney's field technique (Riney, 1960), of the newly released hog deer group was assessed before and after released to TKM as well as compared with the existed hog deer group. The data was collected from November 2007 to December 2008, in the existing hog deer by scan sampling method and in newly released hog deer by direct observation of each individual. The physical condition can be divided into 3 classes. Details of each class are as follows and shown in Figure 2.

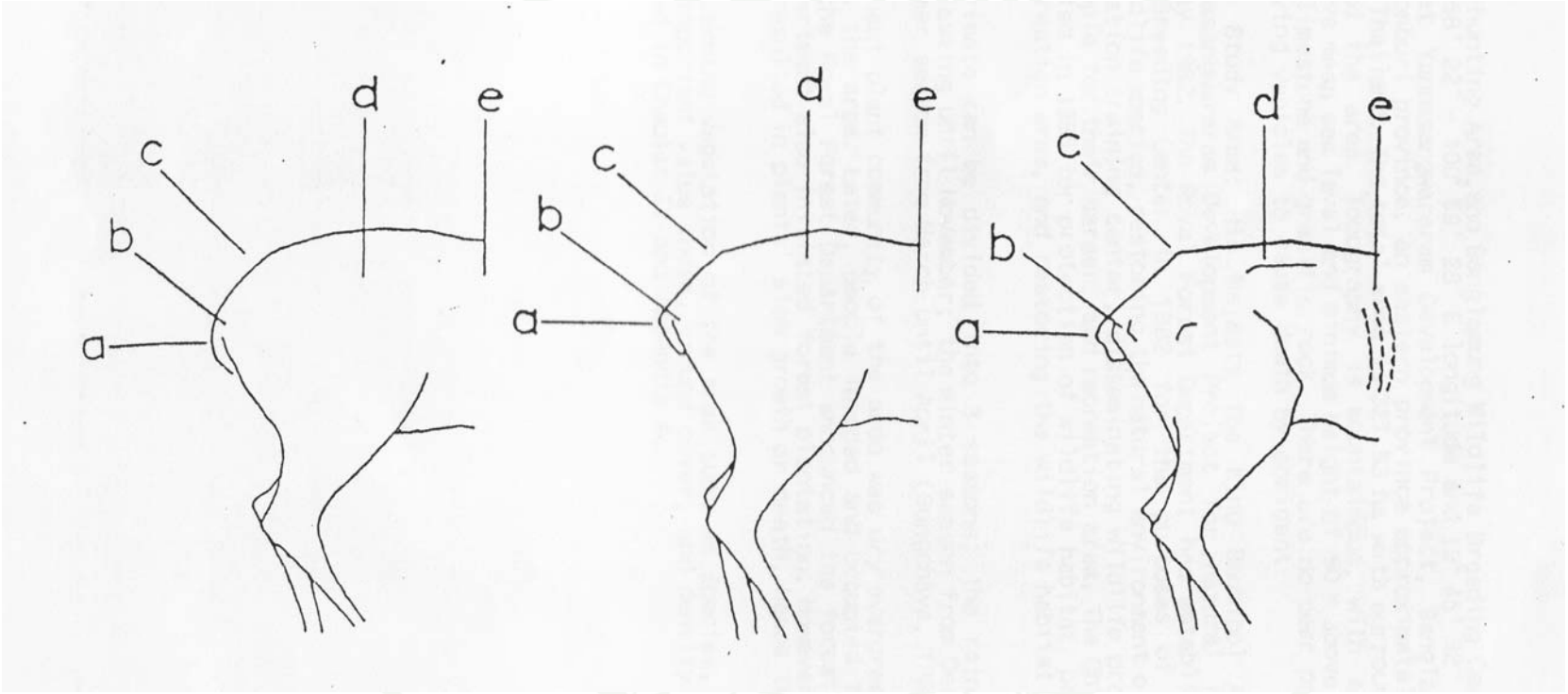


Figure 2 General appearance of the hind quarters of deer in good, fair, or poor condition.

Source: Riney (1960)

2.1.1 Good condition: if there were no angles corresponding to the tail (a) and distinct angle appearing at the point indicated (c) on the Figure 2 left.

2.1.2 Fair condition: between good and poor condition (Figure 2, middle).

2.1.3 Poor condition: if any one of the points indicated at the outline of a point of the pelvic girdle (b) could be seen; or if the lateral processes of the backbone vertebrate (d) could be seen as a faint line; or if the outline of the rips (e) were visible (Figure 2, right).

Rating of the physical condition: The rating sequences for poor, fair, and good condition of each individual were 1, 2, and 3 respectively. The average monthly scores representing the physical condition of the hog deer of the existing and newly released hog deer of each month were calculated and classified into 3 intervals. The class intervals used in this study was 1.00-1.67, 1.68-2.34, and 2.35-3.00 for poor, fair, and good condition respectively.

2.2 Behavior

2.2.1 The newly released hog deer behavior: Before release, each of the eight hog deer (three males and five females) was marked either with an ear tag or neck collar. Animal behaviors were observed via binoculars for more than 15 days per month at the proper distance on about 3 m above the ground-tower (Figure 3) during November 2007 to December 2009. The activity of each released hog deer was observed every 10 min from early morning (0600 hours) until evening (1800 hours). Hog deer's behaviors can be classified as feeding, ruminating, lying down, walking, running and other behavior. Each type of behavior was calculated as a percentage of the total behavior and showed by classified histogram**.**

2.2.2 The existing hog deer behavior: Animal behavior was observed via binoculars during more than 15 days per month during November 2007 to December 2008. The activity of each released hog deer was observed every 10 min from early

morning (0600 hours) until evening (1800 hours). Lying down, feeding, ruminating, walking, running and other behavior were observed and recorded by scan sampling methods (Altmann, 1973). The percentage of total behavior was calculated for all sightings and analyzed. The data were divided by sex and season.

2.2.3 Data analysis: Each type of behaviors was calculated as a percentage of the total behavior according to each hog deer group; the first year after released hog deer, the second year after released hog deer, and the existing hog deer. The data was analyzed using means of non-parametric test by the correlation test for comparison between; the male behavior of the first-year and second year after released hog deer (Altmann, 1973); the female behavior of the first-year and the second-year after released hog deer. The same statistic was used to compare the behaviors among the existing hog deer, the first-year after released hog deer and the second-year after released hog deer. The effect of seasonal difference on the behavior of hog deer was also determined.

Figure 3 Temporary tower for wildlife observation.

2.3 Habitat use

A Global Positioning System (GPS) receiver was used for more than 15 days per month to record the location of sighted animals for 2 years. Locations (based on the Universal Transverse Mercator (UTM) system) from the direct sightings were used to evaluate habitat use utilizing ArcView GIS 3.3 program to analyze the distribution range size in MCP% method (minimum convex polygon) (Kenward, 1987).

2.4 Habitat preference

The location of hog deer in each habitat type from Global Positioning System (GPS) receiver was calculated in percentage of occurrence in each type (percentage of usage), which were compared with available area (percentage of availability), then we can consider the area which was avoided or preferred (Johnson, 1980). Preference refers to habitat types where the animal spent more time than expected. Avoidance refers to habitat types where the animal spent less time than expected.

3. Forage species

3.1 The observation of the plants consumed by hog deer were accomplished by tracking and telescopic observation. Forage species were collected and identified.

Thirty 1x2 m plots were created to assess plant consumption and availability. Food preference ratings were calculated as described by Petrides (1975) in Appendix Table 12. In order to determine food preference relationships in the field, it is necessary to measure the amounts of various foods available (A) for feeding and the extent to which those foods are actually removed (R) by hog deer. The amounts of foods available can be converted directly into percentage available (a). The quantities of forage plants eaten, however, can be calculated as percentages of two types. The first, as explained above under food consumption values, comprises

the percentages (d) of each food species as components of the diet. The second is the relationship between the amount (R) of each species eaten and the amount available (A) of the food species. These latter values yield the percentages (r) of each species which is removed from the habitat by feeding. It is essential to distinguish between the two sets of feeding or utilization relationships (d and r). The preference rating is classified into 4 classes, which are (1) preferred ($p > 1.00$), (2) neglected ($p = 1$), (3) avoided ($p < 1.00$), and (4) totally avoided ($p = 0$).

3.2 The different species of plants that will be observed in (3.1) were classified according with reference to specimens held at the forest herbarium, Department of National Park, Wildlife and Plant Conservation, and the Division of Nature Sciences Research of the National Science Museum.

3.4 In this study was estimation by available forage in the area. Carrying capacity can be determined by the relationship between available forage resources and the specific nutritional requirements of the species. We assess usable plant for hog deer by consumed plot. Carrying capacity was then calculated by equation (Harlow, 1984; Hobbs, 1988):

$$K = \frac{A}{B \times days}$$

Where,

K = Carrying capacity
A = usable forage (gram/m^2)
B = mean daily dry-matter intake (gram / day)
days = days of use

4. Inter-specific Relationship

In this study the inter-specific relationship, which consisted of habitat sharing and competition by related animals (6 ungulate species and 3 predator species) was investigated by line plot system placed in TKM (Figure 4) in March and April 2011.

A total of 15 transect lines of 3 km each were set 200 m apart. The study plots of 2 m radius, in which track and sign and foot print of related animals be identified, were placed every 50 m along the line resulting in a total number of 848 plots in this study.

The percentage of occurrence frequencies of target animals in each habitat type were determined and compared by ANOVA (Duncan's multiple range test) at 95% confident interval.

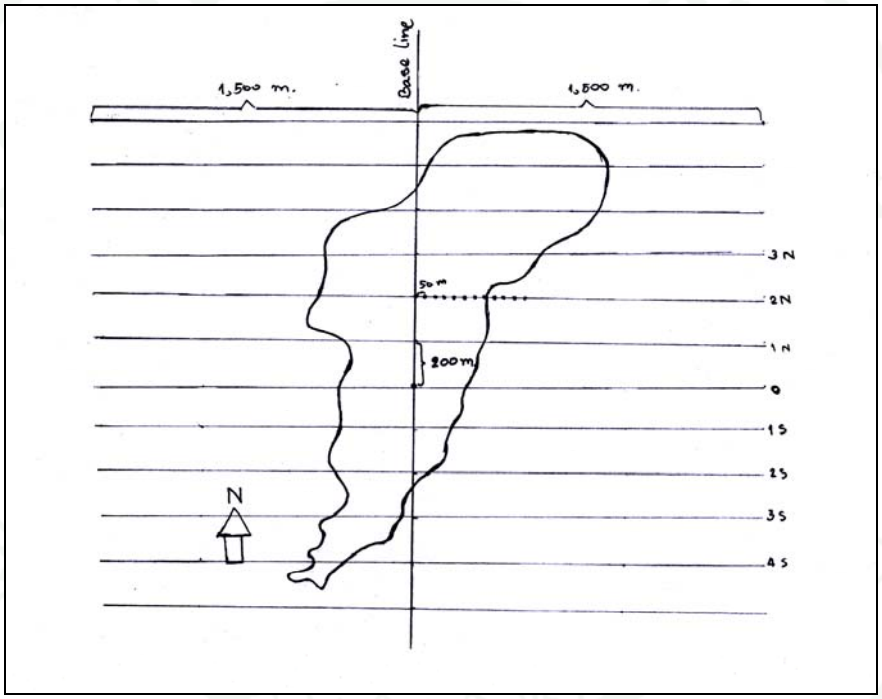


Figure 4 Sketch map of data collection in Thung Ka Mung area for habitat sharing and competition.

5. Probability distribution

In order to make the Maxent method available for modeling species geographic distributions, we implemented an efficient algorithm together with a choice of feature types that are well suited to the task. Maxent assigns a non-negative probability to each pixel in the study area. Because these probabilities must sum to 1, each probability is typically extremely small. The value assigned to a pixel is the sum

of the probabilities of that pixel and all other pixels with equal or lower probability, multiplied by 100 to give a percentage (Phillips *et al*, 2006). In this study we input the spatial data which are the wildlife coordinate from our data collection and environmental data significant to wildlife survival of PKWS which are saltlick, permanent and non-permanent stream, forest type, slope, digital elevation model (DEM), road, village, and ranger station.

A receiver operating characteristic (ROC) graph is a technique for visualizing, organizing and selecting classifiers base on their performance. An ROC curve is a two-dimensional depiction of classifier performance. To compare classifiers we may want to reduce ROC performance to a single scalar value representing expected performance. A common method is to calculate the area under the ROC curve (AUC). Since the AUC is a portion of the area of the unit square, its value will always be between 0 and 1.0. The AUC has an important statistical property: the AUC of a classifier is equivalent to the probability that the classifier will rank a randomly chosen positive instance higher than a randomly chosen negative instance (Fawcett, 2006).

These percent contribution values are only heuristically defined: they depend on the particular path that the Maxent code uses to get to the optimal solution, and a different algorithm could get to the same solution via a different path, resulting in different percent contribution values. In addition, when there are highly correlated environmental variables, the percent contributions should be interpreted with caution (Phillips, 2008).

These response curves show how each environmental variable affects the Maxent prediction. The curve show how the logistic prediction changes as each environmental variable is varied, keeping all other environment variables at their average sample value. The value shown on the y-axis is the predicted probability of suitable conditions, as given by the logistic output format, with all other variables set to their average value over the set of presence localities.

After analyzing, the habitat used probability was divided into 5 levels;

Level 1: Habitat use probability rage from 0-0.2
Level 2: Habitat use probability rage from 0.2-0.4
Level 3: Habitat use probability rage from 0.4-0.6
Level 4: Habitat use probability rage from 0.6-0.8
Level 5: Habitat use probability rage from 0.8-1.0

6. Population Viability Analysis

Fieldwork was conducted from November 2007 to December 2009. The collected ecological and biological data from fieldwork consisted of mortality from age 0 to 1, annual mortality percentage of adult female and male, percent of male in breeding pool, initial size of population, carrying capacity (K), and standard deviation in K due to environmental variation (EV). Other biological data including age of first offspring for females and males, maximum age of reproduction, and maximum number of progeny per year were gathered from report of Achapet (1997). Data concerning sex ratio at birth in percent male, percent adult female breeding, and EV in % adult females breeding (SD) were collected from captive hog deer in Huai Sai Wildlife Breeding Center in Phetburi Province.

The population viability analysis for hog deer was conducted with the Vortex program version 9.7 (Lacy, 2000) using all previously mentioned data. One thousand simulations were run for testing the hog deer population sensitivity to each different parameter.

Place and Duration

1. Study Area

The study site was concentrated in TKM grassland, PKWS (as shown in Figure 5).

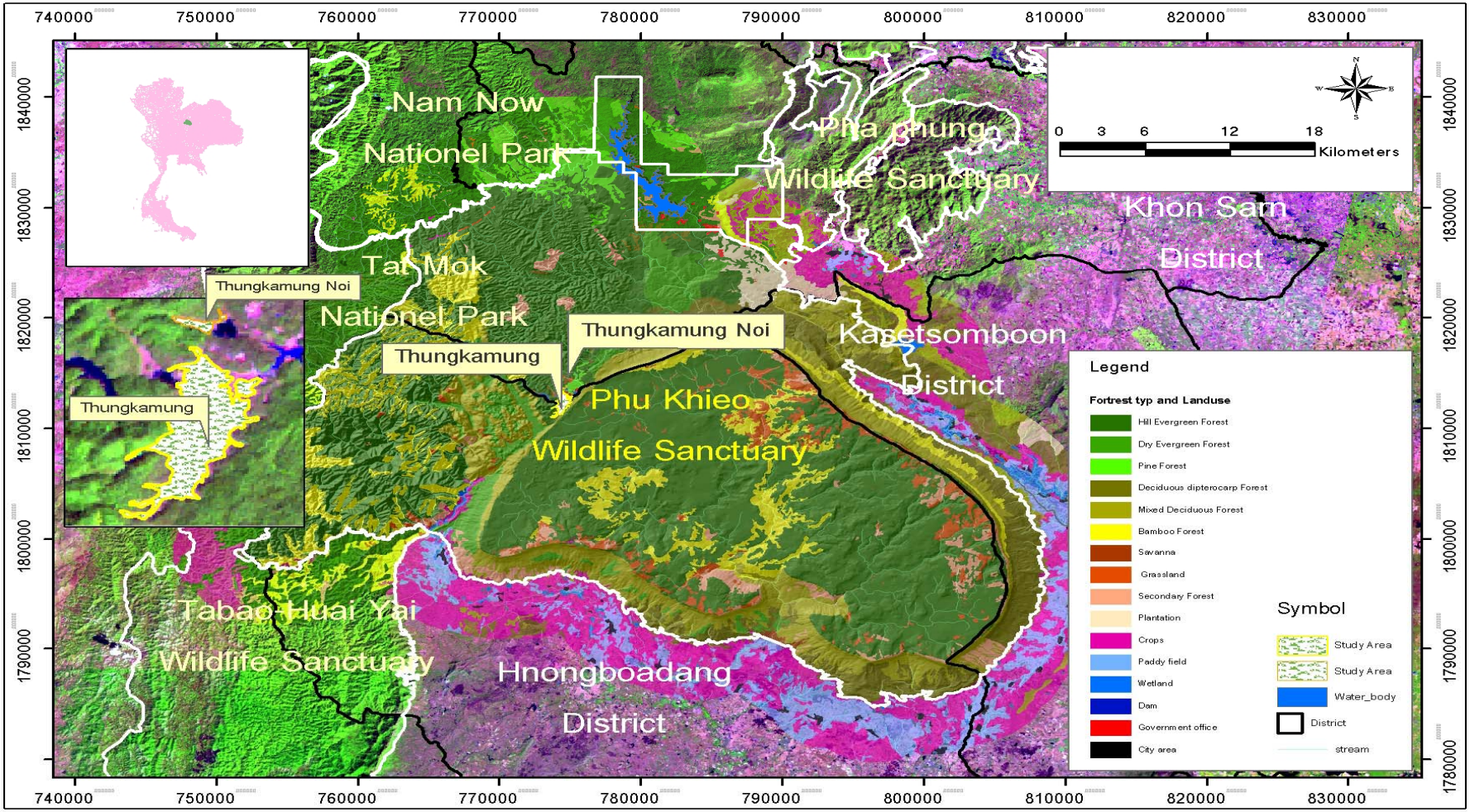


Figure 5 Map of Phu Khieo Wildlife Sanctuary and the location of study site.

1.1 Background Information: PKWS was established in 1972 by Thai government following a revolutionary committee's notice. The area covers approximately 1,560 km^2. It is located in Chaiyaphum Province. Due to the forest concession in the area, those areas encroached for agriculture and wildlife hunting subsistence by local people and settlements were found at TKM and Boung Mon. In 1972, all of 40 families from TKM and 100 families from Saraphrom villages were translocated to relocation sites. Some of them were resettled at Thung Lui Lai Area in Khonsan District, Chaiyaphum Province. In 1979, the Thai Government added some more areas into PKWS. 304 families of privates at Ban Nong Rai Kai, Ban Phromsong, Ban Pha Poung and Ban Somtoei were migrated into Dong Larn Reserved Forest Development Project at Khonkaen Province (Horata and Kreetiyutanond, 1997).

1.2 Location and Surrounding Area: PKWS is located at Latitude between 16º 5' to 16º 35' N and Longitude 101º 20' to 101º 55' E, with a total area 1,573 km^2. The sanctuary extends to Thung Lui Lai Subdistrict, Khonsarn District; Ban Yang, Ban Kha, Ban Boa Subdistrict, Kud Lao Kasetsomboon District; Nang Dad, Hnong Wang, Hnong Boa Dange, Tham Woa Dange Subdistrict, Hnong Boa Dange District; Chaiyaphum Province. The area of PKWS is connected with neighboring areas such as:

North to the Chulabhorn Hydro Electric Dam and Nam Nao National Park, Khonsarn District, Chaiyaphum Province and Muang District, Phetchaboon Province.

South to Ta–Boa Huai Yai Wildlife Sanctuary, Tham Woa Dange, Nang Dad, Hnong Woa Dange Subdistrict, Hnong Boa Dange District, Chaiyaphum Province.

East to Phu Some Pak Nam National Reserved Forest at the time but today there are establishment Pha Poung Wildlife Sanctuary in Kua Lao, Ban Yang, Ban Boa, Hnong Kha Subdistrict, Kasetsomboon District, Chaiyaphum Province.

West to Ta–Boa Huai Yai Wildlife Sanctuary and Tard Mog National Park, Muang District, Petchaboon Province.

1.3 Topography: The sanctuary covers altitudes ranging from 250–1,310 meter above mean sea level (MSL). The west and north side includes steep mountains and slope complexes, which are a part of the Petchaboon Range. They mostly have a steep slope at high elevations with rock outcrop soil. The east and the south are limited by 2 cliffs while in the center a big plain can be found which is covered by several forest types. Seven types of landform predominate, namely: plateau dip slope, plate scarp slope, cuesta, erosion surface, undulating plain, karst topography and hill and mountain.

1.4 Climate: The climate of the PKWS is classified according to Coppen's World Climate System as Tropical Savannah Climate: AW. Variations of this climate can be found on the upper plain as well as on the foot of the hills. The annual rainfalls in TKM for 14 years between 1996 and 2009 were 1,131.91 mm. The average minimum air temperature is 16.26 ºC, while the average maximum is 26.32 ºC. The average relative humidity is 91.71 percent (Table 1).

Based on the Walter's climate diagram of PKWS (as shown in Figure 6), the dry season (November-March) and the wet season (April-October) could be identified and used as reference for the observation periods for hog deer analysis.

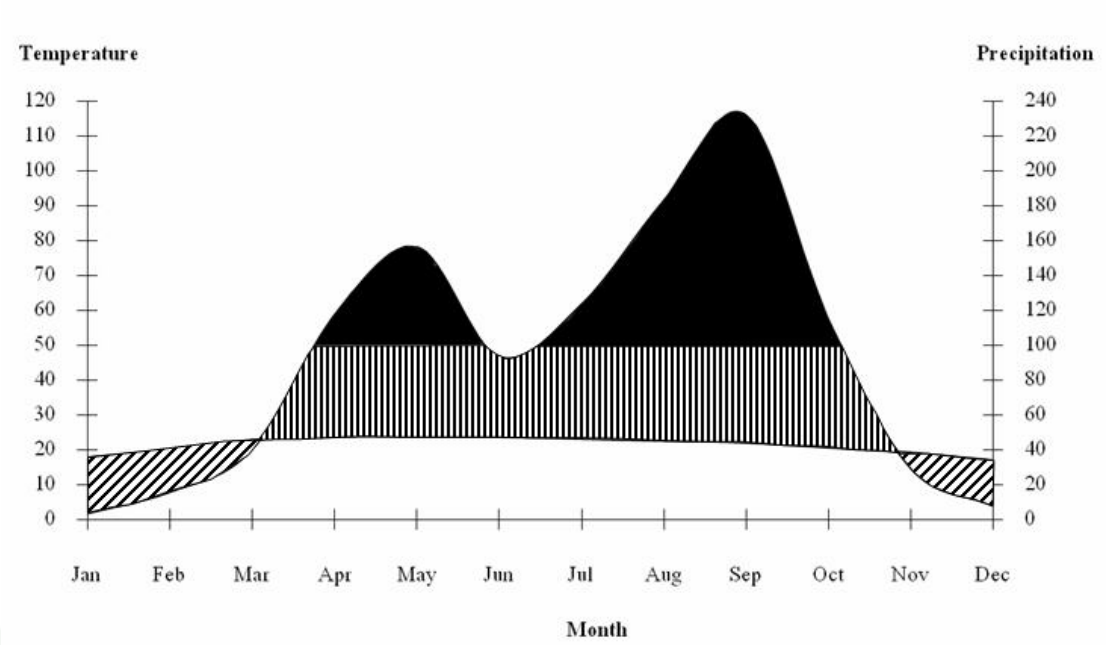


Figure 6 Walter's climate diagram of Phu Khieo Wildlife Sanctuary from the year 1991 - 1996, 1998 - 1999 and 2003 - 2009.

Source: Thung Ka Mung Climatology Station, Phu Khieo Wildlife Sanctuary (2009)

Table 1 Temperature (ºC) and Rainfall (mm) at Thung Ka Mung area in Phu Khieo Wildlife Sanctuary.

Month	2008				2009				1996-2009			
	Min	Max	Avg	Rainfall	Min	Max	Avg	Rainfall	Min	Max	Rainfall	Avg. Humidity
January	6.40	25.40	15.90	8.40	3.00	23.00	20.65	0.10	10.48	24.54	3.01	90.55
February	7.80	25.40	16.60	25.10	13.90	28.90	21.00	25.50	12.71	27.15	21.79	89.79
March	10.30	29.80	20.05	54.90	17.50	29.10	24.93	119.70	17.09	27.76	51.03	88.39
April	13.90	28.80	21.35	221.20	18.80	29.70	25.08	169.30	17.69	28.28	129.92	89.65
May	14.80	26.20	20.50	131.70	19.60	28.50	23.35	326.90	18.96	28.11	144.37	92.35
June	15.20	27.80	21.50	55.90	20.50	27.20	24.65	135.40	19.43	27.71	106.56	91.78
July	14.80	27.90	21.35	76.60	20.40	26.20	24.63	75.80	18.99	27.14	110.84	92.10
August	14.80	26.30	20.55	187.60	19.50	27.20	23.43	282.70	18.76	26.19	172.20	93.25
September	13.90	26.30	20.10	317.30	19.30	27.20	23.20	366.70	19.62	25.87	218.23	95.09
October	13.40	25.90	19.65	280.80	18.40	26.40	22.78	173.40	16.73	25.19	136.63	93.79
November	10.70	24.10	17.40	66.20	13.90	25.40	20.75	34.50	13.73	24.73	32.63	92.52
December	4.30	22.40	13.35	3.00	11.90	25.00	17.88	7.30	10.77	23.16	4.71	91.29
Total	140.30	316.30	228.30	1428.70	196.70	323.80	272.30	1717.30	195.08	315.82	1131.91	1100.54
Average	11.70	26.40	19.03	119.10	16.39	26.98	22.69	143.11	16.26	26.32	94.33	91.71

Source: Thung Ka Mung Climatology Station, Phu Khieo Wildlife Sanctuary (2009)

1.5 Vegetative Type: Horata and Kreetiyutanond (1997) classified vegetation covers around TKM area into 5 forest types as follows:

1.5.1 Hill Evergreen Forest, it prevails at area higher than 800 m., MSL. The mean temperature is less than 24 ºC, the humidity is higher than 90 percent. Dominant tree species are such as *Quercus auricoma, Lithocarpus dealbatus, Aquilaria crassna, Cacrydium elatum* and *Cimocarpus longan.*

1.5.2 Dry Evergreen Forest, it prevails at area lower than 800 m., MSL. The average temperature is higher than in the hill evergreen forest, but it has less average humidity especially in the dry season. Dominant plant species are such as *Lagerstroemia calyculata, Afzelia xylocarpa, Hopea ferrea, Memecylon geddesianum* and *Dendrocalamus strectus.*

1.5.3 Dipterocarp Forest, it can be subdivided into 2 types, there are deciduous dipterocarp forest and mixed pine–deciduous dipterocarp forest. The details are as follows:

1) Deciduous dipterocarp forest, it prevails at the slope of the mountains, with a long dry season and hot weather. It includes dominant plant species such as *Shorea obtusa, S. siamensis, Phyllanthus embrica* and *Phoenix acaulis.*

2) Mixed pine-deciduous dipterocarp forest, it prevails at about 700–900 m., MSL. The temperature is less than 25 ºC throughout the year. The areas are humid, have an intermediate slope and a good drainage. Dominant plant species are *Pinus kesiya, Dipterocarpus obtusifolius, Phyllanthus embrica* and *Quercus kerrii*.

1.5.4 Mixed deciduous forest, it prevails in the area of the north-east hill side, which is less than 600 meters above sea level. Generally, it looks similar to dipterocarp forest but does not have any Dipterocarpaceae. Often these areas contain bamboo. The dominant plant species are *Vitex peduncularis, Schleichera oleosa, Dalbergia nigrescans, Terminalia bellerica* and *Gigantochloa albociliata.*

1.5.5 Man-made Grassland, it prevails in areas which were previously used as agriculture areas such as TKM, Bung Pan, and Bung Ka. The dominant plant species are such as *Arundinaria pusilla* and *Cyperus* sp.

TKM grassland is a man-made grassland occurred after forest clearing for agricultural purpose by the villager living in this area before TKM has become a wildlife sanctuary. Flood plains occur during the rainy season. The data reported by Kumsuk and Kreetiyutanont (1999) in 1995 revealed that the grassland area of TKM was 1.50 km^2 and in 1998 was 1.33 km^2. The reduction in size of TKM was caused by the invasions of the surrounding forests, which are mainly rainforest and partially mixed-pine deciduous dipterocarp forest. TKM is the habitat of several herbivores and the source of food for predators. The herbivores found in this grassland include barking deer, sambar deer, lesser mouse deer, gaur, and elephant. The hunters found include Asian wild dog, small Asian mongoose, leopard cat, leopard and golden cat.

History of hog deer introduction in TKM area

Details of the hog deer introduction programs in TKM were listed in Table 2. In 1983, 4 hog deer (2 pairs) were released into TKM area in PKWS by the hog deer introduction project under Her Royal Queen Patronage and in 1987, other 6 hog deer (3 pairs) were released by the hog deer introduction project under his royal crown prince patronage in the same area. Khobkhet (1992) reported the number of hog deer increased to 21 individuals that separated into two herds, 8 and 13 individuals. These individuals foraged for food within approximately one kilometer radius from the released site. Then in 1992, 10 hog deer (5 pairs) were released under Her Royal Queen Patronage in the same area. Therefore the total introduced hog deer until 1992 were 20 individuals (10 pairs of adult). From the studied by Kuntaro (2002), the author reported that there were at least 68 individuals in TKM area. Recently in 2007, 8 hog deer (three males and five females) (Table 3) were released again at the same area for rehabilitation of the population (Figure 7). Now the released hog deer distribution around in the TKM area was cover an area approximately 5.03 km^2 (as shown in Figure 8).

Table 2 History of releasing hog deer in Thung Ka Mung area.

Year of releasing	Male	Female	Population source	Reference
1983	2	2	-	Kumsuk, *et al.* 1999
1987	3	3	-	Khobkhet, 1992
1992	5	5	-	Natural Resources Management section, 1992
2007	3	5	Nong Yai Private Zoo and Bang La Mong Wildlife breeding Center	our research

Figure 7 The former Prime Minister General (ret.) Surayud Chulanont during wildlife release ceremony at Thung Ka Mung on November 25th, 2007.

Table 3 Description of newly released hog deer in 2007.

Name	Figure	Sex	Age	Source	Identification	Remarks
FHD1		Female	3	Bang La Mong Wildlife Breeding Center	Orange Ear tag on left ear	Gestation before released
FHD2		Female	3	Nong Yai Private Zoo	Yellow Ear tag on left ear and has a radio collar	Gestation before released

)

Table 3 (Continued)

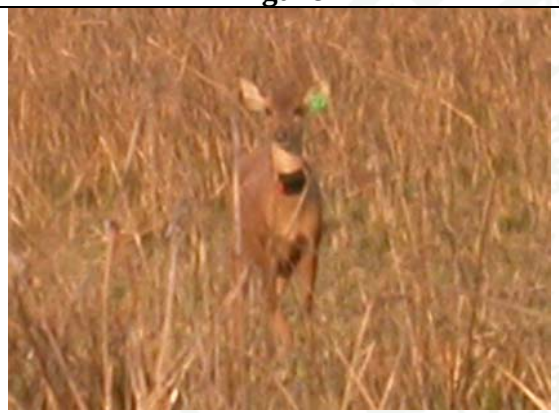
Name	Figure	Sex	Age	Source	Identification	Remarks
FHD3		Female	2	Nong Yai Private Zoo	Green Ear tag on left ear and has a radio collar	-
FHD4	No figure	Female	2	Bang La Mong Wildlife Breeding Center	Orange Ear tag on left ear	Disappear on January 2008
FHD5	No figure	Female		Nong Yai Private Zoo	Yellow Ear tag on left ear	Disappear on February 2008
MHD1		Male	2	Bang La Mong Wildlife Breeding Center	Yellow Ear tag on right ear and has a radio collar	Dark spot found on forehead area

Table 3 (Continued)

Name	Figure	Sex	Age	Source	Identification	Remarks
MHD2	No figure	Male	2	Nong Yai Private Zoo	Yellow Ear tag on left ear and has a radio collar	Disappear on December 2007
MHD3		Male	3	Nong Yai Private Zoo	Yellow Ear tag on right ear and has a radio collar	killed by Asian wild dogs on February 2008

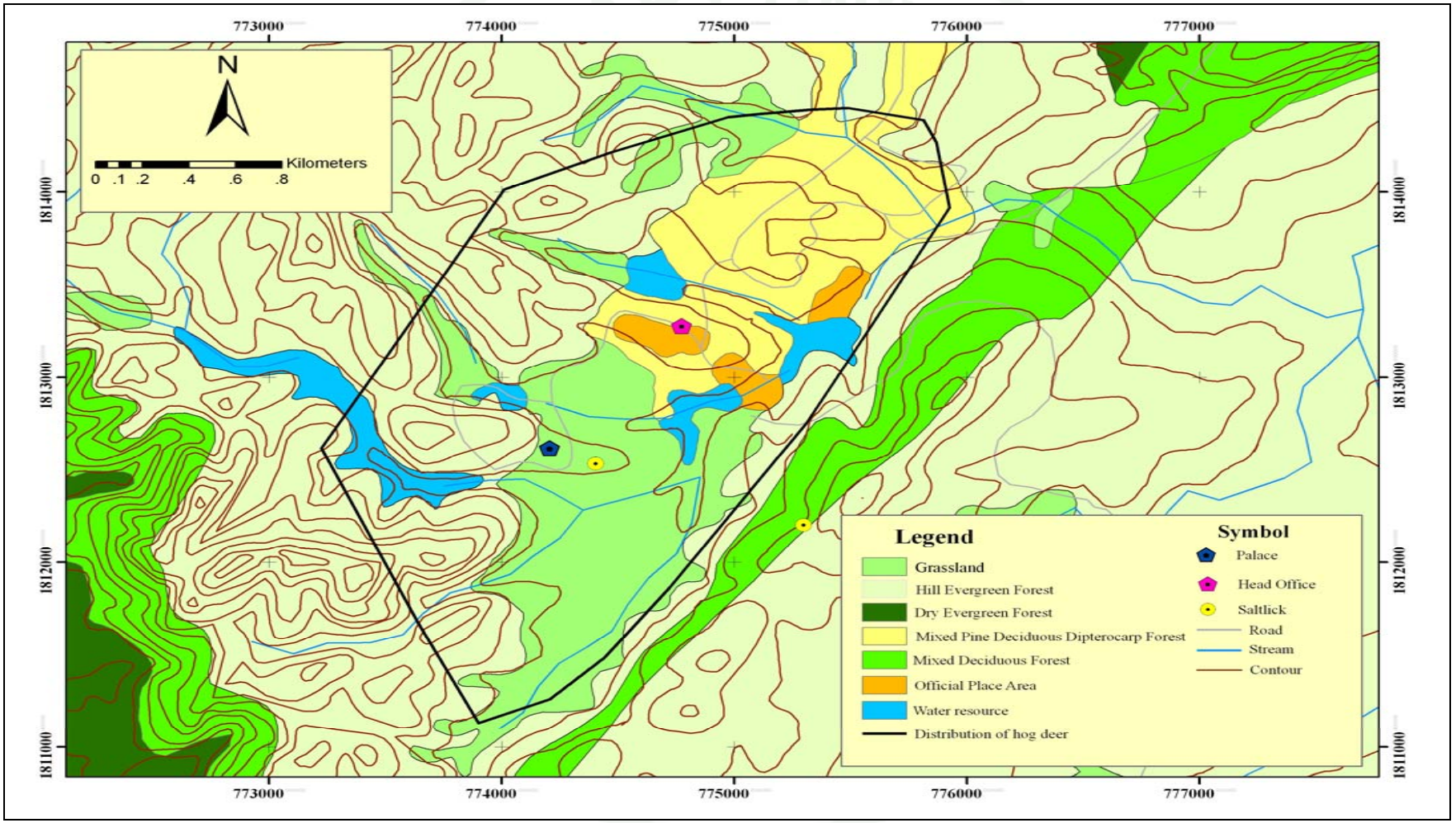


Figure 8 Map of Thung Ka Mung area in Phu Khieo Wildlife Sanctuary and the hog deer distribution.

2. Laboratory used for DNA analysis

DNA diversity was analyzed at operation building, Faculty of Veterinary Medicine, Kasetsart University at Kamphaeng Saen Campus, Nakhonpathom Province.

3. Duration

Data collection in field was conducted from November 2007 to January 2010 and DNA diversity analysis was conducted from January 2010 to April 2010. The total duration of this study covers a period of 2 years and 6 months. Additional study concerning inter–specific relationship was conducted for 2 months from March 2011 to April 2011.

RESULTS

1. Population characteristics

1.1 The density studied by fecal pellet group count method

In this study the population density of hog deer was determined by pellet group count method, which was performed for 2 consecutive years from February 2008 through January 2010. The results of monthly and yearly population density of hog deer are listed in Table 4. The highest population densities of the both periods were found in March 2008 and 2009, which were 4.23 and 4.41 individuals/ha respectively. The lowest population densities of both periods were observed in September, which were 0.43 and 0.74 individuals/ha in 2008 and 2009 respectively. The annually average population density of 2.03 (SD = 1.25) and 2.04 (SD = 1.25) individuals/ha were observed in periods from February 2008 to January 2009 and February 2009 to January 2010 respectively.

The seasonal differences of population density are listed in Table 5. The average density in the dry season (November-March) was higher than in the wet season (April-October) in both years. The average densities in the dry season in the first and second year were 2.51 and 2.34 individuals/ha respectively. The average densities in the wet season in the first and second year were 1.68 and 1.83 individuals/ha respectively. Anyhow statistical analysis revealed no significant difference of the densities between each season (t=0.45, *P*-value=0.63 during 2008-2009 and t=0.13, *P*-value=0.72 during 2009-2010).

Table 4 Monthly differences of average population density of each month at Thung Ka Mung from February 2008 to January 2010.

Month	Number of pellets		Deer/ha	
	2008-2009	2009-2010	2008-2009	2009-2010
February	277	266	3.32	3.19
March	353	368	4.23	4.41
April	278	283	3.33	3.39
May	211	77	2.53	0.92
June	180	118	2.16	1.41
July	112	300	1.34	3.59
August	37	121	0.44	1.45
September	36	62	0.43	0.74
October	129	107	1.54	1.28
November	125	120	1.50	1.44
December	239	79	2.86	0.95
January	54	142	0.65	1.70
Average			2.03	2.04
SD			1.25	1.25

Table 5 Seasonal difference of average hog deer density at Thung Ka Mung in Phu Khieo Wildlife Sanctuary.

Year	Deer density (individual/ha)		t	*P*-value
	The dry season	The wet season		
2008-2009	2.51	1.68	0.45	0.63
2009-2010	2.34	1.83	0.13	0.72
Average	2.43	1.73		

1.2 The total number studied by total count method

The total count method was a procedure to investigate the minimum number of the animal live in the area. The result showed that the average number was 124.33 individuals (SD=2.52). In this study the total count methods (Sinclair *et al.,* 2006) were performed for 3 times. The first total count in March 2009 resulted in a total number of 122 individuals. The second total count was done one month later in April 2009 and a total number of 124 individuals were reported. Age structure was not classified during the first and second count. The third total count was in October 2009 and resulted in a total number of 127 individuals. The hog deer populations composed of 25 adult males (19.69%), 16 juvenile males (12.59%), 49 adult females (35.58%), 25 juvenile females (19.69%) and 12 fawns (9.45%).

1.3 Population structure

The population structure was investigated by direct sighting method based on full time basic data between January 2008 and December 2008. Attempts were made to identify the sex and age class of hog deer which was systematically seen during direct observation.

1.3.1 Group size

The percentage of different types of groups from 1,410 sightings over one year at TKM were calculated to be solitary 8.5%, small (2-3 animals) 30.4%, medium (4-6 animals) 27.5%, large (7-10 animals) 11.5 %, and very large (>10 animals) 22.1% groups. Most of the solitary animals were adult males. Adult females mostly stay with their offspring. During the study period from January to December 2008, the average group size was 9.54 individuals (range 2-78, SD = 5.16). The average group size for the wet and the dry seasons were 12.71 (range 2-78, SD = 4.18) and 5.10 (range 2-43, SD = 2.18) individuals, respectively. Statistical analysis revealed that the herd size in the wet season was significantly higher than in the dry season, may be due to during the wet season is the reproductive period of the species ,

while percentage of solitary animal was significantly higher in dry season than wet season with 95 % confident interval. The frequencies of sighting of group size in the wet season and the dry seasons were shown in Figure 9 and 10.

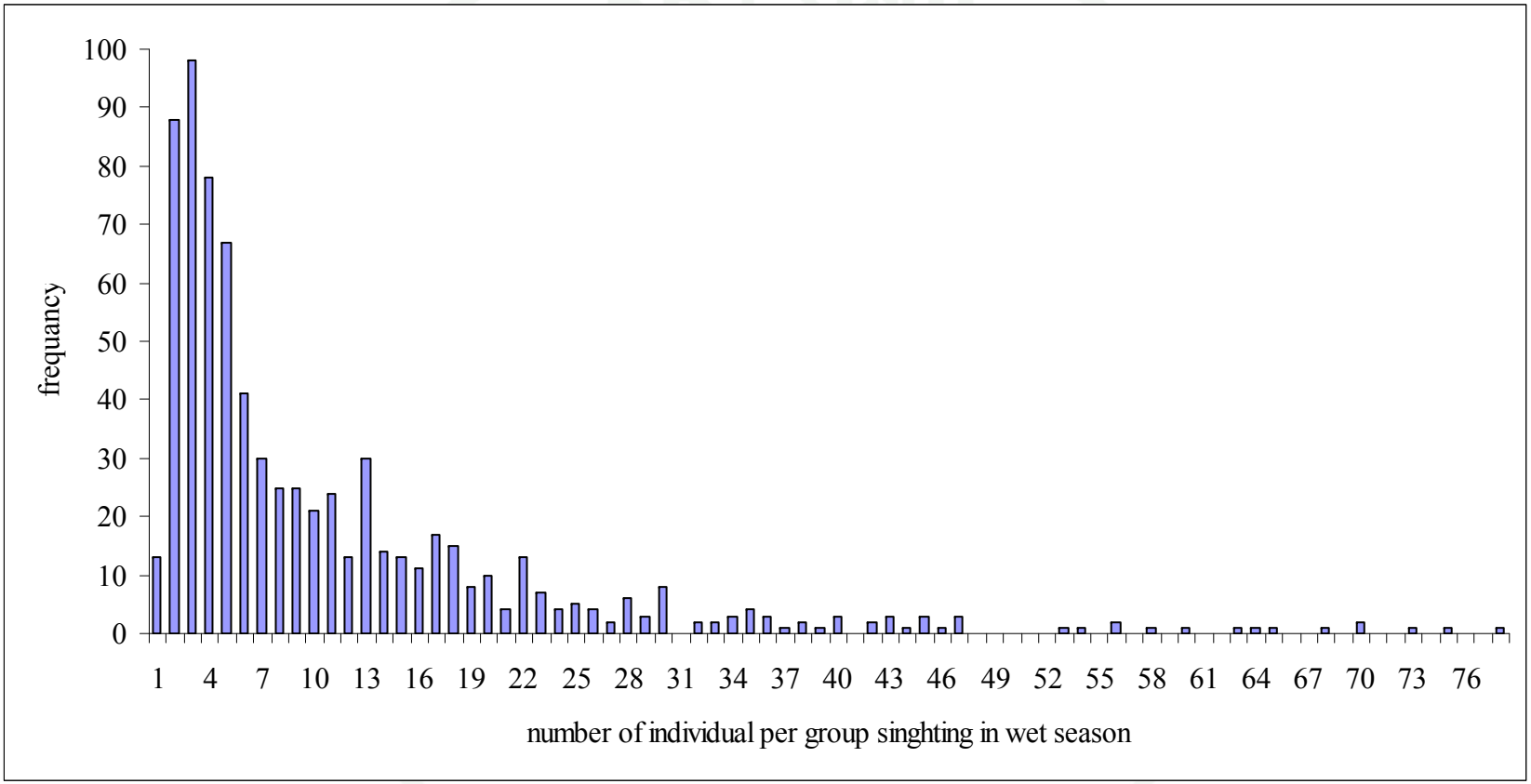


Figure 9 Frequency of sightings of hog deer by group size in the wet season (April to October) at Thung Ka Mung area.

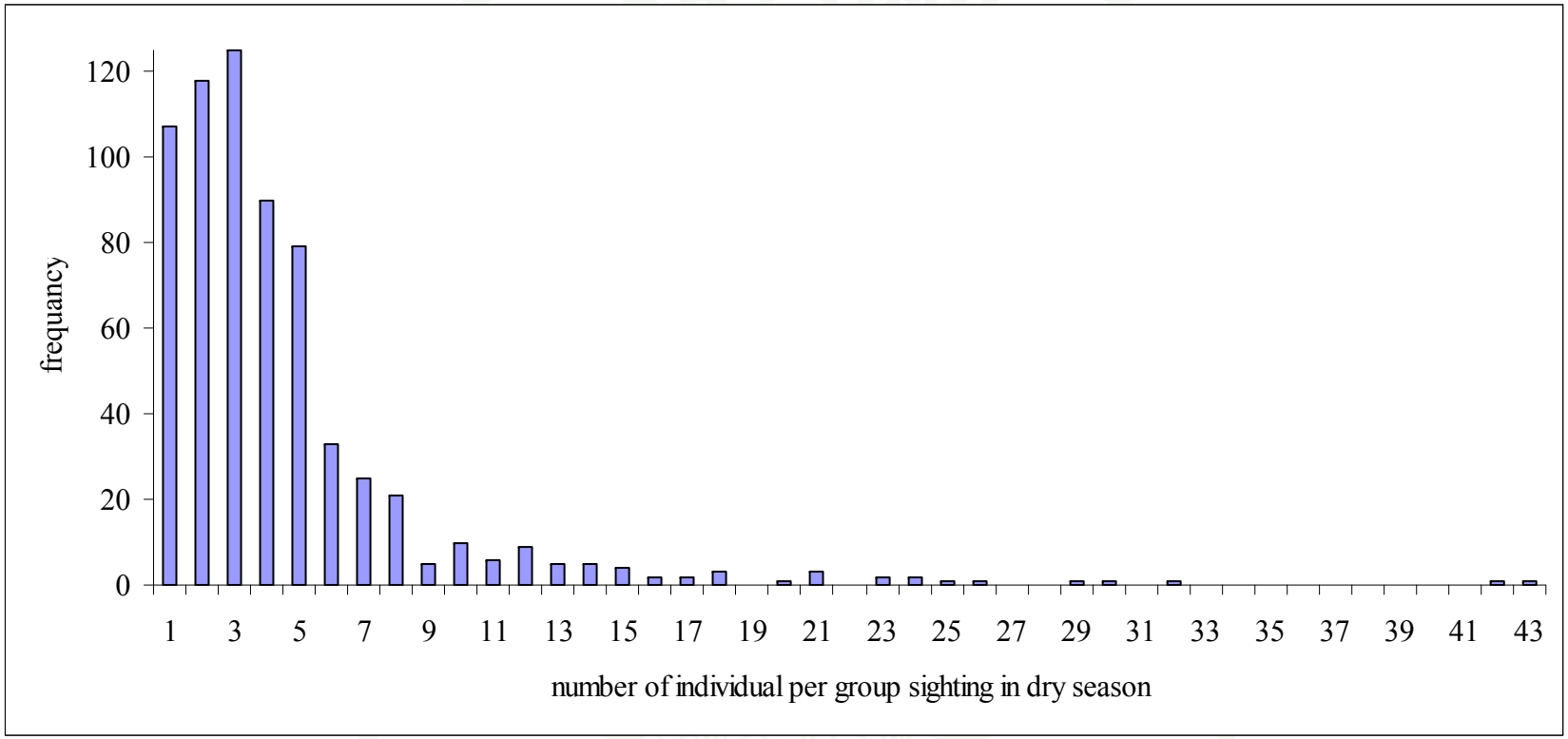


Figure 10 Frequency of sightings of hog deer by group size in the dry season (November to March) at Thung Ka Mung area.

Aggregation into bigger groups found in early the wet season (April), which is also the rutting season (Figure 11), resulted in the higher percentage of animals in groups but lower percentage of solitary animals. The largest number of a group ever found was 78 hog deer in May 2008. The average group size of more than 15 individuals found from May to August that synchronized with the highest peak of group antlers and with the lowest peak of shed or velvet antlers of the male hog deer (Appendix Figure 4).

Figure 11 A group of hog deer in the wet season at Thung Ka Mung area.

1.3.2 Age structure, sex ratio, and recruitment rate

The age structure and sex ratio of the hog deer population in this study was investigated based on the one year through out from January 2008 to December 2008. From 1,410 observation times, total of 11,260 individuals were seen. They comprised 797 shed or velvet antler males, 2,148 hard antler males, 5,423 adult females, 526 juvenile males, 948 juvenile females, and 1,421 fawns (Table 6).

Table 6 Monthly differences of percentage age structure and sex ratio of the hog deer at Thung Ka Mung in Phu Khieo Wildlife Sanctuary.

Month/year	Age structure					Sex ratio	
	Adult		Juvenile		Fawn	Male : Female	Adult female : Fawn
	Male	Female	Male	Female			
January 2008	28.30	41.97	2.70	7.63	19.40	1:1.60	2.16:1
February 2008	19.08	44.59	0.00	6.80	29.53	1:2.69	1.51:1
March 2008	19.22	46.04	1.16	3.70	29.88	1:2.44	1.54:1
April 2008	13.95	50.37	2.66	5.54	27.48	1:3.36	1.83:1
May 2008	25.28	51.33	5.80	3.56	14.04	1:1.76	3.65:1
June 2008	31.98	49.49	5.41	6.93	6.19	1:1.51	7.99:1
July 2008	34.36	41.14	7.23	16.91	0.36	1:1.39	113.75:1
August 2008	34.23	48.54	5.62	10.38	1.23	1:1.48	39.44:1
September 2008	24.15	57.63	5.79	10.03	2.40	1:2.26	24.00:1
October 2008	25.50	47.56	5.61	16.09	5.24	1:2.05	9.07:1
November 2008	32.12	37.67	10.71	15.68	3.82	1:1.25	9.85:1
December 2008	11.83	60.11	2.48	3.05	22.52	1:4.41	2.67:1
Wet season	28.33	49.32	5.48	8.52	8.35	1:1.70	5.09:1
Dry season	21.68	45.82	2.81	6.88	22.81	1:2.15	2.01:1
All year	26.15	48.16	4.67	8.39	12.62	1:1.83	3.82:1

The result showed in Table 6 the age classes of the hog deer in TKM during the study period consisted of 26.15% adult males (7.10% males with velvet or shed antlers and 19.05% males with hard antlers), 48.16% adult females, 4.67% juvenile males, 8.39% juvenile females, and 12.62% fawns. The result from this study revealed that the age structures of hog deer population in the dry and the wet season were different; the fawn percentages were higher in the dry season (22.81%) than the wet season (8.35%). The percentages of fawn found were increasing gradually in the dry season. The peak percentages of fawns were reported from February 2008 to April 2008 (see Figure 13). The percentage of adult male population was higher in the wet season (28.33%) than the dry season (21.68%).

The over all sex ratio (males to females) was 1:1.83 or 54.64:100 and for females to fawns was 3.82:1 or 100:26.18. The monthly comparison of hog deer structure is shown in Figure 12. The sex ratio in the wet season was different from the dry season. The male:female ratio in the wet season and the dry season were 1:1.70 or 58.8:100, and 1:2.15 or 46.5:100 respectively. The adult female: fawn ratio, which indicates the available females for breeding, in the wet season (5.09:1) was higher than in the dry season (2.01:1). The highest adult female:fawn ratio (113.75:1) was reported in July 2008.

The method for calculating the annual recruitment rate as used by Dhungel (1985) was applied to study the hog deer in this area. The formula is (number of (juvenile + fawn) x 100) / total numbers of adult hog deer. Therefore the annual recruitment rate of hog deer population in this study was 34.6 % (2,895 x 100/8,368).

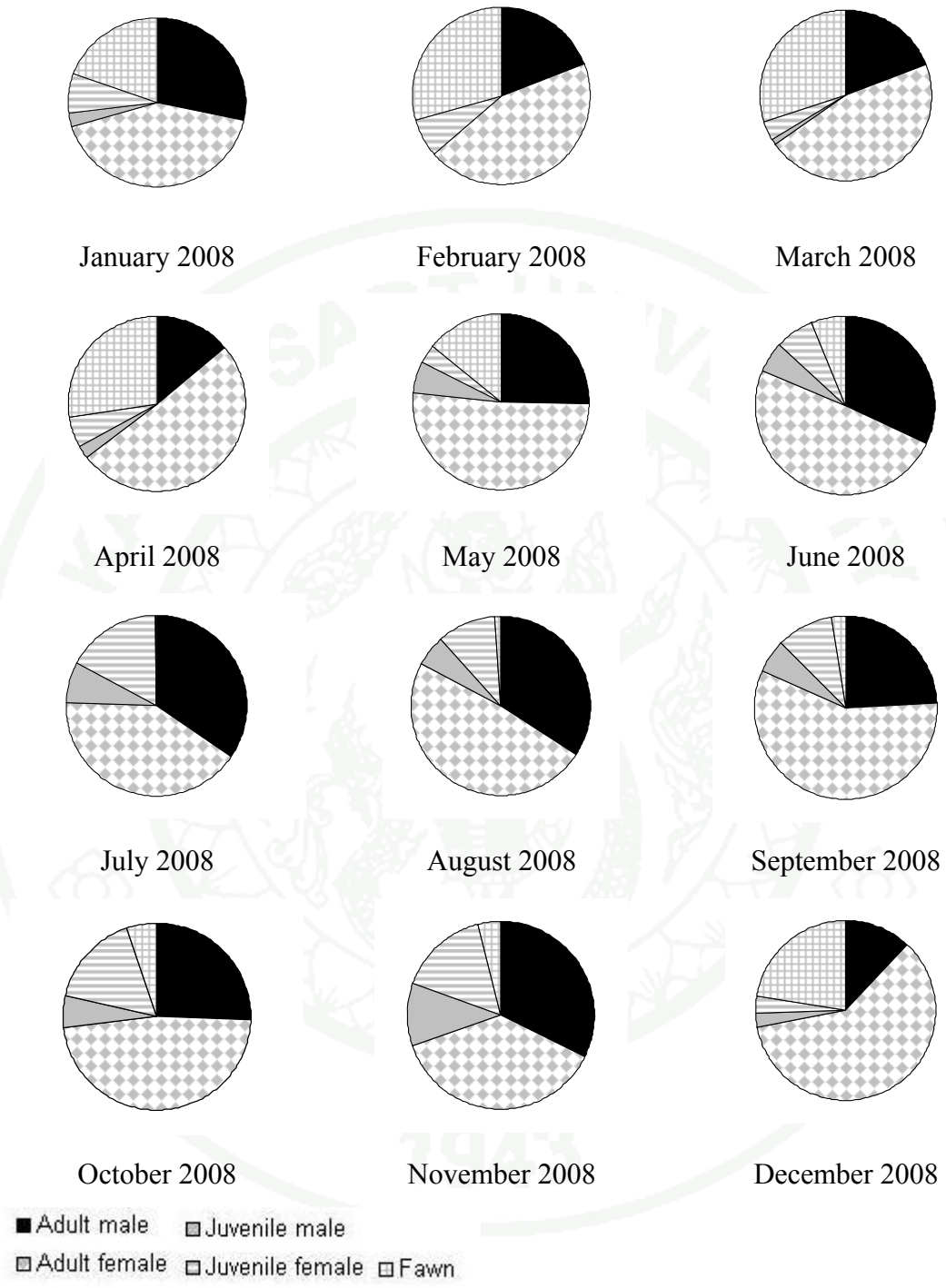


Figure 12 Monthly composition of the hog deer structure in Thung Ka Mung area base on direct sighting.

1.4 Breeding season

This study showed the percentage of adult male hog deer with hard antlers and shed or velvet antlers as well as the percentage of seen fawns in the study area each month synchronized with some climatic conditions over 15 years (Figure 13). Based on the 11,260 individuals hog deer from 1,410 observed time in various months between January 2008 and December 2008, 1,421 fawns were observed. The result from this study indicated that although hog deer has unrestricted breeding season as indicated from fawn stage that can be found all year round, the highest peak of fawns occurred during February and April that synchronized with the increasing in percentage of male with hard antler. The percentage of fawns in this period were almost 30% of the seen animals and the adult female:fawn ratio were 1.51:1-1.83:1 (see Table 6).

In general, breeding season of deer can be observed from its antlers. The breeding period occurs when male hog deer have hard antlers. After the breeding period, the animal will shed their antler (Appendix Figure 3) (Lekagul and McNeely, 1988) which synchronizes with 7-8 months of gestation period of the female. Increased proportion of adult males within the group in May (25.3%) suggests the onset of hog deer breeding season in TKM area. Therefore the conclusion was that the breeding season of hog deer in TKM occurs between May and October with the highest peak occurs during July and September.

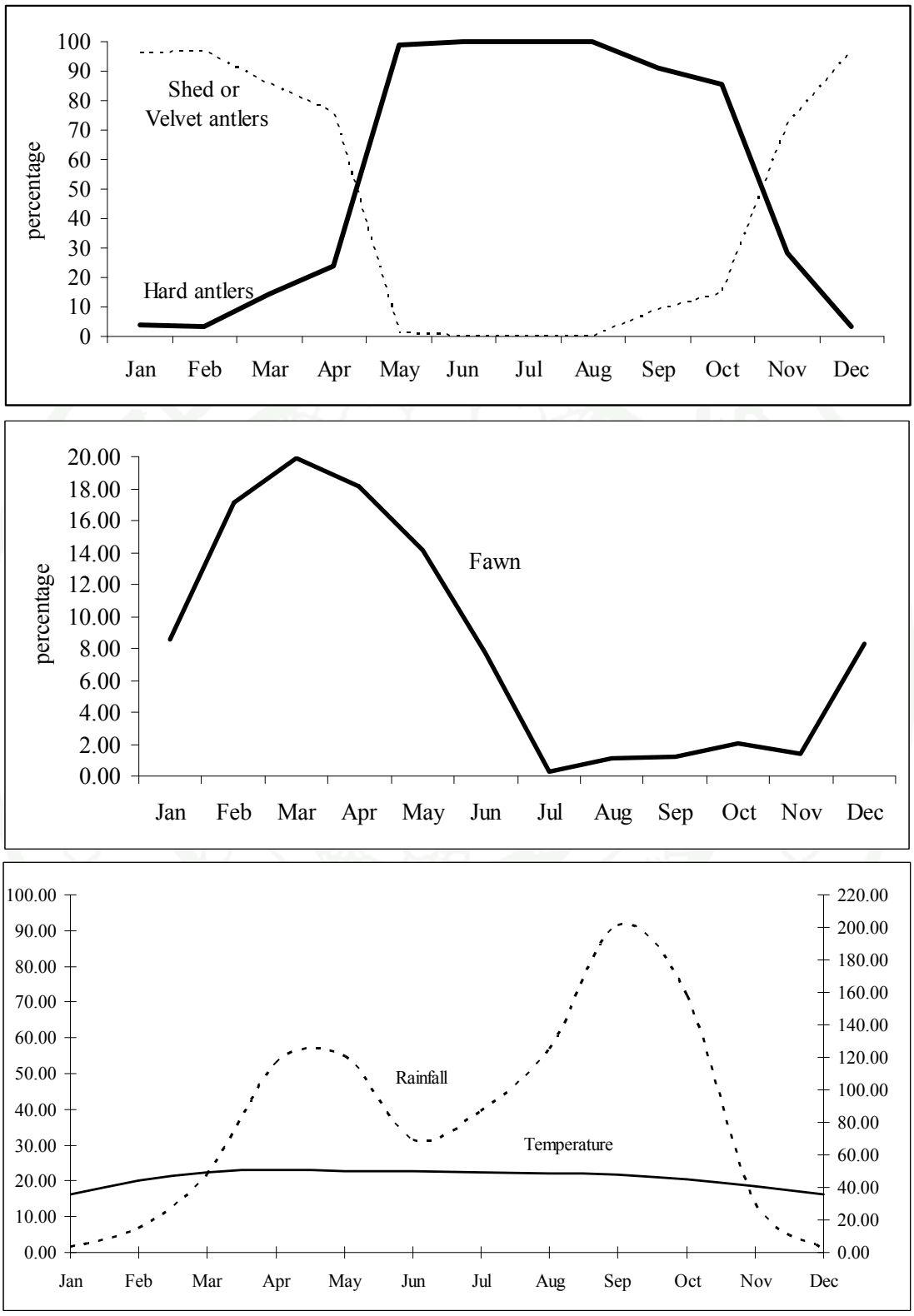


Figure 13 Percentage of seen adult male hog deer with hard and shed or velvet antlers related with percentage of seen fawn in 2008 and some climatic conditions in Thung Ka Mung from 1991-2009.

1.5 Cause of death

Number of death found and causes of death identified and recorded from January 2008 to December 2008 are listed in Table 7. Total numbers of 23 carcasses are comprised of 11 adult male carcasses, 8 adult female carcasses, and 4 fawn carcasses. The causes of death can be identified from the carcass observation or witness of the evidence. Three predator species can be identified to be the cause of death 16 carcasses. Asian wild dogs hunted 11 deer (6 males, 5 females) resulting in 47.82% of the death recorded and became the first in rank of hog deer predators in TKM. Burmese pythons killed 2 males and 2 fawns causing 17.39% of the death and became the second in the rank (Figure 14). Asiatic jackals killed one injured female causing 4.35% of the death and became the third in the rank. Diseases and accidental cases in these hog deer population were not recorded from this study. However the cause of 7 carcasses (3 males, 2 females, and 2 fawns) causing 30.44% of the death could not be identified.

Focusing on the newly released hog deer group, of which all individuals were tagged before release 5 out of 6 carcasses were not found and death could be assumed from their disappearance. One carcass of male found in February 2008 was identified and the cause of death by Asian wild dog was reported (Appendix Figure 16). The mortality rate of the newly released hog deer was 50.0% as presented in Table 8. The mortality of newly released males, females, and fawns was 66.67, 40.00, and 50.00% respectively.

As listed in Table 7, the number of death of male, female, and fawn was 11, 8, and 4 respectively. Mortality rates male, female and fawn can be estimated by comparing the number of death with the total number of the hog deer achieved from total count methods (41 males, 74 females, and 12 fawns). Thus the mortality rate for males, females, and fawns was 26.82%, 10.81%, and 33.33% respectively.

The camera trap technique was employed to investigate the predators around TKM area. This investigation covered 125 days between January 2009 and

September 2009. A total of 16 species of wild animals from 433 photos were gained from 447 trap nights in 14 locations. The study area and locations of the camera trap were shown in Appendix Figure 12. The dominant predators were leopard cats, Asian wild dog (Appendix Figure 13), Asiatic jackal (Appendix Figure 15) and clouded leopards (Appendix Figure 14) and their relative abundances were 1.3%, 1.1%, 0.9%, and 0.4% respectively (see Table 24). Most of the predators found in TKM were small carnivore species that can hunt only the hog deer fawn. Only Asian wild dog and clouded leopards are the potential predators for hog deer in TKM.

Table 7 Number of hog deer carcasses caused by each predator in the study area during January 2008 to December 2008.

Prey/sex	hog deer			Total	%
Predator	Male	Female	Fawn		
Asian wild dog	6	5	-	11	47.82
Burmese Pythons	2	-	2	4	17.39
Asiatic Jackal	-	1	-	1	4.35
Unidentified	3	2	2	7	30.44
Total	11	8	4	23	100.00

Figure 14 Hog deer was being eaten by Burmese python.

Table 8 Number of alive, dead, and mortality rate of the newly released hog deer during January 2008 to December 2008.

Status	Male	Female	New Fawn	Total
Alive	1	3	2	6
Dead	2	2	2	6*
Total	3	5	4	12
% Dead	66.67	40.00	50.00	50.00

*= only 1 adult male carcass was found and identified as killed by Asian wild dog. Other 5 deer have disappeared, thus 5 deaths were assumed for 1 male, 2 females and 2 fawns

1.6 Genetic diversity

From the studied by S. Dejchaisri, 2007 (pers. com.), the author was reported that there are 11 different haplotypes of hog deer in Thailand. In this study, the results from mitochondrial DNA analysis of 32 samples from the existing hog

deer and 3 female samples from newly released adult hog deer identified by five positions of nucleotide that differed are listed in Table 9. The results revealed that there are 3 different haplotypes which were composed of 59.4% haplotype APT02 (19 samples), 37.5% haplotype APT10 (12 samples), and 3.1% haplotype APT06 (1 sample).

Focusing on the mitochondrial DNA analysis of the newly released hog deer, which are 3 females, the result showed that, all three female deer from the newly released hog deer have different haplotypes (APT10, APT06, and APT09). Thus, there are four different haplotypes (APT02, APT10, APT06, and APT09) in TKM (Table 9). The pellet sampling method revealed that the hog deer with different haplotypes were mixing together and scattering throughout the area.

Table 9 Polymorphic sites among genetic haplotypes based on 405 bp of the partial mitochondrial DNA control region.

	Position in base sequencing					Number of samples	
	63	**244**	**262**	**309**	**388**	Existing hog deer	Newly released hog deer
APT02	-	T	G	C	G	19 (59.4%)	0
APT10	A	.	A	T	A	12 (37.5%)	1 (Female)
APT06	-	.	A	.	.	1 (3.1%)	1 (Female)
APT09	-	C	A	.	.	0	1 (Female)

- insertion/deletion base

. same base on top

2. The adaptability of newly released hog deer

2.1 Physical condition

The physical condition of the newly released hog deer were investigated to observe their adaptability to the new habitat by comparing with the existing hog deer.

The result from this study (Table 10) revealed that the newly released hog deer could adapt themselves to the new environment in TKM area (average body score for male was 2.57 and average body score for female was 2.40). After a period of 6 months they have developed their physical conditions and their body scores (male = 3.00, female = 2.67) were comparable to those of the existing hog deer (male = 2.84, female = 2.54) (see detail of body score in Appendix Table 4-5).

Table 10 Average body score of the hog deer determined by seasons.

Average body score	Newly released hog deer		Existing hog deer	
	Male	Female	male	Female
dry season	2.29	2.19	2.56	2.49
wet season	2.86	2.62	2.71	2.61
all year	2.57	2.40	2.64	2.55

During the first two months, the newly released hog deer were smaller and thinner than the existing released hog deer. Their physical condition could be classified as fair condition (average body score was 2.00) according to Riney's classification (Riney, 1960). Their physical conditions were obviously developed by May, which was the sixth month after release (Figure 15). They showed a substantial improvement in their physical condition with the average body score of 3.00 for male and 2.67 for female, which are classified as good condition (average body score was 2.67-3.00). However when comparing the size of the newly released hog deer with the existing hog deer of the same age class, the newly released hog deer was smaller than the existing hog deer.

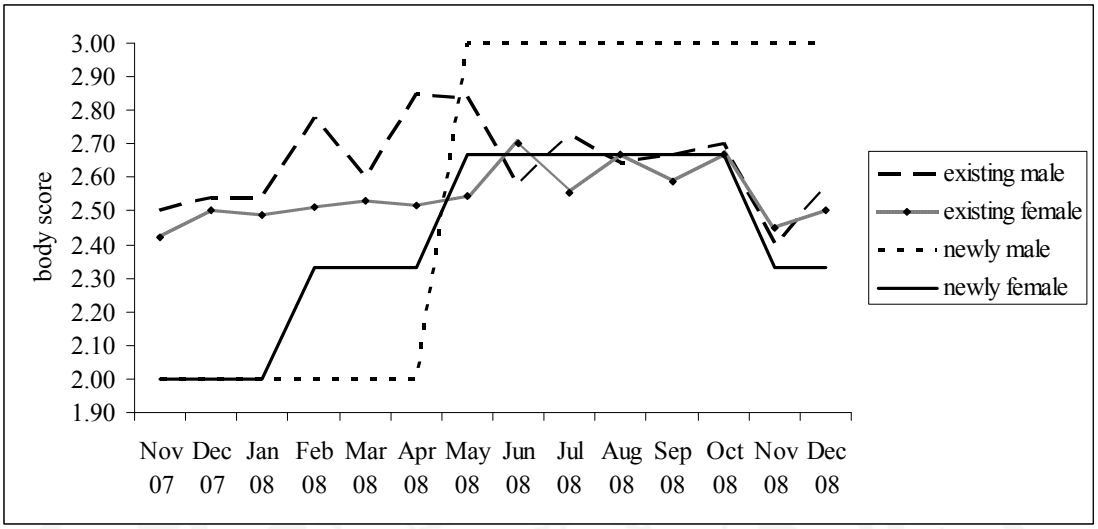


Figure 15 Body score trend of the hog deer in Thung Ka Mung.

In Table 10, based on the scan sampling method used in this study, the results showed that the average body score of the existing hog deer were 2.64 for male and 2.55 for female. The hog deer in TKM have a better physical condition in the wet season (male = 2.71, female = 2.61) than in the dry season (male = 2.56, female = 2.49). In general, male hog deer have a higher body score than female hog deer. The average body score of the newly released hog deer were 2.57 for male and 2.40 for female. The newly released hog deer in TKM have a better physical condition in the wet season (male = 2.86, female = 2.62) than in the dry season (male = 2.29, female = 2.19).

Forage available has an influence on the body score of male hog deer. In the study area, range management by controlled burning was performed in the late dry season (January 2008 – March 2008), resulting in plenty of new grass shoots. The average body score during this period (ranged from 2.54 to 2.78) (see Appendix Table 4) were higher than in the early dry season (ranged from 2.50 – 2.54) (see Appendix Table 4). But its effect on the body scores of the female hog deer was different. The results from this study showed that fawning has strong influence to the body score of the female hog deer. Even with range management by control burning in January 2008 to March 2008, the female hog deer have had the lowest body score ranged from

2.49 to 2.53 during this period, which synchronized with the peak fawning season (see Appendix Table 4).

Breeding season has also strong influence on the body score of male hog deer. The presence of 100% observed males with hard antlers and the increased proportion of adult males within the group in May 2008 suggest the onset of hog deer breeding season in TKM area, which synchronized with highest body score (ranged 2.84 to 2.85) (see Appendix Table 4) of male hog deer in April 2008 and May 2008.

2.2 Reproduction of newly released hog deer

Three months after releasing, one adult female hog deer (FHD2) gave birth in February 2008, but two weeks later the fawn disappeared and the mother deer appeared injured, so that a predator in the TKM area was suspected. The same female (FHD2) then mated with a male hog deer from the existing hog deer and gave birth again in March 2009. The new fawn was a female (Figure 16). Another female (FHD1) in the newly released hog deer gave birth to a male in March 2008. Another female (FHD3) of the newly released hog deer mated with a male from the existing hog deer in September 2008 and gave birth in June 2009, but the fawn disappeared after two weeks. There were 4 fawns belonging to the newly released hog deer but only two can survive. At the end of the study period, all surviving fawns from the newly released hog deer were still dependent on their mothers and remained in the hog deer.

Figure 16 Newly released female hog deer (FHD2) (2007) and its fawn (March 2009).

2.3 Behavior

In this study the hog's behaviors, which comprise of feeding, lying down, walking and running, ruminating, and other, were investigated by scan sampling method. The results revealed the average time of each behavior that the hog deer spent during the observed time from 0600 to 1800.

The behaviors of the existing hog deer were investigated for one year including both the wet and the dry season and used for comparing with the data collected from the newly releasing hog deer in order to determine the adaptability of the newly released group to the new habitat. The 2 consecutive year data of the newly released hog deer was collected from January 2008 to December 2009. It included 2 wet seasons and 2 dry seasons.

1. Behavior of the existing hog deer in TKM

The results from the present study showed that the average times spent for all behaviors of one year data during day time were similar for both males and females. Based on the correlation test at with 95% confidence intervals, there was no significant difference in all behaviors between the existing male and female hog deer. Hog deer spent most of the time feeding, which comprised of 69.4% for males and 69.2% for females. The average times spent of each behavior of the existing males (Figure 17e) were feeding (69.4%), lying down (13.1%), walking and running (7.6%), ruminating (8.0%), and other behavior, such as antler butting, using the salt lick and drinking water (1.9%). The average times spent of each behavior of the existing females (Figure 17f) were feeding (69.2%), lying-down (13.1%), walking and running (7.6%), ruminating (8.3%) and other behavior, such as using the salt lick, and drinking water (1.8%). The result revealed that most observed behaviors including feeding, lying, walking, and running, and ruminating, which occupied almost 98% of the observed time, were similar between males and females in both the wet and the dry seasons. Only the "other" behavior in the wet season of male (2.1%) was significantly different from female (1.1%) as well as the "other" behavior in the dry season of male (1.8%) was significantly different from female (2.2%).

Focusing on the existing male hog deer's behavior; the male hog deer spent significantly more time feeding in the wet season (80.5%) (Figure 19e) than in the dry season (64.4 %) (Figure 18e). The stag spent significantly fewer time lying-down and ruminating in the wet season (7.5%, 1.9% respectively) than in the dry season (15.7%, 10.5% respectively). The average times of walking and running as well as other behavior of them in both seasons were similar.

Focusing on the existing female hog deer's behavior; the hinds spent significantly more time feeding in the wet season (80.6%) (Figure 19f) than in the dry season (64.0%) (Figure 18f). They spent significantly fewer time lying-down, ruminating, and other behavior in the wet season (8.9%, 2.3%, 1.1% respectively)

than in the dry season (15.3%, 10.7%, 2.2% respectively). The average times of walking and running behavior of them in both seasons were similar.

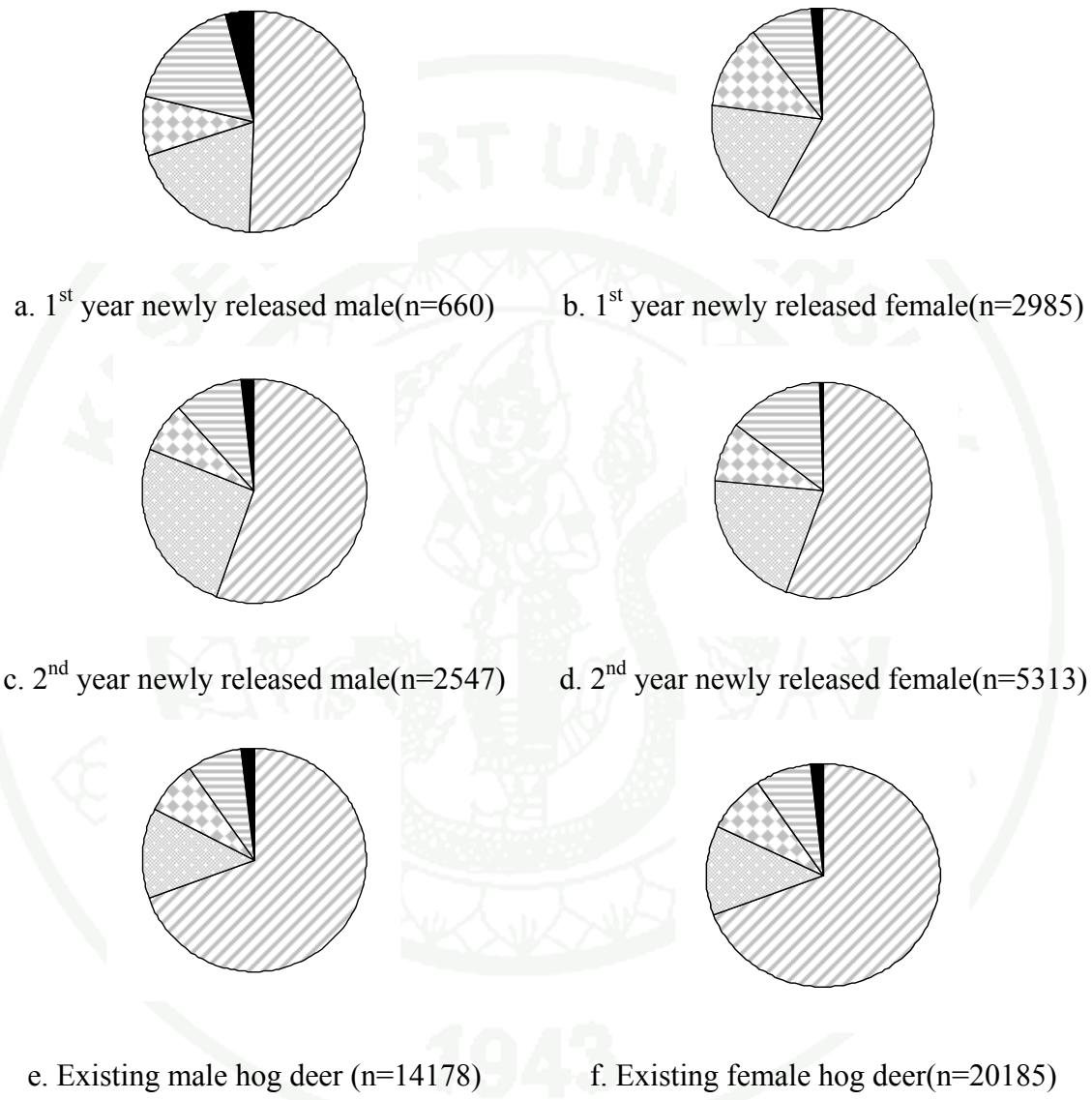


Figure 17 Level of each behaviors for male and female newly released hog deer and the existing hog deer as determined by scan sampling method.

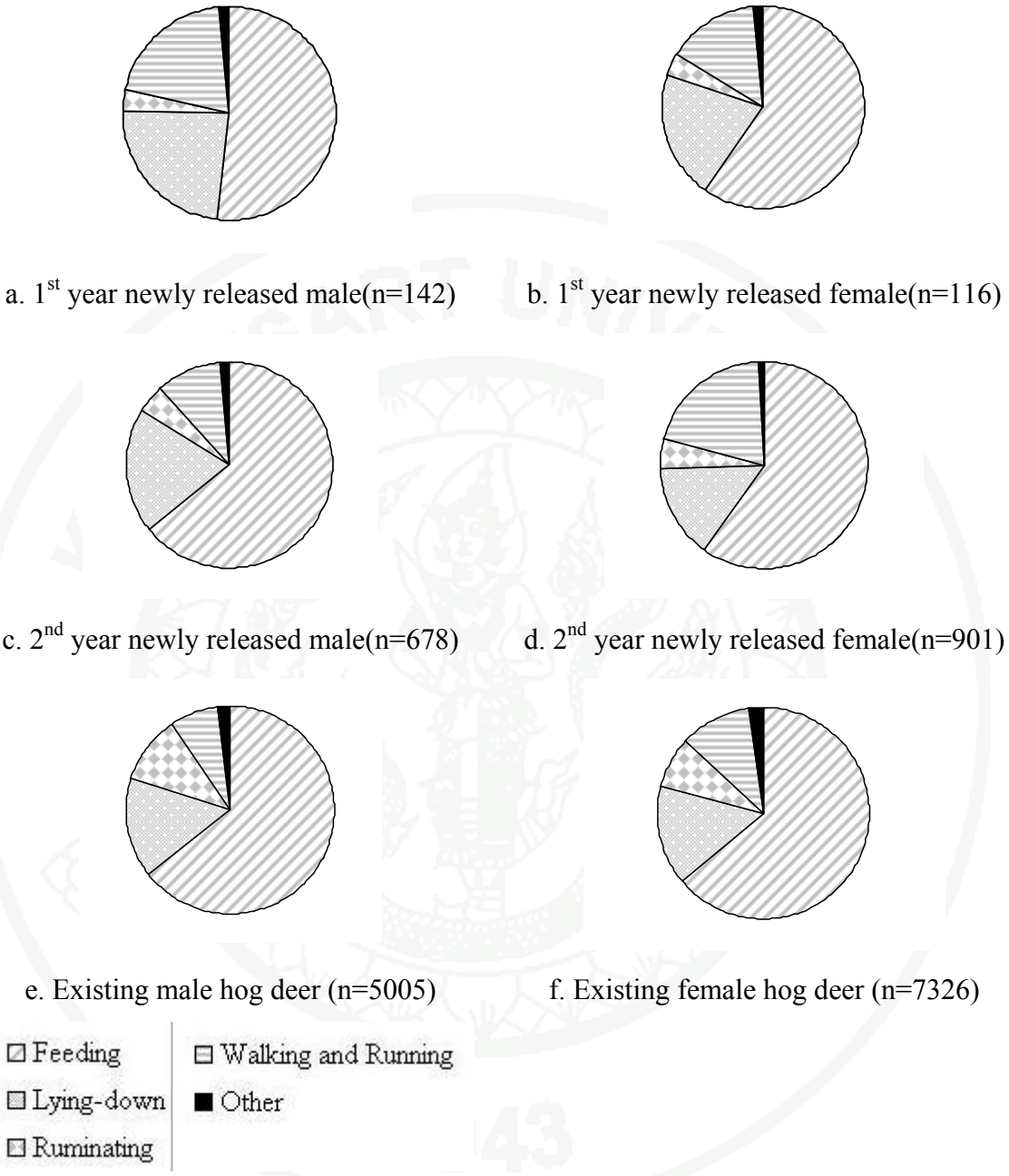


Figure 18 Level of each behaviors for hog deer as determined by scan sampling method in the dry season.

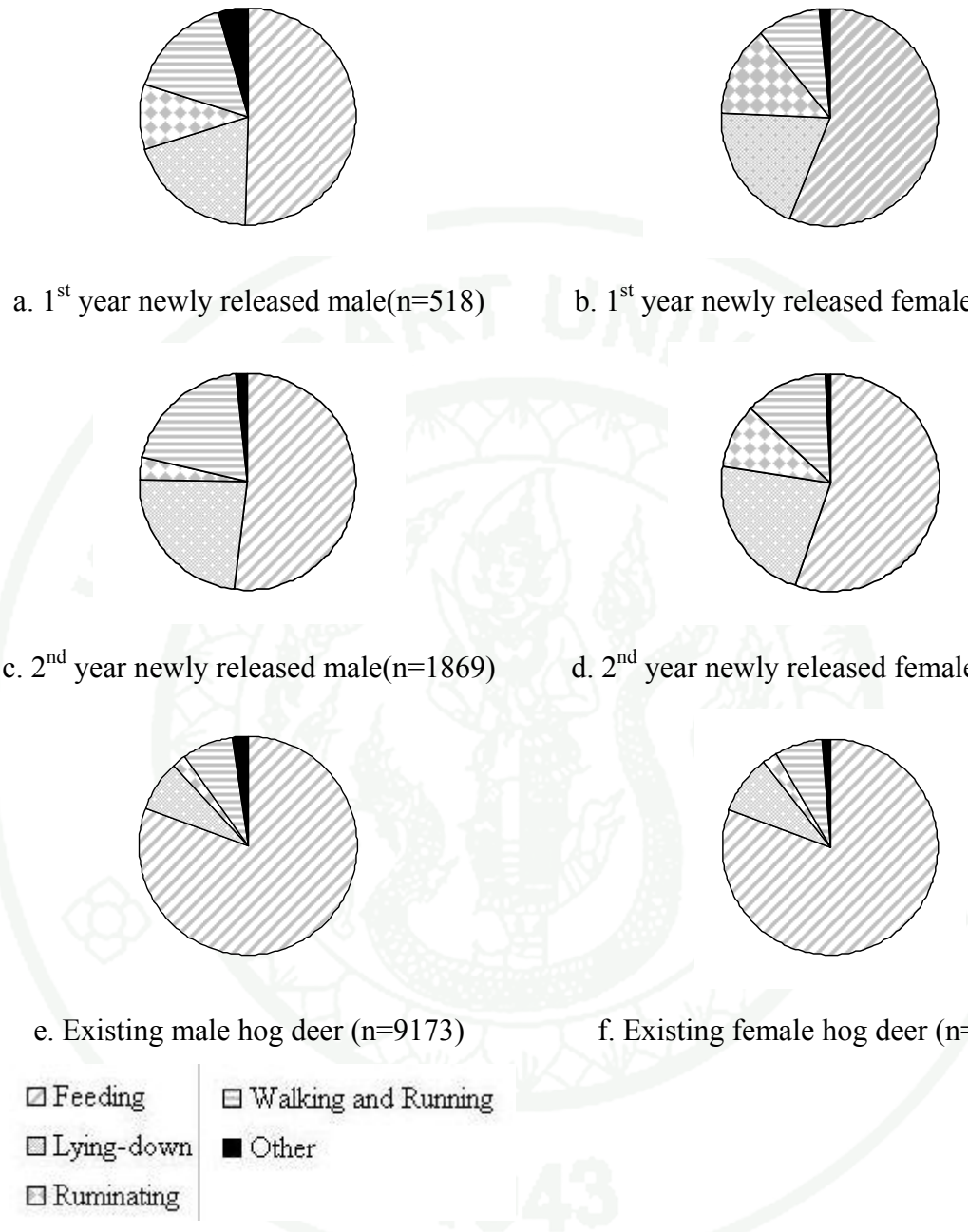


Figure 19 Level of each behaviors for hog deer as determined by scan sampling method in the wet season.

2. Behavior of the newly released hog deer in TKM

The behavior shown by the newly released male and female hog deer in the first and second year after release as well as in different season of two consecutive years were determined in order to indicate their adaptability to the new habitat by comparing to those behaviors of the existing hog deer.

2.1 Focusing on the behaviors of the newly released male hog deer compared to the existing male hog deer:

The annual average time spent of each behavior: The results from the study showed that the annual average times spent for feeding, lying-down and ruminating behaviors of the newly released stag have correlation with the existing male hog deer since the first released year (Table 11). This indicated the adaptability of the male hog deer on its feeding, lying-down and ruminating behaviors. But the walking and running and other behaviors of the newly released hog deer have no correlation with the existing male hog deer for both 2 years. The average times spent of each behavior for the first year (Figure 17a), the second year (Figure 17c), and the existing hog deer (Figure 17e) respectively were as follow: for feeding behavior 50.8%, 62.2%, and 69.5%, for lying-down 21.1%, 21.1%, and 13.1%, for walking and running behavior 16.9%, 8.5%, and 7.5%, for ruminating 7.7%, 6.1%, and 8.0%, for other behavior 3.4%, 2.1%, and 1.9%.

Table 11 Behavior testing by the correlation test between the existing male hog deer, newly released male hog deer after releasing in 1st year and 2nd year data combined all year round (n=73).

Behavior type	Group compare		*P*-value	r
Feeding	Existing group	1st year after releasing	0.000	0.586
	Existing group	2nd year after releasing	0.002	0.355
	1st year after releasing	2nd year after releasing	0.041	0.241
Lying-down	Existing group	1st year after releasing	0.000	0.533
	Existing group	2nd year after releasing	0.000	0.701
	1st year after releasing	2nd year after releasing	0.000	0.430
Walking and running	Existing group	1st year after releasing	0.163	-0.166
	Existing group	2nd year after releasing	0.290	0.127
	1st year after releasing	2nd year after releasing	0.146	-0.173
Ruminating	Existing group	1st year after releasing	0.000	0.533
	Existing group	2nd year after releasing	0.000	0.701
	1st year after releasing	2nd year after releasing	0.000	0.430
Other	Existing group	1st year after releasing	0.051	-0.231
	Existing group	2nd year after releasing	0.881	0.018
	1st year after releasing	2nd year after releasing	0.412	0.098

The dry season average times spent of each behavior: For the first year after releasing, the average time spent for the feeding and lying-down behaviors have no correlation with the existing hog deer. But these behaviors have correlation with the existing hog deer in the second year after releasing. It indicated that the newly released male hog deer needed more time for adapting these behaviors in the dry season. But the walking and running, ruminating and other behaviors of the newly released hog deer have no correlation with the existing male hog deer for both 2 years (Table 12). The average times spent of each behavior for the first year (Figure 18a), the second year (Figure 18c), and the existing hog deer (Figure 18e) respectively were as follow: for feeding behavior 51.9%, 64.4%, and 64.4%, for lying-down 23.4%, 19.9%, and 15.7%, for walking and running behavior 19.2%, 10.2%, and

7.5%, for ruminating 3.3%, 4.5%, and 10.5%, for other behavior 1.5%, 1.5%, and 1.9%.

Table 12 Behavior testing by the correlation test between the existing male hog deer, newly released male hog deer after releasing in 1st year and 2nd year in the dry season (n=73).

Behavior type	Group compare		*P*-value	r
Feeding	Existing group	1st year after releasing	0.162	0.167
	Existing group	2nd year after releasing	0.003	0.340
	1st year after releasing	2nd year after releasing	0.323	0.118
Lying-down	Existing group	1st year after releasing	0.938	-0.009
	Existing group	2nd year after releasing	0.008	0.313
	1st year after releasing	2nd year after releasing	0.010	0.302
Walking and running	Existing group	1st year after releasing	0.543	-0.073
	Existing group	2nd year after releasing	0.328	-0.117
	1st year after releasing	2nd year after releasing	0.160	-0.167
Ruminating	Existing group	1st year after releasing	0.059	-0.223
	Existing group	2nd year after releasing	0.299	-0.124
	1st year after releasing	2nd year after releasing	0.590	0.065
Other	Existing group	1st year after releasing	0.543	-0.073
	Existing group	2nd year after releasing	0.328	-0.117
	1st year after releasing	2nd year after releasing	0.160	-0.167

The wet season average times spent of behaviors: The average time spent for the feeding, lying-down and ruminating behaviors of the newly released stag have correlation with the existing male hog deer since the first released year. The average times spent for walking and running and other behaviors have no correlation with the existing hog deer in the first year after releasing. But these behaviors have correlation with the existing hog deer in the second year after releasing (Table 13). The average times spent of each behavior for the first year (Figure 19a), the second year (Figure 19c), and the existing hog deer (Figure19e) respectively were as follow: for feeding behavior 50.3%, 63.1%, and 80.9%, for lying-down 19.7%, 20.2%, and

7.5%, for walking and running behavior 15.8%, 8.3%, and 7.9%, for ruminating 9.8%, 6.2%, and 2.4%, for other behavior were 4.5%, 2.1%, and 2.1%.

Table 13 Behavior testing by the correlation test between the existing male hog deer, newly released male hog deer after releasing in 1st year and 2nd year in the wet season (n=73).

Behavior type	Group compare		*P*-value	r
Feeding	Existing group	1st year after releasing	0.000	0.536
	Existing group	2nd year after releasing	0.007	0.316
	1st year after releasing	2nd year after releasing	0.012	0.295
Lying-down	Existing group	1st year after releasing	0.000	0.588
	Existing group	2nd year after releasing	0.000	0.672
	1st year after releasing	2nd year after releasing	0.001	0.391
Walking and running	Existing group	1st year after releasing	0.095	-0.198
	Existing group	2nd year after releasing	0.001	0.368
	1st year after releasing	2nd year after releasing	0.180	-0.160
Ruminating	existing group	1st year after releasing	0.011	-0.299
	existing group	2nd year after releasing	0.000	0.570
	1st year after releasing	2nd year after releasing	0.620	-0.059
Other	existing group	1st year after releasing	0.730	-0.041
	existing group	2nd year after releasing	0.007	-0.314
	1st year after releasing	2nd year after releasing	0.665	-0.052

2.2 Focusing on the behaviors of the newly released female hog deer compared to the existing female hog deer:

The annual average time spent of each behavior: The results from the study showed that the annual average times spent for feeding and lying-down behavior of the newly released female hog deer have correlation with the existing female hog deer since the first released year. But the walking and running, ruminating and other behavior of the newly released hog deer have no correlation with the existing female hog deer for both 2 years (Table 14). The average times

spent of each behavior for the first year (Figure 17b), the second year (Figure 17d), and the existing hog deer (Figure 17f) respectively were as follow: for feeding behavior 56.7%, 55.0%, and 69.2%, for lying-down 18.9%, 22.4%, and 13.1%, for walking and running behavior 11.0%, 13.0%, and 7.6%, for ruminating 12.0%, 8.2%, and 8.3%, for other behavior 1.4%, 1.4%, and 1.8%.

Table 14 Behavior testing by the correlation test between the existing female hog deer, newly released female hog deer after releasing in 1st year and 2nd year data combined all year round (n=73).

Behavior type	Group compare		*P*-value	r
Feeding	existing group	1st year after releasing	0.000	0.406
	existing group	2nd year after releasing	0.000	0.568
	1st year after releasing	2nd year after releasing	0.000	0.436
Lying-down	existing group	1st year after releasing	0.000	0.415
	existing group	2nd year after releasing	0.000	0.724
	1st year after releasing	2nd year after releasing	0.000	0.416
Walking and running	existing group	1st year after releasing	0.491	0.083
	existing group	2nd year after releasing	0.751	0.038
	1st year after releasing	2nd year after releasing	0.899	0.015
Ruminating	existing group	1st year after releasing	0.280	-0.129
	existing group	2nd year after releasing	0.080	0.208
	1st year after releasing	2nd year after releasing	0.940	0.009
Other	existing group	1st year after releasing	0.055	-0.325
	existing group	2nd year after releasing	0.588	0.065
	1st year after releasing	2nd year after releasing	0.555	0.071

The dry season average times spent of each behavior: The results from the study showed that the annual average times spent for all behaviors of the newly released female hog deer have correlation with the existing female hog deer since the first released year (Table 15). This indicated the adaptability of the female hog deer on its all behaviors. The average times spent of each behavior for the first year (Figure 18b), the second year (Figure 18d), and the existing hog deer (Figure

18f) respectively were as follow: for feeding behavior 59.7%, 59.7%, and 64.0%, for lying-down 20.5%, 14.8%, and 15.3%, for walking and running behavior 14.3%, 20.0%, and 7.8%, for ruminating 3.6%, 4.7%, and 10.7%, for other behavior 1.8%, 0.8%, and 2.2%.

Table 15 Behavior testing by the correlation test between the existing female hog deer, newly released female hog deer after releasing in 1st year and 2nd year in the dry season (n=73).

Behavior type	Group compare		*P*-value	r
Feeding	existing group	1st year after releasing	0.448	0.083
	existing group	2nd year after releasing	0.000	0.568
	1st year after releasing	2nd year after releasing	0.150	0.171
Lying-down	existing group	1st year after releasing	0.407	0.099
	existing group	2nd year after releasing	0.000	0.533
	1st year after releasing	2nd year after releasing	0.000	0.513
Walking and running	existing group	1st year after releasing	0.149	0.172
	existing group	2nd year after releasing	0.001	-0.383
	1st year after releasing	2nd year after releasing	0.002	-0.355
Ruminating	existing group	1st year after releasing	0.431	-0.094
	existing group	2nd year after releasing	0.002	-0.364
	1st year after releasing	2nd year after releasing	0.011	-0.297
Other	existing group	1st year after releasing	0.162	-0.167
	existing group	2nd year after releasing	0.039	-0.244
	1st year after releasing	2nd year after releasing	0.000	0.415

The wet season average times spent of behaviors: The results from the study showed that the annual average times spent for feeding behavior of the newly released female hog deer have correlation with the existing female hog deer since the first released year. For the first year after releasing, the average time spent for the lying-down, walking and running and ruminating behaviors have no correlation with the existing hog deer. But these behaviors have correlation with the existing hog deer in the second year after releasing. The other behavior of the newly

released hog deer has no correlation with the existing female hog deer for both 2 years (Table 16). The average time spent of each behavior for the first year (Figure 19b), the second year (Figure 19d), and the existing hog deer (Figure 19f) respectively were as follow: for feeding behavior 56.5%, 55.2%, and 80.6%, for lying-down 19.5%, 22.2%, and 8.9%, for walking and running behavior 9.1%, 12.4%, and 7.1%, for ruminating 13.6%, 9.6%, and 2.3%, for other behavior 1.3%, 0.6%, and 1.1%.

Table 16 Behavior testing by the correlation test between the existing female hog deer, newly released female hog deer after releasing in 1st year and 2nd year in the wet season (n=73).

Behavior type	Group compare		*P*-value	r
Feeding	existing group	1st year after releasing	0.106	0.192
	existing group	2nd year after releasing	0.000	0.493
	1st year after releasing	2nd year after releasing	0.016	0.283
Lying-down	existing group	1st year after releasing	0.021	0.272
	existing group	2nd year after releasing	0.000	0.720
	1st year after releasing	2nd year after releasing	0.034	0.250
Walking and running	existing group	1st year after releasing	0.379	-0.105
	existing group	2nd year after releasing	0.018	0.279
	1st year after releasing	2nd year after releasing	0.239	-0.140
Ruminating	existing group	1st year after releasing	0.154	-0.170
	existing group	2nd year after releasing	0.071	0.214
	1st year after releasing	2nd year after releasing	0.250	0.137
Other	existing group	1st year after releasing	0.248	-0.138
	existing group	2nd year after releasing	0.332	0.116
	1st year after releasing	2nd year after releasing	0.048	-0.234

3. The daytime activity of hog deer in TKM by histogram

The newly released hog deer was observed from early morning (0600 hours) until evening (1800 hours) and data was presented all year in histograms in. Lying down was an active behavior in the same way as ruminating because, mostly, both behaviors were detected together. The histograms show data for all individuals. In the first year (N = 4,747), the longest periods of lying-down behavior were observed at several times (0740-0930, 1110-1250 and 1400-1550 hours) (Appendix Figure 5). In the second year (N = 7,282), a high percentage of lying-down behavior occurred during 0750-1000 and 1110-1250 hours (Appendix Figure 6). Feeding behavior was observed throughout the observation period, but was mainly in the morning and evening for both years. It was obvious that sunshine had a strong negative influence on feeding behavior. Hog deer tended to avoid sunshine by lying down in shadows or under bushes during periods of strong sunshine. Whenever the day was dim, both groups of hog deer fed during all the observed periods.

Feeding was active in the same way as walking and running behavior because, mostly, both behavioral types were detected together. The highest percentage of feeding behavior in the first year was found during the periods 0600-0810 and 1600-1800 hours and in the second year during the periods 0600-0750 and 1300-1800 hours (Appendix Figure 7).

The activity data of the newly released hog deer compared with the existing hog deer in the dry season was presented in histograms in Appendix Figures 8-9. In the newly released hog deer (N = 3,617), the longest periods of lying-down behavior were observed at several times (0800-1000 and 1040-1400 hours). Feeding behavior was observed throughout the observation period, but was mainly in the morning and evening for both years (0600-0800 and 1600-1800 hours).

The activity data of the newly released hog deer compared with the existing hog deer in the wet season was presented in histograms in Appendix Figures 10-11. In the newly released hog deer (N = 8,412), the longest periods of lying-down

behavior were observed at 0800-1400 hours, lying down showed longer than the dry season but percentage less than the dry season. Feeding behavior was observed throughout the observation period, but was mainly in the morning and evening for both years (0600-0800 and 1400-1800 hours).

2.4 Habitat use

Distribution of the existing hog deer in TKM determined from 5,166 observation location during the study period covered an area of 5.03 km^2. The habitat within the existing hog deer's overall distribution consist of grassland (GL) type that covered an area of 3.52 km^2 (69.92%), mixed pine-deciduous dipterocarp forest (MPDF) type that covered an area of 0.90 km^2 (17.88%), edge of hill evergreen forest (HEF) type that covered an area of 0.41 $km^2$was (8.13%) and man-made reservoir (MMR) type that covered an area of 0.20 km^2 (4.07%) (Table 17 and Figure 20).

2.4.1 Distribution area

This study found that the distribution area of the newly released hog deer after two years covered an area of 1.23 km^2 (Figure 20). The distribution area of the newly released hog deer was within the distribution area of the existing hog deer dominantly in the GL and both groups are well integrated. The area of the newly released hog deer comprised of GL type 97.52% (N=4,728), MPDF 1.67% (N=81), HEF 0.31% (N=15) and MMR 0.50% (N=24). The distribution areas of the hog deer in the first and second year after releasing were 1.08 km^2 and 0.72 km^2 respectively (Table 17). The results showed that the distribution area of the first year was larger than that of the second year for every newly released hog deer (see Appendix Table 8). It might be due to their need to adapt themselves to the new habitat as well as searching for food.

Table 17 Distribution area of the existing hog deer compared with the newly released hog deer.

Hog deer	No. of location	Area (km^2)
Existing hog deer	5166[1/]	5.03
Newly released hog deer (1st year)	1711[2/]	1.08
Newly released hog deer (2nd year)	3137[2/]	0.72
Newly released hog deer (after 2 year)	4848[2/]	1.23

[1/] data came from occasional observation

[2/] data came from direct observation

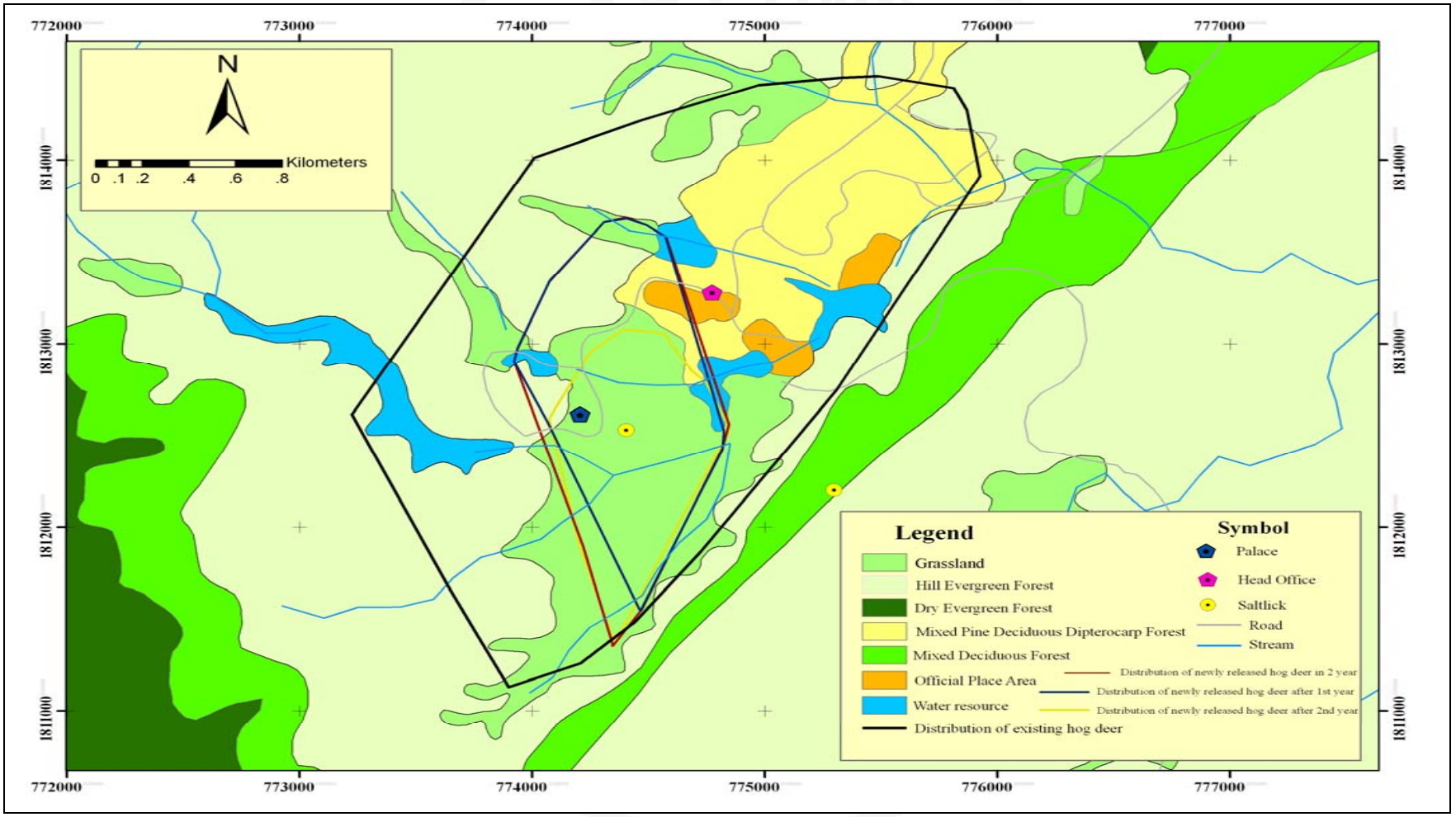


Figure 20 Distribution of the existing hog deer and the newly released hog deer at Thung Ka Mung area, analyzed by combined data.

The distribution area of newly released female hog deer in the first year after releasing somewhat stayed in the area the center of the distribution area of the existed hog deer (Figure 21 and Appendix Table 8), which is GL that would be flooded during rainy season. The GL functions as hiding cover area and provides forages for the hog deer such as *Vietnamosasa pusilla* and *Imperata cylindrica.* The newly released female hog deer were mixed well with the existing hog deer. The distribution area of the newly released female hog deer in the second year after releasing is smaller but the pattern is similar to their distribution area in the first year (Figure 21 and Figure 22). It might be due to their need to adapt themselves to the new habitat as well as searching for food during the first year.

The distribution area of the newly released male hog deer in first and second year after releasing (Figure 23 and Appendix Table 8) has the same pattern of the distribution of the female hog deer. The newly released male hog deer's distribution area was in the center of the distribution area of the existing hog deer.

Concerning the habitat used of newly released hog deer in different season, during the dry season (November-March) the habitat used (see Appendix Table 9) by the females ranged 0.29–0.59 km^2 (average=0.43) (SD=0.15) and by the males ranged 0.55 km^2 (Figure 24). During the wet season (April-October), the habitat used by the females ranged 0.23–1.02 km^2 (average=0.58) (SD=0.40) and by males ranged 0.63 km^2 (Figure 25). The habitat preference differed in the dry and wet seasons, due to limited forage species in the dry season. In the dry season, there was grass management by controlled burning (Appendix Figure 18), resulting in new grass shoots (Appendix Figure 19), so the hog deer occupied a smaller area. In the wet season, there were many available food plant species, as well as water sources and salt licks, so the hog deer spread out over a wider area. The major factor influencing the home range of hog deer in TKM area is the seasonal distribution of food, water and hiding cover in the grassland.

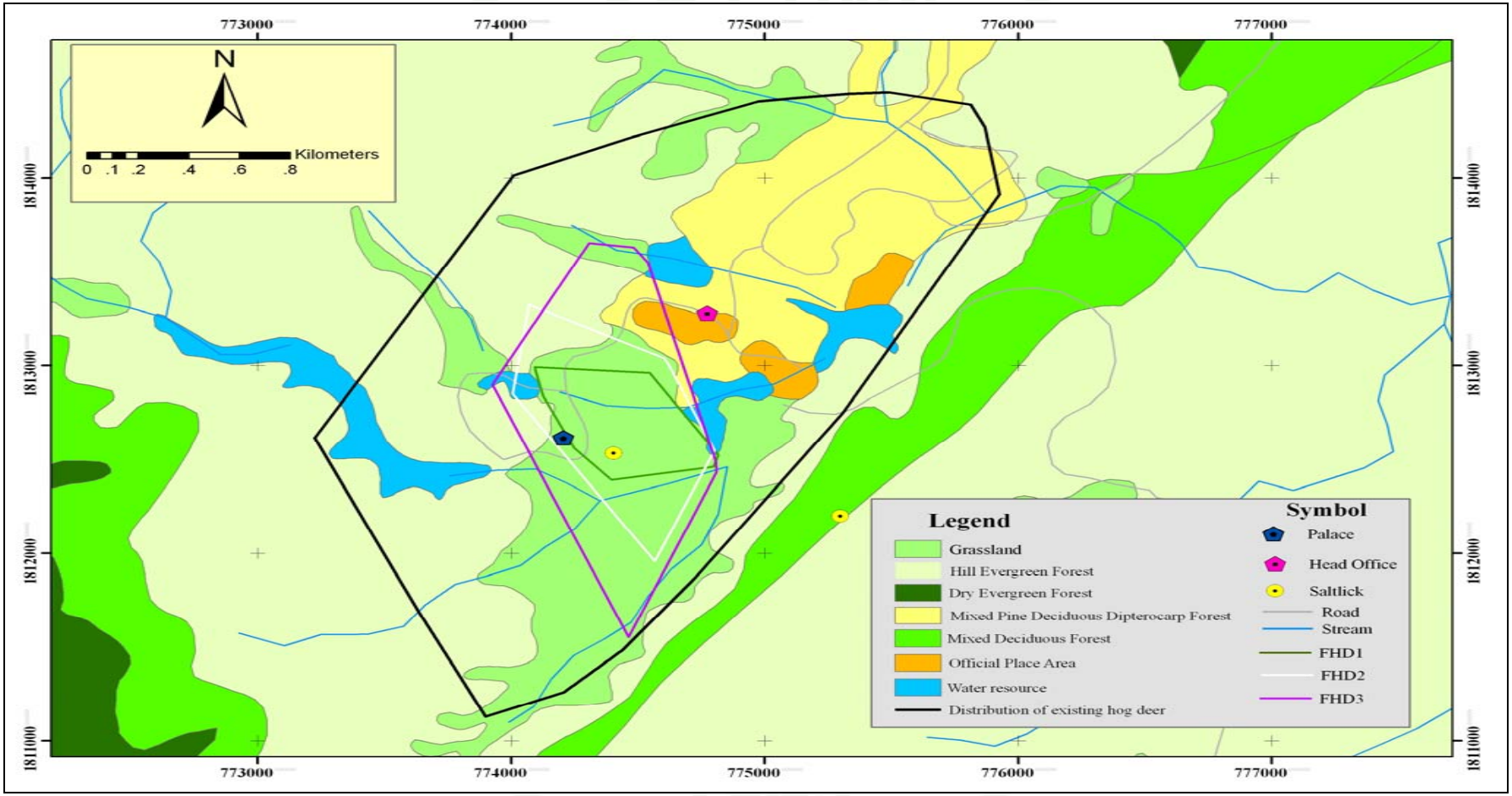


Figure 21 Distribution of the 3 newly released female hog deer individually at Thung Ka Mung area in first year after releasing within distribution area of existing group.

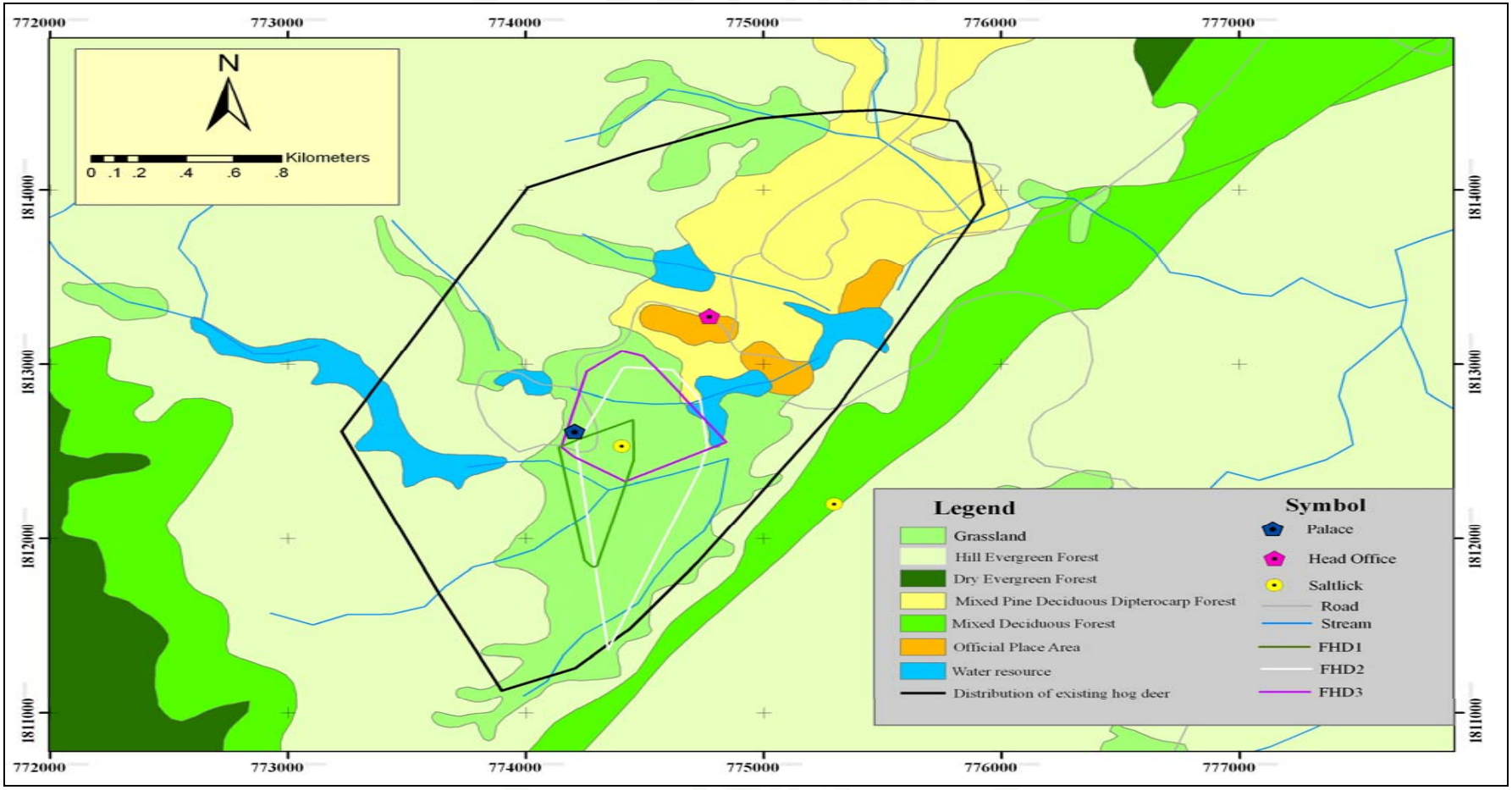


Figure 22 Distribution of the 3 newly released female hog deer individually at Thung Ka Mung area in second year after releasing within distribution area of existing group.

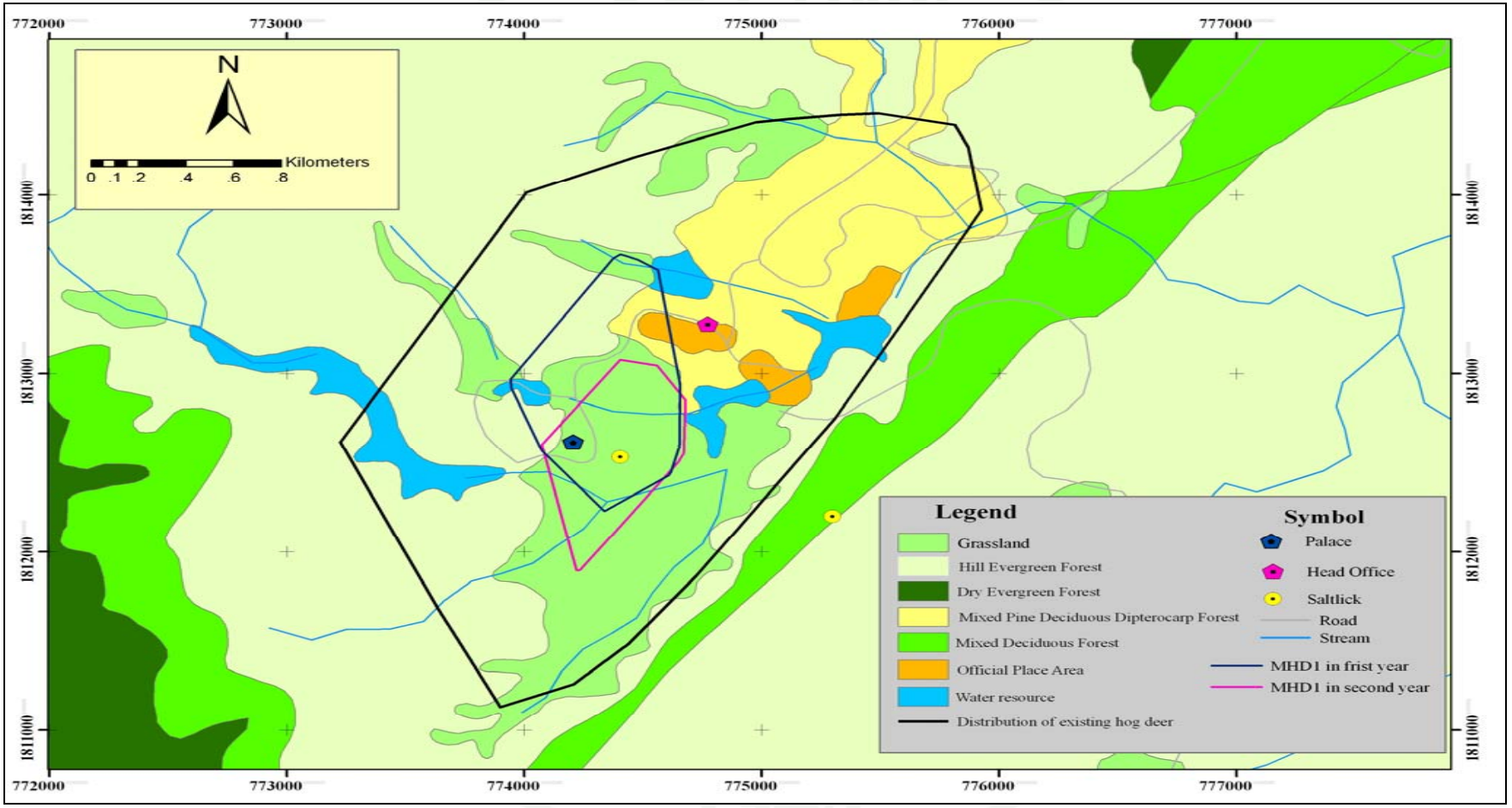


Figure 23 Distribution of the newly released male hog deer individually at Thung Ka Mung area in first and second year after releasing within distribution area of existing group.

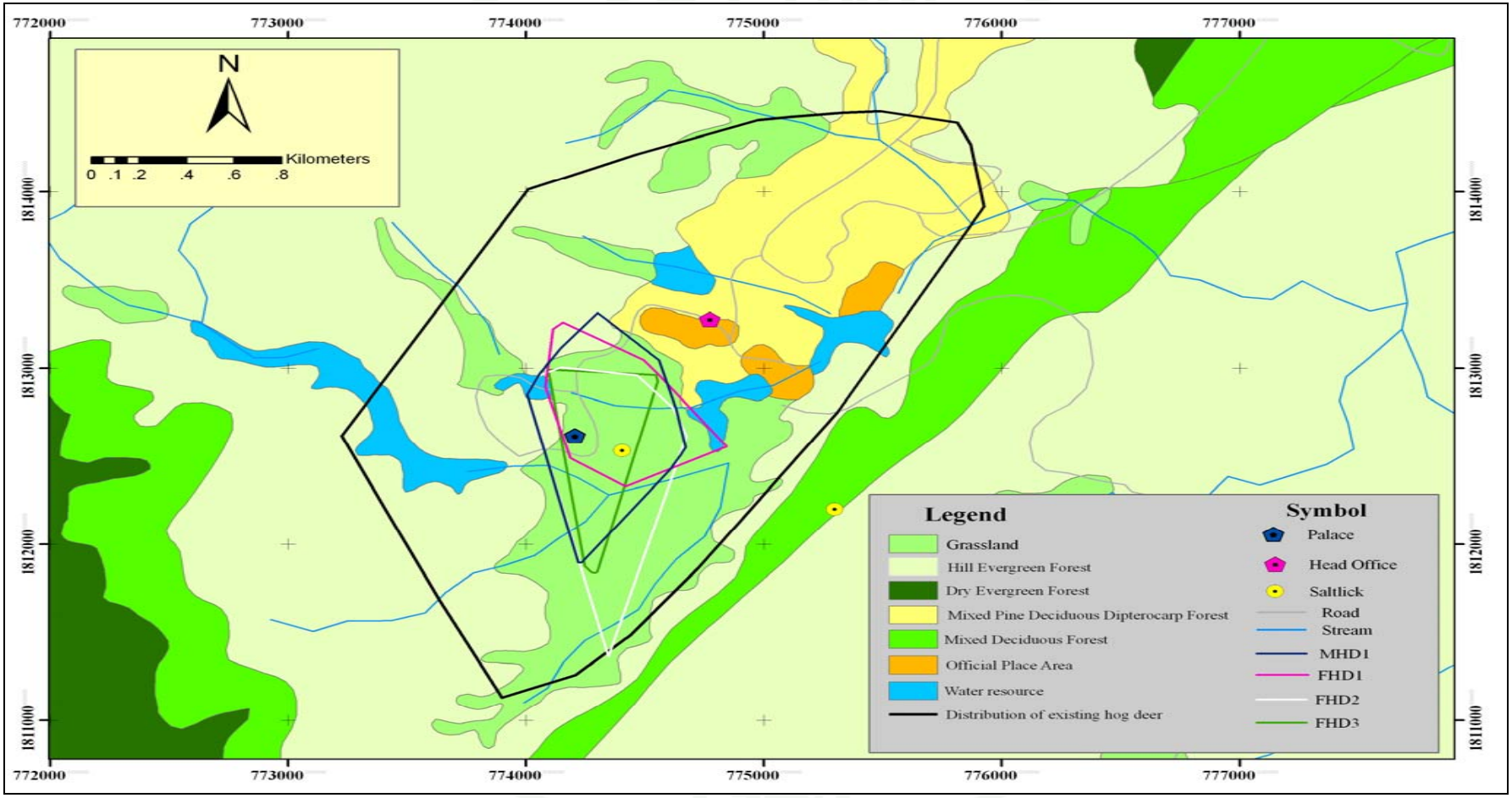


Figure 24 Distribution of the newly released hog deer individually, male and 3 female at Thung Ka Mung area after releasing 2 years in the dry season within distribution area of existing group.

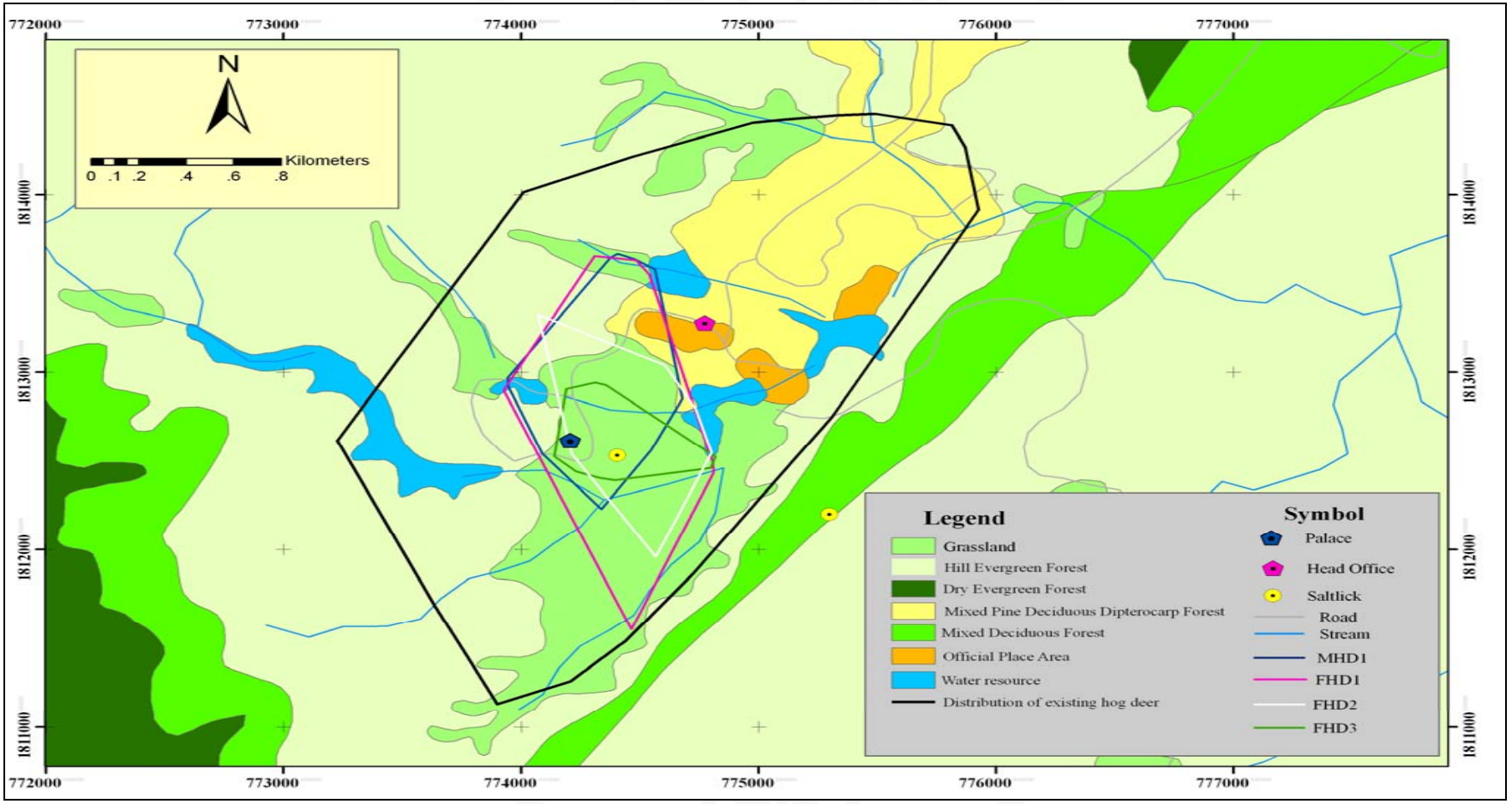


Figure 25 Distribution of the newly released hog deer individually, 1 male and 3 female, at Thung Ka Mung area after releasing 2 years in the wet season within distribution area of existing group.

2.4.2 Habitat preference

Determined the distribution area of the existing hog deer found that the area composed of GL type that covered an area of 3.52 km^2 (69.92%), MPDF type that covered an area of 0.90 km^2 (17.88%), edge of HEF type that covered an area of 0.41 $km^2$was (8.13%) and MMR type that covered an area of 0.20 km^2 (4.07%). Where as used of the newly released hog deer was within the habitat used of the existing group dominantly in the GL and both groups are well integrated. The habitat used of the newly released hog deer occurred in GL type 97.52% (N=4,728), MPDF 1.67% (N=81), HEF 0.31% (N=15) and MMR 0.50% (N=24). Individual preferences may, to some extent. Determine habitat selection by hog deer, but hiding cover to escape predators, food and water availability and accessibility and human activities influence this selection. Food and dense escape cover seem to have the greatest influence on habitat use.

The different habitat types can be classified as preference or avoidance (Johnson, 1980). Preference referred to habitat types where the animal spent more time than expected. Avoidance referred to habitat types where the animal spent less time than expected.

The data of habitat usage and availability of the first year after released hog deer are listed in Table 18. The habitat availability was calculated from distribution area of the newly released hog deer in the first year. The result from this study revealed that the preferred habitats of newly released hog deer in first year were GL, MPDF and MMR but avoid the HEF. This is also the major barrier, which obstructs the distribution of hog deer to other grasslands.

Table 18 Comparing habitat usage and availability data of hog deer in first year after releasing.

Habitat type	Usage (%)	Availability (%)	Rank			Conclusion
			Usage	Availability	Difference	
GL	97.84	68.49	1	1	0	Preferred
HEF	0.58	19.19	4	2	2	Avoided
MPDF	0.18	8.99	3	3	0	Preferred
MMR	1.40	3.33	2	4	-2	Preferred

The data of habitat usage and availability of the second year after released hog deer are listed in Table 19. The habitat availability was calculated from distribution data of the newly released hog deer in the second year. The result from this study revealed that the preferred habitats of newly released hog deer in the second year were GL, MPDF and HEF but avoid the MMR.

Table 19 Comparing habitat usage and availability data of hog deer in second year after releasing.

Habitat type	Usage (%)	Availability (%)	Rank			Conclusion
			Usage	Availability	Difference	
GL	97.35	96.04	1	1	0	Preferred
HEF	0.16	1.23	3	3	0	Preferred
MPDF	2.49	0.89	2	4	-2	Preferred
MMR	0.00	1.84	4	2	2	Avoided

The 2 years data of habitat usage and availability of the newly released hog deer are listed in Table 20. The habitat availability was calculated from 2 years distribution data of the newly released hog deer. The result from this study revealed that the preferred habitats of newly released hog deer 2 years after released were GL, MPDF and MMR but avoid the HEF.

Table 20 Comparing habitat usage and availability data of hog deer 2 years after releasing.

Habitat type	Usage (%)	Availability (%)	Rank			Conclusion
			Usage	Availability	Difference	
GL	97.52	70.14	1	1	0	Preferred
HEF	0.31	17.67	4	2	2	Avoided
MPDF	1.67	8.44	2	3	-1	Preferred
MMR	0.50	3.75	3	4	-1	Preferred

The data of habitat usage and availability of the newly released hog deer in the dry season are listed in Table 21. The habitat availability was calculated from 2 years distribution data of the newly released hog deer in the dry season. The result from this study revealed that the preferred habitats of newly released hog deer in the dry season were GL, MPDF and MMR but avoid the HEF.

Table 21 Comparing habitat usage and availability data of hog deer in the dry season.

Habitat type	Usage (%)	Availability (%)	Rank			Conclusion
			Usage	Availability	Difference	
GL	98.29	87.10	1	1	0	Preferred
HEF	0.70	9.99	3	2	1	Avoided
MPDF	0.00	0.46	4	4	0	Preferred
MMR	1.01	2.44	2	3	-1	Preferred

The data of habitat usage and availability of the newly released hog deer in the wet season are listed in Table 22. The habitat availability was calculated from 2 years distribution data of the newly released hog deer in the wet season. The result from this study revealed that the preferred habitats of newly released hog deer in the wet season were GL, MPDE and MMR but avoid the HEF.

Table 22 Comparing habitat usage and availability data of hog deer in the wet season.

Habitat type	Usage (%)	Availability (%)	Rank			Conclusion
			Usage	Availability	Difference	
GL	97.25	68.49	1	1	0	Preferred
HEF	0.17	19.19	4	2	2	Avoided
MPDF	2.27	8.99	2	3	-1	Preferred
MMR	0.31	3.33	3	4	-1	Preferred

3. Forage species

3.1 The result from this study showed that hog deer foraged at least 56 species of 14 families. The largest group was 35 grass species (62.50%), which comprised of families Gramineae (21 species), Cyperaceae (13 species) and Hypoxidaceae (1 species), with other forage life forms being 9 herb species (16.07%), 6 tree species (10.71%), 5 herbaceous climber species (8.93%) and one fern species (1.79%). The dominant grass species found in TKM were *Vietnamosasa pusilla*, *Imperata cylindrica*, *Eulalia trispicata*, *Rhynchospora rubra*, *Eulalia quadrinervis*, *Eulalia trispicata* and *Fimbristylis dichotoma*. They were commonly found in grasslands, mixed pine-deciduous dipterocarp forests, and transition zones connecting the two communities. *Chrysopogon aciculatus* was not found in the survey plots but available for the hog deer in the office area. *Phyllanthus emblica* was found both in survey plots and office area, but those found in survey plots were still seedling. The hog deer foraged the fallen fruits of *Phyllanthus emblica*.

The result from direct observation of the newly released hog deer found 35 species of 10 families. The largest group was 28 grass species (80.00%), which comprised of families Gramineae (19 species), Cyperaceae (8 species) and Hypoxidaceae (1 species), with other forage life forms being 2 herb species (5.71%) and 5 tree species (14.29%). Figure 26 and Appendix Table 12 compared the forages

of existing hog deer and those of newly released hog deer. The result from this study showed that 62.5 % of forages of the newly released hog deer were as same species as those of the existing hog deer.

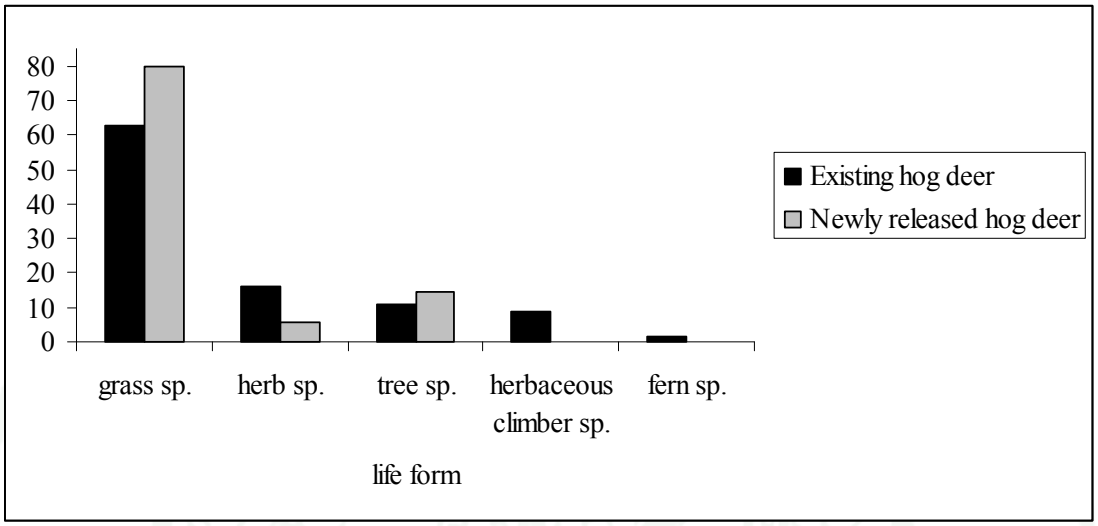


Figure 26 Forage species of hog deer in Thung Ka Mung compare between the newly released hog deer and the existing hog deer.

From food preferences rating listed in Appendix Table 11, a preference value was determined which centers on 1.00 as a reference point. Species with preference values above 1.00 (31 species) are those which are sought out as preferred foods such as *Ammannia baccifera*, *Crotalaria sessiliflora*, *Themeda triandra*, *Arthraxon castratus*, *Arundinella setosa*, *Melicope meliaefolia*, *Leersia hexandra*, *Paspalum orbiculare*, *Eulalia speciosa*, *Sorghum nitidum*, *Panicum sarmentosum*, *Fimbristylis subalata*, *Rhynchospora corymbosa*, *Eragrostis atrovirens*, *Adenosma indiana*, *Melastoma saigonense*, *Eulalia trispicata*, *Setaria sphacelata*, *Curculigo orchidoides*.

Ratings below 1.00 represented forage species (23 species) which for some reason were neglected or avoided as foods such as *Fimbristylis dichotoma*, *Scleria pavula*, *Sacciolepis tenuisima*, *Imperata cylindrica*. *Eulalia quadrinervis*, *Vietnamosasa pusilla*, *Fimbristylis bisumbella*, *Rhynchospora rubra*, *Helicteres*

viscida, *Cyperus haspan*, *Lipocarpha chinensis*, *Hyparrhenia newtonii*, *Eriocaulon henryanum*.

Some species of course might be totally avoided (57 species), having a zero preference rating such as *Phyllathus amarus*, *Ageratum conyzoides*, *Chromolaena odoratum*, *Mitracarpus hirtum*, *Rubus rugosus*, *Cuscuta reflexa*, *Centella asiatica*, *Adinandra integerrima*, *Osbeckia chinensis*, *Helicteres hirsuta*, *Desmodium triflorum*, *Fimbristylis gracilenta*, *Adinandra laotica*, *Utricularia delphinioides*, *Pycreus polystachyos*, *Symplocos racemosa*, *Symplocos sumuntia*, *Aporosa nigricans*, *Catunaregam tomentosa*, *Aporosa octandra*, *Choerosponsdias axillaris*, *Litsea glutinosa*, *Syzygium cinerecum*, *Triadica cochinchinensis*, *Lycopodium cernuum*, *Mallotus barbatus*, *Phyllanthus emblica*, *Uraria lagopodioides*.

Up to 68.42% of *Ammannia baccifera* were utilized and over 50% of each of the next five species was consumed. Twenty-three (see Appendix Table 11) were eaten less than their abundance would indicate. Fifty-seven other plant species showed no utilization by hog deer. Only ten forage species, which consisted of *Vietnamosasa pusilla*, *Ischaemum* sp.1, *Eulalia trispicata*, *Arundinella setosa*, *Panicum sarmentosum*, *Paspalum orbiculare*, *Themeda triandra*, *Fimbristylis dichotoma*, *Imperata cylindrica*, and *Eulalia quadrinervis*, were quantitatively important in the hog deer's diet and comprised 85.2% of the total consumption. Known locally as Phek, *Vietnamosasa pusilla* alone comprised 21.1% of the hog deer's diet was an abundant grass found in TKM. It made up 30.2% of the available forage and was utilized heavily all year round.

Ammannia baccifera, *Crotalaria sessiliflora*, *Themeda triandra*, *Arthraxon castratus* and *Crotalaria* sp.1, with food preference rating of 2.73, 2.49, 2.40, 2.39, and 2.39, respectively, had high preference ranks of the grassland forage. While they were heavily utilized by hog deer, their availabilities were very low (0.06%, 0.02%, 1.88%, 0.01%, and 0.01% respectively). They appeared to be

species, which were sought out by the hog deer and any reduction in their abundance might indicate range overuse.

3.2 Knowledge of carrying capacity is essential for the conservation and management of wildlife populations. In this study was the estimation by available forage in the area. We assess plant availability for hog deer by control plot and consumed plot. In Appendix Table 10, the forage availability in TKM area in the dry season was 20,043.68 grams in 60 m^2 and the total potential habitat used is 103.95 hectare or 1,039,500 m^2 (grassland) and hog deer in captive fed on food approximately 3,500 grams per day (Achapet, 1997). Therefore, the approximate carrying capacity number is 272 individuals in the dry season. Sambar deer and barking deer were sharing same forage in TKM as well.

Carrying capacity is the maximum number of animals of a given population that can be supported by available resources. Therefore, it can increase the carrying capacity of a species in an area by habitat management. The hog deer are grazer and prefer a grassland habitat thus burning control in order to provide more available forage is highly recommended.

4. Inter-specific Relationship

Inter- specific relationship was study to understand the relationship between released hog deer and other wildlife species in the area. This study concentrated to relative abundance gained from camera trap techniques and the relation that studied by present or absent in the line plot system.

In the case of camera trap techniques, 447 trap night that gained from 4 camera trap sets covered an area of 2.95 km^2 was used. The result reflected that 16 species were identified from 433 numbers of photos totally. The important species that related with the hog deer when determined from the relative abundance were sambar deer, barking deer, Malayan porcupine, wild boar, large India civet, red jungle fowl, small India civet, Asian elephant, water monitor, leopard cat, Asian wild dog,

silver pheasant, Asiatic jackal, clouded leopard and Malayan sun bear, which the relative abundance were 29.33%, 7.62%, 7.62%, 4.85%, 4.62%, 3.46%, 3.23%, 2.08%, 1.62%, 1.39%, 1.15%, 0.92%, 0.92%, 0.46% and 0.46% respectively (Table 23). It can be expected that the hog deer have relationship with other herbivorous mammal in term of symbiosis and also in term mutualism. Where as the hog deer have were hunt by carnivorous species especially Asian wild dog and clouded leopard.

Table 23 Relative abundance of some wildlife species studied by camera trap techniques around Thung Ka Mung area during January 2009 and September 2009 and expected relationship with the hog deer.

No	Common name	Total number of photo in TKM	%Relative abundance	Relationship[1/]
1	Hog deer	131	30.25	-
2	Sambar deer	127	29.33	C_1, C_2
3	Barking deer	33	7.62	C_1, C_2
4	Malayan Porcupine	33	7.62	N
5	Wild Boar	21	4.85	M, N
6	Large Indian Civet	20	4.62	N
7	Red Jungle fowl	15	3.46	C_2
8	Small Indian Civet	14	3.23	N, P
9	Asian Elephant	9	2.08	M, N
10	Water Monitor	7	1.62	N
11	Leopard Cat	6	1.39	M, P
12	Asian wild dog	5	1.15	P
13	Silver Pheasant	4	0.92	N, C_2
14	Asiatic Jackal	4	0.92	M, P
15	Clouded Leopard	2	0.46	P
16	Malayan Sun Bear	2	0.46	P
Total number of photos		433		
Trap night		447		
Area coverage (km^2)		2.95		

[1/] P=Predation M=Mutualism C_1=Competition C_2=Commensalism N=Neutralism

In the case of habitat sharing, the results revealed that 6 ungulate species and 3 predator species by line plot system and the results can be interpreted by types of habitat. The percentage of occurrence frequencies of target animals in each habitat

type were determined and compared by ANOVA (Duncan's multiple range test) at 95% confident interval.

The study indicated that both GL and MPDF in TKM, hog deer were the dominant species (Figure 27). The occurrence frequencies of hog deer in GL (71.24%) were significantly different from the sambar deer (41.59%), which were significantly different form barking deer and wild boar. The percentage of occurrence frequencies in MPDF of hog deer and sambar deer were not significantly different and sambar deer also were not significantly different with wild boar. The sambar deer was the dominant ungulate species that used the edge of HEF following by wild boar and barking deer. The occurrence frequency of sambar deer in HEF (36.25%) was significantly more than wild boar (21.78%), barking deer (13.02%) (Table 24). The 3 predators consisted of Asian wild dog, Asiatic jackal and leopard cat were the least found in all areas.

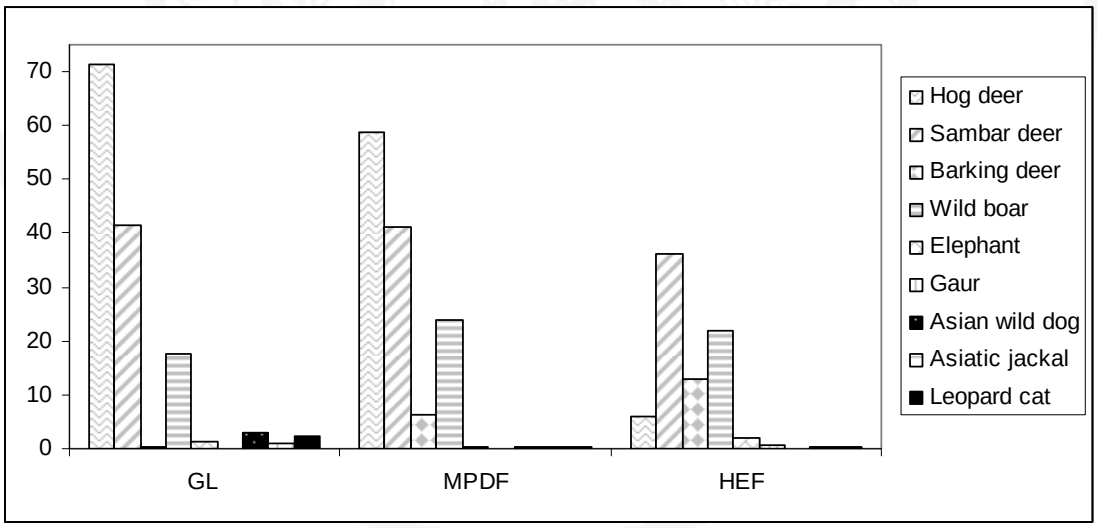


Figure 27 Percentage of occurrence frequency of the target species in each habitat types.

Table 24 Percentage of occurrence frequency of the target species in each habitat types by line plot system method in Thung Ka Mung.

Habitat types	Hog deer	Sambar deer	Barking deer	Wild boar	Elephant	Gaur	Asian wild dog	Asiatic jackal	Leopard cat
GL (n=226)	71.24 [a]	41.59 [b]	0.44 [d]	17.70 [c]	1.33 [d]	0.00 [d]	3.10 [d]	0.88 [d]	2.21 [d]
MPDF (n=226)	58.85 [a]	41.15 [ab]	6.16 [c]	23.89 [bc]	0.44 [c]	0.00 [c]	0.44 [c]	0.44 [c]	0.44 [c]
HEF (n=1244)	5.95 [d]	36.25 [a]	13.02 [c]	21.78 [b]	2.09 [de]	0.56 [e]	0.16 [e]	0.24 [e]	0.24 [e]

Different superscripts (a, b, c, d, e) indicate the significant different among groups in the same distance range at 95% confident interval by one way ANOVA

5. Probability distribution

The initial study of the probability of the hog deer's geographic distribution in dry and wet season by Maximum Entropy (Maxent) method calculated the area under ROC (AUC) to evaluate the reliability of the method. The probabilities of each species geographic distribution are as follow:

5.1 Hog deer: The result revealed that the AUC is 0.964 which means that the method is highly reliable. Concerning the environmental factor that effects the species geographic distribution, the result of this study showed that forest type and ranger station have the highest effect to the hog deer's geographic distribution (see Table 25 and Appendix Table 14). As shown in Figure 28 hog deer has highest habitat use probability mainly in grassland of TKM.

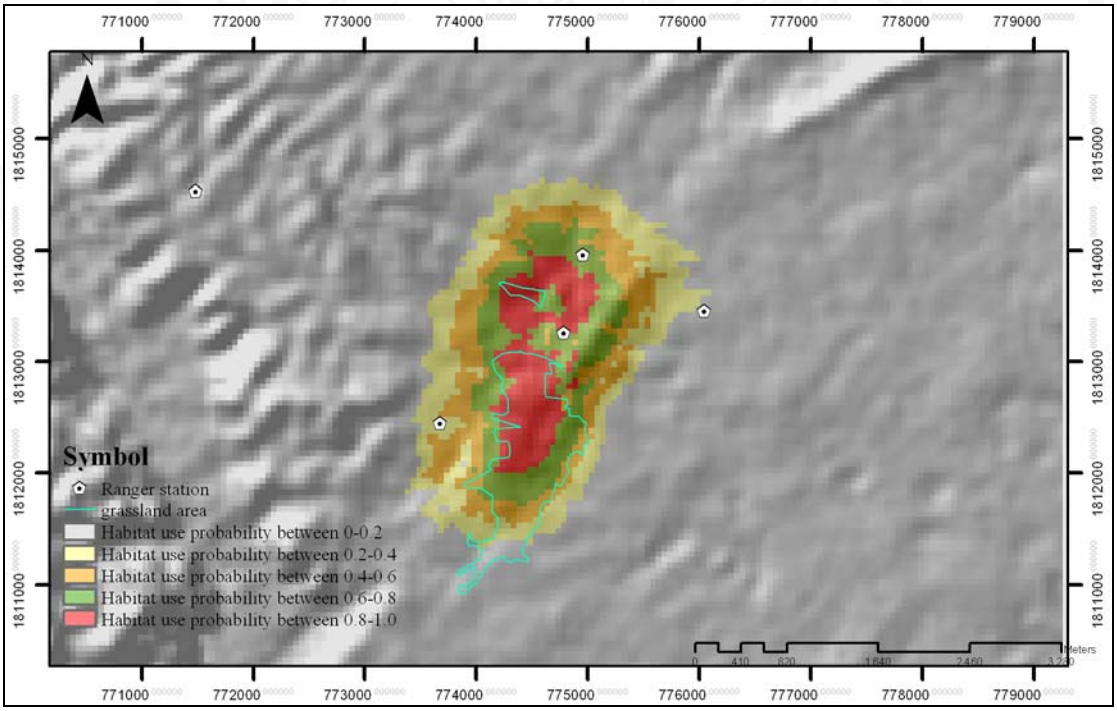


Figure 28 Habitat use probability of hog deer.

5.2 Sambar deer: The result revealed that the AUC is 0.938 which means that the method is highly reliable. Concerning the environmental factor that effects the species geographic distribution, the result of this study showed that saltlick and permanent stream have the high effect to the sambar deer's geographic distribution (see Table 25 and Appendix Table 15). As shown in Figure 29 the habitat use probability pattern of sambar deer is similar to those of hog deer, but covers a larger area. However the highest habitat use probability is not found only in the grassland area, but also in the hill evergreen forest and mixed pine-deciduous dipterocarp forest. Unlike the hog deer's habitat use, the habitat use of sambar deer is not specific to open area. The result also indicated that no correlation between the hog deer and the sambar deer (*P*-value = 0.227, r = 0.420).

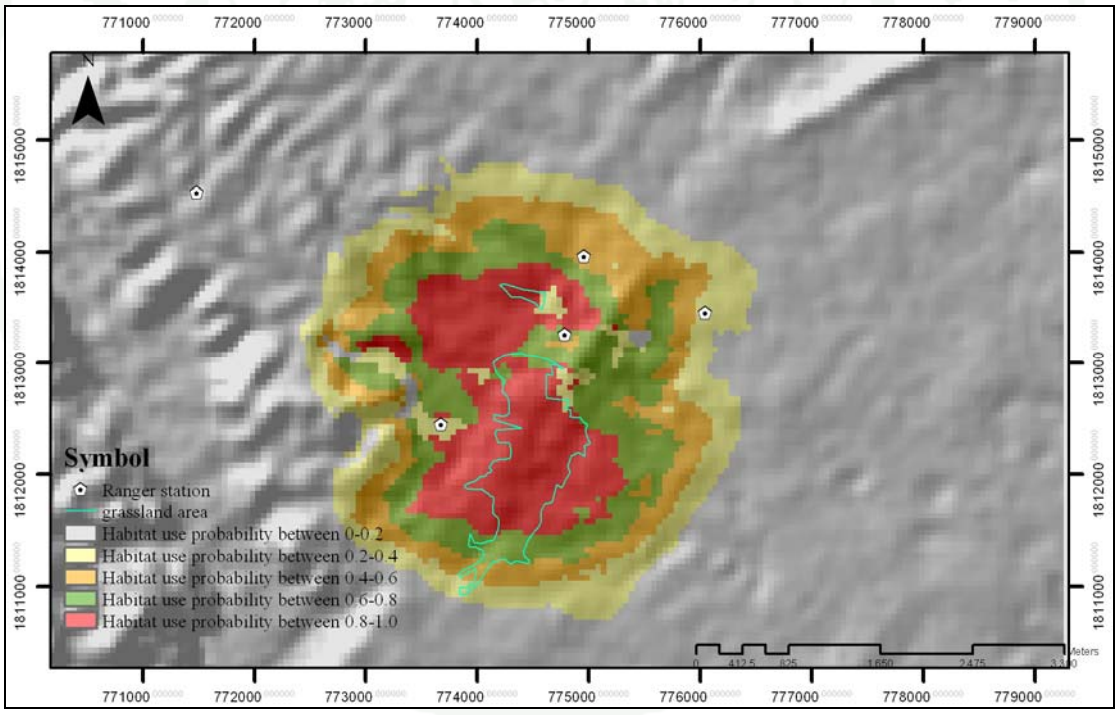


Figure 29 Habitat use probability of sambar deer.

5.3 Barking deer: The result revealed that the AUC is 0.940 which means that the method is highly reliable. Concerning the environmental factor that effects the species geographic distribution, the result of this study showed that the saltlick and permanent stream have the high effect to the barking deer's geographic distribution (see Table 25 and Appendix Table 16). As shown in Figure 30 barking deer has highest habitat use in hill evergreen forest surrounding the grassland. The result also indicated that no correlation between the hog deer and the barking deer (*P*-value = 0.311, r = 0.357).

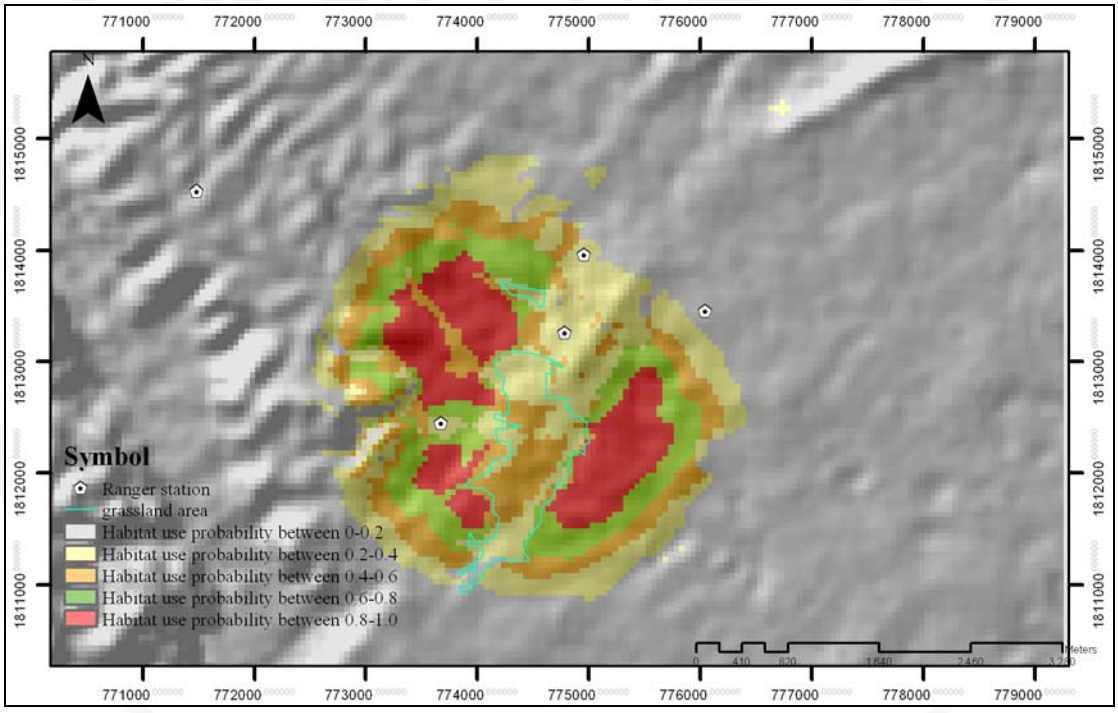


Figure 30 Habitat use probability of barking deer.

5.4 Wild boar: The result revealed that the AUC is 0.943 which means that the method is highly reliable. Concerning the environmental factor that effects the species geographic distribution, the result of this study showed that the saltlick and ranger station have the high effect to the wild boar's geographic distribution (see Table 25 and Appendix Table 17). As shown in Figure 31 shows that the highest habitat use probability of wild boar has involved both hill evergreen forest and southern part of the grassland, which has some pioneer plants from the hill evergreen forest penetrating in to the area. Similar to sambar deer and barking deer, the wild boar habitat use is not specific to the open area when referring to the forest type factor. The result also indicated that no correlation between the hog deer and the wild boar (*P*-value = 0.325, r = 0.348).

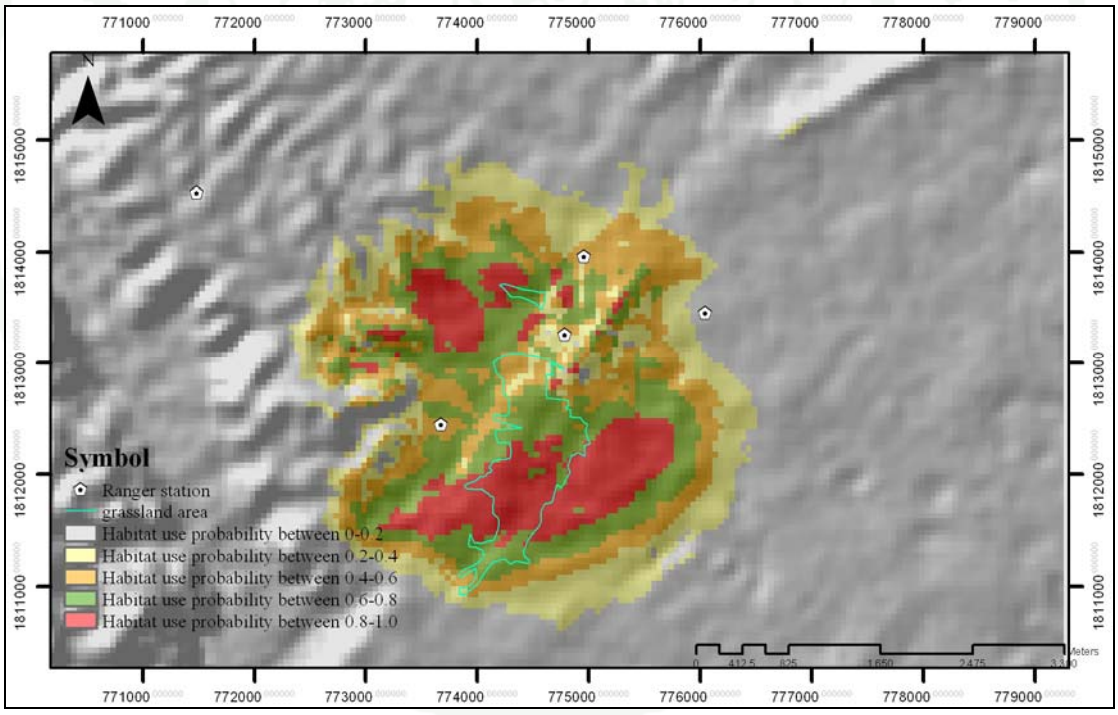


Figure 31 Habitat use probability of wild boar.

5.5 Gaur: The result revealed that the AUC is 0.985 which means that the method is highly reliable. Concerning the environmental factor that effects the species geographic distribution, the result of this study showed that non-permanent stream and permanent stream have the high effect to the gaur's geographic distribution (see Table 25 and Appendix Table 18). As shown in Figure 32 gaur has minimal habitat use probability in grassland. The gaur has highest habitat use probability in hill evergreen forest, which is in the valley beside TKM. The result also indicated that no correlation between the hog deer and the gaur (*P*-value = 0.903, r = -0.044).

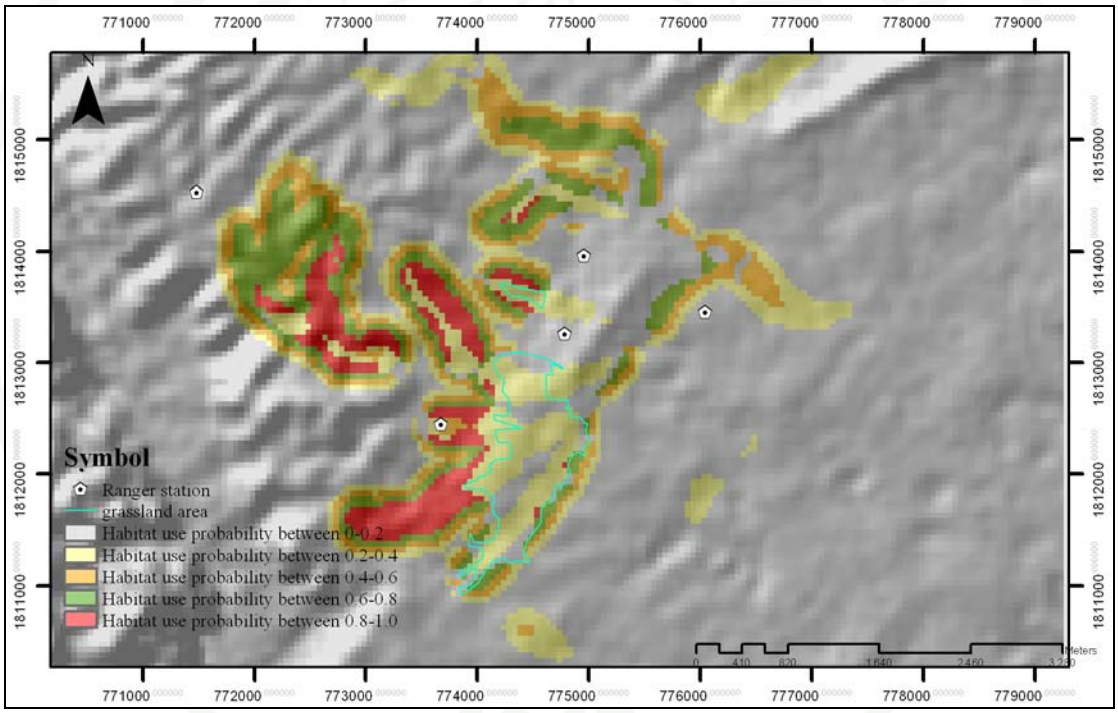


Figure 32 Habitat use probability of gaur.

5.6 Elephant: The result revealed that the AUC is 0.965 which means that the method is highly reliable. Concerning the environmental factor that effects the species geographic distribution, the result of this study showed that the saltlick and ranger station have the high effect to the elephant's geographic distribution (see Table 25 and Appendix Table 19). As shown in Figure 33 the highest habitat use probability of elephant was not only found in the hill evergreen forest but also found in the part of grassland, which has some pioneer plants from the hill evergreen forest penetrating into the area. Similar to sambar deer, barking deer, and the wild boar, the habitat use of the elephant is not specific to the open area when referring to the forest type factor. The result also indicated that no correlation between the hog deer and the elephant (*P*-value = 0.198, r = 0.444).

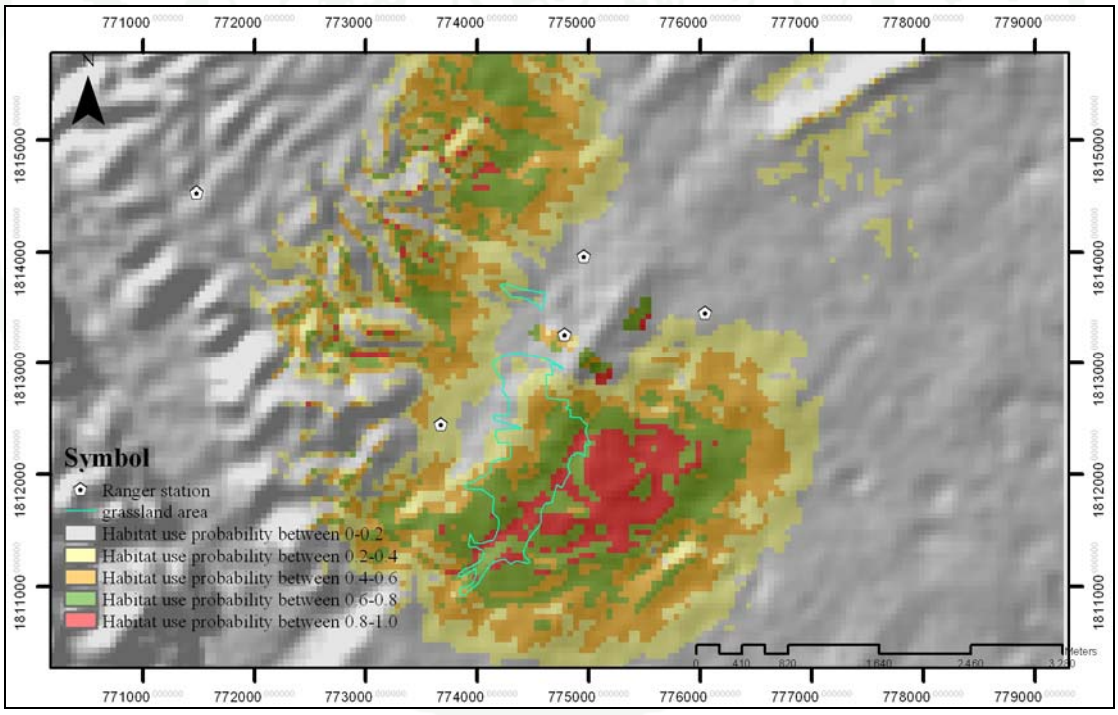


Figure 33 Habitat use probability of elephant.

5.7 Asiatic jackal: The result revealed that the AUC is 0.981 which means that the method is highly reliable. Concerning the environmental factor that effects the species geographic distribution, the result of this study showed that the saltlick and ranger station have the high effect to the Asiatic jackal's geographic distribution (see Table 25 and Appendix Table 20). As shown in Figure 34 Asiatic jackal has the highest habitat use probability in the mixed pine deciduous dipterocarp and hill evergreen forest on the east of TKM including the office area. The result also indicated that no correlation between the hog deer and the Asiatic jackal (*P*-value = 0.080, r = 0.578).

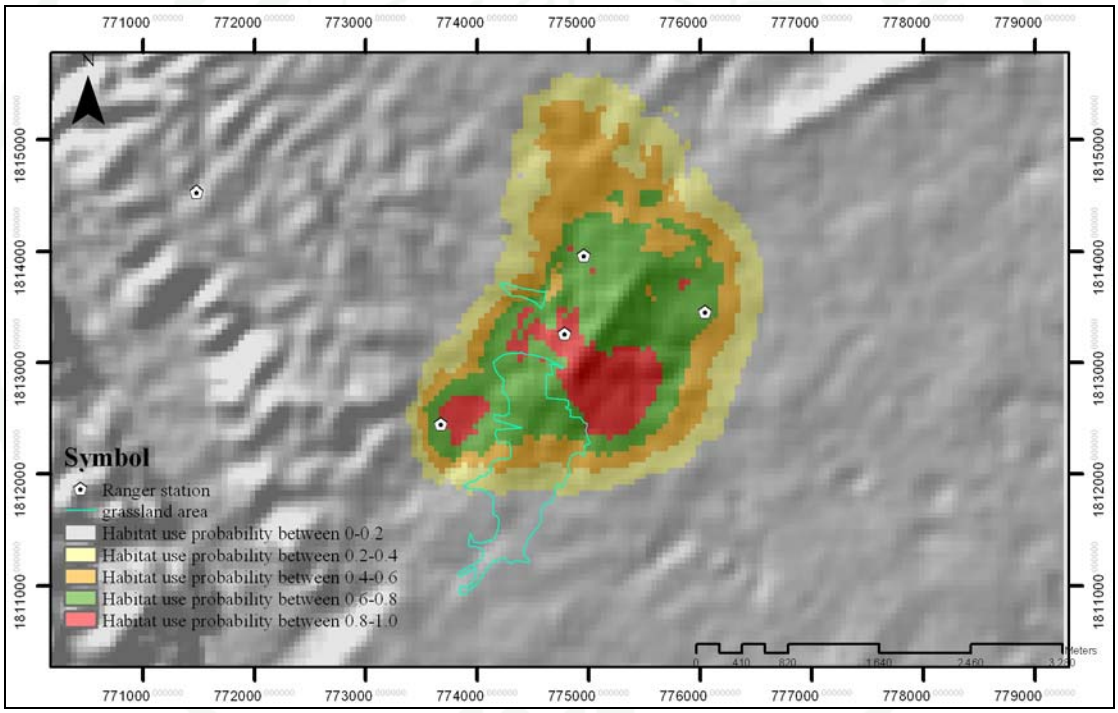


Figure 34 Habitat use probability of Asiatic jackal.

5.8 Asian wild dog: In dry season, the result revealed that the AUC is 0.954 which means that the method is highly reliable. Concerning the environmental factor that effects the species geographic distribution, the result of this study showed that forest type and saltlick has the high effect to the Asian wild dog's geographic distribution (see Table 25 and Appendix Table 21). As shown in Figure 35 the Asian wild dog has the highest habitat use probability in grassland. This is consistent with the probability of habitat use of the hog deer which is their prey in TKM. The result also indicated that no correlation between the hog deer and the Asian wild dog (*P*-value = 0.098, r = 0.553).

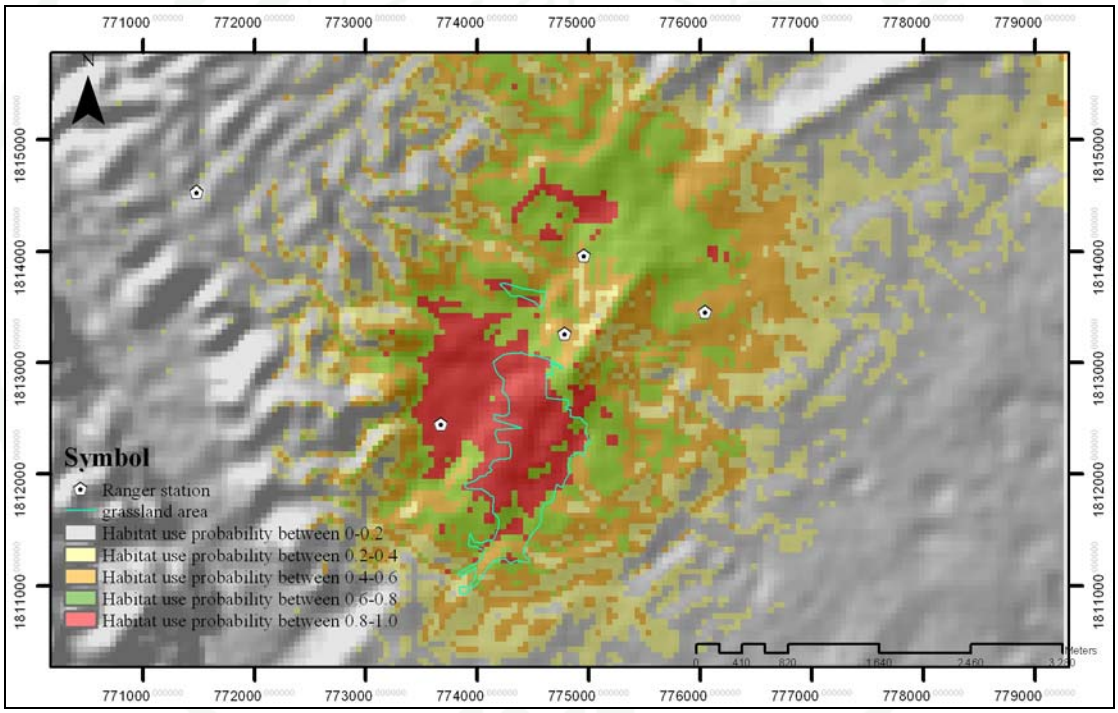


Figure 35 Habitat use probability of Asian wild dog.

5.9 Leopard cat: The result revealed that the AUC is 0.950 which means that the method is highly reliable. Concerning the environmental factor that effects the species geographic distribution, the result of this study showed that forest type and saltlick have the high effect to the leopard cat's geographic distribution (see Table 25 and Appendix Table 22). As shown in Figure 36 leopard cat has the highest habitat use probability in grassland. This is consistent with the probability of habitat use of the hog deer. The leopard cat hunt small animals including new born hog deer which is their prey in TKM. The result also indicated the positive correlation between the hog deer and the leopard cat (*P*-value = 0.017, r = 0.729).

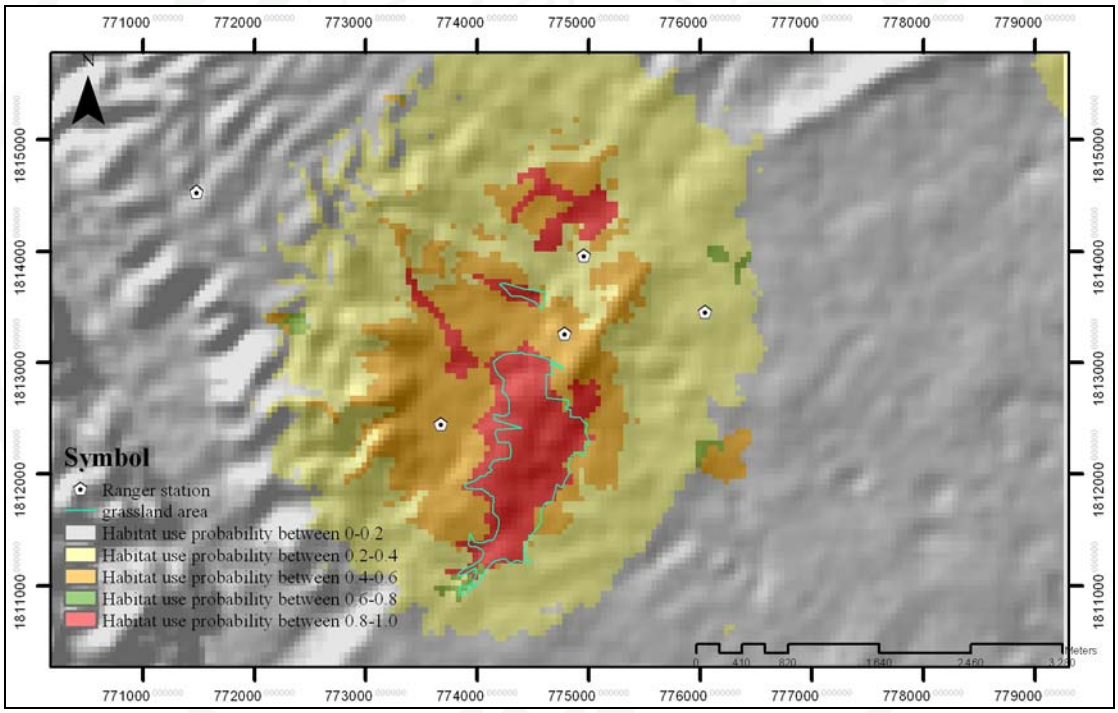


Figure 36 Habitat use probability of leopard cat.

Table 25 Percent contribution of target species by Maximum Entropy method.

Factor	Hog deer	Sambar deer	Barking deer	Wild boar	Gaur	Elephant	Asiatic jackal	Asian wild dog	Leopard cat
Forest type	27.5	6.9	4.6	3.1	5.6	3.1	0.2	15.1	55.8
Dry season, loose surface road	3.3	4.5	4.6	5.5	0.0	6.4	7.0	0.0	1.3
All season, loose surface road	7.1	24.3	19.7	16.8	22.7	2.5	2.4	27.6	14.6
All season, hard surface road	28.8	24.0	23.6	23.9	4.5	37.5	53.3	28.4	14.4
Saltlick	3.2	14.1	17.8	17.8	0.0	23.9	18.4	9.0	6.3
Digital elevation model	5.0	3.1	3.3	3.5	0.0	2.5	0.0	1.8	0.3
Permanent stream	4.7	9.9	11.9	10.9	19.0	7.6	1.2	2.3	3.2
Non-permanent stream	4.5	3.5	2.6	3.8	28.7	2.7	0.1	4.6	0.0
Ranger station	15.0	8.9	10.8	12.5	19.5	8.7	16.4	2.1	3.4
Slope	0.9	0.8	1.1	2.2	0.0	5.1	1.0	9.1	0.7

6. Population viability analysis

Hog deer is a polygynous species. Dhungel and O'Gara (1991) reported that the mating season of hog deer in the Royal Chitwan National Park, Nepal, occurred during July and October, being slightly different from the mating season of hog deer in TMK at PKWS, which could occur at any time throughout the year, but was mostly during May and August. This may have been due to different climatic conditions. The hog deer population was besieged in TKM by dense forest surrounded. Until the study time, the existing hog deer and their offspring, which was introduced to this area in1983, still live and distribute in TKM with a home range of hog deer was introduce to TKM 5.03 km^2. Males become adult and can reproduce once they are older than one year, while females become adult and can reproduce once they reach two years of age. The data recorded from Huai Sai Wildlife Breeding Center in Phetburi Province in 2008 (S. Kanchanarajit, 2008 (pers. com.)) found that the sex ratio of newborns was 0.54:0.46 reported (Appendix Table 24) and the captive hog deer could give birth up until 17 years of age (Chamnankit, 1974). A female hog deer can give birth to just one fawn each year that the similar on our study, we found that the hog deer gave birth only one per time. This report was similar with single young born in 32 births recorded at New York Zoological Park (Crandall, 1964 cited after Dhungel and O'Gara (1991)) but twins were recorded twice in 55 births at London Zoo (Asdell, 1964 cited after Dhungel and O'Gara (1991)).

The heterosis model selects homozygotes without removing the genetic load. Ralls *et al.* (1988) used this model show that the cost of inbreeding varied broadly among different species. According to Ralls *et al.* (1988), 3.14 was the median value of lethal equivalents for mammal species. Cervid species in captive population range from 1.2 to 15.1 lethal equivalents. A small population size usually leads to low heterozygosity (Hedrick, 1996). The impact of low heterozygosity on the hog deer population is unknown. Hedrick (1996) found that high heterozygosity levels do not always lead to high-fitness individuals, nor do low heterozygosity levels to low-fitness individuals. The maximum number of progeny per year,

The average death rate of hog deer during the study period was 21.13%, compared to the overall population found by the total count method. Deaths occurred in both adult and sub-adult age classes. The death rate was 26.83% for males and 10.81% for females. The death rate for fawns was 33.33%. Details are shown in Appendix Table 3.

Utilizing the Vortex program with 1,000 iterations, the sustainable population in the next 50 years was calculated. The program took the following data into account in Table 26:

Table 26 Simulation model parameters of re-introduction of hog deer at Thung Ka Mung in Phu Khieo Wildlife Sanctuary.

Parameter/variable	Value
1. Replication	1,000
2. Generation (year)	50
3. Extinction definition	Only one sex remains
4. Population	1
5. Inbreeding depression: lethal equivalents	3.14
6. Number of Types of Catastrophe	0
7. Breeding system	Polygynous
8. Age of First Offspring for females	2
9. Age of First Offspring for males	1
10. Maximum Age of Reproduction	17
11 Maximum Number of Progeny per year	1
12. Sex ratio at birth in % male	53.85
13. % Adult females breeding	85.71
14. EV in % adult females breeding (SD)	20.20
15 Mortality From Age 0 to 1	33.33
16. Annual mortality percentage (adult female)	10.81
17. Annual mortality percentage (adult male)	26.83
18. % of adult males in the breeding pool	26.15
19. Initial size of population	20
20. Carrying capacity (K)	272
21. Standard deviation in K due to EV	1.25

The simulation model revealed the trend of the mean population size and the probability of survival over a period of 50 years (Table 20). The population size increased every year (Appendix Table 23) from 20 individuals in 1983 (the first introduction year), to 194 individuals in 2008. In 2018, or 35 years after the deer introduction program, the size of the deer population was predicted to reach the approximate maximum carrying capacity for TKM, as determined from Figure 37. The survival probability of the deer population from the initial year (one) after more than 50 years shows the sustainability of this introduced hog deer population. In addition, data from genetic diversity analysis, using the pellet sampling method, showed that hog deer with different haplotypes have interbred and scattered throughout all areas of TKM, which also supports the sustainability of the hog deer in this area.

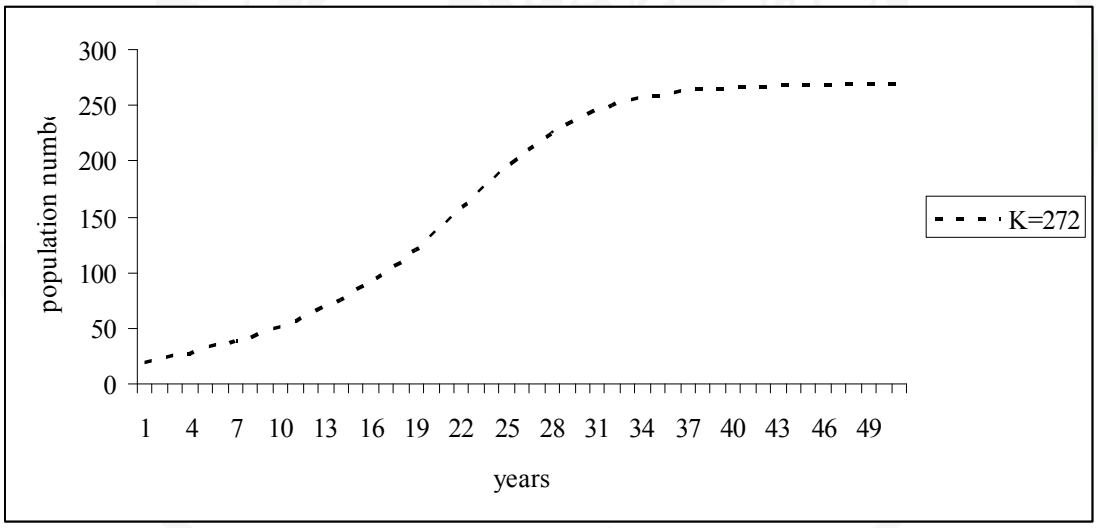


Figure 37 Prediction of population size of hog deer at Thung Ka Mung in Phu Khieo Wildlife Sanctuary from the year 1983 to year 2032.

DISCUSSION

1. Population characteristics

1.1 Population density by fecal pellet group count method

Dhungel and O'Gara (1991) studied the ecology of hog deer in Royal Chitwan National Park, Napal. They said that densities estimates by pellet counts vary because rates of pellet deposition differ among fawn, yearling, and adult deer as well as depend on climatic conditions, seasons, and type and availability of food. Also, ungulates do not defecate evenly through their home ranges, adding a bias that is difficult to evaluate. They concluded that the data gathered by the fecal pellet group count method results in a comparative index of abundance rather than a true density estimate. However several studies indicated that the fecal pellet group count method can provide accurate results (Ngampongsai, 1977; Chinaroonchai, 1983; Sukmasuang 2001; Kuntaro, 2002). The average number of pellet-groups defecated per animal per day can be adopted for calculating the actual or relative number of animals in a given area. Therefore in this study the defecation rate of hog deer in captivity (Kuntaro, 2002), which was 12.10 times/individual/day, was used for estimating the density of hog deer per hectare and the pellet counting method was performed both in the dry and the wet season periods.

The average hog deer population density in TKM was 2.03-2.04 individuals/ha (SD = 1.25) studied during February 2008 and January 2010. The density was higher than that reported of Kuntaro (2002), who studied the hog deer population in the same area and reported that the density was 1.02 individuals/ha. The higher density reported in this study can be explained by the fact that the populations, which has been increasing every year from 2002 to 2010, have remained only in TKM area. This is due to the fact that the deer population of PKWS was specifically concentrated in TKM grassland area for foraging. In the present study, the population density in the wet season is lower than in the dry season. The rainfall during wet season might cause the dissolution of the pellet resulting in a lower density

of hog deer population and according to the fact that hog deer rarely use grassland in the wet season. Thus some studies might neglect to collect the data in rainy season (Sukmasuang 2001, Dhungel and O'Gara 1991). However in this study, the purpose to collect all year data including wet season was to compare the data with that of Kuntaro (2002), who studied the population in the same area. Moreover in the wet season there was a wider distribution of hog deer and the forage was abundance. Therefore the density of hog deer in the grassland became lower in the wet season. Frequently used of TKM grassland was lowed. Mostly hog deer were foraging in forest habitat.

The density of hog deer at TKM in PKWS was higher than population density of hog deer in Khao Chi-on Non-hunting Area (0.55 individuals/ha), which is a semi-natural habitat (Aemsang, 2008). In Khao Chi-on Non-hunting Area, there are more sambar deer than hog deer and the habitat is difference from those of TKM. The density of hog deer in TKM was also higher than that in Royal Chitwan National Park, Nepal (0.155 to 0.191 individuals/ha), which is a natural habitat (Dhungel and O'Gara, 1991). This may be the effect of more competitive animals existing in both areas and also in Royal Chitwan National Park, Nepal there are more chital deer than hog deer. These competitive species use the same habitat and the same forage, thus limiting the resources available for hog deer. This may cause the lower number and density of hog deer in both areas. Moreover it was found that the hog deer's forage overlapping with those of sambar deer and barking deer were 4.9 % and 2.3% respectively. However, determined at the genera level, the hog deer's forage species overlapping with those of sambar deer and barking deer were 22.2 % and 3.2% respectively. Thus sambar deer had the highest inter-specific relationship in term of competition but less than both areas.

The higher density occurred in TKM area may be due to the fact that the area is not natural habitat for the deer. Man-made grassland is only one suitable area for released hog deer whereas in the natural condition in Royal Chitwan National Park, Nepal, hog deer can adapt naturally so the density is lower when compare with

TKM area. Nevertheless the total population in Royal Chitwan National Park, Nepal was higher than that in TKM area.

1.2 The total number studied by total count method

The idea of counting every animal in a population or on a given area has an attractive simplicity to it. It is the method used by farmers to keep track of the size of their flocks (Sinclair *et al*., 2006). No arithmetic beyond adding is called for and the results are easily interpreted. That is why total counting was once very popular in wildlife management and why it is still the most popular method for censusing people. The total count techniques is also appropriate for censusing big animals, however an attempt to search for all animals must be executed in order to reduce the bias (Bouche *et al*., 2012). This method was used in the study of Omondi *et al*. (2006) for aerial wildlife surveying in Yankari Ecosystem in Nigeria.

The hog deer population lives in TKM, which is a grassland habitat, therefore the population can be determined to a reasonable level of accuracy by total count method. However the number of hog deer determined by total count technique is usually lower than the number estimated by fecal pellet-group count technique because a number of fawns hidden in the vegetative covers can be missed in the total count. But we can found the fawn pellets in the sample plots. Therefore, fawns will be included by the fecal pellet-group count technique.

1.3 Population structure

1.3.1 Group size

The results from this study found that the average group size was 9.57 individuals. Percentage of hog deer found being in group or solitary were 91.5% (N=1,290) and 8.5% (N = 120) respectively. The average group size for the wet and dry season was 12.75 and 5.11 individuals, respectively. The percentage of different types of groups from 1,410 sightings over one year at TKM were calculated to be

solitary 8.5%, small (2-3 animals) 30.4%, medium (4-6 animals) 27.5%, large (7-10 animals) 11.5 %, and very large (>10 animals) groups 22.1%. This study, showed that the hog deer in TKM preferred to stay in group similar to that in the studies of Kumsuk and Kreetiyutanont, (1999); Kuntaro, (2002), but was different from the study of Biswas (1999), who reported that the percentage of different types of groups of hog deer, from 710 sightings over 5 months at Jaldapara Wildlife Sanctuary in India, were calculated to be solitary 41%, small (2-3 animals) 41%, medium (4-6animals) 11%, large (7-10 animals) 4 %, and very large groups (>10 animals) 3%. Biswas (1999) reported that hog deer either remained solitary or in family units, depending on the season and the gender. Adult males remained solitary irrespective of the season, while the composition of family units, medium and large groups changed with season. Adult females primarily formed clan units (all-female groups, adult pairs or mother-fawn association) or mixed groups (large and very large groups) depending on the season. Except for mother-fawn association and mixed groups the percent composition of solitary females, adult pairs, and female groups decreased in the summer (Appendix Figure 2). Bhowmik *et al*. (1999) and Bhowmik and Chakaborty (2001) also reported that hog deer in Jaldapara Wildlife Sanctuary and Gorumara National Park in Himalayan West Bengal like to feed on grassland habitat and also hog deer stay in group more than stay alone. The average group size was lager that study of Kuntaro (2002) in TKM, she reported an average group size of 3.35 individuals. May be due to grassland management by controlled burning in TKM was conducted only in small areas during her study compared with during this study controlled burning was done throughout the grassland.

The male hog deer in TKM started to shed their antlers from November until March. The with peak shed antlers was found in January. The percentage of male with shed or velvet antlers was concomitant with the percentage of solitary hog deer (see Table 6 and Figure 13). During November to January, when the percentage of shed antler male was increasing, so was the percentage of solitary animal. During January 2008 and April 2008, both of the percentage of shed or velvet antler males and solitary animals were decreasing and then remained low until October 2008. A major increase in hard antlers was observed during April 2008 with

all antlers hard from May 2008 to August 2008 and remained high until October 2008.

During May, the beginning of the rainy season, the deer group accumulated in grassland related with reproductive period. Obviously, the size of the group varies with the season and good forage source. Thus the herd size in TKM area was higher than other areas due to both factors.

The group size of the hog deer from this study was larger than the group size in natural condition reported by Dhungel and O'Gara (1991). They reported that the average group size of the hog deer at Royal Chitwan National Park, Nepal was only 1.8 individuals, with 65.8% of hog deer found alone and 34.2% in a group. This may be the effect of the habitat different and grassland management. The hog deer in Royal Chitwan National Park, Nepal are wild population, scatter in a small group that can reduce the mortality rate causing by predators such as tiger and leopard. The initial populations of hog deer at TKM in PKWS were captive and were released to the wild. Their habitat was limited only in grassland and open forest area. They preferred to feed in the areas with grass shoots, which grown after controlled burning in February. Hog deer like to stay in tall grass habitat naturally especially along the stream in mixed deciduous forest or open habitat (Dhungel, 1985). Nevertheless the population in PKWS originated from captive and released to TKM for more than 25 years ago. Furthermore, there is no record about wild hog deer population in TKM. Natural habitat around TKM composed of hill evergreen and mix-pine deciduous dipterocarp forest above 800 m from MSL. So grassland in TKM is essential to the population. Important controlled burning every year is need.

1.3.2 Age structure, sex ratio, and recruitment rate

The age structure of a population, the number of individuals in each age category, is very important in determining population increment. This study found that the percentages of adult males, adult females, juvenile male, juvenile

female and fawns were 26.2, 48.2, 4.7, 8.4, and 12.6, respectively. The percentage of adult, juvenile and fawn was 74.3, 13.1, and 12.6%, respectively.

The sex ratio of adult hog deer in TKM, which was 54.6:100 for male:female, 100:26.2 for female:fawn, closed to the sex ratio of hog deer in nature conditions as reported by Seidensticker (1976), Dhungel and O'Gara (1991) and Biswas, (1999). Seidensticker (1976) studied the sex ratio of hog deer in Royal Chitwan National Park and reported that male:female:fawn ratio was 51:100:24. Dhungel and O'Gara (1991) studied the sex ratio of hog deer in Royal Chitwan National Park, Nepal and reported that male:female ratio was 52:100, and female:fawn was 100:22 (Figure 38). Biswas (1999) studied the sex ratio of hog deer in Jaldapara Wildlife Sanctuary and reported that the male:female ratio was 56:100, and the female:fawn was 100:21.

The recruitment rate of hog deer population in PKWS (34.6%), in this study was higher than the result of the recruitment rates in Nepal, which were 15.8% and 13.1% as reported by Seidensticker (1976) and Dhungel (1985) respectively. Nevertheless mortality rate of the deer in TKM was 18.11%. Thus the increment of the population was 16.50% approximately. The recruitment rate higher than that of natural habitat means that the hog deer population in PKWS is not yet stable. TKM can accommodate an increase in hog deer population due to the available habitat and forage factors. The recruitment rate gained from this study was higher than the mortality rate also indicated that the released hog deer can adapt and survive in their new habitat.

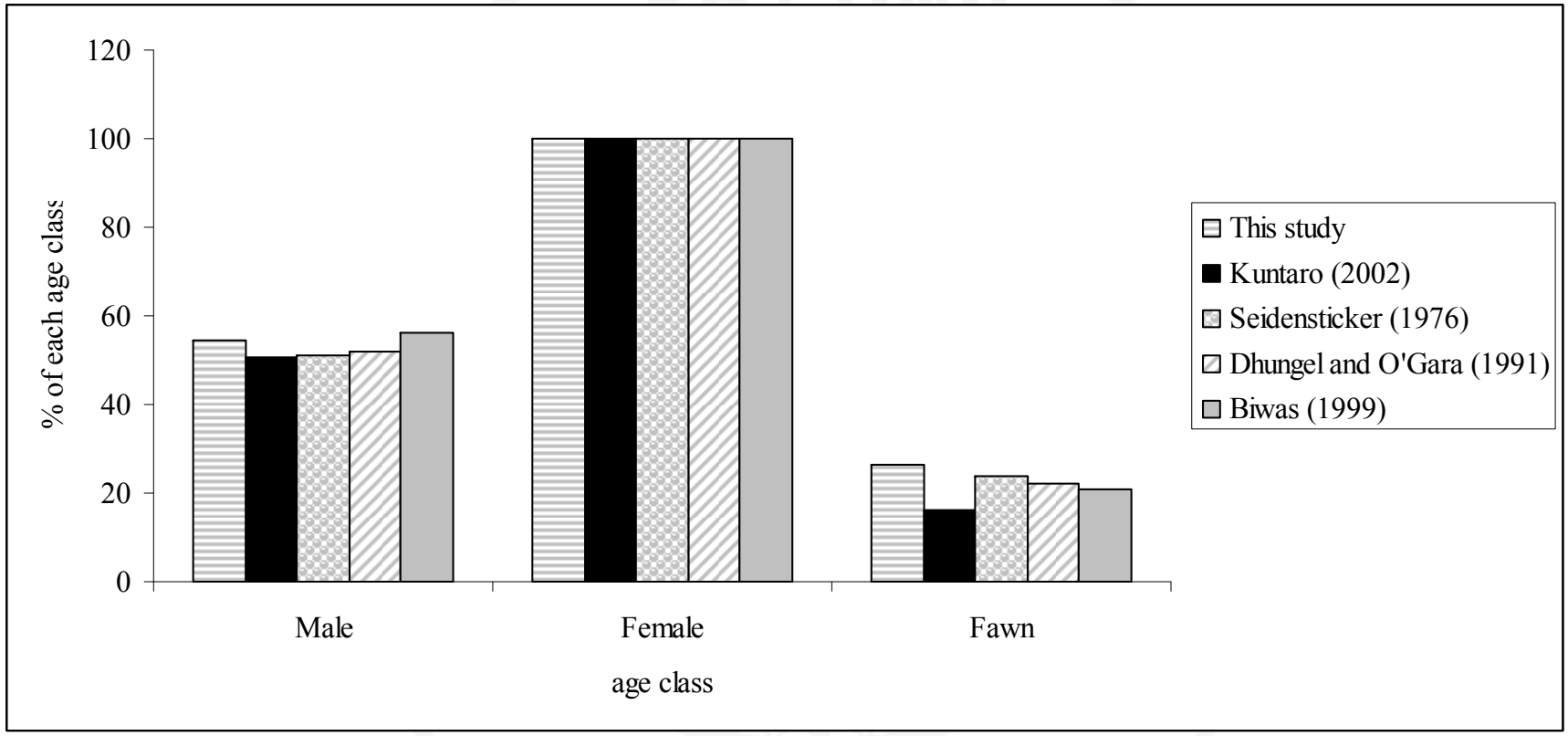


Figure 38 Sex ratio of hog deer at Thung Ka Mung in Phu Khieo Wildlife Sanctuary compared to other study sites.

1.4 Breeding season

In general, breeding season of deer can be observed from male's antler that synchronizes periodically with the female being in estrus. The breeding period occurs when male hog deer have hard antlers. After the breeding period, the animal will shed their antlers (Lekagul and McNeely, 1988) which synchronizes with 7-8 months of gestation period of the female. Increased proportion of adult males within the group in May (25.3%) suggests the onset of hog deer breeding season in TKM area. The highest peak of fawns occurred during February and April that synchronized with the increasing of males with hard antlers. A major increase in hard antlers was observed during April with all antlers hard from May to August and remained in high percentage until October (see Figure 13). Therefore the conclusion was that the breeding season of hog deer in TKM is between May and October with the highest peak occurred during July and September.

Many documents reported differently about the breeding period of hog deer. Lekagul and McNeely (1988) reported that in general the rut of hog deer is in September and October. Dhungel and O'Gara (1991) investigated hog deer in Royal Chitwan National Park, Nepal and reported that breeding season was from July through October with a major breeding peak during September and October that closed to this study. The wild hind hog deer in Royal Chitwan National Park, Nepal gave birth at the beginning of January with a peak fawning season occurring in February and March. In India, hog deer also start rutting by September and October (Lydekkar, 1898; Blanford, 1888-91; Prater, 1980).

In the natural environment, changes in nutrition related to seasonal difference. This may be the principle factor influencing the number of females ovulating and the seasonal pattern of birth (Sukmasuang, 2001). The annual cycle in gonadal activity is also generated endogenously and is entrained to a particular time of the year by response to environmental cues. In tropical regions where seasonal constraints on reproduction are less defined and predictable, births may occur in all months of the year (Lincoln, 1991). The production of spermatozoa continues

throughout the year even when the animal is in the shed antler stage. In temperate region, the effect of season on time of parturition by deer is obvious and pronounced, sperm is produced only when the animal has antlers that synchronize periodically with the female being in estrus. Fawns are born during spring when food is nutritious and abundant (Lincoln, 1991).

1.5 Cause of death

This study found that the mortality rate of the newly released hog deer 50.0%) was higher than the existing hog deer. The mortality rate of newly released males (66.7%) was higher than that of females (40.0%). The mortality rate of the existing hog deer in TKM during the study period was 18.11%. The mortality rate of male hog deer (26.8%) was higher than that of female hog deer (10.8%) and mortality rate of fawn was 33.3% (Appendix Table 3).

Some possible explanations can be pointed out that the male deer not only needed to adapt to the new habitat for food and safety cover, but also had to fight against larger male deer from the existing hog deer. The newly released male deer were often found that separated from the herd, resulting in a higher mortality rate. During the study, we found the hog deer carcasses of hog deer from both groups. The mortality rate of 18.1% reported in this study is close to the mortality rate in Royal Chitwan National Park, Nepal, which were 11.5%, 15.4%, 18.8%, 18.7% and 26.0% as reported by Seidensticker (1976), McDougal (1977), Sunquist (1981), Mishra (1982) and Dhungel and O'Gara (1991) respectively. The similar mortality rate may be the effect of behavioral adaptability of hog deer population in TKM. This means that the hog deer in TKM could adapt well to the new habitat and have become wild population.

Potential predators of the hog deer in the study area were Asian wild dog, Burmese python, Asiatic jackal, leopard cat and clouded leopard. Slangsingh (2007) studied diet of Asian wild dog (*Cuon alpinus*) in PKWS. He reported that hog deer were hunted by Asian wild dogs and ranked fourth out of six prey species. The prey

species were composed of sambar deer (36.4%), barking deer (18.2%), mouse deer (18.2%), hog deer (15.2%), hog-badger (9.1%) and striped squirrel (9.1%). Asiatic jackal hunted an injured hog deer and the species shows omnivorous and carrion feeding habits rather than preying on large or medium size animals by itself (Bhumpakphan, 1997). The clouded leopards were detected by the camera traps in the area near TKM between dense forest and grassland and there was a study of Grassman *et al*., (2005) reported that hog deer killed by the clouded leopard. Another potential predator for hog deer in PKWS was reticulated python. Though there was no record of hog deer hunted by reticulated python in the present study, but reticulated python is in the listed of reptile found in this area. Diseases and accidental cases in these hog deer population were not recorded from this study.

Dhungel and O'Gara (1991) investigated the causes of death for hog deer in Royal Chitwan National Park, Nepal by estimation from death recorded of radio-collared deer. He reported that hog deer ranked the second (21.7%) out of seven prey species hunted by tigers and leopards. Other studies in Royal Chitwan National Park, Nepal reported that tigers and leopards killed about the same percentage of hog deer. Hog deer also are preyed upon by various other carnivores including pythons. The mortality rates ranged from 11.5% up to 18.7% were reported (Seidensticker, 1976; McDougal, 1977; Sunquist, 1981; Mishra, 1982). Fawn mortality is difficult to assess in the wild because fawns are vulnerable to many large and small carnivores such as jungle cats, leopard cats, fishing cats, Bengal foxes, golden jackals, and hyenas, as well as to diseases and parasites (Dhungel and O'Gara, 1991). The potential predators can kill hog deer fawn in the area are leopard cat, Asiatic jackal, python species. Sukmasuang (2001) reported that the civet can kill barking deer fawn, so it also potential predator for the hog deer fawn in TKM too.

1.6 Genetic diversity

Captive breeding and wildlife management programs typically recognize the importance of minimizing loss of genetic diversity and inbreeding. Management actions for captive populations include consulting pedigrees when establishing mating

or choosing individuals to reintroduce into the wildlife. Levels of genetic diversity are analyzed and monitored in wild populations of endangered species, and gene flow between isolated wild population may be augmented (Frankham *et al.*, 2004).

Though the hog deer could be successfully bred in captivity and introduction site, their genetic information is still scarce. Genetic knowledge is important for sustainable population management in captivity and reintroduction program and that is why the application of molecular techniques to the management of endangered animals has become an important tool. In the study by S. Dejchaisri 2007 (pers. com.), she reported that there are 11 different haplotypes of hog deer in Thailand.

The result from this study revealed that, among the existing hog deer in TKM, there are only three different APTs of hog deer in TKM. They were composed of APT02 (59.4%), APT10 (37.5%), APT06 (3.1%). The APTs of the newly released female hog deer, which remained only 3 out of 5, comprised 1 APT10, 1 APT06, and 1 APT09. Though, the pellet sampling method revealed that the hog deer with different haplotypes were mixing together and scattering throughout the area, which can minimize the problem of inbreeding (Figure 39), some APTs of hog deer are small and may be declined in numbers. Small, isolated populations suffer accelerated inbreeding and loss of genetic diversity leading to reduced reproductive fitness and reduced ability to evolve in response to environmental change (Frankham *et al.*, 2004). The haplotype APT02, which was mostly found in TKM in this study, can be found also in Wiang Lo Wildlife Sanctuary, Huai Sai Wildlife Breeding Center and Bang La Mung Wildlife Breeding Center. But the haplotype ATP08, which can be found in Phu Khieo Wildlife Breeding Center, was not found in TKM S. Dejchaisri 2007 (pers. com.)Therefore we recommended that further introduction of hog deer should be focused on the APT06, APT08 and APT09 and other different APTs, which do not exist now in TKM.

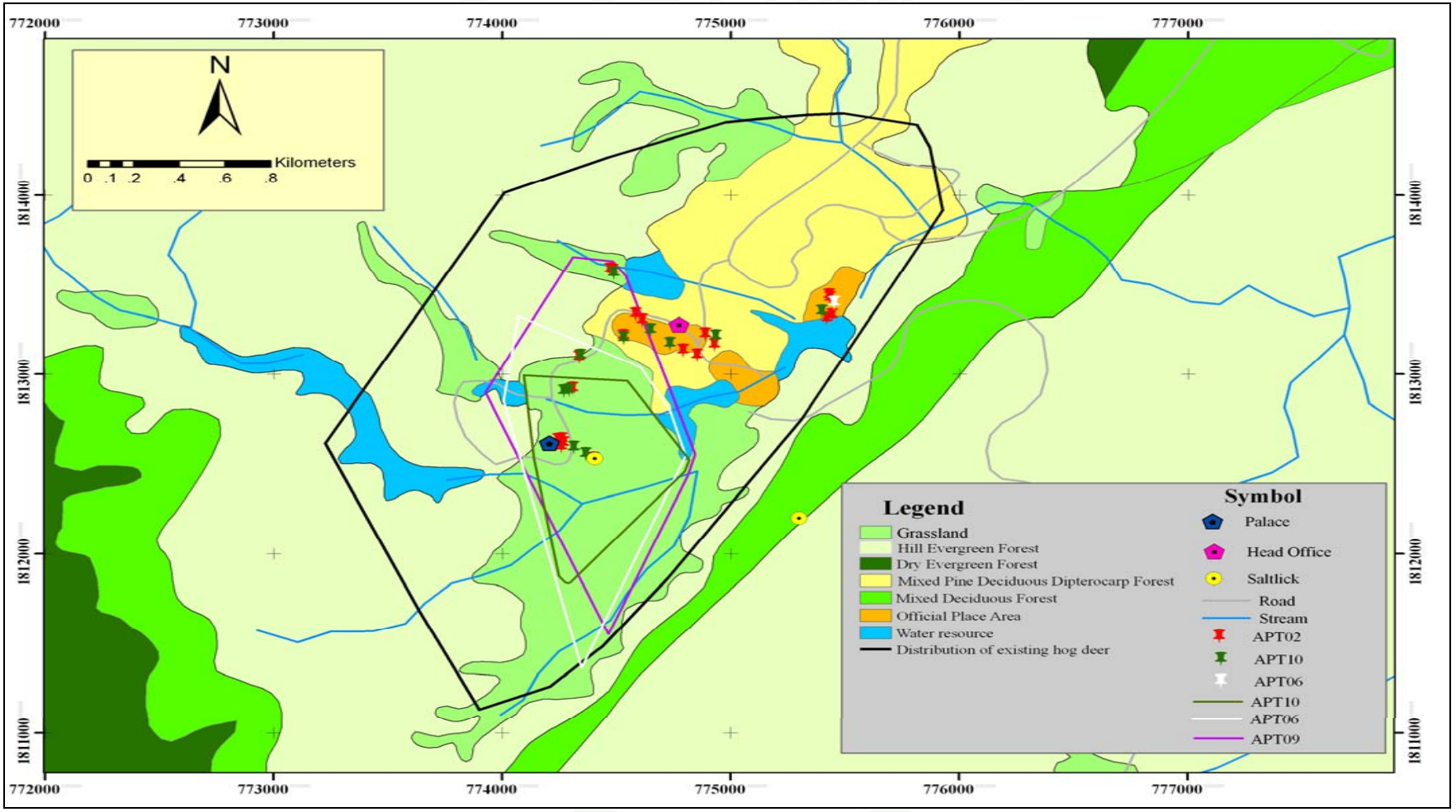


Figure 39 Distribution of each haplotype of hog deer in Thung Ka Mung area.

2. The adaptability of newly released hog deer

2.1 Physical condition

Eight hog deer, three adult males and five adult females, were released in November 2007 but only 4 hog deer remained. The result showed that the newly released hog deer showed substantial improvement in their physical condition within 6 months after release. However when comparing the size of the newly released hog deer with the existing hog deer of the same age class, the hog deer of the newly released hog deer were smaller than the existing hog deer. This might be the captive effect. The newly released hog deer was captive, thus living in limited space while the existing hog deer is free ranging most of them are wild born. The animal has more space for feeding and exercise as well as running to escape predators.

Forages available have strong influence on the body score of male hog deer. Range management in TKM by controlled burning was performed during January and March, resulting in plenty of new grass shoots. The average body score during this period (ranged from 2.54 to 2.78) were higher than in the early dry season (ranged from 2.50 to 2.54). But its effect on the body scores of the female hog deer was different. The results from this study showed that fawning has strong influence to the body score of the female hog deer. Even with range management by controlled burning in January to March, the female hog deer have had the lowest body score ranged from 2.49 to 2.53 during this period, which synchronized with the peak fawning season.

Breeding season also affects the body score of the male hog deer. The presence of 100% observed stags with hard antlers and increased proportion of adult males within the group in May 2008 suggest the onset of hog deer breeding season in TKM area, which synchronized with highest body score (ranged 2.84 to 2.85) of male hog deer in April 2008 and May 2008.

The result from this study was similar to the report of Achapet (1994), which compared the physical condition of hog deer, in Khao Chi-on Non-hunting Area, before and after released. He reported that the released hog deer could adapt themselves well in semi-nature habitat in Khao Chi-on Non-hunting Area and the hog deer had more shiny hair and were more muscular than their counterparts in captivity, which indicated that they could feed well and could exercise better than when they were raised in captive.

The results from the studies revealed that hog deer is a well adaptive species. Therefore, any further project which aims to release any herbivore in the nature should consider high priority for hog deer. The releasing strategy for male and female hog deer for rehabilitation of existed population should be different. It is recommended that sub-adult males should be released in order to reduce the struggle with the existed males. But there is no struggle for female hog deer, therefore it is recommended that adult ready to breed females should be released.

2.2 Reproduction of newly released hog deer

The result showed that the 3 newly released female hog deer were alive in TKM area during study period, 4 fawns were born but only 2 fawns survived. The fawns were a male and a female. Data concerning sex ratio of fawn in captivity collected from Huai Sai Wildlife Breeding Center showed that the male fawn: female fawn ratio was 53.85:46.15.

Base on this study, found that the litter size of hog deer is 1. The females gave birth to one fawn per time. This report was similar with the result reported by Dhungel and O'Gara (1991). Grandall (1964) reported that only single fawns were born in 32 births recorded at New York Zoological Park (Grandall, 1964 cited after Dhungel and O'Gara, 1991). However during this study, a hind accompanied by 2 fawns of the same age were also observed so they might be twin. Asdell (1964) reported that twins were recorded twice in 55 births at London Zoo (Asdell, 1964 cited after Dhungel and O'Gara (1991)).

2.3 Behavior

The behaviors of the existing hog deer, which were introduced to TKM 25 years ago, were investigated during one year including both the wet and the dry season and used for comparing with the data collected from the newly released hog deer in order to determine the adaptability of the newly released hog deer to the new habitat. For the newly released group the data was collected for 2 consecutive years, which included 2 wet seasons and 2 dry seasons. In this study, the hog's behaviors were investigated by scan sampling method from 6 am to 6 pm, so the behavior data of hog deer reported were limited to the day time activities. The behaviors classifications were modified from Chamnankit (1974). Hog deer behaviors were consisted of "feeding", "lying down", "walking and running", "ruminating", and "other".

As previously mentioned in the results part, the annual mean time for all behaviors of existing hog deer were similar between males and females. Concerning the seasonal effect on behaviors of male and female hog deer, most observed behaviors including feeding, lying, walking, and running, and ruminating, which occupied almost 98% of the observed time, were similar between males and females in both the wet and the dry seasons. Both stags and hinds spent more time feeding in the wet season than in the dry season, but lying-down and ruminating in the wet season were less than in the dry season, while walking and running behavior was similar between the wet and the dry season. Only the "other" behavior in the wet season of male (2.1%) was significantly different from female (1.11%) as well as the "other" behavior in the dry season of male (1.85%) was significantly different from female (2.24%). The behaviors of the hog deer in this study were different from the captive hog deer. When comparing with the captive hog deer in Dusit Zoo, Chamnankit (1974) noted that captive hog deer spent 53.03% of the time lying, 21.89% walking, 9.07% feeding, 8.52% ruminating, 6.86% standing, and 0.73% running. Obviously the captive hog deer spend more time lying and less time in feeding since they were confined and fed by human. This means that after release the hog deer can adapt well to the natural habitat and become free-ranging.

The mean time of ruminating behavior of existing hog deer in the dry season was 4-5 times higher than in the wet season. This indicates that the existing hog deer are free-ranging and selective in their forage. In the wet season there are plenty of grass shoot so they spend more time feeding and they select forage, which generally has higher digestibility, higher content of nutrition, and lower fiber content, therefore the ruminating time is less. On the contrary to the newly released hog deer, they were captive and probably less selective in their forage. The mean time of ruminating in the wet season was higher than the dry season.

The activity patterns of hog deer in this study were similar to the hog deer in Nepal (Dhungel, 1985). The author reported that the hog deer are usually active, feeding and moving, during mornings and evenings. Generally, bedding is observed between 10:00 am and 4:00 pm inside the enclosure during cool and hot seasons.

Dhungel and O'Gara, (1991) said that the activity patterns of hog deer probably are influenced by environmental factors including rainfall, food availability, escape cover, reproductive condition, activities of predators, light and especially temperatures.

2.4 Habitat used

The results showed that the distribution of the existing hog deer in TKM covered an area of 5.03 km^2 which is slightly larger than the area of 4.62 km^2 as reported by Kuntaro (2002). The habitat used distribution in the present study has extended more to the southern part where there has been grassland management by control burning as shown in Figure 40.

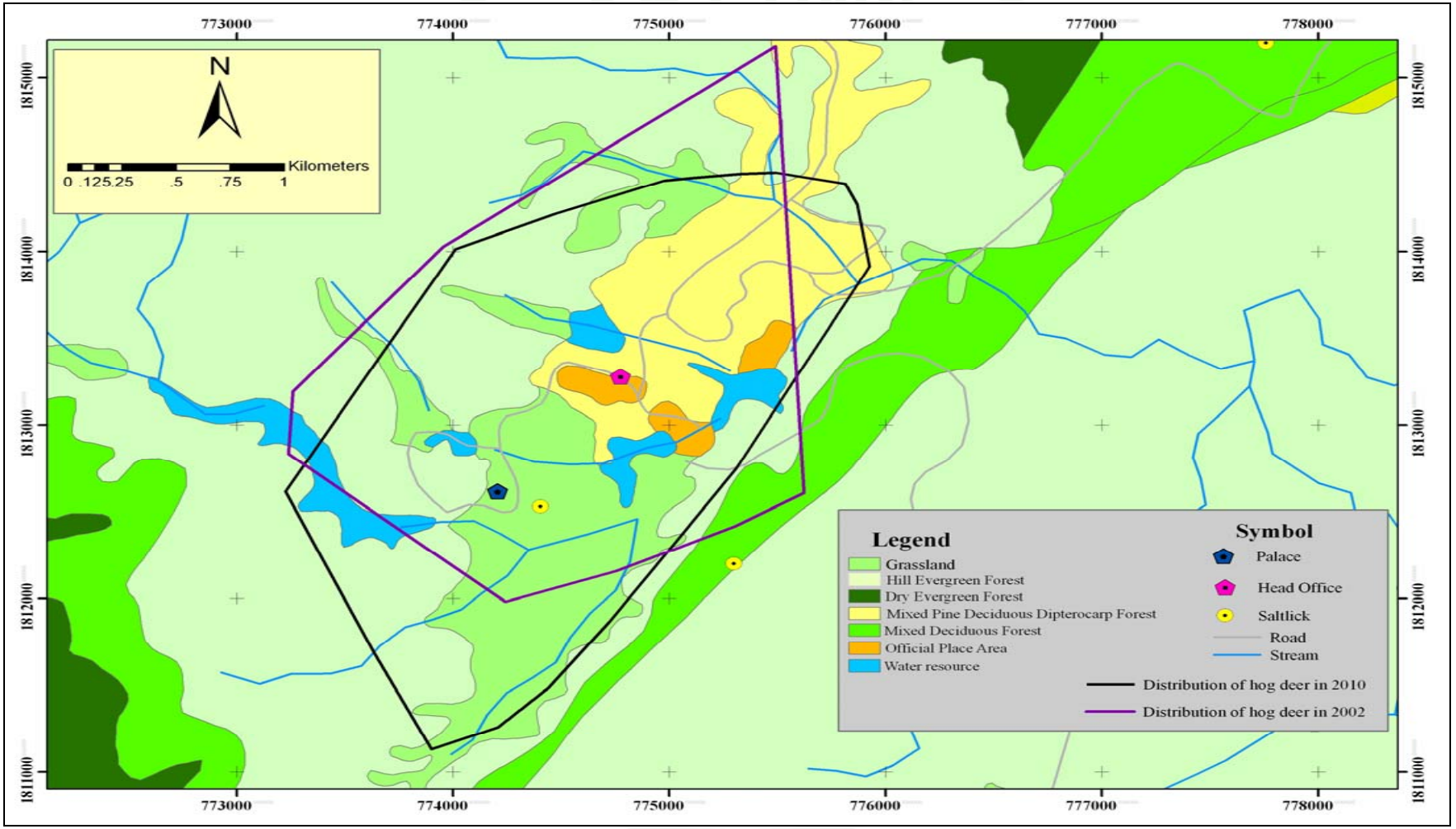


Figure 40 Distribution of hog deer at Thung Ka Mung area comparing between 2002 (Kuntaro, 2002) and 2010.

After two years, an area of 1.23 km^2 was used by the 4 newly released hog deer. The results showed that the distribution range of the first year was larger than the second year for every newly released hog deer. It might be due to their need to adapt themselves to the new habitat as well as searching for food. Distribution area of both males and females overlapped and appeared stable during the study period at TKM. During the dry season (November-March), the habitat used by the females ranged 0.29-0.59 km^2 (average=0.43) (SD=0.15) and by the males was 0.55 km^2. During the wet season (April-October), the habitat used by the females ranged 0.23-1.02 km^2 (average=0.58) (SD=0.40) and by males was 0.63 km^2. Rodrigues and Monteiro-Fillho (2000) also reported larger home ranges for pampas deer in the wet season than in the dry season because biomass of new leaves and flowers, the items most consumed by pampas deer were greatest in the wet season. In general, vegetative biomass in the dry season may be greater or equal to the wet season. Nevertheless, they did not fine relationship between food availability as flower and grass and home ranges of pampas deer.

The result from this study was quite similar to the study of Dhungel and O'Gara (1991), which reported that mean home range size of hog deer in Royal Chitwan National Park, Nepal was 0.60 km^2 for females and 0.80 km^2 for males and home range shape was dictated by food and water. But the result of this study was different from the study of Achapet (1994), which reported that the average hog deer home range size was 1.6 $km^2$with slightly differences between the sexes (1.53 km^2 for females and 1.66 km^2 for males). This may be the effect of grassland management by controlled burning, which was applied both in this study and the study of Dhungel and O'Gara (1991), but were not applied in the study of Achapet (1994).

The habitat used occurred in GL type was 97.52% (N=4,728), MPDF was 1.67% (N=81), HEF was 0.31% (N=15) and MMR was 0.50% (N=24). Some parts of the mixed pine-deciduous dipterocarp forest area were used for human activities, such as offices, football fields and visitor accommodation. The hog deer were found in these areas, since the grass was often cut. The result of our studies were similar to the studied of Mishra (1982), which reported that axis deer in Royal Chitwan National

Park, Nepal use grassland habitats 96.6%, riverine forest 3.1%, and sal forest 2.4%. Dhungel (1985), found that hog deer in the same park used grassland habitats 98.5% of the time, riverine forests 1.4%, and sal forest only 0.2%. Hog deer in the Royal Chitwan National Park, Nepal, also preferred grassland (Dhungel and O'Gara, 1991). The habitat and distribution of the hog deer in PKWS were similar to those reported in previous studies in Thailand, where hog deer were observed in semi swamps, grasslands, nearby rivers or on sandy beaches (Miller, 1975, Bain and Humphery, 1982, Lekagul and McNeely, 1988, Lekagul and Nabhitabhata, 1990).

Home ranges are influenced by the ways in which individuals of a species interact with their habitat and each other (Mares *et al*, 1980; Braun, 1985). The major factor influencing the distribution range of hog deer in TMK Area is the seasonal distribution of food, water and hiding cover in the grassland. Dhungel and O'Gara (1991) said that, if foods are widely distribution, an animal has to make extensive seasonal movements involving uneconomical energy expenditure, but food, water and cover usually are close together in hog deer habitat.

The result from this study revealed that the hog deer avoid the hill evergreen forest. This is also the major barrier, which obstructs the distribution of hog deer to other grasslands. In Vietnam and Laos, hog deer are found in the low lands, with wet marshes and tall grass cover (Whitehead, 1972). In contrast, in India and Sri Lanka, hog deer congregate near tall grass meadows and water sources and groves/thickets (Prater, 1971). In the protected areas of Sub-Himalayan West Bengal in India, hog deer are mainly found in open grasslands with a great variety of food species. They can also be found in areas of dense scrubs because these areas provide more secure shelter at night (Bhowmik *et al.*, 1999). In the Royal Chitwan National Park, Nepal, hog deer are found in meadows with plentiful food supplies, cover, and usable water (Dhungel, 1985; Dhungel and O'Gara, 1991). In Myanmar, the hog deer (*A. p. porcinus*) is found in tall grasslands but not in dense forest or the foothills of the mountains (U Tun Yin, 1967; Whitehead, 1972).

3. Forage species

This result from the present study identified at least 56 forage species from 14 families used by the deer, which were more numerous than the previous study of Kuntaro (2002), which also studied the hog deer using direct observation method in the same area and reported that the released hog deer fed on 29 plants species. The difference in the study method between the present study and the previous study should be suspected. In the present study, both direct observation and line plots system were performed for collecting data.

Most of the forage species were grasses (62.50%), which comprised Family Gramineae and Cyperaceae, with other forage life forms being herbs (16.07%), trees (10.71%), herbaceous climbers (8.93%) and fern (1.79%). Only ten forage species, which consisted of *Vietnamosasa pusilla*, *Ischaemum* sp.1, *Eulalia trispicata*, *Arundinella setosa*, *Panicum sarmentosum*, *Paspalum orbiculare*, *Themeda triandra*, *Fimbristylis dichotoma*, *Imperata cylindrica*, and *Eulalia quadrinervis*, were quantitatively important in the hog deer's diet and comprised 85.18% of the total consumption. Known locally as Phek, *Vietnamosasa pusilla* alone comprised 21.07% of the hog deer's diet and was an abundant grass found in TKM. It made up 30.22% of the available forage and was utilized heavily all year round.

Ammannia baccifera, *Crotalaria sessiliflora*, *Themeda triandra*, *Arthraxon castratus* and *Crotalaria* sp.1, with food preference rating of 2.73%, 2.49%, 2.40%, 2.39%, and 2.39%, respectively, had high preference ranks of the grassland forage. While they were heavily utilized by hog deer, their availabilities were very low (0.06%, 0.02%, 1.88%, 0.01%, and 0.01% respectively). They appeared to be species, which were sought out by the hog deer and any reduction in their abundance might indicate range overuse.

Dhungel (1985) reported that hog deer are solitary grazers. They feed on grasses, low herb and fern species: *Saccharum* spp., *Imperata cylindrica, Vetiveria zyzanoides, Cynodon dactylon, Zizyphus jujube, Dalbergia sissoo, Bombax ceiba*,

Saccharum sp. The *Imperata cylindrica* comprised the highest percentage of their diet, supplemented by nutritious flowers and fruits of various tree species.

Several studies have reported that hog deer could be both browser but more general grassers and they fed on a variety of forage types (Miller, 1975; Dhungel and O'Gara, 1991; Bhowmik *et al*., 1999; Kuntaro, 2002). They could feed on a variety of forage species, as well as discover natural salt licks by themselves, which indicated that the released hog deer could adapt well in the new environment.

Hog deer in captive can eat easily provided instant animal feed and variety food plants such as grass, morning glory, long beans, white cabbage, cauliflower, yams, and bananas. After released they can adapt and feed themselves and develop in a good physical condition.

Carrying capacity is central to the management of wildlife populations. Most biologists have a fairly good idea of what carrying capacity means, but it is used so often in so many ways that the meaning is often obscured (Krausman, 2001). Carrying capacity is the maximum number of animals of a given population that can be supported by available resources. Therefore, we can increase the carrying capacity of a species in an area by habitat management.

Habitat management should be carried out continuously in TKM area, which is the main habitat for hog deer in PKWS. The data reported by Kumsuk and Kreetiyutanont (1999) in 1995 revealed that the grassland area of TKM was 1.5 km^2 and in 1998 was 1.33 km^2. But the recent study in 2008 showed 56.56% reduction of the grass land area in TKM. Now there were only 0.85 km^2 remaining. The shrinkage of the grassland causes by the invasion of the surrounding hill evergreen forest.

The controlled burning is one of the methods to manage the grassland. Moe and Wegge (1997) studied the effects of cutting and burning on grass quality and axis deer use of grassland in lowland Nepal. They compared 3 treatments of grass plots

between cutting plots, burning plots and cutting and burning plots. The authors reported that cutting and burning plots give the best overall increase in nutritional quality and when compare between cutting plots and burning plots, the burning plots had a higher increase in N, P and Na concentrations than cut plots. Higher mineral effects of shoots from burned plots may be explained by the fertilizing effects of ashes (Kelleman *et al.*, 1985). The authors also reported that the highest densities of axis deer occurred with the grass areas of the highest quality and quantity of grasses. Cut plots attracted deer when no burned plots were available, but subsequent burning gave more pronounced effects than only cutting. When burned plots were available, cut plots were no longer preferred although these plots also had newly emerging sprouts. Therefore in this study the controlled burning in order to provide more available forage for the hog deer was performed.

In this study, the carrying capacity number was 272 individuals in the dry season. The carrying capacity for an ungulate species might be affected by the habitat sharing of the others ungulate species, which would be discussed in inter-specific relationship part.

4. Inter-specific Relationship

The results from 4 camera traps set around TKM area revealed that there were 4 ungulate species (see Table 24). They comprised of sambar deer, barking deer, wild boar, and elephant and their relative abundance were 28.41%, 7.38%, 4.70%, and 2.01% respectively. The 56 forage species used by hog deer were compared with sambar deer's forage species as listed by Ngampongsai (1977), who studied the habitat relationship of the sambar deer in Kao Yai National Park and compared with barking deer's forage as listed by Sukmasuang (2001), who studied the ecology of barking deer in Huai Kha Khaeng Wildlife Sanctuary as well as compared with elephant's forage species from Sukmasuang (1993), who studied the ecology of Asian elephant in Huai Kha Khaeng Wildlife Sanctuary. At the species level of forage species, the hog deer's forage were overlapping with those of sambar deer, barking deer and elephant by 5.06 %, 2.35%, and 0.00% respectively, also sambar deer were

overlapping with barking deer and elephant by 1.42% and 1.05% respectively, also barking deer was overlapping with elephant by 12.77% (Table 27). Therefore, it was understood that there was few species of forages in sharing between hog deer and the three ungulates species.

Table 27 Percentage of similarity index (SI) and dissimilarity index (DSI) of the hog deer's forage species in the species level overlapping with sambar deer, barking deer and elephant.

SI\DSI	Hog deer	Sambar deer	Barking deer	Elephant
Hog deer	-	94.94	97.65	100.00
Sambar deer	5.06	-	98.58	98.95
Barking deer	2.35	1.42	-	87.23
Elephant	0.00	1.05	12.77	-

However, when the hog deer's forage species were compared at the genera level with those of sambar deer, barking deer and elephant, the similarity index were 23.73 %, 3.25%, and 5.62% respectively (Table 28). Therefore, it could be concluded that hog deer and sambar deer had the highest inter-specific relationship in term of habitat sharing.

Table 28 Percentage of similarity index (SI) and dissimilarity index (DSI) of the hog deer's forage species in the genera level overlapping with sambar deer, barking deer and elephant.

SI\DSI	Hog deer	Sambar deer	Barking deer	Elephant
Hog deer	-	77.27	96.75	94.38
Sambar deer	23.73	-	91.07	95.21
Barking deer	3.25	8.93	-	70.40
Elephant	5.62	4.79	29.60	-

The result from the present study indicated that among the ungulate species sharing the habitat of TKM, the hog deer has more specificity to the grassland habitat than the others. Therefore it can be concluded that the evergreen forest is the barrier of the distribution of hog deer (see Table 25). However the other ungulate species (sambar deer, barking deer and etc.) were also found in TKM (Figure 41), therefore there might be competitive affected by the habitat sharing among the others ungulate species. Therefore, it was expected that there was little sharing between the animals and the three ungulates species. The result from this study also pointed out that there was only one grass species, which was *Imperata cylindrica*, shared by hog deer and samber deer as well as barking deer (Figure 42). However *Imperata cylindrica* was only 3.98% of total forage usage of hog deer, while it was 88.81% of total forage usage of sambar deer. Therefore the forage competition among the ungulates should be minimized. Forage species that shared by hog deer and barking deer were *Lygodium* sp. and *Phyllanthus emblica*. Forage species that shared by hog deer and sambar deer were *Cyperus haspan* and *Eragrostis atrovirens*.

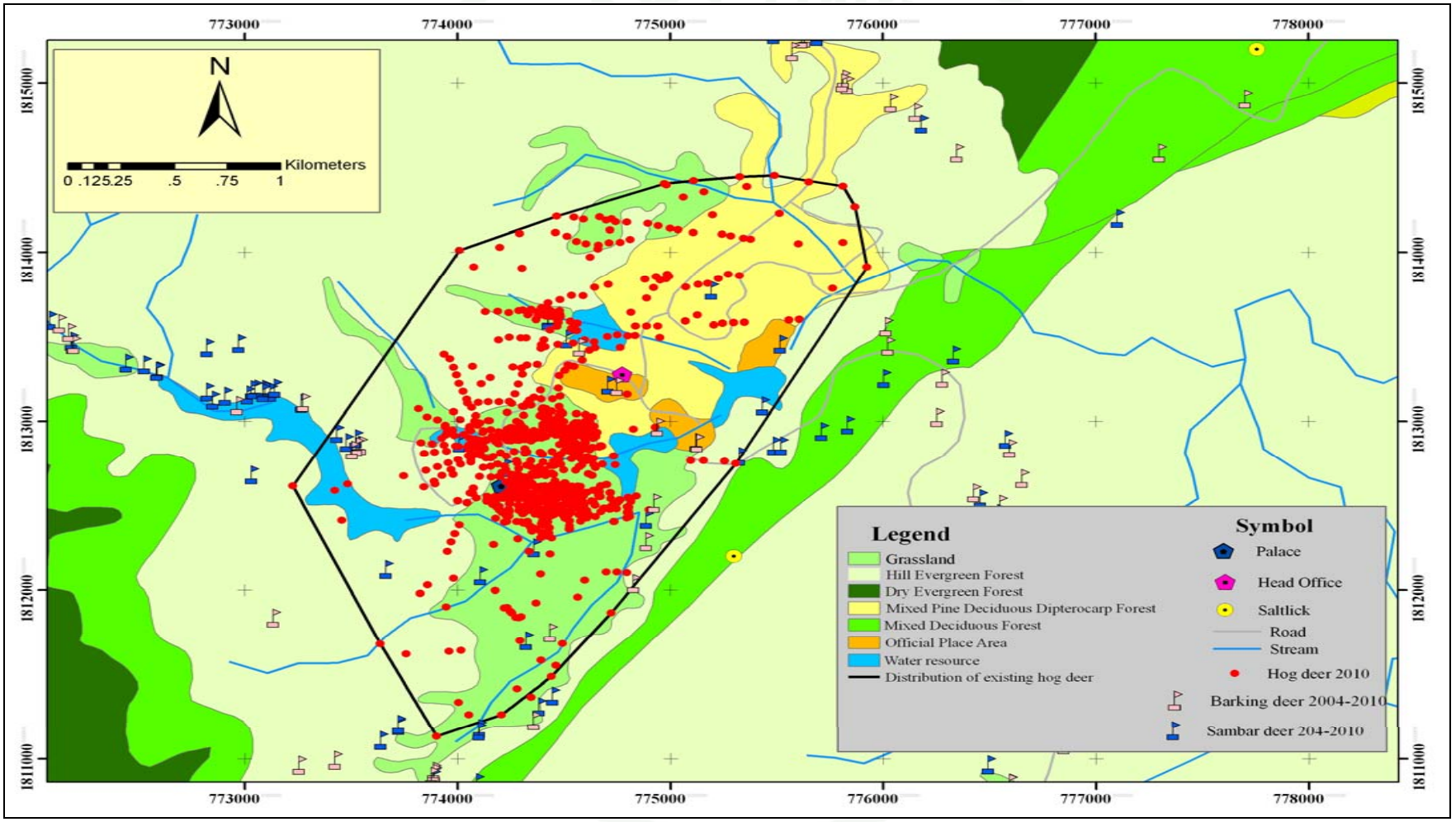


Figure 41 Distribution of sambar deer and barking deer around Thung Ka Mung area.

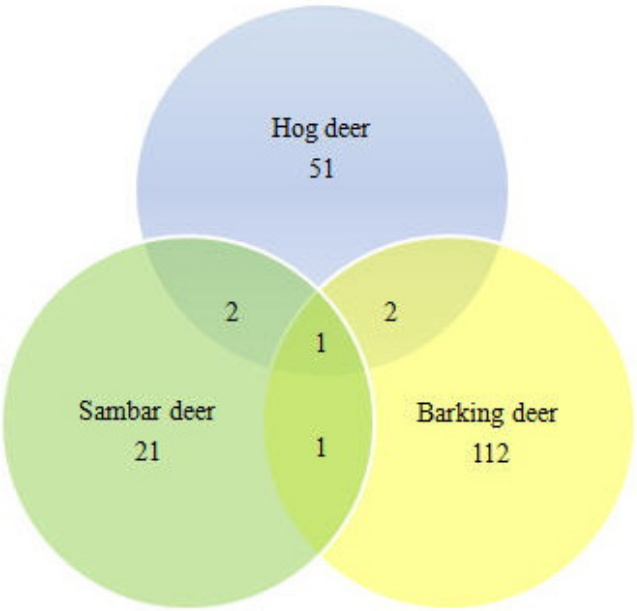


Figure 42 Forage species used and shared by hog deer, sambar deer and barking deer.

5. Probability distribution

Maxent is a general-purpose method for making predictions or inferences from incomplete information. In this study, we introduce it here as a general approach for presence-only datasets. The idea of Maxent is to estimate a target probability distribution by finding the probability distribution of maximum entropy, subject to asset of constraints that represent our incomplete in formation about the target distribution. Maxent offers many advantages and a few draw-backs when comparing with other modeling methods (Phillips *et al*., 2006).

The result from the species geographic distribution probability indicated that the saltlick has strong influence to the high percent contribution of ungulates at TKM in PKWS. It can be explained that the ungulate used this type of environmental factor for welfare factor. Forest type, which includes grassland, mixed deciduous forest and water resources, has also strong effect to the percent contribution of the ungulates.

This result is similar to the study of Podchong (2009). The hog deer distribution is mainly found in TKM area, therefore the land use is highly related to high percent contribution of hog deer. Without the barrier from the evergreen forest, the potential distribution of hog deer might be similar to those of barking deer and sambar deer. Saltlick is the factor that highly related to the presence of elephant which is the biggest ungulate. This result is similar to the study of Vinitpornsawan, (2003) and Podchong, (2009).

The result from this study indicated that the forest type especially grassland has a strong effect on the hog deer distribution. TKM is now the main grassland for the hog deer distribution. The studies of Kumsuk and Kreetiyutanont (1999) in 1995 reported that the grassland area of TKM was 1.5 km^2 and in 1998 was 1.33 km^2. But the recent study in 2008 showed 56.56% reduction of the grass land area in TKM. Now there were only 0.85 km^2 remaining because of the invasion of the surrounding hill evergreen forest. Without the proper grassland management, the gradual reduction of the grassland can not be prohibited. The result from Maxent method showed that the population of sambar deer, barking deer and wild boar will replace the hog deer population. There are several methods for grassland management, but the recommended method for grassland management for TKM is the controlled burning. However, *Schima wallichii* a pioneer species of hill evergreen forest is fire tolerant, therefore the early removal of this species must be applied.

Concerning the factor that related to the presence of predators in PKWS, the result of this study showed that there were a few correlations. Forest type, mainly grassland, has relation with the presence of Asian wild dog. The reason may be explained by the fact that the Asian wild dogs hunt their prey in this area.

6. The population viability analysis

The population viability analysis for hog deer was performed by the Vortex program version 9.7 (Lacy, 2000) using all previously mentioned data. One thousand simulations were run to test the hog deer population sensitivity to each different

parameter. The survival probability of the deer population after more than 50 years from the initial year (one) shows the sustainability of this introduced hog deer population.

Using the available data, the simulations contain most of the possible processes that act on the hog deer population in TKM and also some potential management practices. PVA sensitivity testing, as used in the population and habitat viability analyses (PHVA) (Lacy, 1993-4), was useful in detecting the influence of each factor on the probability of survival for hog deer. The population size increased every year from 20 individuals in 1983 (the first reintroduction year), to 194 (K=272) individuals in 2008. In 2018, or 35 years after the deer reintroduction program, the size of the deer population was predicted to reach the approximate maximum carrying capacity for TKM. This information is useful to maintain or expand grassland habitat for keeping the deer population that depend on the population management objectivities.

Sensitivity of the hog deer survival probability to the carrying capacity was analyzed in the simulation. Hog deer population in the simulations did not exhibit sensitivity to an increase or decrease in carrying capacity and the results showed the 100% probability of survival of hog deer population over 50 years ($p = 1$). The carrying capacity tested was the area for potential use and might be as much as the area currently used. However, livestock use hog deer habitat and might compete with hog deer mainly for space, decreasing the available area and displacing the deer (Barrio, 2004). In TKM, hog deer had highest interaction with sambar deer, which used 56.69% of grassland habitat. This might affect the carrying capacity of hog deer in TKM. Nevertheless, size of the grassland and also habitat quality mainly affect to the hog deer population.

The analysis of sensitivity to mortality rate reflected that the hog deer population in the simulations exhibited sensitivity to an increase in mortality rate and population number was decrease when the mortality had increase. Simulating of

10%, 20%, 30% and 40% increase of actual mortality rates resulted in the probability of survival of 99.6%, 98.4%, 94.1% and 74.1% respectively (Figure 43).

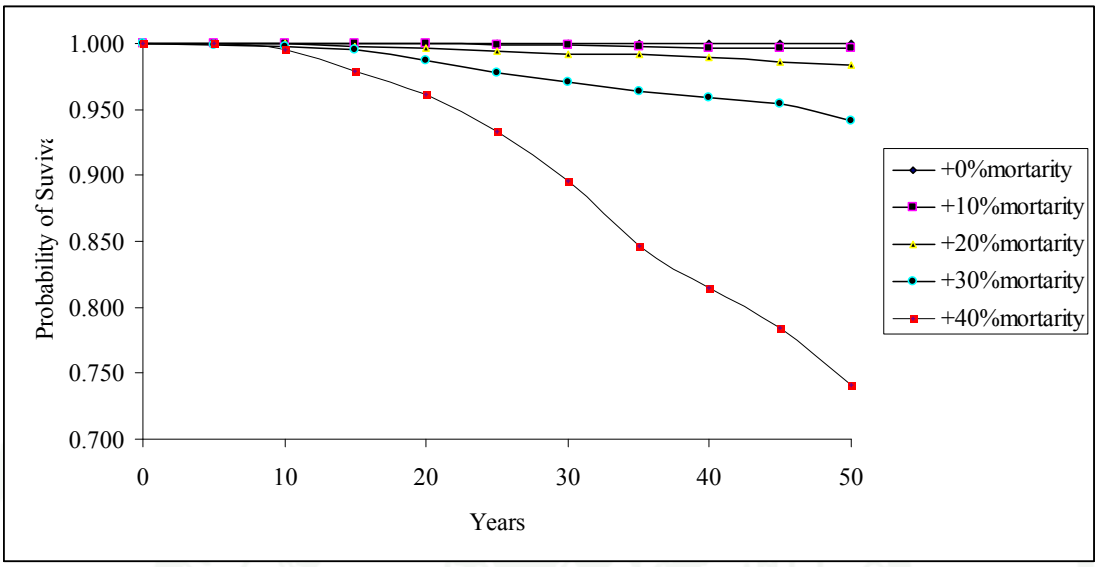


Figure 43 Sensitivity of probability of survival of hog deer in Thung Ka Mung to increasing the mortality rate.

Heterozygosity levels and response of the hog deer to differences in heterozygosity are not known. Studies on heterozygosity level on several mammal species established that responses to different heterozygosity level vary among species (Ralls *et al.*, 1988). Vortex always incorporates heterozygosity in the simulation as inbreeding increases with small populations causing deleterious effects (Lacy, 1993). If the deleterious effects of inbreeding in hog deer larger than resulting from the number of lethal alleles used in the simulations, then we should expect a larger vulnerability to extinction when the population decreases.

The minimum number of animal released (initial population) is always an important consideration of any animal introduction program. The initial population for males and females, which can give a result in a sustainable population, should be determined. Therefore the sensitivity of the probabilities of survival of hog deer to different initial population sizes ranging from 6 to 20 individuals with different sex

ratio of 1:1, 1:2, and 1:3 were simulated and analyzed. With the male:female ratio of 1:1 and the initial population size of 6, 8, 10, 12, 14, 16, 18, 20 individuals, the probability of survival was 72.9%, 88.8%, 96.1%, 97.5%, 99.4%, 99.7%, 99.9%, 99.9% in 50 years respectively (Figure 44 a). With the male:female ratio of 1:2 and the initial population size of 6, 9, 12, 15, 18 individuals, the probability of survival was 75.7%, 96.4%, 99.2%, 99.8%, 99.9% in 50 years respectively (Figure 44 b). With the male:female ratio of 1:3 and the initial population size of 8, 12, 16, 20 individuals, the probability of survival was 94.5%, 99.8%, 100%, 100%% in 50 years respectively (Figure 44 c). The result from this study indicated that probability of survival of more than 90% can be achieved from the initial population of 10 (5:5), 9 (3:6), and 8 (2:6) for male:female ratios of 1:1, 1:2, and 1:3 respectively. However the mortality rate of newly released male of 66.67% was determined in this study. Therefore the minimum number of initial male population can affect the sustainability of the population and must be taken in to account as well. As the result from this study, the minimum initial population with the proper male:female ratios can be used as a guideline for hog deer rehabilitation in other areas. It can be recommended that male hog deer, which has 66.67% mortality rate, should be first released. Once the male hog deer survive and can occupy the area, the female hog deer should then be released. This recommended release technique can promote the population viability. Moreover, the IUCN guide line for rehabilitated wildlife must be followed.

Sensitivity to catastrophes was not analyzed in this study because there has not been any report of catastrophe in TKM. Anyhow the population of hog deer in TKM was non-fragmented population living in TKM. If any catastrophe should occur, it can easily lead to extinction of the population.

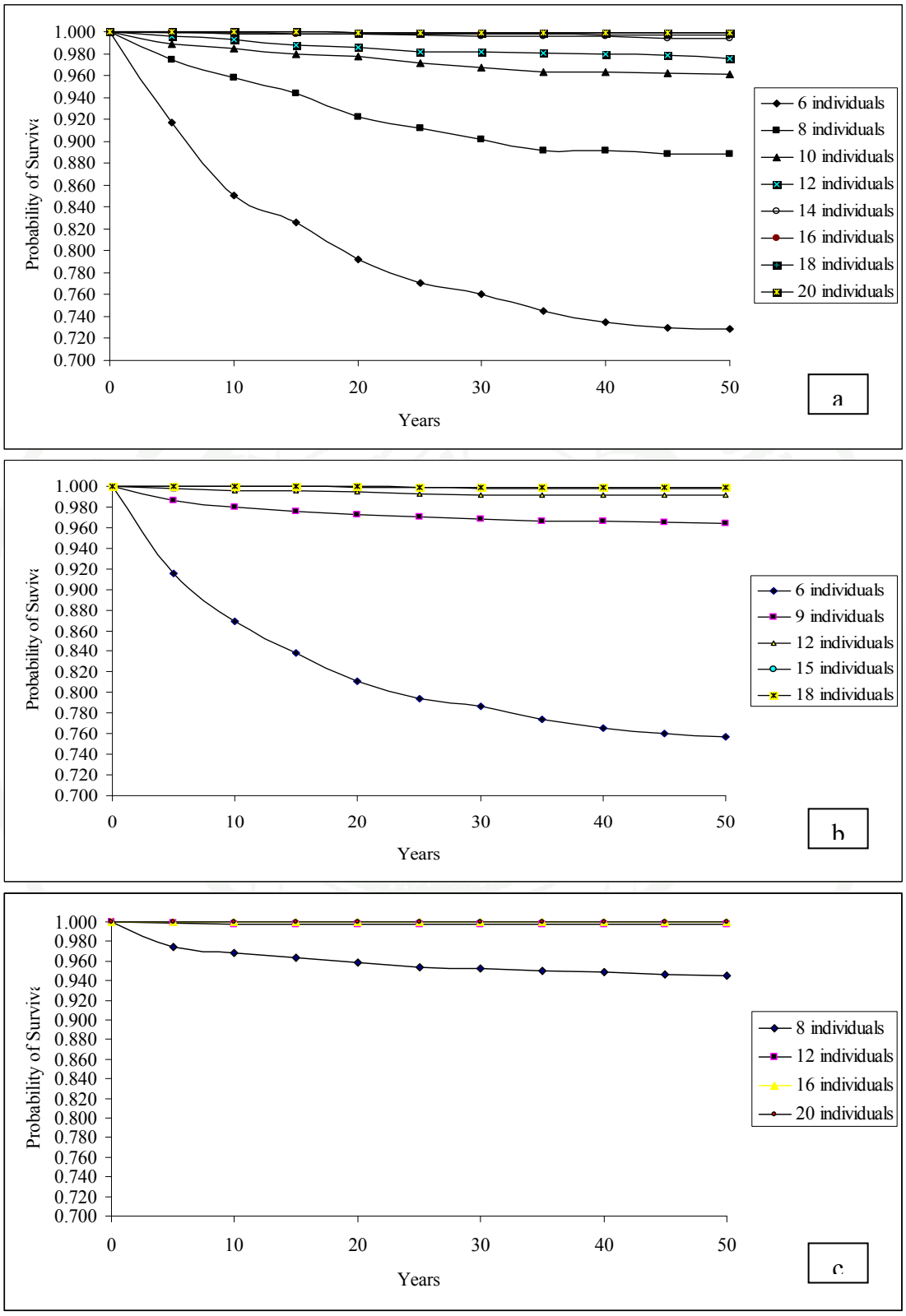


Figure 44 Sensitivity of survival probability of hog deer to initial population size with different male:female ratio, a = 1:1, b = 1:2, c = 1:3.

CONCLUSIONS

This dissertation is based on the data of existing hog deer, which were introduced into Thung Ka Mung (TKM) of Phu Khieo Wildlife Sanctuary (PKWS), Chaiyaphum Province during 1983 to 1992, and 8 newly released hog deer (3 stags and 5 hinds), which were introduced in November 2007 to rehabilitate the existing population. The ecology of the existing hog deer, mortality rate and the adaptability of the newly released group, sustainability of the whole population, and the appropriate initial population size were points of interest.

1. The data collected by fecal pellet-group counts method from February 2008 to January 2010 revealed that the population density of hog deer in TKM was 2.03-2.04 individuals/ha (SD = 1.25). The total population determined by total counting in October 2009 was 127 individuals, which represented the minimum hog deer population in this area.

2. The population structure determined by direct sighting between January and December 2008 showed that the average group size was 9.57 individuals. Hog deer in TKM preferred to stay with a group (91.5%) than being solitary (8.5%). The percentage of different group sizes from 1,410 sightings were small (2-3 animals) 30.4%, medium (4-6 animals) 27.5%, large (7-10 animals) 11.50 %, and very large (>10 animals) groups 22.1%. The age structure, sex ratio, and recruitment rate hog deer population in TKM resembled those of wild hog deer reported in several studies, may indicate that the hog deer population in TKM have become wild population.

3. Breeding season of hog deer in TKM is between May and October with the highest peak occurred during July and September.

4. Nearly 48.0% of the carcasses of hog deer killed by Asian wild dogs, 17.4% killed by Burmese pythons, 4.4% killed by Asiatic jackal, and 30.4% were unidentified. The mortality rate of the existing hog deer in TKM during the study period was 18.1%.

5. Result from mitochondrial DNA analysis of 32 pellet samples of existing hog deer revealed that there were 3 different haplotyps in TKM, which were composed of 59.4% haplotype APT02, 37.5% haplotype APT10, and 3.1% haplotype APT06. The pellet sampling method revealed that the hog deer with different haplotypes were mixing together and scattering throughout the area

6. Only one male and three females remained for data collection through the study period, giving birth to 4 fawns but only 2 fawns survived resulting in 50.0% mortality rate of the newly released hog deer for the first year. DNA analysis from fecal pellet samples revealed that all three hinds have different haplotypes (APT10, APT06, APT09).

7. The newly released hog deer showed substantial improvement in their physical condition within 6 months after release. However when comparing their sizes with the existing hog deer of the same age class, the hog deer of the newly released hog deer were smaller than the existing hog deer.

8. Most observed behaviors of the existing population comprised feeding, lying, walking, and running, and ruminating, which occupied almost 98% of the observed time, were similar between males and females in both wet and dry seasons. Hog deer spent almost 70% of the observed time for feeding. The hog deer spent significantly more time feeding in the wet season (81%) than in the dry season (64%), fewer time lying-down and ruminating in wet season than in the dry season, but the mean times of walking and running in both seasons were similar. Lying down was an active behavior in the same way as ruminating but feeding was active in the same way as walking and running behavior. The hog deer are usually active, feeding and moving, during mornings and evenings.

9. The newly released male, which is the only male survived, showed a better adaptability to the new habitat than the females. The annual average times spent for feeding, lying-down and ruminating behaviors of the newly released stag have correlation with the existing male hog deer since the first released year. For the

female showed that the annual average times spent for feeding and lying-down behavior of the newly released female hog deer have correlation with the existing female hog deer since the first released year. This indicated the adaptability of the hog deer on these behaviors.

10. The distribution area of the deer in TKM resulted that, the area of the first year was larger than that of the second year for every newly released hog deer. The distribution area of both males and females overlapped and appeared stable during the study period at TKM. The study revealed that the hog deer avoid the hill evergreen forest. This is also the major barrier, which obstructs the distribution of hog deer to other grasslands.

11. Hog deer in TKM foraged at least 56 forage species from 14 families. Most of the forage species were grasses. Phek in Thai name, *Vietnamosasa pusilla* alone comprised 21.07% of the hog deer's diet and was an abundant grass found in TKM. It made up 30.22% of the available forage and was utilized heavily all year round. Hog deer in TKM could feed on a variety of forage species, as well as discover natural salt licks by themselves, which indicated that the released hog deer could adapt well in the new environment.

12. The carrying capacities of TKM grassland were 272 individuals by forage availability in the dry season. It can increase the carrying capacity of a species in an area by habitat management. The hog deer are grazer and prefer a grassland habitat thus controlled burning in order to provide more available forage is highly recommended. The carrying capacity for an ungulate species might be affected by the habitat sharing of the others ungulate species. There was only one grass species, which was *Imperata cylindrica*, shared by hog deer and samber deer as well as barking deer.

13. The results from 4 camera trap sets around TKM area revealed that there were 4 ungulate species. They were composed of sambar deer, barking deer, wild boar, and elephant and their relative abundance were 29.33%, 7.62%, 4.85% and

2.08% respectively. The results studied by line plots system from this study indicated that both GL and MPDF in TKM, hog deer were the dominant species. The sambar deer was the dominant ungulate species that used the edge of HEF following by wild boar and barking deer. The 5 predators consisted of Asian wild dog, Asiatic jackal, clouded leopard, Burmese pythons and leopard cat were the least found in TKM area.

14. The result from the species geographic distribution probability indicated that the saltlick has strong influence to the high percent contribution of ungulates in PKWS. It can be explained that the ungulates used this type of environmental factor for welfare factor. Forest type, which including grassland, mixed deciduous forest and water resources, has also strong effect to the percent contribution of the ungulates.

15. Simulation model using the population viability analysis has indicated that in 2018, or 35 years after the deer introduction program, the size of the deer population will reach the approximate maximum carrying capacity. The survival probability of the deer population after more than 50 years from the initial year (one) shows the sustainability of this introduced hog deer population. Hog deer population in the simulations did not exhibit sensitivity to an increase or decrease in carrying capacity. The probability of survival of hog deer in TKM is sensitive to mortality rate and initial population size and sex ratio. The probability of survival of more than 90% can be achieved from the initial population of 10 (5:5), 9 (3:6), and 8 (2:6) for male:female ratios of 1:1, 1:2, and 1:3 respectively. However the mortality rate of newly released male of 66.67% was determined in this study. Therefore the minimum number of initial male population can affect the sustainability of the population and must be taken into account as well. Sensitivity to catastrophes was not analyzed in this study because there has not been any report of catastrophe in TKM. Anyhow the population of hog deer in TKM was non-fragmented population living in TKM. If any catastrophe should occur, it can easily lead to extinction of the population.

RECOMMENDATIONS

Further researches

The genetic diversity analysis of hog deer by extracting mitochondrial DNA from fecal pellet specimen as used in this study can be applied for the DNA study of other species as well. This method is safe and causes no harm to the studied animals and can also be used to identify the forage species that they consume.

It could be recommended that the genetic diversity of hog deer in PKWS should be increased by rehabilitation with more hog deer of other haplotypes. In the future PKWS can become genetic resources of hog deer for Thailand. As the result from this study, the haplotype APT02 and APT10 are commonly found in TKM. Therefore we recommended that further introduction of hog deer should be focused on the APT06, APT08 and APT09 and other different APTs, which do not exist now in TKM. The hog deer of haplotype APT08 whcih does not found in TKM but available in Phu Khieo Wildlife Breeding Center is the nearest available DNA resource.

Furthermore, it is recommended that DNA analysis of the released animal should be performed before the releasing. It can be also recommended that the DNA analysis by fecal pellet should be performed for the former rehabilitation programs.

The genetic diversity analysis studies for hog deer population in TKM have been emphasized by the maternity liniate. Therefore it is recommended that the DNA analysis using the paternity liniate should be performed to achieve better genetic diversity information.

In this study the forage species used by hog deer are already identified, but the nutrition contained of each forage species are not yet determined. Therefore further research focus on the nutrition aspect should be conducted and also forage species of

other ungulate should be study in this area. In case of forage species sharing between hog deer and sympatric species should be studied in the same area for more understanding of the competition or interaction between species.

Captive breeding and initial population for rehabilitated program

Ex-situ and In-situ conservation are importance for wildlife conservation. In Thailand there are 24 wildlife breeding centers and 591 individuals (November, 2010) of hog deer belong to the centers. Hog deer is a high breeding potential animal so they could be successfully bred in captivity. However the population in natural habitat has been found in minimal. Therefore captive breeding programs and rehabilitated to a suitable habitat are reasonable to proceed and the rehabilitated program should strictly follow the animal rehabilitation guide line from IUCN.

Estimation of the initial population for any rehabilitated program can be performed by PVA as in this research. This method is proved to be effective and reliable. Within the limitation of this research, the result indicated that the probability of survival of hog deer more than 90% can be achieved from the initial population of 10 (5:5), 9 (3:6), and 8 (2:6) for male:female ratios of 1:1, 1:2, and 1:3 respectively. However the mortality rate of newly released male of 66.67% was determined in this study. Therefore the minimum number of initial male population can affect the sustainability of the population and must be taken in to account as well. Achapet in 1994 conducted a research of hog deer rehabilitation in Khao Chi-on Non-hunting Area and recommended a guideline for hog deer rehabilitation. The recommended guideline for hog deer from this study is corresponding with the previous study of Achapet 1994. It can be recommended that the guideline for a rehabilitation of hog deer should be as following:

1. Select suitable areas for release hog deer as follow:

1.1 Legally protected areas such as Wildlife Sanctuary, National Park, Preserved National Forest, Non-hunting Area, Forest Park, etc.

1.2 Unless the area does not provide, set up at least one water body and salt lick area of which the animals are safe from being poached. In frequently poaching areas, more water bodies and salt lick areas are needed to prevent the hog deer from being poached while they are drinking or licking.

1.3 There should be sufficient tall grassland and the area should be the historical distribution range.

2. Conduct study on the areas including plants species, local people's attitudes towards animals to take into account to assess suitability of the areas, assess chances of success of the project and use the result of the study as the basic information to manage wildlife projects in the future.

3. Make public the valuation and necessity of the studied projects to let local people to appreciate it so as to ensure success of the project relating to rehabilitation of wildlife. The release days should be on auspicious occasions such as the Queen's Birthday and King's Birthday, inviting honorable people to chair the ceremony and inviting local people to join the ceremony for make them realize the necessity of releasing the wildlife which will, in effect, help reduce the poaching.

4. Prepare enclosure for "soft release period" at least 40 x 40 m in the pre-released area. This size is for about 10 hog deer with crown of tree sporadically covering at least 100 m^2. So the deer can use for temporary lying down, heat prevention, and protection of fighting between them. In this 40 x 40 m area, it should be subdivided into 15 x 15 m area with holding pen to force the animal when it is being caught for the project and to release it to the nature. The soft release period promotes the survival of the released animals. It is necessary for the adaptability of animals before released in to the wild. The released deer should be raised for about 2-3 months in this enclosure with forages in the area. To let the deer be familiar with new environment.

5. The result from this study indicated that the probability of survival of hog deer more than 90% can be achieved from the initial population of 10 (5:5), 9 (3:6), and 8 (2:6) for male:female ratios of 1:1, 1:2, and 1:3 respectively. Select the hog deer for rehabilitation from Wildlife Breeding Center in various sources by DNA information that already have data.

6. Health checking for the selected deer emphasize on diseases and parasites.

7. Move the deer to released area during the night in early rainy season. The animal's transportation should be handled by experts to prevent possible hazard during the transportation. Move the deer in the early rainy season because the forest roads for animal transporting are still available and by the time for releasing (after soft released), there will be abundant of forages.

8. In case that soft released period can not be prepared, the male should be first released. Once the male hog deer survive and can occupy the area, the female hog deer should then be released because of the high mortality rate of newly released male of 66.67% was determined in this study. Once the male hog deer survive and can occupy the area, the female hog deer should then be released. In case that there are already existing hog deer in the area but the rehabilitation aims to increase the genetic diversity, the male hog deer should not be released in the breeding season.

9. Monitor and assess survival of the deer everyday for the first 6 months after releasing and the program to monitor at least 2 years through radio telemetry. If any deer is missing, causes should be investigated together with solutions and prevention measures.

10. To maximize the results, the study should be done together with continuous monitoring and evaluation. The study should concentrate on the deer's daily behavior, feeding area, survival problems and impact to environment.

Habitat improvement

Habitat management should be carried out continuously in TKM area, which is the main habitat for hog deer in PKWS. The data reported by Kumsuk and Kreetiyutanont (1999) in 1995 revealed that the grassland area of TKM was 1.5 km^2 and in 1998 was 1.33 km^2. But the recent study in 2008 showed 56.56% reduction of the grass land area in TKM. Now there were only 0.85 km^2 remaining. The shrinkage of the grassland causes by the invasion of the surrounding hill evergreen forest. Without the proper grassland management, the gradual reduction of the grassland can not be prohibited. The highest densities of hog deer occurred on the highest quality and quantity of grasses area (see Figure 42). The result from Maxent method showed that the population of sambar deer, barking deer and wild boar will replace the hog deer population. There are several methods for grassland management, but the recommended method for grassland management for TKM is the controlled burning. So we recommend that controlled burning should be performed annually in the dry season to improve the habitat for the hog deer and other herbivorous species. However, *Schima wallichii* a pioneer species of hill evergreen forest is fire tolerant, therefore the early removal of this species must be applied.

The result from this study indicated some forages with high preference index for the hog deer such as *Arundinella setosa*, *Ischaemum* sp. and *Paspalum orbiculare*. These forages are mostly found in the center of TKM. Therefore it is recommended that these forages should be managed by seed dispersal in the other areas of TKM.

Besides TKM, in PKWS there are some other grasslands, such as Bung Pan (0.99 km^2), Bung Yao (0.65 km^2), Bung Waeng (0.15 km^2), Bung Kao (0.06 km^2), which can be habitat for hog deer (Figure 45). These grasslands are isolated and surrounded by evergreen forest, which hamper the distribution of the hog deer. Therefore, translocation of hog deer to the other grasslands and corridors connecting the neighbor-grasslands are recommended. The more habitats available, the lesser chance is for hog deer to disappear from PKWS that depend on the population management objectivity.

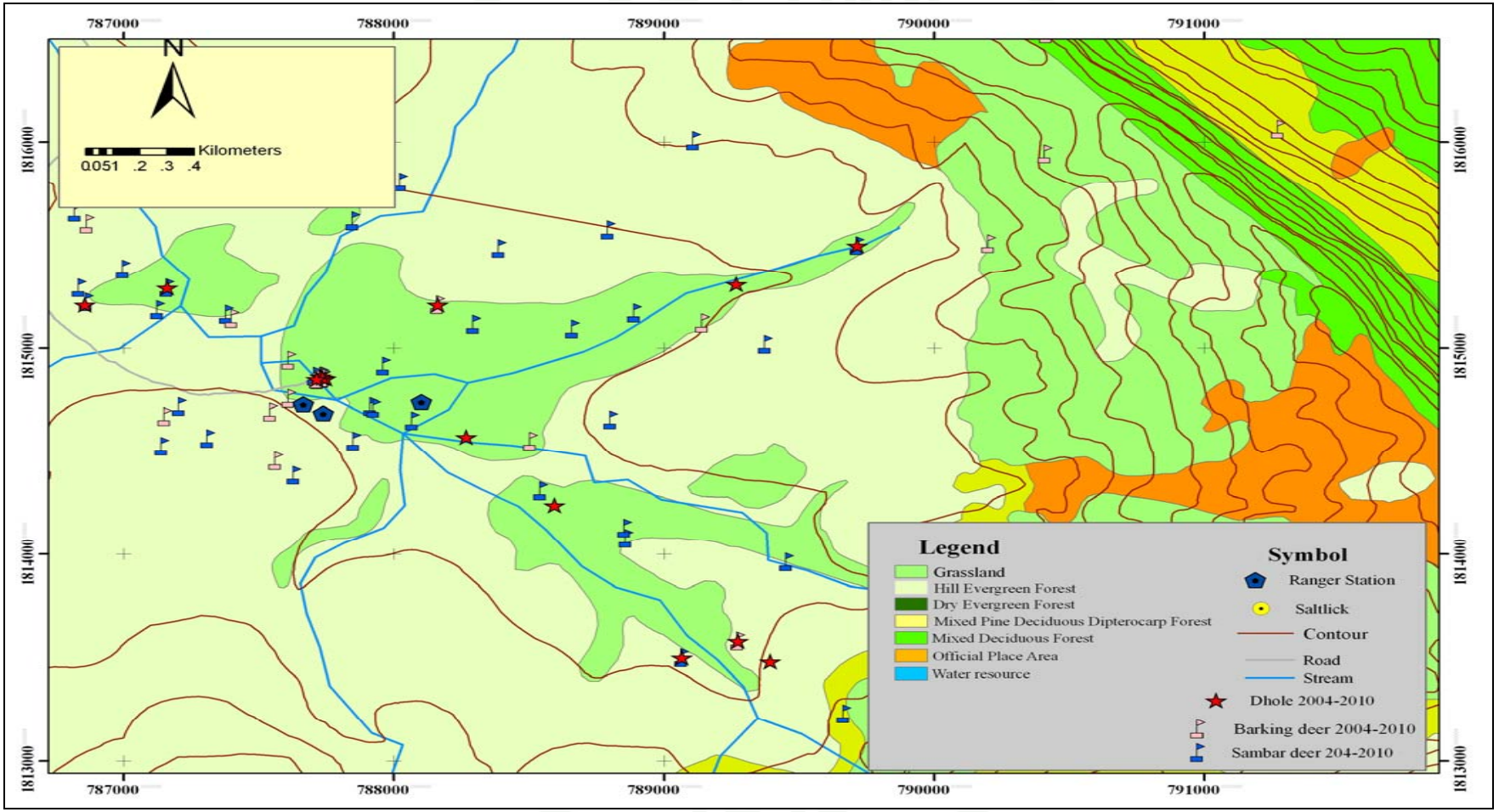


Figure 45 Suitable grassland for hog deer in Phu Khieo Wildlife Sanctuary.

The Maxent analysis indicated that the saltlick has high effect on the probability distribution of the ungulates. Therefore, it is recommended that the artificial saltlick should be prepared by adding common salt in some selected safety areas near herbivores trails, activity sites and in suitable soil. Thus, man-made saltlick should be created to improve the habitat. The animals prefer artificial saltlick from clay soil, bone meal, and salt with the ratios 20-40:2:1, which have the same properties as natural saltlicks (Supmee, 1986).

Population monitoring

Population of hog deer should be monitored regularly. Fecal pellet–group count method is suitable to proceed continuously because this method has sound theoretical basic, uses little manpower and it has been tested rigorously in terms of precision. The result of this method can be used to compare the result from other areas because it is a standard method that uses generally to study wildlife population. The population tends of hog deer as well as that of the sympatric species should be determined for management planning. Thus wildlife biologists should be assigned to work in this sanctuary to help in decision making to control and improve the wildlife habitat.

By fecal pellet-group counts method, it was found that the population density of hog deer in TKM was 2.03 individuals/ha based on the 12.10 defecation rate. This defecation rate was from the hog deer in captivity. However, in the nature hog deer population comprises several age classes. The defecation rates also differ between adult male and adult female. The real value is difficult to evaluate. Moreover, hog deer prefer to use grassland and mixed pine-deciduous dipterocarp forest than hill evergreen forest or evergreen forest. Thus, number of plot needed that uses to study the density in each habitat type should be calculated and uses to create for each habitat.

By total count method, the population represents the minimum number of animals in this area, so we recommended the population of hog deer in TKM should

be done every year, which will be helpful for wildlife management in this area. The most suitable time for the total count method is in the early morning of the dry season after the controlled burning or in wet season during July to September, which is the peak breeding season of hog deer in TKM.

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APPENDIX

Appendix Table 1 Average group size of hog deer in the wet and the dry season in 2008.

The wet season				The dry season			
Month	Group size	Alone (%)	Group (%)	Month	Group size	Alone (%)	Group (%)
April	6.39	12 (8.16)	135 (91.84)	November	8.72	4 (6.67)	56 (93.33)
May	15.57	5 (5.43)	87 (94.57)	December	4.23	4 (3.23)	120 (96.77)
June	15.18	6 (5.13)	111 (94.87)	January	3.18	36 (18.18)	162 (81.82)
July	17.28	0 (0.00)	64 (100.00)	February	5.41	19 (12.50)	133 (87.50)
August	15.66	2 (2.41)	81 (97.59)	March	3.96	31 (12.97)	208 (87.03)
September	9.19	0 (0.00)	77 (100.00)				
October	9.70	1 (1.75)	56 (98.25)				
Seasonal group size	12.71 (SD=4.18)				5.1 (SD=2.18)		
Yearly average group size	9.54 (SD=5.16)						
Seasonal % alone		4.08				12.16	
Seasonal % group		95.92				87.84	
Yearly % alone		8.51					
Yearly % group		91.49					

Appendix Table 2 Monthly different of age structure of hog deer at Thung Ka Mung in Phu Khieo Wildlife Sanctuary.

Month	Age structure						Summary
	Adult			Sub-adult		Fawn	
	velvet antler male	hard antler male	female	male	female		
January	170	8	264	17	48	122	629
February	152	5	367	0	56	243	823
March	155	27	436	11	35	283	947
April	100	31	473	25	52	258	939
May	5	357	735	83	51	201	1,432
June	0	568	879	96	123	110	1,776
July	0	380	455	80	187	4	1,106
August	0	445	631	73	135	16	1,300
September	15	156	408	41	71	17	708
October	20	121	263	31	89	29	553
November	120	48	197	56	82	20	523
December	60	2	315	13	16	118	524
Summary	797	2,148	5,423	526	945	1,421	11,260

Appendix Table 3 Mortality rate of hog deer in the study area during November 2007 and December 2008, (total number of each age class, studied by total count in parenthesis).

	Sex			Total
	Male (41)	Female (74)	Fawn (12)	(127)
Deaths	11	8	4	23
November 2007	-	-	-	0
December 2007	1	-	-	1
January 2008	-	1	1	2
February 2008	1	1	1	3
March 2008	-	2	-	2
April 2008	-	-	-	0
May 2008	1	-	-	1
June 2008	3	1	1	5
July 2008	2	-	-	2
August 2008	2	2	-	4
September 2008	-	1	-	1
October 2008	-	-	1	1
November 2008	-	-	-	0
December 2008	1	-	-	1
Deaths %	26.83	10.81	33.33	18.11

Appendix Table 4 Body score of the existing male and female hog deer by scan sampling method.

Monthly\Body score	existing male					existing female				
	1	2	3	sum	average	1	2	3	sum	Average
November 07	0	6	6	12	2.50	0	11	8	19	2.42
December 07	0	6	7	13	2.54	0	9	9	18	2.50
January 08	0	6	7	13	2.54	0	20	19	39	2.49
February 08	0	4	14	18	2.78	0	20	21	41	2.51
March 08	0	4	6	10	2.60	0	8	9	17	2.53
April 08	0	3	17	20	2.85	0	15	16	31	2.52
May 08	0	5	26	31	2.84	0	21	25	46	2.54
June 08	0	11	15	26	2.58	0	9	21	30	2.70
July 08	0	3	8	11	2.73	0	4	5	9	2.56
August 08	0	5	9	14	2.64	0	4	8	12	2.67
September 08	0	4	8	12	2.67	0	7	10	17	2.59
October 08	0	3	7	10	2.70	0	3	6	9	2.67
November 08	0	6	4	10	2.40	0	6	5	11	2.45
December 08	0	6	8	14	2.57	0	5	5	10	2.50

Appendix Table 5 Body score of the newly released male and female hog deer by scan sampling method.

Monthly\Body score	Newly released male					Newly released female				
	1	2	3	sum	average	1	2	3	sum	Average
November 07	0	3	0	3	2.00	0	5	0	5	2.00
December 07	0	2	0	2	2.00	0	5	0	5	2.00
January 08	0	2	0	2	2.00	0	4	0	4	2.00
February 08	0	1	0	1	2.00	0	2	1	3	2.33
March 08	0	1	0	1	2.00	0	2	1	3	2.33
April 08	0	1	0	1	2.00	0	2	1	3	2.33
May 08	0	0	1	1	3.00	0	1	2	3	2.67
June 08	0	0	1	1	3.00	0	1	2	3	2.67
July 08	0	0	1	1	3.00	0	1	2	3	2.67
August 08	0	0	1	1	3.00	0	1	2	3	2.67
September 08	0	0	1	1	3.00	0	1	2	3	2.67
October 08	0	0	1	1	3.00	0	1	2	3	2.67
November 08	0	0	1	1	3.00	0	2	1	3	2.33
December 08	0	0	1	1	3.00	0	2	1	3	2.33

Appendix Table 6 Percentage of level activity for hog deer as determined by scan sampling method in the wet season.

Activity\Group	newly male		newly female		existing male	existing female
	1^{at} year	2nd year	1^{at} year	2nd year		
Laying-down	34.78	10.16	20.35	14.98	15.69	7.44
Feeding	48.70	55.24	52.05	59.53	59.63	81.86
Ruminating	3.70	1.27	3.63	5.64	10.51	2.42
Walking and Running	10.22	30.79	22.56	18.68	11.01	7.92
Other behavior	2.61	2.54	1.42	1.17	3.16	0.37
Number of observations	460	315	634	514	9173	7326

Appendix Table 7 Percentage of level activity for hog deer as determined by scan sampling method in the dry season.

Activity\Group	newly male		newly female		existing male	existing female
	1^{at} year	2nd year	1^{at} year	2nd year		
Laying-down	22.39	23.70	24.36	23.01	9.23	16.28
Feeding	61.97	49.92	54.20	51.31	77.20	64.40
Ruminating	6.95	10.49	9.79	16.23	3.80	10.63
Walking and Running	6.37	13.27	11.26	8.30	8.09	7.37
Other behavior	2.32	2.62	0.38	1.16	1.68	1.31
Number of observations	518	1869	2869	4412	5005	12859

Appendix Table 8 Size of distribution area (km^2) and number of locations occurrence of newly released hog deer.

Hog deer ID	First year		Second year		All 2 year	
	No. of location	Distribution area (km^2)	No. of location	Distribution area (km^2)	No. of location	Distribution area (km^2)
FHD1	855	1.02	906	0.30	1761	1.05
FHD2	335	0.57	851	0.51	1186	0.85
FHD3	154	0.28	376	0.15	530	0.51
MHD1	367	0.67	1004	0.42	1371	0.80
Average female		0.62(SD=0.37)		0.32(SD=0.18)		0.80(SD=0.27)
Both sex	1711	1.08	3137	0.72	4848	1.23

Appendix Table 9 Size of distribution area (km^2) and number of location occurrence of newly released hog deer with difference season.

Hog deer	The dry season		The wet season		Area Overlapping (km^2)
	No. of location	Distribution area (km^2)	No. of location	Distribution area (km^2)	
FHD1	530	0.40	1231	1.02	0.39
FHD2	279	0.59	907	0.51	0.30
FHD3	61	0.29	469	0.23	0.15
MHD1	417	0.55	954	0.63	0.41
Average female		0.43(SD=0.15)		0.58(SD=0.40)	

Appendix Table 10 Usable of forage species for hog deer in Thung Ka Mung area**.**

No	Botanical name	Fresh weight	Dry weight	Usable
1	*Ammannia baccifera*	9.62	38.22	3.68
2	*Crotalaria sessiliflora*	14.05	46.14	6.48
3	*Themeda triandra*	678.08	81.3	551.28
4	*Arthraxon castratus*	2.84	54.53	1.55
5	*Crotalaria* sp.1	1.55	40	0.62
6	*Arundinella setosa*	457.75	62.94	288.11
7	*Fimbristylis* sp.1	2.14	46	0.98
8	*Melicope meliaefolia*	30.98	33.49	10.38
9	*Leersia hexandra*	24.90	59.18	14.74
10	*Ischaemum* sp.	2617.10	36.34	951.05
11	*Paspalum orbiculare*	656.43	58.66	385.06
12	*Crotalaria* sp.2	17.44	45	7.85
13	*Lygodium* sp.	2.64	46.14	1.22
14	*Crotalaria* sp.3	81.22	40	32.49
15	*Fimbristylis* sp.2	40.53	41.94	17.00
16	*Sporobolus* sp.2	31.60	36.34	11.48
17	*Eulalia speciosa*	1.96	65.02	1.27
18	*Cymbopogon* sp.	1556.49	48.87	760.66
19	*Sacciolepis* sp.	33.49	35	11.72
20	*Sorghum nitidum*	155.27	69.87	108.49
21	*Panicum sarmentosum*	1159.05	33.56	388.98
22	*Fimbristylis subalata*	71.08	63.85	45.38
23	*Rhynchospora corymbosa*	32.3	41.58	13.43
24	*Eragrostis atrovirens*	48.69	59.38	28.91
25	Unknown sp.1	0.22	34.9	0.08
26	*Adenosma indiana*	1.52	27.11	0.41
27	*Melastoma saigonense*	2675.69	46.55	1245.53
28	*Eulalia trispicata*	2513.56	68.19	1714.00

Appendix Table 10 (Continued)

No	Botanical name	Fresh weight	Dry weight	Usable
29	*Setaria sphacelata*	274.22	95.14	260.89
30	*Curculigo orchidoides*	13.46	41.55	5.59
31	*Crotalaria* sp.4	1.19	50.02	0.60
32	*Fimbristylis dichotoma*	623.36	61.58	383.87
33	*Scleria pavula*	778.45	41.58	323.68
34	*Crotalaria* sp.5	23.98	46	11.03
35	*Sacciolepis tenuisima*	27.35	32.49	8.89
36	*Cyperus* sp.1	4.59	49	2.25
37	*Imperata cylindrica*	4390.77	58.49	2568.16
38	*Adenosma* sp.1	6.09	34.4	2.09
39	*Eulalia quadrinervis*	7076.03	65.02	4600.83
40	*Vietnamosasa pusilla*	6416.17	55.88	3585.36
41	*Fimbristylis* sp.3	46.91	57.88	27.15
42	*Adenosma* sp.2	2.54	56	1.42
43	*Adenosma* sp.3	0.86	27.11	0.23
44	*Fimbristylis bisumbella*	16.42	44.25	7.27
45	*Rhynchospora rubra*	592.05	67.12	397.38
46	*Crotalaria* sp.6	2.08	50.02	1.04
47	*Cyperus* sp.2	100.79	52.42	52.83
48	*Kaempferia* sp.	19.81	42.74	8.47
49	*Helicteres viscida*	363.07	53.65	194.79
50	*Cyperus haspan* L.	3.78	29.58	1.12
51	*Selaginella* sp.	2.69	32.93	0.89
52	*Lipocarpha chinensis*	25.78	27.2	7.01
53	*Hyparrhenia newtonii*	1938.16	50.63	981.29
54	*Eriocaulon henryanum*	7.29	92.24	6.72
	Summary			20043.68

Appendix Table 11 Forage species and food preference index of hog deer at Thung Ka Mung area in dry season.

No	Family	Botanical name	Availability (A)	Removed (R)	Available (a)	Diet (d)	Removal (r)	Preference rating:Pr
1	Lythraceae	*Ammannia baccifera*	19	13	0.06	0.15	68.42	2.73
2	Leguminosae-papilionoideae	*Crotalaria sessiliflora*	8	5	0.02	0.06	62.50	2.49
3	Gramineae	*Themeda triandra*	640	385	1.88	4.52	60.16	2.40
4	Gramineae	*Arthraxon castratus*	5	3	0.01	0.04	60.00	2.39
5	Leguminosae-papilionoideae	*Crotalaria* sp.1	5	3	0.01	0.04	60.00	2.39
6	Gramineae	*Arundinella setosa*	1148	638	3.38	7.49	55.57	2.22
7	Cyperaceae	*Fimbristylis* sp.1	35	17	0.10	0.20	48.57	1.94
8	Rutaceae	*Melicope meliaefolia*	11	5	0.03	0.06	45.45	1.81
9	Gramineae	*Leersia hexandra*	9	4	0.03	0.05	44.44	1.77
10	Gramineae	*Ischaemum* sp.	3017	1317	8.87	15.45	43.65	1.74
11	Gramineae	*Paspalum orbiculare*	1180	498	3.47	5.84	42.20	1.68
12	Leguminosae-papilionoideae	*Crotalaria* sp.2	24	10	0.07	0.12	41.67	1.66
13	Schizaeaceae	*Lygodium* sp.	17	7	0.05	0.08	41.18	1.64
14	Leguminosae-papilionoideae	*Crotalaria* sp.3	306	120	0.90	1.41	39.22	1.56
15	Cyperaceae	*Fimbristylis* sp.2	13	5	0.04	0.06	38.46	1.53
16	Gramineae	*Sporobolus* sp.	8	3	0.02	0.04	37.50	1.50
17	Gramineae	*Eulalia speciosa*	11	4	0.03	0.05	36.36	1.45

Appendix Table 11 (Continued)

No	Family	Botanical name	Availability (A)	Removed (R)	Available (a)	Diet (d)	Removal (r)	Preference rating:Pr
18	Gramineae	*Cymbopogon* sp.	476	170	1.40	1.99	35.71	1.43
19	Gramineae	*Sacciolepis* sp.	45	16	0.13	0.19	35.56	1.42
20	Gramineae	*Sorghum nitidum*	68	24	0.20	0.28	35.29	1.41
21	Gramineae	*Panicum sarmentosum*	1674	564	4.92	6.62	33.69	1.34
22	Cyperaceae	*Fimbristylis subalata*	241	76	0.71	0.89	31.54	1.26
23	Cyperaceae	*Rhynchospora corymbosa*	92	29	0.27	0.34	31.52	1.26
24	Gramineae	*Eragrostis atrovirens*	119	37	0.35	0.43	31.09	1.24
25	Polygonaceae	Unknown sp.1	13	4	0.04	0.05	30.77	1.23
26	Scrophulariaceae	*Adenosma indiana*	27	8	0.08	0.09	29.63	1.18
27	Melastomataceae	*Melastoma saigonense*	123	36	0.36	0.42	29.27	1.17
28	Gramineae	*Eulalia trispicata*	3557	1001	10.46	11.75	28.14	1.12
29	Gramineae	*Setaria sphacelata*	375	105	1.10	1.23	28.00	1.12
30	Hypoxidaceae	*Curculigo orchidoides*	86	24	0.25	0.28	27.91	1.11
31	Leguminosae-papilionoideae	*Crotalaria* sp.4	8	2	0.02	0.02	25.00	1.00
32	Cyperaceae	*Fimbristylis dichotoma*	1688	420	4.96	4.93	24.88	0.99
33	Cyperaceae	*Scleria pavula*	647	146	1.90	1.71	22.57	0.90
34	Leguminosae-papilionoideae	*Crotalaria* sp.5	32	7	0.09	0.08	21.88	0.87

Appendix Table 11 (Continued)

No	Family	Botanical name	Availability (A)	Removed (R)	Available (a)	Diet (d)	Removal (r)	Preference rating:Pr
35	Gramineae	*Sacciolepis tenuisima*	124	27	0.36	0.32	21.77	0.87
36	Cyperaceae	*Cyperus* sp.1	79	17	0.23	0.20	21.52	0.86
37	Gramineae	*Imperata cylindrica*	1669	339	4.91	3.98	20.31	0.81
38	Scrophulariaceae	*Adenosma* sp.1	21	4	0.06	0.05	19.05	0.76
39	Gramineae	*Eulalia quadrinervis*	1603	301	4.71	3.53	18.78	0.75
40	Gramineae	*Vietnamosasa pusilla*	10275	1796	30.22	21.07	17.48	0.70
41	Cyperaceae	*Fimbristylis* sp.3	81	14	0.24	0.16	17.28	0.69
42	Scrophulariaceae	*Adenosma* sp.2	6	1	0.02	0.01	16.67	0.67
43	Scrophulariaceae	*Adenosma* sp.3	18	3	0.05	0.04	16.67	0.67
44	Cyperaceae	*Fimbristylis bisumbella*	45	7	0.13	0.08	15.56	0.62
45	Cyperaceae	*Rhynchospora rubra*	1414	207	4.16	2.43	14.64	0.58
46	Leguminosae-papilionoideae	*Crotalaria* sp.6	15	2	0.04	0.02	13.33	0.53
47	Cyperaceae	*Cyperus* sp.2	376	38	1.11	0.45	10.11	0.40
48	Zingiberaceae	*Kaempferia* sp.	176	16	0.52	0.19	9.09	0.36
49	Sterculiaceae	*Helicteres viscida*	185	16	0.54	0.19	8.65	0.35
50	Cyperaceae	*Cyperus haspan*	19	1	0.06	0.01	5.26	0.21
51	Selaginellaceae	*Selaginella* sp.	433	20	1.27	0.23	4.62	0.18

Appendix Table 11 (Continued)

No	Family	Botanical name	Availability (A)	Removed (R)	Available (a)	Diet (d)	Removal (r)	Preference rating:Pr
52	Cyperaceae	*Lipocarpha chinensis*	27	1	0.08	0.01	3.70	0.15
53	Gramineae	*Hyparrhenia newtonii*	237	2	0.70	0.02	0.84	0.03
54	Eriocaulaceae	*Eriocaulon henryanum*	193	1	0.57	0.01	0.52	0.02
55	Scrophulariaceae	*Torenia* sp.1	1	0	0.00	0.00	0.00	0.00
56	Euphorbiaceae	*Phyllathus amarus*	9	0	0.03	0.00	0.00	0.00
57	Compositae	*Ageratum conyzoides*	474	0	1.39	0.00	0.00	0.00
58	Compositae	*Chromolaena odoratum*	235	0	0.69	0.00	0.00	0.00
59	Rubiaceae	*Mitracarpus hirtum*	100	0	0.29	0.00	0.00	0.00
60	Rosaceae	*Rubus rugosus*	81	0	0.24	0.00	0.00	0.00
61	Convolvulaceae	*Cuscuta reflexa*	74	0	0.22	0.00	0.00	0.00
62	Leguminosae-papilionoideae	*Desmodium* sp.1	63	0	0.19	0.00	0.00	0.00
63	Scrophulariaceae	*Adenosma* sp.4	29	0	0.09	0.00	0.00	0.00
64	Scrophulariaceae	*Adenosma* sp.5	21	0	0.06	0.00	0.00	0.00
65	Umbelliferae	*Centella asiatica*	19	0	0.06	0.00	0.00	0.00
66	Theaceae	*Adinandra integerrima*	18	0	0.05	0.00	0.00	0.00
67	Melastomataceae	*Osbeckia chinensis*	18	0	0.05	0.00	0.00	0.00

Appendix Table 11 (Continued)

No	Family	Botanical name	Availability (A)	Removed (R)	Available (a)	Diet (d)	Removal (r)	Preference rating:Pr
68	Commelinaceae	Unknown sp.2	17	0	0.05	0.00	0.00	0.00
69	Leguminosae-papilionoideae	*Desmodium* sp.2	15	0	0.04	0.00	0.00	0.00
70	Leguminosae-papilionoideae	*Desmodium* sp.3	14	0	0.04	0.00	0.00	0.00
71	Sterculiaceae	*Helicteres hirsuta*	14	0	0.04	0.00	0.00	0.00
72	Scrophulariaceae	*Adenosma* sp.6	13	0	0.04	0.00	0.00	0.00
73	Scrophulariaceae	*Torenia* sp.2	10	0	0.03	0.00	0.00	0.00
74	Commelinaceae	Unknown sp.3	9	0	0.03	0.00	0.00	0.00
75	Leguminosae-papilionoideae	*Desmodium triflorum*	8	0	0.02	0.00	0.00	0.00
76	Cyperaceae	*Fimbristylis gracilenta*	7	0	0.02	0.00	0.00	0.00
77	Dioscoreaceae	*Dioscorea* sp.	6	0	0.02	0.00	0.00	0.00
78	Theaceae	*Adinandra laotica*	6	0	0.02	0.00	0.00	0.00
79	Leguminosae-papilionoideae	*Desmodium* sp.4	6	0	0.02	0.00	0.00	0.00
80	Lentibulariaceae	*Utricularia delphinioides*	4	0	0.01	0.00	0.00	0.00
81	Leguminosae-papilionoideae	*Desmodium* sp.5	3	0	0.01	0.00	0.00	0.00
82	Cyperaceae	*Pycreus polystachyos*	3	0	0.01	0.00	0.00	0.00
83	Commelinaceae	Unknown sp.4	3	0	0.01	0.00	0.00	0.00
84	Gramineae	Unknown sp.5	3	0	0.01	0.00	0.00	0.00

Appendix Table 11 (Continued)

No	Family	Botanical name	Availability (A)	Removed (R)	Available (a)	Diet (d)	Removal (r)	Preference rating:Pr
85	Symplocaceae	*Symplocos racemosa*	3	0	0.01	0.00	0.00	0.00
86	Dilleniaceae	*Dillenia* sp.	3	0	0.01	0.00	0.00	0.00
87	Scrophulariaceae	*Torenia* sp.3	3	0	0.01	0.00	0.00	0.00
88	Leguminosae-papilionoideae	*Desmodium velutinum*	3	0	0.01	0.00	0.00	0.00
89	Leguminosae-papilionoideae	*Desmodium* sp.6	2	0	0.01	0.00	0.00	0.00
90	Symplocaceae	*Symplocos sumuntia*	2	0	0.01	0.00	0.00	0.00
91	Leguminosae-papilionoideae	*Crotalaria* sp.7	2	0	0.01	0.00	0.00	0.00
92	Euphorbiaceae	*Aporosa nigricans*	2	0	0.01	0.00	0.00	0.00
93	Euphorbiaceae	*Aporosa* sp.	2	0	0.01	0.00	0.00	0.00
94	Scrophulariaceae	*Torenia* sp.4	2	0	0.01	0.00	0.00	0.00
95	Compositae	*Aster* sp.	2	0	0.01	0.00	0.00	0.00
96	Rubiaceae	*Catunaregam tomentosa*	2	0	0.01	0.00	0.00	0.00
97	Euphorbiaceae	*Aporosa octandra*	2	0	0.01	0.00	0.00	0.00
98	Cucurbitaceae	Unknown sp.6	2	0	0.01	0.00	0.00	0.00
99	Anacardiaceae	*Rhus javanica*	1	0	0.00	0.00	0.00	0.00
100	Anacardiaceae	*Choerosponsdias axillaris*	1	0	0.00	0.00	0.00	0.00
101	Lauraceae	*Litsea glutinosa*	1	0	0.00	0.00	0.00	0.00

Appendix Table 11 (Continued)

No	Family	Botanical name	Availability (A)	Removed (R)	Available (a)	Diet (d)	Removal (r)	Preference rating:Pr
102	Myrtaceae	*Syzygium cinerecum*	1	0	0.00	0.00	0.00	0.00
103	Euphorbiaceae	*Triadica cochinchinensis*	1	0	0.00	0.00	0.00	0.00
104	Melastomataceae	*Osbeckia* sp.	1	0	0.00	0.00	0.00	0.00
105	Myrtaceae	*Syzygium* sp.	1	0	0.00	0.00	0.00	0.00
106	Lycopodiaceae	*Lycopodium cernuum*	1	0	0.00	0.00	0.00	0.00
107	Scrophulariaceae	*Torenia* sp.5	1	0	0.00	0.00	0.00	0.00
108	Euphorbiaceae	*Mallotus barbatus*	1	0	0.00	0.00	0.00	0.00
109	Asclepiadaceae	Unknown sp7	1	0	0.00	0.00	0.00	0.00
110	Euphorbiaceae	*Phyllanthus emblica*	1	0	0.00	0.00	0.00	0.00
111	Leguminosae-papilionoideae	*Uraria lagopodioides*	1	0	0.00	0.00	0.00	0.00
	Total		34051	8519	100.00	100.00		1.00

Appendix Table 12 Forage species of hog deer in Thung Ka Mung compare between newly released hog deer and existing hog deer.

No	Botanical name	Newly released hog deer	Existing hog deer
1	*Fimbristylis* sp.1	-	/
2	*Fimbristylis* sp.2	-	/
3	*Fimbristylis subalata*	/	/
4	*Rhynchospora corymbosa*	/	/
5	*Fimbristylis dichotoma*	/	/
6	*Scleria pavula*	/	/
7	*Cyperus* sp.1	-	/
8	*Fimbristylis* sp.3	-	/
9	*Fimbristylis bisumbella*	/	/
10	*Rhynchospora rubra*	/	/
11	*Cyperus* sp.2	-	/
12	*Cyperus haspan*	/	/
13	*Lipocarpha chinensis*	/	/
14	*Eriocaulon henryanum*	-	/
15	*Phyllanthus emblica*	/	/
16	*Themeda triandra*	/	/
17	*Arthraxon castratus*	/	/
18	*Arundinella setosa*	/	/
19	*Leersia hexandra*	/	/
20	*Chrysopogon aciculatus*	/	/
21	*Ischaemum* sp.	/	/
22	*Paspalum orbiculare*	/	/
23	*Sporobolus* sp.	-	/
24	*Eulalia speciosa*	/	/
25	*Cymbopogon* sp.	/	/

Appendix Table 12 (Continued)

No	Botanical name	Newly released hog deer	Existing hog deer
26	*Sacciolepis* sp.	/	/
27	*Sorghum nitidum*	-	/
728	*Panicum sarmentosum*	/	/
29	*Eragrostis atrovirens*	/	/
30	*Eulalia trispicata*	/	/
31	*Setaria sphacelata*	/	/
32	*Sacciolepis tenuisima*	/	/
33	*Imperata cylindrica*	/	/
34	*Eulalia quadrinervis*	/	/
35	*Vietnamosasa pusilla*	/	/
36	*Hyparrhenia newtonii*	/	/
37	*Curculigo orchidoides*	/	/
38	*Crotalaria sessiliflora*	/	/
39	*Crotalaria* sp.1	-	/
40	*Crotalaria* sp.2	-	/
41	*Crotalaria* sp.3	-	/
42	*Crotalaria* sp.4	-	/
43	*Crotalaria* sp.5	-	/
44	*Crotalaria* sp.6	-	/
45	*Ammannia baccifera*	/	/
46	*Melastoma saigonense*	/	/
47	Unknown sp.1	-	/
48	*Melicope meliaefolia*	/	/
49	*Lygodium* sp.	-	/
50	*Adenosma indiana*	-	/
51	*Adenosma* sp.1	-	/
52	*Adenosma* sp.2	-	/

Appendix Table 12 (Continued)

No	Botanical name	Newly released hog deer	Existing hog deer
53	*Adenosma* sp.3	-	/
54	*Selaginella* sp.	-	/
55	*Helicteres viscida*	/	/
56	*Kaempferia* sp.	/	/

Appendix Table 13 Forage species known from Thung Ka Mung in Phu Khieo Wildlife Sanctuary consumed by hog deer.

No	Family	Botanical name	LF[1/]	SU[2/]
1	Anacardiaceae	*Rhus javanica* L.	ST	-
2	Anacardiaceae	*Choerospondias axillaris* (Roxb.) B.L.Burtt & Hill	T	-
3	Asclepiadaceae	Unknown sp7	C	-
4	Commelinaceae	Unknown sp2	H	-
5	Commelinaceae	Unknown sp3	H	-
6	Commelinaceae	Unknown sp4	H	-
7	Compositae	*Ageratum conyzoides* L.	H	-
8	Compositae	*Chromolaena odoratum* (L.)	H	-
9	Compositae	*Aster* sp.1	H	-
10	Convolvulaceae	*Cuscuta reflexa* Roxb.	C	-
11	Cucurbitaceae	Unknown sp6	HC	-
12	Cyperaceae	*Fimbristylis* sp.1	H	W
13	Cyperaceae	*Fimbristylis subalata* Kern	H	W
14	Cyperaceae	*Rhynchospora corymbosa* (L.) Britton	H	W
15	Cyperaceae	*Fimbristylis dichotoma* (L.) Vahl	H	W
16	Cyperaceae	*Scleria pavula* Steud.	H	W
17	Cyperaceae	*Cyperus* sp.1	H	W
18	Cyperaceae	*Fimbristylis* sp.2	H	W
19	Cyperaceae	*Fimbristylis bisumbella* (Forssk.) Bubani	H	W
20	Cyperaceae	*Rhynchospora rubra* (Lour.) Makino	H	W
21	Cyperaceae	*Fimbristylis* sp.3	H	W
22	Cyperaceae	*Cyperus* sp.2	H	W
23	Cyperaceae	*Cyperus haspan* L.	H	W
24	Cyperaceae	*Lipocarpha chinensis* (Osbeck) Kern	H	W
25	Cyperaceae	*Fimbristylis gracilenta* Hance	H	-
26	Cyperaceae	*Pycreus polystachyos* (Rottb.) P.Beauv.	H	-

Appendix Table 13 (Continued)

No	Family	Botanical name	LF[1/]	SU[2/]
27	Dilleniaceae	*Dillenia* sp.1	T	-
28	Dioscoreaceae	*Dioscorea* sp.1	HC	-
29	Eriocaulaceae	*Eriocaulon henryanum* Ruhle	H	W
30	Euphorbiaceae	*Phyllathus amarus* Schumach. & Thonn.	H	-
31	Euphorbiaceae	*Aporosa nigricans* Hook.f.	T	-
32	Euphorbiaceae	*Aporosa* sp.1	T	-
33	Euphorbiaceae	*Aporosa octandra* (Buch.-Ham. ex D.Dom)	S/ST	-
34	Euphorbiaceae	*Triadica cochinchinensis* Lour.	S/ST	-
35	Euphorbiaceae	*Mallotus barbatus* Mull.Arg.	S	-
36	Euphorbiaceae	*Phyllanthus emblica* L.	S/ST	-
37	Gramineae	*Sorghum nitidum* Pers.	G	D,W
38	Gramineae	*Eulalia speciosa* (Debeaux) O.Ktze.	G	D,W
39	Gramineae	*Panicum sarmentosum* Roxb.	G	D,W
40	Gramineae	*Sporobolus* sp.1	G	D,W
41	Gramineae	*Themeda triandra* Forssk.	G	D,W
42	Gramineae	*Arthraxon castratus* (Griff.) Naray ex Bor	G	D,W
43	Gramineae	*Arundinella setosa* Trin.	G	D,W
44	Gramineae	*Leersia hexandra* Sw.	G	D,W
45	Gramineae	*Ischaemum* sp.1	G	D,W
46	Gramineae	*Paspalum orbiculare* G.Forst	G	D,W
47	Gramineae	*Cymbopogon* sp.1	G	D
48	Gramineae	*Sacciolepis* sp.1	G	D
49	Gramineae	*Eragrostis atrovirens* (Desf.) Trin. ex Steud.	G	D,W
50	Gramineae	*Eulalia trispicata* (Schult.) Henr.	G	D,W
51	Gramineae	*Setaria sphacelata* (Schum.) Stapf et C.E. Hubb. ex Moss	G	D,W
52	Gramineae	*Sacciolepis tenuisima* C.E. Hubb.	G	D,W
53	Gramineae	*Imperata cylindrica* (L.) P.Beauv.	G	D,W

Appendix Table 13 (Continued)

No	Family	Botanical name	LF[1/]	SU[2/]
54	Gramineae	*Eulalia quadrinervis* (Hack.) Kern	G	D
55	Gramineae	*Vietnamosasa pusilla* (Chevalier & A.Camus) Nguyen	G	D,W
56	Gramineae	*Hyparrhenia newtonii* (Hack.) Stapf	G	D
57	Gramineae	Unknown sp5	G	-
58	Hypoxidaceae	*Curculigo orchidoides* Gaertn.	G	D
59	Lauraceae	*Litsea glutinosa* (Lour.) C.B.Rob.	T	-
60	Leguminosae-papilionoideae	*Crotalaria* sp.1	H	D
61	Leguminosae-papilionoideae	*Crotalaria* sp.2	C	D,W
62	Leguminosae-papilionoideae	*Crotalaria sessiliflora* L.	US	D
63	Leguminosae-papilionoideae	*Crotalaria* sp.3	C	D
64	Leguminosae-papilionoideae	*Crotalaria* sp.4	C	D
65	Leguminosae-papilionoideae	*Crotalaria* sp.5	C	D
66	Leguminosae-papilionoideae	*Crotalaria* sp.6	C	D
67	Leguminosae-papilionoideae	*Desmodium* sp.1	C	-
68	Leguminosae-papilionoideae	*Desmodium* sp.2	C	-
69	Leguminosae-papilionoideae	*Desmodium* sp.3	C	-

Appendix Table 13 (Continued)

No	Family	Botanical name	LF[1/]	SU[2/]
70	Leguminosae-papilionoideae	*Desmodium triflorum* (L.) DC.	TrH	-
71	Leguminosae-papilionoideae	*Desmodium* sp.4	C	-
72	Leguminosae-papilionoideae	*Desmodium* sp.5	C	-
73	Leguminosae-papilionoideae	*Desmodium velutinum* (Willd.) DC.	C	-
74	Leguminosae-papilionoideae	*Desmodium* sp.6	C	-
75	Leguminosae-papilionoideae	*Crotalaria* sp.7	US	-
76	Leguminosae-papilionoideae	*Uraria lagopodioides* (L.) Desv. ex DC.	US	-
77	Lentibulariaceae	*Utricularia delphinioides* Thorel ex Pellegr.	AqH	-
78	Lycopodiaceae	*Lycopodium cernuum* L.	F	-
79	Lythraceae	*Ammannia baccifera* L.	H	D
80	Melastomataceae	*Melastoma saigonense* (Kuntze) Merr.	S	W
81	Melastomataceae	*Osbeckia chinensis* L.	S	-
82	Melastomataceae	*Osbeckia* sp.1	S	-
83	Myrtaceae	*Syzygium cinereum* (Kurz) Chantar. & J.Parn.	T	-
84	Myrtaceae	*Syzygium* sp.1	T	-
85	Polygonaceae	Unknown sp1	ST	D
86	Rosaceae	*Rubus rugosus* Sm.	C	-
87	Rubiaceae	*Mitracarpus hirtum* (L.) DC.	H	-

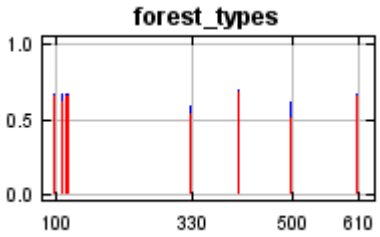
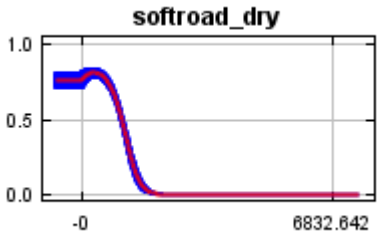
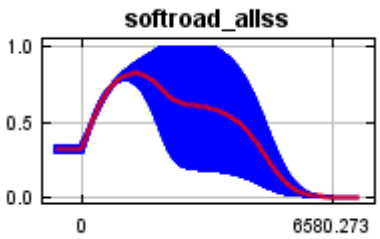
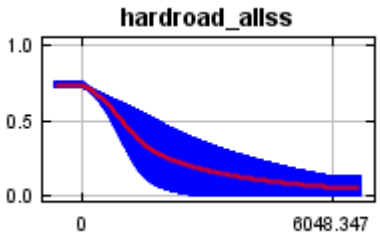
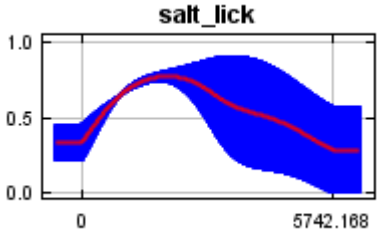
Appendix Table 13 (Continued)

No	Family	Botanical name	LF[1/]	SU[2/]
88	Rubiaceae	*Catunaregam tomentosa* (Blume ex DC.) Tirveng.	S/ST	-
89	Rutaceae	*Melicope meliaefolia* Benth.	ST	D
90	Schizaeaceae	*Lygodium* sp.1	H	D
91	Scrophulariaceae	*Adenosma* sp.1	H	D
92	Scrophulariaceae	*Torenia* sp.1	H	-
93	Scrophulariaceae	*Adenosma indiana* (Lour.) Merr.	H	D
94	Scrophulariaceae	*Adenosma* sp.2	H	D
95	Scrophulariaceae	*Adenosma* sp.3	H	D
96	Scrophulariaceae	*Adenosma* sp.4	H	-
97	Scrophulariaceae	*Adenosma* sp.5	H	-
98	Scrophulariaceae	*Adenosma* sp.6	H	-
99	Scrophulariaceae	*Torenia* sp.2	H	-
100	Scrophulariaceae	*Torenia* sp.3	H	-
101	Scrophulariaceae	*Torenia* sp.4	H	-
102	Scrophulariaceae	*Torenia* sp.5	H	-
103	Selaginellaceae	*Selaginella* sp.1	F	W
104	Sterculiaceae	*Helicteres viscida* Blume	S	D
105	Sterculiaceae	*Helicteres hirsuta* Lour.	S	-
106	Symplocaceae	*Symplocos racemosa* Roxb.	ST	-
107	Symplocaceae	*Symplocos sumuntia* Buch.-Ham ex D.Don	ST	-
108	Theaceae	*Adinandra integerrima* T.Anderson ex Dyer	ST	-
109	Theaceae	*Adinandra laotica* Gagnep.	ST	-
110	Umbelliferae	*Centella asiatica* (L.) Urb.	H	-
111	Zingiberaceae	*Kaempferia sp.*1	H	W

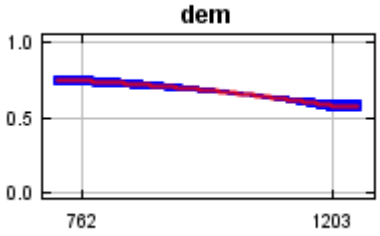
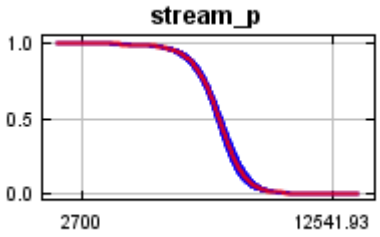
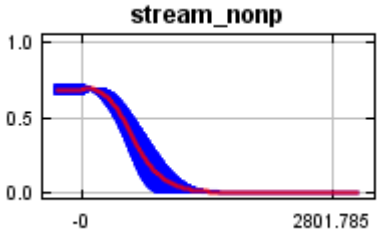
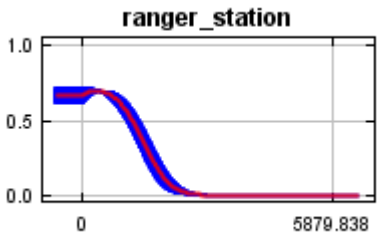
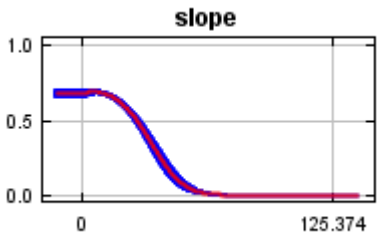
1/ LF : life form
C : climber
H : herb
G : grass included Family Gramineae and Family Cyperaceae
S : shrub
ST : shrubby tree
T : tree
US : undershrub
TrH : trailing herb
HC : herbaceous climber
AqH : aquatic herb
F : fern

2/ SU : seasonal use
D : dry season
W : wet or rainy season

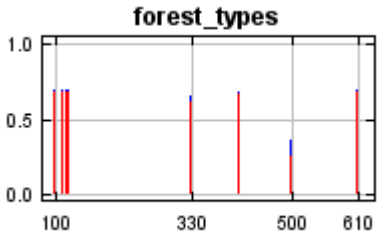
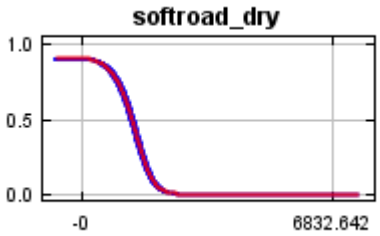
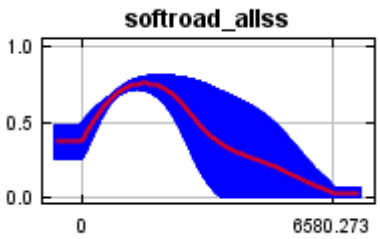
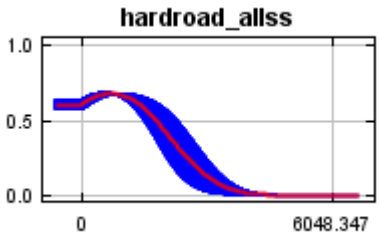
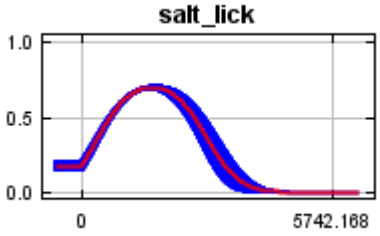
Appendix Table 14 Response curve show how each environment variable affects the hog deer (AUC = 0.964).

Environment factor	Presence trend of hog deer to environment factor	Explanation
Forest type		The probability found in grassland, secondary forest, water reservoir, office area, mixed pine-deciduous dipterocarp forest
Dry season, loose surface road		The closer to the loose surface road, the higher the probability
All season, loose surface road		The closer to the loose surface road, the higher the probability
All season, hard surface road		The closer to the hard surface road, the higher the probability
Saltlick		The closer to the saltlick, the higher the probability

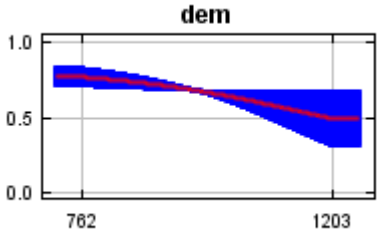
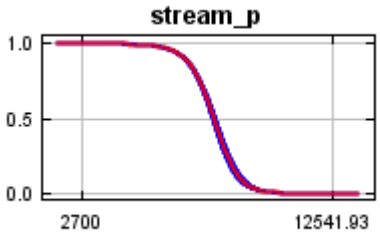
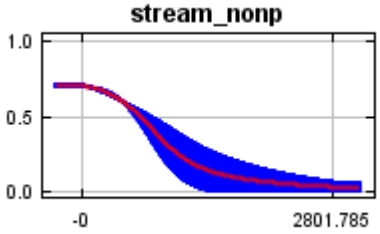
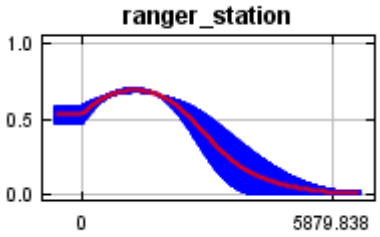
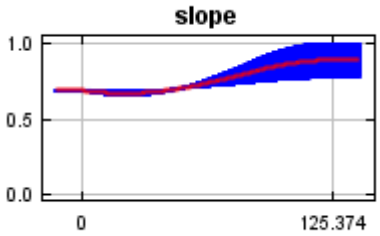
Appendix Table 14 (Continued)

Environment factor	Presence trend of hog deer to environment factor	Explanation
Digital elevation model		The lower of the elevation, the higher the probability
Permanent stream		The closer to the permanent stream, the higher the probability
Non-permanent stream		The closer to the non-permanent stream, the higher the probability
Ranger station		The closer to the ranger station, the higher the probability
Slope		The lower of the slope, the higher the probability

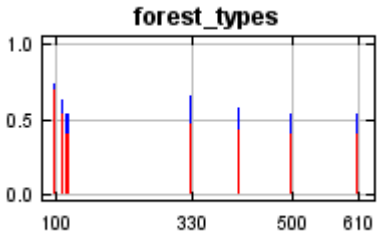
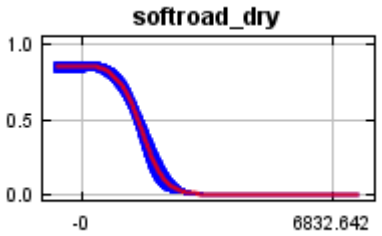
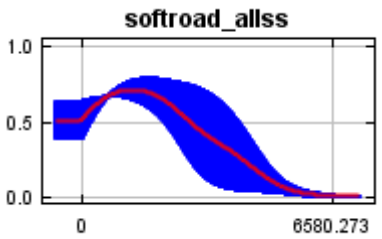
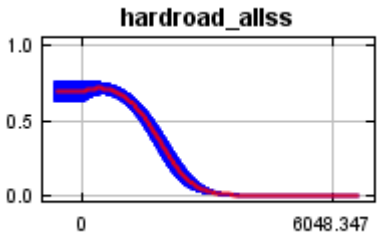
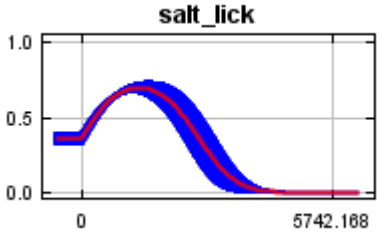
Appendix Table 15 Response curve show how each environment variable affects the sambar deer (AUC = 0.938).

Environment factor	Presence trend of hog deer to environment factor	Explanation
Forest type		The probability found in grassland, secondary forest, water reservoir, office area, mixed pine-deciduous dipterocarp forest
Dry season, loose surface road		The closer to the loose surface road, the higher the probability
All season, loose surface road		The closer to the loose surface road, the higher the probability
All season, hard surface road		The closer to the hard surface road, the higher the Probability
Saltlick		The closer to the saltlick, the higher the probability

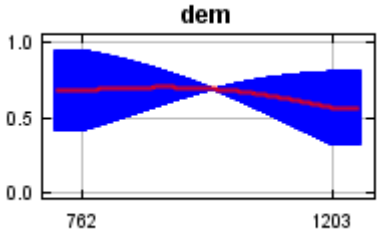
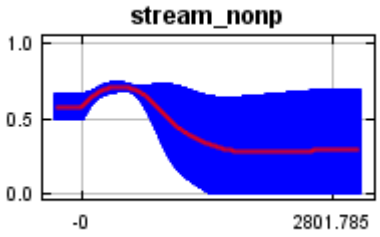
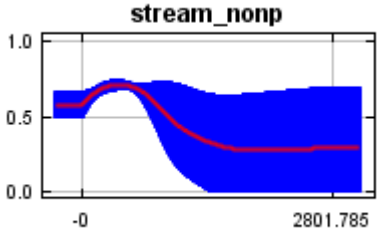
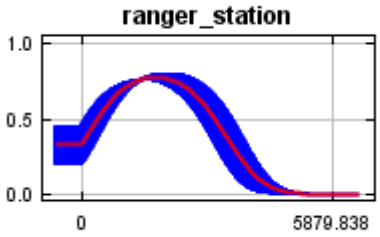
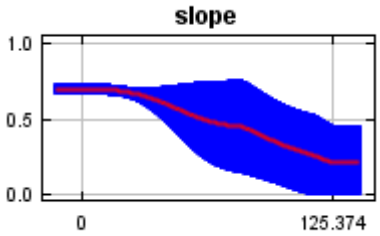
Appendix Table 15 (Continued)

Environment factor	Presence trend of hog deer to environment factor	Explanation
Digital elevation model		The lower of the elevation, the higher the probability
Permanent stream		The closer to the Permanent stream, the higher the probability
Non-permanent stream		The closer to the Non-permanent stream, the higher the probability
Ranger station		The closer to the ranger station, the higher the probability
Slope		The higher of the slope, the higher the probability

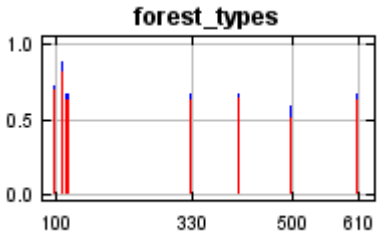
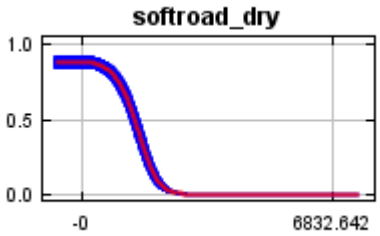
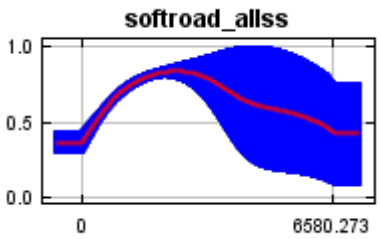
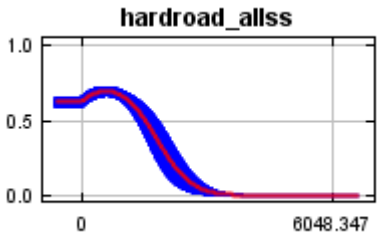
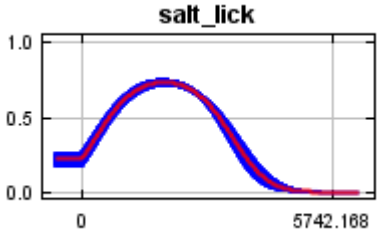
Appendix Table 16 Response curve show how each environment variable affects the barking deer (AUC = 0.940).

Environment factor	Presence trend of hog deer to environment factor	Explanation
Forest type		The probability found in grassland, secondary forest, water reservoir, office area, mixed pine-deciduous dipterocarp forest
Dry season, loose surface road		The closer to the loose surface road, the higher the probability
All season, loose surface road		The closer to the loose surface road, the higher the probability
All season, hard surface road		The closer to the hard surface road, the higher the Probability
Saltlick		The closer to the saltlick, the higher the probability

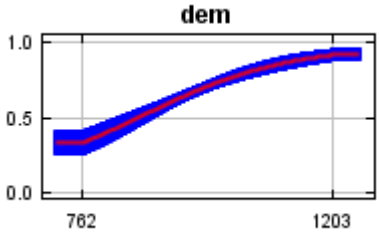
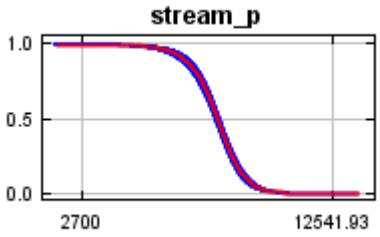
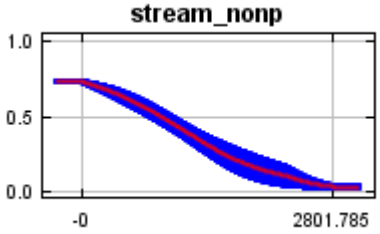
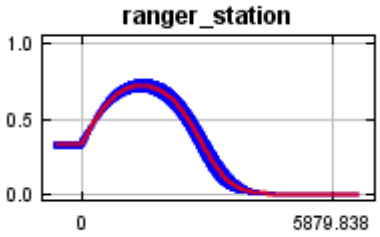
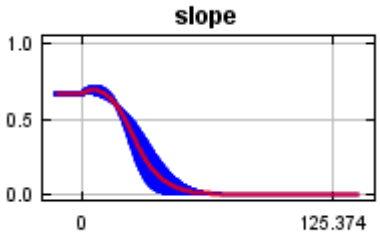
Appendix Table 16 (Continued)

Environment factor	Presence trend of hog deer to environment factor	Explanation
Digital elevation model		The lower of the elevation, the higher the probability
Permanent stream		The closer to the Permanent stream, the higher the probability
Non-permanent stream		The closer to the Non-permanent stream, the higher the probability
Ranger station		The closer to the ranger station, the higher the probability
Slope		The lower of the slope, the higher the probability

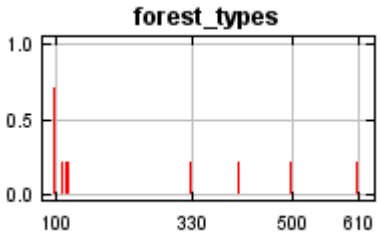
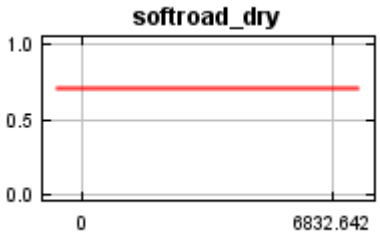
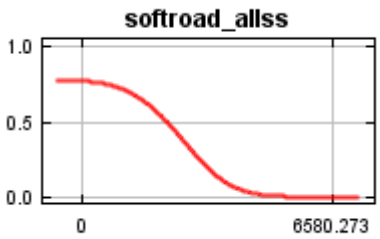
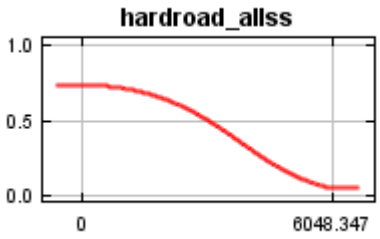
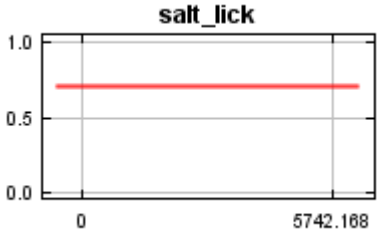
Appendix Table 17 Response curve show how each environment variable affects the wild boar (AUC = 0.943).

Environment factor	Presence trend of hog deer to environment factor	Explanation
Forest type		The probability found in grassland, secondary forest, water reservoir, mixed pine-deciduous dipterocarp forest
Dry season, loose surface road		The closer to the loose surface road, the higher the probability
All season, loose surface road		The closer to the loose surface road, the higher the probability
All season, hard surface road		The closer to the hard surface road, the higher the Probability
Saltlick		The closer to the saltlick, the higher the probability

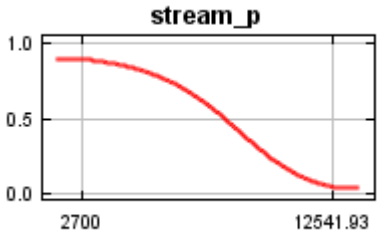
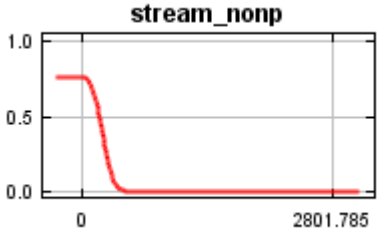
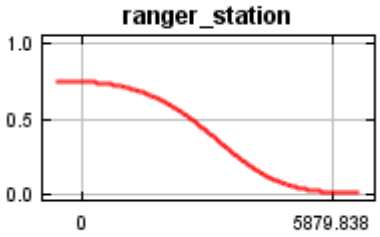
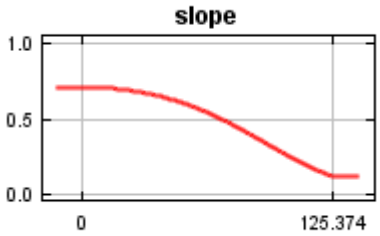
Appendix Table 17 (Continued)

Environment factor	Presence trend of hog deer to environment factor	Explanation
Digital elevation model		The higher of the elevation, the higher the probability
Permanent stream		The closer to the Permanent stream, the higher the probability
Non-permanent stream		The closer to the Non-permanent stream, the higher the probability
Ranger station		The closer to the ranger station, the higher the probability
Slope		The lower of the slope, the higher the probability

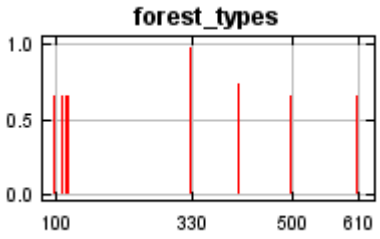
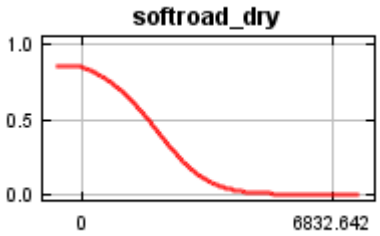
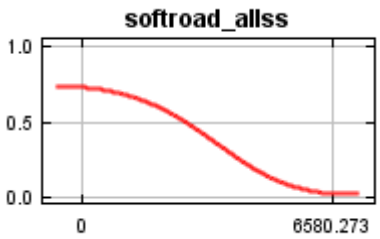
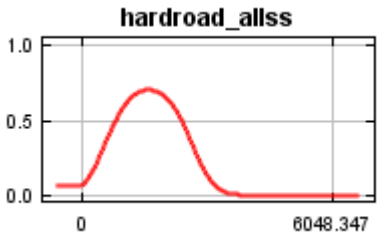
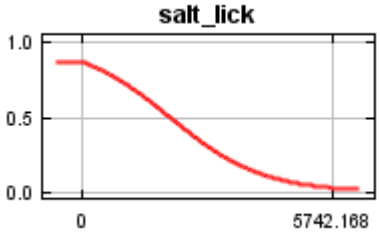
Appendix Table 18 Response curve show how each environment variable affects the guar (AUC = 0.985).

Environment factor	Presence trend of hog deer to environment factor	Explanation
Forest type		The probability found in hill evergreen forest grassland, secondary forest, water reservoir and dry evergreen forest
Dry season, loose surface road		The same effect to distance the loose surface road, the same the probability
All season, loose surface road		The closer to the loose surface road, the higher the probability
All season, hard surface road		The closer to the hard surface road, the higher the Probability
Saltlick		The same effect to the saltlick, the same the probability

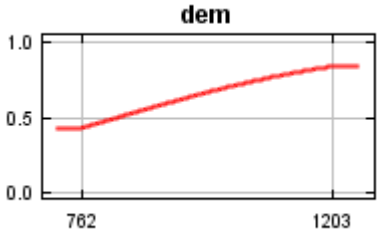
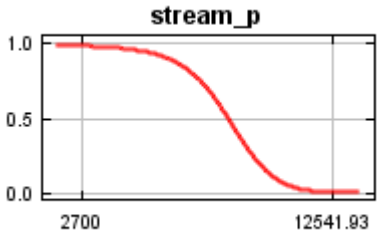
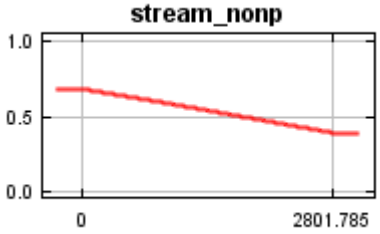
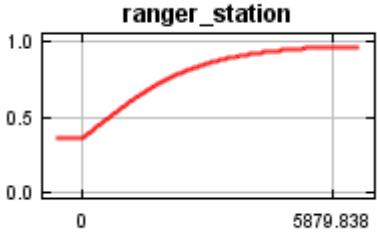
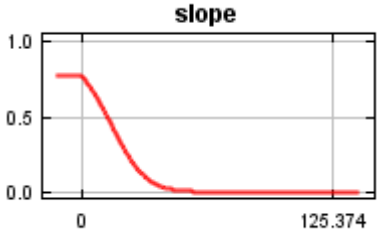
Appendix Table 18 (Continued)

Environment factor	Presence trend of hog deer to environment factor	Explanation
Digital elevation model		The same effect to the elevation, the same the probability
Permanent stream		The closer to the Permanent stream, the higher the probability
Non-permanent stream		The closer to the Non-permanent stream, the higher the probability
Ranger station		The closer to the ranger station, the higher the probability
Slope		The lower of the slope, the higher the probability

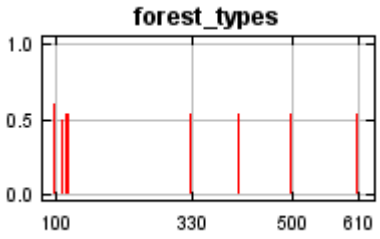
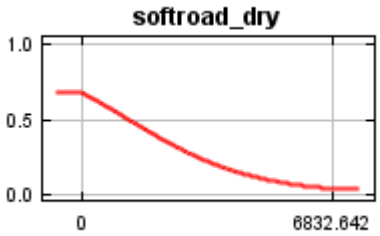
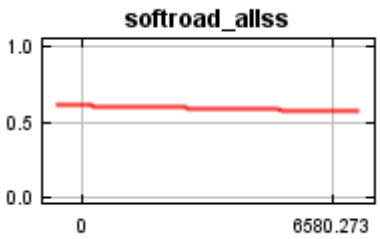
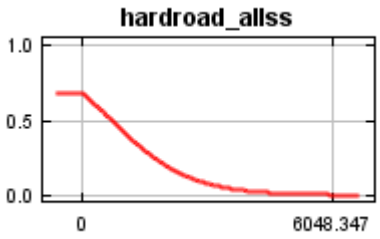
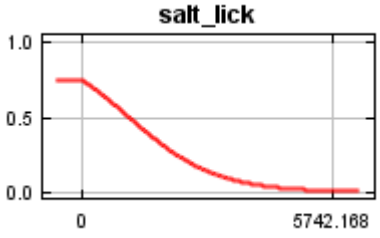
Appendix Table 19 Response curve show how each environment variable affects the elephant (AUC = 0.965).

Environment factor	Presence trend of hog deer to environment factor	Explanation
Forest type		The probability found in hill evergreen forest grassland, secondary forest, water reservoir and dry evergreen forest
Dry season, loose surface road		The closer the loose surface road, the higher the probability
All season, loose surface road		The closer to the loose surface road, the higher the probability
All season, hard surface road		The closer to the hard surface road, the higher the Probability
Saltlick		The closer to the saltlick, the higher the probability

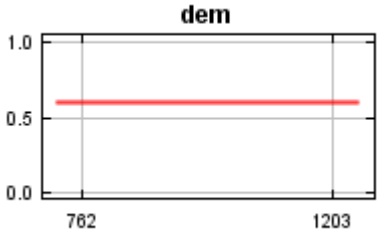
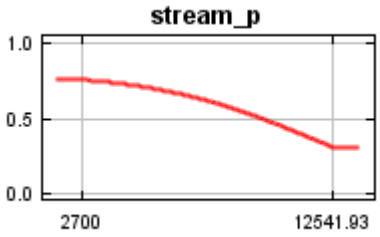
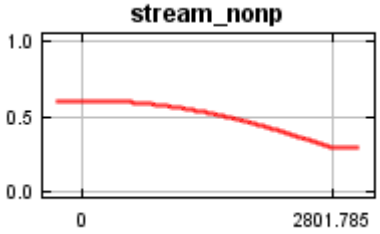
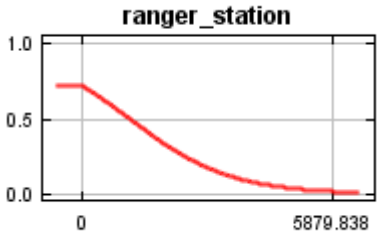
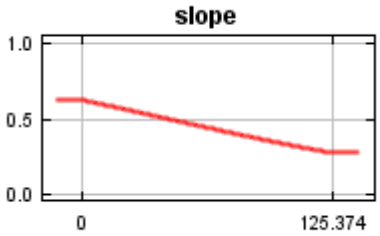
Appendix Table 19 (Continued)

Environment factor	Presence trend of hog deer to environment factor	Explanation
Digital elevation model		The higher to the elevation, the higher the probability
Permanent stream		The closer to the Permanent stream, the higher the probability
Non-permanent stream		The closer to the Non-permanent stream, the higher the probability
Ranger station		The closer to the ranger station, the lower the probability
Slope		The lower of the slope, the higher the probability

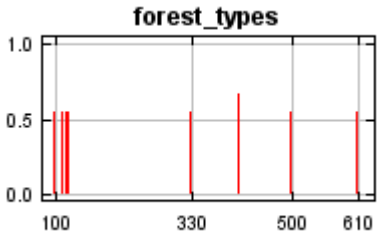
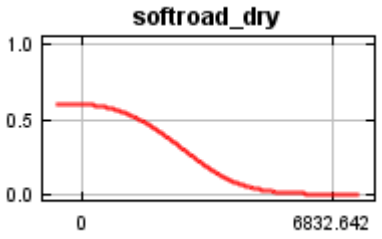
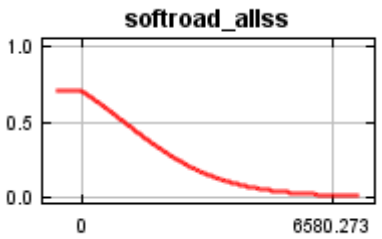
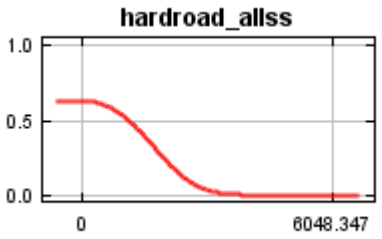
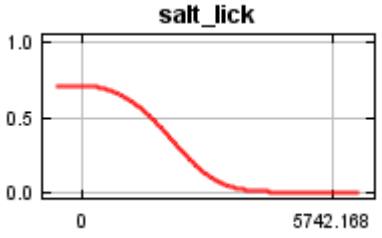
Appendix Table 20 Response curve show how each environment variable affects the Asiatic jackal (AUC = 0.981).

Environment factor	Presence trend of hog deer to environment factor	Explanation
Forest type		The probability found in hill evergreen forest grassland, secondary forest, water reservoir and dry evergreen forest
Dry season, loose surface road		The closer the loose surface road, the higher the probability
All season, loose surface road		The closer to the loose surface road, the higher the probability
All season, hard surface road		The closer to the hard surface road, the higher the Probability
Saltlick		The closer to the saltlick, the higher the probability

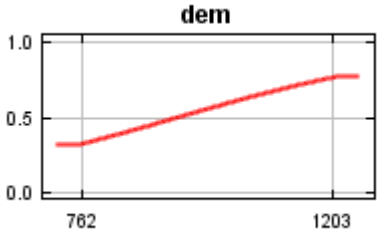
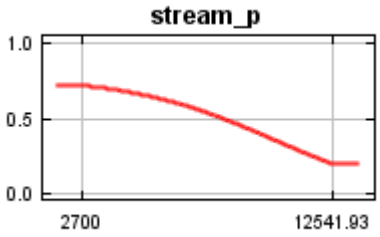
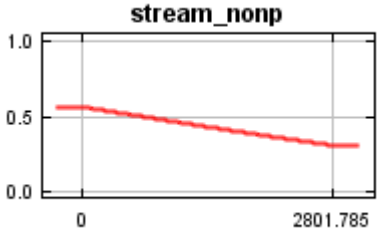
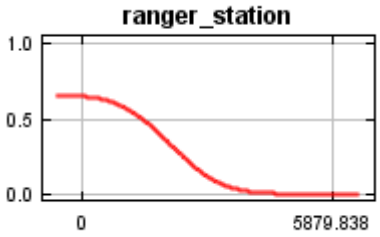
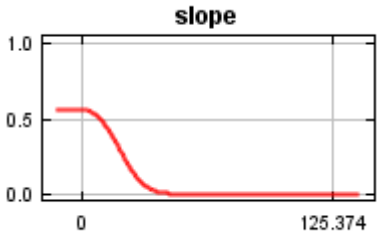
Appendix Table 20 (Continued)

Environment factor	Presence trend of hog deer to environment factor	Explanation
Digital elevation model		The difference effect of the elevation, the same the probability
Permanent stream		The closer to the Permanent stream, the higher the probability
Non-permanent stream		The closer to the Non-permanent stream, the higher the probability
Ranger station		The closer to the ranger station, the higher the probability
Slope		The lower of the slope, the higher the probability

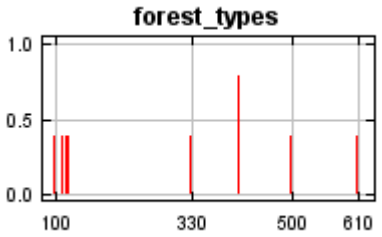
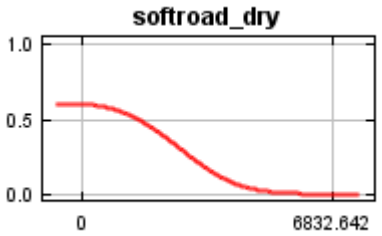
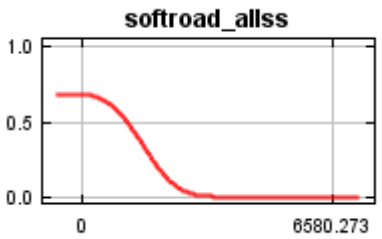
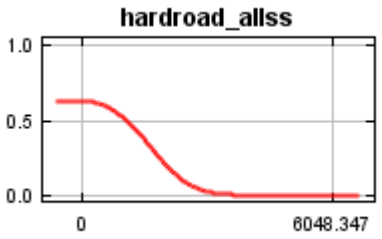
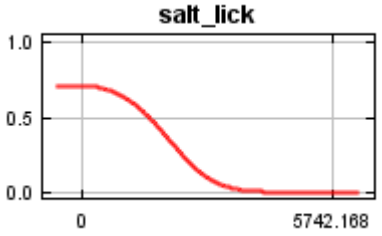
Appendix Table 21 Response curve show how each environment variable affects the Asia wild dog (AUC = 0.954).

Environment factor	Presence trend of hog deer to environment factor	Explanation
Forest type		Probability found in grassland, mixed pine-deciduous dipterocarp forest, office area, dry evergreen forest, secondary forest and hill evergreen forest
Dry season, loose surface road		The closer the loose surface road, the higher the probability
All season, loose surface road		The closer to the loose surface road, the higher the probability
All season, hard surface road		The closer to the hard surface road, the higher the Probability
Saltlick		The closer to the saltlick, the higher the probability

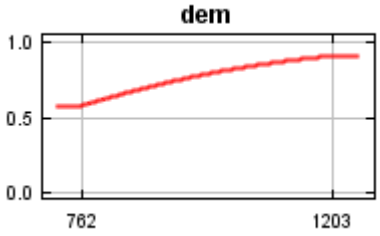
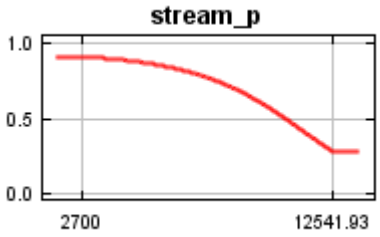
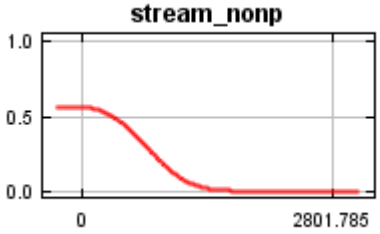
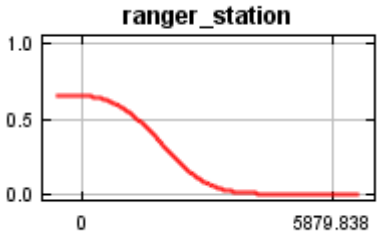
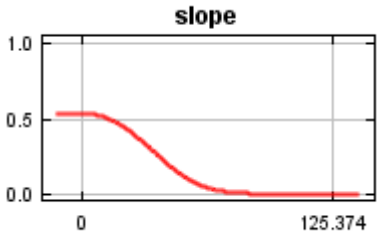
Appendix Table 21 (Continued)

Environment factor	Presence trend of hog deer to environment factor	Explanation
Digital elevation model		The lower to the elevation, the higher the probability
Permanent stream		The closer to the Permanent stream, the higher the probability
Non-permanent stream		The closer to the Non-permanent stream, the higher the probability
Ranger station		The closer to the ranger station, the higher the probability
Slope		The lower of the slope, the higher the probability

Appendix Table 22 Response curve show how each environment variable affects the leopard cat (AUC = 0.950).

Environment factor	Presence trend of hog deer to environment factor	Explanation
Forest type		Probability found in grassland, mixed pine-deciduous dipterocarp forest, office area, dry evergreen forest, secondary forest and hill evergreen forest
Dry season, loose surface road		The closer the loose surface road, the higher the probability
All season, loose surface road		The closer to the loose surface road, the higher the probability
All season, hard surface road		The closer to the hard surface road, the higher the Probability
Saltlick		The closer to the saltlick, the higher the probability

Appendix Table 22 (Continued)

Environment factor	Presence trend of hog deer to environment factor	Explanation
Digital elevation model		The lower to the elevation, the higher the probability
Permanent stream		The closer to the Permanent stream, the higher the probability
Non-permanent stream		The closer to the Non-permanent stream, the higher the probability
Ranger station		The closer to the ranger station, the higher the probability
Slope		The lower of the slope, the higher the probability

Appendix Table 23 Trend of mean population size of introduced hog deer after 50 years.

Year	1	2	3	4	5	6	7	8	9	10
Population size (K=272)	20.00	22.72	25.35	27.99	31.31	34.95	38.47	42.41	47.01	51.58
Year	11	12	13	14	15	16	17	18	19	20
Population size (K=272)	56.73	62.44	69.00	75.69	83.13	90.93	100.17	109.42	120.18	131.78
Year	21	22	23	24	25	26	27	28	29	30
Population size (K=272)	144.06	157.35	169.83	181.98	194.17	205.05	215.30	224.54	232.87	239.32
Year	31	32	33	34	35	36	37	38	39	40
Population size (K=272)	245.24	249.82	253.96	256.39	258.82	261.33	262.78	264.04	265.17	266.09
Year	41	42	43	44	45	46	47	48	49	50
Population size (K=272)	266.40	267.08	267.86	267.99	268.40	268.30	268.36	269.07	269.16	269.10

Appendix Table 24 Percentage of adult female producing progeny per year at Huai Sai Wildlife Breeding Center in 2008.

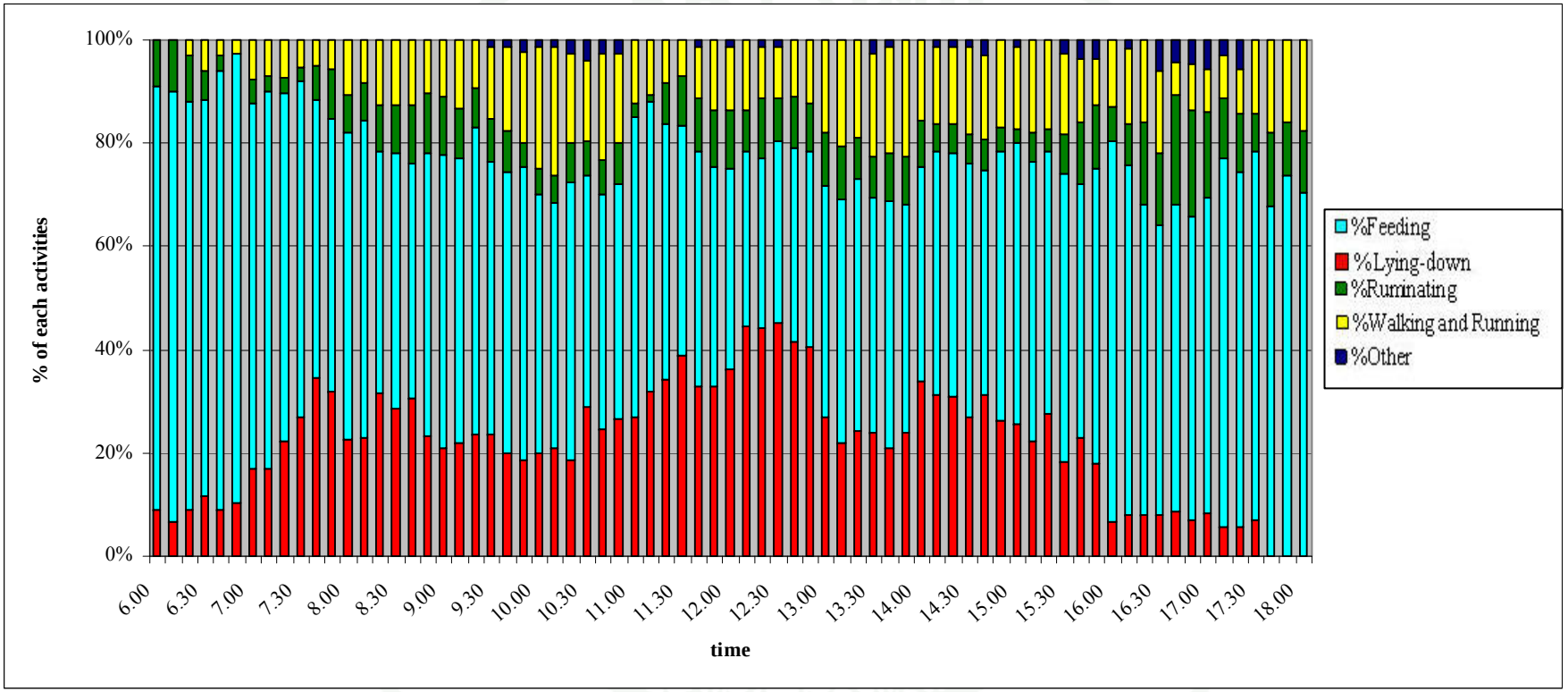
Enclosure	Adult Female	Number of progeny	Alive		% Alive
			Male Fawn	Female Fawn	
1	7	5	3	2	71.43
2	5	5	3	2	100.00
			53.85%	46.15%	85.71
				SD	20.20

Appendix Figure 1 Age structure of hog deer in Thung Ka Mung.

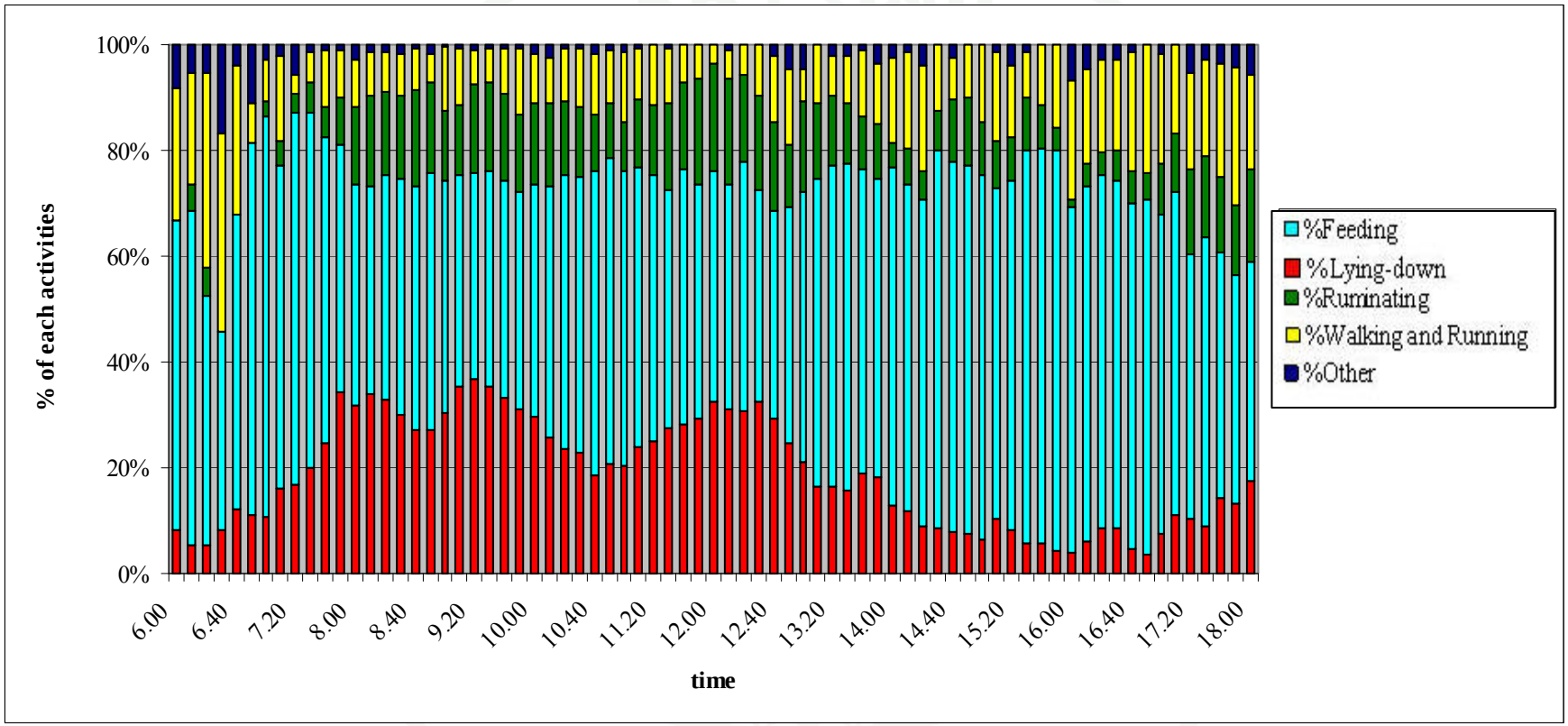
Appendix Figure 2 Adult female and fawn of hog deer in Thung Ka Mung.

Appendix Figure 3 Adult male has recently cast antlers.

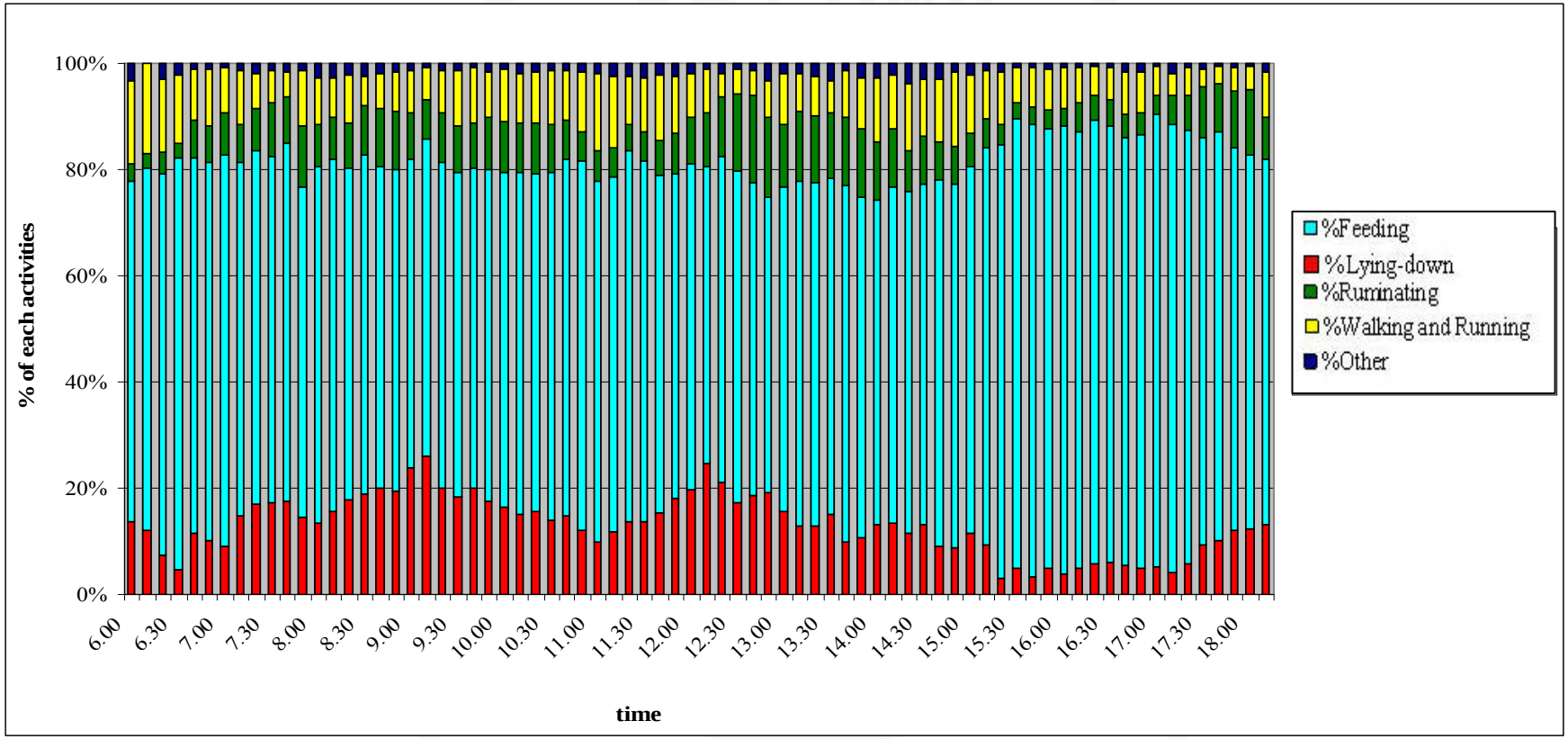
Appendix Figure 4 Adult male at velvet antler phase.



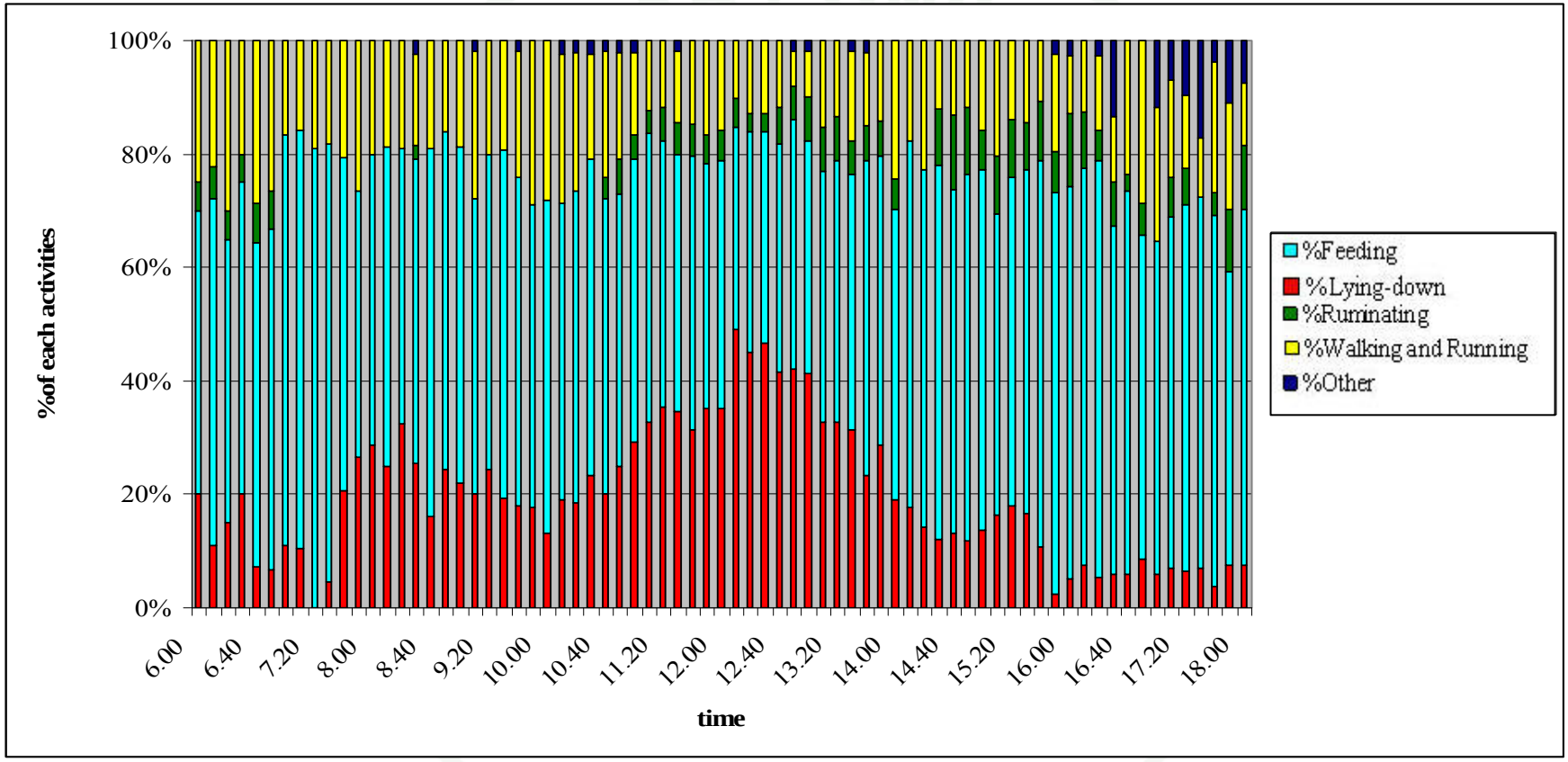
Appendix Figure 5 Behavioral patterns of the newly released groups, (1 year after released), studied by scan sampling.



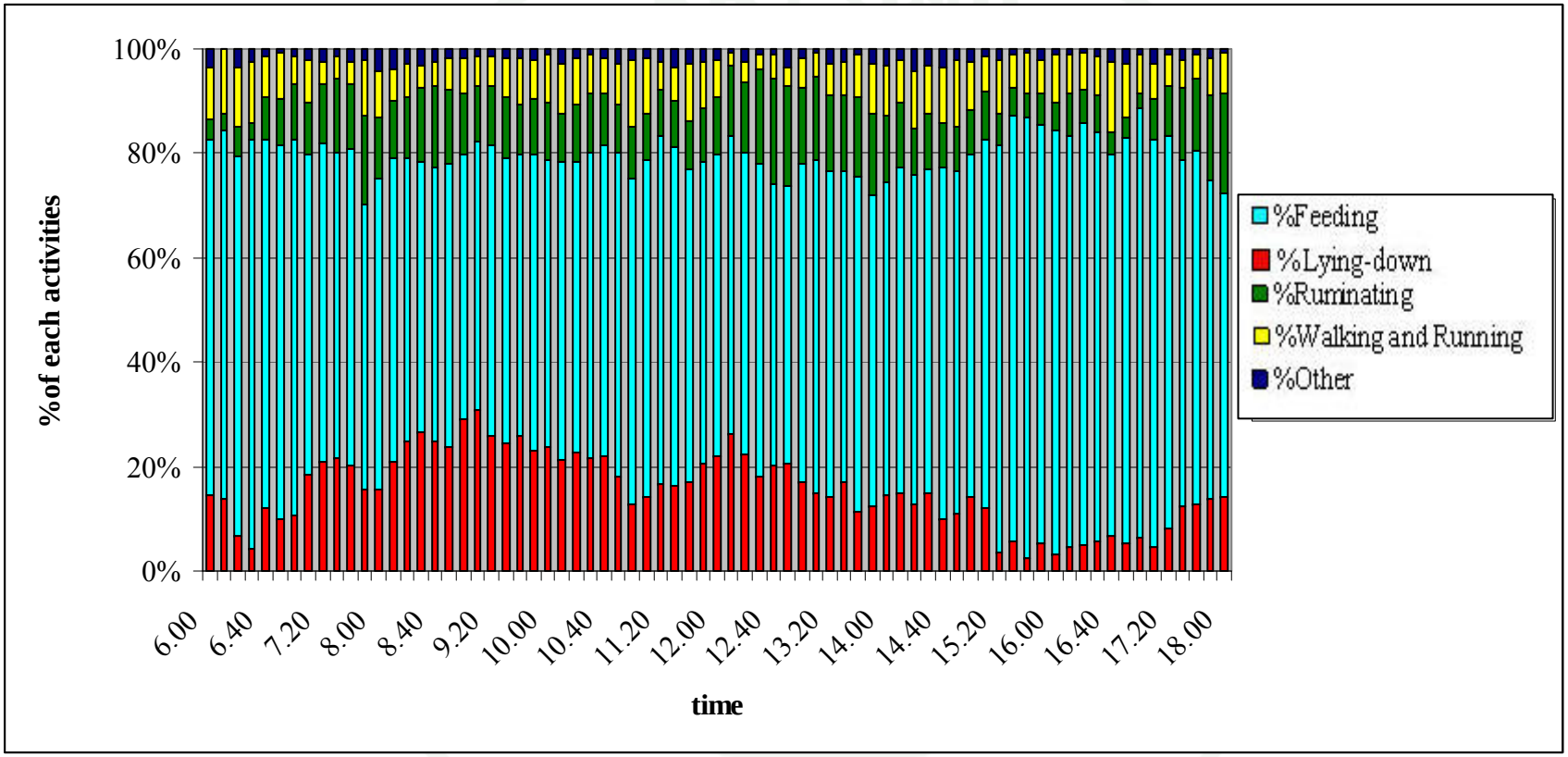
Appendix Figure 6 Behavioral patterns of the newly released groups, (2 year after released), studied by scan sampling.



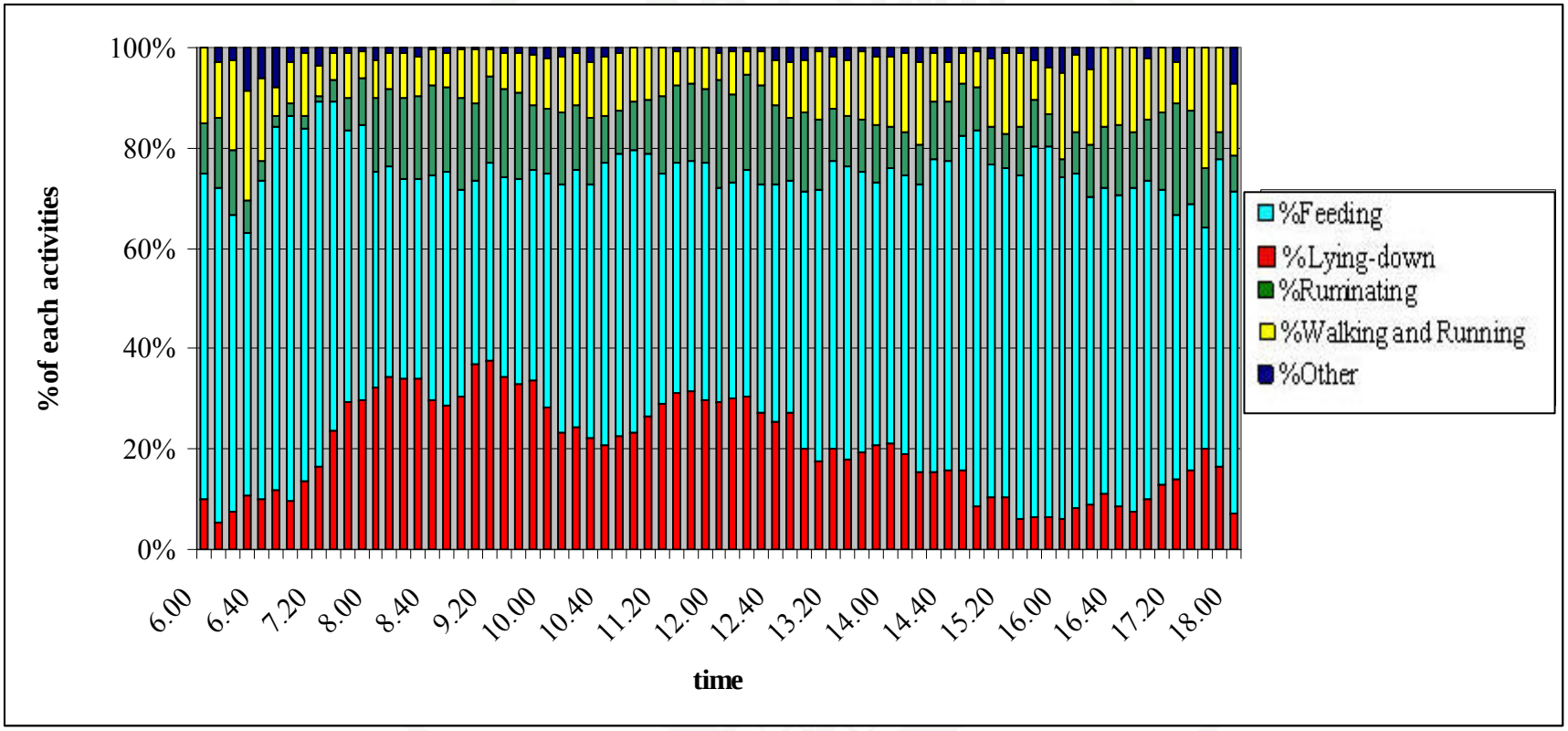
Appendix Figure 7 Behavioral patterns of the existing groups, studied by scan sampling.



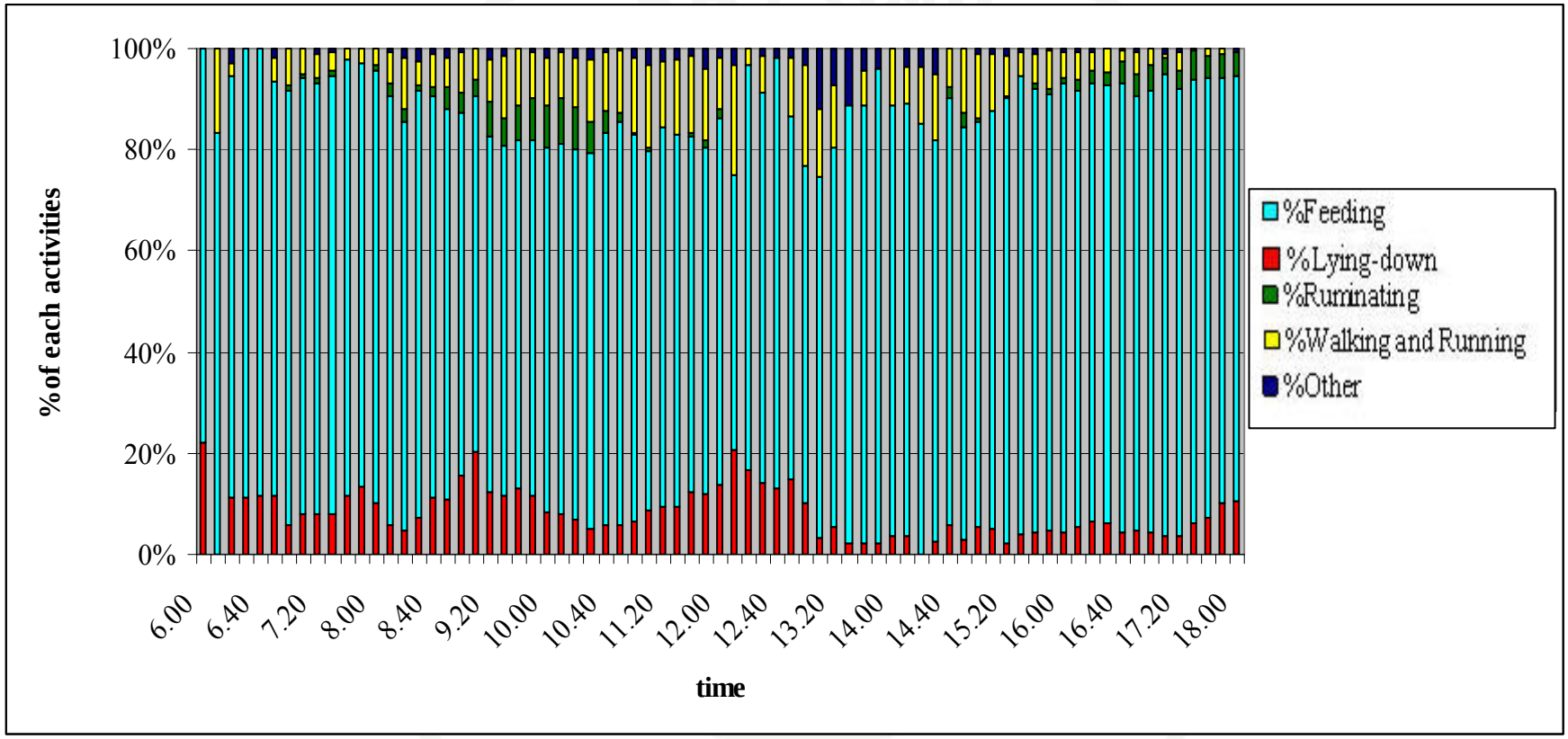
Appendix Figure 8 Behavioral patterns of the newly released groups in the dry season, (2 year after released), studied by scan sampling.



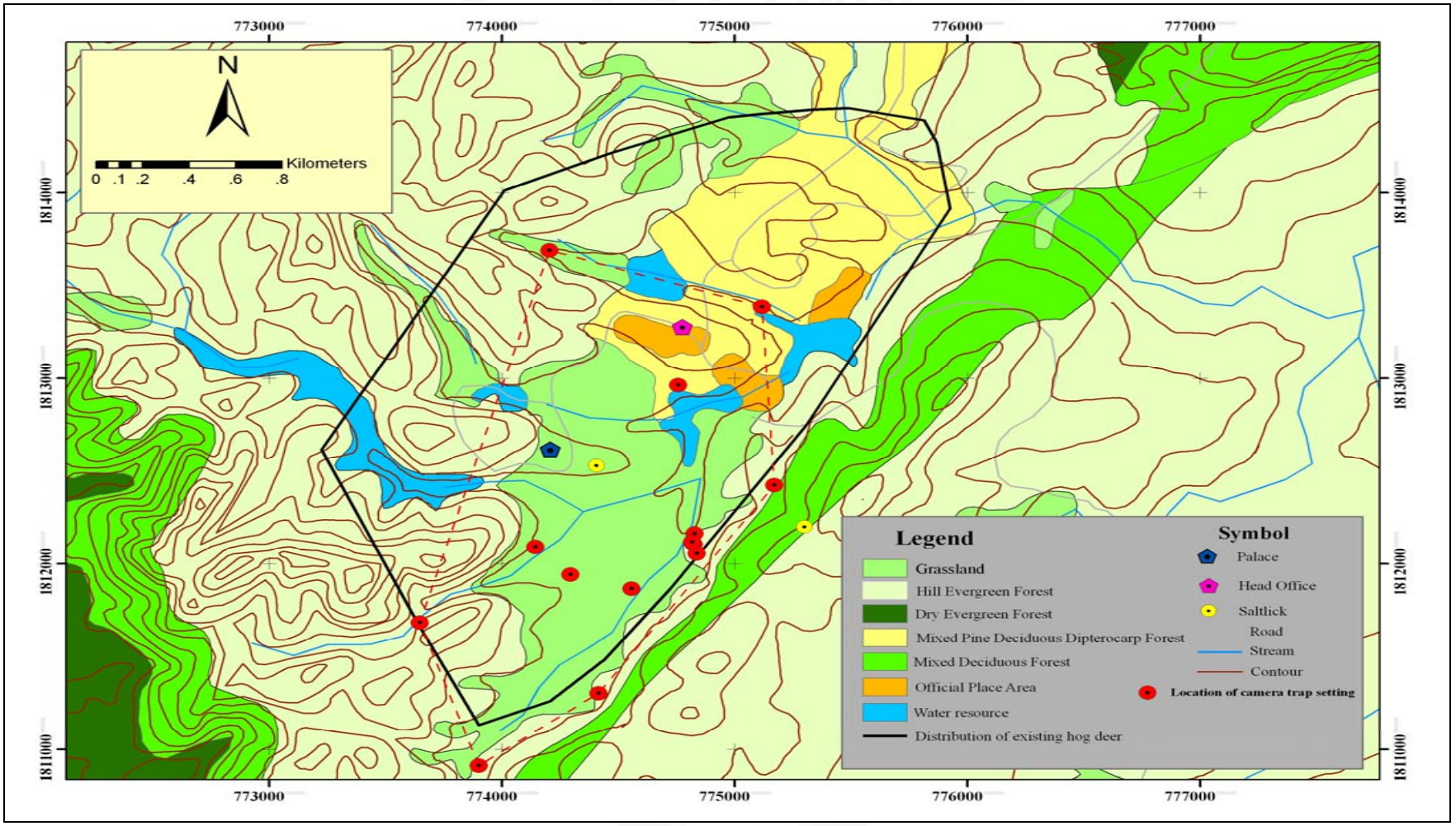
Appendix Figure 9 Behavioral patterns of the existing released groups in the dry season, studied by scan sampling.



Appendix Figure 10 Behavioral patterns of the newly released groups in the wet season, (2 year after released), studied by scan sampling.



Appendix Figure 11 Behavioral patterns of the existing released groups in the wet season, studied by scan sampling.



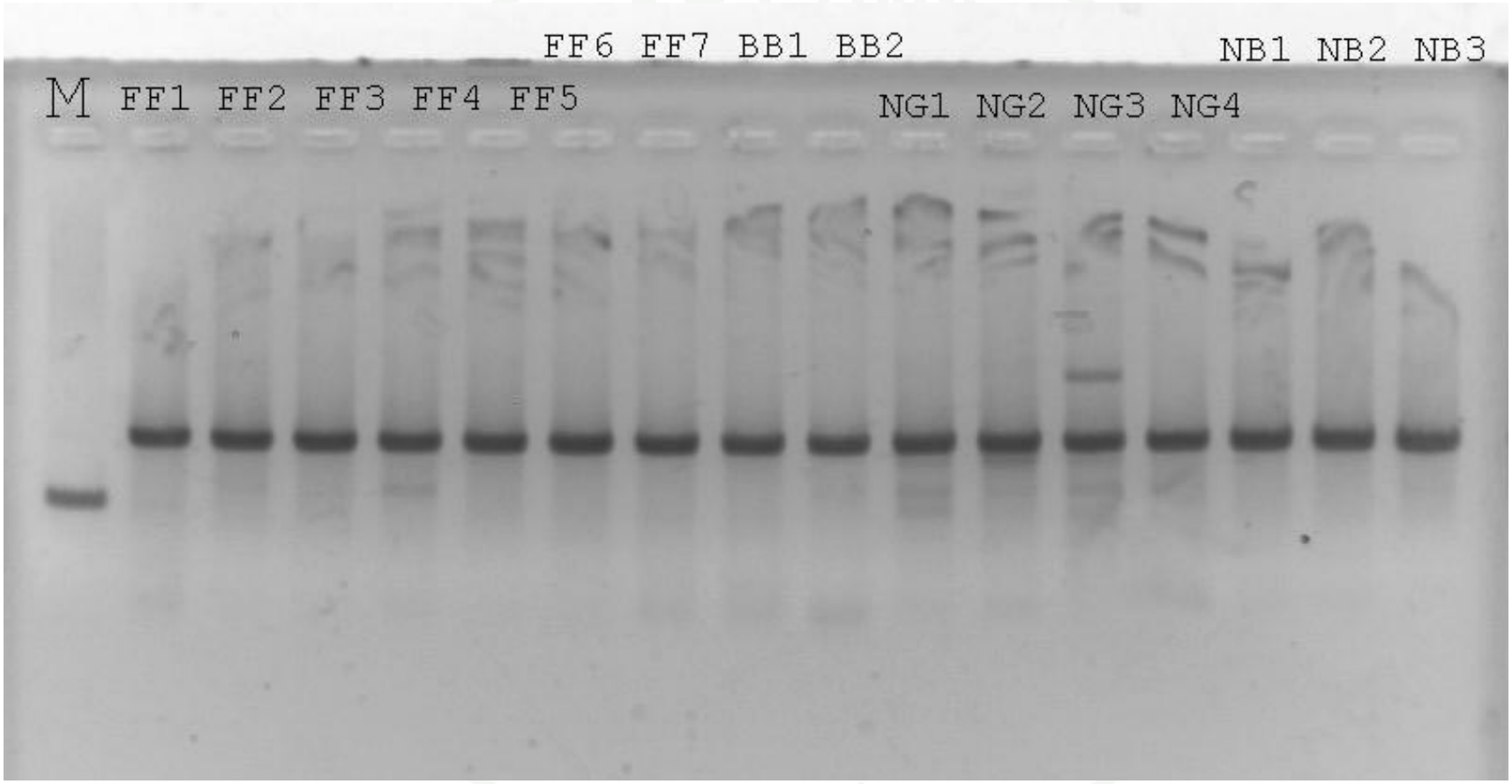
Appendix Figure 12 Study area and 14 locations of the camera trap.

Appendix Figure 13 Asian wild dog by Camera trap in Thung Ka Mung.

Appendix Figure 14 Clouded leopard by Camera trap in Thung Ka Mung.

Appendix Figure 15 Asiatic jackals by Camera trap in Thung Ka Mung.

Appendix Figure 16 Hog deer carcass in Thung Ka Mung.



Appendix Figure 17 PCR product from pellet samples of hog deer.

Appendix Figure 18 Control burning of grassland in Thung Ka Mung.

Appendix Figure 19 The shoot grasses after control burning.

CURRICULUM VITAE

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