Songklanakarin J. Sci. Technol.
34 (3), 263-271, May - Jun. 2012

SJST SONGKLANAKARIN JOURNAL OF SCIENCE AND TECHNOLOGY
http://www.sjst.psu.ac.th

Original Article

Population characteristics and viability of the introduced hog deer (*Axis porcinus* Zimmermann, 1780) in Phu Khieo Wildlife Sanctuary, Thailand

Khanchai Prasanai[1,*], Ronglarp Sukmasuang[1], Naris Bhumpakphan[1], Worawidh Wajjwalku[2], and Kanjana Nittaya[3]

[1] *Department of Forest Biology, Faculty of Forestry, Kasetsart University, Chatuchak, Bangkok, 10900 Thailand.*

[2] *Department of Pathology, Faculty of Veterinary Medicine, Kasetsart University, Kamphaengsaen Campus, Nakhon Pathom, 73140 Thailand.*

[3] *Phu Khieo Wildlife Santuary, Thungluilai Subdistrict, Khon San District, Chaiyaphum, 36180 Thailand.*

Received 9 March 2011; Accepted 23 May 2012

Abstract

The purposes of this study were to study population characteristics of hog deer released into the wild, namely: density, age structure, sex ratio, recruitment rate, threats to hog deer, carrying capacity and inter-specific relationships, as well as to assess the population viability over time. In this study, direct observation was used to study the hog deer population characteristics, and population density was estimated from the pellet-group count method. Vortex program was used to analyze the population viability. Results showed that the population density of hog deer at Thung Ka Mung (TKM) in Phu Khieo Wildlife Sanctuary (PKWS) was 2.03-2.04 individuals/hectare (SD = 1.25). The population structure showed that the average herd size was 9.57 individuals. Hog deer in TKM preferred to stay with a group (91.5%), rather than being solitary (8.5%). The sex ratio for males to females was 54.64:100, and for females to fawns was 100:26.18. The annual recruitment rate was 16.98 %. Their predators 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 habitat sharing by camera traps revealed 4 ungulate species. They were sambar deer, barking deer, wild boar, and elephant, and their relative abundance were 28.41%, 7.38%, 4.70%, and 2.01% respectively. Fifty-year simulation modeling using population viability analysis indicated the sustainability of this population. Hog deer population in the simulations did not exhibit sensitivity to an increase or decrease in carrying capacity. Habitat management should be carried out continuously in TKM area, which is the main habitat for hog deer in PKWS.

Keywords: hog deer (*Axis porcinus*), population characteristic, viability, Phu Khieo Wildlife Sanctuary, Thailand

1. Introduction

Introduction of animals into the wild is a technique used to restore rare or extinct species to an appropriate habitat through natural reproduction (Achapet, 1994; Rabinowit, 1999; IUCN, 2011). Hog deer has been classified as a protected species according to the National Wildlife Protection and Preservation Act of 1992, as well as an endangered species according to IUCN, 2011. 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 in Thailand. The hog deer

* Corresponding author.
Email address: khanchai_64@hotmail.com

has a high survival rate when released to natural conditions because of its adaptability to the new environment (Achapet, 1997).

One of the most important objectives of every wildlife conservation project is the population sustainability. There are several factors which can affect the sustainability of a species, but not all those factors are of equal importance. Simple statistical data gained from ecological study, such as population size and habitat area, are not enough to understand the ability of a species to persist. Population viability analysis (PVA) is a simulation procedure which has been developed to estimate vulnerability to extinction of a species population. It is used to provide wildlife protection and management guidance, especially for rare animals (Shaffer, 1990; Clark and Backhouse, 1991; Armbruster and Lande, 1993; Harcourt,1995; Marmontel *et al.*, 1997). 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 reintroduction programs. Examples of this include 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).

The population characteristics study of released animals has resulted in valuable information for wildlife management. In this study, the population characteristics and viability of the introduced hog deer in "Thung Ka Mung" grassland (TKM) in Phu Khieo Wildlife Sanctuary (PKWS) was investigated from 2007-2010.

2. Study Site

PKWS (Figure 1) is in northeastern Thailand, located between latitudes 16º 5' and 16º 35' N and longitudes 101º 20' and 101º 55' E, with a total area of 1,573 km^2. The sanctuary ranges in altitude from 250 m to 1,310 m, and consists mostly of steep slopes at high elevations with rocky outcrops. The climate of the PKWS is classified according to Coppen's World Climate System as Tropical Savannah Climate (AW). The average annual rainfall is 1,500 mm at in PKWS. The average minimum air temperature is 14ºC, while the average maximum is 27ºC. The average relative humidity is 93.46%. Based on Walter's climate diagram of PKWS, the dry season occurs during November to March, and the wet season occurs during April to October.

TKM grassland is a man-made grassland, originally occurring after forest clearing for agricultural purpose by villagers, before becoming a wildlife sanctuary. According to data reported by Kumsuk and Kreetiyutanont (1999), 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. Three hog deer introduction projects were launched in 1983, 1987 and 1992, resulting in a total of 20 hog deer being released into TKM in PKWS. Kuntaro (2002) reported that there were at least 68 individuals in TKM. Recently in 2007, 8 hog deer (three males and five females) were released again in the same area for rehabilitation of the population.

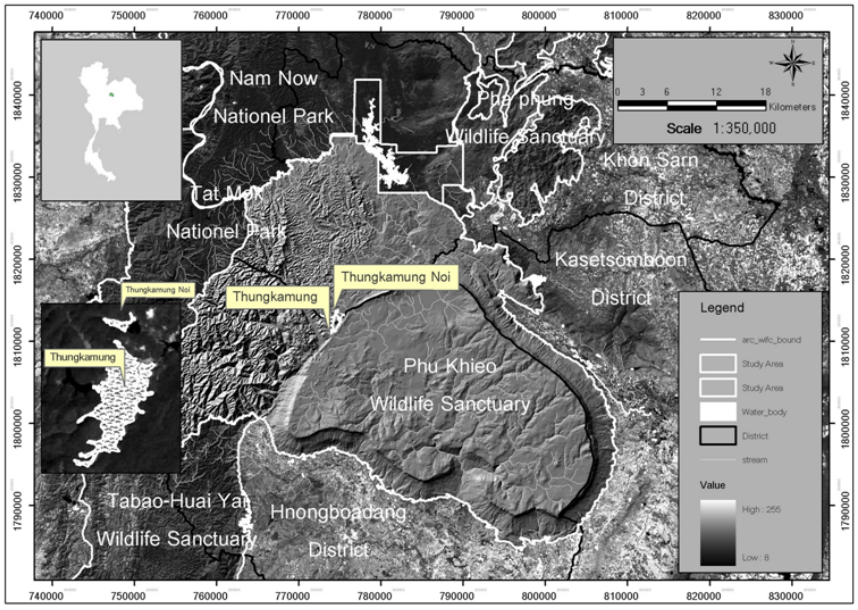

Figure 1. Map of Phu Khieo Wildlife Sanctuary and the location of study site.

3. Materials and Methods

3.1 Population characteristics

3.1.1 Population density

Data were collected by plots on line transect, and analyzed by fecal pellet group count method, according to Ngampongsai, (1977) Dhungel and O'Gara, (1991) Sukmasuang (2001) and Kuntaro (2002).

3.1.2 Population structure and recruitment rate

Population structure of hog deer was investigated by direct sighting. When sightings involved family groups, observed deer were divided into three age classes (Dhungel and O'Gara, 1991). Otherwise, male hog deer were divided into adults with hard antlers, adults with shed antlers and juvenile males. Data were collected from January 2008 to December 2008. The method for the annual recruitment rate estimation by Dhungel (1985) was applied to study the hog deer in this area.

3.2 Threats to hog deer

3.2.1 Direct observation:

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

3.2.2 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 (Bhumpaphan, 1997) and Sukmasuang, 2001).

3.3 Carrying capacity

Plant consumption and availability for hog deer were assessed by thirty 1x2 m consumption plots. Carrying capacity was then calculated according to the equation by Harlow (1984) and Hobbs (1988).

3.4 Inter-specific relationship

The plots on line transect was applied to assess habitat sharing and competition. Each transect line was 200 m apart, with plots placed at 50 m intervals along the line. The plots were distributed throughout 3 km. The data were analyzed using percentage of occurrence frequencies of target animals in each habitat type and compared by ANOVA (Duncan's multiple range test) at 95% confidence interval.

3.5 Population viability analysis (PVA)

Most PVAs are currently available in various computer programs such as Spgpc, Gapps, Popdyn, Ramas, and Vortex (Miller and Lacy, 1999; Lacy, 2000). 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 impact population forces (Miller and Lacy, 1999). The PVA for the hog deer population in this study was conducted using the Vortex program version 9 (Lacy, 1993, 2000; Lindenmayer *et al.*, 2000). The number of replications determines the precision (but not the accuracy) of the risk estimates. Each simulation should be run with a minimum of 1,000 replications (Akcakaya and Sjogren-Gulve, 2000). Most conservation is short-term, and even 50 years is a much longer duration than the legislative system in Thailand would allow for a conservation program. Moreover, events related to population viability more than 100 years in the future are difficult to foresee (Mace and Lande, 1991). All parameters used in this study are listed in Table 1.

4. Results

4.1 Population characteristics

4.1.1 Population density

The highest population densities were found in March 2008 and March 2009, which were 4.23 and 4.41 individuals/hectare respectively. The lowest population densities of both periods were observed in September, at 0.43 and 0.74 individuals/hectare in year 2008 and 2009 respectively. The average yearly population density was 2.03 (SD = 1.25) and 2.04 (SD = 1.25) individuals/hectare in periods from February 2008 to January 2009 and February 2009 to January 2010 respectively.

4.1.2 Population structure

1) Herd size

The frequencies of sightings of different group sizes in wet season and dry season are shown in Table 2. The percentage of different types of groups from 1,410 sightings over one year at TKM were calculated to be 8.51% solitary, 30.43% small (2-3 animals), 27.52% medium (4–6 animals), 11.49% large (7-10 animals), and 22.06% very large (>10 animals). Most of the solitary animals were adult males. Adult females mostly stayed with their offspring. During the study period from January to December 2008, the average herd size was 9.54 individuals (range 2-78, SD = 5.16). The average herd size for wet and dry season 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,

Table 1. Simulation model parameters of re-introduction of hog deer 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

Table 2. Average herd size of hog deer in the wet and dry season in 2008

Wet season				Dry season			
Month	Herd size	Alone (%)	Group (%)	Month	Herd 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 herd size		12.71 (SD=4.18)				5.1 (SD=2.18)	
Yearly average herd size		9.54 (SD=5.16)					

while percentage of solitary animals was significantly higher in the dry than in the wet season with 95% confidence interval.

2) Age structure, sex ratio, and recruitment rate

The age structure and sex ratio of the hog deer population in this study were investigated based on 1 year full time basic data from January 2008 to December 2008. From 1,410 observations, a 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 sub-adult males, 948 sub-adult females, and 1,421 fawns. The age classes of the hog deer in TKM during the study period consisted of 26.15% adult males (7.08% males with velvet or shed antlers and 19.07% males with hard antlers), 48.18% adult females, 4.67% sub-adult males, 8.39% sub-adult females, and 12.62% fawns. The sex ratio for 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 sex ratio in the wet season was different from that in the dry season. The male:female ratio in wet season and dry season were 1:1.70 or 58.8:100, and 1:2.15 or 46.5:100 respectively.

The annual recruitment rate of hog deer population in this study was 16.98 % (1,421 x 100/8,368).

4.2 Threats to hog deer

A total of 23 carcasses were recorded during the study. They comprised 11 adult males, 8 adult females, and 4 fawns. By carcass observation or other direct evidence, three predator species could be identified to be the cause of death for 16 carcasses. Asian wild dogs hunted 11 deer (6 males, 5 females), resulting in 47.83% of the deaths recorded, and was the first in rank of hog deer predators in TKM. Burmese python killed 2 males and 2 fawns, causing 17.39% of the deaths, and was the second most common cause of death. Asiatic jackal killed one injured female, causing 4.35% of the deaths, and was the third most common cause of death. The cause of death for 7 carcasses (3 males, 2 females, and 2 fawns), representing 30.43% of the deaths, could not be identified.

Mortality rates were estimated by comparing the total number of hog deer achieved from total count methods. The number of deaths (and mortality rate) of male, female, and fawn was 11 (26.83%), 8 (10.81%), and 4 (33.33%) respectively.

The camera trap technique was employed to investigate the predators around the TKM area. This investigation took place over 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 dominant predators were leopard cats, Asian wild dog, Asiatic jackal and clouded leopards, and their relative abundances were 1.34%, 1.12%, 0.89%, and 0.45% respectively.

4.3 Carrying capacity

We assessed plant availability for hog deer by control plot and consumption plot. The forage availability in the TKM area was 20,043.68 grams in 60 m^2 and the total potential habitat used was 103.95 hectare or 1,039,500 m^2 (grassland). Hog deer in captivity consume approximately 3,500 grams of food per day (Achapet, 1997). Therefore, the approximate carrying capacity number is 272 individuals in the dry season.

4.4 Inter-specific relationship

4.4.1 The results from 4 camera traps set around TKM area revealed that there were 4 ungulate species. They were sambar deer, barking deer, wild boar, and elephant, and their relative abundance were 28.41%, 7.38%, 4.70%, and 2.01% respectively.

4.4.2 The habitat sharing by related animals (6 ungulate species and 3 predator species) was determined by plots on line transect and the results can be interpreted by types of habitat (Table 3). The frequencies of target animals being observed in each habitat type were determined and compared by ANOVA (Duncan's multiple range test) at 95% confidence interval. The results from this study indicated that for both grassland (GL) and mixed pine-deciduous dipterocarp forest (MPDF) in TKM, hog deer was the dominant species. The frequencies of hog deer being observed in GL (71.24%) were significantly different from that of sambar deer (41.59%), which was significantly different from barking deer and wild boar. The observation frequencies in MPDF of hog deer and sambar deer were not significantly different, and that of sambar deer was also not significantly different from that of wild boar. The sambar deer was the dominant ungulate species that used the edge of hill evergreen forest (HEF), following by wild boar and barking deer. The occurrence frequency of sambar deer in HEF (36.25%) was significantly greater than those of wild boar (21.78%) and barking deer (13.02%). The 3 predators consisted of Asian wild dog, Asiatic jackal and leopard cat.

4.5 Population viability analysis

Population viability analysis for hog deer was conducted using 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 for each different parameter.

The simulation model revealed the trend of the mean population size and the probability of survival over a period of 50 years. 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

Table 3. Percentage of occurrence frequency of the target species in each habitat types by line plot system method (as shown in Figure 4) 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 indicate significant difference among groups in the same distance range at 95% confidence interval by one way ANOVA

reintroduction program, the size of the deer population was predicted to reach the approximate maximum carrying capacity for TKM, as determined from Figure 2. 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.

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 100% probability of survival of hog deer population over 50 years (p =1).

Sensitivity to mortality rate (Figure 3) was analyzed. Hog deer population in the simulations exhibited sensitivity to an increase in mortality rate, and population number decreased when the mortality increased.

The minimum number of animals released (initial population) is always an important consideration of any animal introduction program. The initial population for males and females which can 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 ratios of 1:1, 1:2, and 1:3, were simulated and analyzed (Figure 4 a-c).

5. Discussion

5.1 Population characteristics

5.1.1 Population density by pellet group count method

The result from this study revealed that the average hog deer population density in TKM was 2.03-2.04 individuals/hectare (SD = 1.25) from February 2008 to January 2010. The population density of hog deer in this study was higher than that reported in the studied of Kuntaro (2002), which studied the population of hog deer in the same area and reported a population density of 1.02 individuals/hectare. The higher density reported in this study can be explained by the fact that the hog deer population, which has been increasing every year from 2002 to 2010, have remained only in the TKM area.

The density of hog deer in PKWS is also higher than the population density of hog deer in Khao Chi-on Non-hunting Area (0.55 individuals per hectare), which is a semi-natural habitat (Aemsang, 2008), and in Royal Chitwan National Park, Nepal (0.155 to 0.191 individuals per hectare), which is a natural habitat (Dhungel and O'Gara, 1991). This may be the effect of more competitive animals existing in the 2 latter areas. There are more sambar deer than hog deer in

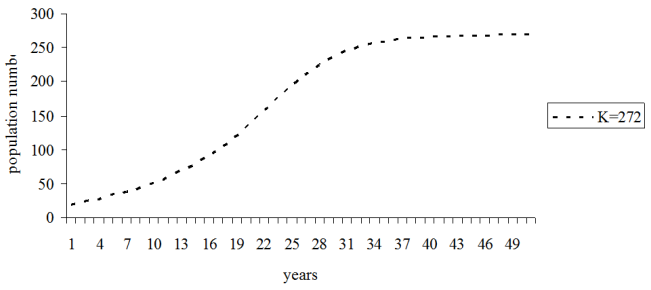

Figure 2. Prediction of population size of hog deer at Thung Ka Mung in Phu Khieo Wildlife Sanctuary from the year 1983 to year 2032.

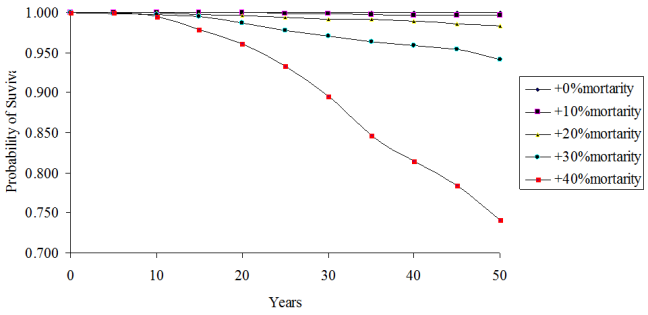

Figure 3. Sensitivity of probability of survival of hog deer in Thung Ka Mung to increasing the mortality rate.

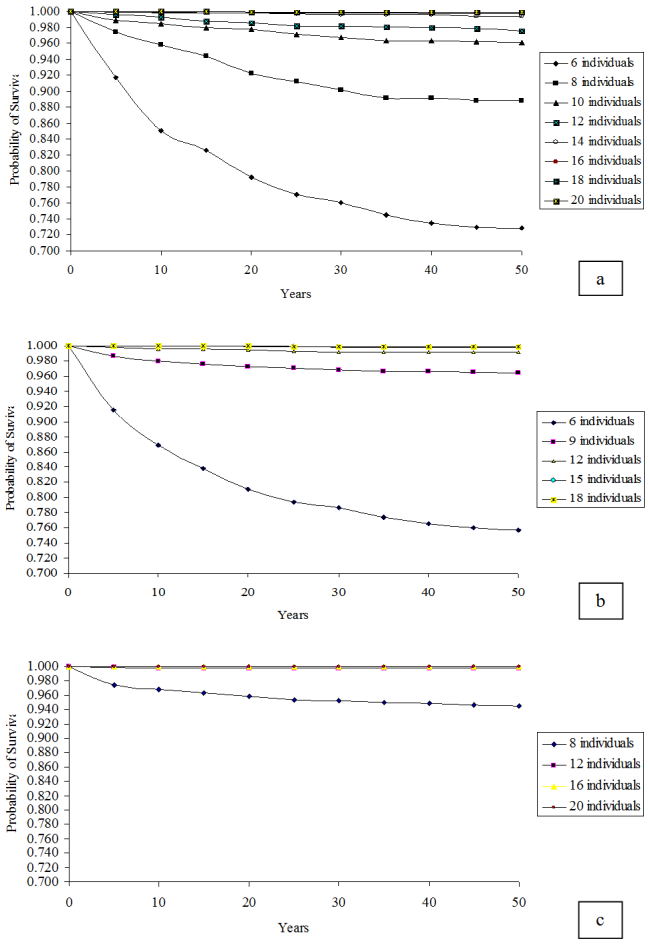

Figure 4. Sensitivity of survival probability of hog deer to initial population size with different male:female ratio, a = 1:1, b = 1:2, c = 1:3.

Khao Chi-on Non-hunting Area while in Royal Chitwan National Park, Nepal, there are more axis 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 be a cause of the lower numbers and densities of hog deer in both areas. In the TKM area, the highest densities of hog deer occurred on the highest quality and quantity of grasses area. Therefore, it is recommended that controlled burning should be performed annually to improve the habitat for the hog deer and other herbivorous species.

5.1.2 Population structure

The results of this study, which found that the hog deer in TKM preferred to stay in groups, was similar to that in the studies of Kumsuk and Kreetiyutanont, (1999); Kuntaro, (2002). However, it was different from the study of Biswas et al. (2002), 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 41% solitary, 41% small (2-3 animals), 11% medium (4–6 animals), 4% large (7-10 animals), and 3% very large groups (>10 animals). Biswas et al. (2002) 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, and medium and large groups changed with season. Adult females primarily formed family 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.

The herd size of the hog deer from this study was larger than the herd size in natural conditions reported by Dhungel and O'Gara (1991). They reported that the average herd size of the hog deer at Royal Chitwan National Park in 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 different habitat and grassland management. The hog deer population in Royal Chitwan National Park in Nepal is wild, and is scattered in a small group that can reduce the mortality rate caused by predators. The hog deer in TKM at PKWS were captive and introduced, and their habitat was limited to grassland, open forest area.

5.2 Threats to hog deer

The mortality rate of 18.11% reported in this study is close to the mortality rate in Royal Chitwan National Park, Nepal, which has been reported as 11.5%, 15.4%, 18.8%, 18.7% and 26% 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 the hog deer population in PKWS. This means that the hog deer in PKWS could adapt well to the new habitat and become part of the wild population.

Asiatic jackal were observed to have hunted injured hog deer, and the species shows omnivorous and carrion feeding habits rather than preying on large or medium size animals (Bhumpakphan, 1997). Slangsingh (2007) reported that hog deer in PKWS were hunted by Asian wild dogs and ranked fourth out of six prey species. The prey species comprised 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%).

Dhungel and O'Gara (1991) investigated the causes of death for hog deer in Royal Chitwan National Park in Nepal by estimation from radio-collared deer. The authors reported that hog deer ranked second (21.7%) out of seven prey species hunted by tigers and leopards. Other studies in Chitwan Park reported that tigers and leopards killed about the same percentage of hog deer, and hog deer were also preyed upon by various other carnivores, including pythons. The mortality rates ranged from 11.5% up to 18.7% (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.

5.3 Carrying capacity

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, the carrying capacity of a species in an area can be increased through habitat management. Controlled burning is one of the methods to manage grassland areas. Moe and Wegge (1997) studied the effects of cutting and burning on grass quality, and axis deer use of grassland in lowland Nepal. The authors reported that cutting and burning plots give the best overall increase in nutritional quality, and when comparing cutting plots and burning plots, the burning plots had a higher increase in N, P and Na concentrations. It is recommended that controlled burning should be performed annually to improve the habitat for the hog deer and other herbivorous species.

5.4 Inter-specific relationship

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 a barrier to the distribution of hog deer. However, the other ungulate species (sambar deer, barking deer etc.) were also found in TKM, therefore competition might exist.

5.5 Population viability analysis

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 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, which would decrease the available area and displace the deer (Barrio, 2007).

The data reported by Kumsuk and Kreetiyutanont (1999) revealed that in 1995 the grassland area of TKM was 1.5 km^2 and in 1998 was 1.33 km^2. The result from this study showed 56.56% reduction of the grassland area in TKM, with only 0.85 km^2 remaining in 2008. The shrinkage of the grassland is caused by the invasion of the surrounding hill evergreen forest. Therefore, the controlled burning technique was performed in the dry season to stop the pioneer flora species from invading from the surrounding land. The highest densities of hog deer occurred in the areas with the highest quality and quantity of grasses.

Sensitivity to catastrophes was not analyzed in this study because there has not been any report of catastrophe in TKM. However, the population of hog deer in TKM is non-fragmented, and if any catastrophe were to occur, it could easily lead to extinction of the population.

Acknowledgement

Special thanks go to Mr Dennapa Konkuntod and all the staff of PKWS for their kind support in assisting with data collection and to Mr Sakol Kanchanarajit for providing information of hog deer in the breeding center.

References

Achapet, A. 1994. Home Range and Habitat Preference of Released Captive-Breed Hog Deer (*Cervus porcinus annamiticus*) in Khao Chi On Non-Hunting Area, Chonburi Province, Thailand. M. Sc. Thesis, Asian Institute of Technology, 54 pp.

Achapet, A. 1997. Knowledge about Hog Deer. Wildlife propagation Section, Wildlife Conservation Division, Natural Resource Conservation Office, Royal Forest Department, Bangkok, 29 pp. (in Thai).

Aemsang, J. 2008. Ecological Separation of the Released Hog Deer and Sambar Deer to Khao Chi-on Non-hunting area, Chon Buri Province. M. S. Thesis, Kasetsart University.

Akcakaya, H. R. and Sjogren-Gulve, P.. 2000. Population viability analyses in conservation planning: an overview. Ecol. Bull. 48, 000-000.

Armbruster P. and Lande, R. 1993. A population viability analysis for African elephant *Loxodonta africana*: how big should reserves be? Conservation Biology 7, 602-610.

Barrio, J. 2007. Population Viability Analysis of the Taruka, *Hippocamelus antisensis* (D'Orbigny, 1834) in Southern Peru. Rev. Peru. Biol. 14(2), 193-200.

Bhumpakphan, N. 1997. Ecological Characteristics and Habitat Utilizations of Gaur (*Bos gaurus* H. Smith, 1827) in Different Sites. Ph. D. Thesis, Kasetsart University.

Biswas, T., Mathur, V.B. and Sawarkar, V.B. 2002. Status of hog deer (*Axis porcinus*) in India. Report submitted to Wildlife Institute of India, Dehradun.

Brito, D. and Fernandez, F. A. S. 2000. Metapopulation viability of the marsupial micoureus demerarae in small Atlantic forest fragments in South-eastern Brazil. Anim. Conserv. 3, 201–209.

Brito, D. and Fernandez, F. A. S. 2002. Patch relative importance to metapopulation viability: the neotropical marsupial micoureus demerarae as a case study. Anim. Conserv. 5, 45–51.

Brito, D. 2002. Conservacao e Manejo do Marsupial Micoureus Demerarae em Fragmentos de Mata Atlantica. M. Sc. Thesis, Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Brito, D. and Figueiredo, M. S. L. 2003. Minimum viable population and conservation status of the Atlantic forest spiny rat *Trinomys eliasi*. Biol. Conserv. 113, 153–158.

Brito, D. and Grelle, C. E. V. 2004. Effectiveness of a reserve network for the conservation of the endemic marsupial micoureus paraguayanus in Atlantic forest remnants in South-eastern Brazil. Biodivers. Conserv. 13, 2519–2536.

Clark T.W. and Backhouse, G.N. 1997. Report of a workshop on population viability assessment as atoll for threatened species management and conservation. Australian Zoologist 27, 28-35.

Dhungel, S. K. 1985. Ecology of the Hog Deer in Royal Chitwan National Park, Nepal. Ph. D. Thesis, University of Montana.

Dhungel, S.K. and O'Gara, B. W. 1991. Ecology of the hog deer in Royal Chitwan National Park, Nepal. Wildl. Monogr. No. 119.

Harcourt, A.H. 1995. Population viability estimates: theory and practice for a wild gorilla population. Conservation Biology 9,134-142.

Harlow, R.F. 1984. Habitat evaluation, pp 601-628. *In* L.K. Halls, editor. White-tailed Deer Ecology and Management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Hobbs, N.T. 1988. Estimating habitat carrying capacity: an approach for planning reclamation and mitigation for wild ungulates. Issues and Technology in Management of Impacted Wildlife 3, 3-7

IUCN. 2011. IUCN/SSC Re-introduction Specialist Group. [Available from http:// www.iucnsscrsg.org]. [Cited

February, 22, 2011]

Kierulff, M. C. M. 1993. Avaliacao Das Populacoes Selvagens De Mico-leao-dourado Leontopithecus Rosalia e Proposta De Estrategia Para Sua Conservacao. M. Sc. Thesis, Universidade Federal deMinas Gerais, Belo Horizonte.

Krausaman, P. R. 2001. Introduction to Wildlife Management: the Basics. Prentice Hall, Upper Saddle River, New Jersey.

Kumsuk, M. and Kreetiyutanont, K. 1999. Report: Grassland Management by Burning Control for Wildlife in Phu Khieo Wildlife Sanctuary Chaiyaphum Province. Natural Resources Management Section, Phu Khieo Wildlife Sanctuary, Wildlife Conservation Division, Natural Resource Conservation Office, Royal Forest Department, Bangkok, 20 pp. (in Thai).

Kuntaro, P. 2002. Adaptability of the Releasing Hog Deer at Thung-Kamang, Phu Khieo Wildlife Sanctuary, Changwat Chaiyaphum. M. S. Thesis, Kasetsart University, 80 pp.

Lacy, R.C. 1993. Vortex: a computer simulation model for population viability analysis. Wildlife Research. 20(1), 45-65.

Lacy, R.C. 1993-4. What is population (and habitat) viability analysis? Primate Conservation 14-15, 27-33.

Lacy, R.C. 2000. Structure of the VORTEX simulation model for population viability analysis. Ecological Bulletins 48: 191-203.

Lindenmayer, D.B., Lacy, R.C. and Pope, M.L. 2000. Testing a simulation model for population viability. Ecol. Appl. 10, 580-597.

Mace, G. and Lande, R. 1991. Assessing extinction threats: toward a reevaluation of IUCN threatened species categories. Conservation Biology 5, 148-157.

McDougal, C. 1977. The face of the tiger. Rivington-Deutch, London, U.K.

Marrrmontel, M.S.R., Humphhrey and O'Shea, T.J. 1997. Population viability analysis of the Florida manatee (*Trichechus manatus latirostris*). Conservation Biology 11, 467-481.

Miller, P. S. and Lacy, R. C.1999. VORTEX: A Stochastic Simulation of the Extinction Process. Conservation Breeding Specialist Group (CBSG-SSC/IUCN), Apple Valley.

Mishra, H. R. 1982. The Ecology and Behavior of Chital (*Axis axis*) in Royal Chitwan National Park, Nepal. Ph. D. Thesis, University Edinburgh, U.K.

Moe S. R. and Wegge, P. 1997. The effects of cutting and burning on grass quality and Axis deer (*Axis axis*) use of grassland in lowland Nepal. J. Trop. Ecol. 13(2), 279-292.

Ngampongsai, C. 1977. Habitat Relations of the Sambar (*Cervus unicolor*) in Khao-Yai National Park, Thailand. Ph. D. Thesis, Michigan State University.

Rabinowit, A. 1999. Manual for Research and Wildlife Conservation. Supnaka Sakean Foundation, Bangkok. (in Thai)

Rall, K., Ballou, J. and Templeton, A. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. Conservation Biology 2, 185-193.

Robinson, J. and Redford, K. 1986. Body size, diet and population density of Neotrotropical forest mammals. American Naturalist, 128, 665-680.

Rylands, A., Strier, K., Mittermeier, R., Borovansky, J., Seal, U. S.1998. Population and Habitat Viability Assessment Workshop for the Muriqui (*Brachyteles arachnoides*). Apple Valley (MN): IUCN/SSC Cons Breed Spec Group.

Seal, U. S., Ballou, J. D. and Padua, C. V. 1990. Leontopithecus: Population Viability Analysis Workshop. Conservation Breeding Specialist Group (IUCN/SSC/CBSG), Belo Horizonte.

Seidensticker, J. C. 1976. Ungulate populations in Chitwan Valley, Nepal. Biol. Cons. 10, 183-210.

Shaffer, M. L. 1990. Population viability analysis. Conserv. Biol. 4, 39-40.

Slangsingha, N. 2007. Diet of asian wild dog (*Cuon alpinus*) in Phu Khieo Wildlife Sanctuary, Chaiyaphum Province, Thailand. J. Wild. Thailand 14 (1), 54-64. (in Thai).

Strier, K. B. 1994. Viability analysis of an isolated population of muriqui monkeys (*Brachyteles arachnoides*): implications for primate conservation and demography. Prim. Cons. 14-15, 43-52.

Strier, K. B. 2000. Population viabilities and conservation implications for Muriquis (*Brachyteles arachnoides*) in Brazil's Atlantic forest. Biotropica 32 (4b), 903-13.

Sukmasuang, R. 1993. Ecology of Asian Elephant (*Elephas maximus* Linnaeus, 1758) in Huai Kha Khaeng Wildlife Sanctuary Chang wat Uthai Thani and Tak. M. S. Thesis, Kasetsart University.

Sukmasuang, R . 2001. Ecology of Barking Deer (*Mubtiacus* spp.) in Huai Kha Khaeng Wildlife Sanctuary. Ph. D. Thesis, Kasetsart University.

Sunquist, M. E. 1981. The Social Organization of Tigers in Royal Chitwan National Park, Nepal. Smithson, Contri. Zool.

Valladares-Padua, C., Padua, S. M. and Cullen, L. Jr. 1994. The conservation biology of the black lion tamarin Leontopithecus chrysopygus: First Ten Year's Report. Neotrop. Primates 2, 36–39.