

Original article

Population Density of Asian Elephants in Huai Kha Khaeng Wildlife Sanctuary

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ABSTRACT

The population density of Asian elephants in Huai Kha Khaeng Wildlife Sanctuary was studied between 1997 and 2003, covering a period of six years. A dung-count method was used both in that area and in the area around Khao Nang Rum Wildlife Research Station (KNRWRS). Data were collected consecutively at six other study sites. Sex ratio, age structure and recruitment rate of the population were also calculated from the data gathered by both transect lines and direct observations. Results reflected that the population density around KNRWRS in both the wet and the dry seasons was 0.30 individuals/km². In the other study sites that were located near the Huai Kha Khaeng River and had less human disturbance, there was an average density of 0.73 individuals/km². The yearly recruitment rate of the population was between 9.31 - 11.64 %. The ratio between calf-plus-juvenile elephants to sub-adult-plus-adult elephants was 1:2.15. The sex ratio between adult males and adult females in the population was 1:6.25. This study showed acceptable results compared with other natural habitats of the animal's distribution in the Asian region. However, elephant poaching for tusks in this area remains a major threat. The population demography, population health and genetic diversity should be investigated in the future to ensure long-term survival of the species.

Keywords: population density, Asian elephant, Huai Kha Khaeng Wildlife Sanctuary

INTRODUCTION

Asian elephants have been classified as an endangered species according to IUCN red list data for some time now. Venkataraman *et al.* (2002) reported that approximately 45 000 individuals live in the wild and are distributed across several ranges over South and Southeast Asia. The species is an important flagship species for the conservation of biodiversity. Rees (2003)

expected that Asian elephants in captivity would disappear within 50 years from now. In Thailand, domestic elephants declined drastically, from approximately 100 000 individuals to 2000 individuals, within 120 years from 1880 to 2000 (Lakka, 2000). The causes of decline are many, including especially: caring difficulty, lack of jobs and lack of feeding range. Therefore, the best way to conserve this species is with *in situ* conservation areas. Thailand is one of the

important natural ranges of this animal. Nevertheless, few population studies have been done. Lack of base knowledge and an understanding of the population characteristics of the animal in the protected areas of Thailand has resulted in insufficient knowledge of both the animal's habitat and population management. The expected results from Huai Kha Khaeng Wildlife Sanctuary can be applied to manage wild elephants in protected areas elsewhere near the sanctuary for the species' *in situ* conservation. This study concentrated mainly on the population density, age structure, sex ratio and recruitment rate of the animals.

MATERIALS AND METHODS

Study Site

Location

Data collection was conducted in Huai Kha Khaeng Wildlife Sanctuary (HKKWS), Uthai Thani province. Due to a very large study area, seven sample sites were intensively investigated to determine the index population density of the total population. The sites were located at: (1) Krapuk Krapiang, (2) Nai Sor, (3) Khao Ban Dai, (4) Nong Ma, (5) Huai Luang, (6) Khlong Kor and (7) Khao Nang Rum Wildlife Research Station.

HKKWS is situated between latitudes N 14° 56' and 15° 48' and longitudes E 99° 00' and 99° 28' in the west of central Thailand. A large portion of the sanctuary is located in the Lansak, Ban Rai and Huai Kod districts of Uthai Thani province. A portion of the northwest area is in Umpang district, Tak province. The sanctuary was gazetted in 1972 and subsequently expanded in 1986 and again in 1992. Presently, it covers an area of 2780.14 km².

Topography

The area is composed of complex mountains ranging from 160–1687 m above mean sea level. It is a part of the Thanon Thongchai Mountain Range. The Huai Kha Khaeng Stream, the main permanent water source, flows from the north to the Srinakarin Reservoir in the south of the area. Most mountain chains run in a north-south direction on both sides of the Huai Kha Khaeng Stream and have narrow plains along the banks.

Climate

The climate of HKKWS is classified as tropical savanna (following Koppen's system). The average annual rainfall and temperature for the 20-year period from 1980 to 1999 were 1554.15 mm and 24.82°C, respectively. Based on rainfall conditions during those 20 years, the climate can be clearly classified into two seasons. The dry season occurs between November and April, with an average rainfall from 6.08–84.22 mm and the wet season occurs between May and October, with an average rainfall from 128.81–304.44 mm. The average relative humidity during the period 1994–1999 was 57.12%.

Vegetation

The Faculty of Forestry (1989) classified the vegetation of HKKWS into six principle categories: (1) hill evergreen, (2) moist evergreen, (3) dry evergreen, (4) mixed deciduous, (5) dry dipterocarp forests and (6) small patches of successional community.

Wildlife

Due to the various vegetation types

plus specific topographical characteristics and suitable climatic conditions, this protected area provides excellent wildlife habitats for various species. Thus, HKKWS has at least 713 vertebrate species, consisting of: 130 mammals, 360 birds, 81 reptiles, 37 amphibians and 105 fresh water fish (Forest Research Center, 1997). Interesting species include: wild water buffalo (*Bubalus bubalis* Linnaeus, 1758), gaur (*Bos gaurus* Smith, 1827), banteng (*B. javanicus* D'Alton, 1823), Asian tapir (*Tapirus indicus* Desmarest, 1819), Asiatic elephant (*Elephas maximus* Linnaeus, 1758), tiger (*Panthera tigris* (Linnaeus, 1758)), green peafowl (*Pavo muticus* Linnaeus, 1766), marbled cat (*Felis marmorata* Matin, 1837), Asian golden cat (*F. temminckii* Vigor and Horsfield, 1827) and clouded leopard (*Neofelis nebulosa* (Griffith, 1821)) (Faculty of Forestry, 1989).

Duration of study

The study period of 72 months occurred between November 1997 and October 2003.

Population Study

Population density around Khao Nang Rum Wildlife Research Station (KNRWRS)

Following Dawson and Dekker (1992), a dung-count method on transect lines was used throughout this study. Fourteen transect lines of 4-5 km in length with a 1-km interval between lines (total length of 65 km) were maintained and used to collect data during 1997-1998. During 1999-2000, seven transect lines, 35 km in total length, were established in the northern area of the study site. Thus, transect lines 100 km in total length

were used for long-term monitoring. Data on transect lines were collected every month at a walking speed of less than 2 km/hour. When a dung pile was detected, the perpendicular distance between the center of the dung pile and the center of transect lines was measured and recorded. The dung piles counted were marked with bamboo stakes ; only new dung piles were measured and recorded in each survey.

Population density in the other areas

Due to the very large area of the sanctuary, only six study sites were used to investigate elephant density. The objective was to understand the population characteristics of the overall area. However, since continuous data collection was not planned to occur at the other five sites, there was only one observation at these sites. Dung data were collected from transect lines of either 10 or 20 km in total length at sampling sites located at: Krapuk Krapiang (20 km), Nai Sor (10 km), Khao Ban Dai (10 km), Huai Lueang (10 km) and Klong Kor (10 km). The Nong Ma site was an exception, where 20 km of total transect length was used and the data collection methods were similar to the KNRWRS study site. However, only three trips were made and 60 km of total transect length was analyzed in this study. It was assumed that the proportion of forest-cover types did not affect elephant sampling, with the important factors affecting elephant distribution being water sources, saltlick areas and human disturbance.

Dung pile density

Dung pile densities were calculated using a Fourier series estimator (Burnham *et al.*, 1980) (Equation 1):

$$D = \frac{n f(0)}{2L} \quad (1)$$

where D = population density
 n = total of the seen animals
 L = total length of transect lines
 f(0) = the probability density function (pdf) at 0 distance

Throughout this study, the computer program called ELEPHANT, developed by Dawson and Dekker (1992), was employed to calculate the density.

Population calculation

The data collected around the Khao Nang Rum Wildlife Research Station and Nong Ma study site were processed every month. This technique of population density estimation was similar to the method used by Santiapillai and Suprahman (1986) and by Kumordzi *et al.* (2008).

Several defecation rates were used in other studies. For example, Reilly (2002) reported a figure of 17.93 per 24 hours for Asian elephants in Way Kambas National Park in Sumatra during the wet season of 1998, but it was lower in the dry seasons of 1994 and 1997 (11.83 per 24 hours in 1994). The average defecation rate was 14.415 according to Angkawanit (2003) who studied defecation rates of captive elephants in the northern part of Thailand, where the results indicated an average rate of 14 dung piles/individual/ day (range 12–16). Thus, a defecation rate of 14 dung piles/individual/day was used in this study. A possible weak point of the current study may be the use of a defecation rate from

another site.

For the population studies at Krapuk Krapieang, Nai Sor Salt lick, Khlong Kor, Huai Luang and Khao Ban Dai, the density estimation was calculated by Dekker *et al.* (1991) (Equation 2):

$$E = \frac{D \times R}{Y} \quad (2)$$

where E = Population density (individual/km²)
 Y = Defecation rate (dung/individual/day)
 D = Dung density (dung/km²)
 R = Decay rate

The decay rate (R) was 0.0078, based on 52 dung piles near Huai Kha Khaeng River, checked every seven days between November and August, covering a period of 305 days, as calculated by the ELEPHANT program.

Age structure

Age structure was determined from animal footprints observed in the study area. Only the circular shape of the fore footprint was determined and its circumference was measured. The circumference data were categorized into four classes: adult (>100 cm), sub-adult (>75–100 cm), juvenile (>50–75) and calf (<50 cm), according to Santiapillai and Suprahman (1986) and Bhumpakphan (2000). Recruitment rate is a good indicator of herd health, predator loads and adequate or inadequate young protection from predators (Dhungel, 1985 and Campbell *et al.*, 2005). The recruitment rate of elephants

in this area was studied using the method of Dhungel (1985) and Bhumpakphan (2000). The recommended formula was (young animal X 100)/(adult animal).

RESULTS AND DISCUSSION

Population Density

Population density around Khao Nang Rum Wildlife Research Station

The results from line transects using the dung-count method between 1997 and 2003 showed that the average population density in the dry season was 0.30 individuals/km² (range = 0.20–0.37, SD = 0.05) gained from 2941 km of transect and 2436 dung piles.

The average population density in the wet season was 0.30 individuals/km² (range = 0.12–0.52, SD = 0.14) gained from 2640 km of transect and 2311 dung piles.

The average population density did not differ significantly between seasons (paired-samples T-test $t = 0.000$, $df = 5$, $P = 1.000$). Thus, the population densities in this area seemed to be precise due to systematic data collection, covering both enough time and space.

The results reflected a declining trend in the elephant population of this area (Table 1.). Causes of the declining population might be the increase of human activities in the study area around KNRWRS. The population study at Nong Ma indicated the population was 0.56 individuals/km² from a total of 60 km of transect length, with 84 dung piles found and 239.09 dung piles/km² (%CV=25.19) (Table 2.). The population density of this site was 1.8 times more than that of KNRWRS, due to less human activities and better welfare factors, especially water supply from the Huai Kha Khaeng permanent stream.

Table 1. Dung densities and population densities during 1997 – 2003 around Khao Nang Rum Wildlife Research Station in Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province.

Season Year	L (km)	Number of dung piles	%CV	Dung density (dungs/km ²)±95%CI		Population density (individuals/km ²)±95%CI				
Dry season	1997	390	313	27.02	132.63	±	70.19	0.32	±	0.16
	1998	390	273	25.16	118.47	±	58.43	0.28	±	0.13
	1999	462	381	16.76	132.46	±	46.51	0.31	±	0.11
	2000	577	573	14.62	157.20	±	45.20	0.37	±	0.11
	2001	600	532	16.65	125.31	±	40.89	0.29	±	0.09
	2002	522	364	16.96	82.15	±	27.31	0.20	±	0.06
Total	2,941	2,436	Mean	124.70	±	48.09	0.30	±	0.11	
Wet season	1997	325	167	26.48	114.89	±	59.62	0.27	±	0.14
	1998	215	262	16.66	216.70	±	70.76	0.52	±	0.16
	1999	462	446	14.90	168.51	±	49.20	0.40	±	0.11
	2000	600	610	15.52	137.80	±	41.92	0.32	±	0.10
	2001	590	561	13.37	51.92	±	13.60	0.12	±	0.03
	2002	448	265	15.39	78.38	±	23.64	0.19	±	0.05
Total	2,640	2,311	Mean	128.03	±	43.12	0.30	±	0.10	

Table 2. Total length of transect, number of dung piles, dung piles densities and population densities of wild elephant in the several areas, Huai Kha Khaeng Wildlife Sanctuary.

Study area	Total transect length (km)	Number of dung piles	Dung piles density (dung piles/km ²)	95% CI	%CV	Population densities (individuals/km ²)
1. Krapok Krapiang	20	193	1139.71	536.26	20.80	0.63
2. Nai Sor saltlick	10	171	1775.82	921.54	22.94	0.98
3. Khao Bai Dai	10	142	1919.14	720.11	16.59	1.06
4. Nong Ma ^{1/}	60	84	239.09	123.14	25.19	0.56
5. Khlong Kor	10	90	719.89	318.88	19.58	0.40
6. Huai Luang	10	64	1111.43	517.61	20.59	0.61
		mean	1333.19		mean	0.73

^{1/} not used in the mean value calculation – see text for detail.

Population density in the other areas

The population density at Huai Luang, based on 10 km of transect length and 64 existing dung piles, was 0.61 individuals/km², with dung pile density estimated at 1111.43 dung piles/km² (%CV= 20.59).

The population density at Krapok Krapiang, in the northern part of the sanctuary, based on 20 km of transect length and 193 dung piles, was 0.63 individuals/km², with dung pile density estimated at 1139.71 dung piles/km² (%CV= 20.80).

The population density at Khlong Kor, in the central part of the sanctuary near KNRWRS, based on 10 km of transect length and 90 dung piles, was 0.40 individuals/km², with dung pile density estimated at 719.89 dung piles/km² (%CV= 19.58).

The population density at Khao Bai Dai, in the central part of the sanctuary, based on 10 km of transect length and 142 dung piles, was 1.06 individuals/km², with dung pile density estimated at 1919.14 dung piles/km² (%CV= 16.59).

The population density at Nai Sor, in the central part of the sanctuary, based on

10 km of transect length and 171 dung piles, was 0.98 individuals/km², with dung pile density estimated at 1775.82 dung piles/km² (%CV= 22.94).

The population study at the Nong Ma area showed a density of 0.56 individuals/km² based on 60 km of transect length and 84 dung piles, with 239.09 dung piles/km² (%CV= 25.19).

The fact that the estimated density values of four sites were higher than KNRWRS and Nong Ma may have been due to the use of different estimation models. In order to provide data for area management that would support the elephant population, two sites, KNRWRS and Nong Ma, used the same methods of data collection and analysis. The data were continuously collected every month throughout the study period to obtain a precise estimate of population density.

The Khlong Kor study area was connected to the KNRWRS study site in the south. Different data collection and analysis methods were used. The objective was to compare the density and methods. The results showed little difference (0.30 and 0.40 individuals/km²). In areas where

assessment was difficult, data to investigate the population density were collected during only one observation period. In this case, the defecation rate of dung piles was used to calculate the population density. This method was used for the study areas of Krapok Krapieng, Nai Sor Saltlick, Khao Ban Dai and Huai Luang. This method agrees with Dawson and Dekker (1992).

Eisenberg and Seidensticker (1976) reported that the wild elephant population in South East Asia in suitable habitats ranged between 0.1–1.0 individuals/km². Population density studies in Malaysia had ranges between 0.27–0.65 individuals/km² (Olivier, 1978). Santiapillai and Suprahman (1986) reported that the population density in Way Kambas Game Reserve on Sumatra Island was 0.2 individuals/km² and the habitat covered an area of 1,300 km²; thus, they concluded that the total population was 260 individuals. In HKKWS, where the total population was estimated based on habitat selection behavior, the area of suitable habitat types and the density in each habitat type, the results ranged between 301 individuals in the dry season and 364 individuals in the wet season.

In the South Asia region, Santiapillai and Jackson (1990) stated that the wild elephant population in hilly habitats was 0.04 individuals/km², whereas the populations ranged from 1 to 2 individuals/ km² in mixed deciduous forests in the south. Sukumar (1989) reported the population density in the Chamarajanagar, Kollegal and Satyamangalam Forest Divisions in the southern part of India, covering an area of 928 km², had an animal density of 0.56 individuals/km² (n = 12, range 0.39–0.75, SD=0.12), with a total population size of 522 individuals. In Sri Lanka, the population density ranged between 0.1–0.46 individuals/ km² (Eisenberg and Lockhart, 1972).

The population density of wild elephants in HKKWS ranged between 0.30–1.06 individuals/km², which is a rather high value compared with populations in both the South Asia and Southeast Asia regions. The wild population in this sanctuary has nevertheless faced illegal poaching and human disturbance, especially in the area between the HKKWS head office and the Khao Nang Rum Wildlife Research Station. Steinmetz *et al.* (2007) reported that elephants were historically abundant in the lowland mosaic of Thung Yai Narae Suan Wildlife Sanctuary, but commercial hunting for ivory over the past 30 years combined with infrastructure development and war in Myanmar had decimated that population, disrupted movement patterns, and extirpated elephants from large portions of the Sanctuary.

Population Structure

The population structure determined from 321 front tracks was 35 calves (10.90%), 67 juveniles (20.87%), 121 sub-adults (37.69%) and 98 adults (30.54%). These proportions reflect an acceptable status for the population structure. A mature to young animal ratio of 1:0.46 indicates a rather high reproductive potential and a low mortality rate of young animals.

It was noticed that the number of calves-plus-juvenile animals in this sanctuary was 102, whereas the number of adult animals was 98. Nevertheless, a sub-adult female can give birth (Table 3.). Thus, the recruitment rate of the population can be estimated by using the total number of calves-plus-juvenile animals, divided by the total number of adult-plus sub-adult animals. The result reflects a 46.58% recruitment rate, noting that the animal has a two-year gestation period and 4–5 years to take care of the young (Lakka, 2000). Thus, the

estimated recruitment rate of the wild elephant population of this sanctuary was between 9.31% and 11.64% per year. This value is close to the rate of the African elephant in the Samburu and Buffalo Springs National Reserves, Kenya, studied

by Wittemyer *et al.* (2005). They reported a growth rate of 4.6% per annum and a mortality rate of 2.6% per annum over the six-year study period. Thus, the recruitment rate of their study site could be estimated at a rate of 7.2% per year.

Table 3. Population structure of the elephant population based on footprint sampling.

Age structure	Fore foot circumference (cm)	n	%
Calf	< 50	35	10.90
Juvenile	50 - 75	67	20.87
Sub adult	75 - 100	121	37.69
Adult	> 100	98	30.54
Total		321	100.00

Wittemyer *et al.* (2005) also reported causes of death over six years of study as: disease; predation by lions and humans; and injury, but the majority of deaths were unspecified because the carcasses were not found.

Six wild elephant carcasses were found during this study period. All of them had been killed by poachers, determined from rifle marks on their skulls, and three of them had had their tusks removed. One calf carcass was also found but the cause of death could not be identified. Tigers, leopards and dholes are potential predators in the area, but signs of death by the predators were not found throughout the study period, which may have been due to good herd protection. The ratio of calves-plus-juvenile animals to adults-plus-sub-adult animals of 1:2.15 indicated strong herd protection.

Human and Elephant Conflict

Serious conflicts between humans and elephants around the sanctuary have never been recorded. During the study period, a local resident was crushed by an animal's

foot and killed while he was collecting edible mushrooms in the early morning near Sub Fah Pha Forest Guard Station. One ranger was also killed by a wild elephant while he was driving a motorcycle on the forest road to the Khao Khiew Forest Guard Station. The most common elephant and human conflict was crop destruction around the sanctuary, which occurred occasionally. However, it is not a serious problem now.

Minimum Viable Population Density

This study found that the wild elephant density ranged between 0.30–1.09 individuals per km². The total population size was estimated to range between 301–364 individuals. The social structure comprised 10.90% calves, 20.87%, juveniles, 37.69% sub-adults and 30.54 % adults. Sex ratio, estimated from direct sighting, was approximately 1:6.25. Silva and Downing (2002) estimated the minimum viable population density of Asian elephants over a long-term conservation period of 100 years to be 0.31 individuals per km². Thus, it is hoped that the elephant population in

HKKWS can survive efficiently. However, the elephant population demography, population health and genetic diversity could be also further investigated continuously for conservation of the species in Thailand.

CONCLUSION AND RECOMMENDATION

1. The average population density around KNRWRS was 0.30 individuals/km², whereas the average density in the other areas was 0.73 individuals/km². There were two weak points in the population estimation process. Firstly, the density at the KNRWRS site came from the formula that was used to determine mean survival time (30 days). In contrast, the other five study sites used the decay rate to calculate the population. Secondly, more plentiful habitat, more permanent water sources and less human disturbance affected the different densities at the other five study sites and the KNRWRS site. The sample sites had little difference in their ratios of cover types; the study found that the elephants preferred to use dry evergreen forests, mixed deciduous forests and dry dipterocarp forests, respectively. The estimated overall elephant population size of this sanctuary was between 301 - 364 individuals.

2. Recruitment rate of the population ranged between 9.31–11.64% per year. The ratio of calf-plus-juveniles to sub-adult-plus-adults in the animal herd was 1:2.15. The adult male to adult female ratio was 1:6.25. The results reflected a very high recruitment rate, but it is expected that the mortality rate of the population was also high. The main cause of death was illegal poaching. The ratio of adults to young animals reflected effective herd protection for young.

3. The population density in HKKWS

was high compared with some natural habitats in both South Asia and Southeast Asia. This protected area seems to have had a very good strategy for elephant protection; nevertheless, the elephant carcasses found showed that the population was still facing illegal poaching. Thus, it is likely that this is the main threat to the population. Human and elephant conflict in the area was not a serious problem. Effective patrolling to protect from poaching will still be needed in addition to further continuing investigation of the demography, health and genetic diversity of the elephant population to provide for long-term species conservation.

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