UNIVERSITY OF MINNESOTA

This is to certify that I have examined this copy of a doctoral thesis by

THEERAPAT PRAYURASIDDHI

and have found that it is complete and satisfactory in all respects,
and that any and all revisions required by the final
examining committee have been made.

DR. JAMES L. D. SMITH

Name of Faculty Adviser

James L. David Smith

Signature of Faculty Adviser

Nov 25, 1997

Date

GRADUATE SCHOOL

THE ECOLOGICAL SEPARATION OF GAUR (*Bos gaurus*) AND BANTENG (*Bos javanicus*) IN HUAI KHA KHAENG WILDLIFE SANCTUARY, THAILAND

A THESIS

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL

OF THE UNIVERSITY OF MINNESOTA

BY

THEERAPAT PRAYURASIDDHI

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

DR. JAMES L. D. SMITH, Adviser

NOVEMBER 1997

BRT 540002

ABSTRACT

The ecological separation of gaur (*Bos guarus*) and banteng (*Bos javanicus*) (two large sympatric wild bovids) was studied in the Huai Kha Khaeng Wildlife Sanctuary (HKKWS), Thailand. The population, herd structures, daily activity patterns and food habits were determined from direct observation during 1983-1996. Four gaur and seven banteng were captured and radio-collared during 1994-1995, then monitored for ≤ 2.5 years to examine the seasonal differences in their home range sizes, daily movements, activity patterns, habitat selections (vegetation type, elevation zone, and distance from water and mineral sources) and food preferences.

During 1994-1995, there were estimated to be 300-335 gaur and 240-270 banteng in HKKWS. Seasonal home range sizes of gaur were slightly larger than banteng in the wet season, whereas they were not significantly different in the dry season. Mean annual home ranges of gaur were larger than those of banteng. Gaur herds shifted longer distances from wet to dry seasons while banteng were sedentary because they were more tolerant to dry areas than gaur. Mixed-deciduous forest in the > 200 to 600 m elevation zones was the preferred habitat for both species in the wet season. Although there was greater overlap in their diets in this season, there was not greater competition for food resources because food resources were more abundant. As food became scarce in the dry season; however, gaur reverted to a browsing diet near shade and water in evergreen of the > 400 m zone while banteng shifted to forage on dry grass and browse further from water in the ≤ 400 m zone. In the dry season when the quality and quantity of forage is lowest, gaur spent relatively more time feeding and less time resting. The inter-specific competition between gaur and banteng was not high in either season because both species optimized their foraging by being strict habitat selectors and allocating their time to different activities. Each of these reasons permitted them to coexist in HKKWS.

Management recommendations for gaur and banteng in HKKWS and surrounding protected area in the western forest complex are presented.

ACKNOWLEDGMENTS

I am grateful to all organizations, colleagues and friends who helped make this project a success. I would like to thank the Thai Royal Forest Department (RFD) for giving me permission to work in Huai Kha Khaeng Wildlife Sanctuary (HKKWS). I express my sincere thanks to Dr. Schwann Tunhikorn, Director of the Wildlife Research Division (WRD) for supporting of this research. Dr. Schwann provided me with the opportunity to work at Khao Nang Rum Wildlife Research Center (KNRWC) and encouraged me to study in the USA.

I express my gratitude to my former advisor Dr. Utis Kutintara, Head of the Forest Biology Department, Kasetsart University. He gave me the opportunity to study wildlife with him at Khao Yai National Park in 1981 and provided valuable advice on this project.

I am especially grateful to Mr. Chatchawan Pitdamkam, Former Chief of Huai Kha Khaeng Wildlife Sanctuary, Mrs. Rattaya Chanthien, Chairwoman of SeubNakhasathien Foundation, Ms. Belinda Stewart-Cox of the SeubNakhasathien Foundation, Dr. Visut Baimai, Director of the Program for Biodiversity Research and Training (BRT), Thailand and Mr. Pummchai Lumsum, Chief Executive Manager of Muang Thai Life Assurance. Their continuous support and encouragement has made a lasting impact on the success of wildlife conservation in HKKWS and Thailand.

This project was funded by the World Wide Fund for Nature (WWF International), WWF-US, WWF-Thailand, the Center for Field Research (Earth Watch), Muang Thai Life Assurance, SeubNakhasathien Foundation, The Government Housing Bank and the

Program for Biodiversity Research and Training (BRT), Thailand (supported by the National Center for Genetic Engineering and Biotechnology, National Science and Technology Development Agency and Thailand Research Fund). Computer equipment and software was provided by the Department of Fisheries and Wildlife, the University of Minnesota, and in particular ArcInfo and Arcview were provided by ESRI.

Very special thanks are given to Dr. Pascale Moehrle, Program Manager of WWF International; Dr. Chris Hails, Director of Asia/Pacific Program for World Wide Fund For Nature; Dr. Robert Mather, WWF Thailand; Ms. Christine Blyth and Mr. Indrani Fernando of the World Wide Fund For Nature; Ms. Corinne Gelchion, Ms. Tracy Smith and Mr. David Hulse of the WWF-US; Ms. Ketty Faijampa, Former Asia/Pacific Project Manager for WWF-US; Mr. Pisit Na Pattalong and Mr. Surapol Duangkae of Wildlife Fund Thailand. Their hospitality and assistance on numerous occasions added to the success of the project.

People from Kasetsart University (KU) and the Thai Royal Forest Department (RFD) helped make my study in the USA and this project successful in a variety of ways. Dr. Niwat Rungpanit, Former Dean of Faculty of Forestry wrote a recommendation letter to the Director of the Conservation Biology Graduate Program at the University of Minnesota in 1992. Dr. Somkid Siripattanadilok allowed me to use a laboratory and additional equipment. Mr. Kusol Tangjaipitak helped me perform fecal analysis. Dr. Wichan Eiathong and Mr. Voradol Chamchumroon assisted in the identification of gaur and banteng food plants. Dr. Pornsri Chairattanayuth of the Department of Animal

Husbandry provided suggestions about domestic cattle diets. Digital GIS coverage of HKKWS and protected areas in Thailand was provided by Mr. Sompun Tunhan, Dr. Suwit Ongsomwang, and Mr. Anuchit Rattanasuwan of the Forest Resources Assessment Division, RFD. Mr. Somchai Kreetapirom of the Department of Soils, Kasetsart University and the staff of the Soil Analysis Division of the Land Development Department helped in the analysis of mineral licks. Mr. Wattana Kaewkamnead, Mr. Pravat Tanadka and Mr. Tavee Nuthong of the RFD gave me the opportunity to extend my study in the USA. I would like to thank the staff of the Thai Agricultural Aviation Division of the Ministry of Agriculture and Cooperative for providing helicopter support during my work in HKKWS from 1994-1995.

I would like to thanks Mr. Frank Davis for his financial contribution. I express special thanks to Dr. Leslie Johnston and Dr. Doug Armstrong of the Henry Doorly Zoo and the veterinarians from Gaur Project in Malaysia. They advised and assisted me in immobilizing animals within HKKWS in 1993.

I want to acknowledge the staff of the KNRWC, HKKWS, WRD and RFD, Thailand for their cooperation during my research in Thailand. I thank Mr. Saksit Simcharoen, Former Chief of KNRWC and his staff for their support. I appreciated help from Mr. Ood Kerdsomboon, Mr. Mug and Mrs. Sunan Vaitayakan, Mr. Samut Krasarikit, Mr. Leap Ketkan, Mr. Kampon, Mr. Chitprapan Krittakom, Mr. Sunthorn Chaiwattana, Mr. Boonchoo Thongnamchaima, Mr. Youngyut Meesangpraw, Mr. Taveep Sripong, Mr. Monton Nuthong, Mr. Preecha Karaket, Mr. Prateep Rojanadilok, Mr. Pratom Boontawee, Mr. Somchai Ponyieam, Ms. Anchara Petdee, Mrs. Thongrat

Phothieng, Mrs. Kalayanee Bunkerd, Ms. Bussabong Kanchanasaka, Ms. Mattana Srikajang, Ms. Sumallee Chaiyapatpanit, Ms. Siriporn Thong-aree, Ms. Buppa Aumpket, Mr. Krairat Emarmpai and Mr. Nopparat Naksatit.

I would like to thank the following friends for their support in many ways during my research in Thailand: Dr. Sompoad Srikosamatara, Dr. Naris Bhumpakphan, Prof. Prapasri Sirijanya, Mr. Wanchai Tantivittayapitak, Ms. Nittaya Wongsawat, Mr. Petch Manopawitr, Ms. Anongrat Petchsumrit, Mr. Narong Changkamol, Mr. Pairoj Limjareon, Ms. Yeimnapa Ponyiem, Ms. Pantippa Chansorn, Mr. Siripong Thonongtoa, Mr. Nivet Sakulsuk, Mr. Sakon Chaisomkom, Dr. Anak and Dr. Rungnapa Pattanavibool. I also express thanks to my friends from the Thai Student Association of Minnesota, Dr. Chalard and Dr. Lerpen Duangkaew, Mr. Saroj Saimek, Mr. Chanin Laliew, Ms. Sukanya Sutthivanit, Ms. Chiraprapa Wattanapong and Ms. Praweena Phukowluan for their help and companionship during my study in the USA.

I want to thank all EarthWatch volunteers (1993-1995) who worked hard while living at KNRWC. I especially want to recognize Mr. and Mrs. Dickens who filmed immobilization of gaur in February 1995. I express special thanks to Dr. Anup Joshi for his suggestions concerning data analysis and for other experience computer advice. I appreciate the many discussions of ungulate ecology I had with Dr. Peter Jordan, Dr. David Plumpton, Mr. Pat Campbell, Mr. David Augustine, and Dr. Paul Elkan. Ms. Linda Wires and Mr. Pete Cutter helped in the editing of my final paper. Ms. Wei-Hsin Fu, Mr. Mahendra Shrestha, Ms. Mei-Hsiu Hwang, Dr. Lauren Wemmer, Mr. Robert

Ouinn and Mr. Robert Ledford were always friendly during my study in the USA. Dr. Simon Hedges invited me to join the Asian Wild Cattle Workshop 1995 in Thailand.

I am indebted to my advisor Dr. James L. D. Smith for taking the time to work with me both in Thailand and the USA. I would like to thank my advisory committee members: Dr. Frank Martin, Dr. Donald Siniff, Dr. David L. Garshelis and Dr. Francie Cuthbert for their comments and valuable suggestions. Dr. Francie Cuthbert deserves a very special thank you for accepting me into the Conservation Biology Graduate Program and providing me with encouragement and funding.

Dr. James L. D. Smith, Dr. Francie Cuthbert, Alex and Charlie have given me good impressions about American culture. Dr. Deane and Mrs. Nancy Manolis were always kind when I visited their home. I would like to thank Dr. Jim Manolis, a conservation biologist, for his encouragement and companionship during my study in the USA.

I am indebted to my mother, Mrs. Tassanee Prayurasiddhi and my father, Dr. Prayun Prayurasiddhi who supported me unquestioningly during my study. I am very sad that my father cannot be with me when I graduate but I know that he will be proud with me. I thank my grandfather and grandmother, Mr. Suthin and Mrs. Vilai Keshagupta, and my younger brothers, Dr. Lerkroj and Mr Ekachat Prayurasiddhi for their encouragement, support and love throughout my life. I would like to thank Ms. Kanyavee Adisornsakulwong for encouraging me during my study in both Thailand and the USA.

I would like to respectfully recognize Mr. Seub Nakhasathien, Former Chief of Huai Kha Khaeng Wildlife Sanctuary, Mr. Boontieng Chomchak Former Assistance Chief of Khao Nang Rum Wildlife Research Center, Mr. Pongsakorn Pattapong, Former Assistance Chief of Huai Kha Khaeng Wildlife Sanctuary and Mr. Kalong Kamsri, Former Ranger of Khao Nang Rum Wildlife Research Center. They sacrified their lives in the protection of wildlife at Huai Kha Khaeng Wildlife Sanctuary.

Finally, I thank all of the animals in Huai Kha Khaeng Wildlife Sanctuary that were so friendly during the many years I spent in the forest.

Theerapat Prayurasiddhi

TABLE OF CONTENTS

CHAPTER 2: FOOD HABITS AND RESOURCE PARTITIONING

CHAPTER 3: MANAGEMENT AND CONSERVATION OF GAUR AND BANTENG IN HUAI KHA KHAENG WILDLIFE SANCTUARY AND SURROUNDING PROTECTED AREAS

LISTS OF TABLES

Table		Page

CHAPTER 3

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

DISTRIBUTION, HERD STRUCTURE, HOME RANGE SIZE AND HABITAT USE OF GAUR AND BANTENG

ABSTRACT

The population, herd structure and habitat use of gaur and banteng, two large sympatric wild bovids, were studied from 1983-1996 to determine how they coexist in the Huai Kha Khaeng Wildlife Sanctuary, Thailand. Four gaur and seven banteng were captured and radio-collared during 1994-1995, then monitored intensively for ≤ 2.5 years to examine the seasonal differences in their home range sizes, daily movements, activity patterns, and habitat use (vegetation type, elevation zone, and distance of animals from water and mineral sources). During 1994-1995, 300-335 gaur and 240-270 banteng were estimated in the sanctuary. Group sizes of gaur and banteng were not different in the dry season but were different in the wet season. Seasonal home range sizes of gaur were slightly larger than those of banteng in the wet season, whereas they were not significantly different in the dry season. Mean annual home ranges of gaur were larger than those of banteng. Group size and predation may influence home range sizes and shapes. Gaur herds shifted longer distances during the change from wet to dry season, while banteng were sedentary being more tolerant of dry areas than gaur. Throughout their ranges, gaur and banteng are able to adapt to a wide continuum of habitats. Mixed-deciduous forest in the above 200 to 600 m zones appeared to be the preferred habitat for both species in the wet season. As food became less abundant in the dry season, gaur reverted to a browsing diet near shade and water in evergreen forest above 400 m zone while banteng shifted to forage on dry grass and browse further from water in mixed-deciduous forest in the below 400 m zone. The inter-specific competition between sympatric gaur and banteng was not high in either season. Inter-specific competition may be avoided by seasonal differences in the two species' use of habitat and elevation which probably allows them to coexist in Huai Kha Khaeng Wildlife Sanctuary.

INTRODUCTION

Diversity of wild bovids is high in the forest ecosystems of mainland South and South-east Asia (Lekagul and McNeely 1977, Byers et al. 1995, Hedges in press). Gaur and banteng are 2 of 3 large bovids in the genus *Bos* in mainland South-east Asia. During past centuries, gaur and banteng habitat declined gradually as deforestation increased due to unprecedented growth of human numbers throughout the region after the Second World War (Lekagul and McNeely 1977, Humprey and Bain 1990). Therefore, gaur are currently considered vulnerable and banteng are considered endangered (IUCN 1994, Byers et al. 1995). The current distribution of gaur is primarily in northern South-east Asia, ranging from peninsular Malaysia, Thailand, Lao PDR, Vietnam, Cambodia, and Myanmar (formerly Burma), west and north to India, Southern Nepal, and Southern China (Midway 1965, Yin 1967, Wharton 1966, 1968, Conry 1981, 1989, Lekagul and McNelly 1977, Salter 1983, Oliver and Woodford 1994, Byers et al. 1995, Khoi 1995, Srikosamatara and Suteethorn 1995). The current distribution of banteng ranges further to the south, from Myanmar, Thailand, Lao PDR, Vietnam, Cambodia to Sabah (Malaysian Borneo), Kalimantan, Java and probably Bali in Indonesia (Yin 1967, Hoogerwerf 1970, Lekagul and McNelly 1977, Alikodra 1987, Ashby and Santiapillai 1988, Payne 1990, Corbet and Hill 1992, Yasuma 1994, Byers et al. 1995, Khoi 1995, Srikosamatara and Suteethorn 1995). Gaur and banteng ranges overlap at a regional scale, but few studies have examined local habitat overlap (Hedges in press).

Srikosamatara (1993) and Srikosamatara and Suteethorn (1995) estimated that 470 banteng and 915 gaur reside in the protected areas of Thailand. Huai Kha Khaeng Wildlife Sanctuary (HKKWS) is part of the largest contiguous complex of forest protected areas where gaur and banteng coexist (Nakhasathien and Stwart-Cox 1990, Prayurasiddhi 1987). Srikosamatara (1993) estimated that approximately 290 banteng and 290 gaur reside in HKKWS. However, as habitat declines and populations become confined to smaller and more isolated areas, inter-specific competition may increase and ultimately deminish bovid diversity, thus it is important to understand the ecology of gaur and banteng.

Inter-specific competition occurs when two or more different species use the same limited resource or harm one another while seeking a resource (Krebs 1994). Weins (1977) and Krebs (1994) suggest that competition is rare in nature because the evolutionary history of communities has resulted in adaptations that serve to minimize competitive effects.

Studies of ecological interaction of large sympatric ungulates have been conducted in North America and Europe. Investigators have studied dispersion, habitat use and habitat relationships between sympatric Columbian white-tailed deer *(Odocoileus virginianus leucurus*) and Columbian black-tailed deer (*O. hemionus columbianus*) in North America (Martinka 1968, Smith 1987). Anthony and Smith (1974) and Krausman (1978) studied the interspecific behavior, dispersion, and habitat use of sympatric populations of desert mule deer (*Odocoileus hemionus crooki*) and white-tailed deer, and Danilkin (1996) examined the behavioral ecology of Siberian roe deer (*Capreolus* *pygargus* Pall.) and European roe deer (*Capreolus capreolus* L.) in Europe. Few studies have been conducted on the ecological separations of sympatric large ungulates in Asia (Hedge in press). Mathur (1991) discussed ecological separation between sympatric populations of chital, sambar deer and nilghai in 3 National Parks in India, in relation to use of both habitat and forage resources. Gaur and banteng are phylogenetically closely related and coexist within many protected areas of Thailand. They are, however, different in body size, color, their use of macro-habitats, and selection of food plant species and food plant parts (Chapter 2). Each of these differences should be sufficient to allow coexistence (Wilson 1975, Krebs 1994).

In HKKWS where gaur and banteng are sympatric, I examined distribution, herd structure, home range, length of daily movement, and habitat use. This study elucidates components of ecological separation between both species. The research will help the Royal Forest Department of Thailand develop a plan for these species as part of the Department's overall conservation strategy for the country's mega-fauna based on landscape principles and ecosystem management.

STUDY AREA

Huai Kha Khaeng Wildlife Sanctuary (HKKWS) is located in the western forest complex of Thailand and encompasses an area of 2,575 km^2 (14° 56'-15° 48' N, 98° 27'-99° 30' E). It was established in 1972 and subsequently expanded in 1986 and again in 1992 (Fig. 1). HKKWS and the contiguous Thung Yai Nareseun Wildlife Sanctuary (3,647 km^2) to the west together were recently designated a Natural World

Heritage Site by UNESCO. These sanctuaries, along with 14 protected areas to the north and south, make up one of the largest protected area complexes in mainland Southeast Asia (Nakhasathien and Stewart-Cox 1990, C. Pitdamkam, RFD, pers. comm. 1995).

I selected two concentric study areas within HKKWS (study areas 1 and 2; Fig 1) which comprised about 851 (33%) and 477 (18.5%) km^2 of HKKWS, respectively. In study area 1, I collected data over 13 years by direct observation, and in study area 2, I intensively studied radio-collared animals for 2 years. The larger study area (study area 1) contained parts of three watersheds, Huai Tap Salao-Huai Song Tang, Huai Chang Tai-Huai Ai Yo and Huai Kha Khaeng. The elevations in the study area ranged from 100 m. to 1,700 m.

Habitat Types

Vegetation in HKKWS is a mosaic of different forest types previously described by Stott (1984,1988), Thitathamakul (1985) and Nakhasathien and Stewart-Cox (1990) (Fig. 2; Appendix 1).

Evergreen forest comprises 1,319 km^2 or 47% of the sanctuary and 30% of study area 1 and 21% of study area 2. Thitathamakul (1985) classified evergreen forest into hill evergreen forest and dry evergreen forest. Hill evergreen forest is found at elevations over 1,000 m. The dominant tree species are oaks of the families Fagaceae (genus *Lithocarpus, Castanopsis* and *Quercus*), Podocarpaceae and Cephalotaxaceae. Dry evergreen forest is found along the tributaries and grows at elevations between 100-1,000 m. This forest type is very tall, dense, and stratified by height, and is dominated by trees of the *Dipterocarpus* genus such as *Dipterocarpus alatus* and *D. turbinatus*. Ground cover

Figure 1. Location of Huai Kha Khaeng Wildlife Sanctuary, and study areas 1 and 2.

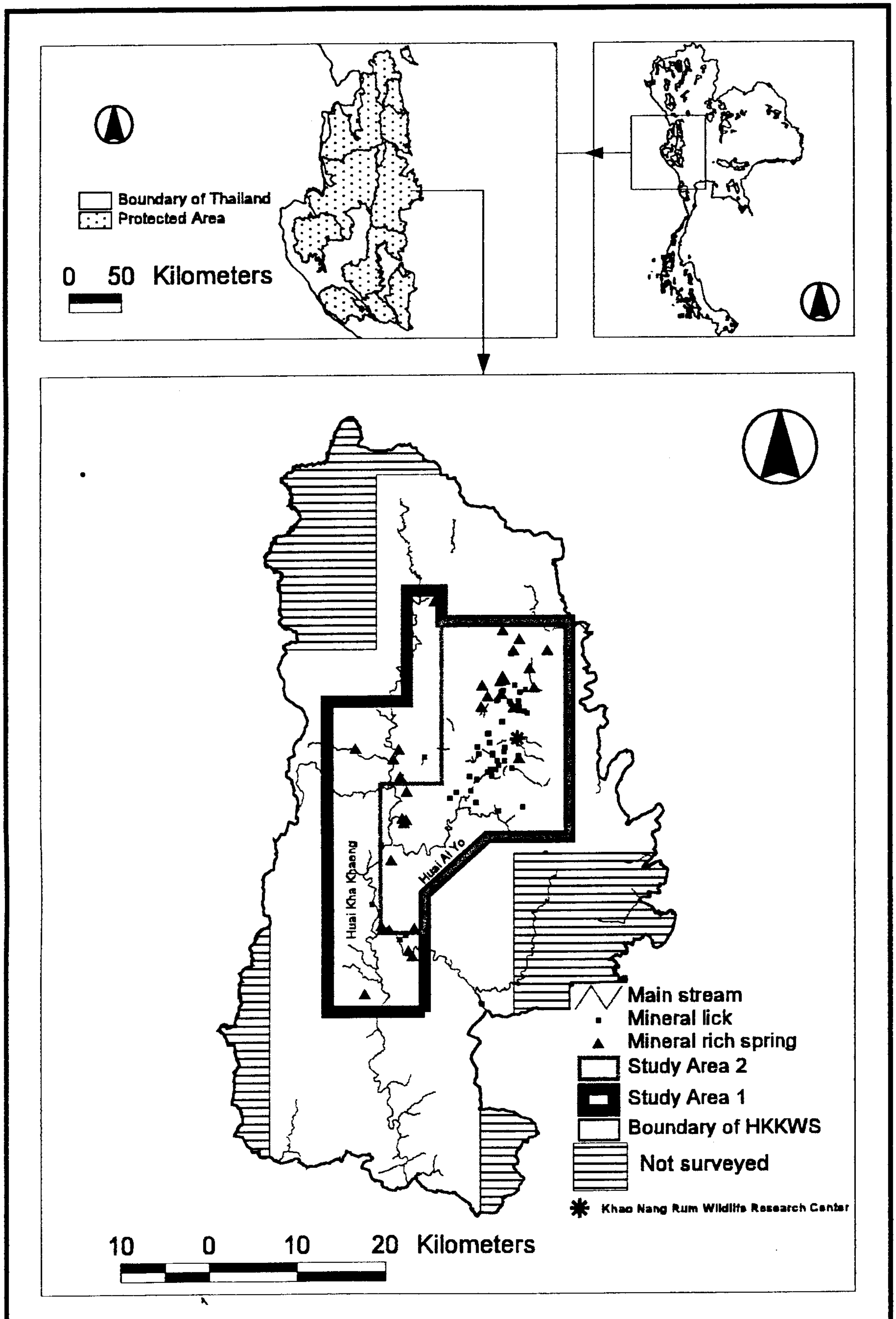
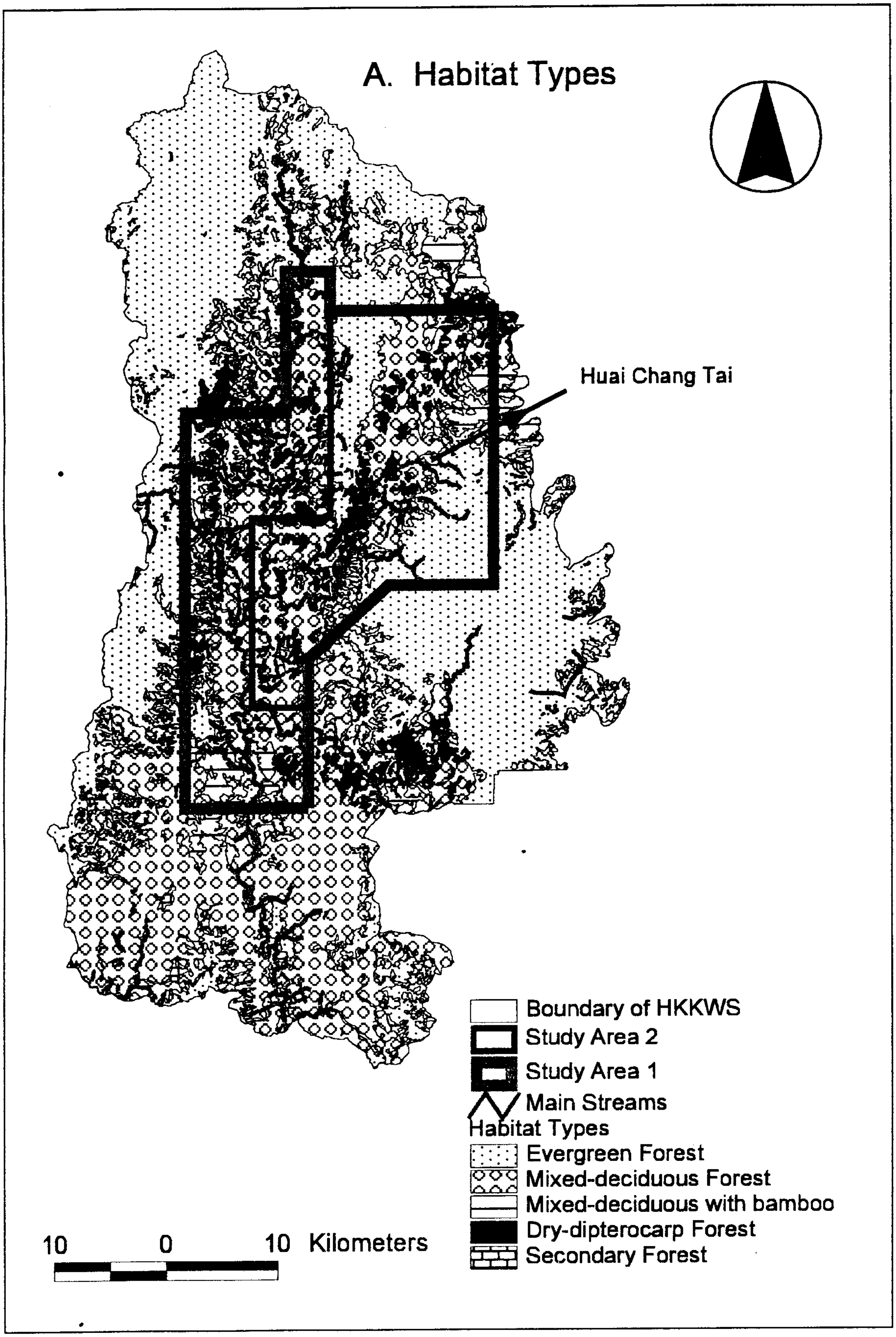
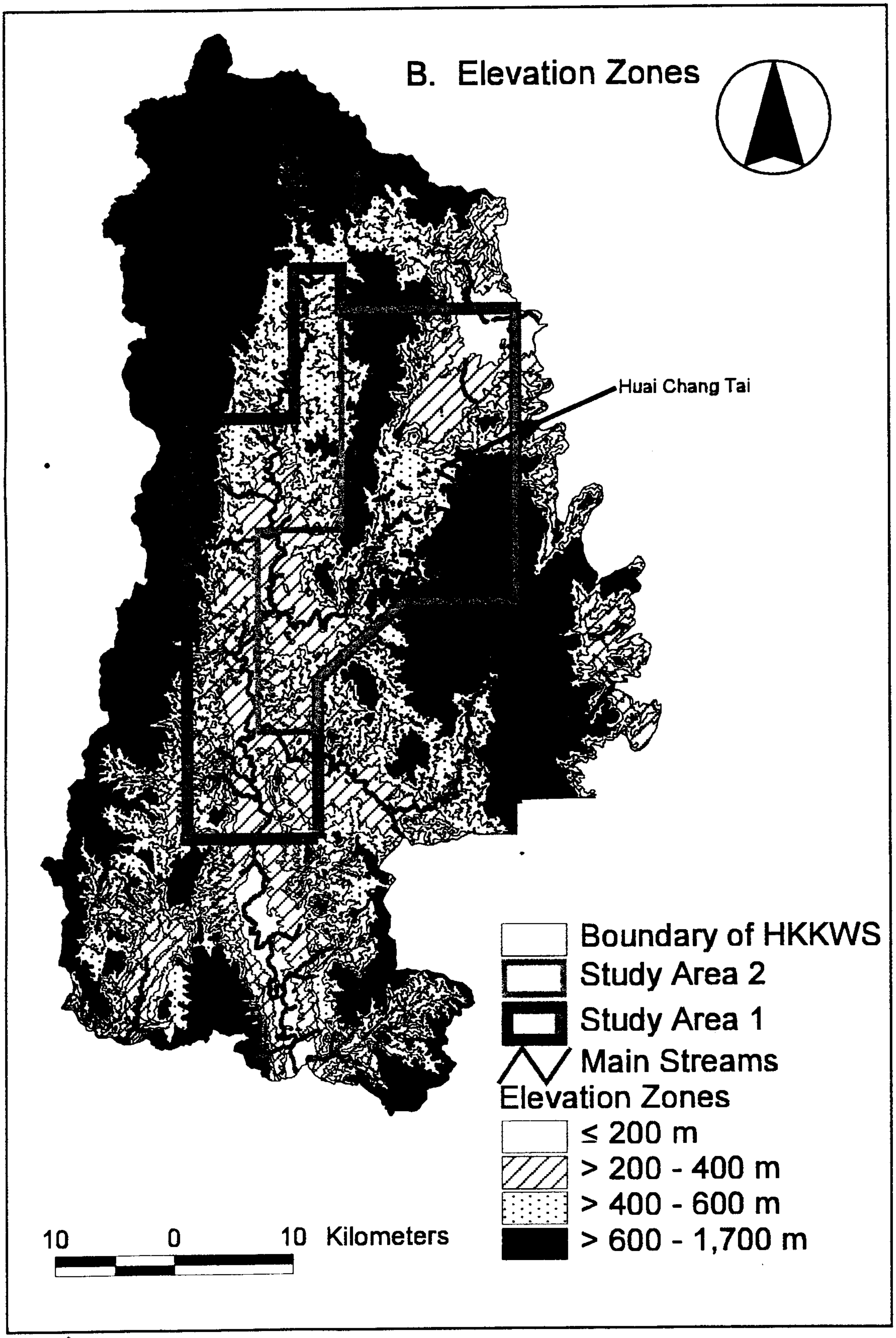

Boundary of Thailand
Protected Area
0 50 Kilometers
Huai Kha Khaeng
Huai Ai Yo
Main stream
Mineral lick
Mineral rich spring
Study Area 2
Study Area 1
Boundary of HKKWS
Not surveyed
Khao Nang Rum Wildlife Research Center
10 0 10 20 Kilometers

Figure 2. Habitat types (A) and Elevation zones (B) in HKKWS, Thailand.


A. Habitat Types
Huai Chang Tai
Boundary of HKKWS
Study Area 2
Study Area 1
Main Streams
Habitat Types
Evergreen Forest
Mixed-deciduous Forest
Mixed-deciduous with bamboo
Dry-dipterocarp Forest
Secondary Forest
10 0 10 Kilometers


B. Elevation Zones
Huai Chang Tai
Boundary of HKKWS
Study Area 2
Study Area 1
Main Streams
Elevation Zones
≤ 200 m
> 200 - 400 m
> 400 - 600 m
> 600 - 1,700 m
10 0 10 Kilometers

consists of seedlings, ferns, rattans, palms, vines, grasses and shrubs.

Mixed deciduous forest comprises 1,307 km^2 or 47% of the sanctuary, and 57 of study area 1 and 49% of study area 2. It is found on flat and moderately sloping areas, and is the most common forest type in both study areas. The dominant species (mostly tall trees) are *Lagerstroemia calyculata, Xylia xylocarpa* and *Afzelia xylocarpa*. Bamboo is quite common among the middle story species and is found in some areas in pure stands. The canopy of mixed deciduous forest is open. Ground cover is very dense in the wet season and more open in the dry season. Dominant ground species are *Pueraria barbarta, Desmodium spp.* and *Dioscorea spp.*

Dry dipterocarp forest comprises 164 km^2 or 6% of the sanctuary, and 13% of study area 1 and 12% of study area 2. It is commonly found further from streams, and has a slightly rocky slope with less fertile soils. The dominant tree species are *Shorea obtusa, S. siamensis, Dipterocarpus tuberculatus,* and *D. obtusifolius*. Ground cover species include grasses, herbs and saplings. In dry areas, a palm like plant, *Cycas siamensis* sometimes occurs. During the dry season, accidental fires burn the undergrowth, playing an important role in the forest ecosystem.

Secondary forest comprises 19 km^2 or 1% of the sanctuary, and 0.08 km^2 of study area 1 and 0.06 km^2 of study area 2. However, I excluded this type of forest from our analysis of habitat use because this area is occupied by humans, and gaur and banteng do not feed here. The land is occupied by local people who practice swidden farming and hold sanctuary buildings. This habitat is mostly in the eastern and southern parts of the sanctuary and is found in the northeast of both study areas. Some secondary forest trees also grow in the primary forest, such as *Lagerstroemia macrocarpa, Vitex peduncularis, Bauhinia acuminata, Melia azedarach, Sterculia spp. and Macaranga spp.* Banana trees occupy wet areas along with bamboo. The under-story is a tangle of thorny shrubs and climbers.

Elevation Ranges

The habitat types are associated with elevation ranges (Thitathamakul 1985). I classified the elevation ranges or vertical zones into 4 classes: 0-200 m (low-flat), > 200-400 m (foothills), > 400-600 m (mid-flat), and > 600-1,700 m (high). Within the sanctuary, each elevation range occupied 88, 624, 835 and 1,262 km^2 or 3, 22, 30, and 45% of the sanctuary respectively (Fig. 2; Appendix 1).

The low-flat zone is found in the eastern part of HKKWS. In the dry season, these areas are very dry because of the rainshadow effect. The foothills zone is comprised of small plains and adjacent hills. Bamboo is abundant in this zone. The mid-flat zone is mainly found along the valley of Khao Khiew-Khao Nam Yen Range in the eastern part of HKKWS and Khao Yang Daeng-Khao Chonglom-Khao Foilom Range in the center of the sanctuary, and there is also a strip between the valley of Khao Yang Daeng-Khao Chonglom-Khao Foilom Range and the mountain ranges in the western part of the sanctuary. Finally, the high steep zone is comprised of mountains ranging from 600 to 1,700 m in the north, east, west and central parts of the sanctuary.

Fauna

There are 17 species of medium and large mammals (> 20 kg) in HKKWS; 8 are carnivores and 9 are ungulates (Nakhasathien and Stewart-Cox 1990, Conforti 1996) (Appendix 2).

Soil Types

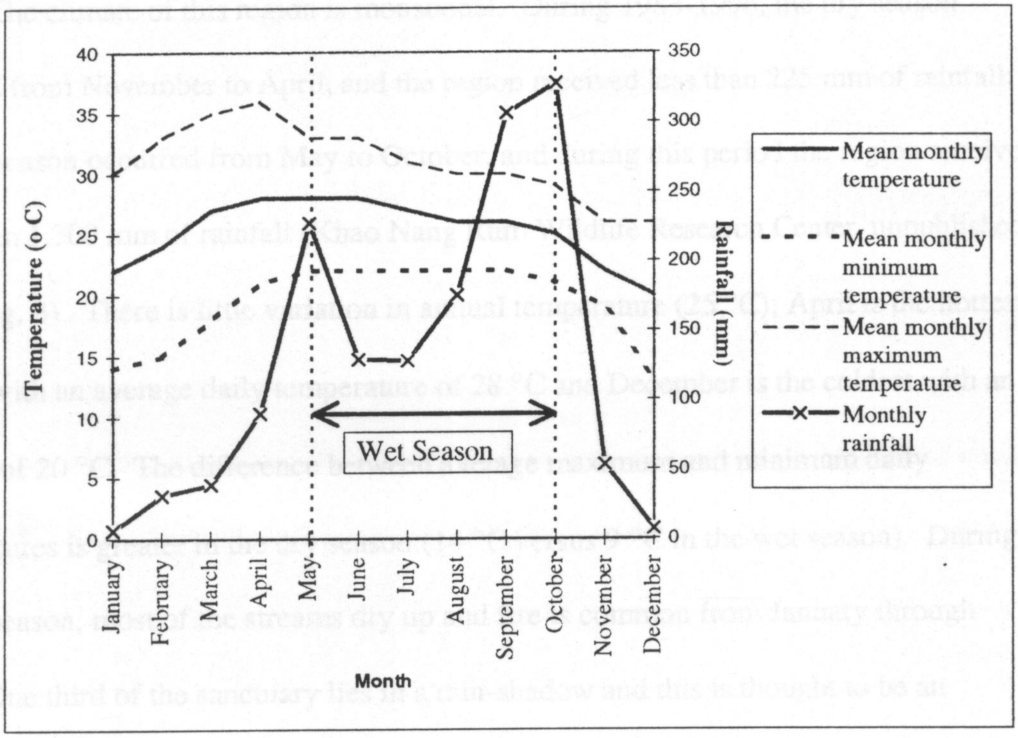
Two main soil groups occur in the sanctuary: red-brown soils derived from limestone, and red-yellow podzolic soils derived from granite (Moorman and Rojanasoonthon 1967, 1972, Nakhasathien and Stewart-Cox 1990). These soils apparently have the same distribution patterns as the rocks from which they were derived (Nakhasathien and Stewart-Cox 1990).

Mineral Licks and Mineral Rich Springs

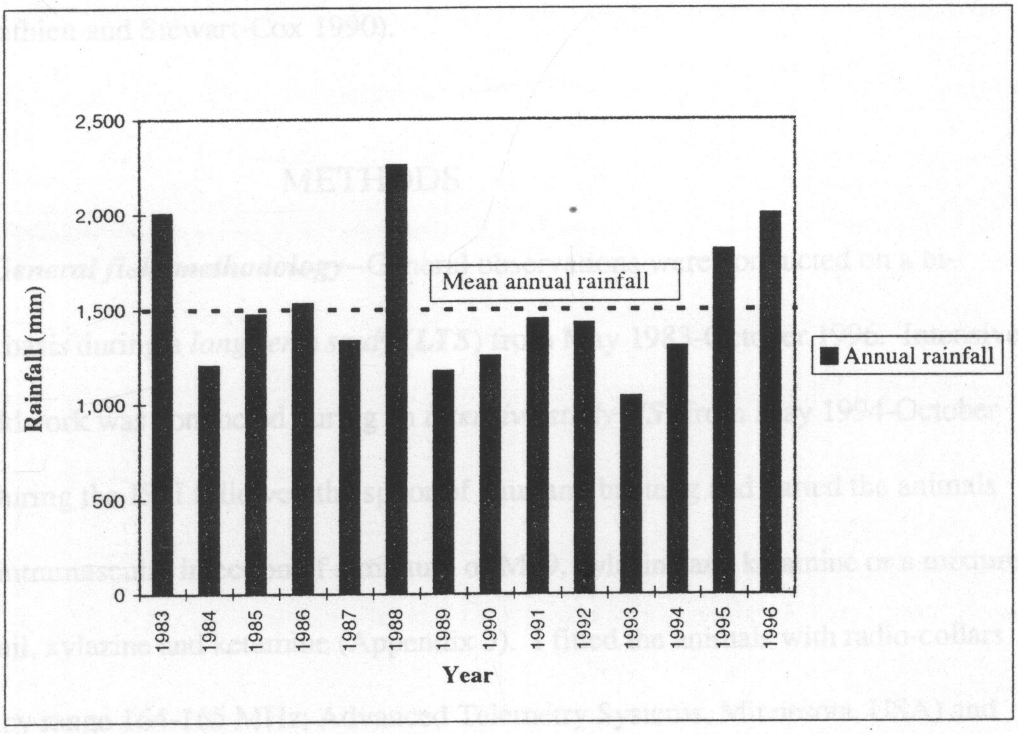
Minerals are very important for all animals, especially herbivores. Mineral requirements vary with age, sex, species, season, maturity, and reproductive condition (Robbins 1993). Deficiencies and imbalances of minerals are well recognized as important determinants of animal condition, fertility, productivity and mortality (UnderWood 1977). Herbivores obtain minerals from food, water and some special sources such as mineral rich springs and mineral licks. Ungulates can not obtain all of their mineral requirements from terrestrial plants. Therefore, they must obtain additional minerals from mineral licks and mineral rich springs. In study area 1, there are at least 61 mineral licks and 30 mineral rich springs; in study area 2, there are at least 45 mineral licks and 23 mineral rich springs (Fig. 1).

Figure 3. Average monthly temperature and rainfall (A), and annual rainfall (B) at Khao Nang Rum Wildlife Research Center, HKKWS, Thailand during 1983-1996.

A



B



Source : Khao Nang Rum Wildlife Research Center, HKKWS, Thailand.

Climate

The climate of this region is monsoonal. During 1983-1996, the dry season occurred from November to April, and the region received less than 225 mm of rainfall; the wet season occurred from May to October, and during this period the region received more than 1,300 mm of rainfall (Khao Nang Rum Wildlife Research Center, unpublished data) (Fig. 3). There is little variation in annual temperature (25 °C); April is the hottest month, with an average daily temperature of 28 °C and December is the coldest with an average of 20 °C. The difference between average maximum and minimum daily temperatures is greater in the dry season (14 °C versus 9 °C in the wet season). During the dry season, most of the streams dry up and fire is common from January through April. One third of the sanctuary lies in a rain-shadow and this is thought to be an important factor governing the overall distribution of forest types within the sanctuary (Nakhasathien and Stewart-Cox 1990).

METHODS

General field methodology--General observations were conducted on a bi-monthly basis during a *long-term study* (*LTS*) from May 1983-October 1996. Intensive daily fieldwork was conducted during an *intensive study* (*IS*) from May 1994-October 1996. During the IS, I followed the spoor of gaur and banteng and darted the animals with an intramuscular injection of a mixture of M99, xylazine and ketamine or a mixture of carfentanil, xylazine and ketamine (Appendix 3). I fitted the animals with radio-collars (frequency range 164-165 MHz; Advanced Telemetry Systems, Minnesota, USA) and followed handling procedures approved by the University of Minnesota animal welfare protocol.

Hand-held, 3 element Yagi antennas and portable radio receivers were used to track gaur and banteng. On the ground, I tracked radio signals until I saw fresh gaur and banteng tracks and I then followed recent spoor to obtain individual or herd locations. I recorded habitat use along the animal route of travel. At least twice a month, I tracked radio signals from a helicopter (using hand held Yagi antennas). I flew over the study areas and attempted to obtain a strong radio signal from each herd, and flew circles until I saw the animals. Once located, I recorded the herd number, size, time, location, activity and habitat use.

Long-term study (LTS).--During 1983-1996, I collected *periodic data* (data that were collected as discrete events). Gaur and banteng direct observations were located by walking throughout all habitats and along 10 permanent transects in study area 1 at different time approximately 7 days per month. I recorded location (UTM) and associated elevation on 1:50,000-scale maps, and noted date, time, group size, behavior, and habitat use. I used these data to determine habitat and elevation selection.

Intensive study (IS).--During 1994-1996, I collected periodic and *continuous data* (the latter were collected every 15-30 minutes for 5 to 6 hours a day over a 2-3 day period). I located radio-collared animals that they all remained in study area 2 by triangulating from 3 fixed hilltops. I located animals at random times between 06:00 and 18:00 hours. The distance between hilltop locations was generally at least 1 km. Data points collected less than 6 hours apart were considered non-independent and were excluded from all analysis. I attempted to obtain 1 radio-location at 1-day interval (10 times a month per group), and then I walked to ground-truth those locations by identifying physical evidence of the animals at the presumed location. I recorded locations in UTM coordinates by using GPS (Trimble Navigation), and compared these locations with the ones derived by triangulation. Triangulated locations were generally within a 50 m radius from the GPS locations. I checked the elevations of those locations by GPS and 2 altimeters, and compared all data with 1:50,000-scale topographic maps. I used all location data to determine seasonal home range sizes, seasonal home range shifts, habitat and elevation use, habitat and elevation selection, daily movements, and the influence of mineral licks and mineral rich springs on distribution.

To measure average daily movement, I tracked and followed each group of radio-collared animals continuously for 2-3 days per month. I walked behind herds of radio-collared animals, maintaining a distance of 200-300 m. Sometimes animals that were unaware of our presence were observed directly for 2-3 hours. When following the spoor of radio-collared gaur and banteng, I recorded location in UTM coordinates approximately every 15 minutes with a GPS to the nearest 100-m. Each location, I set a 20x 20 m^2 plot to check habitat and all signs of animals. Each day observations were for 3-7 hours depending on animal behaviors and weather. On the second and third days of continuous monitoring, the same herd was tracked from the last location of the previous day, and all data were recorded in the same manner as on the first day.

Distribution

To map distribution of gaur and banteng within HKKWS, I use direct observation by foot and helicopter from 1983 to 1996 and from 1994-1996 my staff and I additionally used radio location data. I also obtained data from 9 ranger teams, each including at least one senior ranger who knew tracks and signs of all large animals that patrolled in the vicinity of their ranger-stations at least 7 days per month. Using these methods, approximately 70% of HKKWS was surveyed. I flew at different times (at least 2 hours per time) during the day from 09:00 to 15:00 hours. When I located animals, I took pictures, counted their numbers, and recorded date, time, location and habitat type. Also, to avoid counting the same animals twice (considering the same herds to different herds), I identified the trails of individual herds.

To more precisely determine distribution and density of gaur and banteng in HKKWS, I intensively surveyed study area 2. At least 5 ranger teams surveyed animals along 10 permanent line transects located near Khao Nang Rum Wildlife Research Center during 1990-1994. I surveyed transects for direct sightings twice a month, at different time of day, during the dry and wet seasons.

During 1994-1996, I tracked animals with radio-collars to confirm the movement patterns observed during the LTS. My teams and I surveyed the distributions of other gaur and banteng herds in study area 2 at least 4 times a month in the dry season and 2 times a month in the wet season. In addition, I surveyed by checking and observing the main mineral rich springs and mineral licks in study area 2 twice a month during 1994-1995.

Using all these methods, I estimated the distribution, number, and density of gaur and banteng. I recorded all my observation locations on maps (1:50,000 scale) and in a GIS (Arcview). Distribution of each non-radio-collared or radio-collared animal was examined by plotting its activity center. I calculated each activity center by computing the arithmetic mean X and Y coordinate from all locations. I used 10-15 independent locations to calculate activity centers of non-radio-collared herds and ≥ 50 locations to calculate activity centers of radio-collared herds. Population size was estimated by counting all animals in a herd each time it was observed, and I reported the minimum and maximum sizes for each herd within the study areas.

Herd Size and Herd Structure

Herd size and herd structure were determined by recording number, sex and age structures of individual groups when they were sighted during May 1983-October 1996. Herd sizes of gaur and banteng were classified into 4 classes: 2-5, 6-10, 11-15, and ≥ 16 animals. Basic herd structure of gaur and banteng consisted of adult males, adult females, sub-adults and calves. However, dense vegetation and minimal visibility greatly limited observations; therefore, animal sign provided the predominant source of data. Track sign was carefully examined to distinguish group sizes and then estimated for classification into age categories.

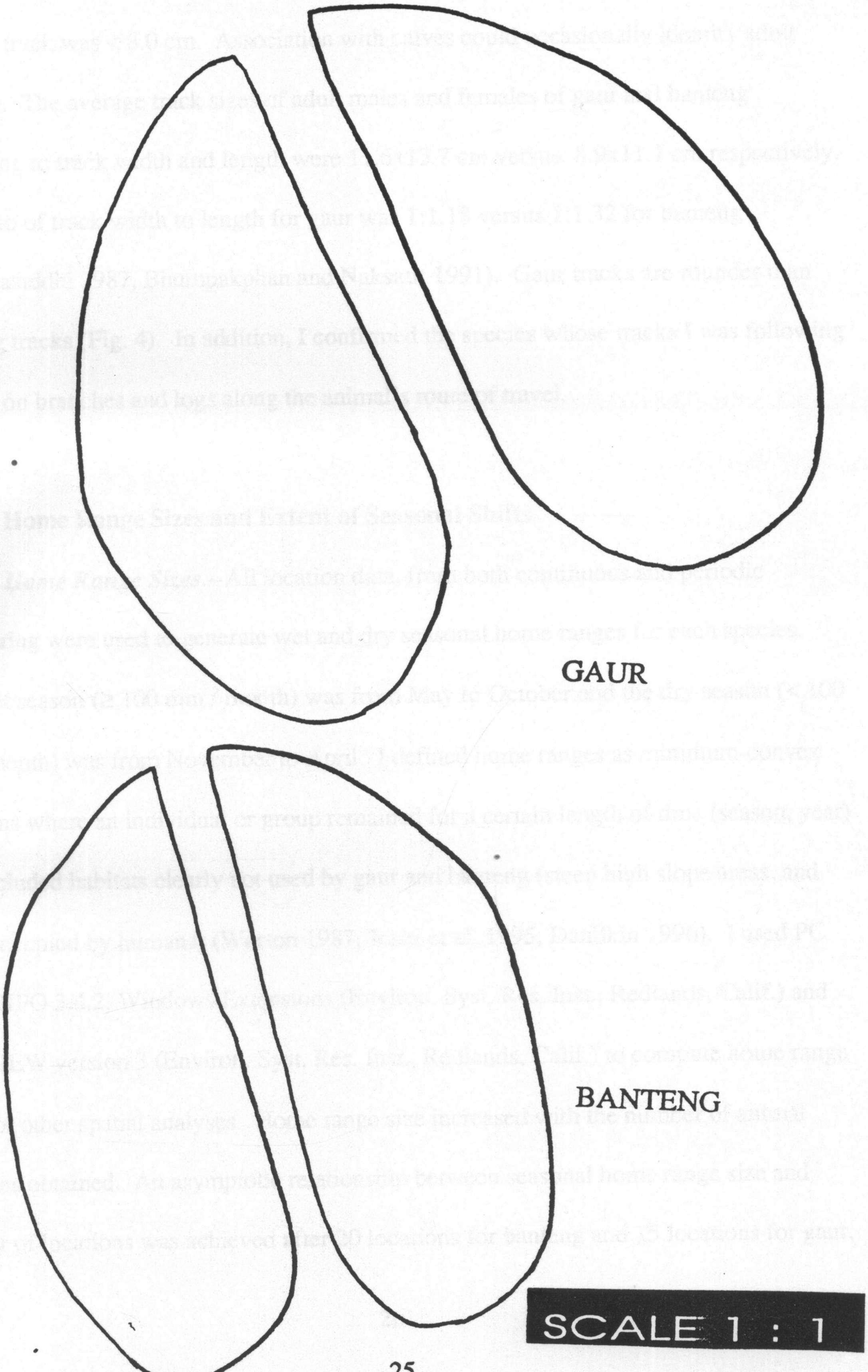
Criteria used for age classification of visually observed animals were based on known-age captive native gaur and banteng at zoos, and adapted from Conry (1981). Both gaur and banteng were classified into age groups based on color, size, markings, and horn length. Age groups were ***calves*** (< 12 months), ***yearlings*** and ***subadults*** (> 1-2.5 years old) and ***adults*** (> 2.5 years old). Both yearling and subadult gaur and banteng are about 3 /4 of adult size and had horn lengths from 30-45 cm. Gaur subadults are light brown in color with white stockings, and banteng subadults are chestnut with white stockings. Adult gaur are dark brown to black with white stockings, 450-1,000 kg, and have well developed horns that curve inward. Adult banteng are chestnut and brown-chestnut with white stockings, 400-900 kg, and also have well developed horns that curve inward horns (Doug Armstrong, pers. comm., Lekagul and McNeely 1977, Prayurasiddhi 1987).

Sex classification of gaur and banteng was made on the basis of external genitalia and morphology (Lekagul and McNeely 1977, Conry 1981, Prayurasiddhi 1987). Adult male and female gaur are brown to black (Lekagul and McNeely 1977, Conry 1981). In females, the horns curve inward sharply, the tips almost meeting in very old cows, and the horns have thin basal diameters. Females show slight muscular development of the neck and shoulders. The male horns grow out and up with thick basal flat diameter shapes. The tip of the horn is black, the middle third is olive-yellow, and the basal third is dark olive-brown, covered with thick corrugations, the extent of which depends on the age of the animal. At the base of their horns, both males and females have yellow or golden hair that contrasts with their black body color. Adult bull gaur are bigger than bull banteng and have more massive muscular development of the neck and shoulders. Both females and males are grayish or golden yellow above the knees and hocks downward to the hoofs. The color of the stockings and the forehead is usually the same; the golden yellow color often seen on these parts comes from the stain of oily body sweat. It was more profuse in bulls in their prime and was reduced or lacking in old bulls (Lekagul and McNeely 1977).

Adult female banteng are mostly bright brown or reddish from birth to old age, and the horns curve inward sharply, the tips almost meeting in very old cows, and the horns have thin basal diameters. Female banteng do not show muscular development of the neck and shoulders. The color of adult male banteng changes from golden to chestnut and brown by >5 years of age (Lekagul and McNeely 1977, Prayurasiddhi 1987). In male, horns grow out and forward, then curve inward at the tips, and have thick basal oval diameters. A unique feature in banteng is the frontal shield, a horny patch of thick skin, which is cracked and bald, located between the bases of the horns (Lekagul and McNeely 1977). In females, horns are uniformly dark, closer together, more upright and smaller than in bulls. Bull banteng show muscular development of the neck and shoulders but not as strongly as bull gaur. Both female and male banteng show white bands or patches on various parts of the body, including white bands around the muzzle, small white patches over both eyelids, white stockings and sharply contrasting white rump patches (Lekagul and McNeely 1977, Prayurasiddhi 1987).

Based on captive gaur and banteng observations, the sizes of calves, subadults, and adult females are almost the same for both species, but adult bull gaur are bigger than adult bull banteng. Male and female tracks were classified into 3 age classes according to track length (Conry 1981): calf, < 8 cm; subadult, 8.0-9.0 cm; and adult, > 9.0 cm respectively. If front and rear track measurements varied and fell into 2 age classes,

Figure 4. The characteristic differences of adult gaur and banteng tracks.


GAUR
BANTENG
SCALE 1 : 1

the animal was classified as an adult if the larger track was > 9.0 cm and as a calf if the smaller track was < 8.0 cm. Association with calves could occasionally identify adult females. The average track sizes of adult males and females of gaur and banteng according to track width and length were 11.6x13.7 cm versus. 8.9x11.7 cm respectively. The ratio of track width to length for gaur was 1:1.18 versus 1:1.32 for banteng (Prayurasiddhi 1987, Bhumpakphan and Naksatit 1991). Gaur tracks are rounder than banteng tracks (Fig. 4). In addition, I confirmed the species whose tracks I was following by hair on branches and logs along the animal's route of travel.

Home Range Sizes and Extent of Seasonal Shifts

Home Range Sizes.--All location data, from both continuous and periodic monitoring were used to generate wet and dry seasonal home ranges for each species. The wet season (≥ 100 mm / month) was from May to October and the dry season (< 100 mm / month) was from November to April. I defined home ranges as minimum-convex polygons where an individual or group remained for a certain length of time (season, year) and excluded habitats clearly not used by gaur and banteng (steep high slope areas, and areas occupied by humans) (Worton 1987, Joshi et al. 1995, Danilkin 1996). I used PC ARC/INFO 3.4.2, Windows Extensions (Environ. Syst. Res. Inst., Redlands, Calif.) and ARCVIEW version 3 (Environ. Syst. Res. Inst., Redlands, Calif.) to compute home range sizes for other spatial analyses. Home range size increased with the number of animal locations obtained. An asymptotic relationship between seasonal home range size and number of locations was achieved after 20 locations for banteng and 15 locations for gaur.

Consequently, individual home ranges with fewer than 20 locations for banteng, and 15 locations for gaur were not included when estimating seasonal home ranges, and only animals monitored for an 8-12 month cycle were included in estimates of annual home ranges. I assumed that most of the time herds always remain intact when estimating seasonal home ranges.

Analysis of variance (ANOVA) with a general linear model (MINITAB Release 11.12 for Windows ™, Minitab Inc. 1996) was used to test for significant differences in the seasonal and annual home range sizes among individual herds in each species and also among seasons and years. Using ANOVA, I checked for differences in individual home range size across years, and when no differences were found, I pooled all seasonal data from different years to test seasonal different within and between species using paired and unpaired t-test respectively.

Extent of Seasonal Shifts.--I measured shifts between seasonal home ranges by measuring the distance between seasonal activity centers (the arithmetic mean of all independent locations). To examine the extent of home range shift in relation to an animal's movement during a single season, I used the ratio of the distance between seasonal activity centers and the longest length of the two adjacent seasonal home ranges (***shift-distance index***) (Joshi et al. 1995). For each species, I measured the shift-distance index across consecutive wet to dry seasons. I used t-test to compare the mean of shift-distance index across species.

Seasonal Length of Daily Movement

I used the data from the continuous-intensive radio-tracking to measure seasonal daily movements. I plotted all seasonal daily locations of each group on 1:50,000 scale HKKWS map, and used ARC/INFO software to calculate the average distance each herd moved per day (24 hours). I used paired t-test to compare means of daily movement distance between wet and dry season within a species. Then I used t-test to compare means of daily movement distance between species within a season.

Habitat Use

Seasonal Habitat and Elevation Compositions and Seasonal Habitat and Elevation Use

Seasonal Habitat and Elevation Compositions.--ArcInfo was used to map and classify gaur and banteng habitat. The locations of mineral licks, mineral rich springs, seasonal and permanent streams, and 100 m contour lines were digitized from 1:50,000 Royal Thai Army maps. Map coverage of water resources and a digital terrain model were generated from the digitized data. Elevation data was also used to establish a set of polygons for 4 major elevation zones (≤ 200 m, > 200 to 400 m, > 400 to 600 m and > 600-1,700 m). Forest cover classes were manually interpreted from a February 8, 1995 Landsat Thematic Mapper Scene and digitized to create a 1:250,000 geo-referenced forest cover map of HKKWS. The areas of different habitats and elevation zones were calculated within seasonal home range for each individual animal. Finally, the total areas of habitat and elevation compositions within composite ranges of all herds were examined.

Seasonal Habitat and Elevation Use.--Analysis of variance indicated no difference among home range sizes across years, so data were pooled to analyze and determine habitat and elevation use for gaur and banteng separately and to compare gaur and banteng use in each season.

For many of the calculations that follow, comparative analyses were performed at 2 levels. The first level compared patterns of habitat use between the wet and dry season for gaur and banteng individually; the second level compared patterns of habitat use between gaur and banteng during a single season:

Level 1 **Compares usages between wet and dry seasons within a species**

1) GAUR---------WET SEASON

2) GAUR---------DRY SEASON

1) BANTENG---WET SEASON

2) BANTENG---DRY SEASON

Level 2 Compares usages between species within a season

1) GAUR---------WET SEASON

2) BANTENG---WET SEASON

1) GAUR---------DRY SEASON

2) BANTENG---DRY SEASON

To test for habitat use I first used a chi-square test of independence to determine whether habitat types and elevation zones were used by gaur and banteng in proportion to availability within their home ranges. Then I used a chi-square test for homogeneity to test data from gaur and banteng observations whether 1) proportions of observations in each habitat type or elevation zone were the same within a species between wet and dry seasons, and 2) whether proportions of observations in each habitat type or elevation zone were the same by gaur and banteng within a season (Habitat selection see in Appendix 9).

Over 95 % of the individual animal locations were obtained more than 24 hours apart. Based on activity patterns of animals and daily location data, the time until two consecutive locations were independent was estimated to be > 6 hours (mean time to traverse the daily range), and locations < 6 hours were not used for either home range or habitat analyses. For all habitat analyses only locations where animals were either seen or located by triangulation were used.

RESULTS

During May 1994-February 1995, I captured and radio-collared 4 gaur in study area 2 from 4 different herds: 1 subadult female; G201, 1.5 years old, 1 adult female, G203, > 5 years old; and 2 adult males; G202, > 8 years old and G205, > 10 years old. I also captured and radio-collared 7 banteng from 7 herds: 3 adult females, B101, B103 and B107, all > 5 years old; 1 subadult male, B102, 1.5 years old; and 3 adult males, B104, B105 and B106 (all > 5 years old). Because gaur and banteng are very social animals that usually exist in a herd, one radio-collared female or a subadult animal (≤ 2.5 years old) was adequate to locate and monitoring an entire herd.

I monitored radio-collared gaur and banteng after capture until radio-collars failed or until October 1996 (Table 1). Two radio-collared female banteng (B101 and B107),

Table 1. Sex, age, capture date, and number of locations obtained for radio-collared gaur and banteng monitored in Huai Kha Khaeng Wildlife Sanctuary, Thailand· during May 1994-October 1996.

Animal ID	Date of first capture	No. of locations obtained Periodic monitoring					No. of locations obtained Continuous monitoring			
		W1	D1	W2	D2	W3	W1	D1	W2	D2
Gaur										
201	28-Apr-94	45	37	71	16	16	64	113	133	31
202	25-May-94	20	n/a	n/a	n/a	n/a	40	n/a	n/a	n/a
203	27-Jul-94	32	33	64	18	15	57	92	140	46
205	1-Feb-95	n/a	18	24	15	n/a	n/a	53	104	43
Total		97	88	159	49	31	161	258	377	120
Banteng										
101	1-May-93	48	64	22	n/a	n/a	82	156	59	31
102	9-May-94	62	62	69	29	20	112	194	169	n/a
103	10-Jun-94	60	59	68	23	20	210	250	151	46
105	11-Sep-94	16	34	n/a	n/a	n/a	13	104	n/a	43
Total		186	219	159	52	40	417	704	379	120

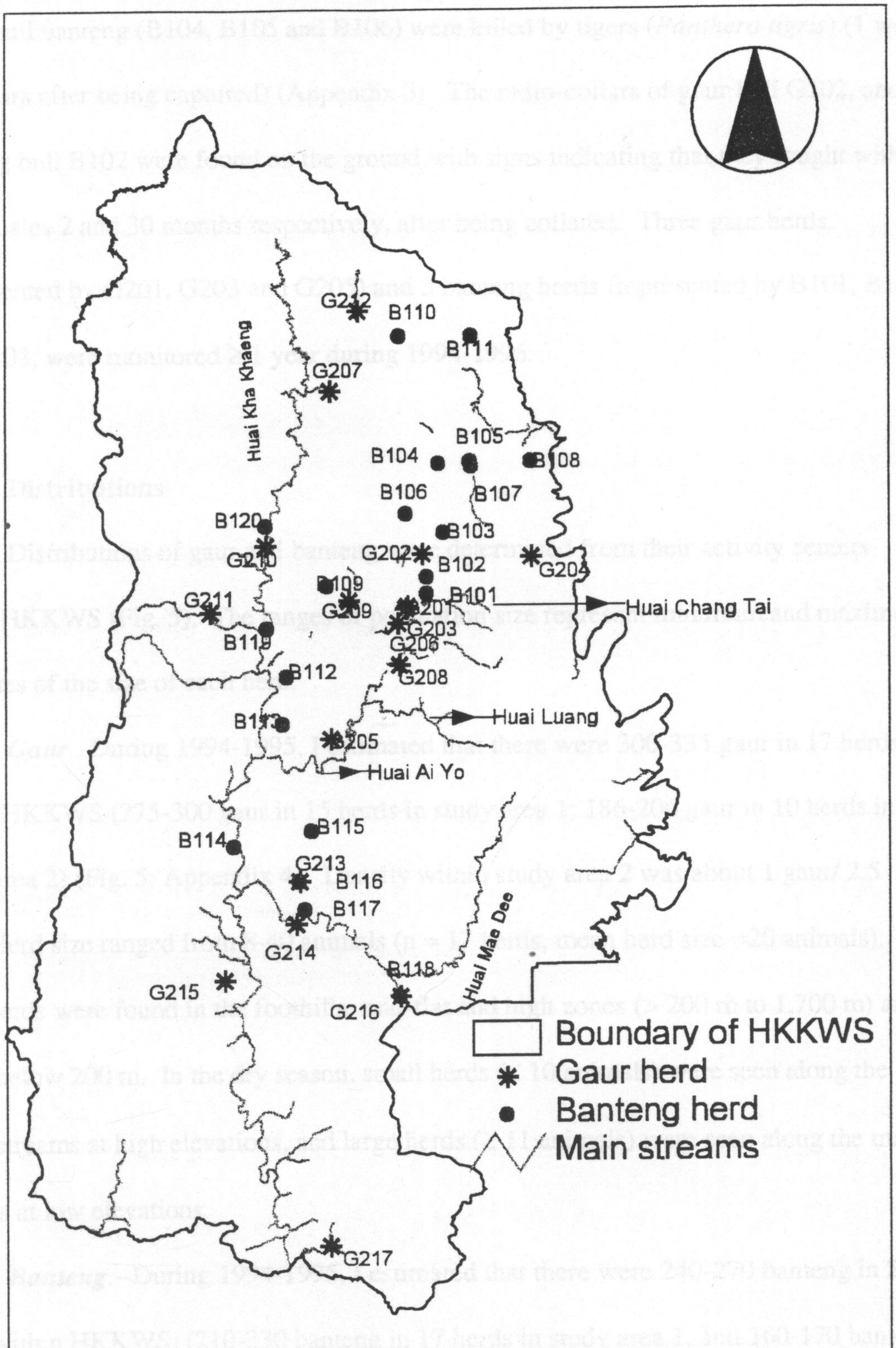
Table 1. (Continued).

<u>Note</u>:

1. Year of monitoring spans the wet season from May to Oct and the dry season from Nov to Apr so as not to split the dry season between years: W = Wet Season; D = Dry Season; W1 = May 1994 - Oct 1994; D1 = Nov 1994 - Apr 1995; W2 = May 1995 - Oct 1995; D2 = Nov 1995 - Apr 1996; W3 = Apr 1996 - Oct 1996.
2. Periodic monitoring used to calculate home ranges, habitat and elevation use.
3. Continuous monitoring used to calculate daily movement.
4. B101 was radio-collared in 1993 but the radio transmitter was broken and then receiving signal again in May 1994.
5. n/a = no data available.

Figure 5. Distributions of gaur and banteng herds in HKKWS during 1994-1996.

Distributions of gaur and banteng were determined from their activity centers.


G212
B110
B111
Huai Kha Khaeng
G207
B105
B104
B108
B106
B107
B120
B103
G210
G202
B102
G204
B109
B101
G211
G209
G201
Huai Chang Tai
B119
G203
G206
B112
G208
Huai Luang
B113
G205
Huai Ai Yo
B115
B114
G213
B116
B117
G214
Huai Mae Dee
B118
G215
G216
Boundary of HKKWS
Gaur herd
Banteng herd
Main streams
G217
20
0
20 Kilometers

and 3 bull banteng (B104, B105 and B106) were killed by tigers (*Panthera tigris*) (1 week to 2 years after being captured) (Appendix 3). The radio-collars of gaur bull G202, and banteng bull B102 were found on the ground with signs indicating that they fought with other males 2 and 30 months respectively, after being collared. Three gaur herds, (represented by G201, G203 and G205) and 3 banteng herds (represented by B101, B102 and B103, were monitored ≥ 1 year during 1994-1996.

Distributions

Distributions of gaur and banteng were determined from their activity centers within HKKWS (Fig. 5). The ranges of population size represent minimum and maximum estimates of the size of each herd.

Gaur. During 1994-1995, I estimated that there were 300-335 gaur in 17 herds within HKKWS (275-300 gaur in 15 herds in study area 1; 186-206 gaur in 10 herds in study area 2) (Fig. 5; Appendix 4). Density within study area 2 was about 1 gaur/ 2.5 km^2. Herd size ranged from 8-40 animals (n = 17 herds, mean herd size =20 animals). Gaur herds were found in the foothills, mid-flat and high zones (> 200 m to 1,700 m) and rarely below 200 m. In the dry season, small herds (≤ 10 animals) were seen along the major streams at high elevations, and large herds (≥ 11 animals) were seen along the major streams at low elevations.

Banteng.--During 1994-1995, I estimated that there were 240-270 banteng in 20 herds within HKKWS, (210-230 banteng in 17 herds in study area 1, and 160-170 banteng in 13 herds in study area 2). Herd size ranged from 6-30 animals (n = 20 herds, mean herd size = 14 animals) (Fig. 5; Appendix 5). The density of banteng within study area 2 was 1 banteng / 2.86 km^2. Banteng herds were typically in low flat, foothill and mid flat zones ($\leq$ 600 m). I did not find banteng in the northern or western high elevation areas of HKKWS. Banteng were generally found in areas where mineral licks and mineral rich springs were located.

Herd Size and Herd Structure

Both species the oldest female in a herd led the group when feeding, moving and fleeing, and the dominant male had a defensive role. There were $\geq$ 2 males in all gaur and banteng groups; but only 1 male was dominant.

***Gaur*.**--The proportions of group size classes were not different between seasons ($\chi^2 = 0.86$, 3 df, $P = 0.834$) (Table 2). In 78% of the observations herd size was < 11 individuals in both seasons. The sex and age ratio of each herd showed no differences between the wet and dry season (3 males: 5 females: 1 subadult: 1 calf, n = 12 versus 4 males: 7 females: 1 subadult: 3 calves, n= 14).

***Banteng*.**-- Banteng herd size slightly varied in numbers in different seasons ($\chi^2 = 7.16$, 3 df, $P = 0.067$). Herd size was commonly between 2-5 individuals in the dry season and 6-10 individuals in the wet season (Table 2). The sex and age ratio of each herd also showed no differences between the wet and dry season (2:5:1:1, n = 45 versus 3:6:1:2, n = 33).

***A comparison of herd sizes*.**-- The distributions of group sizes were not significantly different between gaur and banteng in the dry season ($\chi^2 = 5.5$, 3 df, P = 0.138), but they were different in the wet season (χ^2 = 8.03, 3 df, P = 0.045). In both seasons, gaur formed large herds (≥ 16 individuals) more often than banteng especially in the dry season (Table 2). The sex and age ratios within herds of both species were not different between wet and dry seasons (3:5:1:1 versus 2:5:1:1 in the wet season and 4:7:1:3 versus 3:6:1:2 in the dry season).

Home Range Sizes and Extent of Seasonal Shifts

Gaur.--Between 1994 to 1995, I identified at least 10 herds of gaur within 477 km^2 (19%) of study area 2. I radio-collared and followed 3 of these herds and 7 other herds were recognized by the sex and age classes of herd members. Only G201 and G203 herds were followed in 1996.

Home Range Sizes.--Seasonal and annual home range sizes of gaur herds were determined from radio-collared individuals (G201, G203 and G205) in each herd (Table 3; Fig. 6). The wet season home range size of single bull was obtained, but its collar was lost prior to the dry season. Over a 20-24 month period, a total of 267 locations were obtained on animals in the wet season, while in the dry season 119 locations were obtained. Mean home range size in both the wet and dry seasons was calculated for all herds with a minimum of 15 locations. Mean home range size in the wet season (39.1±12.9 [Standard deviation] km^2) was significantly larger than mean home range size in the dry season (27.3±8.1 km^2) (paired-t = 4.26; n = 5 pairs; P = 0.007). The mean annual home range size of gaur herds was 65.5±27.8 km^2.

Table 2. Gaur and Banteng herd size observations in Huai Kha Khaeng Wildlife Sanctuary during 1983-1996.

Season	% Herd Sizes				n	Range
	2-5	6-10	11-15	≥16		
Gaur (wet season)	42	36	10	12	100	2-32
Gaur (dry season)	37	42	11	11	95	2-40
Banteng (wet season)	28	50	14	9	183	2-24
Banteng (dry season)	41	34	20	6	133	2-30

Remark: n = number of direct observations

Table 3. Home range characteristics of gaur and banteng in Huai Kha Khaeng Wildlife Sanctuary, Thailand during 1994-1996.

Species/ Parameter *ng ≥ 15; nb ≥ 20	Home range area [1] (km^2) Wet [2] Season	Dry [2] Season		The longest length of largest seasonal home range (km)	(km)	Distance between seasonal activity centers (km)	Shift-distance index [4]
Gaur (Herd);			Annual	W-D [3]	Annual	W-D [3]	W-D [3]
Mean	39.1	27.2	65.5	13.6	16.7	7.4	0.6
Minimum	21.3	19.0	46.7	10.4	15.0	2.6	0.2
Maximum	58.1	39.3	114.6	16.8	19.1	12.4	1.2
SD	12.9	8.1	27.8	3.0	1.9	4.5	0.4
n	7	5	5	5	5	5	5
Gaur (Individual Bull)							
Mean	45.2	N/A	N/A	N/A	N/A	N/A	N/A
Minimum	45.2	N/A	N/A	N/A	N/A	N/A	N/A
Maximum	N/A	N/A	N/A	N/A	N/A	N/A	N/A
n	1	N/A	N/A	N/A	N/A	N/A	N/A
Banteng (Herd)							
Mean	30.0	26.4	43.9	10.9	11.2	2.7	0.2
Minimum	20.8	19.6	30.5	9.8	9.8	0.6	0.1
Maximum	42.9	44.8	62.7	13.1	13.9	4.0	0.4
SD	8.5	10.4	12.9	1.3	1.6	1.4	0.1
n	6	5	5	5	5	5	5
Banteng (Individual Bull)							
Mean	10.2	13.0	20.5	5.2	6.4	2.9	0.6
Minimum	3.9	13.0	20.5	5.2	6.4	2.9	0.6
Maximum	16.6	N/A	N/A	N/A	N/A	N/A	N/A
n	2	1	1	1	1	1	1

Table 3. (continued)

Notes: [1] Home range delineated as convex polygons (excluding areas of non-gaur and non-banteng habitat) with gaur ≥ 15 locations and banteng ≥ 20 locations.

[2] Wet season defined as May to October; Dry season included November to April.

[3] W-D = Wet to Dry Seasonal Home Ranges.

[4] Shift-distance index = Distance between seasonal activity centers / the longest length of the two adjacent seasonal home ranges home ranges

* ng = number of gaur locations; nb = number of banteng locations

N/A = Data not available; SD = Standard deviation; n = number of observations

Table 4.1 The mean distance between activity centers of adjacent animal herds within study area 2 in HKKWS during the wet and dry season, Thailand, 1994-1996.

Wet Season	Gaur/ Gaur (km)	Banteng/ Banteng (km)
Mean	5.0	4.0
Minimum	0.6	0.2
Maximum	8.9	7.0
Standard deviation	3.5	2.1
n	6	7
Dry Season	**Gaur/ Gaur (km)**	**Banteng/ Banteng (km)**
Mean	7.4	3.2
Minimum	0.5	0.1
Maximum	12.9	8.4
Standard deviation	5.6	3.1
n	6	5

Table 4.2 The mean distance between activity centers of the closest adjacent gaur and banteng herds within study area 2 in HKKWS during the wet and dry season, Thailand, 1994-1996.

Gaur/ Banteng (km)	Distance in Wet Season	Distance in Dry Season
Mean	3.6	8.2
Minimum	1.7	6.1
Maximum	7.9	10.3
Standard deviation	2.0	1.7
n	15	10

Figure 6. Seasonal home range shifts of 4 radio-collared gaur in HKKWS, Thailand from the dry season 1994 (November 1994 to April 1995) to the wet season 1995 (May 1995 to October 1995) (A, C, D) and the wet season 1994 (May 1994 to October 1994) (B).

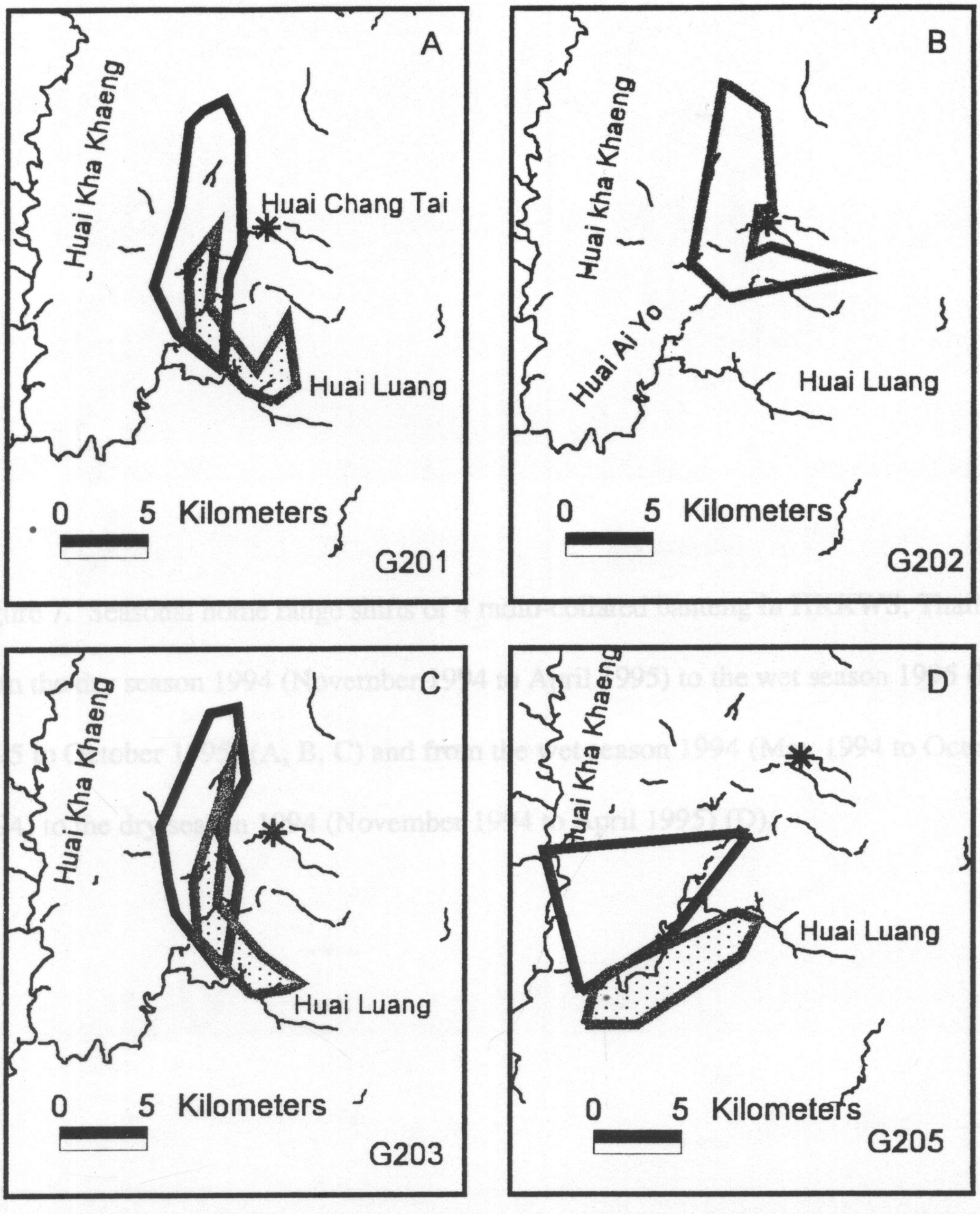
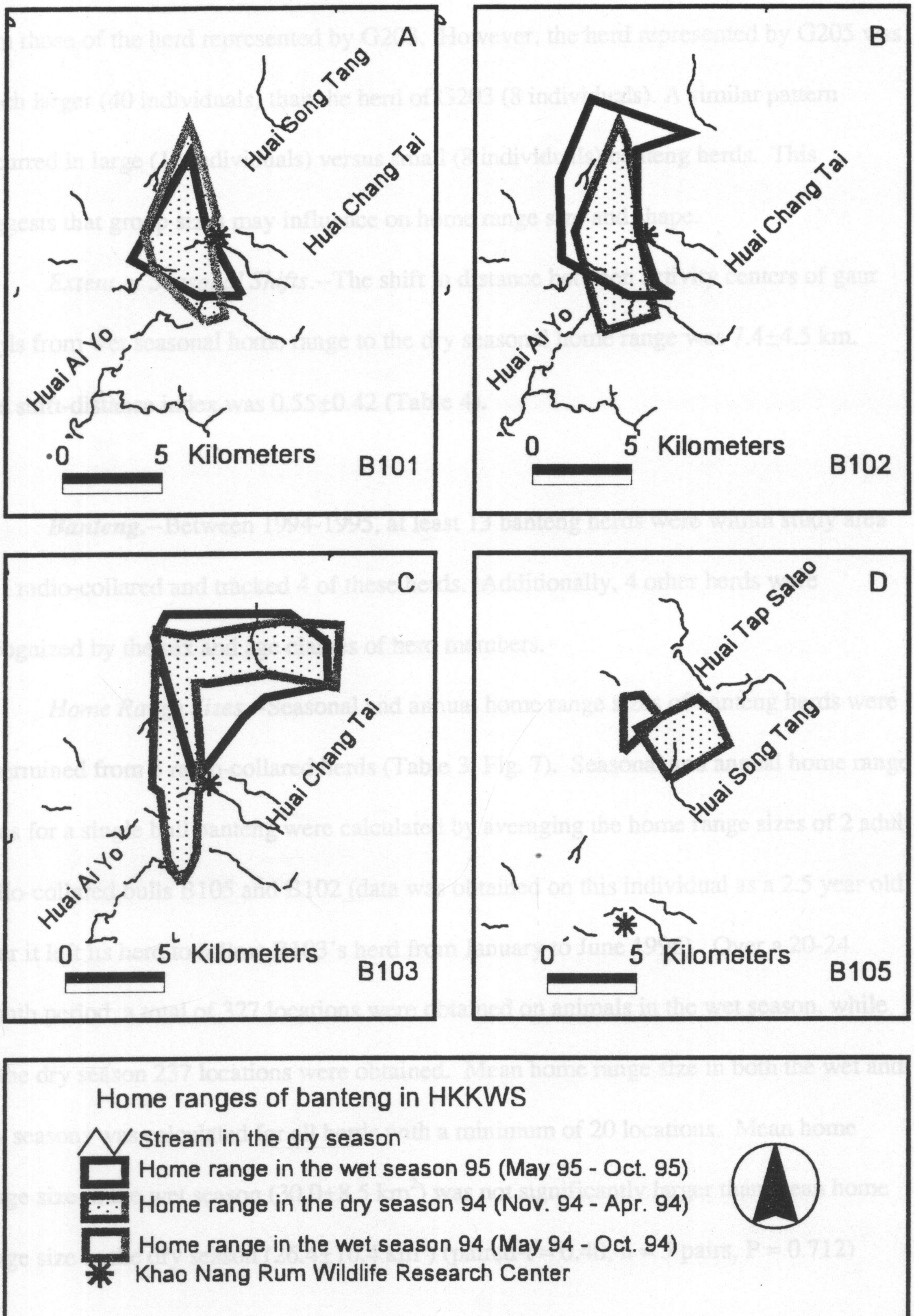

A
Huai Kha Khaeng
Huai Chang Tai
Huai Luang
0 5 Kilometers
G201
B
Huai Kha Khaeng
Huai Ai Yo
Huai Luang
0 5 Kilometers
G202
C
Huai Kha Khaeng
Huai Luang
0 5 Kilometers
G203
D
Huai Kha Khaeng
Huai Luang
0 5 Kilometers
G205
Home ranges of gaur in HKKWS
Stream in the dry season 1994-95
Home range in the wet season 95 (May 95 - Oct. 95)
Home range in the dry season 94 (Nov. 94 - Apr. 95)
Home range in the wet season 94 (May 94 - Oct. 94)
Khao Nang Rum Wildlife Research Center

Figure 7. Seasonal home range shifts of 4 radio-collared banteng in HKKWS, Thailand from the dry season 1994 (November 1994 to April 1995) to the wet season 1995 (May 1995 to October 1995) (A, B, C) and from the wet season 1994 (May 1994 to October 1994) to the dry season 1994 (November 1994 to April 1995) (D).


A
Huai Song Tang
Huai Chang Tai
Huai Ai Yo
0 5 Kilometers
B101
B
Huai Chang Tai
Huai Ai Yo
0 5 Kilometers
B102
C
Huai Chang Tai
Huai Ai Yo
0 5 Kilometers
B103
D
Huai Tap Salao
Huai Song Tang
0 5 Kilometers
B105
Home ranges of banteng in HKKWS
Stream in the dry season
Home range in the wet season 95 (May 95 - Oct. 95)
Home range in the dry season 94 (Nov. 94 - Apr. 94)
Home range in the wet season 94 (May 94 - Oct. 94)
Khao Nang Rum Wildlife Research Center

The seasonal and annual home ranges of the herd represented by G205 were larger than those of the herd represented by G203. However, the herd represented by G205 was much larger (40 individuals) than the herd of G203 (8 individuals). A similar pattern occurred in large (18 individuals) versus small (8 individuals) banteng herds. This suggests that group sizes may influence on home range size and shape.

Extent of Seasonal Shifts.--The shift in distance between activity centers of gaur herds from wet seasonal home range to the dry seasonal home range was 7.4±4.5 km. The shift-distance index was 0.55±0.42 (Table 4).

Banteng.--Between 1994-1995, at least 13 banteng herds were within study area 2. I radio-collared and tracked 4 of these herds. Additionally, 4 other herds were recognized by the sex and age classes of herd members.

Home Range Sizes.--Seasonal and annual home range sizes of banteng herds were determined from 3 radio-collared herds (Table 3; Fig. 7). Seasonal and annual home range sizes for a single bull banteng were calculated by averaging the home range sizes of 2 adult radio-collared bulls B105 and B102 (data was obtained on this individual as a 2.5 year old after it left its herd to follow B103's herd from January to June 1996). Over a 20-24 month period, a total of 327 locations were obtained on animals in the wet season, while in the dry season 237 locations were obtained. Mean home range size in both the wet and dry seasons was calculated for all herds with a minimum of 20 locations. Mean home range size in the wet season (30.0±8.5 km^2) was not significantly larger than mean home range size in the dry season (26.4±10.4 km^2) (paired-t = 0.40, n = 5 pairs, P = 0.712)

(Table 3). Herds represented by B101 and B102 were basically subgroups of a large herd and had very similar sizes of home ranges. The annual home ranges of these 2 sub-herds had a large degree of overlap (> 86%). The herd represented by B103 showed no significant change in seasonal home range pattern, but in 1994 this herd's home range size in the wet season was 20.8 km^2 and expanded to 44.8 km^2 in the dry season. In 1995, the trend was reversed; wet seasonal home range was 42.9 km^2 and in the dry season declined to 19.6 km^2. In the wet season (July 1994) I observed 3 calves in B103's herd. When banteng herds had young calves (< 3 months), they did not walk far and hide their calves. When their calves grew up or predators such as tiger (*Panthera tigris*) and red dog (*Cuon alpinus*) tried to catch their calves, they moved longer distances to new areas. The mean annual home range size of banteng herds was 43.9±12.9 km^2.

Extent of Seasonal Shifts.--The mean distance shift between activity centers of banteng herds from the wet seasonal home range to the dry seasonal home range was 2.7±1.4 km. The shift-distance index was 0.24±0.11 (Table 3).

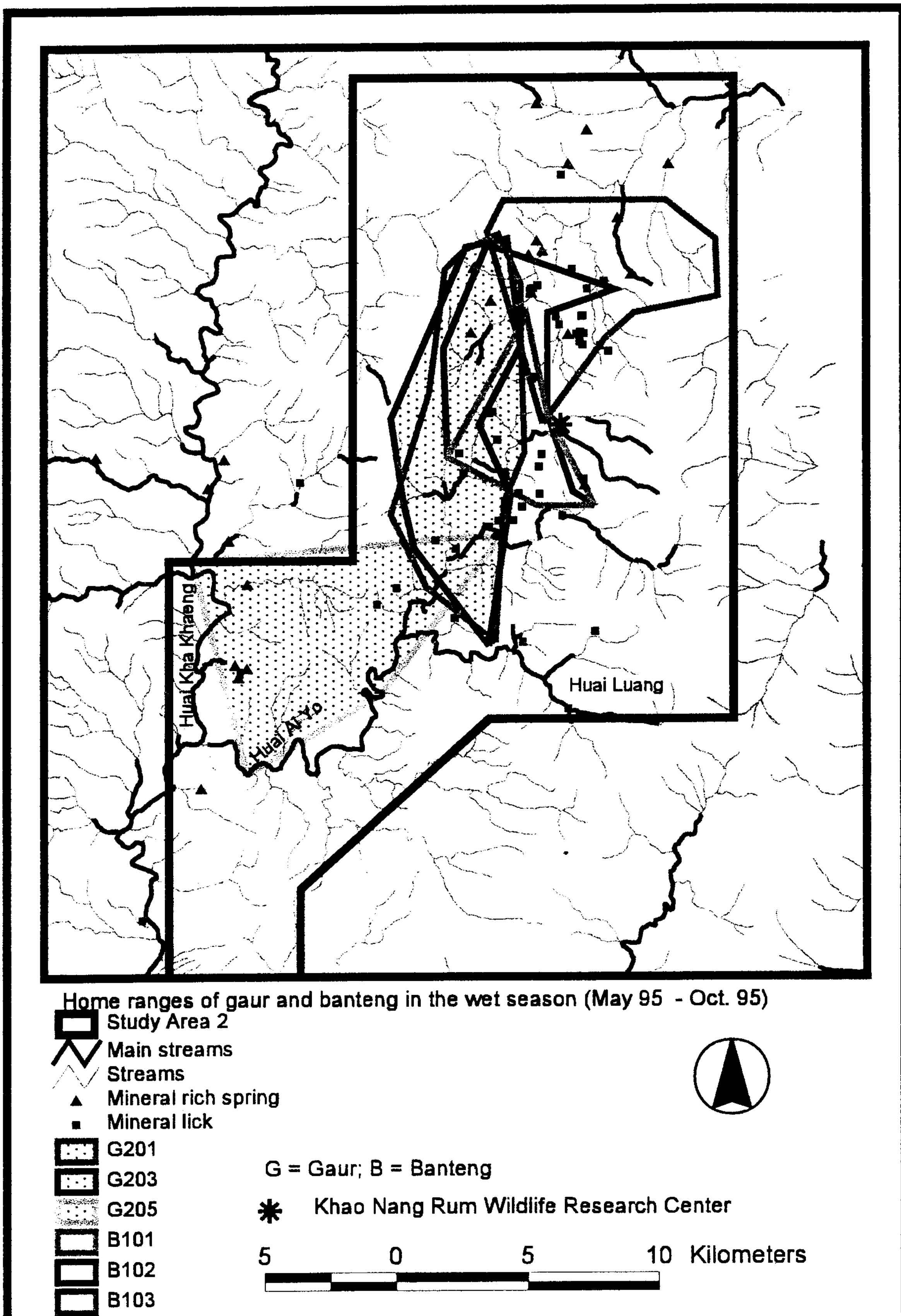
Comparison of Gaur and Banteng

Home Range Sizes and Extent of Seasonal Shifts.--Home range sizes of gaur were slightly larger than those of banteng in the wet season (39.1±12.9 km^2 versus 30.0±8.5 km^2) ($t = -1.51$, 10 df, $P = 0.081$), but they were not significantly different in the dry season (27.2±8.1 km^2 versus 26.4±10.4 km^2) ($t = -0.09$, 8 df, $P = 0.926$) (Table 3). Mean annual home ranges of gaur were significantly larger than those of banteng (65.5±27.8 km^2 versus 43.9±12.9 km^2) ($t = -1.58$, 6 df, $P = 0.083$) mainly because gaur seasonal home range shift was significantly greater than banteng seasonal home range shift ($t = -2.23$, 5 df, $P = 0.038$). The shape of gaur seasonal home ranges appeared to be influenced by the distribution of major streams, while home ranges of banteng were not.

Distances between Radio-Collared Adjacent Herds.--The mean distance between activity centers of adjacent gaur herds did not differ between wet and dry seasons (5.0±3.5 km versus and 7.4±5.6 km) ($t = -0.89$, 8 df, $P = 0.39$) (Table 4). The mean distance between activity centers of adjacent banteng herds also did not differ between wet and dry seasons (4±2.1 km versus 3.2±3.1 km) ($t = 0.45$, 7 df, $P = 0.67$) (Table 4). Overall, the mean distance between activity centers of adjacent gaur herds was longer than that of banteng herds (6.2± 4.6 km, n = 12 versus 3.7±2.5, n = 12) ($t = 1.7$, 17 df, $P = 0.054$). Gaur herds were located closer to banteng herds in the wet season than in the dry season (3.6±2.0 km versus 8.2±1.7 km in the dry season) (Table 4; Figs. 8 and 9).

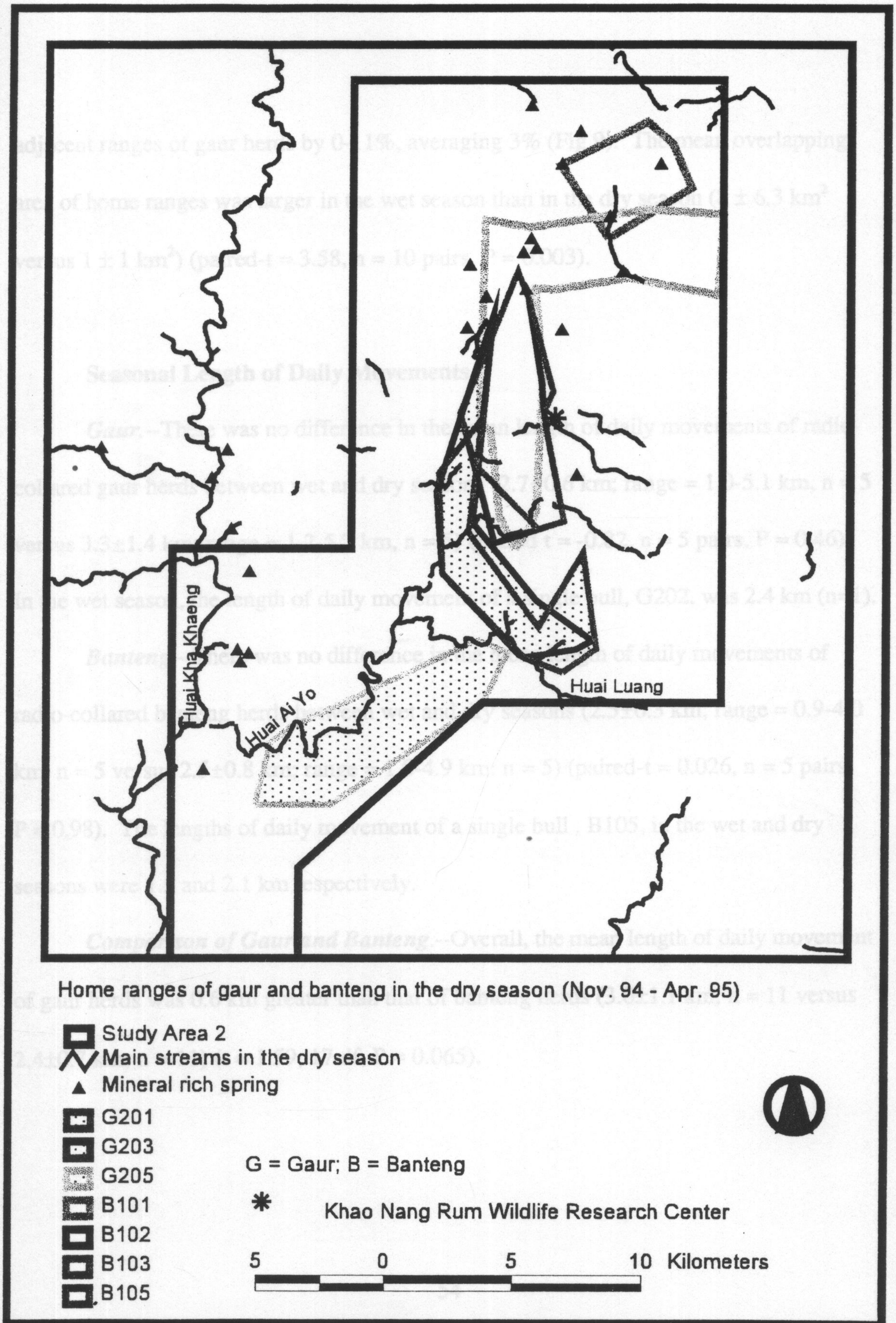
Home Range Overlap between Adjacent Herds.--During 1994-1995, 10 overlapping areas of adjacent 3 radio-collared gaur herds and 3 radio-collared banteng herds were examined in both wet and dry seasons (Table 5). In the wet season, home ranges of radio-collared gaur herds overlapped adjacent ranges of banteng herds by 3-45%, averaging 23%, while home ranges of radio-collared banteng herds overlapped adjacent ranges of gaur herds by 3-61%, averaging 29% (Fig. 8). In the dry season, home ranges of radio-collared gaur herds overlapped adjacent ranges of banteng herds by 0-12%, averaging 3%, while home ranges of radio-collared banteng herds overlapped

Figure 8. Home range overlap of 3 radio-collared gaur and 3 radio-collared banteng in the wet season in HKKWS, during 1994-1995.



Home ranges of gaur and banteng in the wet season (May 95 - Oct. 95)

Figure 9. Home range overlap of 3 radio-collared gaur and 3 radio-collared banteng in the dry season in HKKWS, during 1994-1995.



Home ranges of gaur and banteng in the dry season (Nov. 94 - Apr. 95) adjacent ranges of gaur herds by 0-11%, averaging 3% (Fig 9). The mean overlapping area of home ranges was larger in the wet season than in the dry season (8 ± 6.3 km^2 versus 1 ± 1 km^2) (paired-t = 3.58, n = 10 pairs, P = 0.003).

Seasonal Length of Daily Movements

Gaur.--There was no difference in the mean length of daily movements of radio-collared gaur herds between wet and dry seasons (2.7±0.6 km; range = 1.0-5.1 km, n = 5 versus 3.3±1.4 km; range = 1.2-5.7 km, n = 5) (paired t = -0.82, n = 5 pairs, P = 0.46). In the wet season, the length of daily movement of a single bull, G202, was 2.4 km (n=1).

Banteng.--There was no difference in the mean length of daily movements of radio-collared banteng herds between wet and dry seasons (2.5±0.3 km; range = 0.9-4.0 km; n = 5 versus 2.5±0.8 km; range = 1.0-4.9 km; n = 5) (paired-t = 0.026, n = 5 pairs, P = 0.98). The lengths of daily movement of a single bull , B105, in the wet and dry seasons were 1.5 and 2.1 km respectively.

Comparison of Gaur and Banteng.--Overall, the mean length of daily movement of gaur herds was 0.6 km greater than that of banteng herds (3.0±1.1 km; n = 11 versus 2.4±0.7 km; n = 11) (t = 1.59, 17 df, P = 0.065).

Table 5. Percentage of the overlapping areas between adjacent home ranges of gaur and banteng during the wet and dry seasons [1] in HKKWS, Thailand, 1994-1995.

Wet season	% Overlapping areas within gaur home ranges	Overlapping areas (km^2)	% Overlapping areas within banteng home ranges
Mean	23	8	29
Maximum	45	21.8	61
Minimum	3	1.5	3
n	10	10	10
Dry season	**% overlapping areas within gaur home ranges**	**Overlapping areas (km^2)**	**% overlapping areas within banteng home ranges**
Mean	3	0.7	3
Maximum	12	2.4	11
Minimum	0	0	0
n [2]	10	10	10

[1] Wet season = May-Oct, Dry season = Nov-Apr
[2] = Number of adjacent pairs of home ranges.

Table 6. Habitat use (percentage of locations in each habitat) by gaur and banteng during the wet and dry seasons compared with the habitat composition within home ranges of radio-collared gaur and banteng herd in Huai Kha Khaeng Wildlife Sanctuary, Thailand, 1994-1996.

Gaur	% Availability		Frequency use (%)	
Habitat Types	HRW	HRD	Wet Season	Dry Season
			n=287	n=137
Evergreen	13	27	12	46
Mixed-deciduous	63	61	67	44
Dry-dipterocarp	23	13	21	10

Banteng	% Availability		Frequency use (%)	
Habitat Types	HRW	HRD	Wet Season	Dry Season
			n=385	n=271
Evergreen	12	7.	4	8
Mixed-deciduous	72	76	80	75
Dry-dipterocarp	15	17	16	17

Remarks : HRW = Home range during the wet season
HRD = Home range during the dry season
IS = Observations from the intensive study (1994-1996)

Table 7. Elevation use (percentage of locations in each habitat) by gaur and banteng during the wet and dry seasons compared with the elevation composition of home ranges of radio-collared gaur and banteng herd in Huai Kha Khaeng Wildlife Sanctuary, Thailand, 1994-1996.

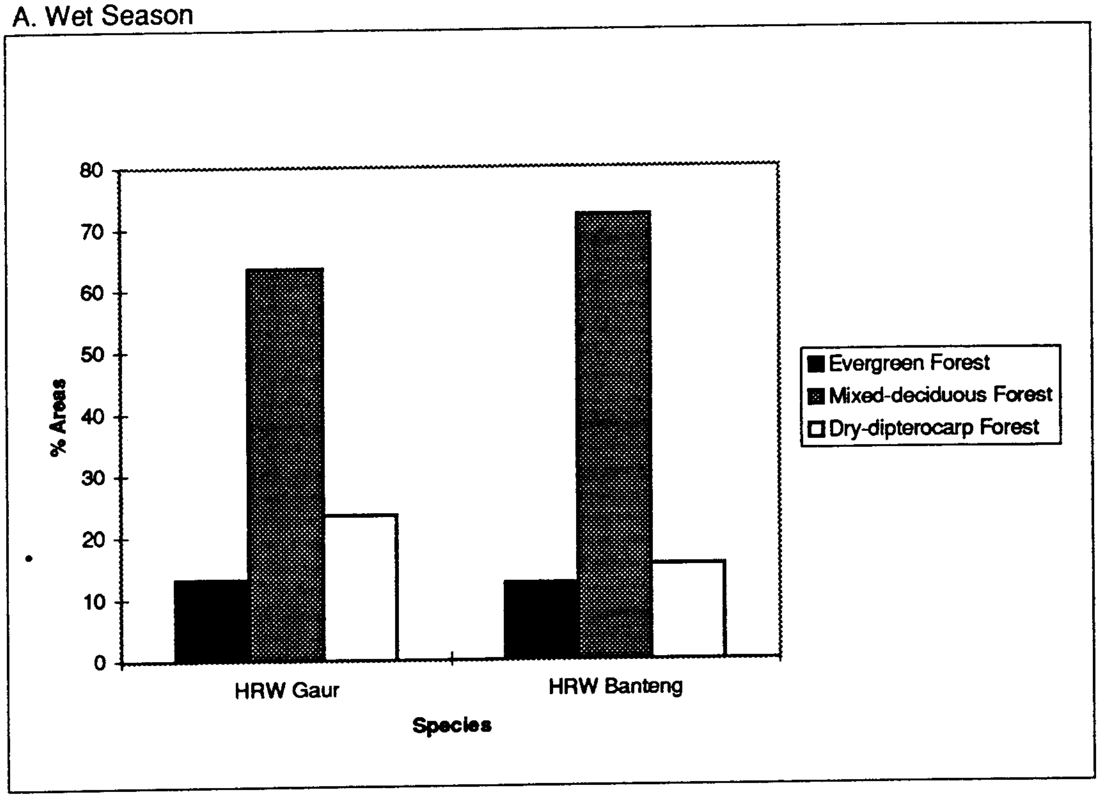
Gaur	% Availability		Frequency use (%)	
Elevation Zones (m)	HRW	HRD	Wet Season	Dry Season
			n=287	n=137
0-200	0	0	0	0
>200-400	26	25	36	27
>400-600	60	55	51	37
>600-1,700	14	20	14	36

Banteng	% Availability		Frequency use (%)	
Elevation Zones (m)	HRW	HRD	Wet Season	Dry Season
			n=385	n=271
0-200	0	5	0	10
>200-400	59	53	60	35
>400-600	40	42	39	55
>600-1,700	1	0	1	0

Remarks : HRW = Home range during the wet season
HRD = Home range during the dry season
IS = Observations from the intensive study (1994-1996)

Figure 10. Habitat types found within home ranges of gaur and banteng in the wet season (A) and in the dry season (B) in HKKWS, during 1994-1996.

A. Wet Season



B. Dry Season

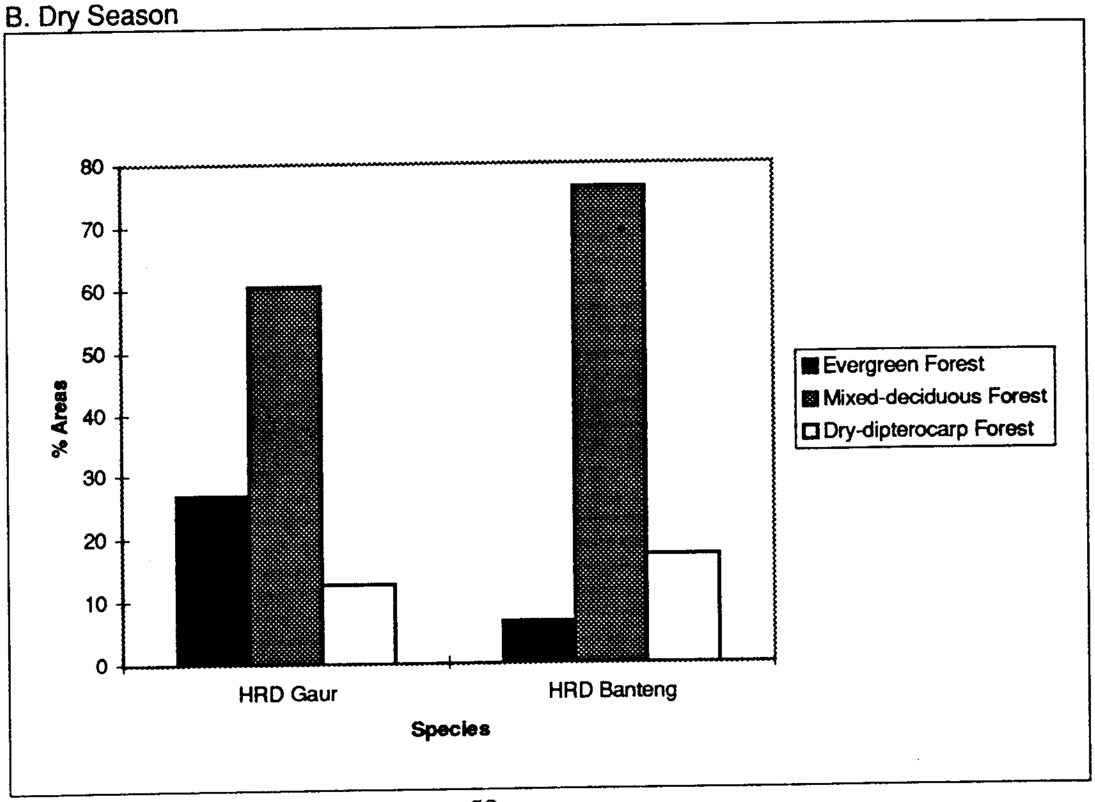
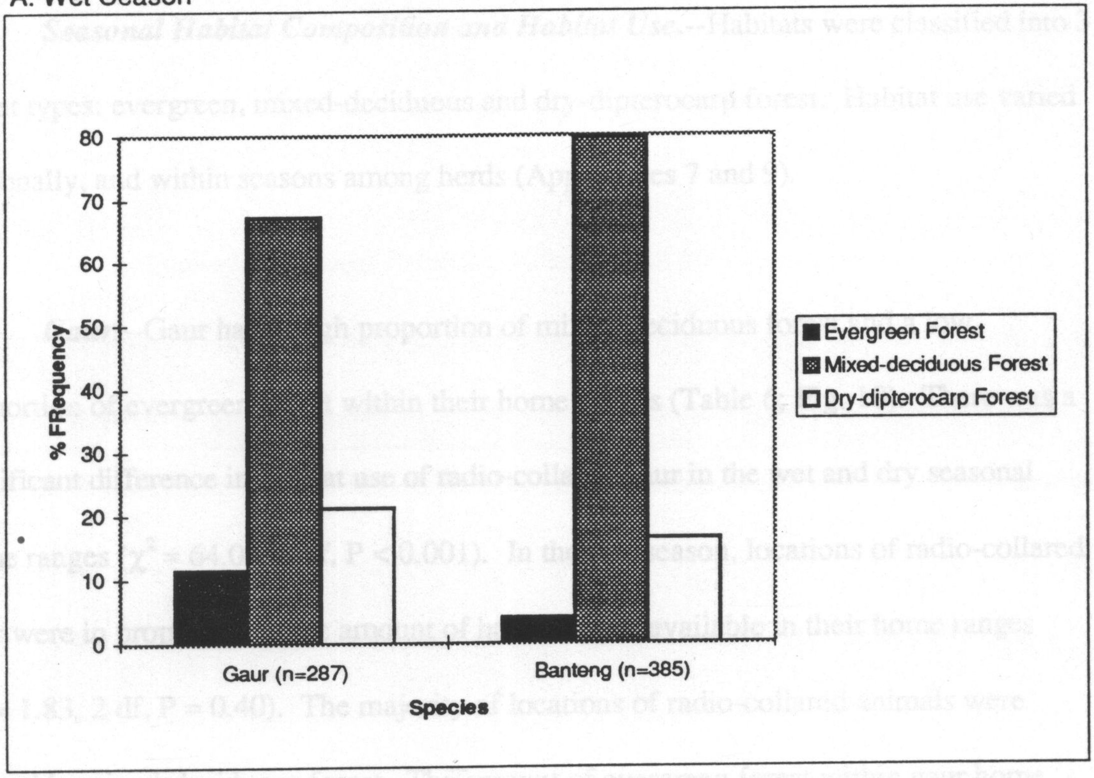
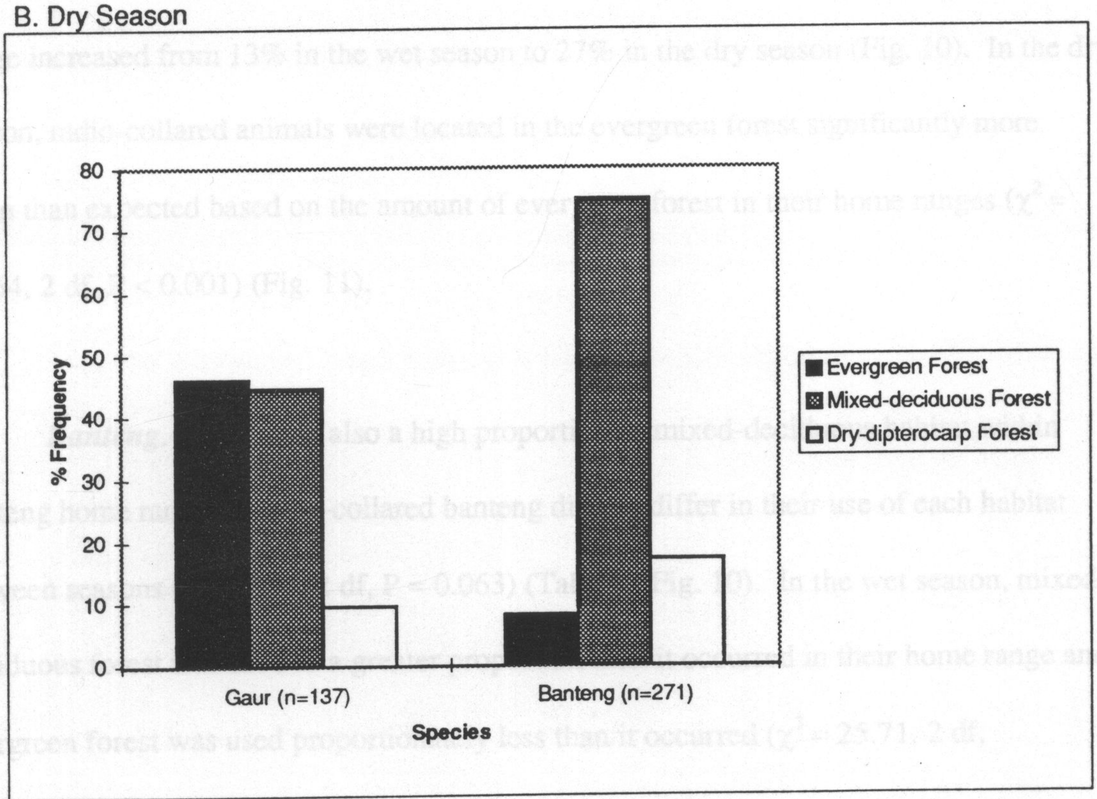


Figure 11. Habitat used by gaur and banteng from the intensive study in the wet season (A) and in the dry season (B) in HKKW, during 1994-1996.

A. Wet Season



B. Dry Season



Habitat Use

Seasonal Habitat Composition and Habitat Use.--Habitats were classified into 3 forest types: evergreen, mixed-deciduous and dry-dipterocarp forest. Habitat use varied seasonally, and within seasons among herds (Appendices 7 and 9).

Gaur.--Gaur had a high proportion of mixed-deciduous forest and a low proportion of evergreen forest within their home ranges (Table 6; Fig. 10). There was a significant difference in habitat use of radio-collared gaur in the wet and dry seasonal home ranges ($\chi^2 = 64.06$, 2 df, $P < 0.001$). In the wet season, locations of radio-collared gaur were in proportion to the amount of habitat types available in their home ranges ($\chi^2 = 1.83$, 2 df, $P = 0.40$). The majority of locations of radio-collared animals were located in mixed-deciduous forest. The amount of evergreen forest within gaur home range increased from 13% in the wet season to 27% in the dry season (Fig. 10). In the dry season, radio-collared animals were located in the evergreen forest significantly more often than expected based on the amount of evergreen forest in their home ranges ($\chi^2 = 25.64$, 2 df, $P < 0.001$) (Fig. 11).

Banteng.--There was also a high proportion of mixed-deciduous habitat within banteng home ranges. Radio-collared banteng did not differ in their use of each habitat between seasons ($\chi^2 = 5.54$, 2 df, $P = 0.063$) (Table 6; Fig. 10). In the wet season, mixed-deciduous forest was used in a greater proportion than it occurred in their home range and evergreen forest was used proportionately less than it occurred ($\chi^2 = 25.71$, 2 df, P < 0.001) (Fig. 11). Dry-dipterocarp forest was used in proportion to its availability. In the dry season all habitats were used in proportion to their availability ($\chi^2 = 1.01$, 2 df, P = 0.60). Radio-collared animals were mainly located in mixed-deciduous forest (Fig. 11).

Comparison of Gaur and Banteng.--The mixed-deciduous forest was the main habitat type found in radio-collared gaur and banteng home ranges (Fig. 10). In both seasons, the percentage of this habitat within banteng home ranges was higher than that within gaur home ranges (72% versus 64% in the wet season and 76% versus 61% in the dry season).

In the wet season, mixed-deciduous forest was the cover type most used by both gaur and banteng (68% and 80% respectively) (Fig. 11). In the dry season, banteng habitat use was similar to that in the wet season, but gaur habitat use of evergreen forest increased from 12% to 46% (Fig. 11). Mixed-deciduous forest is very important for both gaur and banteng all year long and is the habitat type in which they have the largest overlap.

Seasonal Elevation Composition and Elevation Use.--Elevation was classified as: low-flat (≤ 200 m), foothills (> 200 to 400 m), mid-flat (> 400 to 600 m), and high (> 600-1,700 m) zones. Elevation use varied seasonally, and within season among herds (Appendices 8 and 10).

Gaur.--Gaur home ranges had a significantly higher proportion of mid-flat habitats in both seasons (Table 7; Fig. 12). The high zone was smaller than expected in both seasons but increased from 14% in the wet season to 20% in the dry season. Between the wet and dry seasons, radio-collared gaur used elevations in different proportions than they occurred within their home ranges ($\chi^2 = 27.73$, 2df, $P < 0.001$). During the wet season, they had a preference for mid-flat zone (mean elevation = 451±53 m, n = 7 herds) and avoided the low-flat zone($\chi^2 = 15.82$, 2 df, $P < 0.001$) (Fig. 13). In the dry season, they shifted to the higher elevation zone (mean elevation = 566±77 m, n = 8 herds) and also avoided using the ≤ 200 m zone ($\chi^2 = 26.03$, 2 df,

$P < 0.001$).

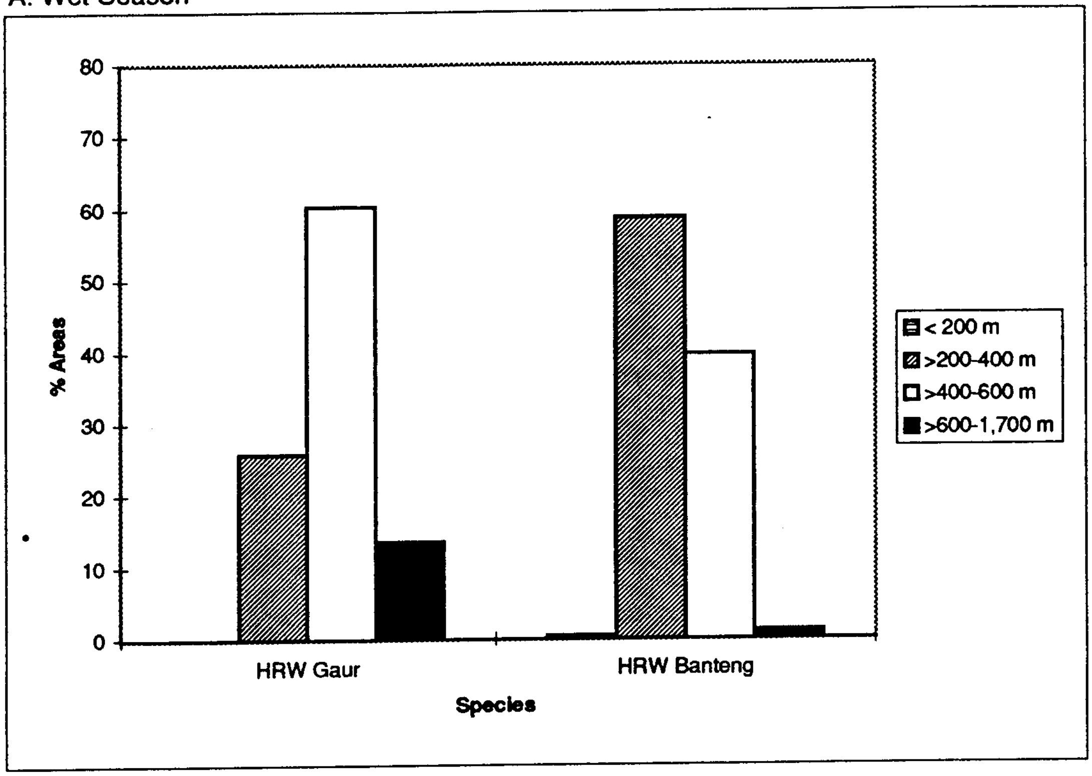
Banteng.--In both seasons, banteng had a high proportion of the foothills and mid-flat zone within their home ranges and a low proportion of the high zone (Table 7; Fig. 12). The distribution of elevation zones within their home ranges did not change between seasons.

Radio-collared banteng used elevation zones in the wet season in proportions different from those used in the dry season ($\chi^2 = 59.79$, 3 df, $P < 0.001$) (Fig. 13). In the wet season, the foothills and mid-flat zone within their home ranges were used in proportion to their availability (mean elevation = 354±80 m, n = 9 herds) ($\chi^2 = 0.22$, 3df, $P = 0.97$). In the dry season, however, they used the low-flat, foothills and mid-flat zone more than expected (mean elevation = 350±113 m, n = 10 herds) and avoided high elevations ($\chi^2 = 36.66$, 3 df, $P < 0.001$).

Comparison of Gaur and Banteng.--In both seasons, the mid-flat zone was the most abundant zone within gaur home ranges while the foothills and mid-flat zones were the most abundant within banteng home ranges (> 94%) (Fig. 12).

Figure 12. Elevation zones found within home range of gaur and banteng in the wet season (A) and in the dry season (B) in HKKWS, during 1994-1996.

A. Wet Season



B. Dry Season

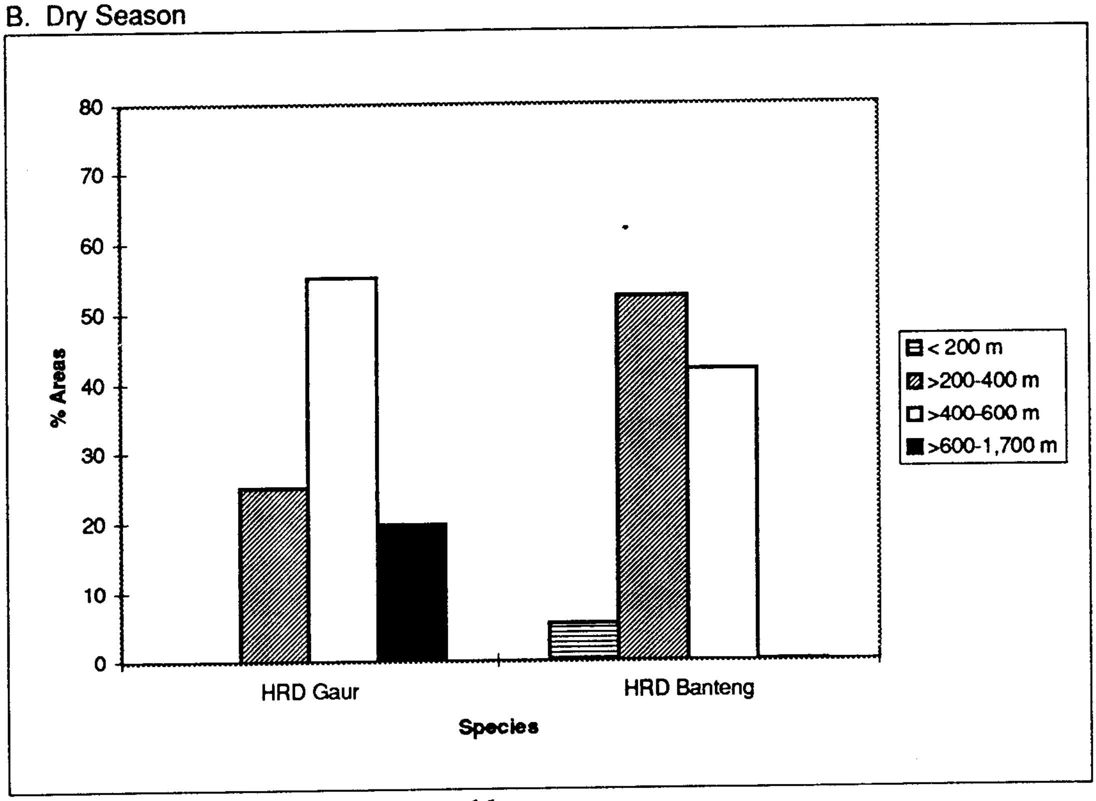
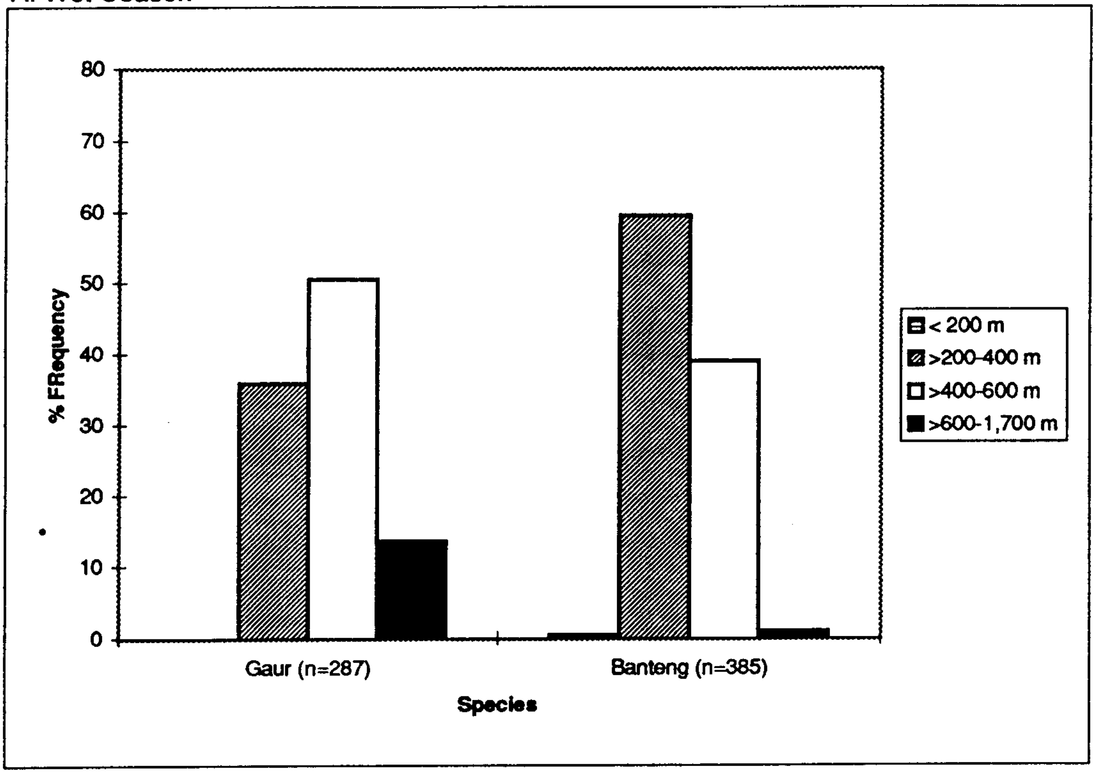
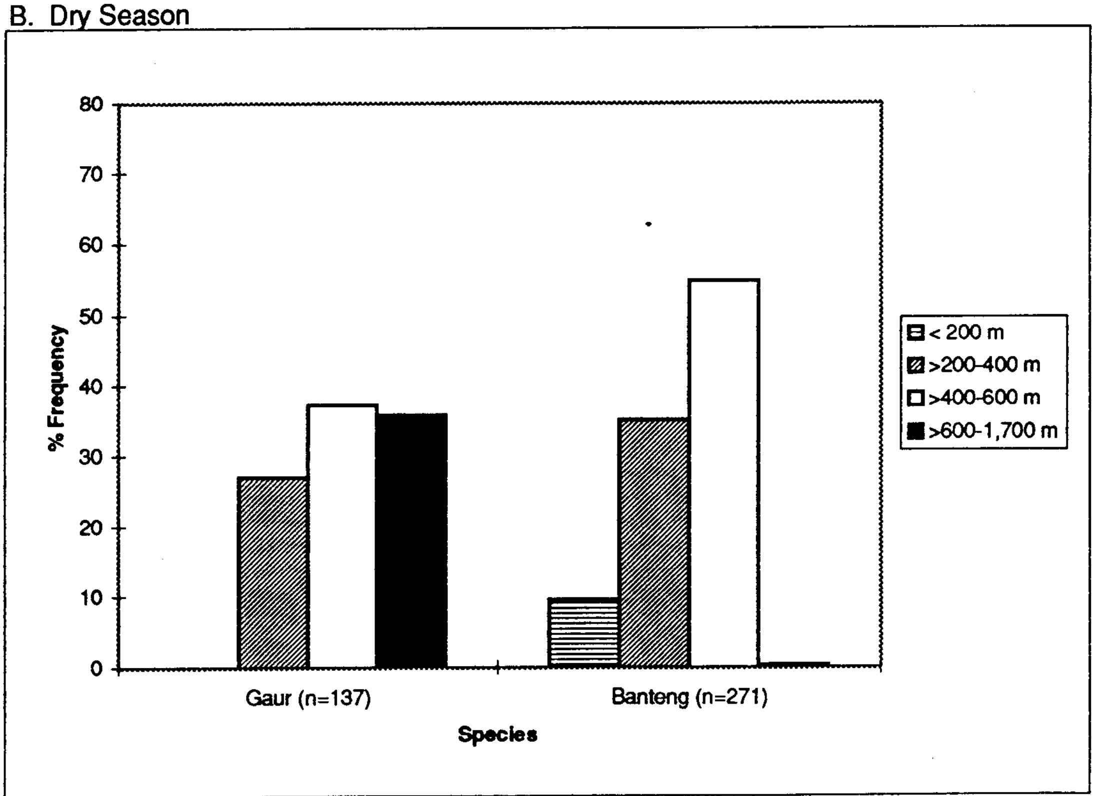


Figure 13. Elevation zones used by gaur and banteng from the intensive study in the wet season (A) and in the dry season (B) in HKKWS, during 1994-1996.

A. Wet Season



B. Dry Season



In the wet season, the foothills and mid-flat zone were the primary overlap zones. The ≤ 200 m zone was avoided by both gaur and banteng ($\chi^2 = 63.95$, 2 df, $P < 0.001$) (Fig. 13). In the dry season, the ≤ 200 m zone was also avoided by gaur but used more than expected by banteng (Fig. 13) ($\chi^2 = 96.79$, 2 df, $P < 0.001$). In both seasons, the high zone was used by gaur but avoided by banteng (Fig. 13).

During the LTS, gaur typically fed at significant higher elevations than banteng in both seasons (mean = 488±128 m, N = 286 versus 371±121 m, N = 409) (Z = 12.08, $P < 0.001$). A similar pattern was also seen during the IS (505±86 m, n = 15 versus 353±96 m, n = 19) (t-test = 4.853, 31 df, $P < 0.001$).

DISCUSSION AND CONCLUSION

Comparison of Distribution, Herd Size and Herd Structure

During 1994-1995, I estimated 300-335 gaur and 240-270 banteng in HKKWS, which is similar to Srikosamatra (1993) who estimated about 290 gaur, and 290 banteng in HKKWS in 1993 by dung count. These 2 estimates are surprisingly similar despite the difference in techniques. The difference between the 2 studies may be due to the animals I overlooked during the aerial surveys or misidentification of tracks associated with dung during Srikosamatra's census.

For most herd classes, group sizes were not different between gaur and banteng in the dry season, though in the wet season they were slightly different. In the largest herd size class (≥ 16 individuals), however, group sizes were often different in both seasons.

I often found higher numbers in the gaur herds than in the banteng herds (40 versus 30 individuals in the wet season and 32 versus 24 in the dry season). These larger sizes represent herds of gaur and banteng gathering near mineral licks or mineral rich springs and have also been observed in Nepal (Smith, JLD, Univ. of Minnesota, pers. comm.).

Both species had large group sizes in the dry season, which was also the birthing season. There may be selective advantages in associating with other individuals, such as greater chances of avoiding predation, even though such a grouping may be at the expense of increased competition for food. Another reason group sizes may be larger in the dry season is that water and mineral sources are limited in this season. Individuals of each species may walk in the same direction to water and mineral sources, and meet another group before or after visiting these resources.

The dry season in HKKWS is 6 months long and the driest period is from January to April. In order to obtain enough food for pregnant and lactating females and new calves, mating and resulting births may vary with the degree to which gaur and banteng were restricted seasonally. According to Lekagul and McNelly (1977), gestation periods of gaur and banteng are 9-10 months, and the peak birth months for both species are February-July and a few brown calves were observed in August. Therefore, June to November should be the mating season for both species and this is when I observed the most mating activity.

Wharton (1957), Hoogerwerf (1970) and Nuthong (1984) reported that pregnant female banteng isolated themselves from the group 3-4 days from giving birth and then rejoined the herd with the calf about 1 week after the calf's birth. This is a similar to what I observed during my direct observations of gaur and banteng.

Comparison of Home Range Sizes and Extent of Seasonal Shifts

Home Range Sizes.--Seasonal home range sizes depends on herd sizes, seasonal variation, the availability of food in each season, mating season and predator disturbance (Mloszewski 1983). According to Conry (1989), home range size and configuration are also strongly influenced by physiographical features. Seasonal home range sizes of gaur were slightly larger than those of banteng in the wet season, whereas there were not significantly different in the dry season. Mean annual home ranges of gaur were larger than those of banteng. Gaur preference for habitat near permanent water is also reflected in the shorter mean distance to water of gaur locations versus banteng locations (Chapter 2).

In Malaysia, the annual home ranges of gaur varied from 26.9 to 137.3 km^2 (Conry 1989). The annual home range of a bull gaur in Malaysia was larger than an entire gaur herd (G205) in Thailand (137.3 km^2 versus 114.6 km^2). The difference between home range sizes of the gaur bull in Malaysia and the herd in HKKWS might be explained by the distribution of mineral sources in these areas. There were several mineral sources around study area 2 in HKKWS while there were only 3 sources at the study site in Malaysia. Additionally, male gaur roam widely to contact females in different herds; therefore, individual seasonal and annual home ranges of bulls might be larger than that of herds.

Male gaur roamed wider than male banteng. I speculated that male banteng were more sedentary because the smaller lone banteng was more susceptible to predation by tigers.

Predators may also influence home range size and movement of animals. During 1994-1995, tigers killed at least 6 adult banteng and a leopard killed 1 calf. Both gaur and banteng will feed in the same area for more than 2 weeks if no predator (e.g. tiger, red dog, leopard or human) disturbs them. The home range size of the banteng herd represented by B103 varied during 1994-1995. During > 60% of the observations of the banteng herd which included B103, tigers were seen directly and indirectly following and chasing females and calves. Additionally, during about 40% of all gaur observations, tiger tracks were observed. However, no gaur were killed by tigers during this study, probably because the gaur habitat choices and greater size makes this animal a less appealing prey species than banteng.

Extent of Seasonal Shifts.--The shift-distance index of gaur was greater than that of banteng. These data showed that gaur herds shifted longer distances from the wet to dry seasons than did banteng. This may be because major streams in the gaur home range were dry and food plants decreased in the dry season; therefore, gaur moved further to search for water and food. Banteng, however, are more tolerant to dry areas and were able to remain more sedentary during this season.

The mean distance between activity centers of adjacent gaur herds did not differ between the wet and dry seasons. Nor did the mean distance of activity centers of adjacent banteng herds differ between seasons. However, the mean distance of activity centers of adjacent gaur and banteng herds did differ between the wet and dry seasons.

Additionally, in the wet season, food was more abundant, and the degree of both intra and inter-specific competition was not high; therefore, animals could feed close to each other. In the dry season, the mean distance between activity centers of adjacent gaur herds was longer than that of adjacent banteng herds. In this season, however, water and resources decreased, bamboo became senescent and hard, and green vegetation was reduced. During this period gaur and banteng competed for resources which might cause clumping. However, the high temperature and dry habitat may affect to a greater body size of gaur and induce gaur to feed in more shade and higher elevations habitat. Therefore, gaur and banteng fed farther away from each other. The mean distance of activity centers of banteng herds to activity centers of adjacent gaur herds increased in the dry season, because gaur shifted to the hills and mean distance between herds increased (8.2 km versus 3.6 km in the wet season). When water and resources decreased, gaur probably experience a higher degree of intra-specific competition than banteng; therefore, gaur herds did not feed close together during the dry season.

Comparison of Seasonal Length of Daily Movements

In Malaysia, overall mean length of daily movement of gaur ranged from 0.6-1.5 km (Conry 1981). In Cambodia, banteng traveled 5-15 km per night (Wharton 1957). In HKKWS, the mean length of daily movement for gaur was longer than that of gaur in Malaysia, while the mean length of daily movement of banteng was shorter than that of banteng in Cambodia. This may be a result of the differences in habitat types and disturbances. The main habitat in Malaysia was evergreen forest with high rainfall, where fresh water and food were provided for gaur all year round; therefore, the mean length of daily movement of gaur was relatively short. The main habitat type in Cambodia was deciduous forest, and was burned by fire every dry season (Wharton 1957), during which time deforestation (slash and burn) and hunting increased (Wharton 1968, Lekagul and McNelly 1977). Thus, in order to find food and to survive, banteng in this habitat type were forced to move further than banteng in HKKWS. In both seasons, gaur moved longer daily distances than did banteng. In the wet season the mean length of gaur daily movement was 0.4 km longer than that of banteng while it was 0.7 km longer in the dry season. This result suggests that gaur, with its larger body and group size, spends more time feeding and searching for food than does banteng.

Comparison of Habitat and Elevation Use

Habitat and Elevation Composition in Home Ranges.--Mixed-deciduous forest was the most abundant habitat type in the sanctuary and it was in even higher proportions in gaur and banteng home ranges than expected in both seasons. Three species of bamboo and *Microstegium spp.*, which were the most preferred species of both animals, grow in this habitat. In the dry season gaur shifted its home range to encompass evergreen forest (27%) which was its second main habitat type. Banteng used this habitat type much less frequency (7%). Gaur liked to feed on green plants (e.g. herbs and shrubs) which were abundant in evergreen forest.

The most frequently found elevation zone within home range of gaur in both seasons was the mid-flat zone while the foothills zone was the most frequently found in banteng home ranges. Theses zones covered a large area of mixed-deciduous forest, in which bamboo and some grasses grew, and where many mineral licks and mineral rich springs were located. The low-flat zone was not found in gaur home ranges but it was found in banteng home ranges. The high zone was much more abundant in gaur home ranges than in banteng home range.

Seasonal Habitat and Elevation Use.--Numerous factors might promote the choice of specific habitats. For example, caribou often select open, windy sites for calving, but whether they do so to enhance the detection of predators, to feed at rich sites, to moderate body temperature, or to reduce insect harassment is uncertain (Downes et al. 1986, Ion and Kershaw 1989). Until the Second World War, gaur and banteng abundance and the extent of their distributions had probably been increasing due to shifting cultivation, which provides openings in the forest canopy and increase the density of ground cover. Both species have a high biomass in secondary forest (Hubback 1937, Yin 1967, Wharton 1968, Krishnan 1972, Medway 1978, Conry 1981). However, as human populations and development increased rapidly after World War II, habitat loss and habitat changed by fire, especially at low and high-flat elevation, increased rapidly. As habitat became more restricted both species were confined to smaller areas, often at high elevations, thus increasing the potential for overlap.

Potential competitors that overlap at a macro level can avoid competition within the general habitat type by ecological segregation in time, space, or food resources (Rosenzweig 1981, Schoener 1986, Putman 1996). In HKKWS gaur and banteng had the highest degree of overlap in mixed-deciduous forest at elevations between > 200-600 m.

Gaur completely avoided areas ≤ 200 m, while the high elevations were hardly used by banteng in either season. In the wet season both gaur and banteng were attracted to mixed-deciduous forest between > 200-600 m where new growth of several grasses, especially *Microstegium spp.* (Ya Pai) and shoots of 3 species of bamboo provide an abundance of high protein. However, gaur used more in the mid-flat zone and banteng used more in the foothills zone. The degree of overlap was much higher than in the dry season. As has been reported for other species, niche overlap was greater in the wet season because food resources were more abundant (Martinka 1968, Smith et al. 1978, Grant and Grant 1980, Putman 1996). Where they do overlap, the greater size of gaur may allow this species to dominate; however, I have never observed aggressive interactions between gaur and banteng when they occurred together at mineral rich spring or while feeding.

In the dry season, reduced shade due to leaf fall and fire, dry less palatable food, and reduced water supply resulted in a reduction in food resources for both species. Most grasses and bamboo within mixed-deciduous and dry-dipterocarp forest became tall, hard and dry. Gaur shifted to increase their use of the high zone by 22%. At this elevation the forest was primarily evergreen, and green browse and herb species were abundant. This habitat and elevation zone provided not only food, but also increased shade during the hottest season and permanent streams. Gaur still spent considerable time in mixed deciduous forest, and in both habitats 80% of their locations were within 1 km of permanent water (Chapter 2). Hutchinson (1961) suggested that animals can coexist because of environmental instability. When gaur shifted to the high zone during the dry season, banteng shifted to both higher and lower elevations. They increased their use of the mid-flat zone by 16% and their use of the low-flat zone by 8%. Banteng forage further from water than gaur and can tolerate more open, dryer areas where they exploit dry grasses, shrubs, herbs and the barks of *Adina cordifolia* and *Mytragyna brunonis*, which are high in calcium and water (Chapter 2).

I assume that gaur avoid the low-flat zone because in the dry season this habitat has little shade, high temperatures and very little water. In the wet season gaur feed heavily on bamboo at elevations > 200 m. In contrast banteng avoid the high zone in both seasons. They apparently are more adapted to grazing than browsing, and in the dry season were often observed feeding on both grasses and browse.

In conclusion, throughout their home ranges, gaur and banteng are able to adapt to a wide continuum of similar habitats (e.g. open to dense forests, dry to wet areas and low to high elevations). Mixed-deciduous forest in the > 200 to 600 m zones appeared to be the preferred habitat for both species, but as food became scarce in the dry season, gaur reverted to a browsing diet near shade and water, and banteng shifted to forage on dry grasses and browse further from water. The differences in their use of seasonal habitat and elevation may reduce the degree of resource competition between two sympatric bovids and allow them to coexist in HKKWS.

LITERATURE CITED

Alikodra H. 1987. The Ecology of banteng (*Bos javanicus*) in the National Park of Ujung Kulon. BIOTROP Spec. Publ. NO.30:161-167.

Anthony, R.G. and N. S. Smith. 1974. Comparison of rumen and fecal analysis to describe deer diets. J. Wildl. Manage. 38(3):535-540.

Ashby, K. R., and C. Santipillai. 1988. The status of the banteng (*Bos javanicus*) in Java and Bali. Tiger Paper Oct-Dec 1988:16-25.

Bhumpakphan, N. and N., Naksatit. 1991. Notes on the footprints of some even-toed ungulates in Huai Kha Khaeng Wildlife Sanctuary. J. Wildl. of Thailand. Vol 1(1) (Thai/English abstract).

Byers, C. R., Steinhorst, R. K., and Krausman, P. R. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050-1053.

Byers, O., S. Hedges and U. S. Seal. 1995. Asian wild cattle conservation assessment and management plan work document. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN.

Corbet, G. B. and J. E. Hill. 1992. The mammals of the Indomalayan region: A systematic review. Oxford University Press. New York. 488 pp.

Conforti, K. 1996. The status and distribution of small carnivores in Huai Kha Khaeng/Thung Yai Nareseun Wildlife Sanctuaries, West-Central Thailand. M. S. Thesis. Univ. Minnesota, St. Paul, MN. 66 pp.

Conry, P.J. 1981. Habitat selection and use, movements, and home range of Malayan gaur (*Bos gaurus hubbacki*) in Central Pahang, Malaysia. M. S. Thesis. Univ. of Montana, Missoula. 120 pp.

________. 1989. Gaur (*Bos gaurus*) and development in Malaysia. Ecological Conservation. 49:47-65.

Danilkin, A. 1996. Behavioral ecology of Siberian and European Roe Deer. Chapman & Hall, London. 277 pp.

Downes, C M., Theberge, J.B. and Smith, S.M. 1986. The influence of insects on the distribution, microhabitat choice, and behavior of the Burwash caribou herd. Can. J. Zool. 64:622-629.

Garshelis, D. L. (in press). Delusions in habitat evaluation: measuring use, selection and importance. Minnesota Department of Natural Resources, Grand Rapids, MN.

Grant, P. R., and B. R. Grant. 1980. The breeding and feeding characteristics of Darwin's Finches on Isla Genovesa, Galapagos. Ecological Monographs. 50(3):381-410.

Hedges, S. (in press). Asian Wild Cattle and Buffaloes: Status Report and an Action Plan for their Conservation. IUCN/SSC Asian Wild Cattle Specialist Group.

Hoogerwerf, A. 1970. Udjung Kulon: The land of the last Javan Rhinoceros. E. J. Brill-Leiden, Netherlands. 512 pp.

Hubback, T. R. 1937. The Malayan gaur or seladang. J. Mammal. 18:267-279.

Hutchinson, G. E. 1961. The paradox of the plankton. American Naturalist. 95:137-145.

Humprey, S. R. and J. R. Bain. 1990. Endangered Animals of Thailand. Sandhill Crane Press, Inc., Gainesville, Florida. 468 pp.

Ion, P.G. and Kershaw, G. P. 1989. The selection of snow patches as relief habitat by woodland caribou (*Rangifer tarandus* caribou), MacMillian Pass, Selwyn/ Mackenzie Mountains, NWT, Canada. Arctic Alp. Res. 203-211 pp.

IUCN 1994. IUCN Red List Categories. IUCN Species Survival Commission. Gland, Switzerland: IUCN.

Joshi A. R., D. L. Garshelis, and J. L. D. Smith. 1995. Home ranges of sloth bears in Nepal: Implications for Conservation. J. Wildl. Manage. 59(2):204-214.

Khoi Vu Le. 1995. The status of wild cattle and their conservation in Vietnam. Faculty of Biology, Hanoi University, Vietnam. 6 pp.

Krausman, P. R. 1978. Forage relationships between two deer species in Big Bend National Park, Texas. J. Wildl. Manage. 42:101-107.

Krebs, C. J. 1994. Ecology: The experimental analysis of distribution and abundance (4^{th}). HapperCollins College Publishers, New York. 801 pp.

Krishnan 1972. Gaur *in* an ecological survey of mammals of India. J. Bombay Nat. Hist. Soc. 69(2):322-349.

Lekagul, B. and J. A. McNeely. 1977. Mammals of Thailand. The Association for the Conservation of Wildlife, Bangkok, Thailand. 758 pp.

Manly, B.F.J., L. M. McDonald, and D. Thomas. 1993. Resource selection by animals: Statistical design and analysis for field studies. Chapman and Hall, London. 177 pp.

Martinka C. J. 1968. Habitat relationships of white-tailed and mule deer in northern Montana. J. Wild. Manage. 32(3):558-565.

Mathur, V. B. 1991. Ecological interaction between habitat composition, habitat quality and abundance of some wild ungulates in India. Ph D. Thesis, University of Oxford (cited in Putman 1996).

Medway, L. 1965. Mammals of Borneo. Malayan Branch of the Royal Asiatic Society, Singapore.

_______, L. 1978. The Wild Mammals of Malaya (Peninsula Malaysia) and Singapore. Oxford University Press, Kuala Lumper.

Mloszewski M. J. 1983. The behavior and ecology of the African buffalo. Cambridge Univ. Press. 256 pp.

Moorman, F. R. and Rojanasoonthon, S. 1967. General soil map of Thailand, Department of Land Use, Ministry of National Development, Bangkok.

______________________________. 1972. The soils of the Kingdom of Thailand: Explanatory text of the general soil map. Land Development Department, Bangkok.

Nakhasathien, S. and B. Stewart-Cox. 1990. Nomination of the Thung Yai - Huai Kha Khaeng Wildlife Sanctuaries to be a U.N.E.S.C.O. World Heritage Site. Wildlife Conservation Division, Royal Forest Department, Thailand, 128 pp.

Neu, C.W., C.R. Byers and J. M. Peck. 1974. A technique for analysis of utilization availability data. J. Wildl. Manage. 38:541-545.

Nuthong, T. 1984. Social behavior of banteng (*Bos banteng lowi*). Pages 131-144 *in* Proceedings of the 1984 Royal Forest Department Annual Seminar, Bangkok (Thai/English abstract).

Oliver, R. and Woodford, M. 1994. Aerial surveys for kouprey in Cambodia March 1994. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

Payne, J. 1990. Transfrontier protected areas in Borneo: (1) Conservation in the Sabah border regions. A report submitted to WWF Malaysia and the Government of Sabah. WWF Malaysia, Kuala Lumpur, West Malaysia.

Prayurasiddhi, T. 1987. Ecology of banteng (*Bos javanicus* D' Alton 1823) in Huai Kha Khaeng Wildlife Sanctuary, Thailand. M. S. Thesis. Kasetsart Univ., Bangkok, Thailand (in Thai / English abstract).

Putman, R. J. 1996. Competition and resources partitioning in temperate ungulate assemblies. Chapman & Hall. London, UK. 131 pp.

Robbins, C. T. 1993. Wildlife feeding and nutrition. Academic Press, Inc., California. 352 pp.

Rosenzweig, M. L. 1981. A theory of habitat selection. Ecology. 62(2):327-335.

Salter, R. E. 1983. Summary of currently available information on internationally threatened wildlife species in Burma. FAO Nature Conservation and National Parks Project. Field Document 7/83 Fo: BUR/80/006. FAO, Rangoon, Burma (cited in Hedge in press).

Schoener, T.W. 1986. Resource Partitioning. Pages 91-126 *in* J. Kikkwa and D. J. Anderson, eds. Community ecology: Pattern and process. Blackwell, Melbourne, Australia..

Smith W. P. 1987. Dispersion and habitat use by sympatric Columbian white-tailed deer and Columbian black-tailed deer. J. Mammal. 68(2):337-347.

Smith, J.N.M., P. R. Grant, B. R. Grant, I. J. Abbott, and L. K. Abbott. 1978. Seasonal variation in feeding habits of Darwin's ground finches. Ecology 59(6): 1137-1150.

Srikosamatara, S. 1993. Density and biomass of large herbivores and other mammals in dry tropical forest, western Thailand. J. Trop. Ecol. 9: 33-43.

Srikosamatara, S. and V. Suteethorn. 1995. Populations of gaur and banteng and their management in Thailand. Nat. Hist. Bull. Siam Soc. 43:55-83.

Stott, P. 1984. The savanna forests of mainland Southeast Asia: an ecological survey. Prog. Phys. Geogr. 8(3):315-335.

______. 1988. The spatial pattern of dry season fires in the savanna forests of Thailand. J. Biogeogr. 13:345-358.

Thitatummakul, P. 1985. Vegetation change along altitudinal gradient in Huai Kha Khaeng Wildlife Sanctuary. M. S. Thesis, Kasetsart Univ., Bangkok, Thailand (Thai/English abstract).

Underwood, E. J. 1977. Trace elements in human and animal nutrition. Academic Press, New York.

Weins, J. A. 1977. On competition and variable environments. American Scientist. 65:590-597.

Wharton, C.H. 1957. An ecological study of the kouprey, *Novibos sauveli* (Urbain). Monographs of the Institute of Science and Technology, Monograph 5, Manila, Philippines (cited in Hedge in press).

___________. 1966. Man, fire and wild cattle in North Cambodia. Proceeding Fifth Annual Tall Timbers Fire Ecology Conference. 5: 23-65

___________. 1968. Man, fire and wild cattle in Southeast Asia. Proceeding Annual Tall Timbers Fire Ecology Conference. Volume 8, Tallshassee, Florida.

White, G. C. and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., London. UK.

Wilson, D. S. 1975. The adequacy of body size as a niche difference. Amer. Natur. 109:769-784.

Worton, B. J. 1987. A review of models of home range for animal movement. Ecol. Model. 38:277-298.

Yin, U. T. 1967. Wild animals of Burma. Rangoon Gazette Ltd., Rangoon, Burma. 301 pp.

Yasuma, S. 1994. An invitation to the mammals of East Kalimantan. Tropical Rain Forest Research Project JTA-9(a)-137, Japan International Cooperation Agency and Directorate General of Higher Education, Republic of Indonesia. *PUSREHUT* Special Publication No. 3 (cited in Hedges in press).

CHAPTER 2

FOOD HABITS AND RESOURCE PARTITIONING OF GAUR AND BANTENG

ABSTRACT

Food habits and resource partitioning of gaur and banteng, two large sympatric wild bovids, were studied from 1983-1996 to determine how they coexist in the Huai Kha Khaeng Wildlife Sanctuary, Thailand. Four gaur and 7 banteng were captured and radio-collared during 1994-1995, then monitored intensively for ≤ 2.5 years to examine food habits, daily activity patterns, and distribution and activity patterns in relation to water and mineral sources. Food plant species and plant types eaten by gaur and banteng were examined through direct foraging observations and fecal analysis. During the wet season, *Microstegium ciliatum* and shoots of 3 bamboo species were the most abundant high protein food sources for both animals in the mixed-deciduous forest. Although there was greater overlap in their diets in the wet season, there was not greater competition for food resources because food resources were more abundant. During this season banteng fed closer to mineral licks than gaur. In the dry season, food resources were more limited because the nutritional quality of plant foods and overall plant biomass declined. Additionally, the availability of mineral and water sources was greatly reduced, forcing both species to restrict their foraging to areas near water sources. During this season, gaur shifted to evergreen forest, which generally occurs at higher elevations, and remained closer to water than did banteng. With this shift to evergreen forest, gaur fed more on green browse and herb species, while banteng fed more on dry grasses and browse at lower elevations. Banteng also consumed the barks of *Adina cordifolia* and *Mytragyna brunonis*, which are high in calcium and water. Finally, in the dry season when the quality and quantity of forage is lowest, gaur spend more time active (feeding and walking), and less time resting. The increase in time spent feeding in the dry season by gaur reflects the greater need to search to obtain an adequate supply of high quality food. Seasonal differences in the two species activity patterns and their use of food and habitat reduce the degree of interspecific competition and enable gaur and banteng to coexist within Huai Kha Khaeng Wildlife Sanctuary.

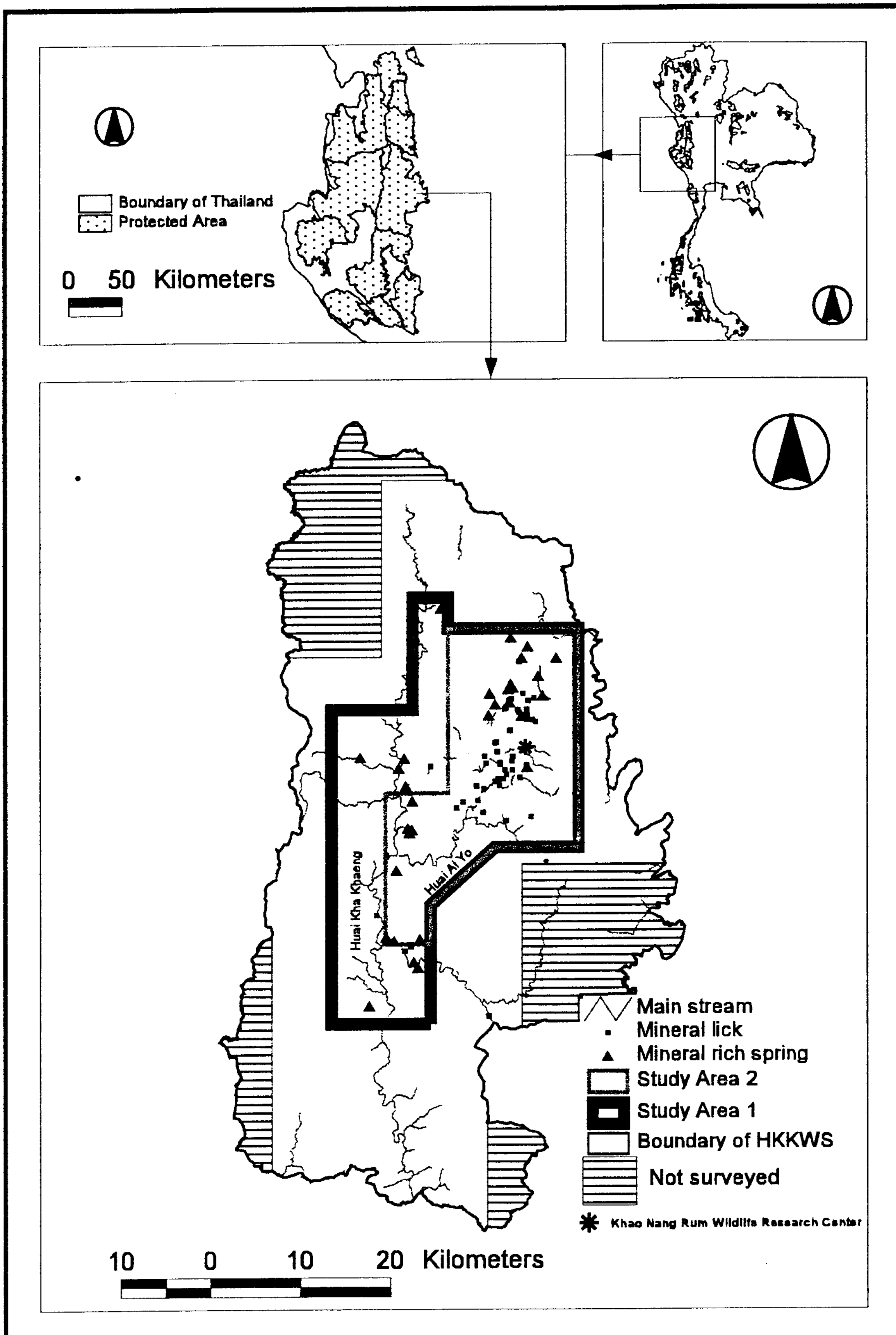
INTRODUCTION

Distribution and utilization of space by individuals of the same or similar species is often a result of competition or competitive avoidance (Hawes 1977). Gaur *(Bos gaurus)* and banteng (*Bos javanicus)* are sympatric, congeneric bovids that occur in various habitats throughout the forest of South east Asia (Byers et al. 1995, Hedges in press). They appear to have similar ecological requirements and coexist within many protected areas of Thailand. Similar physiology and a close phylogenetic relationship suggest that these species may have similar energy and nutritional requirements. The fact that they also have a high degree of home range overlap during part of the year suggests that these species might compete for the same food resources. In this study I examine the food habits of gaur and banteng to determine the overlap in their diet. The degree to which diet and habitat use overlap highlights similarities while the degree to which they use different foods will help elucidate the extent of ecological separation between these species.

There are several methods to investigate wildlife diets. Most of those methods fall into one of three broad categories (Litvaitis et al. 1994): 1) observational, where animals are observed ingesting food; 2) feeding site surveys, where the amount of vegetation removed by foraging animals is measured or estimated; and 3) post-ingestion samples, where the remains of food in gastrointestinal tracts, feces, or regurgitated pellets are identified. Direct foraging observation has been a widely used technique for estimating food habits of large herbivores; however, this technique is limited to diurnal/crepuscular herbivores living in relatively open habitats (Litvaitis et al. 1994). The most commonly used procedure for studying food preferences of ungulates has been by volumetric rumen analysis (Dirschl 1962, Martinka 1968). Consequently, biologists have often analyzed fecal samples microscopically for the remains of identifiable plant cuticles (Anthony and Smith 1974). Since every plant species has unique cuticle characteristics, and most plant cuticles are not digested in ruminant digestive processes, forage plants can be identified in fecal samples of grazing or browsing herbivores (Martin 1955, Adams 1957, Stewart 1965, 1967, Stewart and Stewart 1970). Fecal analysis has been used successfully with large and medium size mammals in many parts of the world (Martin 1955, Hercus 1960, Storr 1961) such as with waterbuck in Africa, serow in Thailand and deer in USA (Kiley 1966, Żyznar and Urness 1969, Chimchom 1993). It has also been used to study food habits of cottontail rabbits and pocket gophers (Dusi 1949, Myers and Vaughn 1964).

In this study, I examined food habits of gaur and banteng from 1983-1996 in both the wet and dry seasons by direct observation of non-radiocollared animals within areas where they overlap and do not overlap; in 1994-1996 in study area 1; non-radio-collared and radio-collared animals within study area 2 were observed from 1994-1995. In addition, fecal samples of radiocollared and non-radio-collared gaur and banteng in different seasons during 1994-1995 were collected, analyzed and compared with the direct observation method within study area 2. The distance that animals fed from mineral licks and springs was examined and the time periods when animals were using the licks and springs were also determined. Finally, activity patterns (feeding, mineral licking and drinking, resting etc.) were observed during 1983-1996.

Figure 1. Location of Huai Kha Khaeng Wildlife Sanctuary, and study areas 1 and 2


Boundary of Thailand
Protected Area
0 50 Kilometers
Huai Kha Khaeng
Huai Ai Yo
Main stream
Mineral lick
Mineral rich spring
Study Area 2
Study Area 1
Boundary of HKKWS
Not surveyed
Khao Nang Rum Wildlife Research Center
10 0 10 20 Kilometers

STUDY AREA

Huai Kha Khaeng Wildlife Sanctuary (HKKWS) is located in the western forest complex of Thailand and encompasses an area of 2,575 km^2 (14° 56' - 15° 48' N, 98° 27' - 99° 30' E). It was established in 1972 and subsequently expanded in 1986 and again in 1992 (Fig. 1). HKKWS and the contiguous Thung Yai Nareseun Wildlife Sanctuary (3,647 km^2) to the west together were recently designated a Natural World Heritage Site by UNESCO. These sanctuaries, along with 14 protected areas to the north and south, make up one of the largest protected area complexes in mainland Southeast Asia (Nakhasathien and Stewart-Cox 1990, C. Pitdamkam, RFD, pers. comm. 1995).

I selected two concentric study areas within HKKWS (study areas 1 and 2; Fig 1) which comprised about 851 (33 %) and 477 (18.5 %) km^2 of HKKWS, respectively. In study area 1, I collected data over 13 years by direct observation, and in study area 2, I intensively studied radio-collared animals for 2 years. The larger study area (study area 1) contained parts of three watersheds, Huai Tap Salao-Huai Song Tang, Huai Chang Tai-Huai Ai Yo and Huai Kha Khaeng. The elevations in the study area ranged from 100 m. to 1,600 m.

Habitat Types

Vegetation in HKKWS is a mosaic of different forest types previously described by Stott (1984,1988), Thitathamakul (1985) and Nakhasathien and Stewart-Cox (1990) (Appendix 1).

Evergreen forest comprises 1,319 km^2 or 47 % of the sanctuary and 30 % of study area 1 and 21 % of study area 2. Thitathamakul (1985) classified evergreen forest into hill evergreen forest and dry evergreen forest. Hill evergreen forest is found at elevations over 1,000 m. The dominant tree species are oaks of the families Fagaceae (genus *Lithocarpus, Castanopsis* and *Quercus*), Podocarpaceae and Cephalotaxaceae. Dry evergreen forest is found along the tributaries and grows at elevations between 100-1,000 m. This forest type is very tall, dense, and stratified by height, and is dominated by trees of the *Dipterocarpus* genus such as *Dipterocarpus alatus* and *D. turbinatus*. Ground cover consists of seedlings, ferns, rattans, palms, vines, grasses and shrubs.

Mixed deciduous forest comprises 1,307 km^2 or 47 % of the sanctuary, and 57 of study area 1 and 49 % of study area 2. It is found on flat and moderately sloping areas, and is the most common forest type in both study areas. The dominant species (mostly tall trees) are *Lagerstroemia calyculata, Xylia xylocarpa* and *Afzelia xylocarpa*. Bamboo is quite common among the middle story species and is found in some areas in pure stands. The canopy of mixed deciduous forest is open. Ground cover is very dense in the wet season and more open in the dry season. Dominant ground species are *Pueraria barbarta, Desmodium spp.* and *Dioscorea spp.*

Dry dipterocarp forest comprises 164 km^2 or 6 % of the sanctuary, and 13 % of study area 1 and 12 % of study area 2. It is commonly found further from streams, and has a slightly rocky slope with less fertile soils. The dominant tree species are *Shorea obtusa, S. siamensis, Dipterocarpus tuberculatus,* and *D. obtusifolius*. Ground cover species include grasses, herbs and saplings. In dry areas, a palm like plant, *Cycas siamensis* sometimes occurs. During the dry season, accidental fires burn the undergrowth, playing an important role in the forest ecosystem.

Secondary forest comprises 19 km^2 or 1 % of the sanctuary, and 0.08 km^2 of study area 1 and 0.06 km^2 of study area 2. However, I excluded this type of forest from our analysis of habitat use because this area is occupied by humans, and gaur and banteng do not feed here. The land is occupied by local people who practice swidden farming and hold sanctuary buildings. This habitat is mostly in the eastern and southern parts of the sanctuary and is found in the northeast of both study areas. Some secondary forest trees also grow in the primary forest, such as *Lagerstroemia macrocarpa, Vitex peduncularis, Bauhinia acuminata, Melia azedarach, Sterculia spp.* and *Macaranga spp.* Banana trees occupy wet areas along with bamboo. The under-story is a tangle of thorny shrubs and climbers.

Elevation Ranges

The habitat types are associated with elevation ranges (Thitathamakul 1985). I classified the elevation ranges or vertical zones into 4 classes: 0-200 m (low-flat), > 200-400 m (foothill), > 400-600 m (mid-flat), and > 600-1,700 m (high). Within the sanctuary, each elevation range occupied 88, 624, 835 and 1,262 km^2 or 3, 22, 30, and 45% of the sanctuary respectively (Appendix 1).

The low-flat zone is found in the eastern part of HKKWS. In the dry season, these areas are very dry because of the rainshadow effect. The foothill zone is comprised of small plains and adjacent hills. Bamboo is abundant in this zone. The mid-flat zone is mainly found along the valley of Khao Khiew-Khao Nam Yen Range in the eastern part of HKKWS and Khao Yang Daeng-Khao Chonglom-Khao Foilom Range in the center of the sanctuary, and there is also a strip between the valley of Khao Yang Daeng-Khao

Chonglom-Khao Foilom Range and the mountain ranges in the western part of the sanctuary. Finally, the high steep zone is comprised of mountains ranging from 600 to 1,700 m in the north, east, west and central parts of the sanctuary.

Fauna

There are 17 species of medium and large mammals (> 20 kg) in HKKWS; 8 are carnivores and 9 are ungulates (Nakhasathien and Stewart-Cox 1990, Conforti 1996) (Appendix 2).

Soil Types

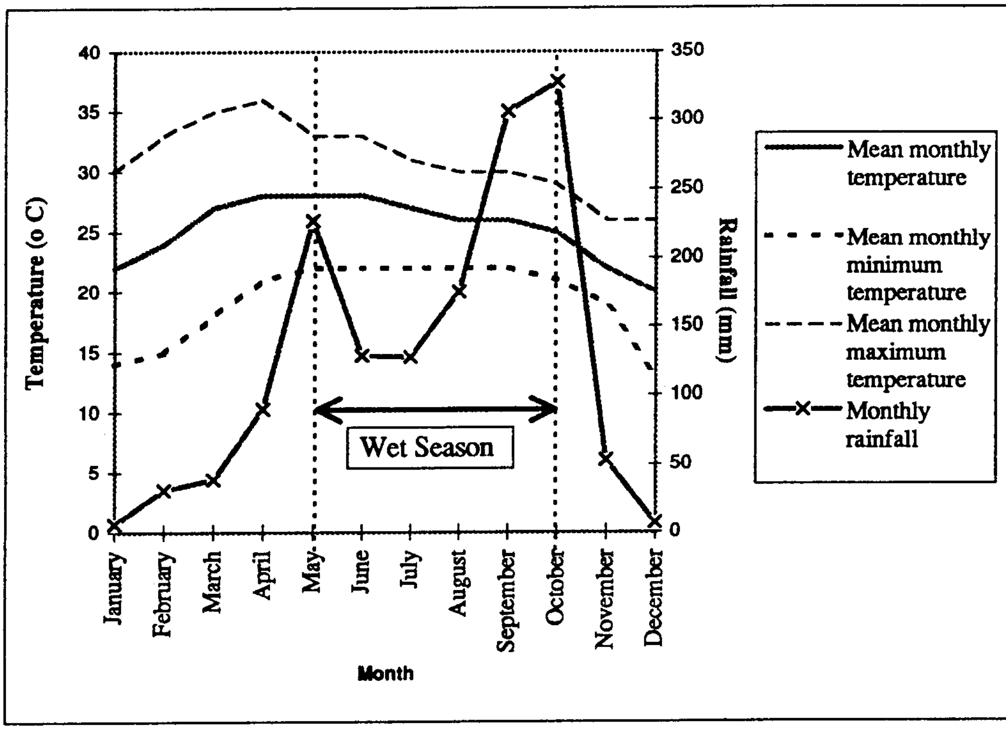
Two main soil groups occur in the sanctuary: red-brown soils derived from limestone, and red-yellow podzolic soils derived from granite (Moorman and Rojanasoonthon 1967, 1972, Nakhasathien and Stewart-Cox 1990). These soils apparently have the same distribution patterns as the rocks from which they were derived (Nakhasathien and Stewart-Cox 1990).

Mineral Licks and Mineral Rich Springs

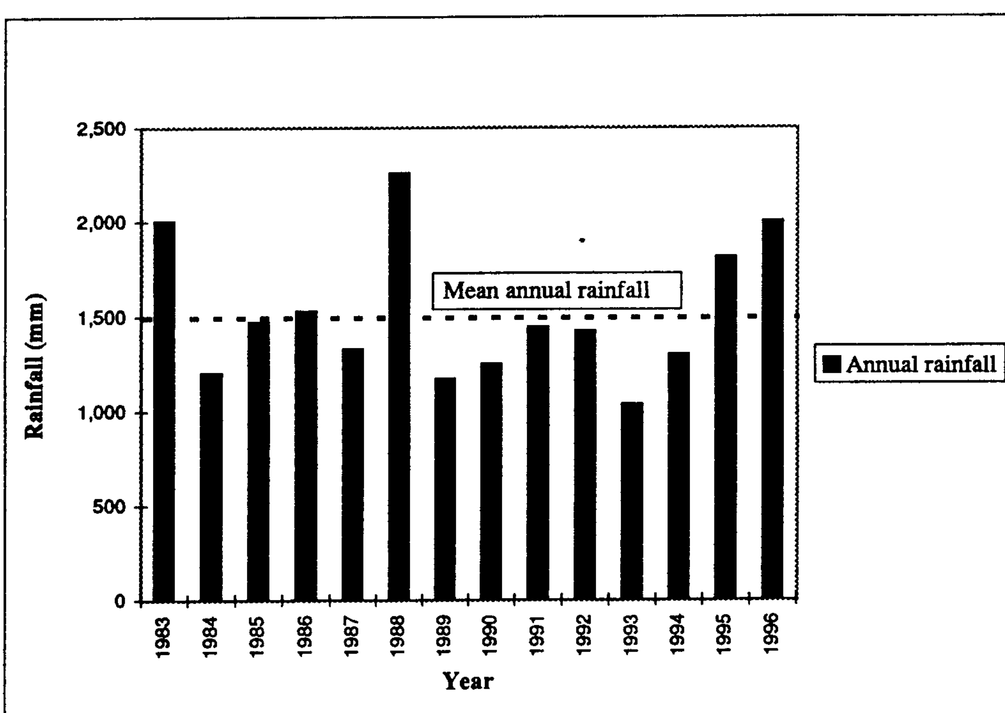
Minerals are very important for all animals, especially herbivores. Mineral requirements vary with age, sex, species, season, maturity, and reproductive condition (Robbins 1993). Deficiencies and imbalances of minerals are well recognized as important determinants of animal condition, fertility, productivity and mortality (UnderWood 1977). Herbivores obtain minerals from food, water and some special sources such as mineral rich springs and mineral licks. Ungulates can not obtain all of their mineral requirements from terrestrial plants. Therefore, they must obtain additional minerals from mineral licks and

Figure 2. Average monthly rainfall and temperature (A), and average annual rainfall (B) at Khao Nang Rum Wildlife Research Center, HKKWS, Thailand during 1983-1996.

A



B



Source : Khao Nang Rum Wildlife Research Center, HKKWS, Thailand.

mineral rich springs. In study area 1, there are at least 61 mineral licks and 30 mineral rich springs; in study area 2, there are at least 45 mineral licks and 23 mineral rich springs (Fig. 1).

Climate

The climate of this region is monsoonal. During 1983-1996, the dry season occurred from November to April, and the region received less than 225 mm of rainfall; the wet season occurred from May to October, and during this period the region received more than 1,300 mm of rainfall (Khao Nang Rum Wildlife Research Center, unpublished data) (Fig. 2). There is little variation in annual temperature (25 °C); April is the hottest month, with an average daily temperature of 28 °C and December is the coldest with an average of 20 °C. The difference between average maximum and minimum daily temperatures is greater in the dry season (14 °C versus 9 °C in the wet season). During the dry season, most of the streams dry up and fire is common from January through April. One third of the sanctuary lies in a rain-shadow and this is thought to be an important factor governing the overall distribution of forest types within the sanctuary (Nakhasathien and Stewart-Cox 1990).

METHODS

General field methodology.--Visual observations of the animals eating were made primarily by walking along 54 km of fixed transects 4 times a month in the study area 1 in the wet and dry seasons from 1983-1993. I followed the fresh spoor of gaur and banteng and checked habitat types and a number of species and types of plants eaten every time when I tracked animals. A more intensive 2 year study in study area 2 began in 1994. Beginning in May of this year, animals were immobilized and radio-collared. Fresh spoor of gaur and banteng were located and followed until we could approach within 15-30 m of an individual animal. The animal was then darted using a Palmer dart gun (Palmer Chemical Company with an intramuscular injection of a mixture of M99, xylazine, and ketamine or a mixture of carfentanil, xylazine and ketamine (Appendix 3). Animal handling procedures followed an approved University of Minnesota animal welfare protocol. Darted animals were fitted with radio-collars (frequency range 164-165 MHz; Advanced Telemetry Systems, Minnesota, USA). Intensive field work was conducted during May 1994-October 1996.

Food Plant Species

I examined overlap in the diet of gaur and banteng in both wet and dry seasons by direct foraging observation and fecal analysis.

Direct Foraging Observation

Species of Plants Eaten.--During the *long-term study (LTS)* (1983-1995), observations of gaur and banteng herds were made while walking throughout study area 1 and during regular walking surveys along 10 permanent transects within study area 2. Observations were recorded in Universal Transverse Mercator units (UTM.) and plotted on 1:50,000 scale Royal Thai Army maps. Elevation, date, time, group size, behavior, habitat use and food plants eaten were recorded. A plant species was counted as eaten on a given day when ≥ 10 bites per day of its leaves were eaten for trees, climbers, herbs, shrubs, and grasses. Bamboo species were counted when ≥ 5 shoots per 1 species of bamboo were eaten per day, and for bark, a species was counted when ≥ $10x10\ cm^2$ of bark was eaten. If I did not know the species of plant that was eaten, I collected a sample which was later identified by botanists at Royal Forest Department in Bangkok. Scientific names of plants eaten by gaur and banteng followed Smitinan (1980). I used this data to develop a list of species and plant parts eaten.

During the *intensive study (IS)* (May 1994-December 1995), 3 radio-collared gaur and 4 radio-collared banteng in study area 2 were located and followed about 12 months (Chapter 1). Both species almost always fed in groups that ranged from 2-40 individuals. I maintained a distance of 200-300 m to avoid disturbing the animals. Sometimes I could directly observe individuals for 2-3 hours, but I also observed freshly eaten plants as I followed their spoor. When following the spoor of radio-collared gaur and banteng, location data were recorded automatically with a GPS (Trimble Navigation) to the nearest 100 m. I followed each group at least 3-7 hours per day. The length of time animals were observed depended on how long I could go undetected by the animals, and additionally was influenced by weather (i.e. rain prevented observation).

As I followed a group of animals, I stopped every 15-30 minutes and recorded the species and structural parts of plants eaten within $20x20\ m^2$ plots. When I could not identify a plant, I collected a sample for identification by a botanist. A tree, climber, herb, shrub, or grass species was counted when ≥ 10 bites per plot were eaten. Bamboo species were counted when ≥ 5 shoots per 1 species of bamboo were eaten per plot, and for bark, a species was counted when ≥ $10x10\ cm^2$ of bark was eaten per plot. I attempted to follow the same group of animals for 2-3 consecutive days. The second and third day, I started at the last location of the previous day, and attempted to pick up the spoor. I used this data to calculate the frequency of food plant species and plant types used by gaur and banteng.

Food plants eaten were divided into 6 categories according to growth forms or morphology: (1) browse = trees, shrubs, climbers and long life woody; (2) herbs = monocotyledon and dicotyledon herbs with little or no lignification or short life non-woody plants. [All herbs in deciduous forest shed their leaves in the dry season and begin growing again in the wet season but in evergreen forest some herbs will die in the dry season while others will grow year-round]; (3) grasses = plants mostly in Family Gramineae and Cyperaceae; (4) bamboo = plants in family Gramineae characteristically larger and stronger shoots than other grasses; (5) palm and fern, and (6) bark = barks of trees and shurbs, are eaten in a different manner than other plant parts.

Food plant parts eaten were divided into 2 categories: (1) leaves = leaves and young shoots of trees, shrubs, climbers, herbs, grasses, bamboo, and palm/fern; and (2) bark = barks of trees and shurbs.

For many of the calculations that follow, comparative analyses were performed at 2 levels. The first level compared food habits between the wet and dry season for gaur and banteng individually; the second level compared food habits between gaur and banteng during a single season:

Level 1 **Compares usages between wet and dry season within a species**

GAUR---------WET SEASON

GAUR---------DRY SEASON

BANTENG---WET SEASON

BANTENG---DRY SEASON

Level 2 **Compares usages between species within a season**

GAUR---------WET SEASON

BANTENG---WET SEASON

GAUR---------DRY SEASON

BANTENG---DRY SEASON

Frequency of Food Types and Species Eaten Based on Direct Foraging Observations.--Based on direct foraging observations made in both the wet and dry seasons, the frequencies of use of different life forms and of different plant species were calculated. The unit of analysis was the "count" by observation day. If a plant species was recorded as eaten on a given day (as defined above), then it was given a 1, if it was not eaten, it was given a 0.

Frequency of use of 6 life form categories was calculated by:

$$(1) \qquad \frac{\textbf{Number of counts by category observed eaten}}{\textbf{Number of observation days}}$$

Frequency of use of different plant species was calculated by:

$$(2) \qquad \frac{\textbf{Number of counts by species observed eaten}}{\textbf{Number of observation days}}$$

These calculations enabled me to identify the most important food plant life forms and food plant species for gaur and banteng (For an examples of these calculations, see Appendix 16).

I consider animals that eat grass and bamboo species to be grazers and animals that eat trees, shrubs, and herbs to be browsers.

Niche Width and Overlap between Seasons

A useful way of assessing similarity between gaur and banteng diets is to calculate the niche widths for each species of different food types used during the wet and dry seasons. Relative niche width (W) was expressed as (Levins 1968 cited in Krebs 1989):

(3) $$W = 1/ \sum p_i^2$$

where p_i = the proportion of the i-th resource utilized

For comparisons, it was more convenient to use a relative niche width (reviewed by Leuthold 1978):

(4) $$W_{rel} = W / N$$

where N = the number of different resources within a resource category

W_{rel} = the values between 1/N and 1

Two measures of dietary overlap were obtained. First, I determined how much the use of individual food plants overlapped between the wet and dry seasons for each mammal species. This measure was obtained by calculating the percentages of individual plant species that were used in both seasons by gaur and by banteng. Second, I determined how much the use of food plant species overlapped between gaur and banteng during the wet season and again during the dry season. This measure was obtained by calculating the percentages of individual plant species common to both gaur and banteng in single a season. For both calculations, I followed Pianka (1973):

$$(5) \qquad O_{jk} = \Sigma\ p_{ij}\ p_{ik} / (\Sigma\ p_{ij}^{\ 2}\ \Sigma p_{ik}^{\ 2})^{1/2}$$

where

O_{jk} = Pianka' s measure of niche overlap between species j and species k

p_{ij} = Proportion resource i is of the total resources used by species j

p_{ik} = Proportion resource i is of the total resources used by species k

n = Total number of resource states

This measure of overlap can range from 0 (no resources used in common) to 1.0 (complete overlap). In the present context, this method provided a more refined, and possibly more realistic, assessment of dietary similarity, as it considered individual plant species and food plant categories as defined above.

Fecal Analysis

During 1994-1995, I collected 20 fecal samples each of gaur and banteng per season while tracking or sighting animals within the study area. Dung was retrieved shortly after the animals vacated the area. Additional samples were collected when they were encountered at other times. Fecal analysis required the preparation of a reference slide collection and the collection, preservation, and preparation of fresh fecal samples (Anthony 1972). Slides for the reference collection were prepared from fresh leaves following the method of Storr (1961) and Zyznar and Urness (1969) at the Forest Biology Department, Kasetsart University, Thailand. Leaf fragments were boiled in 5 ml of 5 percent nitric acid for three minutes until the mesophyll disintegrated and the epidermis separated. Epidermal fragments were mounted to slides with permount mounting media. Three to 5 photos of each species identified were taken using a binocular microscope at 10X and 100X for reference pictures in order to compare with fecal samples.

Dung from each fecal sample was fragmented in a blender. The fragments were boiled in 4 ml of concentrated nitric acid over a water bath for 10 minutes and then placed in 200 ml of water, which was boiled and stirred to completely clear cuticular fragments. The cuticular fragments were allowed to settle to the bottom, and the supernate was poured off. The fragments were stored in 1 part formal acetic acid and 1 part 30% glycerine until they could be analyzed. Epidermal fragments from feces were mounted to slides with permount mounting media. From each prepared fecal sample, sub-samples were spread out on slides under 22 mm^2 cover slips. Fecal samples from five slide (sub-samples) were examined wet at a magnification of 10X with a binocular microscope. If no recognizable structures were evident at 10X, the material was examined under progressively higher magnification to 100X. Also 5-10 photos were made of each fecal sample slide in order to compare with epidermal reference slides and photomicrographs and to confirm identication.

Food plants from fecal analysis were divided according to growth and morphological form into 7 categories: (1) browse = trees, shrubs and climbers that were woody plants; (2) herbs = monocotyledon and dicotyledon herbs or short life non-woody plants; (3) grasses = plants mostly in Family Gramineae and Cyperaceae; (4) bamboo = plants in Family Gramineae; (5) unknown monocotyledons = unidentified monocotyledons and (6) unknown dicotyledons = unidentified dicotyledons. A additional category (7) bark = barks of woody plants eaten by the animals in a different manner than other plant parts was also counted. Food plant parts from fecal samples were divided into 2 categories: (1) *leaves = leaves of all plant types; (2) barks = bark of woody plants.*

From these data several calculation were made. I determined the frequency of individual plant species eaten by the following calculation:

$$(6) \quad \frac{\textbf{Number of times species was observed in dung samples}}{\textbf{Total number of dung samples}}$$

The frequency of different food types was determined by first lumping the 7 categories organized by growth and morphology into 5 slightly broder categories: (1) dicotyledons (browse and unidentified dicotyledons); (2) herbs; (3) monocotyledons (grasses and unidentified monocotyledons); (4) bamboo species and (5) barks. I then calculated the frequency with which each categories was eaten from the list of food plants found in dung samples with the following calculation:

$$(7) \quad \frac{\textbf{Number of species of a particular category type observed in dung}}{\textbf{Total number of all species observed within the total dung samples in one season}}$$

Because fecal samples were collected in both the wet and dry season, I was able to identify the most important seasonal food plant species for gaur and banteng. Finally, I compared the similarity of gaur and banteng diets in each season based on direct foraging observations and fecal analysis. (For the limitation of fecal analysis see Appendix 17).

Distribution and Time Patterns in Relation to Water and Mineral Sources

Water is the most important essential element because of the variety of its functions and the magnitude of its requirement (Robbins 1993). Water balance becomes especially important in body and temperature regulation in all animals (Robinson 1957, MacFarlane and Howard 1972). In addition, certain minerals, particularly sodium, may be present in inadequate amounts in the diet, and may be sought out at sites where such minerals have become concentrated in soil such as mineral licks and springs (Fraser et al. 1980). Amounts of water required are affected by ambient air temperatures, solar and thermal radiation, vapor pressure deficits, metabolic rates, feed intake, productive processes, amount and temporal distribution of activity, and physiological, behavioral, and anatomical water conservation adaptations (Robbins 1993).

Animals obtain water from three sources: (1) free water, such as in streams and lakes; (2) preformed water contained in food; and (3) oxidative or metabolic water produced from oxidation of organic compounds containing hydrogen (Bartholomew and Cade 1963 reviewed by Robbins 1993).

The body's mineral content and requirements varied with age, sex, species, season, maturity, and reproductive condition (Robbins 1993). Deficiencies and imbalances of minerals were recognized as important determinants of animal condition, fertility, productivity, and mortality (Underwood 1977). Where the natural mineral supply was inadequate, supplementary mineral provision might improve conditions for animals (Danilkin1996). Besides obtaining mineral from natural licks, animals might obtain required minerals from alternative sources such as drinking the water at springs rich in mineral salts (Danilkin1996).

Distances Requirement from Water and Mineral Sources.--To determine the importance of water and mineral sources to gaur and banteng, water and mineral source distributions and radio locations of radio-collared gaur and banteng in each season during 1994-1996 were plotted on 1:50,000 scale Royal Thai Army maps. These data were then imported into a Geographic Information System (GIS) using ArcInfo software (ESRI, Redlands, CA). Based on the daily movement of gaur and banteng in the wet and dry seasons, I classified the distances from feeding locations to the nearest permanent water sources (streams and springs) and mineral sources (mineral licks and mineral rich springs) into 3 zones: 0-1 km, >1-2 km and >2 km respectively. Forested areas within < 0.5 km of a water source remained green throughout the dry season. The percentages of each of the 3 zones within study area 2 were measured using an ArcInfo data base from HKKWS which was developed by the Thai Royal Forest Department. Location data was analyzed to determine the distances of radiocollared herds to the nearest water and mineral sources during each season. I determined the proportion of use of each zone with the following the calculation:

$$(3) \quad \frac{\text{Number of locations in a zone}}{\text{Total number of locations within study area 2}}$$

Additionally, to determine how far away an animal feeds from permanent water sources in the dry season and from mineral souces in the wet season, I used an ArcInfo data base to determine the distance from each feeding location to the nearest water and mineral sources at any given time within a season.

I assumed that all radio-collared animal locations were independent (Chapter 1) and pooled data for all individuals of each species. Chi-square tests were performed to test the following hypotheses: 1) habitat use was independent of distance from water sources in the dry season. 2) habitat use was independent of distance from mineral licks in the wet season. 3) habitat use was independent of distance from mineral rich springs in the wet season. If each hypothesis was accepted at the $P = 0.05$ level of significance, I then concluded that the proportions of use in each zone were the same for both of the populations being compared. If the hypothesis was rejected, I concluded that the proportions of use in each zone were not the same for the populations being compared.

I also compared distance from water, mineral licks and mineral springs across species within seasons using chi-square. If each hypothesis was accepted at the $P = 0.05$ level of significance, I then concluded that the proportions of use in each zone were the same for both of the populations being compared. If the hypothesis was rejected, I concluded that the proportions of use in each zone were not the same for the populations being compared (For habitat selection, see Appendix 9).

Time Patterns around Water and Mineral Sources.--To determine the times at which most animals used water and mineral sources, I recorded the times gaur and banteng were observed continuously all day at 10 fixed mineral sources during 1983-1996 in both the wet and dry seasons. Secondly, to determine how much time was spent at mineral sources, my teams and I intensively observed animals continuously all day at 3 fixed mineral sources (Punamron Nai, Punamron Noak and Sub Kao) 4 times a month during 1994-1995 in both the wet and dry seasons. According to animal activities, daily observation times were divided into 2 hour intervals.

Daily Activity Patterns

During 1983-1996, activities of animals were recorded during visual observations that were made opportunistically during a range of field activities. These observations were commonly restricted to the day light hours. Animal activities were classified into 3 types: feeding, walking and licking/drinking at mineral sources, and resting. Feeding was defined as grazing and browsing. Walking was defined as moving from one place to another. In addition, drinking and licking was only recorded as mineral licks and springs utilization. Walking, drinking and licking were recored as the same activity type. Resting consisted of standing, laying or sleeping and often included standing and laying for ruminating.

I compared activity times between wet and dry seasons for both gaur and banteng. Additionally, I compared activity times between gaur and banteng in each season.

RESULTS

Food Plant Species

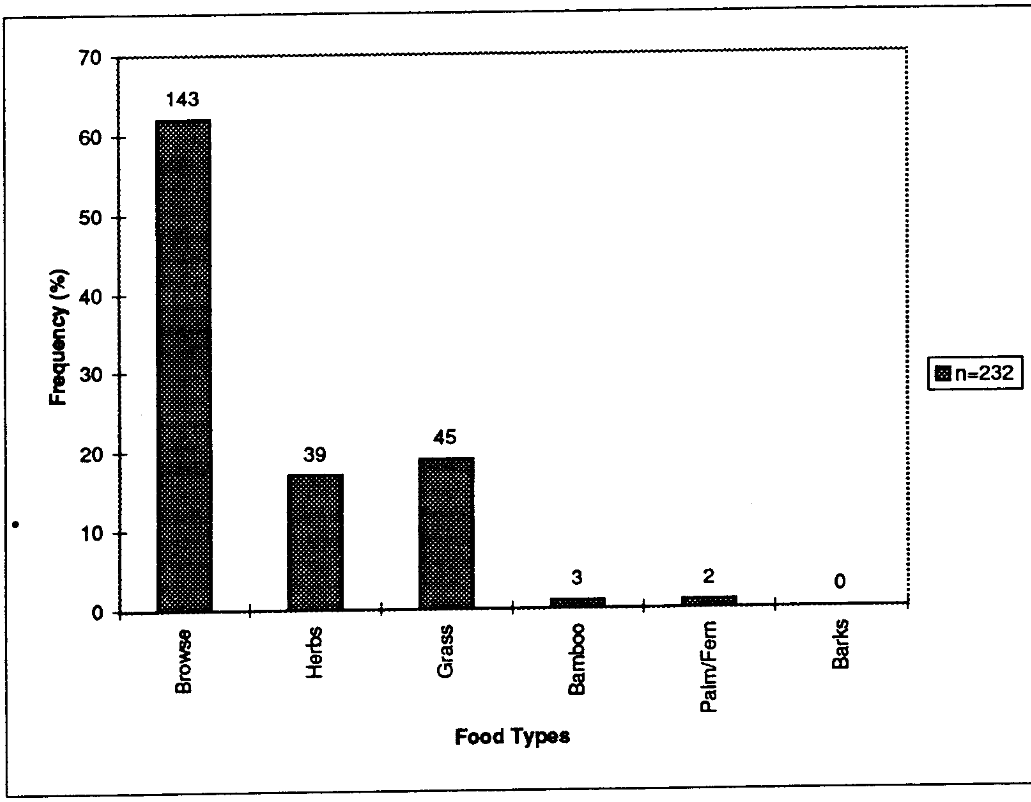
Food plant species determined from direct foraging observations and fecal analysis were recorded and classified into 8 categories: browse, herb, grass, bamboo, palms/ferns, bark, unidentified monocotyledon and unidentified dicotyledon. A large variation in annual rainfall with a distinct dry season created a monsoonal forest ecosystem. Diet shifted seasonally in response to changes in phenology and forest fires during the dry season. Leaf fall began in January and by mid-February to early March leaf litter accumulation allowed fires set by villagers adjacent to HKKWS to spread into the sanctuary. In response to leaf fall and fires, gaur tended to shift from wet season mixed-deciduous habitat where grass and bamboo were important components of their diets to higher evergreen habitat where browse and herb use increased. During this period, banteng became more localized near springs, feeding on bamboo declined and bark became an important food. When rains occasionally came in February, banteng and some groups of gaur would temporarily shift to the new grasses that came up in burned areas.

Gaur

Direct Foraging Observations

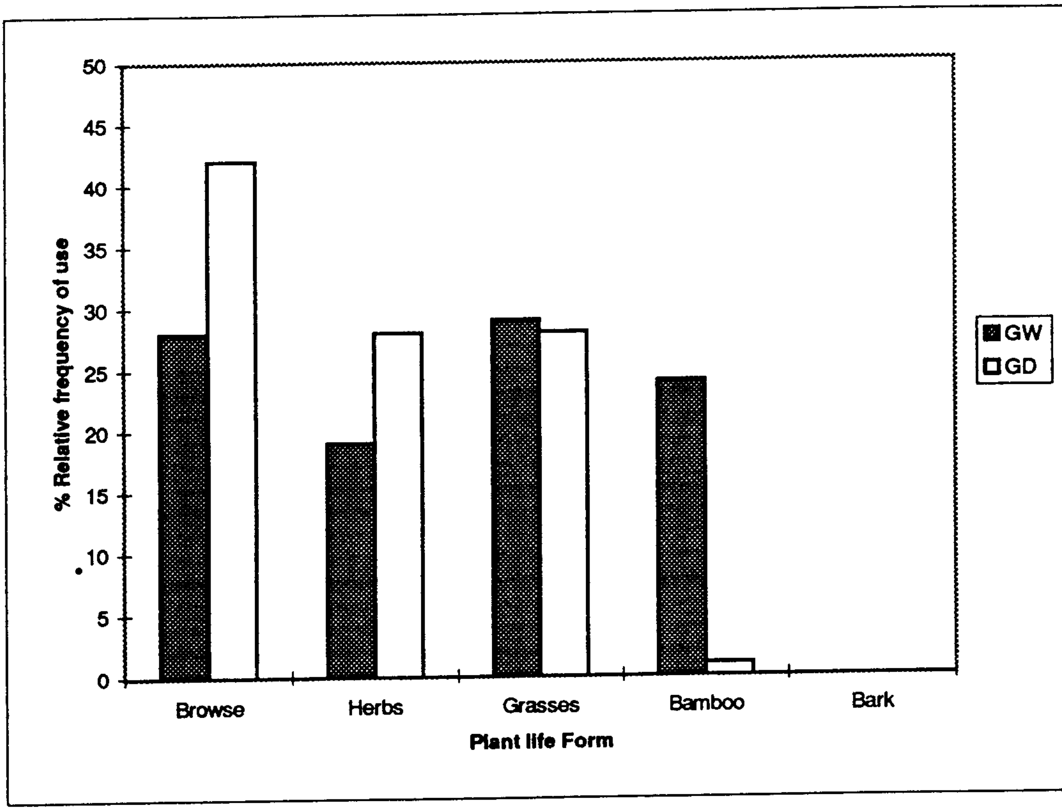
Species of Plants Eaten.--During direct observations of foraging behavior from 1983-1995, gaur were observed feeding on a total of 232 plant species from 127 genera and 54 families (Appendix 10). In the last 2 years of the study when animals were monitored more intensively on a seasonal basis 177 species of plants were recorded in the diets of gaur (Appendix 10). In the wet season, 116 species of plants from 69 genera and

Figure 3. Percentage of total food plants in each food types of gaur based on direct foraging observations in both the wet and dry season during 1983-1995. (Numbers of species eaten in each category are showed above bars).



70
60
50
40
30
20
10
0
Frequency (%)
143
39
45
3
2
0
n=232
Browse
Herbs
Grass
Bamboo
Palm/Fern
Barks
Food Types

Figure 4. Percentage of relative of food plants type eaten by gaur based on direct foraging observation during the wet and dry seasons in 1994-1995. (GW = Gaur in the wet season; GD = Gaur in the dry season).



50
45
40
35
30
25
20
15
10
5
0
% Relative frequency of use
GW
GD
Browse
Herbs
Grasses
Bamboo
Bark
Plant life Form

35 families were eaten. In the dry season, 83 species of plants from 46 genera and 26 families were eaten. Browse was the food category with the most frequently eaten in both seasons (Fig. 3). *Microstegium spp.* and 3 species of bamboo were the most available food plants of herbivores throughout mixed deciduous forest occuring in 57 % of study area 1.

Frequency of Foraging on Different Food Plant Types and Food Plant Species.--Gaur used different proportions of food types between wet and dry seasons. In the wet season, feeding was concentrated in mixed-deciduous forest. They fed on the new, less lignified and high protein shoots of 3 species of bamboo. As bamboo matured its fiber and lignin content increased making bamboo unpalatable. Relative frequency of use of bamboo increased from 2% in the dry season to 24% in the wet season (Fig. 4). Analysis of direct foraging observations of plants species eaten showed that bamboo and grass species *Bambusa arundinacea, Dendrocalamus strictus, Microstegium vegan,* and *Microstegium spp.* were eaten more than 83% of all observation days in the wet season (Table 1).

In the dry season, bamboo shoots became tall hard stems and grasses and broad leaf plants became dry and less palatable. Gaur shifted from mixed-deciduous forest to evergreen habitat and their diet shifted to primarily browse and herbs which were observed eaten more than grass and bamboo species (70% versus 29%) (Fig. 4). However, 1 species of grass *Microstegium ciliatum* (Ya Pai) which was common in mixed deciduous forest was the only species eaten on more than 41% of the observation days in the dry season (Table 2).

Table 1. Frequency of the most common food plants eaten [1] by gaur determined from direct foraging observations during the wet season in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life form [2]	Habitat [3]	% use [4] (n=24) [5]
1	Gramineae	*Bambusa arundinacea*	B	MD	83
2	Gramineae	*Dendrocalamus strictus*	B	MD	83
3	Gramineae	*Microstegium ciliatum*	G	MD	83
4	Gramineae	*Microstegium spp.*	G	MD	83
5	Papilionaceae	*Pueararia barbata*	HC	DD	25
6	Compositae	*Synedrella nodiflora*	H	MD	17
7	Caesalpiniaceae	*Bauhinia spp.*	S	MD	17
8	Gramineae	*Cymbopogon spp.*	G	MD	13
9	Unknown	Unknown 37 (Kla)	H	DE	13
10	Verbenaceae	*Clerodendrum paniculatum*	S	MD	13
11	Papilionaceae	*Desmodium spp.*	US	MD	13
12	Gramineae	*Thyrostacnys siamensis*	B	MD	8
13	Symphoremataceae	*Sphenodesme pentandra*	C	MD	8
14	Cyperaceae	*Cyperus rotundus*	G	MD	8
15	Gramineae	*Themeda spp.*	G	MD	8
16	Gramineae	Unknown A	G	DD	8
17	Commelinaceae	*Commelina disffus*	H	DE	8
18	Zingiberaceae	*Globba sp 1.*	H	MD	8
19	Zingiberaceae	*Globba sp 2.*	H	MD	8
20	Polygonaceae	*Polygonum spp.*	S	MD	8

[1] The most common plants eaten 20 species out of a total of 116 species from direct foraging observations during the wet season in 1994-95.

[2] Life Forms: US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

[3] Habitat: DD = Dry-dipterocarp forest; MD = Mixed deciduous forest; DE = Dry evergreen forest.

[4] % use = no. of counts by species / no. of observation days.

[5] n = no. of observation days. (For an example of these calculations, see in Appendix 16).

Table 2. Frequency of the most common food plants eaten [1] by gaur determined from direct foraging observations during the dry season in Huai Kha Khaeng Wildlife Sanctuary

No	Family	Scientific name	Life form [2]	Habitat [3]	% use [4] (n=29) [5]
1	Gramineae	*Microstegium ciliatum*	G	MD	41
2	Unknown	Unknown 34	S	DE	17
3	Cyperaceae	*Cyperus spp.*	G	MD	14
4	Unknown	Unknown 7	S	DD	14
5	Euphorbiaceae	*Cledion spp.*	T	DE	14
6	Araceae	*Rhaphidophora spp.*	CrH	DE	10
7	Commelinaceae	*Pollia spp.*	H	DE	10
8	Costaceae	*Costus speciosus*	H	DE	10
9	Acanthaceae	*Eranthemum spp.*	S	DE	10
10	Unknown	Unknown B	S	DD	10
11	Unknown	Unknown 9	S	DD	10
12	Rubiaceae	*Morinda angustifolia*	S/ST	DE/HE	10
13	Rubiaceae	*Randia spp.*	ST	DE	10
14	Gramineae	*Arthraxon spp.*	G	MD	7
15	Gramineae	*Arundinaria spp.*	G	DD	7
16	Gramineae	*Chloris spp.*	G	MD	7
17	Gramineae	*Coix spp.*	G	MD	7
18	Gramineae	*Cymbopogon spp.*	G	MD	7
19	Gramineae	*Microstegium vimimeum*	G	MD	7
20	Gramineae	*Panicum mutinodes*	G	DE	7

[1] The most common plants eaten 20 species out of a total of 83 species from direct foraging observations during the dry season in 1994-95

[2] Life Forms: US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark

[3] Habitat: DD = Dry-dipterocarp forest; MD = Mixed deciduous forest; DE = Dry evergreen forest

[4] % use = no. of counts by species / no. of observation days

[5] n = no. of observation days. (For an example of these calculations, see in Appendix 16).

Table 3. Overlap of gaur diets during the wet and dry seasons [1] determined from direct foraging observations in Huai Kha Khaeng Wildlife Sanctuary.

No.	Family	Scientific name	Life Form [2]
1	Amaranthaceae	*Achyranthes spp.*	HUS
2	Commelinaceae	*Commelina spp.*	H
3	Commelinaceae	*Pollia spp.*	H
4	Compositae	*Synedrella nodiflora*	H
5	Cyperaceae	*Cyperus spp.*	G
6	Dioscoreaceae	*Dioscorea spp.*	HC
7	Gramineae	*Arthraxon spp.*	G
8	Gramineae	*Arundinaria spp.*	G
9	Gramineae	*Cymbopogon spp.*	G
10	Gramineae	*Dendrocalamus strictus*	B
11	Gramineae	*Microstegium ciliatum*	G
12	Gramineae	*Panicum mutinodes*	G
13	Opiliaceae	*Melientha suavis*	S/ST
14	Papilionaceae	*Desmodium spp.*	US
15	Papilionaceae	*Desmodium spp.*	US
16	Papilionaceae	*Pueararia barbata*	C
17	Polygonaceae	*Polygonum spp.*	S
18	Rubiaceae	*Randia spp.*	ST
19	Zingiberaceae	*Ammomum spp.*	H
20	Zingiberaceae	*Globba spp.*	H
21	Unknown	UK 28	S
22	Unknown	UK 29	S
23	Unknown	UK 37	H
24	Unknown	UK 44	S

[1] 116 spcies of plant eaten from direct foraging observations in the wet season and 83 species in the dry season.

[2] Life Forms: US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo; T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

Seasonal Niche Width and Overlap in Diet between Seasons.--Relative niche widths were calculated from the frequency with which gaur utilized different food types in different seasons. Relative niche width was greater in the wet season (0.71) when we observed 93 species eaten and narrower in the dry season (0.47) when the number of observed species was 77. Only 24 species were used in both seasons; the most common species were *Melientha suavis, Microstegium ciliatum, Panicum mutinodes, Pueraria barbata,* and *Dendrocalamus strictus* (Table 3).

Niche overlap based on frequency of plant species used (0.32) in the wet compared to the dry season did not indicate much overlap. However, niche overlap based on plant types (0.89) indicated a high degree of overlap. This latter measure is a broder scale and indicate a wide variety of plant types are used by gaur.

Fecal Analysis

During 1994-1995, plant parts from 91 species were identified from 20 fecal samples each in the wet and dry seasons. Species were difficult to identify; therefore, we combined observations into dicotyledons (browse and unknown dicotyledons), herbs, monocotyledons (grasses and unknown monocotyledons) and bamboo species (Table 4; For the limitation of fecal analysis, see Appendix 17).

In the wet season, 59 plant species were counted, and in the dry season 45 species were counted. In both seasons, dicotyledons and herbs were the most common species identifies. Analysis of gaur feces showed that *Bambusa arundinacea, Saccharum spontaneum, Pueraria spp., Dendrocalamus strictus* and *Saccharum spp.* were identified in more than 40% of all fecal samples in the wet season (Table 5) while *Saccharum spp.*

was identified in more than 40% of all fecal samples in the dry season (Table 6). Parts of 13 plant species including *Saccharum spontaneum*, *Dendrocalamus strictus* and *Cymbopogon nardus* were found in fecal samples in both wet and dry seasons (Table 7). Most of the common plants in fecal samples were grass and bamboo species. Leaves were the most common plant parts found in fecal samples from gaur.

In the wet season 11 plant species, including *Bambusa arundinacea*, *Dendrocalamus strictus*, *Cymbopogon nardus*, *Saccharum spontaneum* and *Synedrella nodiflora* were identified through both direct foraging observations and fecal analysis (Appendix 10). In the dry season only *Bambusa arundinacea* and *Cyperus spp*. were observed being eaten or identified in the fecal analysis (Appendix 10). In the wet season, both methods were nearly equal in their ability to identify plant species eaten. However, in the dry season, the methods were not equal. *Microstegium sp*. was not found in the fecal analysis, even though this species was identified through the direct foraging observations as the species most commonly eaten in both the wet and dry seasons.

Banteng

Direct Foraging Observations

Plant Species Eaten.--During direct foraging observations from 1983-1995, a total of 247 plant species from 137 genera and 48 families were eaten by banteng. In the

Table 4. Number of species of different life forms eaten by gaur determined from fecal analysis in Huai Kha Khaeng Wildlife Sanctuary.

Plant Life Forms	Overall of Species[1] (%)[2]	Number of Species[1] (%)[2]		Number of Overlap Species[1] (%)[2]
	Annual	Wet Season	Dry Season	Wet-Dry
	n = 91	n = 59	n = 45	n = 13
Browse	13 (14)	10 (17)	3 (7)	0 (0)
Herbs	7 (8)	6 (10)	2 (4)	2 (15)
Grasses	24 (26)	15 (25)	14 (31)	5 (38)
Bamboo	3 (3)	3 (5)	1 (2)	1 (8)
Barks	0 (0)	0 (0)	0 (0)	0 (0)
UK dicotyledon[3]	38 (42)	19 (32)	17 (38)	4 (31)
UK monocotyledon[4]	6 (7)	6 (10)	8 (18)	1 (8)

[1] No. of plant species eaten determined from fecal analysis.
[2] % of plant life form eaten (% in parenthesis) calculated by
no. of species observed in dung within a particular category type / Total number of all species observed within the total dung samples in one season.
[3] Unknown dicotyledon
[4] Unknown monocotyledon

Table 5. Frequency of the most common food plants eaten [1] by gaur determined from fecal analysis during the wet season in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life Form [2]	% use [3] (n=20) [4]
1	Gramineae	*Bambusa arundinaceae.*	B	40
2	Gramineae	*Saccharum spontaneum*	G	40
3	Papilionaceae	*Pueraria spp.*	US	40
4	Gramineae	*Dendrocalamus strictus*	B	35
5	Gramineae	*Saccharum spp.*	G	30
6	Gramineae	*Saccharum spp.*	G	30
7	Unknowndicotyledon	Unknown 68	Unknown	25
8	Unknowndicotyledon	Unknown 70	Unknown	25
9	Papilionaceae	Unknown	Unknown	20
10	Gramineae	*Cymbopogon nardus*	G	15
11	Gramineae	*Panicum notanum*	G	15
12	Papilionaceae	*Dunbaria longeracemosa*	C	15
13	Zingiberaceae	*Globba spp.*	H	15
14	Unknown dicotyledon	Unknown	Unknown	15
15	Gramineae	*Cymbpogon flexusus*	G	10
16	Gramineae	Unknown 28	G	10
17	Papilionaceae	Unknown 10	Unknown	10
18	Acanthaceae	*Phaulopsis dorsiflora*	H	5
19	Compositae	*Synedrella nodiflora*	H	5
20	Cyperaceae	*Cyperus cyperinus*	G	5

[1] The most common plants eaten 20 species out of a total of 59 species determined from fecal analysis during the wet season in 1994-95.

[2] Life Forms: US = Undershrub; ST = Shurb Tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

[3] % use = Number of times species was observed in dung samples / Total number of dung samples.

[4] n = Total number of dung samples.

Table 6. Frequency of the most common food plants eaten [1] by gaur determined from fecal analysis during the dry season in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life Form [2]	% use [3] (n=20) [4]
1	Gramineae	*Saccharum spp.*	G	45
2	Gramineae	Unknown 38	G	30
3	Papilionaceae	Unknown A	Unknown	20
4	Papilionaceae	*Desmodium spp.*	US	20
5	Gramineae	*Cymbopogon nardus*	G	15
6	Gramineae	*Saccharum spontaneum*	G	15
7	Papilionaceae	Unknown B	Unknown	15
8	Cyperaceae	*Cyperus spp.*	G	10
9	Gramineae	Unknown C	G	10
10	Zingiberaceae	*Zingiber spp.*	H	10
11	Unknown monocotyledon	monocot 4	Unknown	10
12	Unknown monocotyledon	monocot 5	Unknown	10
13	Unknown dicotyledon	Unknown 68	Unknown	10
14	Unknown dicotyledon	Unknown 74	Unknown	10
15	Unknown dicotyledon	Unknown 83	Unknown	10
16	Unknown dicotyledon	Unknown 92	Unknown	10
17	Acanthaceae	*Justicia quadriforia*	S	5
18	Acanthaceae	*Strobilanthes spp.*	S	5
19	Annonaceae	*Polyathia spp.*	Unknown	5
20	Cyperaceae	*Cyperus cyperinus*	G	5

[1] The most common plants eaten 20 species out of a total of 45 species determined from fecal analysis during the dry season in 1994-95.

[2] Life Forms: US = Undershrub; ST = Shurb Tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

[3] % use= Number of times species was observed in dung samples / Total number of dung samples.

[4] n = Total number of dung samples.

Table 7. Overlap of gaur diets during the wet and dry seasons[1] determined from fecal analysis in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life Form[2]
1	Cyperaceae	*Cyperus cyperinus*	G
2	Dioscoreaceae	*Dioscorea spp.*	HC
3	Gramineae	*Cymbopogon nardus*	G
4	Gramineae	*Dendrocalamus strictus*	B
5	Gramineae	*Hyparrheria rufa*	G
6	Gramineae	*Saccharum spontaneum.*	G
7	Gramineae	*Saccharum spp.*	G
8	Zingiberaceae	*Zingiber spp.*	H
9	Unknown monocotyledon	Unknown monocot 4	Unknown
10	Unknown dicotyledon	Unknown 68	Unknown
11	Unknown monocotyledon	Unknown 72	Unknown
12	Unknown dicotyledon	Unknown 73	Unknown
13	Unknown dicotyledon	Unknown 74	Unknown

[1] 59 spcies of plant eaten determined from fecal analysis in the wet season and 45 species in the dry season.

[2] Life Forms: US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo; T = Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

last 2 years of the study when the animals were monitored more intensively, only 195 species were eaten (Appendix 11). In the wet season, 143 plants species from 88 genera and 39 families were eaten. In the dry season, 82 plant species from 53 genera and 25 families were eaten. Browse was the most important plant type (67% of all species eaten) (Fig. 5). Observed foods shifted from a high observed eaten of bamboo shoots (23%) in the wet season to a high observed eaten of barks in the dry season (24%). Barks of 4 species of trees and shrub trees were eaten in both seasons (Fig. 6).

Average calcium contents in leaves of plant species eaten (0.67% in dry matter; n = 16 species) was 0.5 times lower than in barks eaten (1.3% in dry matter; n = 4) in the dry season (t = - 1.70, 4 df, P = 0.08) (Prayurasiddhi, unpubl. data) (Appendices 14 and 15).

Frequency of Foraging on Different Food Plant Types and Food Plant Species.--In the wet season, browse and herb species (42%) were observed eaten less than grass and bamboo species (51%) (Fig. 6). Plant parts eaten were bamboo shoots (22%) and leaves from browse and herb species (74%). Only 4% of plant parts eaten were barks. In the dry season, relative frequency of use of browse and herb species was greater than grass and bamboo species (47% versus 29%) (Fig. 6). Plant parts eaten were bamboo leaves (3%) and leaves from dicotyledons and herbs (74%). Twenty-two percent of the plant parts eaten were barks. Analysis of direct foraging observation showed that

Figure 5. Percentage of total food plants in each food type of banteng based on direct foraging observation during the wet and dry season in 1983-1995. (Numbers of species eaten in each category are showed above bars).

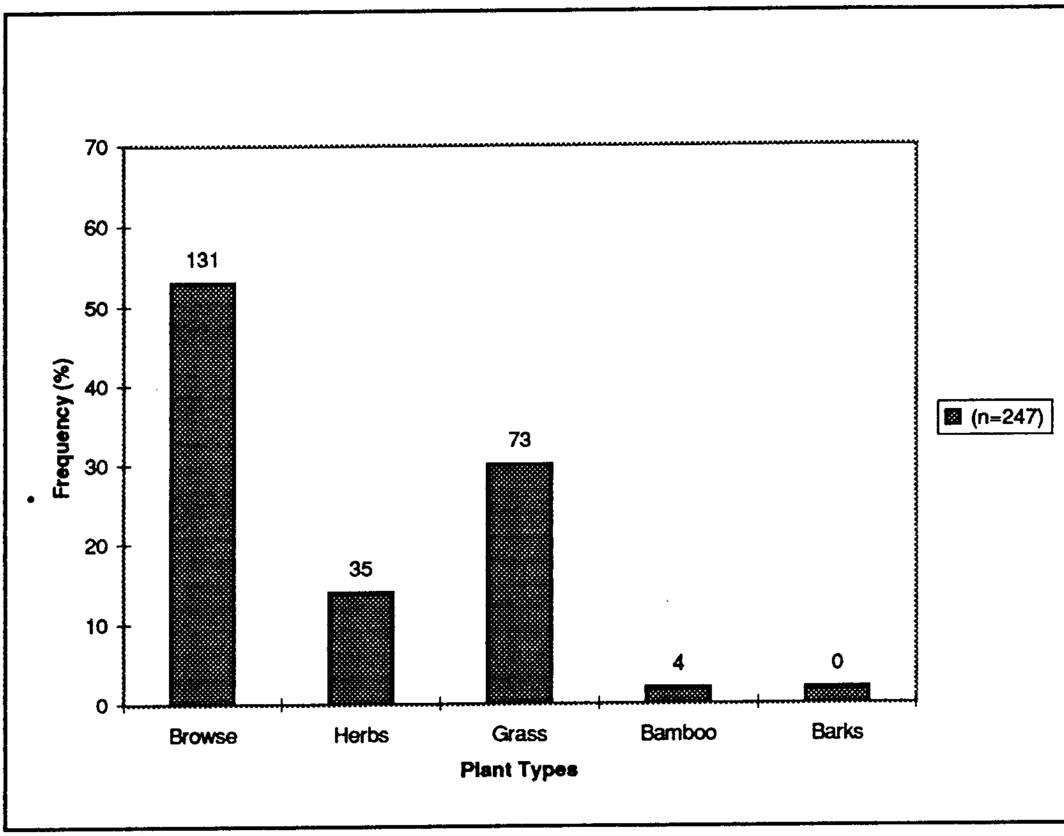
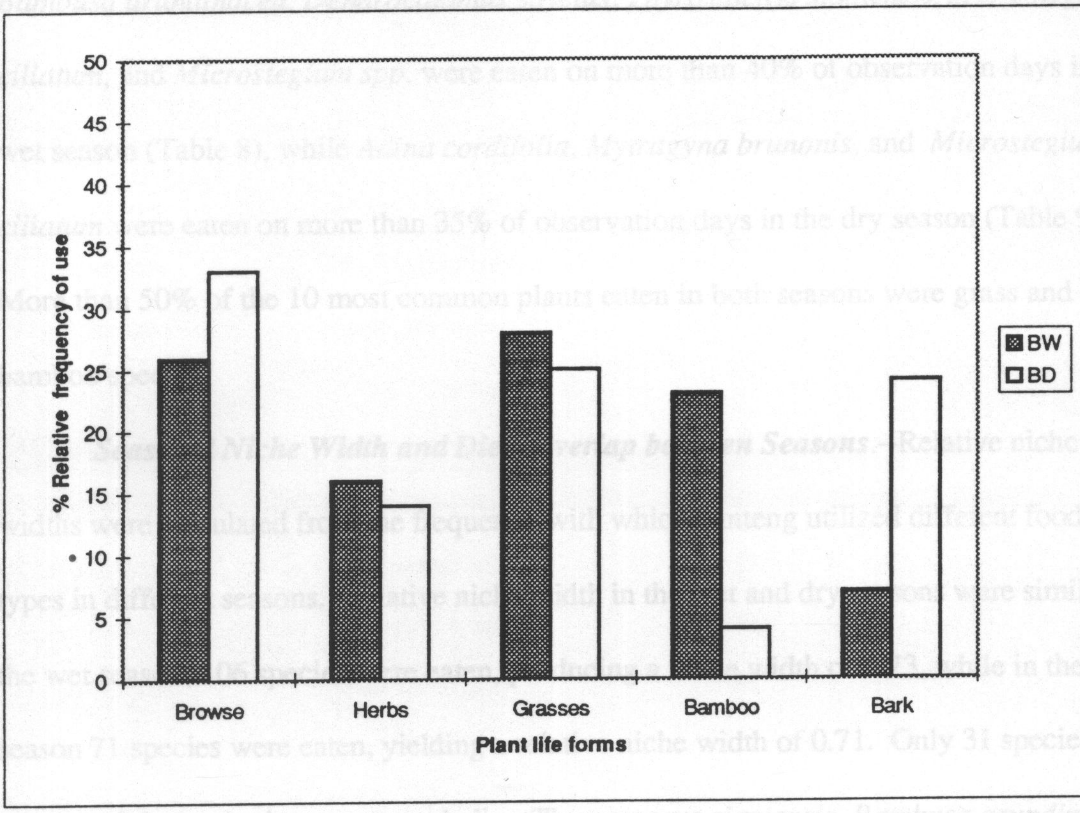

70
60
50
40
30
20
10
0
Frequency (%)
131
35
73
4
0
Browse
Herbs
Grass
Bamboo
Barks
Plant Types
(n=247)

Figure 6. Percentage of relative of food plants type eaten by banteng based on direct foraging observations during the wet and dry seasons in 1994-1995. Number in each category was calculated by number of counts by category observed eaten / number of observation days. (BW = Banteng in the wet season; BD = Banteng in the dry season).



50
45
40
35
30
25
20
15
10
5
0
% Relative frequency of use
Browse
Herbs
Grasses
Bamboo
Bark
Plant life forms
BW
BD

Bambusa arundinacea, Dendrocalamus strictus, Thyrostacnys siamensis, Microstegium ciliatum, and *Microstegium spp.* were eaten on more than 40% of observation days in the wet season (Table 8), while *Adina cordifolia, Mytragyna brunonis,* and *Microstegium ciliatum* were eaten on more than 35% of observation days in the dry season (Table 9). More than 50% of the 10 most common plants eaten in both seasons were grass and bamboo species.

Seasonal Niche Width and Diets Overlap between Seasons.--Relative niche widths were calculated from the frequency with which banteng utilized different food types in different seasons. Relative niche width in the wet and dry seasons were similar: in the wet season, 106 species were eaten, producing a niche width of 0.73, while in the dry season 71 species were eaten, yielding a relative niche width of 0.71. Only 31 species were used during both seasons, including *Thyrostacnys siamensis, Bambusa arundinacea, Dendrocalamus strictus, Barleria siamensis, Apluda mutica, Cymbopogon nardus, Heteropogon triticeus, Microstegium ciliatum, Saccharum arundinaceum, Saccharum spontaneum,* and *Sorghum nitidum* (Table 10). Barks of *Mytragyna brunonis, Adina cordifolia* and 3 bamboo species were the most common species eaten in both wet and dry seasons.

Pianka's (1973) measure of niche overlap based on the frequency of plant species eaten (0.38) and on the frequency of plant types used (0.88) showed that in the wet season banteng fed on plant species that were different from those used in the dry season, but that their diet was made up of all plant types.

Table 8. Frequency of the most common food plants eaten [1] by banteng determined from direct foraging observations during the wet season in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life Form [2]	Habitat [3]	% use [4] (n=30) [5]
1	Gramineae	*Bambusa arundinacea*	B	MD	77
2	Gramineae	*Dendrocalamus strictus*	B	MD	73
3	Gramineae	*Thyrostacnys siamensis*	B	MD	70
4	Gramineae	*Microstegium ciliatum*	G	MD	50
5	Gramineae	*Microstegium spp.*	G	MD	47
6	Simaroubaceae	*Harrisonia perforata*	C	MD	30
7	Papilionaceae	*Pueraria barbata*	C	MD	27
8	Gramineae	*Panicum montanum*	G	MD	27
9	Rubiaceae	*Mitragyna brunonis*	BK	DD	23
10	Rubiaceae	*Adina cordifolia*	BK	MD	20
11	Symphoremataceae	*Sphenodesme pentandra*	C	MD	17
12	Gramineae	Unknown 3	G	MD	17
13	Papilionaceae	*Melletia spp.*	C	MD	13
14	Gramineae	*Panicum spp.*	G	MD	13
15	Gramineae	*Arundinaria spp.*	G	MD	10
16	Gramineae	Unknown 18	G	MD	10
17	Papilionaceae	*Crotalaria montana*	H	DD	10
18	Zingiberaceae	*Globba spp.*	H	DD	10
19	Dioscoreaceae	*Dioscorea cf. hispida*	HC	MD	10
20	Papilionaceae	*Desmodium heterocarpon var. strigosum*	US	DD	10

[1] The most common plants eaten 20 species out of a total of 143 species determined from direct foraging observations during the wet season in 1994-95.

[2] Life Form : US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

[3] Habitat : DD = Dry-dipterocarp forest; MD = Mixed deciduous forest; DE = Dry evergreen forest.

[4] % use = no. of counts by species / no. of observation days.

[5] n = no. of observation days. (For an example of these calculations, see in Appendix 16).

Table 9. Frequency of the most common food plants eaten [1] by banteng determined from direct foraging observations during the dry season in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life Form [2]	Habitat [3]	% use [4] (n=21) [5]
1	Rubiaceae	*Adina cordifolia*	BK	MD	57
2	Rubiaceae	*Mitragyna brunonis*	BK	DD	57
3	Gramineae	*Microstegium ciliatum*	G	MD	38
4	Papilionaceae	*Pueraria barbata*	C	MD	10
5	Gramineae	*Apluda mutica*	G	DD	10
6	Gramineae	*Apluda spp.*	G	DD	10
7	Gramineae	*Chrysopogon orientalis*	G	DD	10
8	Gramineae	Unknown 18	G	MD	10
9	Papilionaceae	*Desmodium spp.*	S	DD	10
10	Meliaceae	*Toona ciliata*	T	DE	10
11	Papilionaceae	*Desmodium oblongum*	US	DD	10
12	Gramineae	*Bambusa arundinacea*	B	MD	5
13	Gramineae	*Dendrocalamus strictus*	B	MD	5
14	Gramineae	*Gigantochloa spp.*	B	MD	5
15	Gramineae	*Thyrostacnys siamensis*	B	MD	5
16	Bignoniaceae	*Dolichandron spp.*	C	MD	5
17	Euphorbiaceae	*Cleidion spp.*	C	DE	5
18	Papilionaceae	*Dysolobium spp.*	C	DD	5
19	Papilionaceae	*Milletia kityana*	C	DD	5
20	Papilionaceae	*Pueraria candolli*	C	DD	5

[1] The most common plants eaten 20 species out of a total of 82 species determined from direct foraging observations during the wet season in 1994-95.

[2] Life Form : US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

[3] Habitat : DD = Dry-dipterocarp forest; MD = Mixed deciduous forest; DE = Dry evergreen forest.

[4] % = no. of counts by species / no. of observation days.

[5] n = no. of observation days. (For an example of these calculations, see in Appendix 16).

Table 10. Overlap of food plants eaten by banteng from direct foraging observations during the wet and dry seasons [1] in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life Form [2]
1	Acanthaceae	*Barleria siamensis*	S
2	Acanthaceae	*Barleria spp.*	S
3	Bignoniaceae	*Dolichandron spp.*	C
4	Caesalpiniaceae	*Bauhinia spp.*	T
5	Commelinaceae	*Commelina spp.*	H
6	Dioscoreaceae	*Dioscorea cf. hispida*	HC
7	Gramineae	*Apluda mutica*	G
8	Gramineae	*Bambusa arundinacea*	B
9	Gramineae	*Cymbopogon nardus*	G
10	Gramineae	*Dendrocalamus strictus*	B
11	Gramineae	*Heteropogon triticeus*	G
12	Gramineae	*Microstegium ciliatum*	G
13	Gramineae	*Saccharum spp.*	G
14	Gramineae	*Saccharum spontaneum*	G
15	Gramineae	*Sorghum nitidum Pers.*	G
16	Gramineae	*Thyrostacnys siamensis*	B
17	Gramineae	Unknown 18	G
18	Gramineae	Unknown 2	G
19	Mimosaceae	*Acacia spp.*	T
20	Papilionaceae	*Crotalaria melanocarpa*	H
21	Papilionaceae	*Desmodium oblongum*	US
22	Papilionaceae	*Moghania macrophylla*	S
23	Papilionaceae	*Pueraria barbata*	C
24	Papilionaceae	*Pueraria wallichii*	C
25	Rubiaceae	*Adina cordifolia*	BK

Table 10. (Continued)

No	Family	Scientific name	Life Form [2]
26	Rubiaceae	*Mitragyna brunonis*	BK
27	Sapindaceae	*Schleichera oleosa*	T
28	Simaroubaceae	*Harrisonia perforata*	C
29	Staphyleaceae	*Turpinia cochinchinensis*	ST
30	Sterculiaceae	*Sterculia guttata*	T
31	Tiliaceae	*Triumfetta pilosa*	S

[1] 143 spcies of plant eaten from direct foraging observations in the wet season and 82 species in the dry season.

[2] Life Form: US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo; T = Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

Fecal Analysis

Plants from 142 species were identified from 40 fecal samples collected in the wet and dry seasons of 1994-1995. Plants were difficult to identify at the species level, so I lumped species into broader categories based on morphology: dicotyledons (browse and unknown dicotyledons), herbs, monocotyledons (grasses and unknown monocotyledons) and bamboo species (Table 11, Appendix 17).

In the wet season, 63 plant species were counted from 20 fecal samples, while in the dry season 108 species were counted. Dicotyledons and herbs were the most common types identified in both seasons, followed by grass and bamboo species.

Analysis of fecal samples collected in the wet season showed that *Thyrostacnys siamensis, Pueraria spp., Bambusa arundinacea* were presented in more than 40% of the samples (Table 12). In the dry season, *Adina cordifolia, Mitragyna brunonis, Pueraria spp., Thyrostacnys siamensis,* and *Globba spp.* were identified in more than 40% of the samples (Table 13). Plant parts of 29 plant species, including *Thyrostacnys siamensis, Cymbopogon nardus, Saccharum spontaneum, Pueraria spp., Globba spp., Zingiber spp., Adina cordifolia,* and *Mitragyna brunonis* were common to fecal samples in both seasons (Table 14). In the wet seasons 22 plant species, including *Bambusa arundinacea, Dendrocalamus strictus, Thyrostacnys siamensis* and *Globba spp.* were identified through both direct foraging observations and fecal analysis, while 21 plant species, including

Table 11. Number of species of different life forms eaten by banteng determined from fecal analysis during the wet and dry seasons in Huai Kha Khaeng Wildlife Sanctuary.

Plant Life Forms	Overall of Species [1] (%) [2]	Number of Species [1] (%) [2]		Number of Overlap Species [1] (%) [2]
	n = 142	Wet Season (n = 63)	Dry Season (n = 108)	Wet-Dry (n = 29)
Browse	23 (16)	12 (19)	20 (19)	10 (34)
Herbs	9 (6)	7 (11)	7 (6)	5 (17)
Grass	41 (29)	18 (29)	32 (30)	8 (28)
Bamboo	4 (3)	4 (6)	3 (3)	3 (10)
Barks	2 (1)	2 (3)	2 (2)	2 (7)
UK dicotyledons [3]	42 (29)	16 (25)	27 (25)	1 (3)
UK monocotyledons [4]	21 (15)	4 (6)	17 (16)	0 (0)

[1] No. of plant species eaten determined from fecal analysis.

[2] % of plant life form eaten (in parenthesis) calculated by

- no. of species eaten within a particular category type / no. of all species eaten.

[3] Unknown dicotyledon

[4] Unknown monocotyledon

Table 12. Frequency of the most common food plants eaten [1] by banteng determined from fecal analysis during the wet season in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life Form [2]	% use [3] (n=20) [4]
1	Gramineae	*Thyrostacnys siamensis*	B	55
2	Papilionaceae	*Pueraria spp.*	US	55
3	Gramineae	*Bambusa arundinacea*	B	50
4	Gramineae	*Dendrocalamus strictus*	B	35
5	Rubiaceae	*Adina cordifolia*	BK	30
6	Rubiaceae	*Mitragyna brunonis*	BK	30
7	Zingiberaceae	*Globba spp.*	H	30
8	Dioscoreaceae	*Dioscorea spp.*	HC	20
9	Gramineae	Unknown (Yapongkeenu)	G	20
10	Gramineae	*Cymbopogon nardus*	G	15
11	Gramineae	*Ishnanthus spp.*	G	15
12	Unknown	Unknown 39	Unknown	15
13	Acanthaceae	*Strobilanthes spp.*	S	10
14	Araceae	*Rhaphidophora spp.*	CrH	10
15	Dioscoreaceae	*Dioscorea spp.*	HC	10
16	Gramineae	*Heteropogon contortus*	G	10
17	Gramineae	*Hyparrhenia rufa*	G	10
18	Gramineae	*Saccharum spontaneum*	G	10
19	Papilionaceae	*Desmodium velotinum*	US	10
20	Papilionaceae	*Phaseolus spp.*	HC	10

[1] The most common plants eaten 20 species out of a total of 63 species determined from fecal analysis during the wet season in 1994-95.

[2] Life Forms : US = Undershrub; ST = Shurb Tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo T = Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

[3] % = Number of times species was observed in dung samples / Total number of dung samples.

[4] n = Total number of dung samples.

Table 13. Frequency of the most common food plants eaten by banteng [1] determined from fecal analysis during the dry season in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life Form [2]	% use [3] (n=20) [4]
1	Rubiaceae	*Adina cordifolia*	BK	100
2	Rubiaceae	*Mitragyna brunonis*	BK	100
3	Papilionaceae	*Pueraria spp.*	US	85
4	Gramineae	*Thyrostacnys siamensis*	B	60
5	Zingiberaceae	*Globba spp.*	H	45
6	Gramineae	*Cymbopogon nardus*	G	30
7	Simaroubaceae	*Harrisonia perforata*	T	30
8	Compositae	*Synedrella nodiflora*	H	25
9	Gramineae	*Heteropogon contortus*	G	25
10	Gramineae	*Saccharum spontaneum*	G	25
11	Papilionaceae	*Desmodium velotinum*	US	25
12	Cyperaceae	*Cyperus cyperinus*	G	20
13	Gramineae	*Bambusa arundinacea*	B	20
14	Gramineae	*Hyparrhenia rufa*	G	20
15	Gramineae	Unknown (Yapongkeenu)	G	20
16	Papilionaceae	*Desmodium oblongum*	S	20
17	Dipterocarpaceae	*Shorea obtusa*	T	15
18	Gramineae	*Sorghum nitidum*	G	15
19	Gramineae	Unknown (Yapai1)	G	15
20	Sterculiaceae	*Sterculia spp.*	T	15

[1] The most common plants eaten 20 species out of a total of 108 species determined from fecal analysis during the dry season in 1994-95.

[2] Life Forms : US = Undershrub; ST = Shurb Tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

[3] % = Number of times species was observed in dung samples / Total number of dung samples.

[4] n = Total number of dung samples.

Table 14. Overlap of banteng diets during the wet and dry seasons [1] determined from fecal analysis in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life Form [2]
1	Araceae	*Rhaphidophora sp.*	CrH
2	Compositae	*Synedrella nodiflora*	H
3	Dioscoreaceae	*Dioscorea sp 1.*	HC
4	Dioscoreaceae	*Dioscorea sp 2.*	HC
5	Gramineae	*Apluda spp.*	G
6	Gramineae	*Aristida balansae*	G
7	Gramineae	*Bambusa arundinacea*	B
8	Gramineae	*Cymbopogon nardus*	G
9	Gramineae	*Cymbpogon flexusus*	G
10	Gramineae	*Dendrocalamus strictus*	B
11	Gramineae	*Heteropogon contortus*	G
12	Gramineae	*Hyparrhenia rufa*	G
13	Gramineae	*Saccharum spontaneum*	G
14	Gramineae	*Thyrostacnys siamensis*	B
15	Gramineae	Unknown (Yapongkeenu)	G
16	Mimosaceae	*Acacia spp.*	T
17	Papilionaceae	*Desmodium oblongum*	S
18	Papilionaceae	*Desmodium velotinum*	US
19	Papilionaceae	*Dunbaria longeracemosa*	C
20	Papilionaceae	*Milletia kityana*	C
21	Papilionaceae	*Pueraria spp.*	US
22	Rubiaceae	*Adina cordifolia*	T
23	Rubiaceae	*Mitragyna brunonis*	T
24	Simaroubaceae	*Harrisonia perforata*	T
25	Sterculiaceae	*Sterculia spp.*	T

Table 14. (Continued)

No	Family	Scientific name	Life Form [2]
26	Symphoremataceae	*Sphenodesme involuerta*	C
27	Tiliaceae	*Colona spp.*	ST
28	Zingiberaceae	*Globba spp.*	H
29	Unknown dicotyledon (Kratogrok)		C

[1] 63 species of plant eaten determined from fecal analysis in the wet season and 108 species in the dry season.

[2] Life Forms: US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo; T = Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

Pueraria spp., *Adina cordifolia* and *Mitragyna brunonis* were identified in the dry season. The most common food plants eaten in both seasons were identified with both methods and both methods identified most of the same plants. Only *Microstegium ciliatum* and *Microstegium spp.* were not found in the fecal analysis, even though these species were the most common species identified during direct foraging observations in both seasons.

Overlap between Gaur and Banteng

Between 1987 to 1996, gaur and banteng herds were seen at springs around dusk on 5 separate occasions. There were also observed during the day feeding < 200 m from each other on 4 separate occasions.

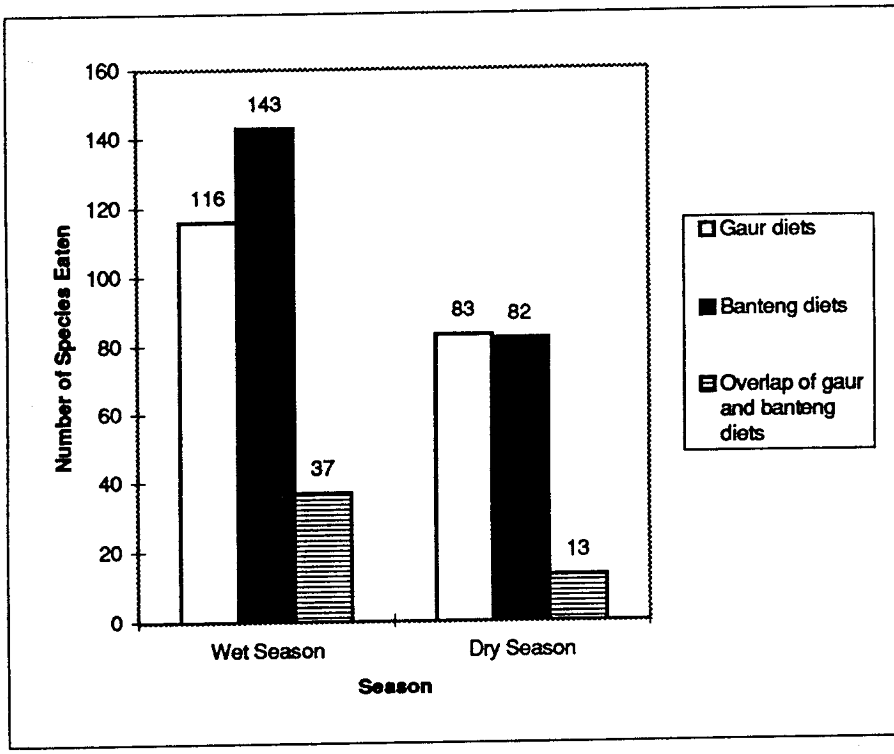
Direct Foraging Observation

Overlap of Plant Species Eaten.-- Overall, 44 species of plants from 35 genera and 23 families were eaten by both gaur and banteng during 1994-1995. In the wet season, 37 species were eaten by both gaur and banteng. For gaur, this comprised 32% of all species eaten; while for banteng this comprised 26% of all species eaten (Table 15). In the dry season, only 13 plant species were eaten by both gaur and banteng, and for both animals this comprised about 16% of all species eaten (Table 16).

Browse and herb types comprised 78% of the total number of species observed eaten that overlapped in the wet season, whereas herb was the most common overlap species (54%) eaten in the dry season (Fig. 7).

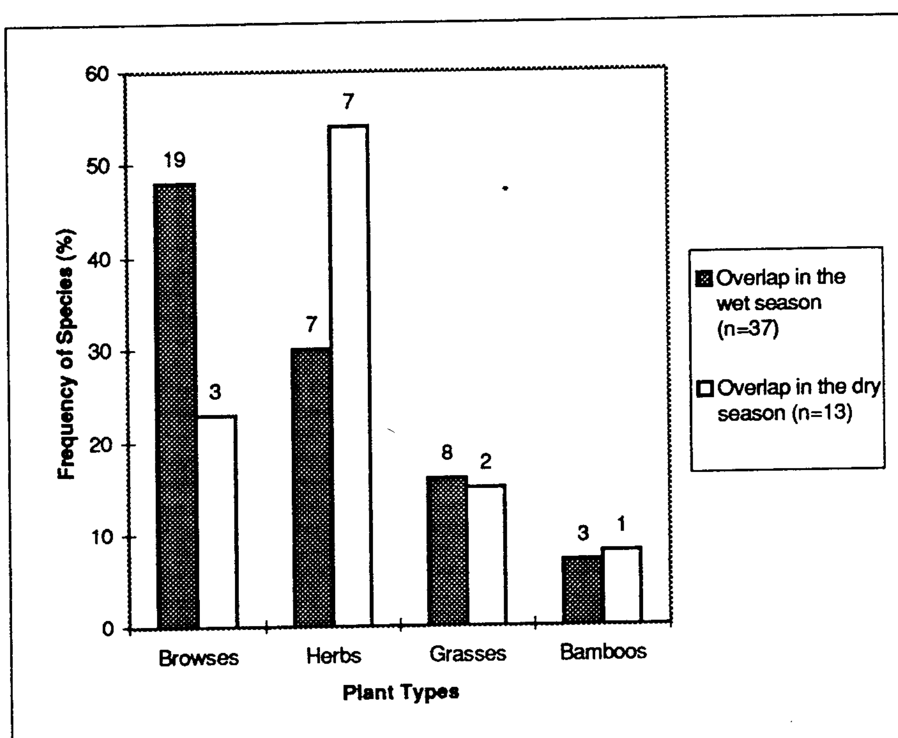
Figure 7. Overlap species of gaur and banteng diets in the wet and dry seasons during 1994-1995. (A) Number of overlap species eaten. (B) Number of overlap food plant types eaten. (Numbers of species eaten are above bars.)

A



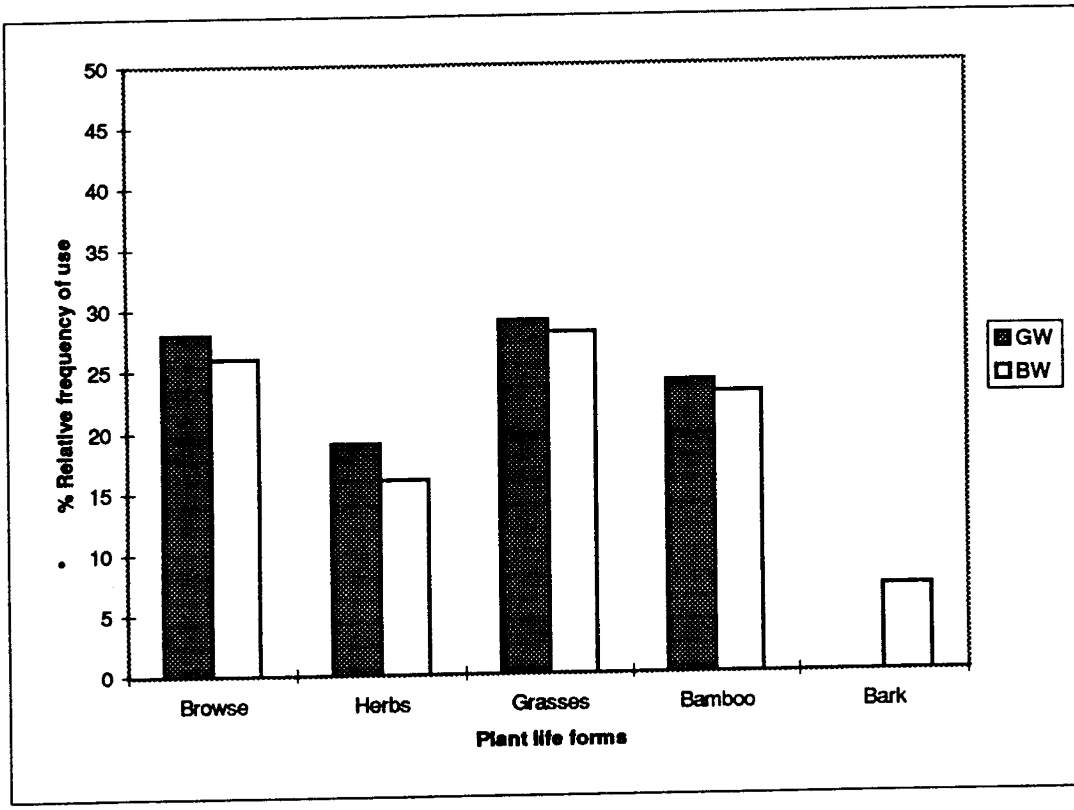
160
140
120
100
80
60
40
20
0
Number of Species Eaten
143
116
37
83
82
13
Wet Season
Dry Season
Season
Gaur diets
Banteng diets
Overlap of gaur and banteng diets

B



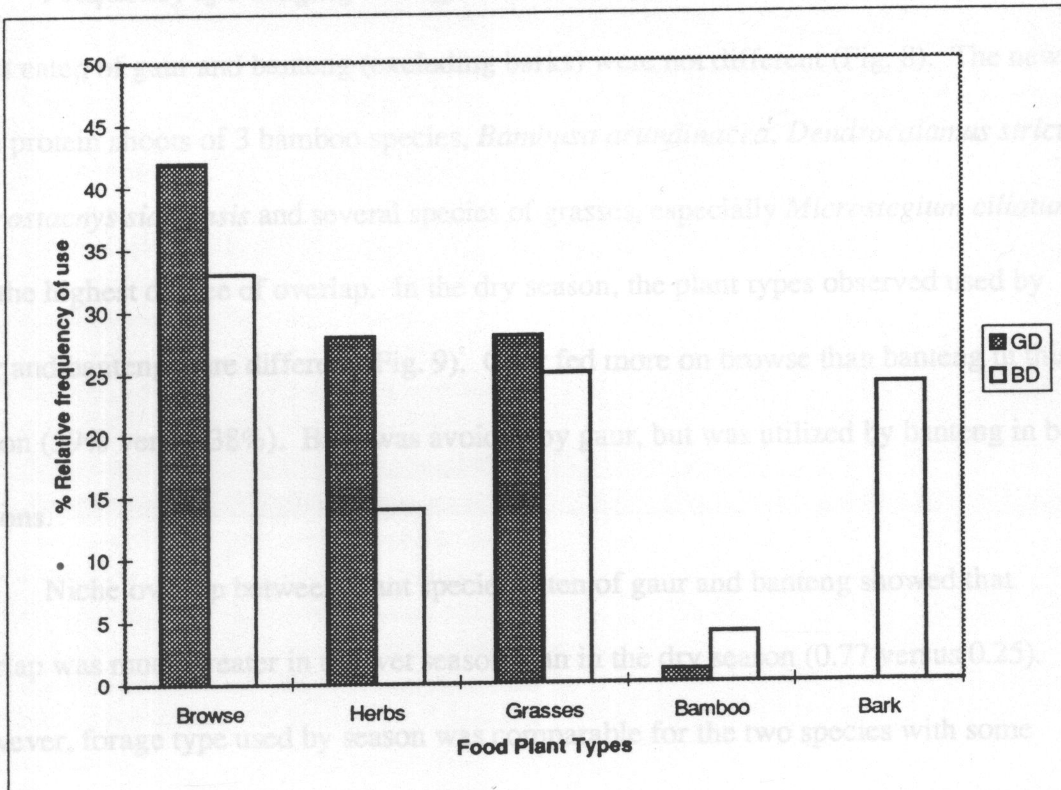
60
50
40
30
20
10
0
Frequency of Species (%)
19
3
7
7
8
2
3
1
Browses
Herbs
Grasses
Bamboos
Plant Types
Overlap in the wet season (n=37)
Overlap in the dry season (n=13)

Figure 8. Percentage of relative frequency of use of different food types eaten per season by gaur and banteng in the wet season during 1994-1995. Number in each category was calculated by number of counts by category observed eaten / number of observation days. (GW = Gaur in the wet season; BW = Banteng in the wet season).



50
45
40
35
30
25
20
15
10
5
0
% Relative frequency of use
Browse
Herbs
Grasses
Bamboo
Bark
Plant life forms
GW
BW

Figure 9. Percentage of relative frequency of different food types eaten by gaur and banteng in the dry season during 1994-1995. Number in each category was calculated by number of counts by category observed eaten / number of observation days. (GD = Gaur in the dry season; BW = Banteng in the dry season).



% Relative frequency of use
50
45
40
35
30
25
20
15
10
5
0
GD
BD
Browse
Herbs
Grasses
Bamboo
Bark
Food Plant Types

Frequency of Foraging on Different Food Types.--In the wet season, the plant types eaten of gaur and banteng (excluding barks) were not different (Fig. 8). The new, high protein shoots of 3 bamboo species, *Bambusa arundinacea, Dendrocalamus strictus, Thyrostacnys siamensis* and several species of grasses, especially *Microstegium ciliatum*, has the highest degree of overlap. In the dry season, the plant types observed used by gaur and banteng were different (Fig. 9). Gaur fed more on browse than banteng in this season (59% versus 38%). Bark was avoided by gaur, but was utilized by banteng in both seasons.

Niche overlap between plant species eaten of gaur and banteng showed that overlap was much greater in the wet season than in the dry season (0.77 versus 0.25). However, forage type used by season was comparable for the two species with some minor differences (0.98 in the wet season versus 0.87 in the dry season).

Distribution and Activity Patterns in Relation to Water and Mineral Sources

Distances Requirement from Water and Mineral Sources

Water and Mineral Sources.--The daily locations of gaur and banteng were classified with respect to distance from 2 critical resources: permanent water sources in the dry season and mineral sources (mineral rich springs and mineral licks) in the wet season.

Water sources*: *Gaur versus Banteng.--In the wet season, the entire study area was within 1 km of water, but in the dry season the distribution of water became greatly reduced: only 44% of the 477 km^2 study area 2 was $\leq$ 1 km from water (Table 17).

Table 15. Overlap of gaur and banteng diets during the wet season [1] determined from direct foraging observations in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life form [2]
1	Berberidaceae	*Mahonia siamensis*	T
2	Caesalpiniaceae	*Bauhinia spp.*	T
3	Combretaceae	*Anogeissus acuminata*	T
4	Commelinaceae	*Pollia spp.*	H
5	Dioscoreaceae	*Dioscorea hispida*	HC
6	Euphorbiaceae	*Bridelia spp.*	C
7	Gramineae	*Apluda mutica*	G
8	Gramineae	*Arthraxon castratus*	G
9	Gramineae	*Bambusa arundinacea*	B
10	Gramineae	*Cymbopogon nardus*	G
11	Gramineae	*Dendrocalamus strictus*	B
12	Gramineae	*Heteropogon triticeus*	G
13	Gramineae	*Microstegium ciliatum*	G
14	Gramineae	*Microstegium spp.*	G
15	Gramineae	*Saccharum arundinaceum*	G
16	Gramineae	*Saccharum spontaneum*	G
17	Gramineae	*Thyrostacnys siamensis*	B
18	Liliaceae	*Ophiopogon spp.*	H
19	Ochnaceae	*Ochna integerrima*	S/ST
20	Opiliaceae	*Melientha suavis*	S/ST
21	Papilionaceae	*Crotalaria melanocarpa*	H
22	Papilionaceae	*Crotalaria montana*	H
23	Papilionaceae	*Desmodium heterocarpon*	US
24	Papilionaceae	*Desmodium heterocarpon var.strigosum*	US
25	Papilionaceae	*Desmodium oblongum*	US
26	Papilionaceae	*Pueraria barbata*	C
27	Simaroubaceae	*Harrisonia perforata*	C
28	Sterculiaceae	*Sterculia guttata*	T
29	Stilaginaceae	*Antidesma spp.*	T
30	Symphoremataceae	*Sphenodesme mollis*	C
31	Symphoremataceae	*Sphenodesme pentandra*	C
32	Tiliaceae	*Triumfetta bartramia*	S
33	Verbenaceae	*Gmelina elliptica*	ST/S
34	Verbenaceae	*Vitex canescens*	T
35	Verbenaceae	*Vitex liminotolia*	T
36	Zingiberaceae	*Globba schomburgkii*	H
37	Unknown	Unknown 44 (Kradungkai)	S

[1] 116 species of plant eaten by gaur and 143 species of plant eaten by banteng during the wet season.

[2] Life Forms : US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo; T = Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

Table 16. Overlap of gaur and banteng diets during the dry season [1] determined from direct foraging observations in Huai Kha Khaeng Wildlife Sanctuary.

No	Family	Scientific name	Life form [2]
1	Acanthaceae	*Barleria siamensis*	S
2	Araceae	*Rhaphidophora spp.*	CrH
3	Commelinaceae	*Commelina spp.*	H
4	Compositae	*Synedrella nodiflora*	H
5	Cyperaceae	*Cyperus spp.*	G
6	Gramineae	*Bambusa arundinacea*	B
7	Gramineae	*Microstegium ciliatum*	G
8	Meliaceae	*Toona ciliata*	T
9	Papilionaceae	*Desmodium spp.*	US
10	Papilionaceae	*Phaseolus spp.*	HC
11	Papilionaceae	*Pueraria barbata*	C
12	Zingiberaceae	*Ammomum spp.*	H
13	Unknown	Unknown 37 (Kla)	H

[1] 83 spcies of plant eaten by gaur and 82 species of plant eaten by banteng during the dry season in 1994-95.

[2] Life Forms : US = Undershrub; ST = Shurb tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; B = Bamboo; T = Tree; S = Shrub; H = Herb; G = Grass; C = Climber; BK = Bark.

In this season 80% of all gaur locations were within 1 km of water (mean distance = 0.6 km; range = 0-2.3 km, n = 137) (χ^2 = 76.21, 2 df, P < 0.001). Banteng showed a similar preference for habitat ≤ 1 km from water (mean= 0.8 km; range = 0-4.2 km, n= 271) (χ^2 = 83.59, 2 df, P <0.001) (Table 17). However, gaur showed a stronger preference for habitat closer to water sources than banteng in the dry season (80 % versus 66 %) (χ^2= 10.13, 2 df, P = 0.006).

Mineral sources.--In the wet season, the movements of gaur and banteng were influenced by the distributions of mineral licks and mineral rich springs which had high mineral contents. Animals obtained minerals in the dry season while drinking water from springs. Mineral licks were not often used by animals in the dry season because soil was very hard and dry. I identified 23 mineral rich springs and 55 mineral licks within study area 2 (Fig. 1).

Gaur.--In the wet season, gaur fed ≤ 2 km from mineral licks more often than expected (χ^2 = 141.13, 2 df, P < 0.001) (Table 18). They also fed ≤ 1 km from mineral rich springs more often than expected (χ^2 = 159.91, 2 df, P < 0.001) (Table 19). Gaur showed a stronger preference for mineral licks than for mineral rich springs in the wet season (mean distance = 1.4 km versus 2.6 km) (χ^2 = 25.76, 2 df, P < 0.001).

Banteng.--In the wet season, banteng showed the same preference for mineral licks and mineral rich springs which had high mineral contents. They prefered to be ≤ 2 km from mineral licks (χ^2 = 578.92, 2 df, P < 0.001) (Table 18) and ≤ 2 km from springs (χ^2=232.84, 2 df, P < 0.001) (Table 19). Banteng also had a stronger preference for mineral licks than for mineral rich springs in the wet season (mean distance = 1 km versus 1.5 km) ($\chi^2 = 72.25$, 2 df, $P < 0.001$).

Overlap of Gaur and Banteng.--In the wet season, banteng showed a stronger preference than did gaur to be ≤ 1 km of a mineral lick (mean distance = 1 km versus 1.4 km) ($\chi^2 = 40.79$, 2 df, $P < 0.001$). Banteng also showed a stronger preference than did gaur to feed ≤ 2 km of mineral rich springs (1.5 km versus 2.6 km) ($\chi^2 = 18.7$, 2 df, $P < 0.001$).

Activity Patterns around Water and Mineral Sources

During 1983-1996, gaur and banteng were observed continuously all day at 10 fixed mineral rich springs and mineral licks. Data were recorded during 2 hour intervals througout the day in each season.

Gaur.--The highest use of mineral sources occurred from 16:01 to 18:00 hours in both seasons (Fig. 10). In the dry season, heavy use of water and mineral sources had a longer duration, and occupied >15 % of all mineral utilization observations from 14:01-20:00 hours.

Banteng.--Banteng also utilized mineral rich springs and mineral licks throughout the day (Fig. 11). In the wet season, banteng used mineral rich springs and mineral licks to the greatest extent from 10:01 to 12:00 hours and continued heavy use until 16:00 hours. In the dry season, banteng utilized mineral sources intensively during 10:01-16:00 hours (>15 % of all mineral utilization observations).

Table 17. Area of total study area 2 at difference distances from water and the frequency of use by gaur and banteng of each zone during the dry season in Huai Kha Khaeng Wildlife Sanctuary [1].

Species	Gaur (n=137)			Banteng (n=271)		
Distance from water (km)	0-1	>1-2	> 2	0-1	>1-2	> 2
Area of zone (km^2)	212	142	123	212	142	123
% Area of zone	44	30	26	44	30	26
Frequency of use	110	22	5	179	83	9
% Utilization	80	16	4	66	31	3
Index of use [2, 3]	+	-	-	+	ns	-
Mean distance (km)		0.6			0.8	
Range (km)		0 - 2.3			0 - 4.2	

[1] Observations from the intensive study (1994-1996)
[2] Habitat selection analysis was calculated by the method of Neu et al. (1974)
[3] Index of use : + = use significantly greater than availability (95% confidence interval [CI])
- = use significantly less than availability (95% CI)
ns = no selection (95% CI)

Table 18. Area of total study area 2 at difference distances from mineral lick and the frequency of use by gaur and banteng of each zone during the wet season in Huai Kha Khaeng Wildlife Sanctuary [1].

Species	Gaur (n =287)			Banteng (n =385)		
Distance from mineral lick (km)	0-1	>1-2	>2	0-1	>1-2	>2
Area of zone (km^2)	79	100	298	79	100	298
% Area of zone	17	21	62	17	21	62
Frequency of use	112	88	87	231	106	48
% Utilization	39	31	30	60	28	12
Index of use [2, 3]	+	+	-	+	+	-
Mean distance (km)		1.4			1	
Range (km)		0 - 4.8			0 - 4.5	

[1] Observations from the intensive study (1994-1996)

[2] Habitat selection analysis was determined by the method of Neu et al. (1974)

[3] Index of use : + = use significantly greater than availability (95% confidence interval [CI])

- = use significantly less than availability (95% CI)

ns = no selection (95% CI)

Table 19. Area of total study area 2 at difference distances from mineral rich spring (MRS) and the frequency of use by gaur and banteng of each zone during the wet season in Huai Kha Khaeng Wildlife Sanctuary [1].

Species	Gaur (n=287)			Banteng (n=385)		
Distance from MRS (km)	0-1	>1-2	>2	0 -1	>1-2	>2
Area of zone (km^2)	56	95	326	56	95	326
% Area of zone	12	20	68	12	20	68
Frequency of use	104	45	138	132	113	140
% Utilization	36	16	48	34	29	36
Index of use [2, 3]	+	ns	-	+	+	-
Mean distance (km)		2.6			1.5	
Range (km)		0 - 7			0 - 4.9	

[1] Observations from the intensive study (1994 -1996)

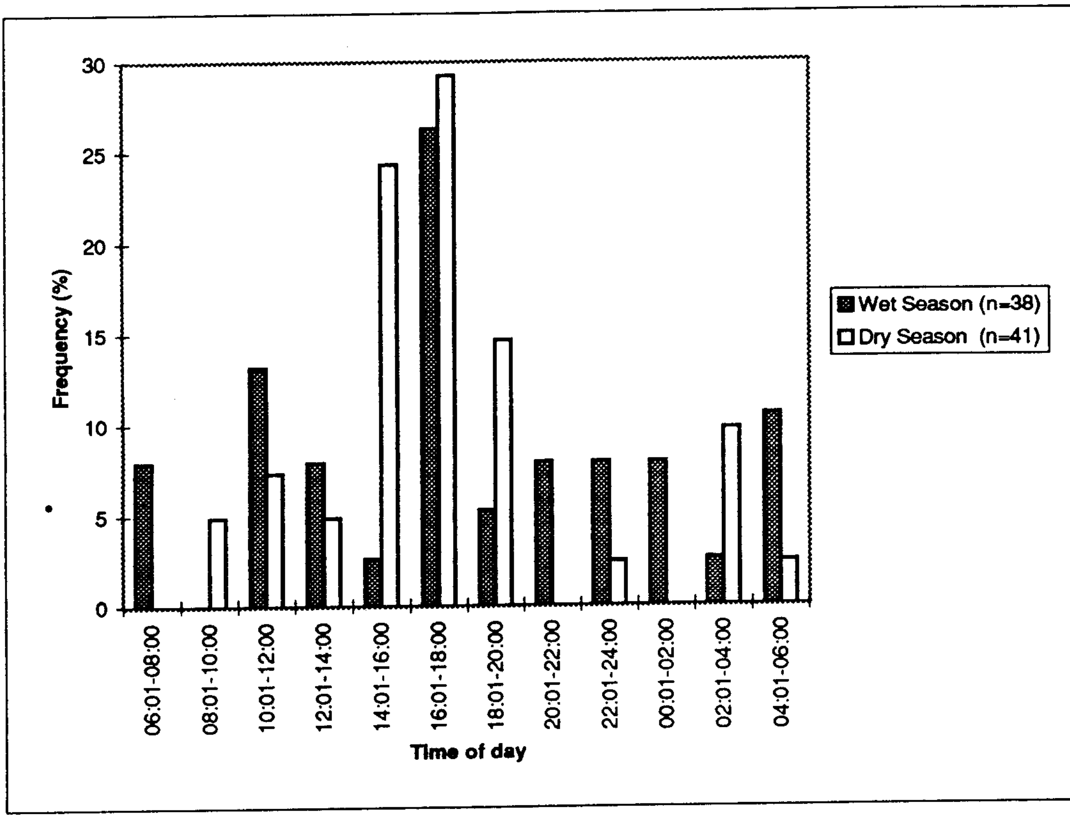
[2] Habitat selection analysis was determined by the method of Neu et al. (1974)

[3] Index of use : + = use significantly greater than availability (95% confidence interval [CI])

- = use significantly less than availability (95% CI)

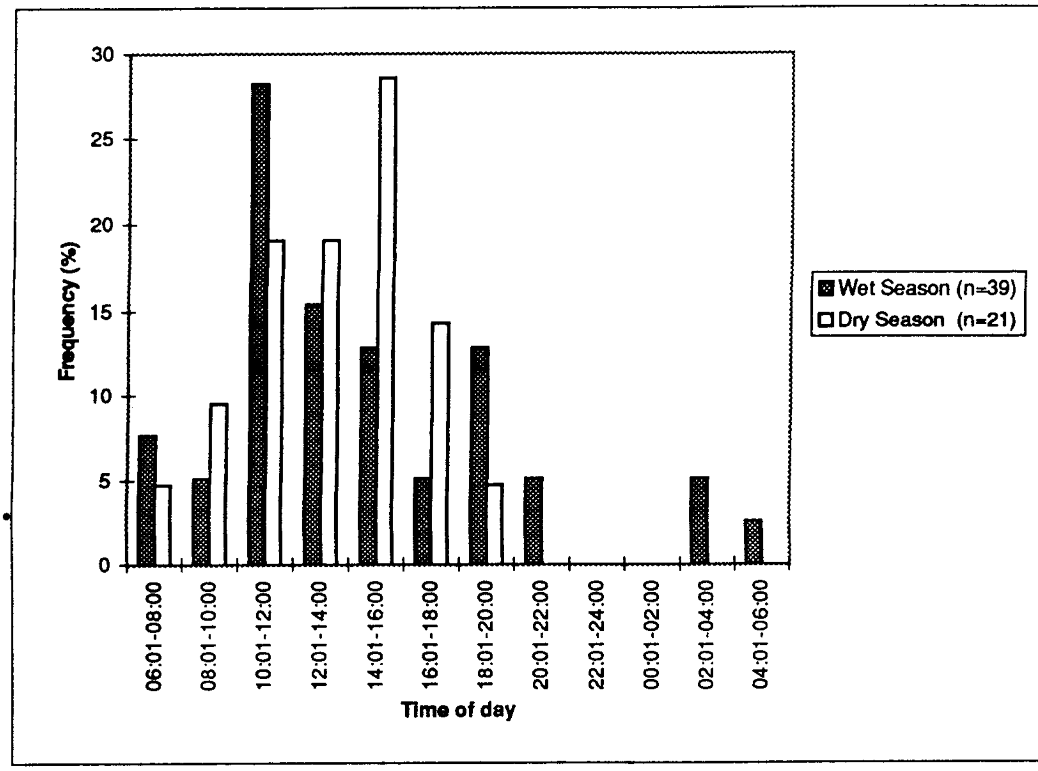
ns = no selection (95% CI)

Figure 10. Diurnal use of mineral sources by gaur during the wet and dry seasons, 1983-1995. Data were collected at 10 sites by sitting in a blind at a site from 06:00 am to 06:00 pm.



Frequency (%)
30
25
20
15
10
5
0
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
18:01-20:00
20:01-22:00
22:01-24:00
00:01-02:00
02:01-04:00
04:01-06:00
Time of day
Wet Season (n=38)
Dry Season (n=41)

Figure 11. Diurnal use of mineral sources by banteng during the wet and dry seasons, 1983-1995. Data were collected at 10 sites by sitting in a blind at a site from 06:00 am to 06:00 pm.


Frequency (%)
30
25
20
15
10
5
0
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
18:01-20:00
20:01-22:00
22:01-24:00
00:01-02:00
02:01-04:00
04:01-06:00
Time of day
Wet Season (n=39)
Dry Season (n=21)

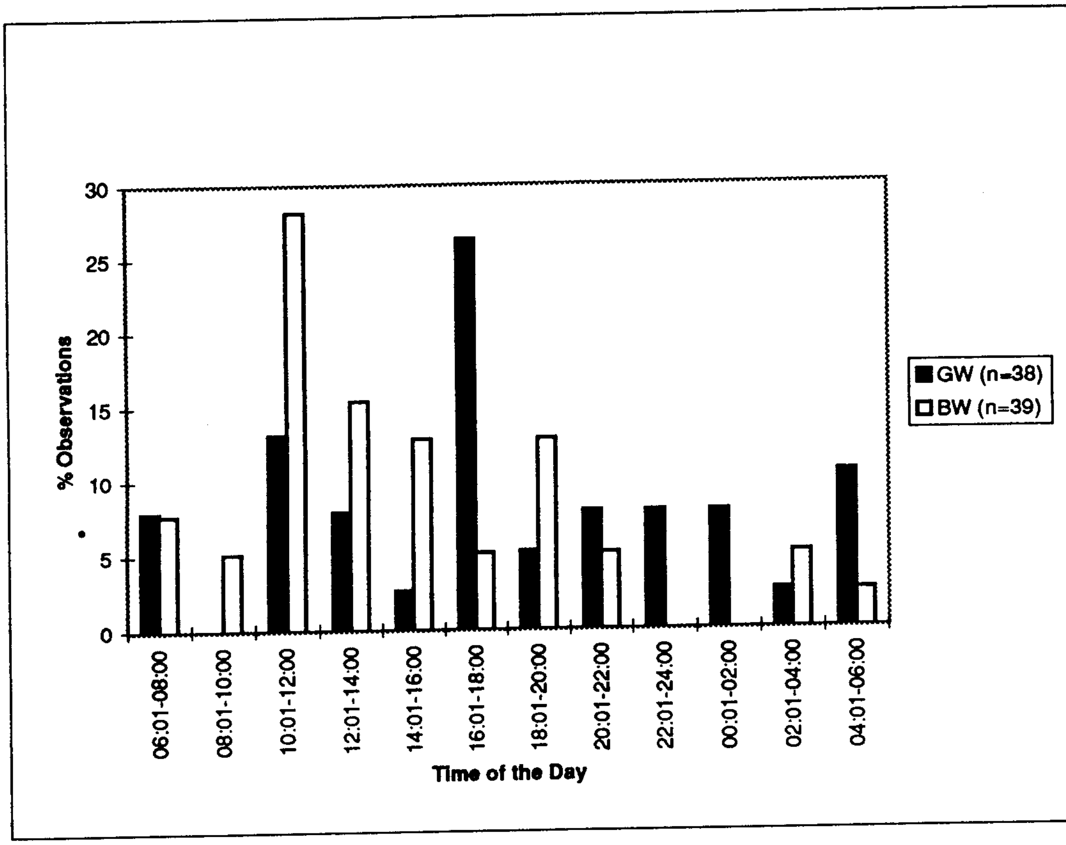
Overlap of Mineral Use by Gaur and Banteng.--In the wet season, peak mineral resource use by banteng was highest between 10:01 to 12:00 hours, and by gaur 4 hours later (16:01-18:00 hours) (Fig. 12). The mineral utilization periods of both gaur and banteng was broader in the dry season (Fig. 13). Mineral rich springs were intensively used by banteng from mid morning to afternoon then used by both species between 14:01 to 16:00 hours and then intensively used by gaur until dark. The average time spent at mineral rich springs throughout the year by gaur and banteng herds was not different, 31 minutes versus 30 minutes ($t = 0.08$, 12 df, $P = 0.935$). However, the average time spent at springs by single male gaur and banteng was different, 21 minutes vursus 8 minutes ($t = 2.43$, 10 df, $P = 0.035$) (Appendices 12 and 13).

On at least 3 separate occasions, direct intraspecific territorial interactions were observed during 1994-1996 in both gaur and banteng herds. Males of each species were very aggressive and involved in fights during breeding season (June to November) (Prayurasiddhi, unpubl. data). Only 5 incidents of direct interspecific territorial interactions were observed during 1987-1996. One event involved a big male gaur that tried to mate with an undefended female banteng (S. Chaisomkom, pers. comm. 1994). In addition, one male banteng followed an undefended female gaur herd while feeding (Prayurasiddhi, unpubl. 1995).

Daily Activity Patterns

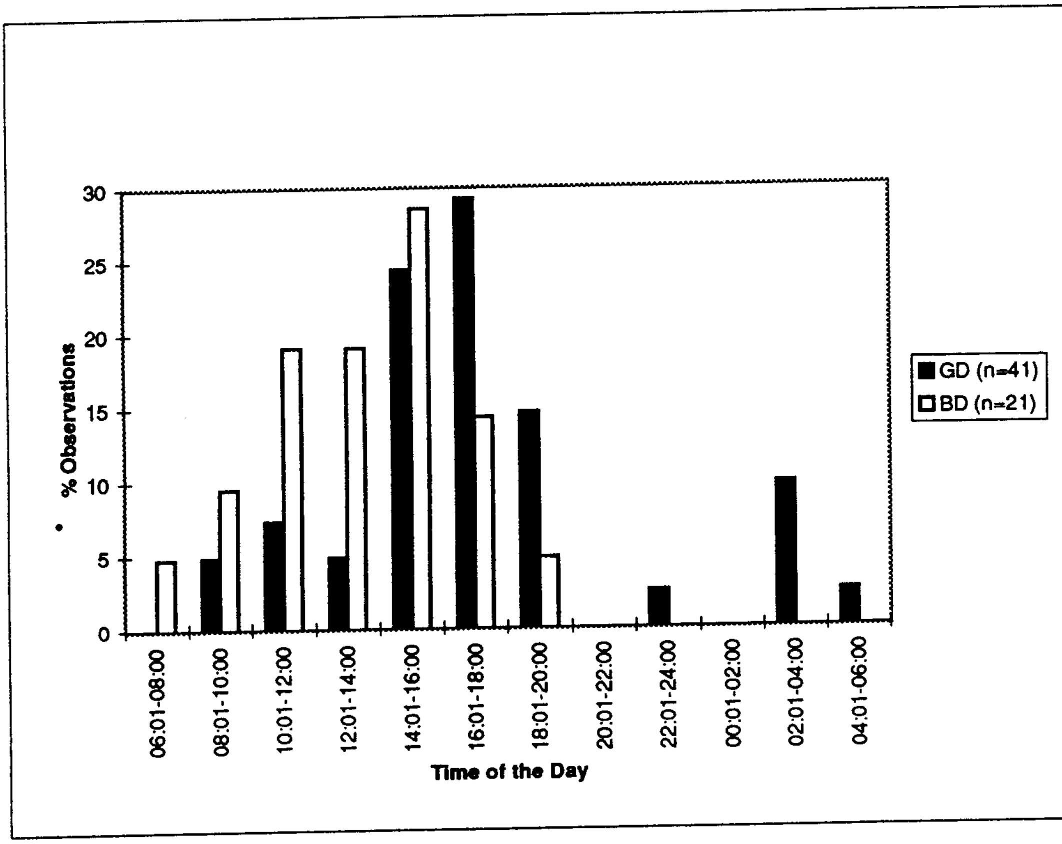
Most direct observations were recorded in daylight because at night animals were difficult to see and approach. Occasionally, night observations were made at water holes

Figure 12. Diurnal use of mineral sources by gaur and banteng during the wet season, 1983-1995. Data were collected at 10 sites by sitting in a blind at a site from 06:00 am to 06:00 pm (GW = Gaur in the wet season; BW = Banteng in the wet season).



30
25
20
15
10
5
0
% Observations
GW (n=38)
BW (n=39)
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
18:01-20:00
20:01-22:00
22:01-24:00
00:01-02:00
02:01-04:00
04:01-06:00
Time of the Day

Figure 13. Diurnal use of mineral sources by gaur and banteng during the dry season, 1983-1995. Data were collected at 10 sites by sitting in a blind at a site from 06:00 am to 06:00 pm (GD = Gaur in the dry season; BD = Banteng in the dry season).



30
25
20
15
10
5
0
% Observations
GD (n=41)
BD (n=21)
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
18:01-20:00
20:01-22:00
22:01-24:00
00:01-02:00
02:01-04:00
04:01-06:00
Time of the Day

and near trails. Animal activities were classified into 3 types: feeding, walking and visiting mineral sources, and resting. Feeding was defined as grazing and browsing. Walking and visiting mineral sources was defined as moving from one area to another, and walking to mineral sources. Resting consisted of standing, laying or sleeping and often included standing and laying for ruminating. Daily observations were made in 2 hour intervals.

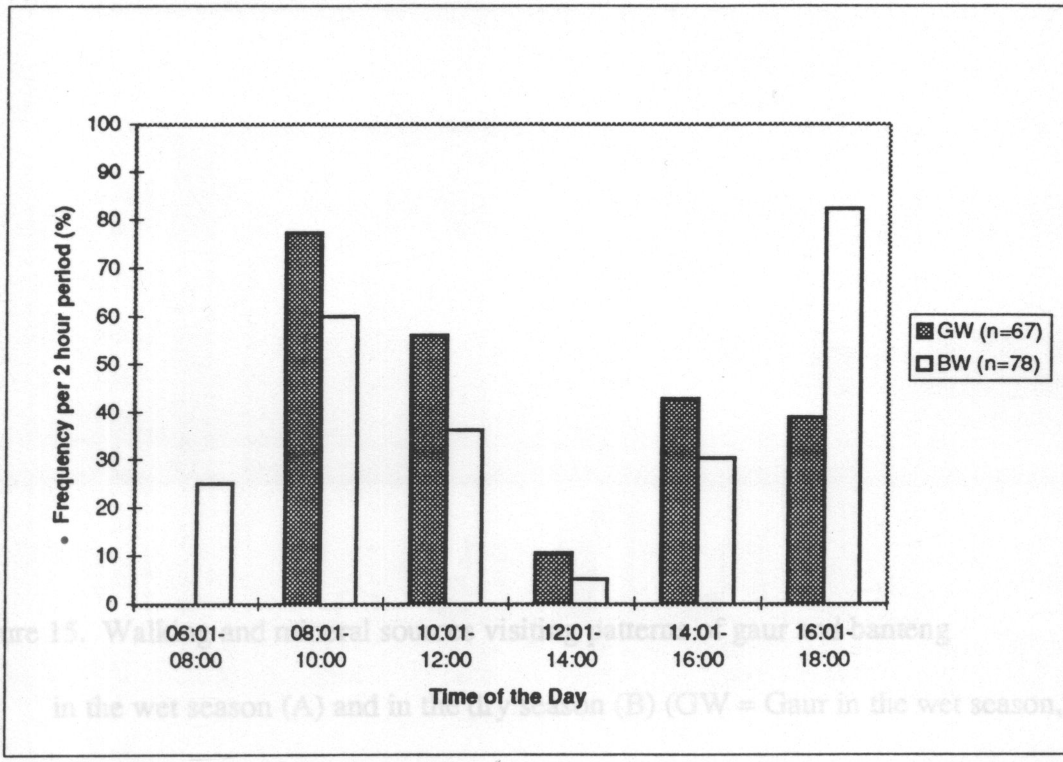
Gaur.--The proportion of time spent in each activity type differed in the wet and dry seasons ($\chi^2 = 9.20$, 2 df, $P = 0.01$) (Figs. 14-16). During the wet season, gaur devoted 64% of the total daily activity to feeding, walking and visiting mineral sources (Fig. 17). They were most active at dawn and dusk and rested in the afternoon from 12:01-14:00 hours. In the dry season 80% of daily activity was occupied by feeding, walking and visiting mineral sources. Activity was higher in the morning and gradually declined throughout the day in this season, and in general was earlier and broader.

In the wet season, feeding peaked between 08:01-12:00 hours and at 14:01-18:00 hours. In the dry season, feeding was most intense in the morning and then declined gradually from noon to dusk. Walking and visiting mineral sources occurred most intensely at dawn and dusk in the wet season and only at dusk in the dry season. The major rest period occurred from 12:01-14:00 hours in the wet season and in general was a more common activity in the wet versus the dry seasons.

Banteng.--The proportion of time spent in each activity was not different between seasons for banteng ($\chi^2 = 2.17$, 2 df, $P = 0.338$) (Figs. 14-16). During day light hours in the wet season, banteng devoted 53% of the total daily activity to feeding, walking and visiting mineral sources, while in the dry season 58% of total activity was devoted to these

Figure 14. Feeding patterns of gaur and banteng in the wet season (A) and in the dry season (B) (GW = Gaur in the wet season, BW = Banteng in the wet season, GD = Gaur in the dry season; BD = Banteng in the dry season).

A


100
90
80
70
60
50
40
30
20
10
0
Frequency per 2 hour period (%)
GW (n=67)
BW (n=78)
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
Time of the Day

B

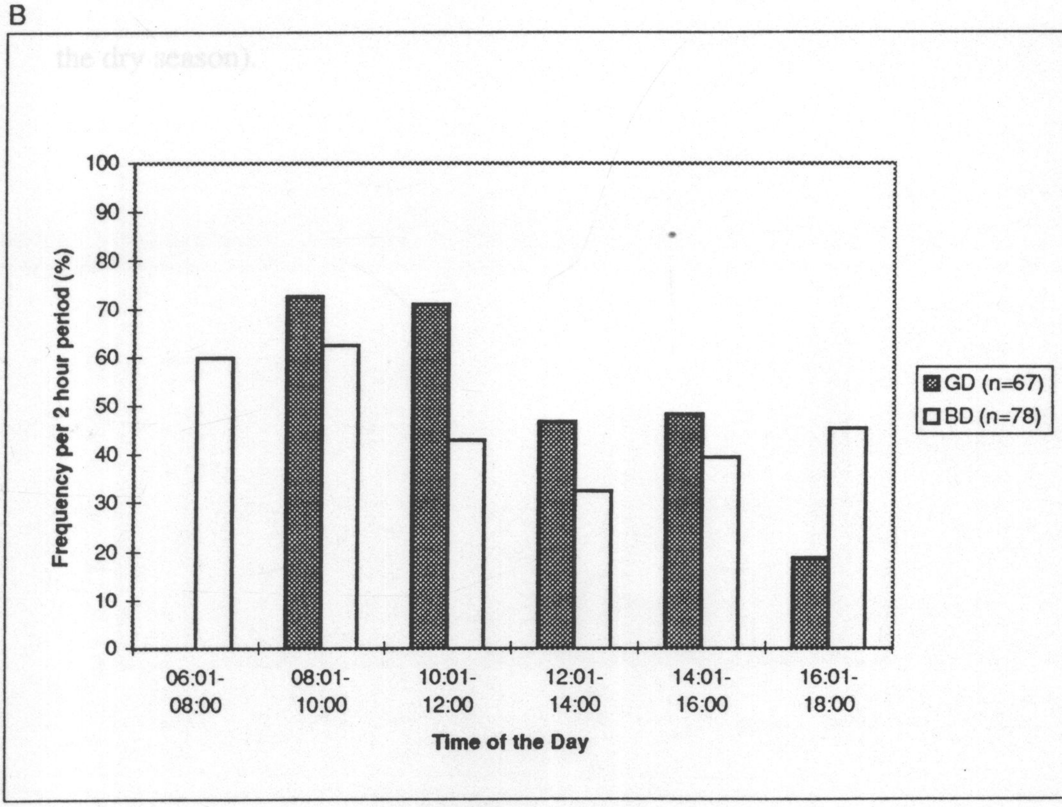
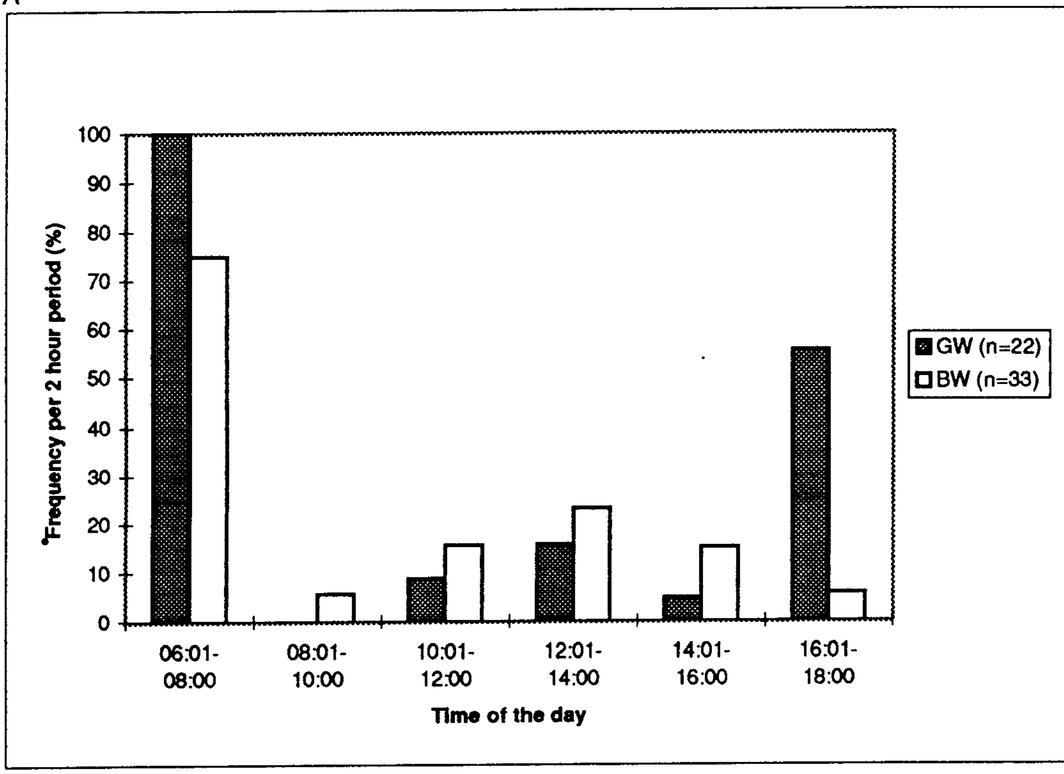

100
90
80
70
60
50
40
30
20
10
0
Frequency per 2 hour period (%)
GD (n=67)
BD (n=78)
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
Time of the Day

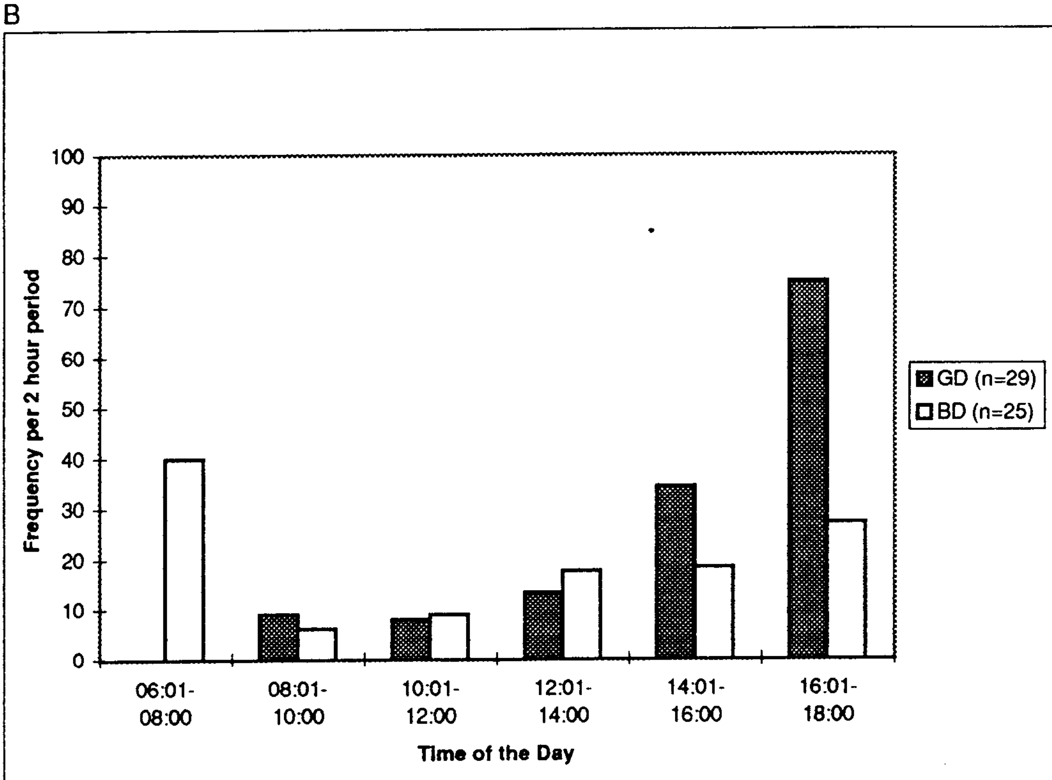
Figure 15. Walking and mineral sources visiting patterns of gaur and banteng in the wet season (A) and in the dry season (B) (GW = Gaur in the wet season, BW = Banteng in the wet season, GD = Gaur in the dry season; BD = Banteng in the dry season).

A



100
90
80
70
60
50
40
30
20
10
0
Frequency per 2 hour period (%)
GW (n=22)
BW (n=33)
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
Time of the day

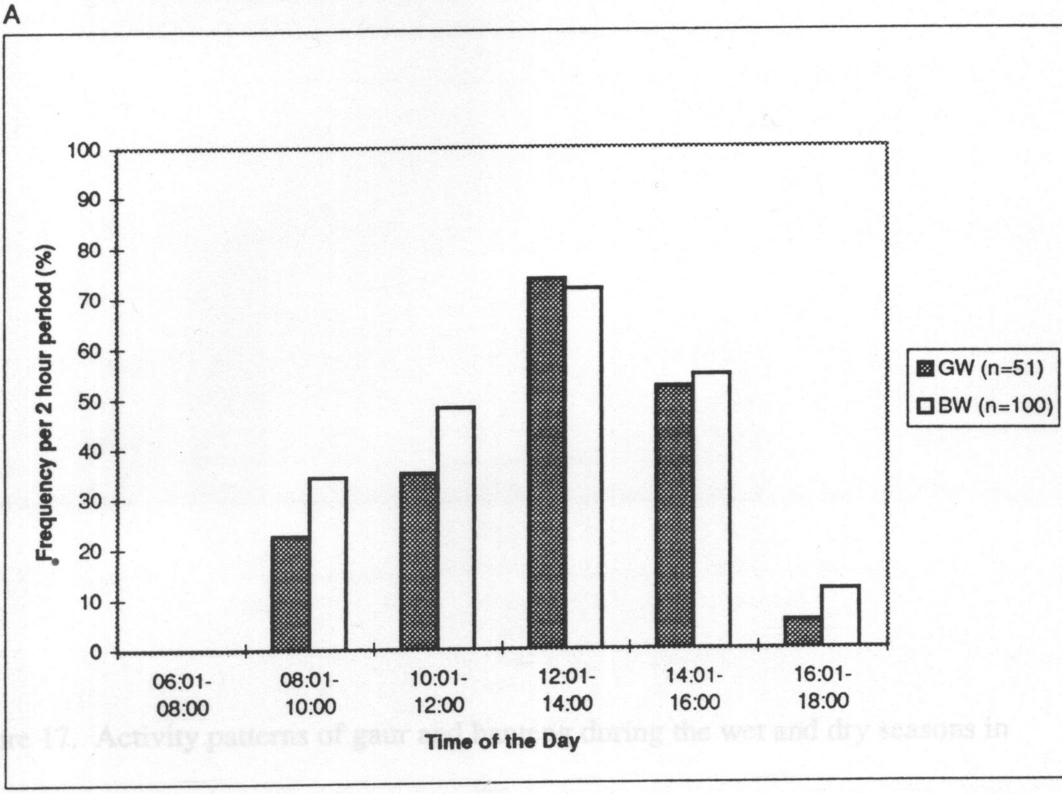
B



100
90
80
70
60
50
40
30
20
10
0
Frequency per 2 hour period
GD (n=29)
BD (n=25)
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
Time of the Day

Figure 16. Resting pattern of gaur and banteng in the wet season (A) and in the dry season (B) (GW = Gaur in the wet season, BW = Banteng in the wet season, GD = Gaur in the dry season; BD = Banteng in the dry season).

A


Frequency per 2 hour period (%)
100
90
80
70
60
50
40
30
20
10
0
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
Time of the Day
GW (n=51)
BW (n=100)

B

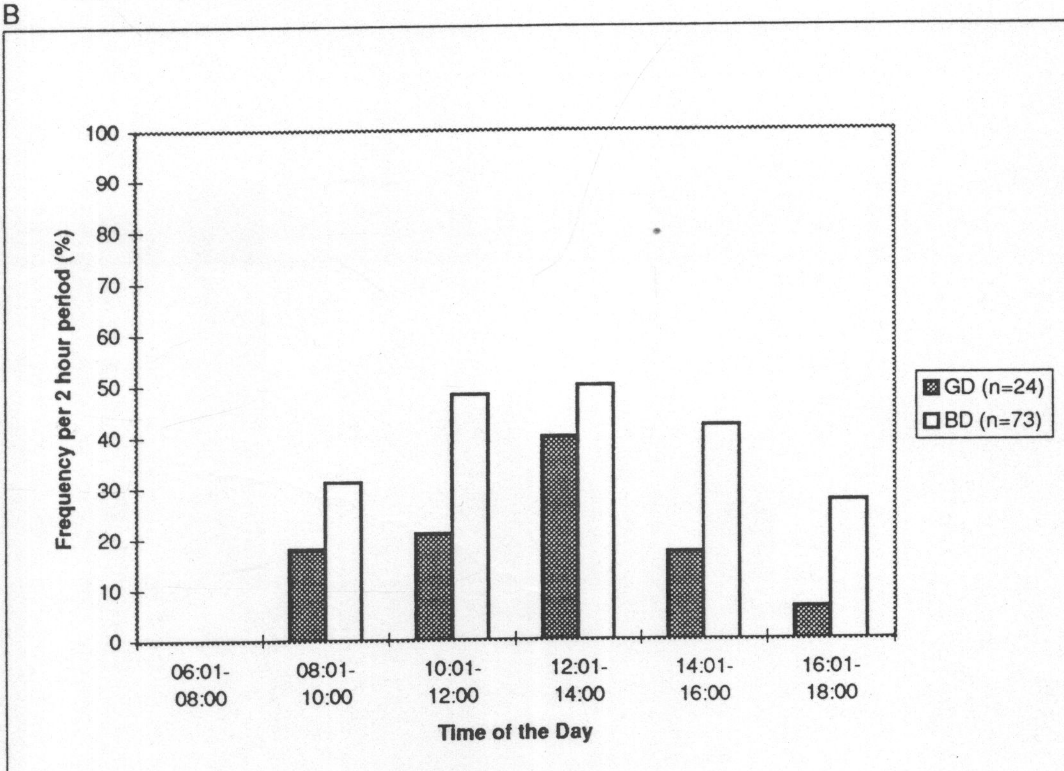
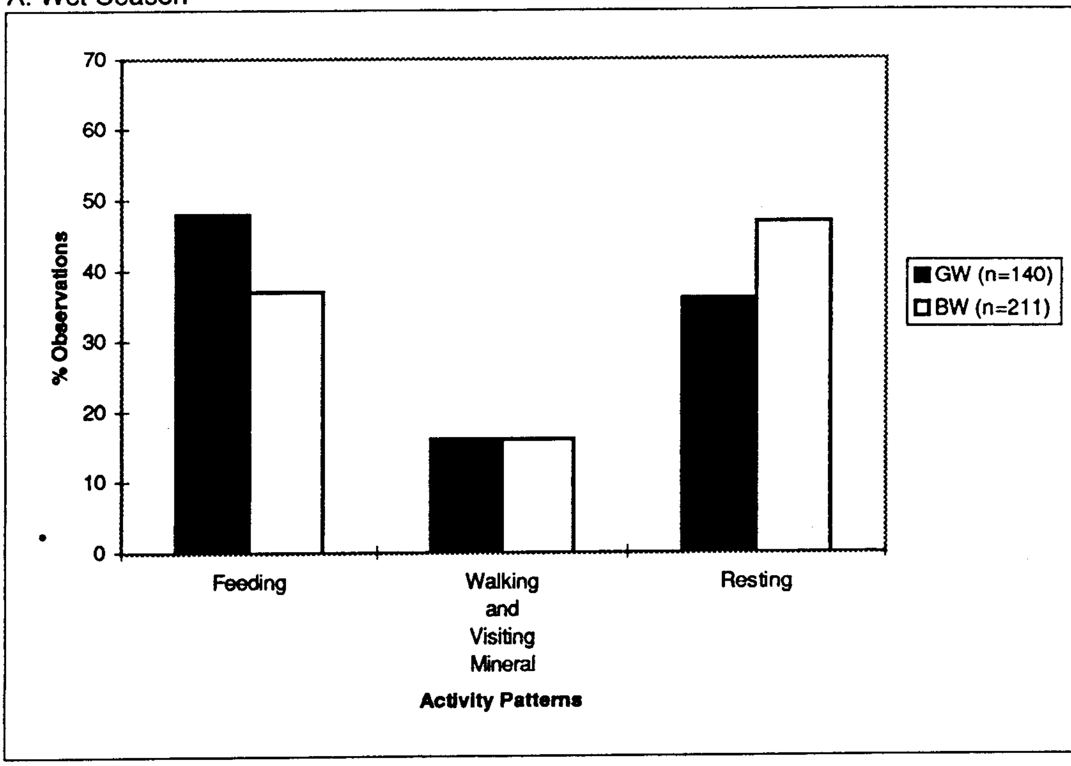
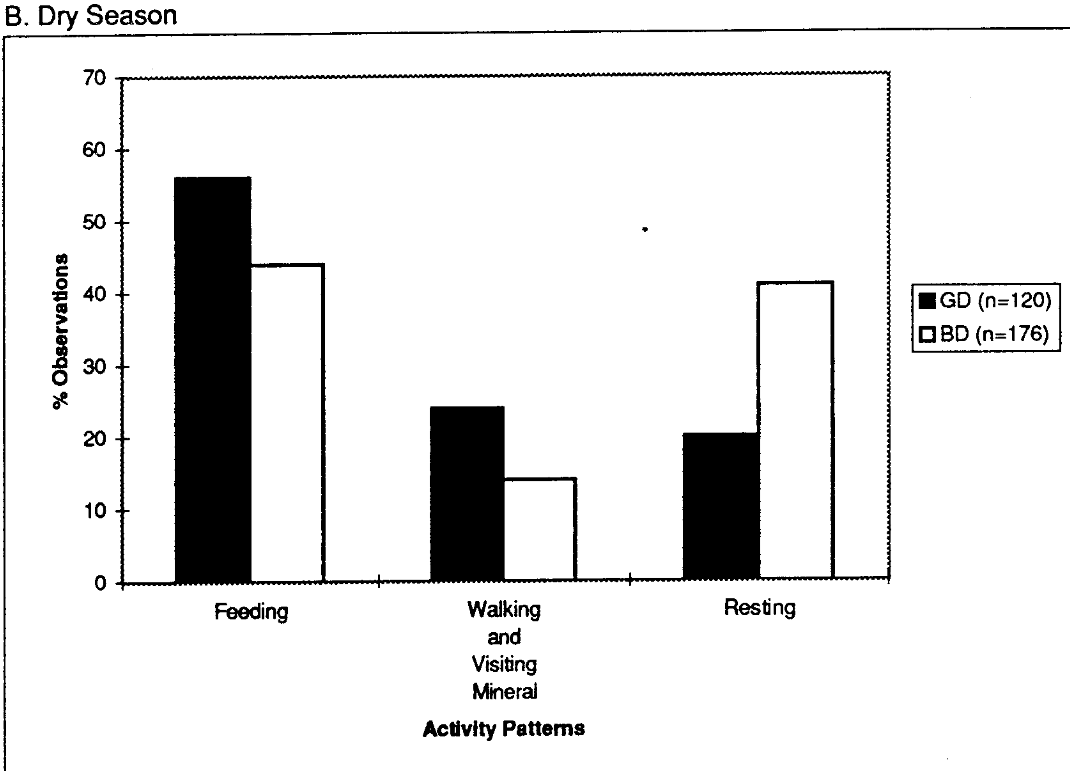

Frequency per 2 hour period (%)
100
90
80
70
60
50
40
30
20
10
0
06:01-08:00
08:01-10:00
10:01-12:00
12:01-14:00
14:01-16:00
16:01-18:00
Time of the Day
GD (n=24)
BD (n=73)

Figure 17. Activity patterns of gaur and banteng during the wet and dry seasons in HKKWS, 1983-1996.

A. Wet Season



B. Dry Season



activities (Fig. 17). They were most active at dawn and dusk in both seasons. Peak activity times were also earlier in the dry season.

In the wet season, feeding peaked between 08:01-10:00 hours and again between 16:01-18:00 hours. In the dry season, feeding peaked in the morning and then declined gradually until noon and then increased again slightly from late afternoon to dusk. Walking and visiting mineral sources occurred at dawn and again around mid day, and then declined slowly at dusk in the wet season. In the dry season this activity type peaked at dawn and again at dusk. In both seasons, resting progressively increased from morning to noon and declined gradually from late afternoon to dusk. The major rest period occurred from 12:01-14:00 hours in the wet season and in general was a more common activity in the wet versus the dry season.

Overlap of Gaur and Banteng.--The proportion of time spent in each activity type for gaur and banteng was slightly different in the wet season ($\chi^2 = 4.77$, 2 df, $P = 0.092$) but it is different in the dry season ($\chi^2 = 15.86$, 2 df, $P < 0.001$) (Figs. 14-16). During daylight hours in both seasons, gaur devoted more time to feeding and less time to resting than banteng (Fig. 17). However, the duration of feeding periods for gaur was narrower than that of banteng.

Feeding in the wet season had similar patterns for both gaur and banteng. In the dry season, feeding patterns differed. Both species peaked in the morning but then in the afternoon the amount of time gaur spent feeding declined gradually until dusk, while banteng feeding declined slowly until noon and then increased again slightly until dusk. Peaked times for walking and visiting mineral sources in the wet season for gaur were at dawn and dusk, whereas, the peak time for this activity for banteng was at dawn. In the dry season gaur walked and visited mineral rich springs at dusk, whereas banteng walked and visited springs most intensively before dawn. Resting patterns were similar for both species in both seasons, generally increasing slightly from morning to noon and then declined slowly from late afternoon to dusk. Resting activity peaked for gaur and banteng in both seasons between 12:01-14:00 hours.

DISCUSSION

Interactions between populations can be classified on the basis of the mechanism of the interaction or on the basis of the effects of the interaction (Abrams 1987). Interspecific competition occurs when two or more species use the same limited resource or harm one another while seeking a resouce (Krebs 1994). The effect of competition between two similar species may be that one species is displaced or that both reach a stable equilibrium state (Krebs 1994). Weins (1977) and Krebs (1994) have suggested that competition is rarely observed in nature because of high environmental fluctuation over evolutionary time; however, competition has been very common and has resulted in adaptations that serve to minimize competitive effects. Gaur and banteng are phylogenetically closely related and coexist within many protected areas in Thailand. They are, however, different in color, size, their use of macro-habitats and food selection. All of these reasons may explain their coexistence in HKKWS.

Food Habits and Resource Partitioning

Gaur in India, Thailand and Myanmar demonstrated similar grazing and browsing patterns (Krishnan 1972, Lekagul and McNeely 1977, Humprey and Bain 1990). In India, when gaur were not disturbed by humans, they most commonly fed early in the morning until noon and again from late afternoon until dusk (Krishnan 1972, Lekagul and McNeely 1977). In the dry season, gaur spent more time grazing at lower elevations and in the wet season they browsed at high elevations (Krishnan 1972). In Indonesia, Thailand and Myanmar, banteng also demonstrated similar feeding patterns (Yin 1967, Hoogerwerf 1970, Lekagul and McNeely 1977, Humprey and Bain 1990). In Indonesia, they grazed at the forest edge from late afternoon to dusk and returned to the forest after dark (Yin 1967, Lekagul and McNeely 1977, Alikodra 1987). Banteng fed on grasses, sedges, forbs, and bamboo as well as the leaves, fruits, flowers, bark and young branches of woody shrubs and trees, including palms. The young shoots of alang-alang grass (*Imperata cylindrica*) were apparently a favoured food source (Schenkel and Schenkel-Hulliger 1969 cited by Hedges in press, Hoogerwerf 1970, Sumardja and Kartawinata 1977).

Wet Season.--During the early wet season, new growth of several grasses, especially *Microstegium ciliatum* and *Microstegium spp*. in mixed-deciduous habitat provide an abundant high protein source which attracted gaur, banteng and other ungulates. Later in mid monsoon, shoots of 2 bamboo species (*Bambusa arundinacea* and *Dendrocalamus strictus*) replaced the grasses as the most abundant high protein food source of gaur and banteng. In July, a third bamboo species sprouts (*Thyrostacnys* *siamensis*), but it grows in dryer, lower elevations and is primarily fed on by banteng (Prayurasiddhi 1987). During this period, the time that each species spends feeding is much less than in the rest of the year, indicating that there is an abundant food supply that can be obtained more rapidly than in the dry season.

During this part of the wet season gaur and banteng have a high degree of dietary and spatial overlap, which suggests a high degree of competition. The fact that over 50% of the new bamboo shoots are grazed to the point that they die supports this hypothesis. There is the potential for strong interspecific competition during the wet season whenever a major die off of bamboo occurs. In 1987-1988 such a die off resulted in a 50 % reduction of bamboo (Prayurasiddhi, unpubl. data, Sukmasrong 1993). The effect of this die off was not recorded, but it may have been less severe than it would be currently or in the near future because at that time gaur and banteng were recovering from several years of intense poaching. Strict protection for gaur and banteng was initiated in 1992, and populations have been increasing since then (C. Pitdamkam, Thai Royal Forest Department, pers. comm. 1995), thus a die off of bamboo at current population levels is likely to result in strong intra and interspecific competition. This season banteng herds fed closer to mineral licks and visited mineral licks more frequently than gaur herds.
I hypothesize that they need more mineral in the wet season because they fed in the poor and dry habitat and all mineral licks were very hard to lick in the dry season. Moreover, females banteng have many calves in the late dry and early wet seasons.

Dry Season.--By September to October, late in the wet season, bamboo shoots grow high and become hard and unpalateable. As the vegetation continues to dry gaur and banteng shift to feed on grasses in dry dipterocarp forest. By late November, early dry season, most of the streams are dry and both species shift their feeding to within 1 km of water sources. The extent to which gaur and banteng depend on water is a vital factor in their ecologies. Gaur in HKKWS shift to evergreen forest which generally occur at higher elevations and remain closer to water than banteng. Banteng shift to lower more open habitat, but they also remain near permanent streams. The gaur's stronger association with permanent water may reflect the physiological constraint of larger body size; gaur are 1.2-1.3 times larger than banteng (D. Armstrong, Henry Doorly Zoo, pers. comm., Lekagul and McNeely 1977). Gaur show an even stronger preference for wetter habitat in Malaysia where they prefer to remain within 250 m of main rivers in the evergreen forest habitats despite living in an environment that is characterized by > 2,500 mm of precipitation (Conry 1981, 1989). Conversely, banteng can perserve for several days without drinking water (National Research Council 1983).

With the shift to evergreen forest, gaur fed on green browse and herb species, while, banteng fed on dry grasses and browse at lower elevations as well as the barks of *Adina cordifolia* and *Mytragyna brunonis* (which were higher in calcium and water contents than other vegetation in the banteng's diet). Gaur did not feed on the bark of plants as they do in India, probably because minerals and water were readily available in the higher evergreen habitat. This may be because of the greater availability of mineral sources in HKKWS than in the forests of India. Foraging theory predicts that when resource availability decreases and fiber content increases (Emlen 1966, MacArthur and Pianka 1966, MacArthur 1972, Sinclair 1977), search time of gaur and banteng per item eaten will increase in this season. In the dry season at HKKWS when the quality and quantity of forage is at its lowest, gaur and banteng spend more time feeding and less time resting. They also shift to different food plants so that there is less overlap in diet.

In the wet season, overall dietary overlap is greater than during the dry season (37 species versus 13 species). Additionally, overlap among the 10 most frequently eaten species is stronger in the wet season than in the dry season (5 in the wet season of the 10 most common species are shared versus only 1 in the dry season). Based on the frequency with which the top 10 species of food plants were observed eaten and relative frequency of use of different food types, both animals were classified as grazers in the wet season, but in the dry season, gaur were classified as browsers while banteng fed both grasses and browse. Grazers feed primarily on grasses and other graminoid plants while browsers concentrate on dicotyledonous plants, both woody and herbaceous (Owen-Smith 1982, 1991). The varity of habitats and the season may influence the food habits of gaur and banteng because in Malaysia, forest cover is predominantly evergreen and gaur are primarily browsers. However, the overall nutrient quality of forage in Malaysia is at or slightly above maintenance requirements, but lacking in crude protein and phosphorus for optimum reproduction and growth of calves (Conry 1981, 1989). I hypothesize that although there was greater overlap in diets in the wet season, there was not greater competition for food resources. This is because food resources were more abundant in the wet season; whereas, in the dry season, they were more limited because the nutritional quality of food resources declined (e.g. level of protein decreased and the level of lignin increased) and overall plant biomass declined (plants became senescent or died and parts above ground were burned by fire). Additionally, the distribution of mineral and water sources were greatly reduced, forcing both species to restrict their foraging to areas near water sources. Finally, the increase in time spent feeding by gaur in the dry season reflects the greater need to search and obtain an adequate supply of high quality food.

Potential competitors that overlap at a macro level can avoid competition within the general habitat type by ecological segregation in time, space, or food resources (Rosenzweig 1981, Schoener 1986, Putman 1996). Many studies have demonstrated reduction in niche overlap between similar sympatric species during seasons of resource shortage (Martinka 1968, Smith et al. 1978, Grant and Grant 1980, Welson 1975). Martinka (1968) found that white-tailed and mule deer used different food plants during the winter when food is most limited. Smith et al. (1978) and Grant and Grant (1980) showed that species of Darwin's ground finches differed more in foraging behavior and diet during the dry season when food is limited. Expectations of competition theory as well as empirical studies lead to the prediction that seasonal food shortage generally causes divergence in an animal's foraging behavior and a change in its dietary width (Thirakhupt 1985).

In the dry season, gaur and banteng have different evolutionary adaptations to cope with lower food resources. Gaur with a larger body size is able to exist on lower protein levels, but the trade off of large body size is that gaur require more shade (dense mixed deciduous and evergreen forest) and greater access to water. This combination of resources occurs at higher elevations where gaur shift from a wet season diet of grass and bamboo to fresh browse and herb species. In contrast, the banteng with lighter coloration and a smaller body size is sedentary and able to forage in open and drier areas (open mixed deciduous and dry-dipterocarp forest) where it feeds on dry grasses, browse and barks. The reddish coloration of banteng reflects light better than the darker body of gaur allowing the banteng to forage in more open environment. Also, the banteng's color makes it more cryptic in dry grasses, while, the darker colored gaur is more cryptic in the shaded evergreen habitat. The dark color potentially absorbs more heat but gaur with its large body size may be selecting evergreen forest to exploit food resources. Gaur in general feed in more open areas during the cool weather and at dusk use the same springs that banteng use earlier in the afternoon.

CONCLUSION

The seasonal differences in food choices habitat use, and daily activity patterns may be the principal factors which have allowed sympatric gaur and banteng to coexist in HKKWS. Although there was greater overlap in gaur and banteng diets during the wet season, there was not greater competition for food resources because food resources were more abundant. In the dry season, gaur and banteng were more limited because the nutritional quality of food resources and overall plant biomass declined. Additionally, mineral and water sources were much less abundant, forcing both species to restrict their foraging to areas near water and mineral sources in different habitats and elevations. Differences in time spent feeding by gaur reflects the greater need to search and obtain an adequate supply of high quality food. The degree of interspecific competition was minimized because gaur became more strict in their habitat and food selections, while banteng, able to use a broader range of habitat types than gaur in this season more to lower and dryer habitats.

LITERATURE CITED

Abrams, P. A. 1987. On classifying interactions between populations. Oecologia 73:272-281.

Adams, L. 1957. A way to analyze herbivore food habits by fecal examination. Trans. N. Am. Wildl. Conf. 22:152-159.

Alikodra, H. 1987. The ecology of banteng (*Bos javanicus*) in the National Park of Ujung Kulon. BIOTROP Spec. Publ. 30:161-167.

Anthony, R. G. 1972. Ecological relationships of mule deer and white-tailed deer in south eastern Arizona. Ph.D. Thesis. Univ. Arizona, Tucson. 123 pp.

Anthony, R.G. and N. S. Smith 1974. Comparison of rumen and fecal analysis to describe deer diets. J. Wildl. Manage. 38(3):535-540.

Bartholomew, G. A., and Cade, T. J. 1963. The water economy of land birds. Auk 80:504-539.

Byers, C. R., Steinhorst, R. K., and Krausman, P. R. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050-1053.

Byers, O., S. Hedges and U. S. Seal. 1995. Asian wild cattle conservation assessment and management plan work document. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN.

Chimchome, V. 1993. Study on serow forage species by fecal analysis. M. S. Thesis. Graduate School. Kasetsart Univ., Bangkok, Thailand.

Conforti, K. 1996. The status and distribution of small carnivores in Huai Kha Khaeng/Thung Yai Nareseun Wildlife Sanctuaries, West-Central Thailand. M. S. Thesis. Univ. Minnesota. 66 pp.

Conry, P.J. 1981. Habitat selection and use, movements, and home range of Malayan gaur (*Bos gaurus hubbacki*) in Central Pahang, Malaysia. M. S. Thesis. Univ. of Montana, Missoula, USA.

________. 1989. Gaur (*Bos gaurus*) and development in Malaysia. Ecological Conservation. 49:47-65.

Danilkin, A. 1996. Behavioural ecology of Siberian and European Roe Deer. Chapman & Hall, London. 277 pp.

Dirschl, H. J. 1962. Sieve mesh size related to analysis of antelope rumen contents. J. Wildl. Manage. 26(3):327-328.

Dusi, J. L. 1949. Methods for determination of food habits by plant microtechniques and histology and their applications to cottontail rabbits in Ohio. J. Wildl. Manage. 13(2):295-298.

Emlen, J. M. 1966. The role of time and energy in food preference. American Naturalist 100: 611-617.

Fraser, D., Reorden E., Dicken, F. and Loescher, B. 1980. Sampling problems and interpretations of chemical analysis of mineral springs use by wildlife. J. Wildl. Manage. 44:623-631.

Grant, P. R., and B. R. Grant. 1980. The breeding and feeding characteristics of Darwin's Finches on Isla Genovesa, Galapagos. Ecological Monographs. 50(3):381-410.

Hawes, M. L. 1977. Home range, territoriality and ecological separation in sympatric shrews, *Sorex vagrans* and *Sorex obscurus*. J. Mammal. 58(3):334-367.

Hedge, S. (in press). Asian Wild Cattle and Buffaloes: Status Report and an Action Plan for their Conservation. IUCN/SSC Asian Wild Cattle Specialist Group.

Hoogerwerf, A. 1970. Udjung Kulon: The land of the last Javan Rhinoceros. E.J. Brill-Leiden, Netherlands. 512 pp.

Humprey, S. R. and J. R. Bain. 1990. Endangered animals of Thailand. Sandhill Crane Press, Inc., Gainesville, Florida. 468 pp.

Kiley, M. 1966. A preliminary investigation into the feeding habits of the waterbuck by fecal analysis. E. Afr. Wild. J. 4(1):153-157.

Krebs, C. J. 1989. Ecological methodology. Happer & Row Publishers, New York. 654 pp.

Krebs, C. J. 1994. Ecology : The experimental analysis of distribution and abundance (4th). HapperCollins College Publishers, New York. 801 pp.

Krishnan 1972. Gaur. In an ecological survey of mammals of India. J. Bombay Nat. Hist. Soc. 69(2):322-349.

Lekagul, B. and J. A. McNeely. 1977. Mammals of Thailand. The Association for the Conservation of Wildlife, Bangkok, Thailand. 758 pp.

Leuthod, W. 1978. Ecological separation of browsing ungulates in TSAVO East National Park, Kenya. Olclogia (Berl.) 35(2)241-251.

Levins, R. 1968. Evolution in Changing Environments: Some Theoretical Explorations. Princeton University Press, Princeton, N. J.

Litvaitis, A. L., K. Titus, E. M. Anderson. 1994. Measuring vertebrate use of terrestrail habitats and foods. Pages 254-274 *in* T. A. Bookhout ed., Research and Management Techniques for Wildlife and Habitats. Fifth ed. The Wildlife Society, Bethesda, Md.

MacArthur, R. H. 1972. Geographical Ecology. Harper and Row, New York.

MacArthur, R. H., and E. R. Pianka. 1966. On optimal use of a patchy environment. American Naturalist. 100: 603-609.

MacFarlance, W. V. and Howard, B. 1972. Comparative water and energy economy of wild and domestic mammals. Symp. Zool. Soc. London. 31:261-296.

Martin, D. J. 1955. Features of plant cuticle: an aid to analysis of the natural diet of grazing animals, with especial reference to Scottish hill sheep. Trans. Proc.Int. Edenb. 36:278-288.

Martinka C. J. 1968. Habitat relationships of white-tailed and mule deer in Northern Montana. J. Wild. Mange. 32(3):558-565.

Moorman F. R. and Rojanasoonthon, S. 1967. General soil map of Thailand. Department of Land Use, Ministry of National Development, Bangkok.

______________________________. 1972. The soils of the kingdom of Thailand: Explanatory Text of the General Soil Map. Land Development Department, Bangkok.

Myers, G. T., and T. A. Vaughn 1964. Food habits of the plains pocket gophers in eatern Colorado. J. mammal. 45(4):588-598.

Nakhasathien, S. and B. Stewart-Cox. 1990. Nomination of the Thung Yai - Huai Kha Khaeng Wildlife Sanctuaries to be a U.N.E.S.C.O. World Heritage Site. Wildlife Conservation Division, Royal Forest Department, Bangkok, Thailand. 128 pp.

National Research Council. 1983. Little-Known Asian Animals with a Promising Economic Future. National Academy Press, Washington D.C., USA.

Neu, C.W., C.R. Byers and J. M. Peck. 1974. A technique for analysis of utilization availability data. J. Wildl. Manage. 38:541-545.

Owen-Smith, N. 1982. Factors influencing the consumption of plant products by large herbivores. Pages 359-402 *in* the Ecology of Tropical Savannas. B. J. Huntley & B. H. Walker (Eds), Springer-Verlag, Berlin.

________________. 1991. Grazers and browsers: ecological and social contrasts among African ruminants *in* F. Spitz, G. Janeau, Gonzalez and S. Aulagnier, eds. Ongules/ Ungulates 91. Société Francaise pour l'Etude et la Protection des Mammiféres-Paris and Institutde Recherche Sur les Grands Mammiferes-Toulouse.

Pianka, E. R. 1973. The structure of lizard communities. Annu. Rev. Ecol. Syst. 4:53-74.

Prayurasiddhi, T. 1987. Ecology of banteng (*Bos javanicus* D'Alton 1823) in Huai Kha Khaeng Wildlife Sanctuary, Thailand. MSc. Thesis. Kasetsart Univ., Bangkok, Thailand (in Thai / English abstract).

Putman, R. J. 1996. Competition and resources partitioning in temperate ungulate assemblies. Chapman & Hall. London, UK. 131 pp.

Robbins, C. T. 1993. Wildlife feeding and nutrition. Academic Press, Inc., California. 352 pp.

Robinson, J. R. 1957. Functions of water in the body. Proc. Nutr. Soc. 16:108-112.

Rosenzweig, M. L. 1981. A theory of habitat selection. Ecology. 62(2):327-335.

Schenkel, R. and Schenkel-Hulliger, L. 1969. The Javan Rinoceros (*Rhinoceros sondaicus* Desm.) in Udjung Kulon Nature Reserve. Its ecology and behaviour. Field Study 1967 and 1968. Acta Tropica 26(2):97-135.

Schoener, T.W. 1986. Resource Partitioning. Pages 91-126 *in* J Kikkwa and D. J. Anderson, eds. Community ecology: Pattern and process. Blackwell, Melbourne, Australia.

Sinclair, A. R. E. 1977. The African buffalo: A study of resource limitation of population, Univ. Chicago Press, Chicago. 355 pp.

Smith, J.N.M., P. R. Grant, B. R. Grant, I. J. Abbott, and L. K. Abbott. 1978. Seasonal variation in feeding habits of Darwin's ground finches. Ecology 59(6): 1137-1150.

Smitinan, T. 1980. Thai Plant Names : Botanical names-Vernacular names. Royal Forest Department, Bangkok, Thailand. 379 pp.

Stewart, D. R. M. 1965. The epidermal characters of grasses, with special reference of African plainsspecies. Bot. Jb. 84:63-174.

______________. 1967. Analysis of plant epidermis in faeces: A technique for studying the food preferences of grazing herbivores. J. Appl. Ecol. 4(1):83-111.

Stewart, D. R. M. and Stewart, J.E. 1970. Food preference data by fecal analysis for African plains ungulates. Zool. Afr. 5:115-129.

Storr, G. M. 1961. Microscopic analysis of faeces: A technique for ascertaining the diet of herbivores mammals. Aust. J. Biol. 14:157-164.

Stott, P. 1984. The savanna forests of mainland Southeast Asia: An ecological survey. Prog. Phys. Geogr. 8(3):315-335.

______. 1986. The spatial pattern of dry season fires in the savanna forests of Thailand. J. Biogeogr. 13:345-358.

Sumardja, E. A. and K. Kartawinata. 1977. Vegetation analysis of the habitat of banteng (Bos Javanicus) at the Pananjung-Pangandaran Nature Reserve, West Java. BIOTROP, Bulletin No.13. SEAMEO, Regional Center for Tropical Biology, Bogor, Indonesia.

Sukmasrong, R 1993. Ecology of Asian Elephant (*Elephas maximus* Linnaeus, 1758) in Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani and Tak. M.S. Thesis. Graduate School, Kasetsart Univ., Bangkok, Thailand. (Thai/ English abstract).

Thirakhupt, K 1985. Foraging ecology of sympatric parids : Individual and population responses to winter food scacity. Ph.D Thesis. Purdue Univ.

Thitatummakul, P. 1985. Vegetation Change along Altitudeinal Gradient in Huai Kha Khaeng Wildlife Sanctuary. M. S. Thesis, Kasetsart Univ., Bangkok, Thailand (Thai/English abstract).

Underwood, E. J. 1977. Trace elements in human and animal nutrition. Academic Press, New York.

Weins, J.A. 1977. On competition and variable environments. American Scientist. 65:590-597.

Welson, D. S. 1975. The adequacy of body size as a niche difference. Amer. Natur. 109:769-784.

Yin, U.T. 1967. Wild animals of Burma. Rangoon Gazette Ltd., Rangoon, Burma. 301 pp.

Zyznar, E. and P. J. Urness. 1969. Qualitative identification of forage remnants in deer feces. J. Wildl. Manage. 33:506-510.

CHAPTER 3

MANAGEMENT AND CONSERVATION OF GAUR AND BANTENG IN HUAI KHA KHAENG WILDLIFE SANCTUARY AND SURROUNDING PROTECTED AREAS

INTRODUCTION

A high diversity of wild ungulates, including nine species of bovini, is found in the forest ecosystems of mainland South and Southeast Asia (Yin 1967, Hoogerwerf 1970, Grzimek 1975, Lekagul and McNeely 1977, Ashby and Santipillai 1988, Conry 1981, 1989, Corbet and Hill 1992, Khoi 1995, Hedges in press). Gaur (*Bos gaurus*), banteng (*Bos javanicus*), kouprey (*Bos sauveli*) and wild water buffalo (*Bubalus bubalis*) are wild bovids in Thailand (Wharton 1968, Grzimek 1975, Lekagul and McNeely 1977). Only gaur and banteng are widely distribute in Thailand (Lekagul and McNeely 1977). During past centuries, gaur and banteng habitat declined gradually as deforestation increased due to unprecedented growth of human populations throughout the region after World War II. In addition, domestic cattle around protected areas increased and may compete with wild cattle for food resources and habitat as well as transmit disease. Gaur are currently considered vulnerable; banteng are listed as endangered (IUCN 1994, Byers et al. 1995).

Today many gaur and banteng populations may be isolated and near the minimum size below which inbreeding, loss of genetic variability, and random ecological and demographic events pose serious threats to survival even where the remnant numbers and habitats are securely protected. Of the 124 terrestrial protected areas in Thailand, gaur exist in 39 National Parks and Wildlife Sanctuaries and 1 national forest; banteng are found in 25 National Parks and Wildlife Sanctuaries. Gaur and banteng coexist in only 22 protected areas (Prayurasiddhi 1987, Srikosamatara and Suteethorn 1995, Wildlife Technical Division, pers. comm. 1996, The Nation 1997a) (Table 1). Srikosamatara

(1993) and Srikosamatara and Suteethorn (1995) estimated 470 banteng and 915 gaur in the protected areas of Thailand.

To conserve these two species in Thailand, especially in sympatry, will require a strategy to conserve the forest ecosystems of Thailand. Huai Kha Khaeng and Thung Yai Naresuan Wildlife Sanctuaries are the core sanctuaries of the largest and most important habitat supporting gaur and banteng in Thailand (Prayurasiddhi 1987, Nakhasathien and Stwart-Cox 1990, Byers et al. 1995) (Fig 1). Therefore, management for both species within the Western Forest Complex needs to be based on regional planning. This chapter will 1) outline the problems of small population size; 2) report the locations of gaur and banteng herds in HKKWS and domestic livestock around HKKWS; 3) outline threats to gaur and banteng in HKKWS and surrounding protected areas; and 4) make specific recommendations for the management and conservation of gaur and banteng within HKKWS and the development of an effective management plan for protecting the Western Forest Complex in the future.

The Problem of Small Population Size

All populations eventually go extinct; very large populations may last for thousands of generations, while small populations are much more vulnerable to extinction due to genetic, demographic and environmental stochasticity (Soulé and Wilcox 1980a, 1980b, Gilpin and Soulé 1986, Meffe and Carroll 1997). Based on the experience of animal breeders, population geneticists have attempted to estimate minimum population size to ensure genetic viability and ecological resilience (Franklin 1980, Soulé 1980, Frankel and Soulé 1981). They recommend there should be no more than 1% inbreeding per generation to avoid reduced fertility, decreased resistance to disease, and high juvenile mortality. Using this information and recent analyses of breeding histories from zoos, populations should probably be ≥ 50 breeding individuals (Seal 1977, Ralls et al. 1979). Fifty breeders is not the critical threshold for all species, it is simply a reasonable guideline (Smith 1984). Some species persist successfully at fewer than 50, while others show deleterious effects well above 50 (Soulé 1980). In the case of gaur and banteng, information to calculate the specific inbreeding threshold does not exist.

Background

Huai Kha Khaeng Wildlife Sanctuary (HKKWS) is located in the Western Forest Complex of Thailand and has a current area of 2,575 km^2 (15° 00'-15° 48' N, 98° 27'-99° 30' E). It was established in 1972 and subsequently expanded in 1986 and 1992 (Fig. 1). HKKWS and the contiguous Thung Yai Nareseun Wildlife Sanctuary (3,647 km^2) to the west were recently designated a World Heritage Site by UNESCO (Nakhasathien and Stewart-Cox 1990).

HKKWS is located at the junction of mainland South-east Asia's bio-geographic zones; the Sino-Himalayan, Sundaic, Indo-Burmese and Indo-Chinese (Nakhasathien and Stewart-Cox 1990). This sanctuary and the 5 adjacent protected areas contain 3

Table 1. Gaur and Banteng occurrences in protected areas of Thailand.

No.	Name	PA Status[1]	Gaur Status[2]	Banteng Status[3]	Gaur Sources[4]	Banteng Sources[5]
1	Chalerm Rattanakosin *	NP	1	0	4	4
2	Doi Khun Tan	NP	1	0	4	4
3	Erawan *	NP	1	1	1, 2, 3, 4	3
4	Hala Bala	WS	1	N/A	3, 4	1
5	Huai Kha Khaeng *	WS	1	1	1, 2, 3, 4	1, 2, 3, 4
6	Huai Sala	WS	N/A	1	1	4
7	Huai Tabtan-Huai Samart	WS	1	1	4	4
8	Khaeng Krung	NP	1	1	2, 4	2, 4
9	Khang Krachan	NP	1	1	1, 2, 4	2, 3
10	Khao Ang Runai	WS	1	1	1, 3, 4	1, 3, 4
11	Khao Chamao-Khao Wong	NP	1	N/A	4	1
12	Khao Laem *	NP	1	1	4	4
13	Khao Sanam Preng *	WS	0	0	3, 4	3, 4
14	Khao Soi Dao	WS	1	1	2, 3	2, 3
15	Khao Sok	NP	1	1	1, 2, 3, 4	1, 2, 3, 4
16	Khao Yai	NP	1	0	1, 2, 3, 4	1, 2, 3, 4
17	Klong Naka	WS	1	1	2, 4	2, 3
18	Klong Saeng	WS	1	1	1, 2, 3, 4	1, 2, 3, 4
19	Klong Wang Chao *	NP	N/A	N/A	1	1
20	Klong Yan	WS	1	1	4	4
21	Klonglan *	NP	1	N/A	4	1
22	Lam Khao Hur *	NP	N/A	N/A	1	1
23	Mae Nam Pachi	WS	1	N/A	4	1
24	Mae Ping	NP	0	1	3	3
25	Mae Wong *	NP	1	N/A	3, 4	1, 3, 4
26	Nam Nao	NP	1	1	4	2
27	Namtok Huai Yang	NP	N/A	N/A	1	1
28	Omkoi	WS	1	1	2	2, 3
29	Pang Sida	NP	1	1	2, 3, 4	2, 4
30	Panom Donrak	WS	N/A	N/A	1	1
31	Phu Khiew	WS	1	N/A	2, 3, 4	1
32	Phu Luang	WS	1	0	1, 2, 4	1, 2, 4
33	Phu Miang-Phu Thong	WS	1	N/A	4	1
34	Phuchong-Na Yoi	NP	1	N/A	4	1
35	Prince Chumphon Park	WS	1	1	3, 4	4
36	Phutoid *	NP	1	N/A	1	1
37	Sai Yok *	NP	1	1	4	4

Table 1 (Continued)

No.	Name	PA Status[1]	Gaur[2] Status	Banteng[3] Status	Gaur Sources[4]	Banteng Sources[5]
38	Salak Phra *	WS	1	1	3, 4	3, 4
39	Sri Phangnga	NP	1	1	2, 4	2, 4
40	Sri Satchanalai	NP	1	1	2	4
41	Sri Nakarin *	NP	1	1	3, 4	3, 4
42	Tai Rom Yen	NP	N/A	N/A	1	1
43	Thap Lan	NP	1	1	2, 4	2, 4
44	Thong Pha Pom *	NP	N/A	N/A	1	1
45	Thung Raya Nasak	WS	1	N/A	4	1
46	Thung Salaeng Luang	NP	1	0	2, 4	2, 4
47	Thung Yai Naresuan *	WS	1	0	1, 2, 3, 4	1, 2, 3, 4
48	Umphang *	WS	1	N/A	1	1
49	Yod Dom	WS	N/A	1	1	1, 3
50	Pakthongchai	NF	1	0	1, 5	5

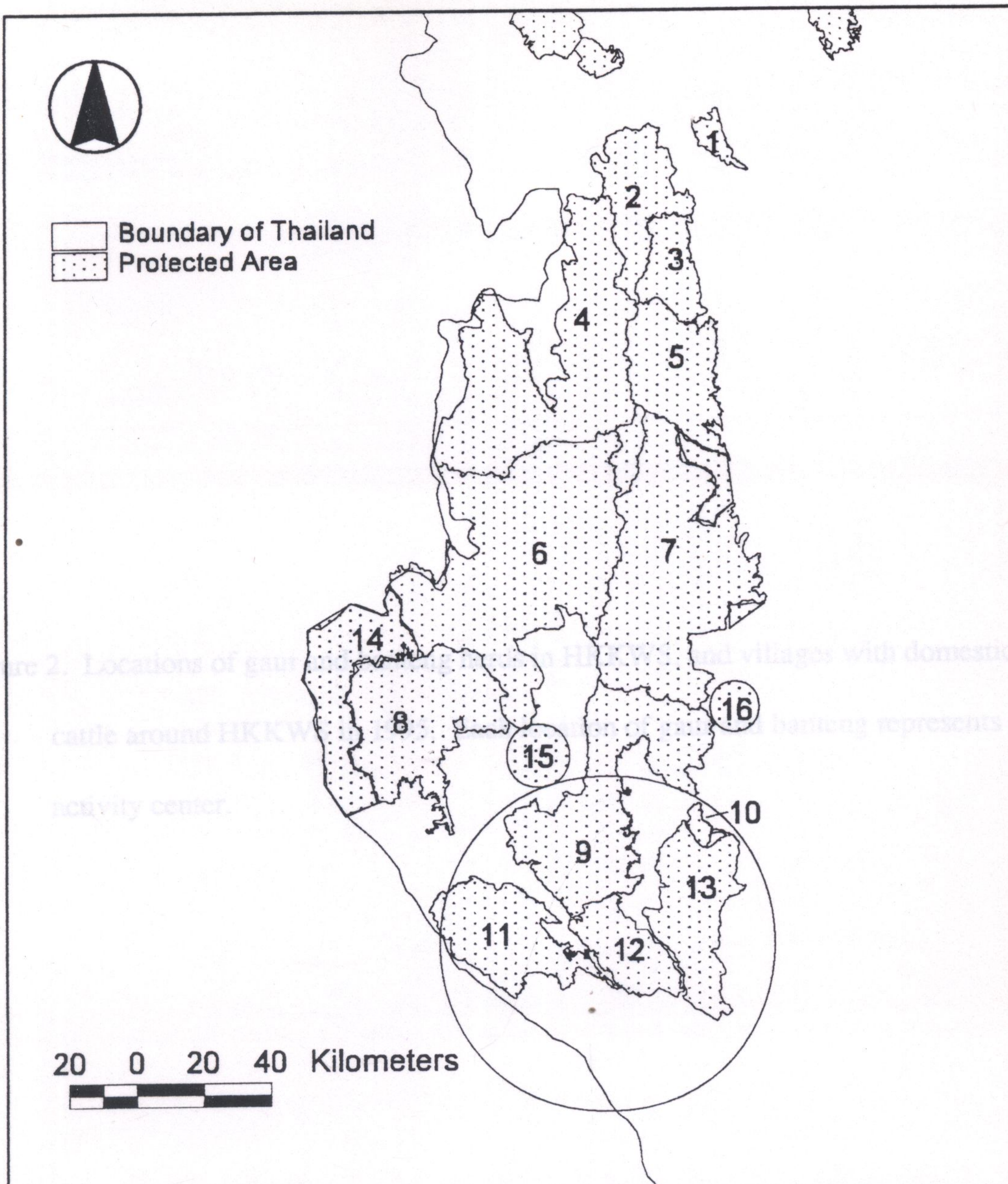
* Protected Area in the Western Forest Complex

[1] Protected Area Status (PA) : NP = National Park
WS = Wildlife Sanctuary
NF = National Forest

[2], [3] Gaur and Banteng Status: 0 = Absence; 1 = Presence; N/A = No Data Available

[4, 5] <u>Sources</u>: 1. Prayurasiddhi, unpublished. data. 1995
2. Srikosamatara and Suteethorn 1995
3. Wildlife Conservation Division & National Park Division, pers. comm. 1996
4. Wildlife Research Division, pers. comm. 1996
5. Wildlife Fund Thailand, pers. comm. 1996

Figure 1. Huai Kha Khaeng Wildlife Sanctuary and 15 surrounding protected areas in the Western Forest Complex. Circle represents the 5 isolated protected areas. Five of the protected areas, Sai Yok National Park, Erawan National Park, Sri Nakarin National Park, Chalerm Rattanakosin National Park and Salak Phra Wildlife Sanctuary are isolated by narrow gaps of highly developed forest.

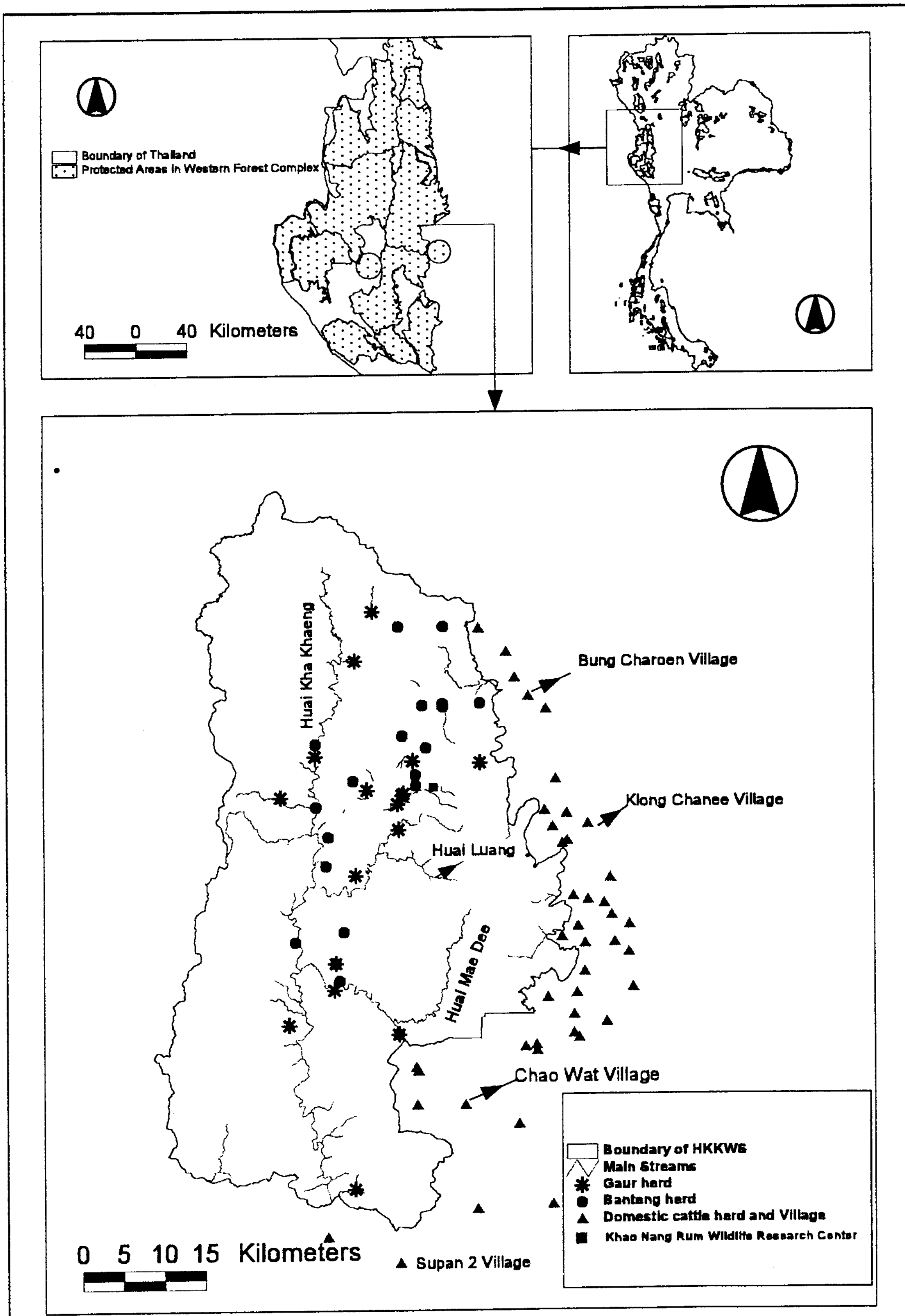


Western Forest Complex

1. Khao Sanam Phiang WS
2. Klong Wang Chao NP
3. Klong Lan NP
4. Umphang WS
5. Mae Wong NP
6. Thung Yai Naresuan WS
7. Huai Kha Khaeng WS
8. Khao Laem NP
9. Sri Nakarin NP
10. Chalerm Rattanakosin NP
11. Sai Yok NP
12. Erawan NP
13. Salak Phra WS
14. Thong Papomm NP
15. Lam Khao Hur
16. Putoi NP

NP=National Park; WS=Wildlife Sanctuary

Figure 2. Locations of gaur and banteng herds in HKKWS, and villages with domestic cattle around HKKWS in 1995. Each location of gaur and banteng represents its activity center.


Boundary of Thailand
Protected Areas in Western Forest Complex
40 0 40 Kilometers
Huai Kha Khaeng
Bung Charoen Village
Klong Chanee Village
Huai Luang
Huai Mae Dee
Chao Wat Village
Supan 2 Village
0 5 10 15 Kilometers
Boundary of HKKWS
Main Streams
Gaur herd
Banteng herd
Domestic cattle herd and Village
Khao Nang Rum Wildlife Research Center

undisturbed river systems (Huai Kwai Yai, Huai Kha Khaeng and Huai Mae Wong), seasonal swamps and lakes, and includes significant variations in topography, altitude, rainfall, and soil types. These features create a mosaic of different habitats. Because of this landscape, many species reach the southern, northern, western or eastern limit of their range within the sanctuary and co-occur nowhere else in Thailand. Therefore, this region supports a unique assemblage of plant and animal communities. For example, at least 27 species of carnivores (Rabinowitz and Walker 1991, Conforti 1996), all five of the region's macaques (genus *Macaca*) and two species of leaf monkeys (genus *Presbytis*) occur in this area (Nakhasathien and Stewart-Cox 1990).

This sanctuary, along with 15 protected areas to the north and south, and adjoining forest lands in Myanmar make up one of the largest protected area complex in mainland Southeast Asia. It is large enough, and sufficiently undisturbed to support truly natural communities containing populations of large herbivores and predator species (C. Pitdamkam, Thai Royal Forest Dept., pers. comm. 1995).

Populations and Distribution of Wild Cattle and Domestic Livestock

Gaur.--During 1994-1995, there were 300-335 gaur from 17 herds within HKKWS (Chapter 1; Fig. 2). The group sizes varied ranging from 8-40 (n=17). Gaur were found throughout HKKWS in the > 200-1,700 m zone (Chapter 1). They had wider distribution than banteng. In the dry season, small groups fed along the major stream in dense forest at high elevation; whereas, larger groups fed along the major streams at lower elevations. Gaur avoid dry and low areas that are ≤ 200 m (Chapter 1). Gaur currently exist in at least 12 protected areas in the Western Forest Complex (Prayurasiddhi 1987, Srikosamatara and Suteethorn 1995, Wildlife Technical Division, unpubl. data 1996) (Table 1).

Banteng.--During 1994-1995, 240-270 banteng from 20 herds were distributed within HKKWS (Chapter 1; Fig. 2). The group sizes varied ranging from 6-30 (n=20) (Chapter 1). The distribution of banteng herds typically were in low-flat and foothills zones along the valley. They were usually in the eastern and middle part of HKKWS that covered Huai Kha Khaeng and Huai Mae Dee watershed area. No banteng were found in the northern mountainous part of the sanctuary. Banteng were distributed near mineral licks and springs and never above 1,000 m sea level. Banteng currently exist in only 7 protected areas in the Western Forest Complex (Prayurasiddhi 1987, Srikosamatara and Suteethorn 1995, Wildlife Technical Division, unpubl. data. 1996) (Table 1). Banteng prefer dry habitats and do not occur in protected areas that are mountainous with annual precipitation > 2,000 mm. High elevation and greater rainfall may explain why banteng do not occur in Thung Yai Naresuan Wildlife Sanctuary, adjacent to HKKWS.

Domestic Livestock.--At least 45 villages from 6 districts and 4 provinces are located within the 5 km buffer zone in the eastern and southern parts of HKKWS (C. Pitdamkam, pers. comm. 1995) (Fig. 2). During my study, the total human population of these villages was approximately 15,300 (C. Pitdamkam, pers. comm. 1995). At least 8,400 domestic cows and 1,600 domestic buffaloes grazed near and within 5 km width of the HKKWS buffer zone in 1995 (Lansak Livestock Office, Banrai Livestock Office and Huai Kud Livestock Office, unpubl. data 1995).

Threats to Gaur and Banteng

Poaching is done by local people living around the sanctuary who sell the horns as trophies to middle men in nearby villages. Middle men sell all horns to the Black Market in Bangkok. Between 1985-1988, 16 gaur, 8 banteng and 1 wild buffalo were found dead within HKKWS, apparently killed by poachers. Three calves were probably taken from their mothers and sold (2 gaur and a buffalo) (Prayurasiddhi 1987, Nakhasathien and Stewart-Cox 1990). During 1994-1996, 3 gaur (2 males and 1 unidentified sex) and 17 banteng (8 males, 8 females and 1 calf) were killed by poachers, tigers (*Panthera tigris*), and leopards (*Panthera pardus*) (Prayurasiddhi, unpubl. data. 1996) (Appendix 18).

Illegal logging and habitat degradation are the most serious contemporary threats to the adjacent lowland forest (≤ 400 m above sea level) or within buffer zone of HKKWS (Nakhasathien and Stewart-Cox 1990). These areas that are ≤ 400 m above sea level are important for wild cattle especially banteng (Chapter 1). If human activities continue to degrade the lowland and foothills zone, competition between gaur and banteng may increase within the overlapped zones (≥ 200-600 m). During 1989-1992, the forest in the eastern part of HKKWS was legally logged by the Thai Plywood Company and illegal logged by local people (Nakhasathien and Stewart-Cox 1990 and Prayurasiddhi, unpubl.

data.). However, after intensive enforcement during 1993-1996, the illegal logging and habitat degradation decreased (C. Pitdamkam, pers. comm. 1995).

Fires sweep through the deciduous forests of HKKWS every dry season (Stott 1986, Rabinowitz 1989, 1991, Nakhasathien and Stewart-Cox 1990, Kanjanavanit 1991). Fires are started by poachers and local farmers in the eastern part of the sanctuary (Nakhasathien and Stewart-Cox 1990). Fires undoubtedly impinge on the population dynamics of many species. During 2-3 months of the dry season fires reduce the quantity and quality of food in herbivore diets and the underground water content in the dry dipterocarp and mixed-deciduous forests. Many thin gaur and banteng were seen and also several banteng were killed by tiger during this period (Prayurasiddhi, pers. obs. 1995). Fire prevents succession from dry dipterocarp to mixed-deciduous or evergreen forest, and frequently fire can change mixed-deciduous and evergreen forests to dry-dipterocarp forest (U. Kutintara, Kasetsart Univ., pers comm.). Dry dipterocarp forests are more open and have a higher evaporation rate lowering the water table. In the early dry season of 1988 and 1992, almost 90% of the sanctuary was damaged by fire but the overall effect was unknown (Prayurasiddhi, unpubl. data). In 1992, the Huai Kha Khaeng Forest Fire Control Unit was established to control fire within HKKWS and adjacent areas. During 1994, 30 km^2 within HKKWS and adjacent areas were burned, but in the last 2 years, only 4-5 km^2 in buffer zone and HKKWS were damaged (Huai Kha Khaeng Forest Fire Control Unit, unpubl. data). In other protected areas in the Western Forest Complex, fires burn extensive areas every dry season.

Finally, domestic livestock can pass disease to wild cattle (Ashby and Santipillai 1983, National Research Council 1983) In the past, many gaur in India died because of rinderpest (Choudhury, pers. comm.). In 1995-1996, 2 banteng (1 female and 1 unidentified sex) died near Khao Nang Rum Wildlife Research Center due to foot rot (C. Jirapreutisir, Lansak Livestock Office, pers. comm. 1996, Prayurasiddhi, unpubl. data). In 1997, many domestic cattle in Bangkok and adjacent provinces died due to anthrax (The Nation 1997b). Every year domestic cattle from Myanmar are released into the Western Forest Complex for grazing (C. Jirapreutisir, pers. comm. 1995). Animals from surrounding domestic populations as well as from Myanmar may bring disease into the Western Forest Complex. In addition, domestic cattle may compete with banteng to feed on bamboo shoots in the mixed-deciduous forest that are adjacent to some villages in the wet season.

Management for Conservation

To conserve wild cattle and biodiversity in this region, I recommend a 3 part program of *land management*, *research* and *conservation education.*

Land Management--The Western Forest Complex Coordinating Committee has recently been convened to establish management at the level of the entire Western Forest Complex ecosystem. This committee will draw up a comprehensive plan which addresses issues that span the entire complex. Recommendations include:

1. Establish a system of systematic ranger patrol (HKKWS and other sanctuaries from > 120 substations) to reduce illegal poaching and logging within the low and foothills zone ($\leq$ 400 m) of the sanctuary and adjacent protected areas. To be effective rangers need training, additional equipment and life insurance.

2. Develop a stronger link among HKKWS official, local government agencies, local non-government organizations (NGO) and local people around the sanctuary to eliminate illegal poaching and logging, and forest degradation in the future.

3. Extend the 1993 Buffer Zone Management Plan and community forest to all protected areas of the Western Forest Complex to improve the life style of local people and decrease the utilization of forests around protected areas by local communities.

4. Coordinate with local district livestock officials located near HKKWS and the Western Forest Complex to determine cause of death wild animals and to monitor disease symptoms of wild and domestic cattle within the buffer zone and the adjacent areas. In addition, a program is needed to vaccinate domestic livestock around the protected areas of the Western Forest Complex.

5. Restrict forest fire control project within the buffer zone of HKKWS to prevent the forest succession of evergreen and mixed-deciduous forest inside the sanctuary.

6. Establish travel corridors between isolated habitat islands in some protected areas within the Western Forest Complex to facilitate movements and genetic exchange among population of wild cattle in this region. Five of the protected areas, Sai Yok National Park, Erawan National Park, Sri Nakarin National Park Chalerm Rattanakosin

National Park and Salak Phra Wildlife Sanctuary are isolated by narrow gaps of highly developed forest (Fig. 1). Restoration projects in these areas could reconnect these reserves to the rest of the complex and provide pilot studies to test restoration techniques.

Monitoring and Research

1. Establish a long term monitoring program to census and map the distribution and movement of large mammals especially wild cattle within HKKWS and the Western Forest Complex.

2. Continue research on ecological separation of wild cattle and wild water buffalo in the southern part of HKKWS.

3. Study interactions among wild cattle and all big predators, especially tigers within HKKWS.

4. Use satellite photos and GIS to analyze the distribution and density of large bovids in relation to forest cover and quality, elevation, water, mineral licks and human activities near forest villages (in Thung Yai Naresuan Wildlife Sanctuary) and in the buffer zone.

5. Conduct research on fire ecology to determine short term and long term forest succession patterns and the role of fire in increasing food plants for wild ungulates in the early dry season within restricted patrolling areas.

Conservation Education

1. Implement a conservation education and public awareness campaign about the value of the forest and the importance of wild cattle to the ecosystem. This should be

developed for local governmental agencies, NGOS and communities within buffer zones and the adjacent areas of the Western Forest Complex.

2. Establish a wild cattle conservation group in local schools near HKKWS and surrounding protected areas and link all group in the network. All of these groups will support and help to protect all protected areas in the Western Forest Complex.

CONCLUSION

HKKWS is the only protected area in mainland Southeast Asia known to support 3 species of wild cattle and buffalo (gaur, banteng and wild water buffalo). This sanctuary is the core area of the Western Forest Complex because it is under the strictest protection. A strategy of ecosystem management is needed to extend protection and stricter management to the other sanctuaries. This complex is unique because it is one of the truly large reserve complexes in Asia. The mixed-deciduous and dry-dipterocarp forest of the ≤ 400 m zones of gaur and banteng habitat within HKKWS and 15 surrounding protected areas are overlapped by human use. Therefore, effective land management and conservation strategies must be planned for the entire complex to improve the life style of local people, and decrease poaching, habitat degradation and disease. A long term monitoring research program utilizing rangers at the more than 120 substations in the complex is needed to provide information on the status and dynamics of large mammals in the Complex in addition to social and economics aspects of human land use adjacent to HKKWS. A conservation education and public awareness campaign should target local government agencies, NGOS and local people around HKKWS and surrounding protected areas to participate in all conservation activities. All of these appropriate management strategies and local participation within the complex will contribute to long term conservation of biological diversity in Thailand.

LITERATURE CITED

Ashby, K. R., and C. Santipillai. 1988. The Status of the Banteng (*Bos javanicus*) in Java and Bali. Tiger Paper Oct-Dec 1988:16-25.

Byers, O., S. Hedges and U. S. Seal. 1995. Asian Wild Cattle Conservation Assessment and Management Plan Work Document. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN.

Conforti, K. 1996. The status and distribution of small carnivores in Huai Kha Khaeng/ThungYai Nareseun Wildlife Sanctuaries, West-Central Thailand. M. S. Thesis. U of Minnesota, St. Paul. 66 pp.

Conry, P. J. 1981. Habitat selection and use, movement, and home range of Malayan gaur (*Bos gaurus hubbacki*) in central Pahang, Malaysia. M. S. Thesis. University of Montana, Montana. 120 pp.

_________. 1989. Gaur (*Bos gaurus*) and Development in Malaysia. Ecological Conservation. 49:47-65.

Corbet, G. B. and J. E. Hill. 1992. The mammals of the Indomalayan region: A systematic review. Oxford University Press, New York. 488 pp.

Franklin, I. R. 1980. Evolutionary change in small populations. Pages 151-170 *in* M.E. Soulé and B. A. Wilcox, eds. Conservation Biology Sunderland, Massachusetts, Sinauer Associatie, Inc.

Frankel, O. H. and M. E. Soul. 1981. Conservation and evolution. Cambridge, Cambridge University Press.

Gilpin M. E. and M. E. Soulé. 1986. Minimum viable population: Processes of spices extinction. Pages 19-34 *in* M. E. Soulé (ed). Conservation Biology: The Science of Scarcity and Diversity, Sinauer Associates, Sunderland, MA.

Grzimek, B. 1975. Grzimek's Animal Life Encyclopedia. Mammals, I-IV. Van Nostrand Reinhold Company, New York. Vol.10-13.

Hedges, S. (in press). Asian Wild Cattle and Buffaloes: Status Report and an Action Plan for their Conservation. IUCN/SSC Asian Wild Cattle Specialist Group.

Hoogerwerf, A. 1970. Udjung Kulon: The Land of the Last Javan Rhinoceros. E. J. Brill-Leiden, Netherlands. 512 pp.

IUCN 1994. IUCN Red List Categories. IUCN Species Survival Commission. Gland, Switzerland: IUCN.

Kanjanavanit, S. 1991. Aspects of the temporal pattern of dry season fires in the dry dipterocarp forest of Thailand. Ph. D. Thesis. Department of Geography, School of Oriental and African Studies, UK.

Khoi Vu Le. 1995. The status of wild cattle and their conservation in Vietnam. Faculty of Biology, Hanoi University, Vietnam, 6 pp. (Unpublished).

Lekagul, B. and J. A. McNeely. 1977. Mammals of Thailand. The Association for the Conservation of Wildlife, Bangkok, Thailand. 758 pp.

Meffe, G. K. and C. R. Caroll. 1997. Genetics: Conservation of diversity within species. Pages 161-201 *in* Meffe, G. K., C. R. Caroll and contributors, eds. Principles of Conservation Biology (2^{nd} ed.). Sinauer Associates, Inc. Sunderland, Massachusetts.

Nakhasathien, S. and B. Stewart-Cox 1990. Nomination of the Thung Yai - Huai Kha Khaeng Wildlife Sanctuaries to be a U.N.E.S.C.O. World Heritage Site. Wildlife Conservation Division, Royal Forest Department, Thailand. 128 pp.

Prayurasiddhi, T. 1987. Ecology of Banteng in Huai Kha Khaeng Wildlife Sanctuary. M. S. Thesis. Graduate School. Kasetsart Univ., Bangkok, Thailand (In Thai with English abstract).

Rabinowitz, A. R. 1989. The density and behavior of large cats in dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. Nat. Hist. Bull. Siam Soc. 37(2):235-251.

______________. and S. Walker. 1991. The carnivore community in dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. J. of Tropical Ecology 7:37-47.

Ralls, K. K. Brugger, and J. Ballou 1979. Inbreeding and juvenile mortality in small populations of ungulates. Science 206:1101-1103.

Seal, U.S. 1977. The Noah's Ark problem: Multigeneration management of wild species in captivity. *In* Endangered Birds, Management Techniques for Preserving Endangered Species ed. by S. A. Temple. Madison, Univ. Wisconsin Press.

Smith, J. L. D. 1984. Dispersal, Communication, and Conservation Strategies for tiger (*Panthera tigris*) in Royal Chitwan National Park, Nepal. Ph.D. Thesis, St. Paul, Univ. Minnesota.

Soulé, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-170 *in* M.E. Soulé and B. A. Wilcox, eds. Conservation Biology: An Ecological Evolutionary Perspective. Sunderland, Massachusetts, Sinauer Associatie, Inc.

__________. and B. A. Wilcox (eds.) 1980a. Conservation Biology: An Evolutionary-Ecological Perspective. Sinauer Associates, Sunderland, MA.

__________. and B. A. Wilcox (eds.) 1980b. Conservation Biology: Its scope and its challenge. Pages 1-8 *in* M. E. Soulé and B. A. Wilcox, eds. Conservation Biology: An Evolutionary-Ecological Perspective,. Sinauer Associates, Sunderland, MA.

Srikosamatara, S. 1993. Density and biomass of large herbivores and other mammals in dry tropical forest, western Thailand. J. Trop. Ecol. 9:33-43.

______________. and V. Suteethorn 1995. Populations of gaur and banteng and their management in Thailand. Nat. Hist. Bull. Siam Soc.43:55-83.

Stott, P. 1986. The spatial pattern of dry season fires in the savanna forests of Thailand. J. Biogeogr. 13:345-358.

The Nation. 1997a. Gaur avoid game hunter. The Nation: *Thailand's Independent Newspaper*. Nation Multimedia Group, Bangkok, Thailand. April 16, 1997.

__________. 1997b. Anthrax. The Nation: *Thailand's Independent Newspaper*. Nation Multimedia Group, Bangkok, Thailand. February 12 1997.

Wharton, C.H. 1968. Man, Fire and Wild Cattle in southeast Asia. Proceeding Annual Tall Timber Fire Ecology conference. Volumn 8 , Tallshassee, Florida.

Wright, S. 1978. Evolution and the genetics of populations, Vol. 4 Variability within and among natural populations. Chicago, Univ. Chicago Press, Chicago.

Yin, U. T. 1967. Wild Animals of Burma. Rangoon Gazette Ltd., Rangoon, Burma. 301 pp.

APPENDICES

Appendix 1. Habitat types and elevation zones within Huai Kha Khaeng Wildlife Sanctuary (HKKWS) and study areas 1 and 2, during 1994-1995.

Appendix 1.1. The areas of habitat types in each elevation zone

Habitats/Elevations (m)	Areas (km²)				Total (km²)	Total (%)
	0-200 m	≥ 200-400 m	≥ 400-600 m	≥ 600-1,700 m		
Evergreen Forest	11	106	231	970	1,319	47
Mixed-deciduous Forest	59	428	475	247	1,210	43
Mixed-deciduous Forest with Bamboo	1	49	39	8	97	3
Dry-dipterocarp Forest	11	38	87	27	164	6
Other habitats	5	3	3	8	19	1
Total (km²)	88	624	835	1,262	2,809	100
Total (%)	3	22	30	45		

Appendix 1.2. The areas of habitat types in each elevation zone within study area 1.

Habitats/Elevations (m)	Areas (km²)				Total (km²)	Total (%)
	0-200 m	≥ 200-400 m	≥ 400-600 m	≥ 600-1,700 m		
Evergreen Forest	2	40	62	153	258	30
Mixed-deciduous Forest	14	244	188	36	482	57
Dry-dipterocarp Forest	5	28	62	16	111	13
Total (km²)	22	312	312	206	851	100
Total (%)	3	37	37	24		

Appendix 1.3. The areas of habitat types in each elevation zone within study area 2.

% Habitats/Elevations(m)	Areas (km^2)				Total (km^2)	Total (%)
	0-200 m	> 200-400 m	> 400-600 m	> 600-1,700 m		
Evergreen Forest	2	14	36	132	185	39
Mixed-deciduous Forest	14	115	87	21	236	49
Dry-dipterocarp Forest	5	15	30	7	57	12
Total (km^2)	21	143	153	160	477	100
Total (%)	4	30	32	33		

Appendix 2. List of medium and large carnivores and ungulate mammals (>20 kg) in Huai Kha Khaeng Wildlife Sanctuary, Thailand during 1994-1996.

No	Family	Common Name	Scientific Name
1	Felidae	Asian Golden Cat	*Felis temmincki*
2	Felidae	Fishing Cat	*Felis viverrina*
3	Felidae	Clouded Leopard	*Neofelis nebulosa*
4	Felidae	Leopard	*Panthera pardus*
5	Felidae	Tiger	*Panthera tigris*
6	Ursidae	Malayan Sun Bear	*Helarctos malayanus*
7	Ursidae	Asiatic Black Bear	*Selenarctos tibetanus*
8	Canidae	Red Dog	*Cuon alpinus*
9	Cervidae	Sambar Deer	*Cervus unicolor*
10	Cervidae	Common Muntjak	*Muntiacus muntjak*
11	Cervidae	Fea's Muntjak	*Muntiacus feae*
12	Bovidae	Gaur	*Bos gaurus*
13	Bovidae	Banteng	*Bos javanicus*
14	Bovidae	Wild Water Buffalo	*Bubalus arnee*
15	Bovidae	Serow	*Capricornis sumatraensis*
16	Elephantidae	Asian Elephant	*Elephas maximus*
17	Suidae	Wild Boar	*Sus scrofa*

Appendix 3. Immobilization of gaur and banteng in Huai Kha Khaeng Wildlife Sanctuary, Thailand (1994-95).

Animals	Dose (mg)[1]							Sex	Age	Weight	Reaction time*			Date	Distance
ID	C	X	K	E	N	Y	R			(kg)	(minutes)				after dated (m)
											F	D	R		
Gaur															
201	16.0	66.7	0	0	2,250	32.5	0	F	1.5+	450	25	10	4	28-Apr-94	350
202[2]	16.5	75	400	0	2,750	60	0	M	10+	1,000	16	13	4	25-May-94	410
203	0	300	300	9.8	0	30	21	F	5+	600	10	10	10	24-Jul-94	250
205	16.5	75	300	0	3,000	22.5	0	M	10+	800	15	10	7	1-Feb-95	300
Banteng															
101[3]	12	75	0	0	1,700	10	0	F	5+	500+	15	10	5	Jul-93	150
102[4]	12	75	0	0	1,700	10	0	M	1.5	350+	25	10	4	22-Apr-94	350
103	16.5	75	400	0	2,850	30	0	F	5+	600	15	10	4	9-May-94	350
104[5]	0	350	250	9.8	0	30	19.5	M	6+	850+	35	7	5	26-Jul-94	800
105[6]	16.5	50	200	0	3,000	25	0	M	10+	850+	15	10	4	11-Sep-94	250
106[7]	22.8	95	0	0	2,100	27.5	0	M	7+	900	157	7	4	25-Apr-94	2,000
107[8]	5.9	141.3	392.5	0	1,200	125	0	F	5+	500+	14	7	5	10-Jun-94	500

Appendix 3. (Continued)

[*] F = Finding animal (minutes), D = Down time (minutes), and R = Recovery time (minutes).

[1] C = Carfentanil (3 mg/ml); X = Xylaxine (100 mg/ml); K = Ketamine (100 mg/ml); E = Etorphine (2.45 mg/ml); N = Naltrexone (50 mg/ml); Y = Yohimbine (5 mg/ml); R = Revivon (3 mg/ml).

[2] Second darted with Ketamine 100 mg and and Naltrexone expired Feb 94 and Mar 94. Collar fell down in July 1994.

[3] Killed by tiger after capturing 2 years.

[4] Collar found on the ground in March 1997.

[5] Immobilon and Revivon expired Jan 94. Killed by tiger after capturing 2 weeks.

[6] Killed by tiger after capturing 7 months.

[7] First darted with Carfentanil 15.5 mg, Xylaxine 64.4 mg, animal did not sleep. Second immobilized after the first dart 170 minutes. Killed by tiger after capturing 2 weeks.

[8] First darted with Carfentanil 7.5 mg, Xylaxine 180 mg, Ketamine 500 mg but drug still remained in dart. Naltrexone expired Dec 93. Killed by tiger after capturing 10 days.

Appendix 4. Locations [3] of gaur herds in Huai Kha Khaeng Wildlife Sanctuary, Thailand during 1994-1996.

No.	Code	Min *	Max *	Herd Compositions [2]						Activity Centers UTM Coordination		Date	ST1[1]	ST2[1]
				M	F	S	C	UN	Totals	X	Y			
1	G201	8	8	1	5	1	-	1	8	529108	1710461	1994-96	1	1
2	G202	10	10	2	5	-	-	3	10	530238	1714436	1994	1	1
3	G203	8	8	2	4	1	1	0	8	528962	1710273	1995	1	1
4	G204	20	25	2	5	1	-	17	25	538500	1714200	1995	1	1
5	G205	40	40	3	25	5	2	5	40	523261	1700372	1995	1	1
6	G206	10	10	1	2	-	-	7	10	528373	1709190	1995	1	1
7	G207	25	25	-	-	-	-	25	25	523200	1726800	1995	1	1
8	G208	10	15	1	4	-	-	10	15	528500	1706000	1995	1	1
9	G209	15	15	1	1	-	-	13	15	524665	1710871	1995	1	0
10	G210	34	34	-	-	-	-	34	34	518371	1715061	May-94	1	0
11	G211	20	20	1	1	-	-	18	20	514200	1710000	1995	1	0
12	G212	10	15	1	1	-	-	13	15	525332	1732899	1995	1	0
13	G213	35	40	2	9	3	3	23	40	520867	1689550	25-Nov-95	1	1
14	G214	20	25	1	5	-	-	19	25	520624	1686290	1995	1	1
15	G215	10	10	1	5	-	-	4	10	515200	1682000	1995	1	0
16	G216	10	15	1	1	-	-	13	15	528500	1680800	1995	0	0
17	G217	15	20	1	1	-	-	18	20	523108	1661772	1995	0	0
Totals		300	335						335				15	10

Remarks
[1] ST1 = Study area 1; ST2 = Study area 2
[2] M = Adult males; F = Adult females; S = Subadult; C = Calves;
[3] Location represents activity center of each herd;
* Min = Minimum number; Max = Maximum number.

Appendix 5. Locations [3] of banteng herds in Huai Kha Khaeng Wildlife Sanctuary, Thailand during 1994-1996.

No.	Code	Min *	Max *	Herd Compositions [2]						Activity Centers UTM Coordination		Date	ST1 [1]	ST2 [1]
				M	F	S	C	UN	Total	X	Y			
1	B101	6	6	0	2	1	1	2	6	530626	1711430	1994-1995	1	1
2	B102	12	12	2	6	2	2	0	12	530629	1712703	1995	1	1
3	B103	16	16	1	8	3	3	1	16	531902	1716069	1994-1996	1	1
4	B104	15	15	2	8	1	2	2	15	531500	1721300	26-Jun-95	1	1
5	B105	20	20	2	5	-	3	10	20	534022	1721093	1995	1	1
6	B106	8	8	-	4	2	-	2	8	529000	1717500	1995	1	1
7	B107	10	10	1	3	2	-	4	10	533918	1721489	6-Dec-94	1	1
8	B108	15	15	1	9	-	-	5	15	538500	1721500	1995	1	1
9	B109	15	20	1	7	-	2	10	20	523000	1712000	1995	1	1
10	B110	10	10	1	1	-	-	8	10	528500	1731000	1995	0	0
11	B111	10	15	1	1	-	-	13	15	534000	1731000	1995	0	0
12	B112	10	10	1	1	-	-	8	10	520000	1705100	1995	1	1
13	B113	15	15	1	2	-	-	12	15	519665	1701526	1995	1	1
14	B114	7	10	1	5	-	-	4	10	515973	1692213	1995	1	0
15	B115	8	8	-	7	-	1	0	8	521800	1693400	6-Jun-95	1	1
16	B116	10	15	3	4	1	-	7	15	520867	1689550	12,23/Dec/95	1	1
17	B117	10	10	1	5	-	-	4	10	521302	1687396	8-Feb-95	1	0
18	B118	10	15	1	5	-	-	9	15	528500	1680800	1995	0	0
19	B119	23	30	4	12	1	6	7	30	518500	1708800	25-May-92	1	0
20	B120	10	10	2	5	1	-	2	10	518416	1716568	1995	1	0
Total		240	270						270				17	13

Appendix 5. (Continued)

Remarks

[1] ST1 = Study area 1; ST2 = Study area 2
[2] M = Adult males; F = Adult females; S = Subadult; C = Calves;
[3] Location represents activity center of each herd
* Min = Minimum number; Max = Maximum number

Appendix 6. All data of seasonal and annual home ranges of radio-collared gaur and banteng in Huai Kha Khaeng Wildlife Sanctuary, Thailand during 1994-1996.

Species /Parameter		Home range area[1] (km^2)			The longest length of largest seasonal home range (km)		Distance between seasonal activity centers (km)	Shift-distance index
	No./Year	Wet[2] Season	Dry[2] Season	Annual	W-D[3]	Annual	W-D[3]	W-D[3]
Banteng Herd	B10194	22.5	22.5	30.5	10.2	10.4	2.4	0.24
	B10195	18.1	N/A	N/A	N/A	N/A	N/A	N/A
	B10294	25.9	24.6	33.4	10.8	11.2	2.7	0.25
	B10295	36	20.7	48.6	10.6	10.6	3.9	0.37
	B10394	20.8	44.8	62.7	13.1	13.9	4	0.3
	B10395	42.9	19.6	44.1	9.8	9.8	0.6	0.06
	B10396	32	N/A	N/A	N/A	N/A	N/A	N/A
Individual Bull	B10594	3.9	13	20.5	5.2	6.4	2.9	0.56
	B10296	16.6	N/A	N/A	N/A	N/A	N/A	N/A
Gaur Herd	G20194	36.4	19	53.9	16.8	18.5	11.6	0.69
	G20195	48.9	29.1	55.2	15.7	15.6	3.6	0.23
	G20196	25.4	N/A	N/A	N/A	N/A	N/A	N/A
	G20394	21.3	20.3	46.7	10.4	15	12.4	1.2
	G20395	45.2	27.3	56.8	10.4	15.3	2.6	0.17
	G20396	38.2	N/A	N/A	N/A	N/A	N/A	N/A
	G20594	N/A	28.5	N/A	N/A	N/A	N/A	N/A
	G20595	58.1	39.3	114.6	14.9	19.1	6.6	0.44
Individual Bull	G20294	45.2	N/A	N/A	N/A	N/A	N/A	N/A

Appendix 6. (Continued)

Notes: [1] Home range delineated as convex polygons (excluding areas of non-gaur and non-banteng habitat) with gaur ≥ 15 locations and banteng ≥ 20 locations.

[2] Wet season defined as May to October; Dry season included November to April.

[3] W-D = Wet to Dry Seasonal Home Ranges.

[4] Shift-distance index = Distance between 2 seasonal activity centers / the longest length of the two adjacent seasonal home ranges home ranges

* ng = number of gaur locations; nb = number of banteng locations

N/A = Data not available; SD = Standard deviation; n = number of observations

Appendix 7. The percentage of habitat compositions within radio-collared gaur and banteng home ranges in Huai Kha Khaeng Wildlife Sanctuary during 1994-1996.

Gaur Herd				Banteng Herd			
Dry Season		(%)		Dry Season	(%)		
(n=6)	10	20	30	(n=5)	10	20	30
20194D	48	44	8	10194D	9	73	18
20394D	30	61	9	10294D	11	72	18
20195D	16	71	13	10394D	5	76	19
20395D	21	61	18	10295D	6	78	16
20594D	51	47	3	10395D	4	84	12
20595D	10	71	19				
Wet Season		(%)		Wet Season	(%)		
(n=7)	10	20	30	(n=7)	10	20	30
20194W	13	64	. 23	10194W	7	78	14
20394W	21	62	17	10294W	6	77	16
20195W	12	61	28	10394W	4	71	25
20395W	16	59	25	10195W	10	71	19
20595W	13	57	30	10295W	6	73	21
20196W	8	72	21	10395W	6	80	14
20396W	5	75	19	10396W	7	81	12
Individual gaur (n =1)				Individual banteng (n = 3)			
20294W	18	64	18	10594D	4	76	20
				10594W	0	96	4
				10296W	8	77	15

Remarks: 10 = Evergreen Forest; 20 = Mixed-deciduous Forest; 30 = Dry-dipterocarp Forest
D = Dry Season; W = Wet Season; 94 = 1994; 95 = 1995, 96 = 1996

Appendix 8. The percentage of elevation zones within each radio-collared gaur and banteng home ranges in Huai Kha Khaeng Wildlife Sanctuary during 1994-1996.

Gaur					**Banteng**				
Dry Season		% Areas			Dry Season		% Areas		
n=6	0-200 m	≥200-400 m	≥400-600 m	≥600-1,700 m	n=5	0-200 m	≥200-400 m	≥400-600 m	≥600-1,700 m
20194D	0	5	53	42	10194D	0	19	81	0
20394D	0	6	69	25	10294D	0	15	85	0
20594D	0	43	32	25	10295D	0	82	18	0
20195D	0	9	76	15	10394D	0	62	38	0
20395D	0	7	72	21	10395D	0	94	6	0
20595D	0	56	38	5					
Wet Season		% Areas			Wet Season		% Areas		
n=7	0-200 m	≥200-400 m	≥400-600 m	≥600-1,700 m	n=7	0-200 m	≥200-400 m	≥400-600 m	≥600-1,700 m
20194W	0	18	64	18	10194W	0	37	63	0
20394W	0	20	47	34	10195W	0	6	91	2
20195W	0	14	73	14	10294W	0	33	67	0
20395W	0	13	67	20	10295W	0	33	65	2
20595W	0	41	45	14	10394W	0	76	18	6
20196W	0	32	67	1	10395W	2	87	11	0
20396W	0	35	63	2	10396W	0	86	14	0
Individual gaur		% Areas			**Individual banteng**		% Areas		
n=1	0-200 m	≥200-400 m	≥400-600 m	≥600-1,700 m		0-200 m	≥200-400 m	≥400-600 m	≥600-1,700 m
20294W	0	31	59	11	10594D	60	40	0	0
					10594W	0	94	6	0
					10296W	0	84	16	0

Appendix 9. Habitat Selection

It is often assumed that a species will select resources that are best able to satisfy its life requirements, and that high quality resources will be selected more than low quality ones (Manly and et al. 1993). The availability of various resources is not generally uniform, and use may change as availability changes. Therefore, used resources should be compared to available resources in order to reach valid conclusions concerning resource selection (Manly and et al. 1993). When resources are used disproportionately to their availability, use is said to be selective (Manly and et al. 1993). Selection of individual habitats was determined by the method of Neu et al. (1974), Byers et al. 1984 and Manly et al. (1993).

According to this study, analysis of variance indicated no difference among home range size across years, so data were pooled across gaur or banteng herds to analyze and determine habitat and elevation selection (***Index of Use***).

To test for habitat selection I first used a chi-square test of independence to determine whether habitat types were used in proportion to availability by gaur and banteng. I tested 1) whether habitat types were selected in proportion to their availability in study areas 1 and 2 and in the animals' home ranges in the wet and dry seasons, 2) whether elevation zones were selected in proportion to their availability in study areas 1 and 2 and in the animals' home ranges in the wet and dry seasons. If tests were significant at alpha 0.10, I then used several methods (see below) to more precisely test the difference between availability and selection of habitat by gaur and banteng for long term and intensive data sets. These are discussed separately below.

1) *The Long Term Study*.--Data from all herds of each species were pooled and I calculated the proportions of each habitat parameter selected and available (e.g. vegetation types and elevation zones) to identify habitat and elevation selection of gaur and banteng. If the initial screening chi-square test was significant then it was followed by the computation of simultaneous confidence intervals for the proportions of resources selected compared with the proportions available (Neu et al. 1974, Byers et al. 1984). Bonferroni confidence interval Z-test was used to test the difference between availability and selection of habitat and elevation by gaur and banteng (Neu et al. 1974, Byers et al. 1984). I calculated a 90 % simultaneous confidence interval for the difference in proportion of use and availability for each habitat category:

$$(1)\ p'_i - Z_{\alpha/2k}\,(p'_i\,(1-p'_i)/n)^{1/2} \leq p_i \leq p'_i + Z_{\alpha/2k}\,(p'_i\,(1-p'_i)/n)^{1/2}$$

where p_i was the true proportion or use,

p'_i was n_i/N, a sample of N observations, let n_i be the number of observations that fell in type i, i = 1,2,....,k;

$Z_{\alpha/2k}$ is the upper standard normal table value corresponding to a probability tail area of $\alpha/2k$;

k was the number of categories tested.

When selection was greater than expected given availability of a habitat category, there was significant selection for that habitat zone. When selection was less than expected given availability for a habitat category, there was significant selection against that habitat zone.

2) *The Intensive Study, periodic data.*-- 2.1) To identify habitat and elevation selection in study area 2, I first tested whether the chi-square test was significant, then I followed a method defined by Manly et al. (1993:54) to examine habitat and elevation selection by individuals. The results were an estimate of relative probabilities of selection for different habitats and elevations. With this method, I considered the herd as the primary sampling unit, and based statistical inferences on herds as replicates. Hence sampling the resource used by the jth herd is viewed as "sub-sampling" the primary sampling unit. I assumed at all times that these samples of herds were random samples.

Suppose that the proportions of available resources in the categories 1 to I were known to be π_1 to π_I for the entire study area.

u_{ij} = the number of type i resource units used by herd j

u_{i+} = the number of type i resource units used by all herds

u_{+j} = the total number of units used by herd j

u_{++} = the total number of units used by all herds.

The selection ratio for all radio-collared herds could be used to give

$$(2) \qquad w'_i = u_{i+} / (\pi_i u_{++})$$

The variance of w'_i is estimated by a special case of the following equation:

$$(3) \qquad Var(w'_i) = \{\sum_{j=1}^{n}(u_{ij} / \pi_i - w'_i u_{+j})^2 / (n-1)\}\{n / u_{++}^2\}$$

Ninety percent simultaneous Bonferroni confidence intervals for population selection ratios could be constructed with an overall confidence level of approximately 100 (1-α)%, so that the probability of all the intervals containing the true value was approximately 1-α. These intervals were of the form:

$$(4) \qquad w'_i \pm Z_{\alpha/(2I)} Se(w'_i),$$

where $Z_{\alpha/(2I)}$ = the percentage point of standard normal distribution corresponding to an upper tail probability of $\alpha/(2I)$,

when I = the number of habitat types.

When the interval included the value 1, there was no selection for that habitat. When use was greater than expected given availability for a habitat category, there was significant selection for that habitat zone. When use was less than expected given availability for a habitat category, there was significant selection against that habitat zone.

2.2) To identify habitat and elevation selection within the home range of radio-collared gaur and banteng, I pooled all observation data from individual radio-collared animals to calculate the proportions used in each habitat. If the initial screening chi-square test was significant then Bonferroni confidence interval Z-test was used to test the difference between availability and use of habitat and elevation for both radio-collared gaur and banteng (Neu et al. 1974, Byers et al. 1984). I calculated a 90 % simultaneous confidence interval for the difference in proportion of use and availability for each habitat category. When selection was greater than expected given availability of a habitat category, there was significant selection for that habitat zone. When selection was less than expected given availability for a habitat category, there was significant selection against that habitat zone.

Habitat and Elevation Selection Differences between the LTS and IS

During the LTS, visual observation showed that gaur selected mixed-deciduous forest more than expected in study area 1, but during the IS they did not select this habitat in study area 2 (Appendices 9.1 and 9.2). They used this habitat less than expected when compared with amounts available within their home range. One reason for this difference is that in mid and late dry seasons during the LTS (1983-1994), fire burned more than 70% of the study area and new growth of several grasses, especially *Microstegium spp.*, within mixed-deciduous forest provided an abundance of high protein, which attracted gaur back from the evergreen forest to graze in the mixed-deciduous forest. By 1994-95, HKKWS was under stricter fire control and no large fires occurred inside the sanctuary. Therefore, gaur were not as attracted to mixed-deciduous forest during the IS.

Two other factors may help explain the differences in habitat and elevation selection between the LTS and the IS. I may have spent more time at high elevations in steep evergreen forest during the IS because I was following radio-collared animals that readily moved up and down very steep terrain. A second important factor, relevant to any habitat preference study, is that the results are dependent on the definition of the study area. A slight difference in defining the boundaries of a study area can have a major effect on the ratio of available habitats (White and Garrott 1990, Manly et al. 1993, Garshelis, in press).

Appendix 9.1. Habitat selected (% number of locations in each habitat) by gaur and banteng during the wet and dry seasons compared with the habitat composition of the study areas or home ranges of radio-collared gaur and banteng herd in Huai Kha Khaeng Wildlife Sanctuary, Thailand, 1983-1996.

Gaur	% Availability				Frequency use (%)				Frequency use (%)	
					Wet Season				Dry Season	
Habitat Types	ST1E	ST2E	HRW	HRD	LTS ST1E	IS ST2E	IS HRW	LTS ST1	IS ST2	IS HRD
					n=156	n=287	n=287	n=130	n=137	n=137
Evergreen	30.8	39.98	13.12	26.82	19.87 -	11.5 -	11.5 n	27.69 n	45.99 n	45.99 +
Mixed-deciduous	56.43	48.72	63.42	60.53	71.79 +	67.25 +	67.25 n	70.00 +	44.53 n	44.53 -
Dry-dipterocarp	12.77	11.3	23.45	12.65	8.33 n	21.25 +	21.25 n	2.31 -	9.49 n	9.49 n
Banteng	% Availability				Frequency use (%)				Frequency use (%)	
					Wet Season				Dry Season	
Habitat Types	ST1	ST2	HRW	HRD	LTS ST1	IS ST2	IS HRW	LTS ST1	IS ST2	IS HRD
					n=226	n=385	n=385	n=183	n=271	n=271
Evergreen	30.29	38.69	12.4	6.6	7.52 -	3.9 -	3.9 -	5.46 -	8.12 -	8.12 n
Mixed-deciduous	56.66	49.43	72.2	76.2	65.04 +	79.74 +	79.74 +	74.86 +	74.91 +	74.91 n
Dry-dipterocarp	13.04	11.88	15.4	17.2	27.43 +	16.36 n	16.36 n	19.67 n x	16.97 n	16.97 n

Appendix 9.1. (Continued)

Remarks :

ST1 = Study Area 1; ST2 = Study Area 2;
ST1E = ST1 excluding area ≤ 200 m; ST2E = ST2 excluding area ≤ 200 m;
HRW = Home range during the wet season; HRD = Home range during the dry season;
LTS/ST1 = Observations from the long term study (1983-1996) : Habitat selection analysis was calculated by the method of Neu et al. (1974) and Byers et al. 1984
IS/ST2 = Observations from the intensive study (1994-1996) : Habitat selection analysis was calculated by the method of Manly et al. (1993).
IS/ HRW (or HRD) = Observations from the intensive study (1994-1996) : Habitat selection analysis was calculated by the method of Neu et al. (1974) and Byers et al. 1984

Index of use :

a = avoid using or no use
+ = use significantly greater than availability (90% confidence interval)
- = use significantly less than availability (90% confidence interval)
n = not significant difference between use and availability (90% confidence interval)
x = 95% confidence interval

Appendix 9.2. Elevation selected (% number of locations in each habitat) by gaur and banteng during the wet and dry seasons compared with the elevation composition of the study areas or home ranges of radio-collared gaur and banteng herd in Huai Kha Khaeng Wildlife Sanctuary, Thailand, 1983-1996.

Gaur	% Availability				Frequency use (%)			Frequency use (%)		
					Wet Season			Dry Season		
Elevation Zones (m)	ST1E	ST2E	HRW	HRD	LTS ST1E	IS ST2E	IS HRW	LTS ST1E	IS ST2E	IS HRD
					n=156	n=287	n=287	n=130	n=137	n=137
0-200	0	0	0	0	a	a	a	a	a	a
>200-400	37.61	31.39	25.8	25.07	23.08 -	35.89 n	35.89 +	29.23 n	27.01 n	27.01 n
>400-600	37.58	33.57	60.45	55.18	66.67 +	50.52 +	50.52 n	52.31 +	37.23 n	37.23 -
>600-1,700	24.81	35.04	13.68	19.74	10.26 -	13.59 -	13.59 n	18.46 n	35.77 n	35.77 +

Banteng	% Availability				Frequency use (%)			Frequency use (%)		
					Wet Season			Dry Season		
Elevation Zones (m)	ST1	ST2	HRW	HRD	LTS ST1	IS ST2	IS HRW	LTS ST1	IS ST2	IS HRD
					n=226	n=385	n=385	n=183	n=271	n=271
0-200	2.55	4.44	0.42	5.43	0.44 -	0.52 -	0.52 n	8.74 +	9.59 n	9.59 +
>200-400	36.65	29.99	58.72	52.48	54.42 +	59.48 +	59.48 n	46.99 +	35.06 n	35.06 -
>400-600	36.62	32.08	39.72	41.97	44.69 +	38.96 n	38.96 n	43.17 n	54.98 n	54.98 +
>600-1,700	24.18	33.49	1.14	0.12	0.44 -	1.04 -	1.04 n	1.09 -	0.37 -	0.37 n

Appendix 9.2. (Continued)

<u>Remarks</u> :

ST1 = Study Area 1; ST2 = Study Area 2

ST1E = ST1 excluding area ≤ 200 m; ST2E = ST2 excluding area ≤ 200 m

HRW = Home range during the wet season; HRD = Home range during the dry season

LTS/ST1(ST1E) = Observations from the long term study (1983-1996) : Habitat selection analysis was calculated by the method of Neu et al. (1974) and Byers et al. 1984

IS/ST2 (ST2E) = Observations from the intensive study (1994-1996) : Habitat selection analysis was calculated by the method of Manly et al. (1993).

IS/ HRW (or HRD) = Observations from the intensive study (1994-1996) : Habitat selection analysis was calculated by the method of Neu et al. (1974) and Byers et al. 1984

<u>Index of use</u> :

a = avoid using or no use

\+ = use significantly greater than availability (90% confidence interval)

\- = use significantly less than availability (90% confidence interval)

n = not significant difference between use and availability (90% confidence interval)

Appendix 10. Food plants of gaur from direct foraging observations during the wet and dry season in Huai Kha Khaeng Wildlife Sanctuary, 1983-1995.

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
1	Acanthaceae	*Asystasia gangetica*	US	MD	W	2	
2	Acanthaceae	*Asystasia salicifolia*	US	MD	W	1	
3	Acanthaceae	*Barleria siamensis*	US	DE	D	2	
4	Acanthaceae	*Eranthemum spp.*	S	DE	D	2	
5	Acanthaceae	*Eranthemum spp.*	S	DE	D	2	
6	Acanthaceae	*Strobilanthes cystolithigera*	S	HE	W	1	
7	Actinidiaceae	*Saurauia spp.*	S/ST	HE	W	1	
8	Agavaceae	*Dracaena spp.*	S	DE/HE	D	2	
9	Amaranthaceae	*Achyranthes aspera*	HUS	HE	W	1	
10	Amaranthaceae	*Achyranthes spp.*	HUS	MD	D/W	2	
11	Amaranthaceae	*Aerva sangvinolenta*	C	HE	W	1	
12	Amaranthaceae	*Deeringia amaranchoides*	C	MD	W	1	
13	Annonaceae	*Desmos spp.*	S	DE	D	2	
14	Araceae	*Rhaphidophora spp.*	CrH	DE	D	2	
15	Berberidaceae	*Mahonia siamensis*	T	MD	W	2	
16	Bignonaceae	*Stereospermun spp.*	T	MD	W	2	
17	Burseraceae	*Protium serratun*	T	MD	W	2	
18	Caesalpiniaceae	*Banhinia malabarica*	T	MD	W	2	
19	Caesalpiniaceae	*Bauhinia spp.*	S	MD	W	2	
20	Caesalpiniaceae	*Bauhinia spp.*	C	MD	W	2	
21	Caesalpiniaceae	*Bauhinia viridescens*	S	MD	W	1	
22	Combretaceae	*Anogeissus acuminata var.lancedata*	T	MD	W	2	
23	Commelinaceae	*Commelina disffus*	H	DE	W	2	

Appendix 10. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
24	Commelinaceae	*Commelina spp.*	H	DE	D/W	2	
25	Commelinaceae	*Floscopa scandens*	HC	MD	W	1	
26	Commelinaceae	*Pollia spp.*	H	DE	D/W	2	
27	Compositae	*Blumea spp.*	H	MD	W	1	
28	Compositae	*Spilanthes spp.*	H	MD	W	2	
29	Compositae	*Synedrella nodiflora*	H	MD	D/W	2	FW
30	Compositae	*Vernonia spp.*	H/ST	DE/HE	D	2	
31	Costaceae	*Costus spp.*	H	DE/HE	D	2	Broad leaf
32	Costaceae	*Costus speciosus*	H	DE	D	2	
33	Cyperaceae	*Cyperus compactus*	G	MD	W	2	
34	Cyperaceae	*Cyperus rotundus*	G	MD	W	2	
35	Cyperaceae	*Cyperus spp.*	G	MD	D/W	2	FD
36	Cyperaceae	*Fimbristylis aestivalis*	G	MD	W	2	
37	Cyperaceae	*Scleria levis*	G	MD	W	2	
38	Cyperaceae	*Scleria terrestris*	G	HE	W	1	
39	Dioscoreaceae	*Dioscorea burmanica*	HC	DE	D	2	
40	Dioscoreaceae	*Dioscorea hispida*	HC	MD	W	2	
41	Dioscoreaceae	*Dioscorea spp.*	HC	DE	D/W	2	
42	Dipterocarpaceae	*Shorea siamensis*	T	MD / DD	W	2	
43	Ebenaceae	*Diospyros montana*	T	MD	W	2	
44	Elaeocarpaceae	*Elaeocarpus floribundus*	T	HE	W	1	
45	Euphorbiaceae	*Breynia glauca*	S	MD	W	2	

Appendix 10. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
46	Euphorbiaceae	*Bridelia spp.*	S	MD	W	2	
47	Euphorbiaceae	*Cledion spp.*	T	DE	D	2	
48	Euphorbiaceae	*Mallotus philippensis*	S/ST	HE	W	1	
49	Euphorbiaceae	*Phyllanthus reticulatus*	S/ST	DE	W	2	
50	Euphorbiaceae	*Sauropus spp.*	S	DE	D	2	
51	Fagaceae	*Castanopsis tribuloides*	T	HE	W	1	
52	Gramineae	Unknown	G	DD	D/W	2	
53	Gramineae	*Andropogon spp.*	G	MD	W	1	
54	Gramineae	*Apluda mutica*	G	MD	W	2	
55	Gramineae	*Arthraxon castratus*	G	DD	W	2	
56	Gramineae	*Arthraxon spp.*	G	MD	D/W	2	
57	Gramineae	*Arundinaria spp.*	G	DD	D/W	2	
58	Gramineae	*Arundinella rupestis*	G	MD	W	2	
59	Gramineae	*Bambusa arundinacea*	B	MD	W	2	FW/FD
60	Gramineae	*Chloris spp.*	G	MD	D	2	
61	Gramineae	*Coix spp.*	G	MD	D	2	
62	Gramineae	*Cymbopogon nardus.*	G	MD	D/W	2	FW
63	Gramineae	*Cymbopogon spp.*	G	MD	D	2	
64	Gramineae	*Cyrtococcum accrescens*	G	HE	W	1	
65	Gramineae	*Dendrocalamus stictus*	B	MD	D/W	2	FW
66	Gramineae	*Heteropogon spp.*	G	MD	W	2	
67	Gramineae	*Heteropogon triticus*	G	DE	W	2	
68	Gramineae	*Hyparrhenia rufa*	G	MD	W	2	FW
69	Gramineae	*Isachna alben*	G	MD	W	1	

Appendix 10. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
70	Gramineae	*Leersia hexandra*	G	MD	W	1	
71	Gramineae	*Microstegium ciliatum*	G	MD	D/W	2	
72	Gramineae	*Microstegium spp.*	G	MD	W	2	
73	Gramineae	*Microstegium vegan*	G	MD	W	2	
74	Gramineae	*Microstegium vimimeum*	G	MD	D	2	
75	Gramineae	*Oplismenus compositus*	G	HE	W	1	
76	Gramineae	*Panicum mutinodes*	G	DE	D/W	2	
77	Gramineae	*Panicum notanum*	G	MD, HE	D	2	
78	Gramineae	*Paspalum spp.*	G	MD, HE	D	2	
79	Gramineae	*Paspalum thumbergii*	G	MD	W	1	
80	Gramineae	*Rottboellia exaltata*	G	MD	W	1	
81	Gramineae	*Saccharum arundinaceum*	G	MD	W	2	FW
82	Gramineae	*Saccharum spontaneum*	G	MD	W	2	FW
83	Gramineae	*Sclerostachya fusca*	G	MD	W	2	
84	Gramineae	*Setaria pallide-fusca*	G	MD	W	1	
85	Gramineae	*Setaria palmifolia*	G	MD, HE	W	1	
86	Gramineae	*Themeda spp.*	G	MD	W	2	
87	Gramineae	*Thyrostacnys siamensis*	B	MD	W	2	FW
88	Gramineae	UK 3	G	MD	W	2	
89	Gramineae	UK 76	G	MD	W	2	Yakonkratai
90	Gramineae	Unknown	G	MD	W	2	Yakaotom

Appendix 10. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
91	Gramineae	UK 83	G	MD	D	2	YaKayeang
92	Gramineae	UK 2	G	MD	W	2	
93	Gramineae	UK1	G	MD	W	2	
94	Hypoxidaceae	*Curculigo latifolia*	H	DE	D	2	
95	Hypoxidaceae	*Curculigo megacarpa*	H	DE	D	2	
96	Labiatae	*Dysophylla stellata*	H	MD	W	2	
97	Labiatae	*Gomphostemma strobilinum*	H	HE	W	1	
98	Leeaceae	*Leea spp.*	S	MD	W	2	
99	Liliaceae	*Ophiopogon spp.*	H	MD	W	2	
100	Malvaceae	*Abelmoschus moschatus*	H	HE	W	1	
101	Malvaceae	*Sida rhombifolia*	US	MD, HE	W	1	
102	Meliaceae	*Toona ciliata*	T	DE	D	2	
103	Mimosaceae	*Acacia comosana*	T	MD	W	2	
104	Moraceae	*Artocarpus lakoocha*	T	MD	W	2	
105	Moraceae	*Streblus asper*	T	MD	W	2	
106	Myrsinaceae	*Ardisia crenata*	S	HE	W	1	
107	Myrsinaceae	*Ardisia spp.*	S	DE/HE	D	2	
108	Myrsinaceae	*Ardisia spp.*	S	DE	D	2	
109	Myrsinaceae	*Embelia spp.*	S	HE	W	1	
110	Ochnaceae	*Ochna integerrima*	S/ST	DD	W	2	
111	Onagraceae	*Ludwigia spp.*	H	MD	D	2	
112	Opiliaceae	*Melientha suavis*	S/ST	MD	D/W	2	
113	Palmae	*Wallichia spp.*	P	HE	W	1	
114	Papilionaceae	*Crotalaria melanocarpa*	H	MD	W	2	

Appendix 10. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
139	Papilionaceae	*Pueararia candollei*	C	MD	W	1	
140	Papilionaceae	*Pueararia phascoloides*	C	HE	W	1	
141	Papilionaceae	*Uraria crinita*	C	HE	W	1	
142	Polygonaceae	*Polygonum chinensis*	S	MD, HE	W	2	
143	Polygonaceae	*Polygonum spp.*	S	MD	D/W	2	
144	Polygonaceae	*Polygonum spp.*	S	HE	D	2	
145	Rubiaceae	*Morinda angustifolia*	S/ST	DE/HE	D	2	
146	Rubiaceae	*Mussaenda kerrii*	C	HE	W	1	
147	Rubiaceae	*Mussaenda sanderiana*	C	HE	W	1	
148	Rubiaceae	*Psychotria spp.*	C	DE	D	2	
149	Rubiaceae	*Randia oocarpa*	ST	DE/HE	D/W	2	
150	Rubiaceae	*Randia sp 1*	S	DE/HE	W	1	
151	Rubiaceae	*Randia sp 2.*	ST	DE	D	2	
152	Rutaceae	*Clausena spp.*	S	DE	D	2	
153	Rutaceae	*Euodia cf. glomerata*	T	HE	W	1	
154	Rutaceae	*Micromelum minutum*	S/ST	HE	W	1	
155	Sapindaceae	*Paranephelium longifoliotatum*	T	HE	W	1	
156	Simaroubaceae	*Brucea javanica*	S	MD	W	1	
157	Simaroubaceae	*Harrisonia perforata*	C	MD	W	2	FW
158	Smilacaceae	*Heterosmilax spp.*	C	HE	W	1	
159	Smilacaceae	*Smilax spp.*	C	MD	W	2	
160	Solanaceae	*Lycianthes biflora*	S	HE	W	1	
161	Stemonaceae	*Stemona tuberosa*	HC	MD	W	2	
162	Sterculiaceae	*Sterculia foetida*	T	MD	W	2	

Appendix 10. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
163	Sterculiaceae	*Sterculia hypochra*	T	MD	W	2	
164	Sterculiaceae	*Sterculia spp.*	T	MD	W	2	FW
165	Sterculiaceae	*Sterculia villosa*	T	MD	W	2	
166	Stilaginaceae	*Antidesma spp.*	ST	MD	W	2	
167	Symphoremataceae	*Sphenodesme mollis*	C	MD	W	2	
168	Symphoremataceae	*Sphenodesme pentandra*	C	MD	W	2	
169	Symplocaceae	*Symplocos spp.*	ST	DE	D	2	
170	Thelypteridaceae	*Thelypteris menisciicarpa*	F	HE	W	1	
171	Thunbergiaceae	*Thunbergia fragrans*	C	MD	W	2	
172	Tiliaceae	*Corchorus siamensis*	H	HE	W	1	
173	Tiliaceae	*Grewia hirsuta*	ST	DE	D	2	
174	Tiliaceae	*Grewia laevigata*	ST	DE	D	2	
175	Tiliaceae	*Grewia sapida*	T	HE	W	1	
176	Tiliaceae	*Triumfetta bartramia*	ST	MD	W	2	
177	Tiliaceae	*Triumfetta pilosa*	ST	DE	D	2	
178	Tiliaceae	*Triumfetta repens*	ST	DE	W	2	
179	Tiliaceae	*Triumfetta spp.*	S	MD	W	2	Pomein
180	Urticaceae	*Debregeasia spp.*	S	MD	W	1	
181	Urticaceae	*Debregeasia spp.*	S	DE	D	2	
182	Verbenaceae	*Clerodendron infortunatum*	S	DE	D	2	
183	Verbenaceae	*Clerodendrum colebrookianum*	S	HE	W	1	
184	Verbenaceae	*Clerodendrum paniculatum*	S	MD	W	2	
185	Verbenaceae	*Clerodendrum serratum*	S	MD,HE	W	1	

Appendix 10. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
186	Verbenaceae	*Gmelina elliptica*	T	MD	W	2	
187	Verbenaceae	*Vitex canescens*	T	MD	W	2	
188	Verbenaceae	*Vitex liminotolia*	T	MD	W	2	
189	Verbenaceae	*Vitex quinata*	ST	HE	W	1	
190	Verbenacee	*Hymenopyramis spp.*	C	MD	W	2	
191	Zingiberaceae	*Ammomum spp.*	H	MD	D/W	2	
192	Zingiberaceae	*Ammomum spp.*	H	MD	W	2	
193	Zingiberaceae	*Globba reflexa*	H	HE	W	1	
194	Zingiberaceae	*Globba schomburgkii*	H	MD	W	2	
195	Zingiberaceae	*Globba sp 1.*	H	MD	W	2	FW
196	Zingiberaceae	*Globba sp 2.*	H	MD	D/W	2	
197	Zingiberaceae	*Zingiber spp.*	H	HE	D	2	
198	Unknown		S	DE	D	2	
199	Unknown	UK 79	S	HE	D	2	
200	Unknown		S	DE	D	2	
201	Unknown		S	DE/HE	D	2	
202	Unknown		S	MD	W	1	
203	Unknown		S	MD	W	1	
204	Unknown	UK 44	S	DE	D/W	2	Kradungkai
205	Unknown		S	DE	W	2	Kraom
206	Unknown		S	MD	W	2	Kaotuaog
207	Unknown		S	DE	D	2	Kram
208	Unknown		S	DE	D	2	Kadkao
209	Unknown	UK 33	S	MD	W	2	Kansong

Appendix 10. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
210	Unknown		S	MD	W	2	Chatsamchun
211	Unknown		S	DD	W	2	Tanluang
212	Unknown		H	MD	W	2	Tandeaw
213	Unknown		S	DE	D	2	Nangann
214	Unknown		S	MD	W	2	Ruangkreep
215	Unknown		S	DE	D	2	Makug
216	Unknown		S	DE	D	2	Muadhom
217	Unknown		S	DE	W	2	Yabpa
218	Unknown		S	MD	W	2	Yapunkukao
219	Unknown		S	DE	W	2	Banchunpa
220	Unknown		S	MD	W	2	UK 11
221	Unknown		S	MD	W	2	UK 26
222	Unknown		S	MD	W	2	UK 28
223	Unknown		S	DD	D/W	2	UK 29
224	Unknown		S	DE	D	2	UK 34
225	Unknown		H	DE	D/W	2	UK 37 (Kla)
226	Unknown		S	MD	D	2	UK 4
227	Unknown		S	DE	D	2	UK 58
228	Unknown		S	DD	D	2	UK 6
229	Unknown		S	DD	D	2	UK 7
230	Unknown		S	DD	D	2	UK 75
231	Unknown		S	DD	D	2	UK 9
232	Unknown		S	DE	D	2	UK43

Appendix 10. (Continued)

Life Forms: US = Undershrub; ST = Shurb Tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; B = Bamboo, BK = Bark

Habitats : DD = Dry-deciduous forest; MD = Mixed deciduous forest; DE = Dry evergreen forest

Season : D = Dry season; W = Wet season

Year : 1 = 1983-1995; 2 = 1994-1995

Remarks : FW = Found in both direct foraging observation and fecal analysis in the wet season

FD = Found in both direct foraging observation and fecal analysis in the dry season

Appendix 11. Food plants of banteng from direct foraging observations during the wet and dry seasons in Huai Kha Khaeng Wildlife Sanctuary, 1983-1995.

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
1	Acanthaceae	*Acanthus spp.*	S	MD	W	2	
2	Acanthaceae	*Barleria cristata*	S	DD	W	2	
3	Acanthaceae	*Barleria siamensis*	S	MD	D/W	2	
4	Acanthaceae	*Barleria spp.*	S	DE	D/W	2	
5	Acanthaceae	*Justicia quadrifolia*	S	MD	D	2	
6	Acanthaceae	*Ruellia kurrii*	H	MD	W	1	
7	Acanthaceae	*Strobilanthus spp.*	S	MD	W	2	FW
8	Amaryllidaceae	*Crinum asiaticum*	H	MD	W	2	
9	Anacardiaceae	*Choerospondias axillaris*	T	MD	D	2	
10	Anacardiaceae	*Lannea grandis*	T	MD, DD	D	2	
11	Annonaceae	Unknown A	S	MD	D	2	
12	Apocynaceae	*Wrightia tomentosa*	T	MD	W	2	
13	Araceae	*Rhaphidophora spp.*	CrH	MD	D	2	FD
14	Berberidaceae	*Mahonia siamensis*	T	MD	W	2	
15	Bignoniaceae	*Dolichandron spp.*	C	MD	D/W	2	
16	Bignoniaceae	*Stereospermum neuranthum*	T	MD, DD	W	1	
17	Burseraceae	*Canarium subilatum*	T	DD	W	2	
18	Burseraceae	*Garuga pinnata*	T	DD	W	1	
19	Caesalpiniaceae	*Bauhinia glocca*	C	DD	W	2	
20	Caesalpiniaceae	*Bauhinia spp.*	T	MD	D/W	2	
21	Caesalpiniaceae	*Bauhinia virideacens*	C	MD	W	2	
22	Caesalpiniaceae	*Pterolobium cf. integrum*	C	MD	W	2	
23	Celastraceae	*Salacia spp.*	C	MD	W	1	

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
24	Combretaceae	*Anogeissus acuminata*	T	MD	W	2	
25	Combretaceae	*Terminalia chebula*	T	DD	W	1	
26	Combretaceae	*Terminalia nigrovenulosa*	T	MD	W	1	
27	Commelinaceae	*Commelina spp.*	H	MD	D/W	2	
28	Commelinaceae	*Commelina spp.*	H	MD	W	2	
29	Commelinaceae	*Cyanotis barbata*	H	DD	W	1	
30	Commelinaceae	*Cyanotis cristata*	H	DD	W	2	
31	Commelinaceae	*Pollia spp.*	H	DD	W	2	
32	Compositae	*Synedrella nodiflora*	H	MD	D	2	FD
33	Compositae	*Vernonia spp.*	S	MD	W	2	
34	Convolvulaceae	*Argyreia spp.*	C	DD	W	2	
35	Convolvulaceae	*Merremia spp.*	C	MD	W	2	
36	Convolvulaceae	*Merremia vitifolia*	C	MD	W	2	
37	Cucurbitaceae	*Melothria cf. heterophylla*	HC	DD	W	2	
38	Cucurbitaceae	*Zehneria indica*	HC	MD	W	2	
39	Cyperaceae	*Cyperus cyperinus*	G	DD	D	2	FD
40	Cyperaceae	*Cyperus cyperoices*	G	DD	W	1	
41	Cyperaceae	*Cyperus rotundus*	G	DD	D	2	
42	Cyperaceae	*Cyperus spp.*	G	DD	D	2	
43	Cyperaceae	*Fimbristylis cf. aestivalis*	G	DD	W	1	
44	Cyperaceae	*Fimbristylis cinnamometorum*	G	DD	W	1	
45	Cyperaceae	*Fimbristylis dichotoma*	G	DD	W	1	
46	Cyperaceae	*Fimbristylis eragrostis*	G	DD	W	1	

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
47	Cyperaceae	*Fimbristylis monostachos*	G	DD	W	1	
48	Cyperaceae	*Rhynchospera rubra*	G	DD	W	1	
49	Cyperaceae	*Scleria scrobiculata*	G	DD	W	2	
50	Dioscoreaceae	*Dioscorea cf. hispida*	HC	MD	D/W	2	FW
51	Dioscoreaceae	*Dioscorea sp 1.*	HC	MD	W	2	FW
52	Dioscoreaceae	*Dioscorea sp 2.*	HC	MD	W	2	FW
53	Dioscoreaceae	*Dioscorea sp 3.*	HC	MD	W	2	
54	Dipterocarpaceae	*Shorea obtusa*	T	MD	W	2	
55	Dipterocarpaceae	*Shorea siamensis*	T	MD, DD	D	2	FD
56	Ebenaceae	*Diospyros spp.*	C	MD	W	2	
57	Euphorbiaceae	*Bridelia spp.*	C	MD	W	2	
58	Euphorbiaceae	*Bridelia stipularis*	C	MD	W	2	
59	Euphorbiaceae	*Bridelia tomentosa*	S	MD	W	2	
60	Euphorbiaceae	*Cleidion spp.*	C	DE	D	2	
61	Euphorbiaceae	*Cleistanthus spp.*	ST	MD	W	2	
62	Euphorbiaceae	*Glochidion kerrii*	ST	MD,DD	W	2	
63	Euphorbiaceae	*Phyllanthus emblica*	T	MD	W	2	
64	Euphorbiaceae	*Phyllanthus reticulatus*	S/ST	MD	D	2	
65	Euphorbiaceae	*Phyllathus amavus*	H	DD	W	2	
66	Euphorbiaceae	*Sauropus amoediflorus*	S	DD	W	2	
67	Euphorbiaceae	*Securinega virosa*	S	MD	W	2	
68	Gramineae	*Andropogon filipendulus*	G	D	W	1	
69	Gramineae	*Andropogon sanguineus*	G	DD	D	2	
70	Gramineae	*Andropogon spp.*	G	DD	D	2	

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
71	Gramineae	*Apluda mutica*	G	DD	D/W	2	
72	Gramineae	*Apluda spp.*	G	DD	D	2	FD
73	Gramineae	*Apocopis siamensis*	G	D	W	1	FW
74	Gramineae	*Aristida balansae*	G	DD	W	2	FW
75	Gramineae	*Arthraxon spp.*	G	MD	W	2	
76	Gramineae	*Arundinaria ciliata*	G	D	W	1	
77	Gramineae	*Arundinaria spp.*	G	MD	W	2	
78	Gramineae	*Bambusa arundinacea*	B	MD	D/W	2	FW/FD
79	Gramineae	*Bothriochloa glabra*	G	DD	W	1	
80	Gramineae	*Brachiaria kurzii*	G	DD	W	1	
81	Gramineae	*Centotheca lappacea*	G	DD	W	1	
82	Gramineae	*Chrysopogon orientalis*	G	DD	D	2	
83	Gramineae	*Coelorachis cancellata*	G	DD	W	1	
84	Gramineae	*Coelorachis glandulosa*	G	DD	W	1	
85	Gramineae	*Coix spp.*	G	DD	W	2	
86	Gramineae	*Cymbopogon flexuosus*	G	DD	D	2	FD
87	Gramineae	*Cymbopogon nardus*	G	DD	D/W	2	FD
88	Gramineae	*Cymbopogon spp.*	G	DD	W	2	FW
89	Gramineae	*Cynodon dictylon*	G	DD	W	1	
90	Gramineae	*Cyrtococcum accrescens*	G	MD	W	1	
91	Gramineae	*Dendrocalamus strictus*	B	MD	D/W	2	FW/FD
92	Gramineae	*Digitaria ternata*	G	DD	W	1	
93	Gramineae	*Eragrostis malayana*	G	DD	W	1	
94	Gramineae	*Eragrostis tanella*	G	DD	W	1	

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
95	Gramineae	*Eulalia spp.*	G	DD,MD	W	1	
96	Gramineae	*Gigantochloa spp.*	B	MD	W	2	FW
97	Gramineae	*Heteropogon contortus*	G	DD	D	2	FD
98	Gramineae	*Heteropogon spp.*	G	MD	W	1	
99	Gramineae	*Heteropogon triticeus*	G	DD	D/W	2	
100	Gramineae	*Imperata cylindrica*	G	DD	W	1	
101	Gramineae	*Microstegium ciliatum*	G	MD	D/W	2	
102	Gramineae	*Microstegium spp.*	G	MD	W	2	
103	Gramineae	*Ophiuros exallatus*	G	MD	W	2	
104	Gramineae	*Ottochloa nodosa*	G	DE	D	2	
105	Gramineae	*Panicum montanum*	G	MD	W	2	
106	Gramineae	*Panicum notatum*	G	MD	W	2	
107	Gramineae	*Panicum oblongum*	G	DD	W	2	
108	Gramineae	*Panicum repens*	G	MD	W	2	
109	Gramineae	*Panicum spp.*	G	MD	W	2	
110	Gramineae	*Pennisetum polystachyon*	G	DD	D	2	
111	Gramineae	*Rottboellia exaltata*	G	MD	W	1	
112	Gramineae	*Saccharum arundinaceum*	G	MD	D/W	2	
113	Gramineae	*Saccharum spp.*	G	MD	D	2	
114	Gramineae	*Saccharum spontaneum*	G	MD	D/W	2	FW/FD
115	Gramineae	*Setaria geniculata*	G	DD	W	1	
116	Gramineae	*Setaria pallide-fusca*	G	DD	W	1	
117	Gramineae	*Sorghum nitidum*	G	MD	D/W	2	FD
118	Gramineae	*Themeda australis*	G	DD	W	1	

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
119	Gramineae	*Themeda triandra*	G	DD	W	1	
120	Gramineae	*Thyrostacnys siamensis*	B	MD	D/W	2	FW/FD
121	Gramineae	*Vetiveria zizanioides*	G	DD	W	1	
122	Gramineae		G	DD	W	2	Yapongkai
123	Gramineae		G	MD	W	2	Unknown 1
124	Gramineae		G	MD	W	2	Unknown 3
125	Gramineae		G	DD	W	2	Unknown 11
126	Gramineae		G	MD	W	2	Unknown 15
127	Gramineae		G	MD	D/W	2	Unknown 18
128	Gramineae		G	MD	D/W	2	Unknown 2
129	Gramineae		G	DD	D	2	Unknown 31
130	Gramineae		G	MD	W	2	Unknown 4
131	Gramineae		G	MD	D	2	Unknown 47
132	Gramineae		G	DD	W	2	Unknown 5
133	Gramineae		G	DD	W	2	Unknown 6
134	Guttiferae	*Cratoxyum spp.*	T	DD	W	1	
135	Ixonanthaceae	*Irvingia malayana*	T	MD,DD	W	1	
136	Juglandaceae	*Engelhardtia spicata*	T	DD	W	2	
137	Liliaceae	*Ophiopogon spp.*	H	DD	W	2	
138	Malvaceae	*Hibiscus scandens*	C	MD	W	2	
139	Malvaceae	*Sida acuta*	US	DD	W	1	
140	Meliaceae	*Aglaia spp.*	ST	DD	W	2	
141	Meliaceae	*Toona ciliata*	T	DE	D	2	
142	Mimosaceae	*Acacia spp.*	T	MD	D/W	2	

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remar
143	Mimosaceae	*Xylia xylocarpa*	T	DD	W	2	
144	Myrtaceae	*Eugenia spp.*	T	MD	W	1	
145	Ochnaceae	*Ochna integerrima*	S/ST	DD	W	2	
146	Oleaceae	Unknown B	S	DD	W	2	
147	Opiliaceae	*Melientha suavis*	ST	DD	W	2	
148	Papilionaceae	*Crotalaria melanocarpa*	H	DD	D/W	2	
149	Papilionaceae	*Crotalaria montana*	H	DD	W	2	
150	Papilionaceae	*Dalbergia cultrata*	T	DD	W	1	
151	Papilionaceae	*Dalbergia dongnaiensis*	T	DD	W	1	
152	Papilionaceae	*Dendrobium lanceotatum*	US	DE	D	2	
153	Papilionaceae	*Desmodium floribundum*	US	DD	D	2	
154	Papilionaceae	*Desmodium gangeticum*	H	DD	W	1	
155	Papilionaceae	*Desmodium heterocarpon*	US	DD	W	2	
156	Papilionaceae	*Desmodium heterocarpon var. strigosum*	US	DD	W	2	
157	Papilionaceae	*Desmodium oblongum*	S	DD	D/W	2	FW/Fl
158	Papilionaceae	*Desmodium renifolium*	S	DD	W	2	
159	Papilionaceae	*Desmodium sp 1.*	US	DD	D	2	
160	Papilionaceae	*Desmodium sp 2.*	S	DD	D	2	
161	Papilionaceae	*Desmodium motorium*	US	DD	D	2	
162	Papilionaceae	*Desmodium velutinum*	C	MD	W	2	FW
163	Papilionaceae	*Dunbaria longeracemosa*	C	DD	W	2	FW
164	Papilionaceae	*Dunbaria spp.*	H	MD	D	2	
165	Papilionaceae	*Dysolobium spp.*	C	DD	D	2	

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
166	Papilionaceae	*Melletia spp.*	C	MD	W	2	
167	Papilionaceae	*Milletia brandisiana*	T	DD	W	1	
168	Papilionaceae	*Milletia ef. caerulea*	C	MD	W	1	
169	Papilionaceae	*Milletia kityana*	C	DD	D	2	FD
170	Papilionaceae	*Milletia leucantha*	T	MD	W	1	
171	Papilionaceae	*Moghania macrophylla*	S	DD	D/W	2	
172	Papilionaceae	*Mucuna pruriens*	C	DD	W	2	
173	Papilionaceae	*Phaselus spp.*	HC	MD	D	2	
174	Papilionaceae	*Phaseolus barbata*	HC	MD	W	2	
175	Papilionaceae	*Phaseolus lunatus*	HC	MD	D	2	
176	Papilionaceae	*Phyllodium insigne*	S	MD	W	2	
177	Papilionaceae	*Phyllodium spp.*	S	MD	D	2	
178	Papilionaceae	*Pterocarpus macrocarpus*	T	DD	W	2	
179	Papilionaceae	*Pueraria barbata*	C	MD	D/W	2	FW/FD
180	Papilionaceae	*Pueraria candolli*	C	DD	D	2	
181	Papilionaceae	*Pueraria wallichii*	C	DD	D/W	2	
182	Papilionaceae	*Spatholobus spp.*	C	MD	W	2	
183	Papilionaceae	*Tephrosia repentina*	US	DD	D	2	
184	Papilionaceae	Unknown 71	C	DD	W	2	
185	Rubiaceae	*Adina cordifolia*	T	MD	D/W	2	FW/FD
186	Rubiaceae	*Gardenia sootepensis*	ST	DD	W	2	
187	Rubiaceae	*Gardenia spp.*	ST	DD	D	2	
188	Rubiaceae	*Gardenia erythroclada*	ST	DD	D	2	
189	Rubiaceae	*Hedyotis tenellifolia*	H	DD	W	2	

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
190	Rubiaceae	*Hymenodictyon excelsum*	T	MD,DD	W	1	
191	Rubiaceae	*Mitragyna brunonis*	T	DD	D/W	2	FW/FD
192	Rubiaceae	*Randia nutans*	S/ST	MD	W	2	
193	Rubiaceae	*Randia tomentosa*	T	MD	D	2	
194	Rubiaceae	*Tarenna spp.*	S	MD	W	2	
195	Rutaceae	Unknown 88	ST	MD	D	2	Manaope
196	Sapindaceae	*Lepisanthes tetraphylla*	T	MD	D	2	
197	Sapindaceae	*Schleichera oleosa*	T	MD	D/W	2	
198	Simaroubaceae	*Harrisonia perforata*	C	MD	D/W	2	FW/FD
199	Smilaceae	*Smilax lanceifolia*	C	MD	D	2	
200	Staphyleaceae	*Turpinia cochinchinensis*	ST	MD	D/W	2	
201	Sterculiaceae	*Sterculia guttata*	T	MD	D/W	2	FD
202	Stilaginaceae	*Antidesma ghaesembilla*	ST	D, MD	W	1	
203	Stilaginaceae	*Antidesma spp.*	T	MD	W	2	FW
204	Symphoremataceae	*Sphenodesme involuerta*	C	MD	W	2	FW
205	Symphoremataceae	*Sphenodesme mollis*	C	MD	W	2	
206	Symphoremataceae	*Sphenodesme pentandra*	C	MD	W	2	
207	Symplocaceae	*Symplocos spp.*	ST	MD	W	2	
208	Tiliaceae	*Triumfetta bartramia*	S	MD	W	2	
209	Tiliaceae	*Triumfetta pilosa*	S	MD	D/W	2	
210	Tliaceae	*Grewia spp.*	S	MD	W	2	
211	Verbenaceae	*Gmelina elliptica*	ST	MD	W	2	
212	Verbenaceae	*Premna spp.*	C	MD	W	2	

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
213	Verbenaceae	*Vitex limonifolia*	T	DD	W	2	
214	Verbenaceae	*Vitex peduncularis*	T	DD	W	2	
215	Verbenaceae	*Vitex pinnata*	T	MD	W	1	
216	Verbenaceae	*Vitex spp.*	T	MD	W	2	
217	Verbenaceae	*Vitex vestita*	T	MD	W	2	
218	Vitidaceae	*Cissus spp.*	C	DD	W	2	
219	Zingiberaceae	*Amomum krenanh*	H	MD	W	2	
220	Zingiberaceae	*Amomum spp.*	H	MD	D	2	
221	Zingiberaceae	*Curcuma aeruginosa*	H	DD	W	1	
222	Zingiberaceae	*Curcuma parviflora*	H	DD	W	1	
223	Zingiberaceae	*Globba spp.*	H	DD	W	2	FW
224	Zingiberaceae	*Kaempferia elegans*	H	MD	W	2	
225	Zingiberaceae	*Kaempferia spp.*	H	MD	W	2	
226	Zingiberaceae	*Zingiber spp.*	H	DD	W	2	
227	Unknown		H	DE	D	2	Kraitandeaw
228	Unknown		S	MD	W	2	Gusticia
229	Unknown		S	DD	W	1	Hmarthria
230	Unknown		ST	DD	D	2	Tanluang
231	Unknown		S	MD	W	2	Thladiantha
232	Unknown		S	MD	W	2	Kradugkai
233	Unknown		S	MD,DD	W	2	Kinkungnoi
234	Unknown		S	DE	D	2	Potongtab
235	Unknown		S	MD	W	2	Kraduangkai
236	Unknown		S	MD	W	2	Keeyafoi

Appendix 11. (Continued)

No.	Family	Scientific names	Life forms	Habitats	Seasons	Year	Remark
237	Unknown		S	MD	W	2	Krampa
238	Unknown		S	MD	W	2	Tuluvou
239	Unknown		S	MD	W	2	Fonsanhah
240	Unknown		S	MD	W	2	Koglan
241	Unknown		S	MD	W	2	Tongtang
242	Unknown		ST	MD	D	2	Patub
243	Unknown		ST	MD	D	2	Sakae
244	Unknown		S	DE	D	2	Sonkra
245	Unknown		S	DE	D	2	Kwaikeng
246	Unknown		H	DE	D	2	Unknown 37 (Kla)
247	Unknown		C	DD	W	2	Unknown 60

Life Forms : US = Undershrub; ST = Shurb Tree; HC = Herbaceous Climber; CrH = Creeping Herb; HUS = Hubaceous Undershrub; T =Tree; S = Shrub; H = Herb; G = Grass; C = Climber; B = Bamboo; BK = Bark

Habitats : DD = Dry-deciduous forest; MD = Mixed deciduous forest; DE = Dry evergreen forest

Season : D = Dry season; W = Wet season

Year : 1 = 1983-1995; 2 = 1994-1995

Remark : FW = Found in both direct foraging observation and fecal analysis in the wet season

FD = Found in both direct foraging observation and fecal analysis in the dry season

Appendix 12. Mineral sources utilization time of gaur in Huai Kha Khaeng Wildlife Sanctuary, 1994-95.

No	Date	Time in (hours)	Time out (hours)	Minutes	Number	Location	Observer
1	7-Sep-94	12:03	12:06	10	1	Punamron	HKK
2	14-Sep-94	18:59	19:30	20	3	Punamron	HKK
3	5-Oct-94	17:32	18:14	42	3	Punamron	HKK
4	12-Oct-94	18:19	18:29	10	3	Punamron	HKK
5	13-Oct-94	4:25	4:49	24	3	Punamron	HKK
6	14-Oct-94	16:41	16:02	21	1	Punamron	HKK
7	16-Oct-94	17:25	17:55	30	10	Punamron	HKK
8	26-Oct-94	17:35	18:19	44	1	Punamron	HKK
9	21-Dec-94	18:09	18:45	31	17	Punamron	HKK
10	22-Dec-94	19:21	19:26	5	1	Punamron	HKK
11	25-Nov-95	14:35	14:50	15	1	Pong Ya	Dr. Srayut
12	25-Nov-95	14:55	15:10	15	7	Pong Ya	Dr. Srayut
13	25-Nov-95	15:40	15:50	10	1	Pong Ya	Dr. Srayut
14	25-Nov-95	16:20	17:03	43	1	Pong Ya	Dr. Srayut
15	25-Nov-95	17:05	18:30	85	20	Pong Ya	Dr. Srayut
16	26-Nov-95	14:10	14:20	10	2	Pong Ya	Dr. Srayut
17	26-Nov-95	15:10	15:20	10	1	Pong Ya	Dr. Srayut
18	26-Nov-95	16:00	16:30	30	1	Pong Ya	Dr. Srayut
19	26-Nov-95	17:00	17:40	45	7	Pong Ya	Dr. Srayut
			Mean	26.3	1 to 25		
			Range	5 to 85			

Appendix 13. Mineral sources utilization time of banteng in Huai Kha Khaeng Wildlife Sanctuary, 1994-95.

No	Date	Time in (hours)	Time out (hours)	Minutes	Number	Location	Observer
1	6-Oct-85	12:00	13:00	60	≥15	Sub Kao	TP
2	21-Jan-88	13:00	13:08	8	1	Pong Ya	Kasem
3	7-Sep-94	16:17	16:31	14	1	Punamron	HKK
4	1-Sep-95	10:43	11:15	32	3	Punamron	HKK
5	7-Sep-95	14:54	14:58	4	1	Punamron	HKK
6	21-Sep-95	18:51	19:31	40	7	Punamron	HKK
7	27-Oct-95	16:00	16:05	5	1	Sub Kao	HKK
8	23-Nov-95	17:26	17:51	25	8	Punamron	HKK
9	25-Nov-95	13:30	13:50	20	12	Pong Ya	Dr.Srayut
10	23-Dec-95	14:00	14:05	5	8	Pong Ya	TP
			Mean	21.3	1 to 15		
			Range	4 to 60			

Appendix 14. Average mineral and nutritional contents in leaves of food plants of banteng during the wet and dry seasons in Huai Kha Khaeng Wildlife Sanctuary, 1994-95.

Appendix 14.1 Average mineral and nutritional contents in leaves of food plants of banteng during the wet season.

No	Scientific Name	Habitats	Wet season (% in dry matter)							Cal/g
			Na (ppm)	Ca	P	Ash (%)	Protein (%)	NDF (%)	ADF (%)	Energy
1	*Hyparrhenia rufa*	DD	411.9	0.3	0.2	8.0	6.0	67.0	37.8	3854.3
2	*Heteropogon spp.*	DD	337.8	0.3	0.1	9.0	5.2	70.3	42.7	3832.9
3	*Saccharum spontaneum*	DD	354.6	0.3	0.3	10.0	10.2	73.4	50.6	3759.6
4	*Saccharum arundinaceum*	MD	346.8	0.3	0.3	14.0	18.8	78.0	41.9	3741.0
5	*Microstegium spp.*	MD	352.8	0.3	0.3	6.0	11.0	67.1	41.2	3968.1
6	*Crotalaria spp.*	MD	573.1	0.4	0.1	9.0	21.6	54.2	39.3	3571.5
7	*Pueraria barbata*	MD	325.5	1.0	0.2	11.0	14.7	50.1	39.8	3798.8
8	*Dendrocalamus strictus*	MD	345.0	0.2	0.5	13.0	26.7	42.2	13.7	3814.9
9	*Bambusa arundinacea*	MD	310.3	0.2	0.5	12.0	25.3	36.6	15.0	3847.4
10	*Melientha suavis*	MD	365.5	2.4	0.8	25.0	17.5	43.1	33.8	3454.7
11	*Synedrella nodiflora*	MD	408.8	1.1	0.5	22.0	14.6	40.9	36.9	3187.9
12	*Desmodium spp.*	MD	305.0	0.5	0.2	6.0	9.4	61.0	55.8	4209.1
13	*Desmodium motorium*	DD	533.0	0.4	0.2	7.0	13.2	58.6	52.8	3973.4

Appendix 14.1 (Continued)

No	Scientific Name	Habitats	Wet season (% in dry matter)							Cal/g
			Na (ppm)	Ca	P	Ash (%)	Protein (%)	NDF (%)	ADF (%)	Energy
14	*Heteropogon spp.*	DD	340.0	0.2	0.2	7.0	8.0	78.0	52.2	3962.5
15	*Cymbopogon spp.*	DD	475.0	2.3	0.2	7.0	4.6	69.9	43.3	3886.8
16	*Chrysopogon orientalis*	DD	509.0	0.3	0.2	8.0	7.6	73.1	51.0	3838.8
			393.4	0.7	0.3	10.9	13.4	60.2	40.5	3793.9

Remarks : Habitat : MD = Mixed-deciduous forest; DD = Dry-dipterocarp forest

Appendix 14. 2. Average mineral and nutritional contents in leaves of food plants of banteng during the dry season.

No	Scientific Name	Habitat	Dry season (% in dry matter)							Cal/g
			Na (ppm.)	Ca	P	Ash (%)	Protein (%)	NDF (%)	ADF (%)	Energy
1	*Hyparrhenia rufa*	DD	338.9	0.3	0.3	8.0	6.9	69.1	40.6	3786.0
2	*Heteropogon spp.*	DD	292.1	0.2	0.2	7.0	13.2	73.8	44.5	3870.7
3	*Saccharum spontaneum*	DD	311.4	0.3	0.2	6.0	12.1	79.9	45.0	4087.4
4	*Saccharum arundinaceum*	MD	303.0	0.2	0.3	13.0	20.6	80.0	41.3	3812.4
5	*Microstegium spp.*	MD	306.1	0.3	0.2	8.0	9.6	72.5	49.9	3824.8
6	*Crotalaria spp.*	MD	349.6	1.5	0.1	11.0	11.3	45.9	34.3	3531.5
7	*Pueraria barbata*	MD	400.5	1.4	0.3	15.0	12.8	44.1	34.1	3719.5
8	*Dendrocalamus strictus*	MD	533.9	0.2	0.7	15.0	25.1	44.1	22.5	3806.7
9	*Bambusa arundinacea*	MD	360.6	0.2	0.6	14.0	29.9	36.9	31.8	3829.0
10	*Melientha suavis*	MD	369.4	2.4	0.2	13.0	16.2	42.1	28.4	3345.7
11	*Synedrella nodiflora*	MD	911.3	1.1	0.4	20.0	16.0	53.8	39.0	3273.9
12	*Desmodium spp.*	MD	342.9	0.9	0.3	9.0	6.8	72.5	43.6	4184.4
13	*Desmodium motorium*	DD	383.3	0.9	0.2	8.0	12.9	54.1	47.5	4047.9

Appendix 14.2 (Continued)

No	Scientific Name	Habitat	Dry season (% in dry matter)							Cal/g
			Na (ppm.)	Ca	P	Ash (%)	Protein (%)	NDF (%)	ADF (%)	Energy
14	*Heteropogon spp.*	DD	327.8	0.3	0.2	8.0	5.3	74.3	48.3	3551.1
15	*Cymbopogon spp.*	DD	364.9	0.3	0.2	8.0	5.5	70.7	44.9	3981.8
16	*Chrysopogon orientalis*	DD	360.5	0.3	0.2	8.0	5.8	70.6	49.7	3722.8
	Mean		391.0	0.7	0.3	10.7	13.1	61.5	40.3	3773.5

Remarks : Habitat : MD = Mixed-deciduous forest; DD = Dry-dipterocarp forest

Appendix 15. Average mineral and nutritional contents in barks of plants eaten by banteng during the wet and dry seasons in Huai Kha Khaeng Wildlife Sanctuary, 1994-95.

No	Scientific Name	Habitats	Mineral and nutritional contents in the wet season (% in dry matter)							Cal/g
			Na (ppm)	Ca	P	Ash (%)	Protein (%)	NDF (%)	ADF (%)	Energy
1	*Mitragyna brunonis*	DD	318.25	0.8	0.1	4.0	3.6	55.0	45.5	3775.8
2	*Adina cordifolia*	DD	326.63	0.6	0.1	6.0	4.6	52.6	35.2	3602.3
3	Unidentified 2 (Patab)	DD	308.25	3.7	0.1	19.0	12.9	63.5	39.8	3080.8
4	Unidentified 3 (Sakarkraw)	MD	337.63	1.6	0.1	10.0	9.5	54.6	42.7	3665.5
	Mean		322.69	1.7	0.1	9.8	7.6	56.4	40.8	3531.1

No	Scientific Name	Habitats	Mineral and nutritional contents in the dry season (% in dry matter)							Cal/g
			Na (ppm.)	Ca	P	Ash (%)	Protein (%)	NDF (%)	ADF (%)	Energy
1	*Mitragyna brunonis*	DD	341.6	1.1	0.1	7.0	2.2	39.0	30.7	3739.6
2	*Adina cordifolia*	DD	359.3	1.8	0.1	16.0	4.4	57.1	48.2	3386.2
3	Unidentified 2 (Patab)	DD	385.0	1.9	0.8	20.0	4.7	56.7	48.9	3393.8
4	Unidentified 3 (Sakarkraw)	MD	375.6	0.4	0.2	9.0	11.1	34.7	27.2	4037.5
	Mean		365.4	1.3	0.3	13.0	5.6	46.9	38.7	3639.3

Remarks : Habitat : MD = Mixed-deciduous forest; DD = Dry-dipterocarp forest

Appendix 16. Calculation of frequency of use of different food plant life forms and food plant species eaten by gaur and banteng.

Example data for calculating frequency of the most common food plants types [1] and species [2] eaten by gaur were from Table 1.

Total observation days = 24

Column 1 No. Scientific name	2 Life Form	3 Observation Days 1 2 3 4 5 6 7... 24	4 No. of counts by species	5 % use
1. *Bambusa arundinacea*	B	1 1 1 1 0 1 1......1	20	(20/24)*100= 83
2. *Dendrocalamus strictus*	B	1 1 1 1 0 1 1......1	20	(20/24)*100= 83
:	:			:
:	:			:
:	:			:
116. Unknown	T	1 0 0 0 0 0 0 0	1	4

[1] Frequency of use of different plant types was calculated by (1):

$$(1) \qquad \frac{\text{Number of counts by category observed eaten}}{\text{Number of observation days}}$$

Number of observation days = 24

Appendix 16 (Continued)

For example of use of different food plant types

Number of days grasses observed eaten	= 24
Number of days browse observed eaten	= 23
Number of days bamboo observed eaten	= 20
Number of days bark observed eaten	= 0

Frequency use of grasses	=	(24/24)*100	= 100% (Bamboo was eaten everyday)
Frequency use of browse	=	(24/24)*100	= 100% (Browse was eaten everyday)
Frequency use of bamboo	=	(23/24)*100	= 96% (Bamboo was eaten 96% of the observation days)
Frequency use of bark	=	(0/24) *100	= 0% (Bark was not eaten)

Total of % frequency of use of all food plant types = 100+100+96+0 = 296

Relative frequency of use of grasses	=	(100/296)*100	= 34%
Relative frequency of use of browse	=	(100/296)*100	= 34%
Relative frequency of use of bamboo	=	(96/296)*100	= 32%
Relative frequency of use of bark	=	(0/296)*100	= 0

[2] Frequency of use of different food plant species was calculated by (2):

(2) $$\frac{\textbf{Number of counts by species observed eaten}}{\textbf{Number of observation days}}$$

Number of observation days = 24

For example, frequency of use of *Bambusa arundinacea* = $\frac{20}{24}$ (From column 4) = 0.83

% use of *Bambusa arundinacea* = (20/24) * 100 = 83%

Appendix 17. Limitation of Fecal Analysis

According to Zyznar and Urness (1969), fecal analysis had limitations. Results of their study showed that it was difficult to identify the amount and species of plants which were eaten by animals from fecal analysis because some heavily used plants were more completely digested. In this study, gaur were directly observed feeding on 116 food plant species in the wet season and on 83 species in the dry season. Conversely only 59 and 45 species, respectively, were identified from fecal samples in the wet and dry seasons. A similar pattern in banteng makes it difficult to analyze the amount of diets from fecal analysis. For example, in the wet season both species foraged heavily on young shoots of the grass, *Microstegium spp.*, but only small amounts of this species were present in fecal analysis. This under representation may have been a result of 1). low levels of cell wall in the young shoots of this grass species, 2). the methodology of cleaning fecal samples, and 3) the unidentified specimen from fecal samples.

Appendix 18. Causes of dead wild cattle in Huai Kha Khaeng Wildlife Sanctuary during 1994-1996.

No	Species	Sex [1]	Date	Causes
1	Gaur	M	1994	Unknown
2	Gaur	M	Nov-94	Poacher
3	Gaur	M	Apr-95	Tiger
4	Banteng	M	1994	Unknown
5	Banteng	M	May-94	Tiger
6	Banteng	F	Jun-94	Tiger
7	Banteng	M	Jun-94	Tiger
8	Banteng	F	1995	Tiger
9	Banteng	M	1995	Tiger
10	Banteng	M	Mar-95	Poacher
11	Banteng	M	Mar-95	Poacher
12	Banteng	F	Apr-95	Tiger
13	Banteng	F	Apr-95	Tiger
14	Banteng	F	Apr-95	Tiger
15	Banteng	SA	Apr-95	Leopard
16	Banteng	F	Apr-95	Poacher
17	Banteng	F	Jun-95	Disease (Foot Rot)/Tiger
18	Banteng	M	Jun-95	Tiger
19	Banteng	M	Jul-95	Poacher
20	Banteng	F	Aug-95	Tiger
21	Banteng	F	1996	Disease (Foot Rot)/Tiger

[1] M = Male; F = Female; SA = Subadult