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THE STATUS OF THE TIGER *(PANTHERA TIGRIS TIGRIS)*
AND ITS IMPACT ON PRINCIPAL PREY POPULATIONS
IN THE ROYAL CHITAWAN NATIONAL PARK, NEPAL

presented by

Kirti Man Tamang

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Geo. A. Petrides
Major professor

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THE STATUS OF THE TIGER (*PANTHERA TIGRIS TIGRIS*) AND ITS IMPACT ON PRINCIPAL PREY POPULATIONS IN THE ROYAL CHITAWAN NATIONAL PARK, NEPAL.

By

Kirti Man Tamang

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ABSTRACT

THE STATUS OF THE TIGER (*PANTHERA TIGRIS TIGRIS*) AND
ITS IMPACT ON PRINCIPAL PREY POPULATIONS
IN THE ROYAL CHITAWAN NATIONAL PARK, NEPAL

By

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The status of the tiger (*Panthera tigris tigris*) and its impact on principal prey populations in the Royal Chitawan National Park, Nepal, were studied between December 1973 and May 1977. A total of nine tigers and twenty ungulates of four species were immobilized using the Parke-Davis drug CI-744 and fitted with radio-transmitter collars.

Methods used for the immobilization, capture and handling of tigers and ungulates are described. A traditional "ring" method used for hunting of tigers by royalty in Nepal was modified for the purpose of darting. Trained domestic elephants were used to drive the tigers which were lured to live buffalo baits. They were then eased by carefully-handled elephant crews into a funnel-shaped white-cloth fence and near the trees in which dart shooters were stationed.

A line transect method was used to estimate the numerical and biomass densities of ungulates in all vegetation types. Herd composition counts were carried out on all ungulates to determine herd size, sex and age ratios, and other prey population characteristics. Home range sizes also were estimated for the tiger and its principal prey animals.

The relative importance of various ungulates in the tiger diet and prey preference ratios were determined by species and sex. In order of the total biomass consumed, the sambar (*Cervus unicolor*), hog deer (*Axis porcinus*), chital (*Axis axis*), wild boar (*Sus scrofa*) and barking deer (*Muntiacus muntjak*) were the principal prey. These species in the order that they evidently were preferred as prey by tigers was sambar, hog deer, wild boar, barking deer and chital. A comparison of kill percentages and availability by sex indicated males of sambar, chital and wild boars were sought out as victims of tiger predation in preference to females.

The resident tiger population was estimated at 5 adult males and 16 females, an average density of one per 43 km^2. An estimated total predation of 7 percent of the standing crop indicates that tiger predation does not limit the prey populations in the park.

Sex and age proportions, reproductive potential and mortality factors have been discussed. Home ranges, territoriality, defense of territory by tiger are examined. Intraspecific competition seems to be the factor limiting tiger density.

Dedicated to

My mother

D. Maya Tamang

ACKNOWLEDGEMENTS

The study reported here was part of a team effort to investigate the ecology of the tiger and its principal prey species in the Royal Chitawan National Park, Nepal. Permission from His Majesty's Government of Nepal (HMGN) was received in January 1973 and the study began in September 1973. This project was a cooperative effort between the Smithsonian Institution and the National Parks and Wildlife Conservation Office, HMGN. I am grateful to the Smithsonian Institution, and the World Wildlife Fund (U.S. Appeals) for their generous financial support of the study. I would like to express my gratitude to Dr. S. Dillon Ripley, Secretary of the Smithsonian Institution, Dr. David Challinor, Assistant Secretary for Science, and Project Administrators, Mr. Ross B. Simons and Mr. Michael R. Huxley for their keen interest and continuous support.

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I wish to express my gratitude to Dr. George A. Petrides, my academic advisor and chairman of my guidance committee for his valuable advice, help and understanding throughout the course of this study and to other members Drs. Leslie W. Gysel, Victor J. Rudolph, Milton H. Steinmueller. I wish to express my appreciation of Dr. Niles R. Kevern, Chairman, Department of Fisheries and Wildlife, and Dr. Lee M. James, Department of Forestry, Michigan State University for their advice and assistance. I wish to express my appreciation of the late Dr. C. C. Beck, Parke-Davis and Company, Ann Arbor, Michigan for advising me on the use of immobilization drug CI-744 and for providing me with initial stock of the drug in 1973.

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I wish to acknowledge the cooperation and assistance of Mr. M. Sunquist, Co-principal Investigator on the project. Dr. J. Seidensticker and myself began with the initial phase of the study by developing capture and immobilization techniques on tigers and leopards till April 1974, after which Dr. Seidensticker left the project. Mr. M. Sunquist joined in November 1974 and remained with the project until June 1976.

I would also like to thank Ms. Susan Hazard for typing drafts of this thesis and Ms. Heidi Grether for preparing the figures. Special thanks go to my sisters, Mrs. B. M. Chhetri and Dr. A. M. Rajlawot for providing finances when it was most needed. Last but not the least, I wish to express my deep gratitude to my wife, Patricia, for her patience, understanding, encouragement and for her help in the field, and to my sons Kiran and Sonam for their enthusiasm, for making our camp more lively and work more enjoyable.

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INTRODUCTION

Perhaps nowhere else in the world does the human population exert as much pressure on the natural resources and environment as in South and Southeast Asia. The population of Asia, excluding the Soviet Union, estimated at 1.9 billion in 1950, rose to about 3.2 billion in 1975 and is expected to be over 5.3 billion by the year 2000. As a result of this exponential growth and the lack of a proper land use program, approximately 5 million hectares of forests and natural areas in Asia are converted every year to agriculture and other land uses and abuses (Ranjitsinh 1979). The loss of their habitats has resulted in a serious threat to the survival of many Asian species.

Historically, Nepal has been renowned for both the variety and abundance of large wild animals and the unique royal hunts of big game including tigers (*Panthera tigris*) and rhinos (*Rhinoceros unicornis*) (Smythies 1942). With the advent of democracy in 1950, people in different parts of Nepal began moving and migrating freely to the richer *duns* or valleys between the outer Himalayas and the Siwalik Hills, and to the *terai* or plains south of the Siwaliks.

Excessive rainfall, landslides and floods during the monsoon in 1954 caused one of the worst natural disasters in the recent history of Nepal and affected the majority of the population. Families by the thousands migrated to the savannas, grasslands, swamps and forests of the dun valleys and the terai plains. These hitherto had been avoided because of malaria and climatic conditions that were considered adverse. Since then malaria eradication and other health programs have accelerated encroachment and settlement in these areas. Rapid destruction of habitats has resulted in a drastic decline in the numbers and distribution of many important wildlife species, including elephants (*Elephas maximus*), gaur (*Bos gaurus*), rhinos, swamp deer (*Cervus duvauceli*), blackbuck (*Antilope cervicapra*), and four-horned antelope (*Tetracerus quadricornis*).

During the course of sixteen years of my career (1954-1969) with the Forest Department of Nepal and afterwards, I have personally observed the devastating effect the settlement of forest areas, uncontrolled grazing by livestock, cattle diseases and poaching have had on wildlife and its habitat throughout Nepal. Elephants are gone from the wilds, except for a few scattered individuals. The swamp deer which once abounded in the western third of the terai districts of Banke, Bardia, Kailali as well as the sizeable population that existed in Chitawan District as late as the 1950's are now gone forever. Swamp deer populations are confined to Sukla Phanta Wildlife Reserve in Kanchanpur District and a few in Karnali Wildlife Reserve in Bardia District.

Except for a few individuals in the Mainapokhar portion of area in Bardia District, the blackbuck is on the verge of extinction in Nepal as it is in India. The once-large population of wild buffalo (Bubalis bubalis) is now confined to one location at Koshi Tappu Reserve and has shrunk to about 40 to 50 animals. Royal Chitawan National Park has the only Nepali rhino population.

In Nepal, the tiger is considered to be the king of the jungle. It has a unique place in the culture, religion and history of the Nepalese people. The tiger is admired, feared and respected by the human population for its beauty, grace, strength, ruthlessness and other natural and supernatural attributes. Claws adapted to strike and hold struggling prey, canines designed for biting and killing, short strong jaws controlled by powerful muscles, strong carnassial teeth to shear meat, soft pads for stealth approach, supple and well-developed muscles built around a strong skeleton make this carnivore capable of sudden speed and bursts of power. Combined with highly developed senses of hearing, vision and smell - its species adaptations and characteristics make the tiger a perfect carnivore.

The carnivorous way of life must be nearly as old as life itself on this planet. Showing a range of specializations, some mammals are herbivores and others are carnivores. As the herbivores have evolved increasingly-effective defenses, the carnivores have developed efficient anatomical "weapons" and hunting methods. Members of the order Carnivora are the most highly developed specialists among meat-eating mammals.

The Miacids were the most primitive carnivores, flourishing 40 to 50 million years ago (Boorer 1969). Although descended from small insectivorous mammals, the ancestral forms of the Miacids remain obscure (McKenna in Eisenberg 1981). The Miacids themselves died out, but their descendants grew more highly developed, increasing in numbers and importance as they adopted different modes of carnivorous life.

Perhaps the most highly-evolved mammalian carnivores are the members of Felidae family - the cats. A line of evolution which occurred in the Oligocene period reached its peak in the sabre-toothed tiger (Smilodon) which was as large as a present-day Asian tiger but had remarkable canine teeth, seven or eight inches long (Boorer 1969). Sabre-toothed tigers mostly inhabited the northern hemisphere at the times that mammoths and mastodons flourished. The sabre-tooths were specialists which died out in the

Pleistocene period, a time when many giant land mammals declined in numbers.

It was another branch of felids which eventually gave rise to all modern cats, including the tigers. Fossil remains of tigers indistinguishable from the existing species have been found in Pleistocene deposits in the arctic regions of northern Asia. The species existed then far north of its present range and its remains are associated there with those of the elk (moose), reindeer, musk ox, saiga antelope, brown bear, polar bear, arctic fox, wolf, mammoth and woolly rhinoceros (Pocock 1929).

The climatic conditions in northern Asia were relatively mild throughout the Pleistocene period. The region then supported grass, shrubs, trees and abundant animal life (Pocock 1929; Stracey 1968). Based on the earliest remains of the species, it seems that the tiger first evolved in arctic Asia, but evidently under more temperate climatic conditions than prevail there today.

With the change in climate and glaciation that followed, tigers spread from arctic Siberia and central Asia east to Manchuria and Korea, and south to China, Burma, Thailand and the Malayan Peninsula into the islands of Sumatra, Java and Bali (Pocock 1929). Tigers also spread from central Asia southwest to the slopes of the Caucasus and to Iran and Afghanistan (Pocock 1929, Perry 1964, Stracey 1968, Prater 1971).

Of the eight recognized tiger subspecies, several are extinct and the rest are listed as endangered (IUCN 1971). The tiger has an uncertain future, not only in Nepal but throughout its range. As a species, it once ranged from Turkey, Iraq and Iran in the Middle East to Korea in the Far East, from the Soviet Union and China in the north to the Indian subcontinent in the south, and to the islands of Java, Sumatra and Bali in the southeast (Figure 1).

The Bali tiger (P. t. balica) has been considered extinct for some time, although recent reports claim that there may be a few left (Jackson 1979). Sightings of the Caspian tiger (P. t. virgata) have been reported from Iran but the records are unconfirmed and that form too may be extinct (Fisher 1978). The Javan tiger (P. t. sondaica) population is estimated at only 4 or 5 individuals (Jackson 1979). The Sumatra tiger (P. t. sumatrae) is reported to number about 1000 but is decreasing rapidly (Fisher 1978, Jackson 1979).

About 150 Siberian tigers (P. t. altaica) are said to survive in the Soviet Union (Jackson 1979) and Zhu-Jin (1979) considers that another 150 may exist in the northeast provinces of China. He believes that the number of Chinese tigers (P. t. amoyensis) in southern China may be greater than for its related subspecies in the northeast provinces. Exact figures, however, are not available.

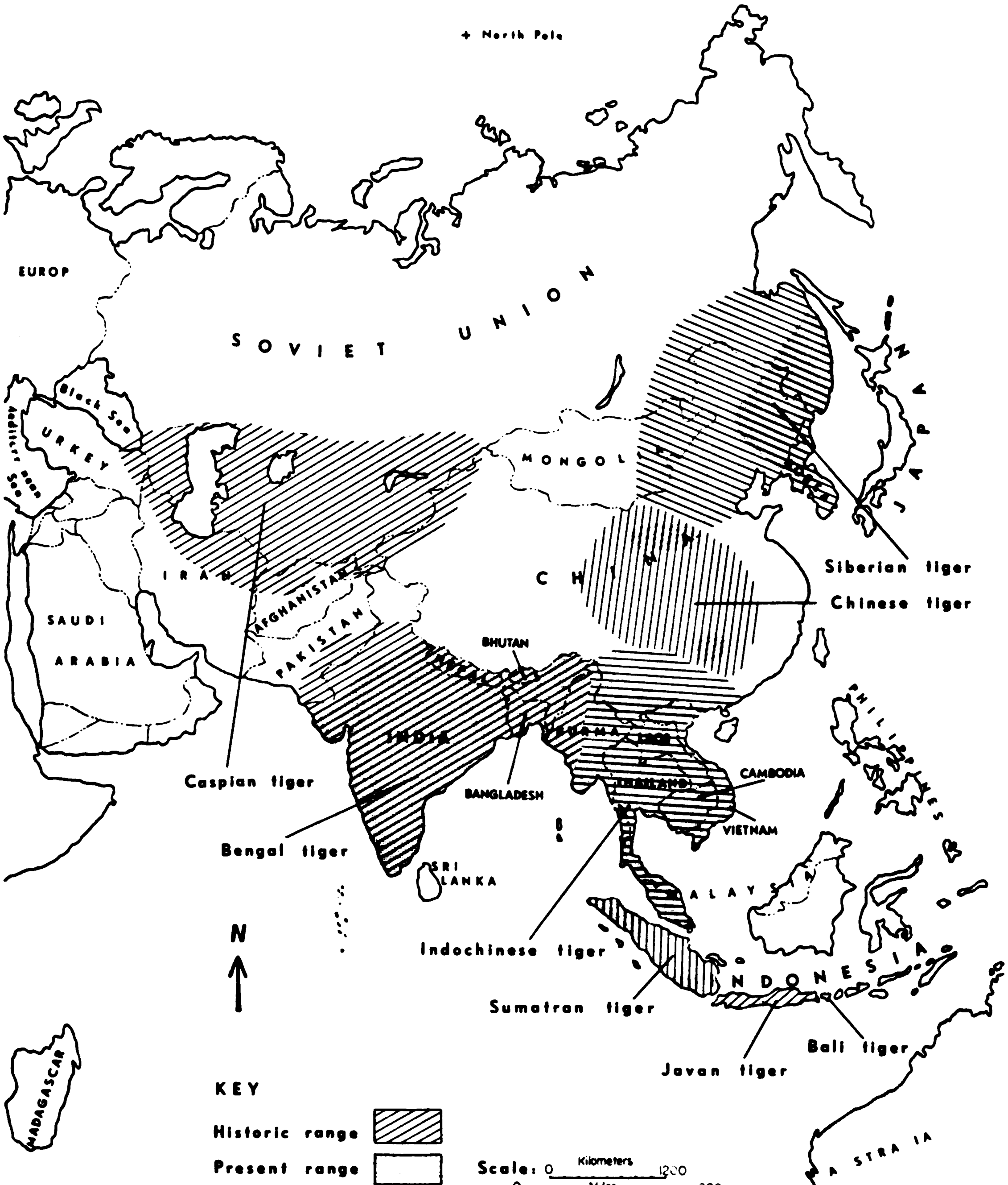


Figure 1. The tiger's range.

The Indochinese tiger (*P. t. corbetti*), ranging from the southern tip of China through Burma, Malaysia, Thailand, Cambodia, Laos, and Vietnam, numbers perhaps 2000 (Fisher 1978). Census figures in 1972 indicated that about 1800 of the Indian subspecies (*P. t. tigris*) may remain in India (Srivastava 1979), with another 400 to 500 estimated for Nepal, Bhutan, Bangladesh and Burma.

Pocock (1929), Stracey (1968), Prater (1971), McDougal (1977) and others have suggested that tigers entered the Indian subcontinent from Burma via Assam in the northeast, westward through Bhutan and Nepal, south to Cape Comorin at the southern tip of peninsular India. The fact that the Perso-Turkestan tigers were somewhat different in size and color from those in northwestern India plus the absence of tigers on the Tibetan plateaux and on the northern slopes of the Himalayas, strengthens the view that the Hindu Kush Mountains and the desert areas of Iran and adjacent Baluchistan excluded the spread of tigers into the subcontinent from the northwest (Pocock 1929). Nevertheless, Sankhala (1977) believes that the color and coat-pattern of the Indian tiger indicates that their evolution was in tall grasslands and savannas, conditions that he believes did not prevail in Siberia during the Teritary and Quarternary periods. He suggests, therefore, that tigers may indeed have entered from the northwest like so many of their prey animals.

That the tiger arrived in extreme southern India only after Sri Lanka separated from it is indicated by the absence of tigers on that island. Leopards, interestingly enough must have reached the area before that land mass separated. It now occurs in Sri Lanka.

In Nepal, tigers inhabit the dun valleys and terai forests of the foothills and plains. They survive only in some parks, reserves and adjoining forest areas (Figure 2). They have been known, however, to range freely to high altitudes. As recently as 1966, a tiger was killed in the Nagarjung forest of Kathmandu Valley at 1340 m. In the more distant past, tigers have been reported even at altitudes of 3000 m or more pursuing and preying on sheep, yaks, wild boars, and bears, descending to lower altitudes during winter snows. Perry (1964) mentions tigers following herds of wild elephants migrating across the Rechi La Pass (West Bengal, India) at a height of over 3000 m. He also writes of a tiger that in 1934 crossed Nathu La Pass at over 4000 m in coming from Sikkim into Chhumbi Valley, Tibet, where it killed a domestic yak.

Tigers were royal game for the rulers and their distinguished guests. Elaborate arrangements were made for big game shikar (hunting). In the winter of 1861, Prime Minister Jang Bahadur Rana assembled 975 domestic elephants and shot 31 tigers, captured 21 wild elephants, and killed 11 wild water buffaloes, 10 wild boars, 4 bears, 3 leopards, 1 rhinoceros, and many other game animals

Figure 2. National parks and wildlife reserves in Nepal.

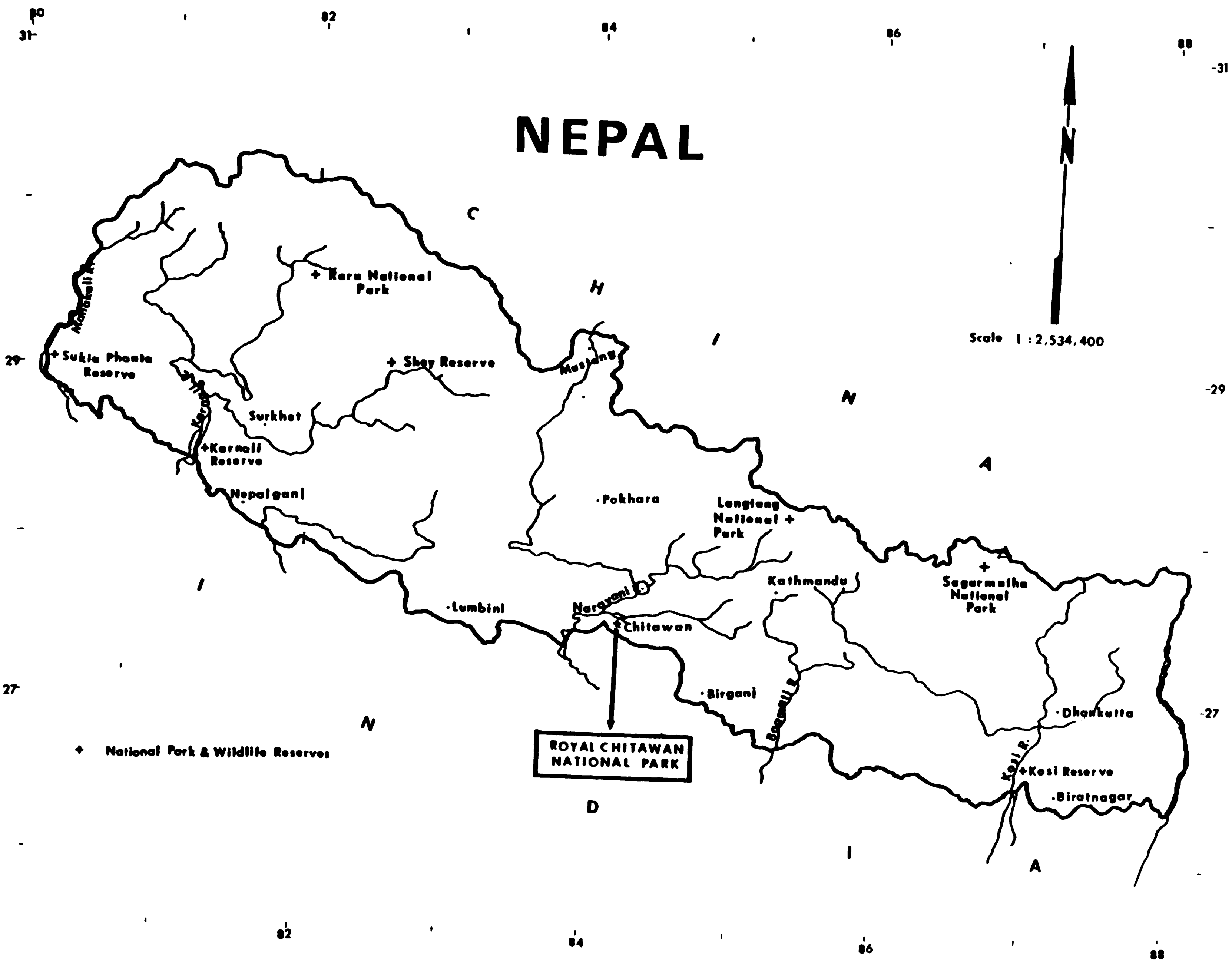

NEPAL
N
Scale 1 : 2,534,400
C H I N A
I N D I A
+ Kara National Park
+ Shey Reserve
+ Sukla Phanta Reserve
Mahakali R.
Karnali R.
+ Karnali Reserve
Surkhet
Nepalganj
Lumbini
Mustang
Pokhara
Narayani R.
+ Chitawan
ROYAL CHITAWAN NATIONAL PARK
Langtang National Park +
Kathmandu
Birganj
Bagmati R.
+ Sagarmatha National Park
Dhankutta
Kosi R.
+ Kosi Reserve
Biratnagar
+ National Park & Wildlife Reserves
80
82
84
86
88
31
29
27

Figure 2.

(Gurung 1980). Chandra Shumsher assembled 600 trained elephants in Chitawan for King George V in December 1911 and where he and his party bagged 58 tigers, 28 rhinoceroses, 6 sloth bears in a period of five days. According to the same author, 418 elephants were mobilized in December 1921 for the Prince of Wales (later Edward VIII) and 18 tigers, 10 rhinoceroses and 2 bears were shot in a week's hunt in Chitawan. Extreme though these past organized <u>shikars</u> might seem, these were only occasional events that occurred in otherwise-protected habitats. As for other game species, too, there was no evidence that they had any lasting adverse effect on tiger populations. It has been the recent intense human population pressure since 1950 and the resulting drastic change in land use with its destruction of wildlife habitats which seems certain to have been the major factor which caused the rapid decline of tigers in Nepal.

The hunting of tigers was prohibited in 1972 for the whole of Nepal and the long term survival of this magnificant species has been recognized as a major concern since then. The human population continues to grow at a rapid rate (now 2 percent per year), however, and an ever-increasing intensity of land use seems destined to continue to limit Nepal's tiger populations.

The precarious status of tigers was formally recognized at the 1969 meeting of the general assembly of the International Union for the Conservation of Nature and

Natural Resources (IUCN) in Delhi, India. Since then, national and international efforts have been focused on the conservation and protection of this spectacular species.

Basic background information on its ecology and behavior is vital to making the proper management decisions for maintaining viable tiger populations in the wild. Such data, however, are either scarce or lacking. Not only are tigers secretive, of low density and essentially solitary hunters, but surviving populations are isolated, scattered and mostly confined to parks, reserves and adjoining forest areas. On other lands, habitat alteration and disturbance by man is overwhelming the few remaining animals.

The bulk of the vast literature on the tiger consists of stories concerning man-eating individuals and hunting adventures (Smythies 1942, Corbett 1946, Singh 1959). The first and most notable quantitative investigation is the study of the tiger and its prey in Kanha National Park, India, by Schaller (1967). Recent observations by Singh (1973), Sankhala (1977), and McDougal (1977) have provided additional insights into tiger behavior and ecology.

In January 1973, after negotiations, permission was obtained from His Majesty's Government of Nepal (HMGN) to carry out the Smithsonian Tiger Ecology Project in the Royal Chitawan National Park. The goal of the Project was to gather that basic ecological information, both on the tiger and its principal prey species, which was necessary for the conservation and management of the tiger in the wild.

The reasons for selecting the Royal Chitawan National Park for the study were: the park contained more of Nepal's remaining tiger population than any other single place, it was a relatively undisturbed situation, there were abundant prey animals present, and accessibility was better than in other reserves.

I began the study with Dr. J. C. Seidensticker in November 1973. The initial fieldwork lasted four months, after which Dr. Seidensticker left the project. During this phase our efforts were concentrated towards perfecting methods for the capture and immobilization of tigers and leopards so as to expedite their handling and marking. The Parke Davis drug CI-744, which is chemically a 1:1 combination of 2(ethylamino)-2-(2-thienyl) cyclohexanone hydrochloride (known also as tiletamine hydrochloride or CI-634) and CI-716 which is chemically 4-(0-fluorophenyl)-6, 8-dihydro-1, 3, 8-trimethylpyrazolo- 3,4-3 1,4 diazepin-7 (IH)-one mono-hydrochloride (known also as zolazepam HCl), was used to immobilize tigers (Seidensticker et al. 1974).

One each of adult male and female tigers and a female tiger cub plus two adult female leopards were immobilized initially. They were equipped with small radio-transmitters and released into the population at the places of capture. Movements and activities of the four adult animals were monitored with radio-receivers. The female tiger had two cubs (one male and one female), and one of the female leopards also produced a litter of two cubs, both males.

I continued with the study after the departure of Dr. Seidensticker, and was joined in November 1974 by Mr. Melvin E. Sunquist. My field study continued from November 1973 eventually carried through to mid-June 1977.

During the entire study period nine tigers were captured 17 times, seven leopards 9 times, twenty different hoofed animals (ungulates) and one sloth bear were captured. Of this I darted seven tigers 11 times, seven leopards 7 times, sixteen ungulates, one sloth bear and assisted in most of the other captures (Table 1). The animals were immobilized, fitted with radio-transmitter collars (except cub 103) and released on their home grounds. Some individuals lost their collars or needed replacement and these animals were darted more than once. All specimens were darted as free ranging individuals, except leopard female 202 which was box trapped both times and immobilized for handling.

Systematic observations of both marked and unmarked ungulates were carried out from the backs of elephants and from on foot and vehicles, blinds and machans (platforms built in trees). Line transects were used to estimate animal densities in all vegetation types. Further information on tiger populations and behavior was collected from natural kills and from bait animals killed by tigers and leopards. The principle wild prey species, their group sizes and composition, sex and age ratios, numerical and biomass densities, food preferences and impacts of the tiger population were also studied intensively.

Table 1. Large mammals captured and radio-collared in the Royal Chitawan National Park, Nepal, 1973-1977.

Species	Serial Number	Age/Sex	Weight (Kg)	Capture date	Darted by	Remarks
Tiger	101	adult F	150	Dec. 18, 73	Tamang	
	101	adult F	164	Mar. 3, 75	Tamang	
	101	adult F	153	May 11, 76	Tamang	
	102	adult M	200	Feb. 20, 74	Tamang	
	102	adult M	200	Feb. 6, 76	Tamang	
	103	cub F*	52	Mar. 21, 74	Seidensticker	offspring of 101
	103	sub-adult F	114	Jan. 23, 75	Sunquist	
	103	adult F	129	Dec. 26, 75	Tamang	
	104	sub-adult M	159	Dec. 17, 74	Sunquist	offspring of 101
	105	adult M	227+**	Dec. 31, 74	Sunquist	
	105	adult M	227+**	Dec. 31, 75	Tamang	
	106	adult F	141	Feb. 16, 75	Tamang	
	106	adult F	141	May 14, 76	Tamang	
	107	adult F	148	Feb. 15, 76	Rai	
	107	adult F	154	Feb, 26, 77	Smith	
	108	adult F	116	Apr. 23, 76	Tamang	died same day
	109	adult F	152	Jan. 6, 77	Tamang	
Leopard***	201	adult F	40	Dec. 7, 73	Tamang	
	201	adult F	40	Dec. 9, 73	Tamang	
	202	adult F	48	Mar. 26, 74	Seidensticker	

Table 1. (cont'd.)

Species	Serial number	Age/Sex	Weight (Kg)	Capture date	Darted by	Remarks
Leopard	202	adult F	45	Feb. 1, 75	Tamang	
	203	sub-adult M	32	Mar. 5, 75	Tamang	offspring of 201
	204	sub-adult M	32	Mar. 9, 75	Rai	offspring of 201
	205	sub-adult M	38	Dec. 30, 75	Tamang	Associated with 206
	206	adult F	48	Dec. 30, 75	Tamang	
	207	cub M	20	Feb. 21, 76	Tamang	offspring of 206
Sambar	301	adult M	227+**	Jan. 16, 75	Tamang	
	302	adult F	193	Feb. 6, 75	Tamang	
	303	adult M	227+**	Feb. 25, 75	Tamang	
	304	adult M	227+**	Jan. 23, 76	Tamang	
	305	adult F	152	Jan. 28, 76	Tamang	
	306	adult M	227+**	Apr. 7, 76	Tamang	
	307	adult F	180	Apr. 8, 76	Tamang	
Spotted deer (chital)	401	adult M	61	Mar. 14, 75	Sunquist	
	402	adult M	91	Apr. 8, 75	Tamang	
	403	adult F	50	Apr. 9, 75	Tamang	
	404	adult M	91	Jan. 21, 76	Tamang	
	405	adult M	84	Apr. 7, 76	Tamang	
	406	adult M	93	Apr. 8, 76	Tamang	
	407	adult F	61	Apr. 15, 76	Tamang	

Table 1. (cont'd.)

Species	Serial number	Age/Sex	Weight (Kg)	Capture date	Darted by	Remarks
Hog deer	501	adult M	39	Mar. 11, 75	Sunquist	
	502	sub-adult M	27	Apr. 11, 75	Sunquist	
	503	adult F	36	Apr. 9, 76	Tamang	
	504	adult M	68	Apr. 14, 76	Tamang	
Barking deer	601	adult F	20	Feb. 28, 75	Sunquist	
	602	adult M	23	Mar. 18, 75	Tamang	
Sloth bear	701	adult M	105	Mar. 28, 75	Tamang	

* Cub 103 was not radio-collared

** Scale weighed only 227 kg (500 lbs)

***The results of leopard study will be a separate report.

STUDY AREA

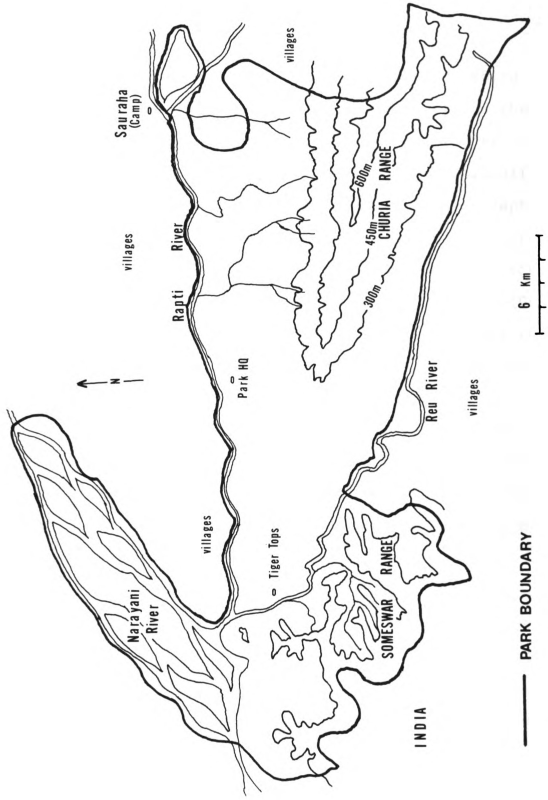
Location and Boundary

The Royal Chitawan National Park, in the district of Chitawan, Narayani Zone, lies approximately sixty air miles west-southwest of Kathmandu at 27°30' North latitude and between 84° and 84°30' East longitude. The park is elongate in shape with the main axis running east-west. It covered an area of 540 km^2 when declared in 1973, but additions in 1976 increased its size to approximately 910 km^2.

Also known as the Rapti Valley, Chitawan is a dun - a wide valley between the foothills of the Mahabharat Range in the outer Himalayas and the Siwaliks (low-lying hills of ancient river deposits) situated south of the outer Himalayan Range and also called the Churia or Someswar Range.

The park is bounded on the north by the Rapti River and on the south mostly by the Reu River and the Siwalik (Someswar) Range. To the southwest, this range forms the international boundary between Nepal and India. The Narayani River is the western park border and the Hasta, Dharang and Amwa Kholas (streams) plus the Thori-Maadi road comprise the eastern boundary (Figure 3).

Figure 3. Royal Chitawan National Park, Nepal.



Sauraha
(Camp)
villages
Rapti River
villages
Park HQ
N
600m
450m
300m
CHURIA RANGE
villages
Reu River
villages
6 Km
Narayani River
villages
Tiger Tops
SOMESWAR RANGE
INDIA
PARK BOUNDARY

Figure 3.

Recent History

In the late sixteenth century Bihang Sen, third son of Mukund Sen of Palpa, is said to have inherited the Tanahu district including Chitawan when his father distributed the vast kingdom among his sons. A Gorkhali force under the command of Abhiman Singh Basnyat captured Chitawan and Upardang Garhi from Harkumardutt Sen, the last ruler of Tanahu, thus bringing the area under the rule of Prithvi Narayan Shah in the summer of 1777 (Gurung 1980). Since then and especially during the family rule of the Ranas in Nepal from 1846 to 1950, Chitawan remained protected as a royal hunting preserve.

The district of Chitawan was practically uninhabited before 1950, except for a few scattered villages. This fertile valley with a rich variety of swamps, grasslands and forests, then was a hunter's paradise, renowned as a hunting ground for rulers and royalties of Nepal and their guests (Smythies 1942). Tigers, leopards, bears, rhinos, and sambar and other large ungulates were among the big game there.

In 1955, in cooperation with the United States Operations Mission, the Government of Nepal launched the Rapti Valley Multi-purpose Development Project. Basically agricultural, this program envisaged the construction of roads, the eradication of malaria, the improvement of other health facilities, and the settlement of many swamps, grassland and forest areas. This was to be achieved by distributing land to the landless and providing irrigation facilities.

Over 2000 families were settled in Chitawan by 1959. In addition, many more thousands were scattered throughout the valley living under trees and encroaching on forest lands (Tamang 1965). More than 100,000 people (Willan 1965a) were involved in this settlement. Millions of trees were indiscriminately girdled, felled and burned, swamps were drained and most of the extensive tall-grass savannas were plowed and put under cultivation.

Recognizing that extensive destruction of habitat and wildlife had occurred, the government in 1959 established both the Mahendra Mrigakuja (Mahendra National Park) north of the Rapti River and a Rhino Sanctuary south of the Rapti. These had the objectives of protecting the remaining populations of rhinos and other wildlife and their habitats. The Chitawan Wildlife Management Division was established at the same time for the protection of wildlife and its habitats, with headquarters at Tikowli.

Beginning in 1959, various investigative commissions and administrative bodies were formed by the government to look into and check the destruction of natural areas in Chitawan. In October 1963, a commission headed by a cabinet minister was formed by the government to establish policies and to settle land use problems permanently. This commission included the local zonal commissioner, one representative each from the district panchayat (assembly) and the farmer's organization, with an official of the Forest Department as its secretary/member. The commission functioned effectively and by 1965 had relocated 4000 families to the Reu Valley and near Thori, and 600 families north of the Rapti. By 1965, encroachment and cultivation south of the Rapti were vacated and the present national park saved.

Chitawan's population was 20,520 in 1920, 26,239 in 1941, 42,833 in 1954 and had increased to 67,882 by 1961 (Gurung 1980). The population of Chitawan district rose to 193,644 in 1971 and continued to grow. Chitawan had food grain production of 73,800 metric tons in 1971 (Gurung 1980) and was considered important for the export of rice, mustard and timber.

As a Divisional Forest Officer in a neighboring forest division, I assisted in the demarcation of the northern Mahendra Mrigakunja in 1958 and the Rhino Sanctuary south of Rapti in 1963.

The late E. P. Gee's reports to the Survival Service Commission of the International Union for the Conservation of Nature and Natural Resources (IUCN) (Gee 1959), to the Fauna Preservation Society of London (Gee 1963) plus R. G. M. Willan's (the Chief Conservator of Forests, Nepal) accounts (Willan 1965a, 1965b) revealed the status of wildlife and the magnitude of the then-prevailing habitat destruction problems in Chitawan. Rhinos that numbered about 1000 in 1953 had dwindled to 600 by 1957, according to Forest Department estimates. Visiting Chitawan in 1957, P. D. Stracey, Director of Forest Education in India, estimated about 400 rhinos then in Chitawan. Two years later, Gee (1959) estimated that only 300 rhinos still survived in the valley. Of these, moreover, no fewer than 140 were killed by poachers during the subsequent two years (Gee 1963). Although these population figures are not based on actual counts, they were the judgements of knowledgeable officials. They document the then-deteriorating trend of wildlife populations in the valley.

With the total destruction of extensive grasslands and swamps north of the Rapti River by settlement and other encroachments, the plentiful swamp deer population there declined to a very few individuals by 1963. The species became extinct in this valley by 1965. The history of these species is but an indication of the general tremendous destruction of wildlife and wild habitats throughout Nepal at that time.

Although the settlers were evacuated by 1965 from the grasslands south of Rapti, that area was still heavily abused as a result of public rights of access. Excessive grazing by livestock and intensive collections of firewood, timber, thatchgrass, reeds, bamboos and other vegetative products continued.

Administration

The decision to create the present national park south of the Rapti was made in 1970 and the demarcation of boundaries was completed in 1971 (Upreti 1973, Bolton 1975). Grazing and the collection of forest products began to be regulated in earnest only after boundary delineation in 1971.

The National Parks and Wildlife Conservation Act became law in 1973. The Royal Chitawan National Park was legally established then and its area enlarged in 1976. Most of the grasslands and riverine forests now included in the park were in fact originally forest areas cleared and vacated by the settlers of 1963-1965. They have been recovering their original vegetation ever since, especially after 1971.

Wildlife matters in Nepal have always been under the jurisdiction of the Forest Department in the Ministry of Forests. 'Rhino Guards,' or Gainda Gasti, of the Forest Department were responsible for the protection of wildlife and its habitat in Chitawan. In 1959, the first Wildlife Management Division was established with headquarters at Tikowli, Chitawan.

The National Parks and Wildlife Conservation Office (NPWCO) was established in 1970 as a section of the Forest Department with its main office at Kathmandu. Since then the Park Warden in charge of Chitawan has been responsible to NPWCO. There are over 150 guards stationed in chowkis (guard stations) throughout the park manned by Royal Nepal Army Personnel. The commanding officer has headquarters at Kasra, where the park warden's main office is located. A senior officer, usually a colonel, in the Royal Nepal Army headquarters at Kathmandu serves as liaison between the Army and the NPWCO. Since 1981 the NPWCO has been established as a full-fledged department, the Department of National Parks and Wildlife Conservation, in the Ministry of Forests with Mr. B. N. Upreti as the first Director-General.

Climate

The climate of this lowland park is typically monsoonal and has three distinct seasons. The monsoon rainy season extends from mid-June to mid-October, the cool dry season from mid-October to mid-February and the hot dry season from mid-February to mid-June.

A steady southeasterly wind from the Bay of Bengal accompanies the monsoon. Total annual rainfall (Figure 4) recorded at Rampur, Chitawan from 1971-1977 averaged 208 cm (His Majesty's Government of Nepal Report 1978).

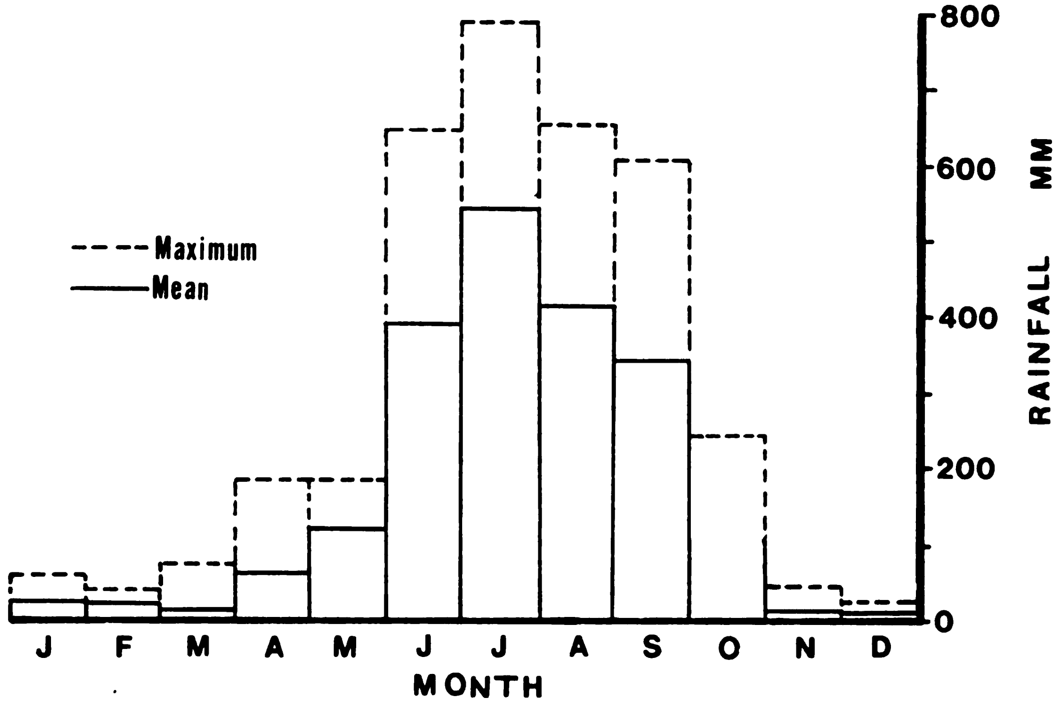


Figure 4. Rainfall at Rampur, Chitawan.

Ninety percent of the rainfall occurs from May through September. Relative humidity during the monsoon period is very high. Average temperature extremes are 32°C in daytime and 24°C at night during the monsoon (Figure 5).

Dry northerly winds from the Himalayas reduce temperatures following the monsoon and a cool season extends until mid-February. Maximum daytime temperatures average 25°C during these winter months and minimum nighttime temperatures average 9°C. As is usual in river valleys with very high relative humidity, heavy fog and dew occur as a common feature during the nights and in the mornings at this season. Frosts occur occasionally in late December or early January.

It starts warming by mid-February. Dry hot southwesterly winds from the plains of India makes this season, extending through mid-June, the driest and hottest part of the year. Relative humidity is very low, maximum daytime temperature averages 34°C and minimum nighttime temperature averages around 18°C (Figure 5). Occasional dust storms, rain and hail occur during March. Premonsoon showers with thunderstorm activity increases from April to May.

Topography

The flood plains in the park include the low lying riverine areas south of the Rapti River, east of the Narayani

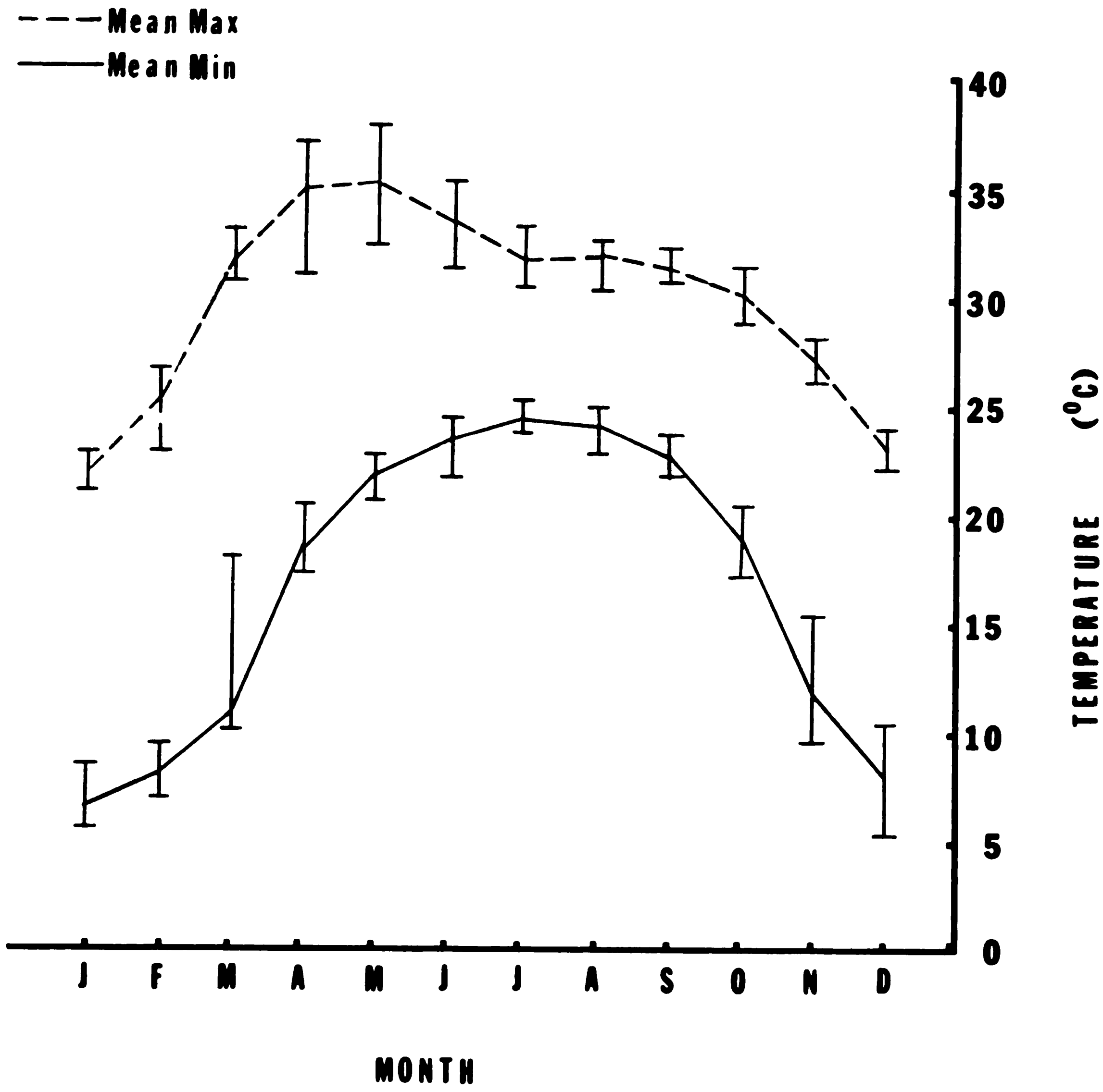


Figure 5. Mean daily maximum and minimum temperature with ranges at Rampur, Chitawan (1970-1977).

River and north of the Reu River (Figure 3). The south flood plain extends from the eastern park boundary to the Narayani in the west and is about 50 km long and 2 to 5 km wide. Park altitudes vary from 150 m above mean sea level at the flood plain to about 800 m at the Churia ridge close to the eastern boundary. It is about 500 m at the Someswar ridge in the southwestern boundary bordering India. The Churia ridge between the Rapti and Reu Rivers gradually loses altitude as it extends westward and falls to the flood plain level at Sukebhaar.

Drainage and Water Resources

The Churia ridge between the Rapti and Reu Rivers is the source of numerous streams that flow northwards into the Rapti and southwards into the Reu. A number of streams flow northwards from the Someswar Range into the Reu and Narayani Rivers. Most of these streams are only seasonal, remaining dry part of the year. Both the Rapti and Reu Rivers flow westwards, meet about 1 km east of the Narayani River before joining it, one of the three largest rivers in Nepal.

Because of its source in the Great Himalayan Range the water level in the Narayani River begins to rise in March with the melting snow in the higher mountains. It remains at high level until November. The mean discharge rate of the Narayani River during the January low is 347 cubic feet per second and 4,750 during the August high (Gurung 1980). Water levels in the Rapti and Reu Rivers rise considerably during the monsoon, becoming impassable on foot. Much of the flood plains become flooded and waterlogged for extensive periods. Swamps and small lakes (taals) with permanent water are scattered throughout the park.

Geology and Soils

The park area is composed of late tertiary Siwalik formation composed of sandstones, conglomerates, quartzites, shales and micaceous sandstones (His Majesty's Government of Nepal Report 1968; Hagen 1969). The alluvial plains adjacent to the Rapti, Reu and Narayani Rivers consist of recent deposits of deep, sandy loam. Sandy loams or loams mixed with eroded gravels and dark in color occur on the higher slopes. Parent rock material is exposed on the steep portions of the Churia and Someswar Range. The southern aspect of the Siwalik is steeper and drier with poorer vegetative cover than the northern aspect.

Vegetation

Recent studies of habitat utilization in South Asia (Eisenberg and Lockhart 1972), in Karnali-Bardia Wildlife Reserve, Nepal (Dinerstein 1979) and in the Royal Chitawan National Park (this study) indicate that some of the best wildlife habitats are areas in early stages of vegetative succession. Changes in vegetative composition in relation to the stages of successional development are vital in determining the types and abundance of wildlife inhabiting the area.

According to Champion's (1938) classification, the major forest in the park falls into the North Indian Tropical Moist Deciduous subtype of the Tropical Moist Deciduous Forest Type (Champion and Seth 1968). On the basis of observations on vegetative physiognomy and species composition the forest habitat has been classified into three main broad categories: sal forest, riverine forest and grassland (Figure 6). During the time I worked for the forest resources survey (1963-1967), aerial photos made for this project in 1964 (1:12,000 in scale) were used to prepare a detailed forest type and stock map. Aerial photos made for the Department of Hydrology, HMGN in 1973 (1:21000 in scale) provides an up-to-date comparative land use picture of the area.

Sal Forest

About 70 percent of the park is in sal (*Shorea robusta*) forest. This species occupies the elevated and better drained soils and predominates in this vegetation type. In 1968, sal constituted over 80 percent of the canopy and attained heights of 25-40 m. Because of its

Figure 6. Distribution of vegetation types in Chitawan National Park, Nepal.

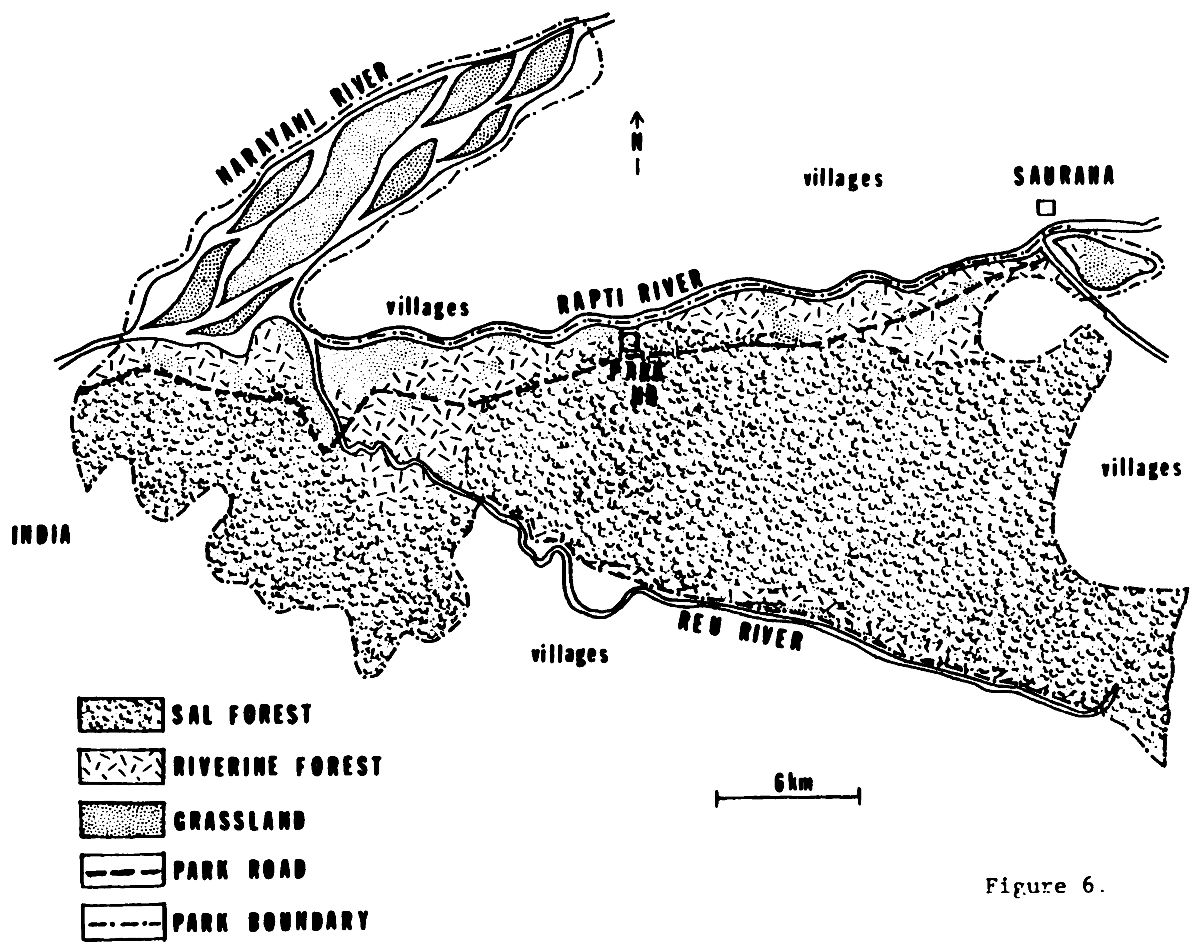

NARAYANI RIVER
N
villages
SAURAHA
villages
RAPTI RIVER
villages
INDIA
REU RIVER
villages
6km
SAL FOREST
RIVERINE FOREST
GRASSLAND
PARK ROAD
PARK BOUNDARY

Figure 6.

ability to regenerate in areas subjected to burning and grazing and its coppicing characteristics, sal forest remains stable and is considered a climax or fire-climax. Properly-managed sal forest protected from fire, progresses towards a semi-evergreen type. During hot weather sal remains deciduous for a brief period of one to two weeks with the new foliage developing rapidly. Its associates include Terminalia tomentosa, T. bellerica, T. chebula, Lagerstroemia parviflora, Anogeissus latifolia, Adina cordifolia, Dillenia pentagyna, Stereospermum suaveolens, Schleichera oleosa, Syzygium cuminii, S. cerasoideum and Madhuca indica in the top canopy. Mallotus philippensis, Ougeinia oojeinensis, Emblica officinalis, Miliusa velutina, M. tomentosa, Semecarpus anacardium, Butea monosperma, Holarrhena antidysenterica, Careya arborea and Cassia fistula form the second story trees. Clerodendron viscosum, Murraya koenigii, Moghania chappar, Eupatorium odoratum occupy the forest floor with Themeda arundinacea, Saccharum spontaneum, Imperata cylindrica, Cymbopogon martinii and other grasses in varying densities. Bauhinia vahlii and Milletia auriculata are common climbers found on sal trees.

Riverine Forest

Riverine forests occupy about 7 percent of the park along Rapti, Reu and Narayani Rivers, swamps and streams and vary a great deal in composition depending upon the stages in succession. On the recent alluvial deposits, early colonisers are khair (Acacia catechu) and sissoo (Dalbergia sissoo), both moderate sized trees. Tamarix dioica, Calotropis gigantea, Pogostemon plectranthroides, Zizyphus mauratiana, Colebrookia oppositifolia and other shrubs are found in the understory with long and short grasses such as: Saccharum spontaneum, Erianthus munja, Vetiveria zizanoides, Cynodon dactylon, Chrysopogon and Erogrostis sp. At a later stage of successional development Bombax ceiba, Trewia nudiflora, Albizzia procera, Anthocephalus cadamba, Litsea monopetala, Bauhinia malabarica, Butea monosperma, Spondias pinnata, are found in various degrees of association with shrubs of Colebrookia oppositfolia, Callicarpa macrophylla, Clerodendron viscosum, Mimosa himalayana, Polygonum sp. In low lying waterlogged areas Syzygium cuminii, Ficus glomerata, other Ficus sp. occur in profusion. Pure stands of Bombax ceiba and sometimes in association with Butea monosperma and Erythrina suberosa are found in scattered patches in grasslands giving it a savanna appearance.

Grassland

About 18 percent of the park area is in grassland extending from the low alluvial flood-plains to the elevated sal forest areas. Grassland associations are interspersed between blocks of riverine forest and provide an intricate distribution of diverse vegetation types. Heights attained by grasses are variable at different sites, being poorer on heavier soils. Rank growth of grass sometimes up to 7 m is a characteristic feature in the new alluvial flood plains consisting of *Saccharum spontaneum*, *S. procerum*, *Erianthus munja*, *Erianthus ravennae*, *Narenga porphyrocoma*, and short grass species such as *Cynodon dactylon*, *Brachiaria ramosa*, *Erogrostis japonica* and *Chrysopogon* sp. underneath the tall grasses. *Phragmites karka*, *Narenga* and *Saccharum* sp. association is found in dense patches on the older alluvium. Open areas and fringes of sal forests may have *Themeda villosa*, *T. arundinacea* association attaining in places heights up to 6 m. Around lakes, in swamps and close to streams dense growth of *Arundo donax*, *Typha elephantina*, *Phragmites karka*, *Saccharum* and *Cyperus* sp. are commonly found. *Imperata cylindrica* also called the thatch grass, is found in abandoned cultivation areas. Some of the grasses are associated with shrubs like *Zizyphus mauratiana*, *Calotropis gigantea*, *Colebrookia oppositifolia*, *Clerodendron viscosum*, *Adhatoda vasica*.

Fires and Other Influences

Fire is a common annual occurence in almost all forest and grasslands in the *duns* and *terai* plains of Nepal. Most, if not all, fires are started by man and usually occur from December to April in this park. Beginning sometime in January, people from neighboring villages are permitted once a year to enter the park for a month to cut thatchgrass (Imperata cylindrica), used for thatching house roofs. They also collect reeds from the tall-grass species such as Themeda arundinacea and Erianthus ravennae, for the construction of walls for houses. After a week or two of the initial cutting of thatchgrass, villagers burn the tall-grasses which at this time removes only the outer leaves making it easier to cut and collect the stems.

Early fires in January and February are relatively cool and are not sufficiently intense to burn shrubs or trees. These fires also are not extensive, and only burn scattered patches through March and April. This staggered burning distributed over time and space is beneficial to wildlife, the prolific growth of succulent new shoots attracting the ungulates. Most of the existing tree species such as Shorea robusta, Schleichera oleosa, Syzygium cuminii, Bombax ceiba, Butea monosperma, Erythrina suberosa are fire resistant to a great degree.

Another beneficial aspect of fire may be its influence in the maintenance of grasslands by preventing establishment of tree regeneration. Intensive grazing by livestock in addition to regular annual burning, however, has a devastating effect on desirable forage species and results in adverse change in species composition. For example, in Itarni Tappu riverine forest on the bank of Rapti at the northeast corner of the park (bordering cultivated areas) intense grazing by livestock, wild ungulates and fire have caused the disappearance of many forage species. These have been replaced by Eupatorium odoratum, Colebrookia oppositifolia, Pogostemon plectranthroides, Murraya koenigii, Clerodendron viscosum, Adhatoda vasica, Zizyphus mauratiana shrubs in dense profusion and with troublesome weeds such as Cassia tora, Ageratum conyzoides, Artemisia vulgaris, Cannabis sativa, etc.

With the destruction of natural forests outside the park boundaries, there has been an ever-increasing pressure from the growing population of over 200,000 people in the valley scattered around the park (Figure 3). The demand for firewood, grass, reeds and fodder for their livestock is serious and increasing. Grazing by livestock in the fringes and indiscriminate burning by grazers is and will remain a problem, although it is illegal according to the National Parks Act.

Fauna

Chital (Axis axis), hog deer (Axis porcinus), sambar (Cervus unicolor), barking deer (Muntiacus muntjak) and wild boar (Sus scrofa) are fairly abundant (Table 2) among the large mammalian fauna presently found in the park.

Table 2. Large mammals found in the Royal Chitawan National Park, Nepal.

Scientific Name*	Common Name
Order Primata	
Macaca mulatta	Rhesus monkey
Presbytis entellus	Common langur
Order Carnivora	
Canis aureus	Asiatic jackal
Vulpes bengalensis	Indian fox
Cuon alpinus	Indian wild dog
Melursus ursinus	Sloth bear
Lutra perspicillata	Smooth-coated Indian otter
Prinodon pardicolor	Spotted linsang
Herpestes edwardsii	Common grey mongoose
Herpestes urva	Crab-eating mongoose
Felis chaus	Jungle cat
Felis bengalensis	Leopard-cat
Felis viverrina	Fishing cat
Panthera pardus	Leopard
Panthera tigris tigris	Bengal tiger
Order Proboscidea	
Elephas maximus	Asian elephant
Order Perissodactyla	
Rhinoceros unicornis	Great one-horned rhinoceros
Order Artiodactyla	
Sus scrofa	Wild boar
Muntiacus muntjak	Barking deer
Axis axis	Spotted deer, Chital
Axis porcinus	Hog deer
Cervus unicolor	Sambar
Tetracerus quadricornis	Four-horned antelope, chowsingha
Bos gaurus	Gaur
Capricornis sumatraensis	Serow
Nemorhaedus goral	Goral

Table 2. (cont'd.)

Scientific Name*	Common Name
Order Lagomorpha	
Lepus nigricollis	Indian hare
Order Rodentia	
Hystrix indica	Indian porcupine
Order Cetacea	
Plantanista gangetica	Gangetic dolphin

*Nomenclature follows Ellerman and Morrison-Scott (1966).

These five large ungulates comprise the principal prey of the tiger.

Serow (*Capricornis sumatraensis*) and goral (*Nemorhaedus goral*) are confined to the hills of the Someswar Range in the southwest corner of the park close to the Indian border. Wild Asiatic elephant (*Elephas maximus*) occasionally visit the southeastern part of the park near Thori. Four-horned antelope or chowsingha (*Tetracerus quadricornis*) occur in the sal forest in the southern slopes of the Churia close to Amuwa in the east but are not common.

Gaur (*Bos gaurus*) are found in the sal forest on the slopes of the Churia and Someswar Ranges. Disease reportedly took a heavy toll of the population in 1972 and 1973. In the following years, however, herds of 20-30 individuals were seen grazing in the open grass areas close to the foothills during the hot dry months of March and April.

METHODS

Capture and Immobilization

In the last two decades, fast-acting immobilizing drugs with suitable projectile syringes and portable telemetry equipment have made substantial contributions to the study of wild animal populations.

Immobilization drugs have made it possible to capture free ranging animals, to make physical measurements and observations. The marking and placing of radio-transmitters on captured animals enables individual recognition. Many animals can be marked and located on a regular basis and their movements and activities related to the structure of their environment.

These techniques have been successfully used in the study of grizzly bears *Ursus arctos* (Craighead, F. C. 1963; Craighead, F. C. and J. J. Craighead 1966), mountain lions *Felis concolor* (Hornocker 1969, 1970; Seidensticker et al. 1973), African lions *Panthera leo* (Harthoorn et al. 1971; Ebedes 1972), deer (Tester et al. 1964; Heezen and Tester 1967) and other species.

The "Ring" Method of Capturing Tigers

In this study one to three year old live domestic water buffaloes were used as baits. They weighed between 40-210 kg and were large enough to last for more than one meal. Several bait animals were tied at points along routes frequently travelled by tigers. Roads, dry stream-beds, stream banks, and trails used by elephants, rhinos and other animals were the usual tiger routes. Old pug-marks (tracks) indicated recent past use of desirable capture sites.

Several important aspects had to be considered in deciding the locations of bait points. The proximity of dense cover had to be nearby into which tigers could drag their kill. Such thicket had to be adequate in size to keep the tiger for a day or two. The presence of suitable trees nearby also was essential. These had to be large enough so that one person could stand and be concealed in them. Also, they had to be located within a reasonable distance from which tigers could be darted. Proximity of water during hot and dry weather also was an important factor in trying to keep a tiger at the desired location.

Baits were staked out late in the afternoon and checked early the following morning. After a bait was taken, the kill site and drag marks were examined quietly to make sure that the kill was made by a tiger and to determine the approximate direction of the drag. If a tiger was judged still to be in the vicinity, a drive was organized.

In the past, royal hunts were organized to hunt tigers in the dense jungles and tall-grass areas of the terai and duns of Nepal. With the plentiful supply of trained elephants then available for shikar (hunting) purposes, a successful and popular way of driving a tiger was the "ring" method. Scores of elephants (the more the better) and bundles of white cloth "bhith" were used to encircle an area close to its kill where a tiger was known to have taken cover. Several moving elephants within the ring of elephants and white cloth were used to drive the tiger towards the hunter's gun.

Our drive operation for the purpose of darting tigers was a modification of the ring method. The idea for this method originated from my personal experience in witnessing such hunts (while with the Forest Department) and from our Assistant Prem Bahadur Rai's lifelong experience in baiting and driving tigers on royal hunts. Usually four to six elephants with a dozen or more men were used for a drive.

The operation usually began at the end of the ring which was farthest from the bait point. This was done as soon as possible after a kill was discovered. There, one or more suitable trees was selected in which one or more persons with Capchur guns were positioned 4 m or more above the ground. Trees were chosen so that existing animal trails and other expected lines of retreat for the tiger passed within the 30 m maximum darting range.

Leaving the darting area open, sections of cloth 1.5 m wide and 40 m long were tied to vegetation or sticks to form a low fence. This fence was arranged in the form of a funnel, with the darting trees at the narrow end. A tiger being disturbed by approaching elephants would avoid the white cloth and head in the direction desired. The number of sections of white cloth used depended upon the size and shape of the area surrounded.

The total length of the funnel-drive was 500 m to 1 km or more.

Two or three persons were stationed in trees at vantage points at the wider end of the funnel. They observed movements of the tiger and guided the elephant drivers by signalling. One or two persons also were placed in trees 100 m or so behind the dart shooters so as to observe the direction that the tiger ran after being darted. The whole operation up to this point was carried out with as little noise as possible.

The drive then began with shouts by the elephant drivers and persons perched in trees at the wide end of the funnel and noises made by the moving elephants. As the assistants at vantage points in the trees guided the elephant drivers by signals and shouts, the elephants slowly moved forward through the dense jungle thrashing the vegetation and swerving in a zig zag fashion. Most often a tiger would move slowly but cautiously at first, stopping now and then, and usually following existing animal trails towards the darting site.

Aimed at the muscular area of the front or hind quarters, the syringe projectile from a Cap-Chur gun (Palmer Chemical Co., 1970) injected the drug into the animal upon impact.

All noise ceased after a tiger was darted. We waited for a timed period of at least 5 minutes to allow the drug to take effect and to reorganize our crew for the search. It was determined that 3-5 minutes were required for the drug to immobilize a tiger.

The first animal darted on this project, perhaps the first tiger immobilized in the wild, was an adult female captured on December 18, 1973 and tattooed as no. 101 in the ear. She was not taken in a ring drive. Rather I darted her from a tree as she moved away from her natural kill, a hog-deer. She came toward me when my elephant driver moved his mount so as to circle and approach her from the opposite direction.

Tigers were located after darting by following their trails and tracks. Once immobilization was certain, the tiger was moved to the shade, placed on its side and eyes covered with a piece of cloth to prevent damage by sunlight. The animal then was weighed, photographed, standard measurements taken, a serial number tattooed within each ear, and fitted with a radio-collar. In addition, ectoparasites were collected and information on the individual's general condition and reaction to the drug was recorded. During this time, the elephants and their handlers remained nearby to drive away any rhino that might wander close before the tiger was fully recovered. Finally, the radio-collar was checked for satisfactory performance and all our crew moved away. The tiger was left alone in the shade while we kept watch from a tree to observe that the animal fully recovered and moved away.

Ungulates

Two methods were followed in the capture of ungulates. One was a procedure similar to that followed for tigers. Strips of white cloth were made into a "V" shaped fence using elephants to herd them, the enclosed deer were slowly driven in the desired direction for darting. The other was simply to make a slow and gradual approach and dart animals directly from elephant-back.

The drivers of elephants moved their elephants slowly, sidled the elephants so that the animals could watch the elephant's movements. They avoided a direct straight-line head-on approach. Most of the elephant drivers were excellent shikaris (hunting-guides) and knew the best way to approach deer and get within darting range without scaring them. Discreet approaches by riding elephants would not scare the ungulates as they were used to their presence. Signalling with his toes on the back of the elephant's ear, the driver could stop an elephant motionless for the purpose of shooting darts without uttering a vocal command.

Radio-Location System and Procedure

The radio-location system included a transmitter with its power supply and transmitting antennas, a receiver and a direction-finding antenna. For the first year, we used equipment in the 30 MHz frequency-range constructed by A. R. Johnson, Moscow, Idaho. For the rest of the study period, our equipment operated in the 164.000 to 165.000 MHz range and was supplied by the Bioelectronics Laboratory of the University of Minnesota, Minneapolis, Minnesota. Special permission was required in advance for frequency allocations and the operation of equipment. Permits were secured from the Ministry of Telecommunications, the Ministry of Home Affairs and the Ministry of Defense with endorsements from the Ministry of Forests, HMGN.

Radio Transmitter-collars

The transmitter units were constructed in the form of collars (Figure 7) and were made in sizes to fit the necks of the several study species. Two-stage transmitters emitting signals at 65-80 pulses per minute were used in all collars. Each unit transmitted on a different

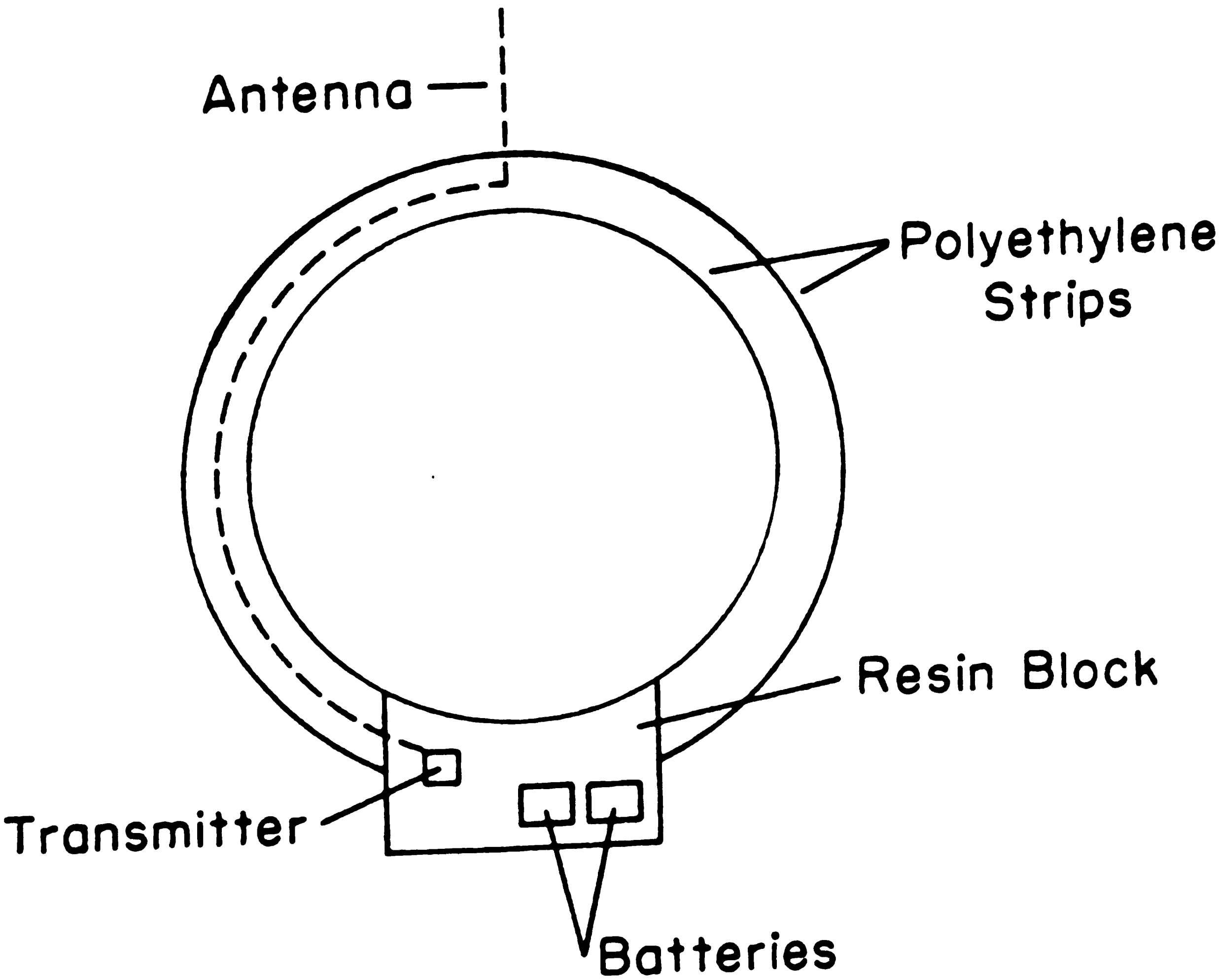


Figure 7. Radio-collar (Sunquist 1981).

frequency. A length of coaxial cable served as the transmitter-antenna. One or two 2.8 v lithium cells (Model 550, 660-4, Mallory Battery Company) connected in series provided the power supply. The radiated power of the transmitter was less than 1 mw, yielding an expected life of about 600 days. Current drain on the batteries averaged 5 ma.

Two polyethelene strips each 25-50 mm wide and 3 mm thick were riveted together to form the collar. The width of the polyethelene strip depended on the size of the animal species for which the collars were intended. The transmitter circuitry and batteries were enclosed in a waterproof electrical resin block and wrapped between the two strips. The coaxial antenna lay between the layers and emerged at the top of the collar with 15 cm protruding (Figure 7).

The negative ends of the transmitter and power supply wires were left exposed in a small opening in the resin block. Before the collar was placed on an animal's neck, these ends were soldered together, activating the transmitter. The small opening in the resin block then was filled with resin. The two ends of the collar were bolted together after the collar was adjusted to the proper neck size. The collar was then wrapped continuously and completely with plastic electrical tape. The finished collars weighed about 500 g for barking deer, 700 g for spotted deer and between 900-1200 g for tiger and sambar.

Receiver and Antenna

We used a frequency synthesizer-controlled receiver that operated in 1 KHz increments over a 1 MHz band (Sunquist 1979). Twelve internal 1.5v C-sized battery cells (Mallory Duracell, Model No. 1400) supplied power. The receiver measured 21 cm x 17 cm and weighed 1.8 kg. Telex Model 610-2000 headphones were attached to the receiver with a standard co-axial cable as was the four element hand-held yagi directional antenna (Cushcraft, Model A147-A). The antenna was tuned to 164.000 MHz.

Tracking Procedure

We attempted to maintain daily contact with each collared animal. A systematic search was made from elephants, vehicles and on foot, covering as much area as possible each morning and afternoon. Maintaining contact on a regular basis was easy for ungulates since their movements were limited. In the case of tigers, however, this was difficult since their travels covered large areas.

Once a signal was heard we moved towards the source until we reached the general area. The maximum aural signal was obtained by rotating the yagi antenna, thus indicating the direction of the collared animal. We determined the rather-precise location of the animal by circling it and obtaining a number of bearings or we used triangulation from known reference points. Tiger locations were plotted on 1:21000 scale aerial photographs of 1973. Other relevant information such as habitat type, date, time and evident activities was also recorded for each location. Visual contacts were made occasionally in the case of tigers but were possible more often in the case of the ungulates. After a tiger moved from its location, we returned to the site to determine whether the remains of a kill were present.

Most animal locations were obtained from elephant back. The position of the receiver at this (10-foot) height greatly improved the range of reception in comparison to the signal strength received while on foot. Reception was best in open grassland areas, poor in the sal forest and intermediate in the riverine forest type. Signal-strength varied also with seasonal changes in the density and height of vegetation. Reception ranges over 3 km in grassland but under 1 km in sal forest were usual.

The use of elephants had definite advantages over tracking from vehicles or on foot. Not only did the height of the elephant improve the range of reception but an elephant was able to move through dense vegetation and to cross streams and swamps. These "land-rovers" greatly facilitated locating collared animals in the dense cover and difficult terrain.

"Minimum Home Range"

Resident animals do not wander through an area at random but repeatedly traverse the same general area. The home range of an animal is the area it normally covers in its day-to-day travels. Burt (1943), Mohr (1947), Hayne (1949) and Calhoun et al. (1958) have written on the concept and calculation of home range. The "minimum home range" concept as described by Mohr (1947) was most suitable for this study. The area of a polygon formed by lines connecting the outermost radio-locations were considered to bound the home range of an individual animal.

Age Classification

Tigers were classified as cubs, sub-adults and adults. Tiger cubs are born blind. Their eyes open between 7 and 14 days after birth, but the animals remain very short-sighted for several weeks (Perry 1964). The incisor milk teeth are replaced at about six months of age. Canine teeth are replaced by permanent ones after 12 to 15 months. Tigers less than 15 months of age were classified as cubs. They were less than 100 kg in weight, less than 250 cm in total length and dependent on their mothers. Sub-adult tigers were 15 to 30 months of age and semi-independent of their mothers. They had permanent canines, were almost the size of adults. Sexually mature full-grown independent animals were classified as adults (see sexual maturity).

Ungulates were observed from elephants, vehicles, machans (platforms in trees) and also along trails. They were tallied by species, sex, herd size and according to the type of vegetation occupied. Using binoculars, specimens were classified as young, yearlings, or adults, using the criteria of Schaller (1967). Precise age classification for the young and yearlings was difficult because of the prolonged birth season. Schaller used January 1 as the dividing line in separating the two age classes: young born during the first half of the year were recorded as yearlings, but those born between July and December were considered still to be young. The age of young ungulates was estimated on the basis of comparative size. Bucks were considered to be yearlings until they lost their spikes at 18 to 24 months of age. Herd composition counts throughout the study period were used to determine average herd size, herd composition and sex and age ratios.

Ungulate Density

Vegetation remained dense and visibility was poor in all forest types both during monsoon (June to September) and post-monsoon (October to December) seasons. In both grassland and riverine forest types grasses were tall, growing to 5 m or more in height. In sal forests, densities and heights of grasses and shrubs varied greatly depending upon the density and age of sal and trees of associated species. Direct observations of ungulates to estimate their abundance was impossible most of the year.

The burning of vegetation throughout the entire park was an annual occurrence and was of human origin. The grasslands were burned in January and February while riverine and sal forests were fired in February, March and April. Overall visibility was best in March and April, even though the grasses began growing soon after being burned. The March-April season, therefore, was the only time when animal counts were feasible.

Poor visibility combined with the lack of roads and trails made it impractical to census animals from foot or vehicles. Riding elephants were the best and, indeed, the only useful transportation available. Trained domestic elephants have been used successfully in Nepal for hunting, for forestry works and in wildlife studies (Smythies 1942; Gee 1959, 1963; Spillet and Tamang 1967). Wild elephants, domesticated government- and privately-owned elephants have been present in the park area for a very long time. As indicated, wild ungulates were used to the presence of elephants and not much disturbed by them.

A line transect method as described by Eberhardt (1968) was used in the estimation of ungulate densities. Line transect methods have been applied to studies of lizard (Eberhardt 1978a), grouse (Gates _et al_. 1968), deer (Kelker

1945), African ungulate (Hemingway 1971), whale (Doi 1970) and other populations. Recent works on this method by Anderson et al. (1978, 1979), Burnham et al. (1976, 1980), Crain et al. (1978), Eberhardt (1978a, 1978b), Gates (1969, 1979), Rao et al. (1980) and Seber (1973) provide an insight into its usefulness and wide applicability to various animal species under different environmental conditions.

Several (replicate) random transect lines were established and traversed in all vegetation types. These lines were marked and their lengths estimated from 1:21,000 aerial photographs. Animal counts were made with four observers on the back of an elephant with all persons contributing to the total count. For all animals on either side of the line, one observer recorded the estimated perpendicular distances from the transect lines to where animals were first seen.

The line transect method in its simplest form involves an observer traversing in a straight line for some distance across the population's habitat over non-intersecting and non-overlapping lines. The observer keeps track of the number of animals sighted, recording either perpendicular distance from the transect line, or actual sighting distance and sighting angle, or both. This technique in its various forms seems to be most useful for populations in which animals are seen only when they are disturbed (Seber 1973). It is usually acknowledged that all subjects potentially detectable from the transect line will not be seen, that some subjects will be missed and that the farther the subject is from the line the greater is the probability that it will be missed (Burnham _et_ _al_. 1980).

An important factor that may influence animal-observations and hence the population estimation, is variability in the spatial arrangement of the subjects. Variability in population estimates is least for regular distributions (uniformly spaced) and greatest for aggregated (clumped) spatial distributions. If the transect lines are randomly located it is not necessary to assume that subjects are either randomly or independently distributed throughout the area (Eberhardt 1978a).

The confidence limits of a population estimate are proportional to the square root of the number of animals actually counted on the survey (Eberhardt 1968). Hence, it is highly desirable that all animals seen on transect (indefinite width) lines be recorded. The greater the number of animals counted on strips of indefinite width, therefore, the greater the added precision of an estimate. Similarly, large counts along transects of fixed width reduce experimental error (Caughley 1977). Transects of indefinite width are generally more appropriate for animals at low densities (Caughley 1977).

Eberhardt (1968) used three assumptions, Burnham _et_ _al_. (1980) named four and Seber (1973) recognized seven which underlie the transect sampling process. The four most important of these are:

(1) Animals directly on the transect line (0 distance) will never be missed, mathematically expressed as $g(0)=1$ (seen with probability 1). The function $g(x)$ defines the detection probability of the subjects as a function of their distance (x) from the line.

(2) When sighted, each animal is seen at the position it occupied when startled by the observer's approach.

(3) No animal is counted more than once on a given transect line.

(4) The sighting of one animal is independent of the sightings of another.

All animals may be sighted for a limited distance from the transect line, after which the probability of sighting drops off quite sharply and then gradually tapers to zero. Mathematical complications occur if an attempt is made to derive a curve. Eberhardt (1968) suggested a simple flexible curve to fit an array of possible choices.

The probability that an animal is sighted at distance x is $P_x = 1 - \left(\frac{x}{W}\right)^k$

where P_x is the probability of seeing an animal at distance x, W is the maximum distance at which an animal can be seen and the constant k describes the shape of the curve.

Assuming that all animals are sighted to a distance W and none were sighted beyond, it yields the "intensity function" shown by curve (1) Figure 8 (Eberhardt 1968). If it is assumed that indefinitely long distances are possible, which does not require an outer bound, it results in curve (2) (Gates _et al_. 1968). When k=1 the relation is a straight line, (curve 3), k>1 the form of the curve is convex (curve 4) and k<1 the curve is concave (curve 5, Figure 8).

The constants k and W are estimated from the regression of $\log(1 - P_x)$ on log x for all intervals other than the first. The regression constants a and b estimate -k log W and k respectively.

$$Y = a + bX$$

where $Y = \log(1 - P_x)$, $a = -k \log W$, $b = k$

and $X = \log x$

$$a = \bar{Y} - b\bar{X} \quad \text{and} \quad b = \frac{\Sigma xy}{\Sigma x^2}$$

The values of k and W thus estimated will generate a curve closely tracking the observed decline of sightings with distance (Figure 9) (Caughley 1977). After fitting the curve in this manner, density estimates can be made using Eberhardt's (1968) model.

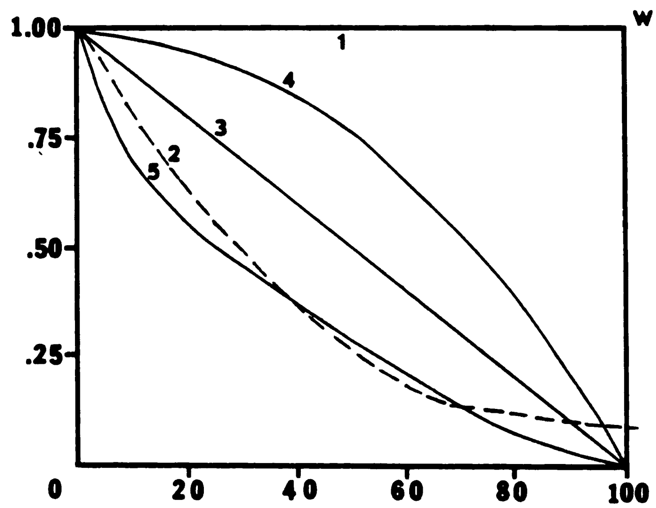


Figure 8. "Flushing intensity" curves (Eberhardt 1968).

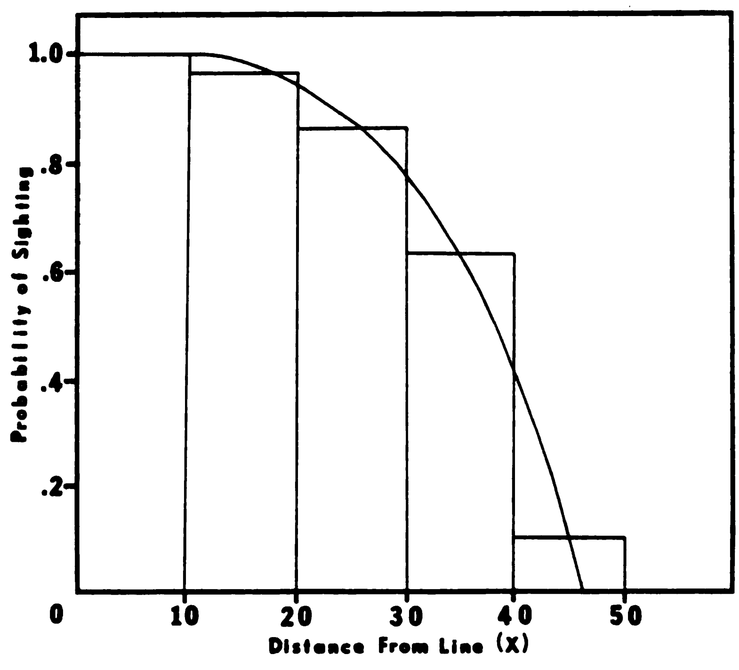


Figure 9. Probability of seeing an animal at varying distances from transect line (Caughley 1977).

TIGER

The tiger's color and stripes, while sitting motionless or during stealthy approach, help in achieving concealment and avoiding detection. The black markings overlaid on the white hair area of the cheeks and above each eye are different and distinct between animals. They seem to provide reliable identification marks for individual tigers.

Sexual dimorphism is quite pronounced in tigers. Males are significantly heavier and longer than females and the male has a thick ruff of hair around its neck. Fully adult males also are much fewer in number than females.

Of the two adult males that I darted, one weighed 200 kg. The other was over 227 kg (500 lbs) but its exact weight could not be determined since the only scale available weighed only up to 500 lbs. The total length of the smaller male was 292 cm (9'7") while the larger measured 310 cm (10'2"). All length measurements were made from the tip of the nose to the tip of the tail and followed the curves along the back. Tail measurements were 107 and 113 cm, respectively, for these males. Neck girths were 75 and 80 cm, and chest measurements were 127 and 140 cm, respectively. The exposed portions of the upper canines were 5.7 and 6.5 cm long (measured from the gum line) while the lower canines were 1 cm shorter.

Six adult tigresses weighed between 116 kg (255 lbs.) and 164 kg (360 lbs.) and averaged 143 kg (315 lbs.). The total length of these six adult females varied between 251 cm (8'3") and 282 cm (9'3") and averaged 267 cm (8'9"). The average tail length was 93 cm. Neck girth averaged 63 cm and they measured 108 cm as a mean around the chest.

Two sub-adults, male and female of the same litter were captured when approximately 18 months old. The male weighed 159 kg and measured 289 cm in length; the female weighed 114 kg and measured 251 cm. When about 9 months of age, this female weighed 52 kg. At 30 months as an adult, its weight was 129 kg.

Immobilizing Drug and Dosages

Using the Parke-Davis drug CI-744 (Beck 1972, Parke-Davis 1974, Seidensticker et al. 1974), initial drug dosages ranged between 2.5 and 7.7 mg/kg and averaged 4.15 mg/kg of body weight (Table 5). Additional drug dosages were often necessary to calm the tiger for safe handling. These were administered by hand syringe.

Usually it was not possible to observe the animal immediately after darting because of dense vegetation and the distance travelled. In three instances, however, such observations were made.

On the morning of December 31, 1975 an adult male tiger (No. 105) turned around after I darted and ran towards the drivers. From my tree after 2.5 minutes, I saw the tiger reappear. It slowly staggered out of brush and grass moving towards me following an evident animal trail. He was walking with effort, went down at 3 minutes and got up and went down three more times before becoming recumbent at 4 minutes. The dosage of the drug for this tiger was 4 mg/kg of body weight.

On the afternoons of May 11, 1976 and May 14, 1976 I darted two adult female tigers, (Nos. 101 and 106, respectively). Each individual moved between 5-10 m into a burnt-grass area after being darted. There each could be observed from my tree. The tigers were recumbent in 3 minutes with drug dosages of 3.95 and 4.26 mg/kg. On both of these occasions, the afternoons were rather hot with temperatures of 33°C (92°F).

The darting distance for tigers averaged 21 m (N=17). It took an average of 24 minutes and a maximum of 65 minutes to find the animals. The average distance travelled after being darted was 128 m, with a maximum of 450 m. Minimum distances travelled were on the above two occasions in May 1976 and may have been due to the high afternoon temperatures.

There was no antidote for this drug and the slow and gradual recovery took several hours (Table 5). The mean recovery period was 5.4 hours and ranged from 3.5 to 8.0 hours.

One female tiger (No. 108) died seven hours after darting. The initial dose of 5.17 mg/kg was high but not unusually high and no additional injection was given. She was, however, in poor physical condition, weighing only 116 kg. An autopsy was performed and revealed infected fractured carpal and metacarpal bones in one forelimb and a gangrenous area on one hip. Her emaciated condition, the high ambient temperature of the day and anaesthetic hyperthermia may have contributed to her death.

There was no evidence to suggest any adverse effects on tigers as a result of darting and handling. In six instances the tiger returned the same evening to feed on its kill. In four cases the tiger killed a new bait the same day. One tigress returned to her cubs after recovery and brought them to feed on the kill remains. Subsequent radio-tracking showed no short- or long-term shifts in the utilization of any home ranges.

Population Dynamics

Population Size and Composition

Various attempts were made to estimate the tiger population of the park. Sunquist (1979) estimated a total of 32 tigers for early 1976: 2-3 resident males, 12 resident females, 4 sub adults, 10 cubs and 3 transients. The park was, however, extended in 1976 and the total area included within the park increased from 540 to 910 km^2.

My own estimate for May 1977 was 5 adult males, 16 adult females and 9 sub adults of both sexes for the whole park including the eastern and western extensions (Tamang 1979). These 21 adult tigers were distributed as 1 adult male and 4 adult females in the eastern extension; 1 adult male and 3 adult females in the western extension, and 3 adult males (2 in the north and 1 in the south of Churia Range) plus 9 adult females in the initial park area.

These are rather conservative estimates based on collared and known tigers in the study area and on preliminary reconnaissances of pug marks which I carried out with our <u>shikari</u> staff in the eastern and western extensions during November/December 1976. Although the number of cubs could not be determined for the May 1977 estimate, there were at least 8 cubs with 3 of the radio-collared female tigers in the northern section of the park: tigress no. 101 had 2 cubs born December 1976; no. 103 had 3 cubs born October 1976; and no. 109 had 3 cubs born December 1976. A later census by J. L. D. Smith in April 1978 based on known tigers plus a track count estimated 6 adult males, and 20 adult females.

In all estimates, the female to male ratio among adult tigers was between 3:1 and 4:1. An unbalanced adult sex ratio seems to be the norm and typical of tiger populations everywhere as reported by Perry (1964), Schaller (1967), Sankhala (1977) and Panwar (1979).

Past hunting records from India and Nepal, however, indicate that more males were shot than females (Schaller 1967, Prater 1971). Males may be bolder and less cautious than females (Perry 1964). Probably more important, however, is that males have larger home ranges and territories and wander more widely (see beyond). Females, with much smaller home ranges, may be restricted most of their breeding lives by raising cubs.

The sex ratio at birth in various zoological gardens (N=196) and from fetuses in tigresses shot (N=25), however, was 1:1 (Schaller 1967). The equal sex ratio in the young and a preponderance of females in the adult population may be indicative of a high mortality of males at predispersal and dispersal stages. Panwar (1979) based on observations in Kanha National Park, India, has suggested that a disproportionate adult sex ratio in favor of females is true only in the core area of the national park, where breeding tigers are at a maximum and prey density is relatively high. He states that there is preponderance of adult males (2:1 - 3:1 sex ratio in favor of males) in buffer-zone areas surrounding the core and outside of the national park. There, he says, wild-prey density is low to medium, grazing disturbance by domestic cattle is high and breeding tigers are few.

Reproduction

The precise age at which wild tigers are sexually mature and capable of mating is not known. Copulation has been reported at 2.5 years in some captive tigers (Baudy in Schaller 1967). One tigress is said to have had its first litter of cubs at 2 years of age at the Whipsnade zoo (Pocock 1939). Crandall (1964) mentions that a tigress in the New York zoo reached sexual maturity at 3 years 8 months. Chowdhury (1976) reports that the first peak estrus of Khairi, a captive tigress was at 22 months.

In this study, the onset of first estrus was noticed at age 28 months in tigress no. 103. Heat periods seemed to be indicated by distinct roarings and an association with an adult male. It is difficult to determine estrus condition based entirely on either vocalization or association alone since resident males were observed associating with resident females at other times and at kills.

The roarings and associations of no. 103 were observed on October 18-19, November 12-18, December 3-8, December 28-31, 1975 and at intervals to April 1976. At the beginning of the period, she roared at night. After two to three days, however, she roared day and night. The frequency of roarings reached a peak on the third to the fourth day when roaring was almost continuous and as many as 55-69 times in fifteen minutes. Roars could be heard in the daytime clearly from a distance of 3 km. Pug marks indicated her association with the resident male of the area on each of these occasions.

Various intervals between estrus cycles have been recorded for tigers in zoos: 45-55 days (Schaller 1967) and 49 days (range 34-61) (Sankhala 1977). As judged from the continuous roaring and simultaneous associations with an adult male by tigress no. 103 in her initial estrus, the average interval was 24 days (range 21-27).

The length of time tigresses in estrus remain receptive has been reported to average 5-7 days (Schaller 1967) and 6.3 days (Sankhala 1977).

Very close to Jarneli Guard Post at Chitawan, a tigress remained in association with an adult male throughout the period February 18-24, 1974. Both were heard roaring day and night by our staff and park guards and were seen together several times during this period. I darted the male (102) in a drive organized on the morning of February 20, 1974. Three minutes after the male was darted, the tigress followed the trail of the male and came out in the open short grass area. The tagged tiger (102) was darted at 9:47 a.m. and moved away fully recovered at 3:45 p.m. While the tiger remained immobilized recovering from the effects of the drug and we were keeping watch on him, the tigress evidently moved in a semicircle at about 400 m distance around us. At best, this distance and extent of movement was indicated by her roarings between 2 and 3 p.m. On checking the kill in the afternoon, we found that the tigress had returned to the kill while we were with the male tiger, moved it 20 m and ate some.

Tigress 103 was in estrus and associated with the resident male again December 7-8, 1975. The pug marks on the morning of December 9 indicated that the male had left, crossed the Rapti River and moved westward away from the area. On the evening of December 9 at our base camp at Sauraha, we listened to roarings of tigress 103 less than a kilometer away. My staff assistant, Prem Bahadur Rai, who was good at imitating a tiger's roar, called from a corner hut. Tigress 103 responded immediately by answering his calls, moved rapidly crossing two streams until her call was within 50 m of our hut. It was too close for comfort and I asked him to stop calling. A little while later she got into a minor scuffle with and chased away a male leopard that was on a goat bait killed close to our camp. For several hours each night tigress 103 was within 200 m of our camp on December 9 and 10.

Wild tigresses with cubs evidently are in anestrous condition until the latter become independent. When tigress 101 lost her cubs, however, she came into heat in three weeks.

The age at which a male becomes sexually mature remains uncertain. A known-age male tiger (no. 104) from the same litter as tigress 103, separated from his litter mate and their mother at 18 months of age and became independent. The female sibling (103) remained in the vicinity of their mother. It associated with the resident male at 28 months of age and was then judged to be sexually mature. The male (tiger 104) dispersed well outside of its mother's territory at 30 months of age and could have been sexually mature at that time. It was not found again. Mohan, a male tiger cub captured with its mother after she was shot at Rewa, India, in May 1951, was bred with a tigress which gave birth to a litter of 2 cubs in September 1953 (Sankhala 1977). Mohan must have been less than 3 years when he mated successfully in June 1953.

From observations in the wild, no definitive courtship and mating season for tigers can be established. Sankhala (1977) suggests two peak seasons for mating, a major one in winter (December to early March) and a minor one in summer (March to June). According to Perry (1964) mating may occur at any time of the year but is perhaps more often in winter and spring. Schaller (1967) indicates that November to February is the peak mating season with some pairings occurring throughout the year. Panwar (1979) reports that there is no fixed season for courtship and mating.

From my observations in the Birgunj-Bagmati forests, Nepal (1966-1968), in Chitawan (1969-1970) and in this study (1973-1977), the intense roarings of mating tigers were most prevalent from October to March.

The gestation period for tigers has been given as 100-108 days (Crandall 1964), 98-112 days (Perry 1964), 105-112 days (Stracey 1968, Prater 1971) and 96-110 days (Sankhala 1977). An average of the medians of these ranges is 105 days. Based on 8 known litters born during this study and extrapolating the conception times, 14 of 15 matings must have occurred from September through April.

In this study, tigress no. 101 had 4 litters over a period of 42 months. She had her first litter about June 1973. Only one of each sex survived of this litter. The second litter was born April 4, 1975, about 22 months after the first litter. This litter of three male cubs perished in a grass fire on April 15, 1975. The third litter was born December 14, 1975, but evidently did not survive more than a few months since she was observed without cubs between March and May 1976. The fourth litter was born in December 1976, 42 months after the first successful litter. Two males survived of this litter.

Despite the ill-fortunes of no. 101, the reproductive potential of the tiger population of Chitawan National Park was high. Three radio-collared tigresses had litters totalling 8 cubs in the northeastern section of the park in early 1977 (Tamang 1979) and later that year 4 known females had 11 cubs in 4 litters in the northwestern section (Smith 1978).

A wild tigress remains confined with the cubs for several days after giving birth. It is almost impossible to know the litter size immediately after parturition. The litter killed in the grass fire at 11 days of age consisted of three male cubs. Seven litters seen on the study area in 1977 averaged 2.7 cubs. Although litter size apparently varies between 1 and 6 (Perry 1964, Schaller 1967, Sankhala 1977, Panwar 1979), 2-3 seems to be the usual number of cubs seen with tigresses. I watched a female with 4 cubs on a kill for two nights in Chitawan on December 30, 1969. Schaller (1967) and Panwar (1979) each mention a tigress with 4 cubs in Kanha National Park, India. For tigers in captivity, Schaller (1967) reported an average of 2.8 cubs (N=79 litters) and Sankhala (1977) 2.9 cubs (N=55 litters).

The maximum life expectancy for wild tigers is not known. Under zoo conditions, tigers have been reported to have lived for 19 years (Crandall 1964), 20 years (Schaller 1967) and 19-20 years (Sankhala 1977). A total of six litters could be produced in a life time if a tigress reaches sexual maturity and produces her first litter at 3 years of age, produced a litter every two years until the maximum reproductive age is reached at 15 years. Assuming an average litter size of 2.5 (2-3) cubs, 15 cubs could be produced by such a female in her lifetime. Under the conditions that prevailed in

Chitawan, which may be considered to be close to optimum under the present circumstances, perhaps half this number would survive to become adults.

Mortality

The extent of both prenatal and postnatal mortality among tiger cubs is believed to be high. Although there are some instances of females with 4 cubs, it is usual to see a tigress accompanied by 2-3 cubs. Since the exact litter size at parturition remains unknown it is difficult to determine cub mortality at early stages or mortality rate. In Chitawan among the many possible causes of tiger mortality, the poisoning of tiger-killed livestock carcasses by villagers in areas adjacent to park boundaries perhaps should be treated as the most important one. Confrontations with other tigers, fires, floods, and accidents also certainly take their toll.

A total of eight tigers was recorded dead in Chitawan between 1975 and early 1977. Park guards found a dead adult tigress at Surung in the northwestern end of the park during February 1975. According to the report received there were no external injuries and the cause of the death was unknown. Three cubs died in a fire on April 15, 1975, as reported above. An emaciated sub-adult male tiger entered Khoria Mohan park quarters where it died the next day, July 6, 1975. It was disabled by a porcupine quill imbedded in its shoulder and causing death by starvation.

Signals from the collar transmitter revealed the death of a collared adult tigress (no. 106) north of Jarneli guard post on July 23, 1976. The remains of an adult male collared tiger (no. 102) were found in February 1977 adjacent to Dhruba guard post. On January 8, 1977, a sub adult male was found dead at Bangain, close to the Narayani River, on the western boundary of the park. The evidence gathered indicated that each of these three tigers had died from eating villager-poisoned livestock carcasses. All three locations were on the periphery of the park and in areas subjected to intensive cattle grazing and frequent livestock-killing by tigers.

In February 1966, an adult male tiger was killed in a fight with a large wild boar close to Bhimile guard post (J. V. Coapman, pers. comm.). The encounter was heard by guards at the post during the night and the dead tiger was discovered in the morning. In another case, at Surung in January 1967 (P. B. Rai, pers. comm.), an intruding adult male tiger attacked and killed two of three male cubs while they were feeding on a bait with their mother. This incident occurred while park visitors were observing animals from a blind 50 m away. Another natural danger was indicated when three two-week old cubs drowned in a monsoon flood on July 16, 1978 (T. M. Maskey, pers. comm.).

Home Ranges and Territories

We tried to maintain daily contact with collared animals. Since tigers ranged over wide areas this was not always possible on a regular basis. Locations were plotted on aerial photographs and records maintained of the distances individual animals travelled between consecutive relocations. Altogether eight tigers were collared and radio-tracked for various lengths of time between December 1974 and May 1977 (Table 3; Figure 10). In addition, tigress 101, collared on December 18, 1973, was tracked until March 1974. She had 2 cubs, one male and one female, during this period. These were captured and radio-tracked as sub-adults, 104 (male) and 103 (female) respectively. Tiger 104 dispersed, moving off the area at 30 months of age. We were unable to locate him as an adult. Tigress 103, however, remained in the vicinity and was tracked as a sub-adult and then as an adult.

Of the eight tigers collared and radio-tracked seven were residents, having established home ranges: two males and five females (including tigress 103 that became resident after attaining adulthood). At least five transient tigers were encountered during the study period but none were captured or collared.

The home range sizes of resident males were much larger than those of the resident females. Based on its 147

Table 3. Yearly number of days located and minimum home range size of tigers

Tiger Number	Age/Sex	1975		1976		1977	
		Days located	Home Range (Km^2)	Days located	Home Range (Km^2)	Days located	Home Range (Km^2)
101	adult F	183	20	43	18	19	11*
102	adult M			12	52		
103	sub-adult F	156	23				
103	adult F			82	17	44	13*
104	sub-adult M	155	48				
105	adult M	83	48	35	62	29	62
106**	adult F	42	19	107	15*		
107	adult F			13	5*	15	20
109	adult F					31	12*

* With young cubs

**Died in July, 1976

Figure 10. Periods over which tigers were radio-tracked.

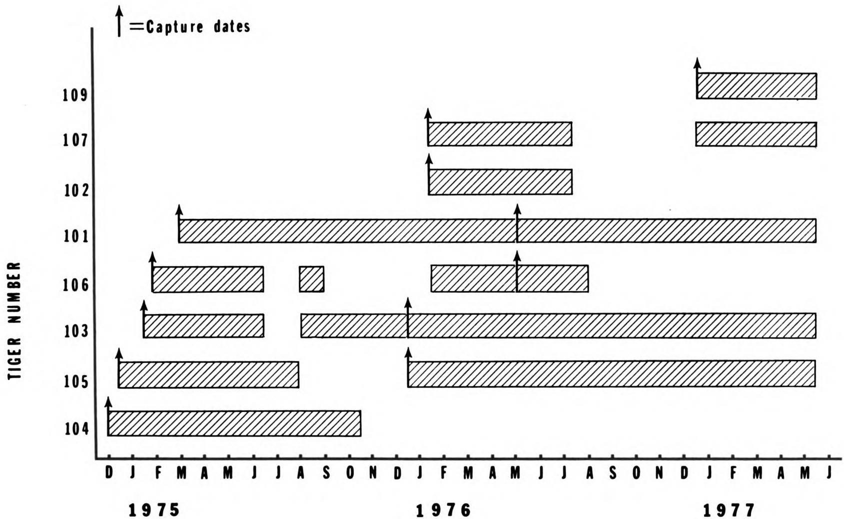

=Capture dates
TIGER NUMBER
109
107
102
101
106
103
105
104
D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
1975
1976
1977

Figure 10.

location/days, the home range of resident male 105 was estimated to be 62 km^2 (Table 3). The home range of resident male 102 was estimated at 52 km^2. Tiger 102 died sometime in the latter part of 1976, 105 moved in to occupy the area of the dead male 102. It expanded its home range to include both its original range and the newly available one.

Sub-adult male tiger 104 was captured and radio-collared in December 1974 at about 18 months of age. It used an area of 20 km^2 during December 1974 and January 1975, with its mother 101. By April 1975, tiger 104 ranged over an area of 33 km^2. At the time of its dispersal December 1975, at 30 months of age, it was covering a total area of 48 km^2.

The resident tigresses occupied much smaller areas with home range sizes averaging about 20 km^2. Those ranges fluctuated evidently depending upon the age and mobility of their cubs. Between December 1973 and February 1974, resident female 101 and her two 6-month cubs ranged over an area of 6-10 km^2. In March 1975, the same tigress covered an area of 20 km^2 with its two semi-independent 21-month old offspring. One of these sub-adults, female 103, traversed the same 20 km^2 area as her mother 101, at the same time that her litter-mate, male 104, covered an area of 33 km^2.

On October 26, 1976, tigress 103 dropped her first litter of cubs at the same location where her mother 101 had her last two litters (April 4, 1975 and December 14, 1975). While with her newborn cubs, female 103 remained confined within a one km^2 area of her cubs between October 26 and November 12, 1976. She gradually expanded her home range as the cubs grew older and took over the home range of her mother 101. Similar reductions in the home range sizes of females with cubs were observed in the cases of collared tigresses 106, 107 and 109 (Table 3).

Tigress 103 after becoming sexually mature in late 1975 remained in the area and established herself in her mother's home range in 1976 and early 1977. This happened while female 101 was confined to a corner of her range with a new litter born December 14, 1975 and which survived only for about three months. After that, female 101 shifted its range and established itself adjacent to her daughter 103. Panwar (1979) mentioned a similar occurrence where a tigress established itself in her mother's home range in Kanha National Park, India.

The home ranges of resident tigers remained relatively stable during the study period. The combined ranges of several resident females formed the home range of a resident male. There were no overlaps in the occupation of home ranges by individuals of the same sex at the same time.

The home range in fact, represented the territory of the resident tiger and was exclusively used by the resident.

Two instances of confrontation in defense of their territories by resident tigers were observed. Roarings of fighting tigers were heard close to our Jarneli camp on the night of May 9, 1976. I recaptured both females 101 and 106 on May 11 and 14, 1976, respectively, at Jarneli camp. They were less than one kilometer from each other and inside female 106's territory. Scratches and injuries on the bodies of the captured females and two deep canine wounds on the neck of female 106 were judged to be evidence of the confrontation that had taken place on May 9. This incursion of female 101 into resident tigress 106's territory, however, proved to be a temporary foray. Based on the radio-locations after her recapture and change of collar female 101 returned to her original home range. This intrusion of one resident tigress into another resident female's area may have been caused by female 101's then estrous condition and association with the resident male 105 following the loss of cubs about two months earlier.

The second instance of an encounter took place on the afternoon of December 30, 1976 between female 103 and an unknown tiger. Female 103 had made a buffalo kill on December 28 about three kilometers away from her cubs (born October 26, 1976). She visited the kill in the evening and returned to her cubs during the night. A new set of pug marks on the morning of December 30 indicated presence of an unidentified tigress in the area.

While a buffalo bait was being tied nearby in the afternoon, a furious fight broke out about 100 m away between two tigers. The fight occurred with loud roars and growls close to female 103's kill and lasted about five minutes. The next morning the bait was found to have been dragged away. A drive was arranged in an attempt to capture this new animal. Although we were unable to dart it, the new tiger was identified as a female and observed at close range. It had scratch marks on its sides and blood was found on the grass and bushes at the place of encounter. Panwar (1979) has reported fights between two males on one occasion and two females on another in Kanha National Park, India.

In summary, the size of the tiger population in the Royal Chitawan National Park was fairly stable during the study period. The reproductive rate of the population was high. Mortality occurred in cubs, and the poisoning of tiger-decimated livestock carcasses by villagers in areas adjacent to park boundaries killed some adults. Intraspecific competition, including combats between individuals, seems to be the factor limiting tiger density.

THE UNGULATES (HOOFED ANIMALS), PRINCIPAL PREY OF THE TIGER

The welfare of the tiger population is dependent on maintenance of its habitat, including the prey species. The role of the tiger in its ecosystem can be assessed properly only with a parallel determination of the status and characteristic of the prey populations.

In the Royal Chitawan National Park, sambar, chital (spotted deer), hog deer, barking deer (muntjac) and wild boars were fairly abundant and comprised the principal prey species of the tiger (Table 13). Young sloth bears and rhino calves were killed occasionally by tigers.

Gaur were few in number during the study period and were not preyed upon. Diseases transmitted from domestic cattle reportedly (Ram Lotan pers. comm.) took a heavy toll of the gaur populations in 1972 and 1973. Records of tiger kills at Kanha and elsewhere in India (Shaller 1967, Sankhala 1977, Panwar 1979) indicate, however, that there is a potential for gaur to be important in the tiger diet.

Distribution and Description

Sambar

The sambar (*Cervus unicolor*) is a typical forest deer in south and southeast Asia. It is widely distributed and occurs in a variety of forest types. Of the 16 recognized subspecies (Ngampongsai 1977), C. u. niger occurs in Nepal, Bhutan and India. In Nepal, it inhabits the riverine and sal forests and savannas of the tropical moist deciduous forest type. It occurs also in the coniferous, oak and maple forests of the Himalayan temperate forest type to an altitude of 2000 m or more.

Adult sambars stand 120-148 cm at the shoulder and measure 210-254 cm in total length (Table 4). Antler lengths range from 53 to 71 cm. Hinds weigh an average of 175 kg. A selective bag of 8 sambar stags killed in 1976 on an area adjacent to Chitwan measured 137-156 cm ($\bar{X}$ = 143) at the shoulder and 201-259 cm ($\bar{X}$ = 241) in total length. They weighed 295-380 kg ($\bar{X}$ = 327) and antler lengths scaled 52-89 cm ($\bar{X}$ = 72).

The coloration is a uniform light- to dark-brown, being dark or almost black on old males. The hair is shaggy and coarse in texture. It forms a ruff around the neck and is larger and heavier in adult stags. Small fawns have a chestnut brown coat without spots. The hair is shed in hot weather (April/May) and a thick winter coat develops in October/November.

Sambar foods consist of grass, leaves and various kinds of wild fruits. This large deer is mainly nocturnal in habit, feeds at night, enters thick cover in early morning and usually does not come out till dusk. The sense of hearing

Table 4. Weights (kg) and measurements (cm) of deer from the Royal Chitawan National Park, Nepal 1974-1977.

			Weight (kgs)		Shoulder ht. (cms)		Total length (cms)		Tail length (cms)		Antler length (cms)		
Species	Sex	N	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Remark
Cervus unicolor	F	5	175	152-193	121	120-122	212	210-215	34	28-41			
	M	4	227+		133	124-148	244	230-254	36	30-45	65	53-71	
	M	8*	327	295-380	143	137-156	241	201-259			72	52-89	Hunting record 1976
Axis axis	F	3	56	50-61	81	79-82	164	158-169	28	28-29			
	M	5	84	61-93	90	85-96	179	170-185	30	26-35	76	69-85	
	M	28*	85	70-96	99	81-122	188	170-239			84	73-94	Hunting record 1976
Axis porcinus	F	3	36	34-39	64	62-66	137	133-139	25	24-27			
	M	3	43	39-47	66	64-69	140	138-141	26	22-27	35	35-36	
Muntiacus muntjak	F	2	20	20-21	55	53-58	122	121-124	17	17	-	-	
	M	2	22	21-23	64	60-68	126	125-127	19	19-20	7	7-8	

*shot on an adjacent area (see text)

and scent are very acute (Prater 1971). Its preference for thick cover, shy nature and alertness makes it one of the hardest animals to observe.

Chital

The chital (Axis axis), also called the spotted or axis deer, is considered the most beautiful of all cervids. It is widely distributed in southern Nepal, India and Sri Lanka. The chital and hog deer, both belong to the genus Axis, and are considered to be among the most primitive of the true cervids (Schaller 1967). Ellerman and Morrison-Scott (1966) have recognized two subspecies, A. a. axis occurring in Nepal and India, and A. a. ceylonensis in Sri Lanka. The chital inhabits and utilizes the forest, forest edge and savannas and ranges to an altitude of about 1000 m.

Adult chital stand 79-96 cm at the shoulder and range 158-185 cm in total length. Antler lengths measure 69-85 cm. Bucks weighed an average of 84 kg and adult does weighed 56 kg. Twenty-eight adult bucks killed in a hunt in 1976 on an adjacent area measured an average of 99 cm at the shoulder and 188 cm in total length. Antler lengths averaged 84 cm and weighed 85 kg (Table 4).

The coat is a bright rufous-fawn marked with white spots which are usually arranged in longitudinal rows. The spots are retained throughout the animals' life.

There is a dark dorsal stripe. The underparts, inner legs and undertail are white. Adult bucks are darker than does and have black facial markings.

Hog Deer

The hog deer (*Axis porcinus*), a close relative of the chital, is smaller and stouter in build. It is widely distributed in Nepal, northern India, Burma and Sri Lanka but is not found in central or southern (peninsular) India. It inhabits grasslands, often with shrubs and swamps. It avoids tree forests.

Adult hog deer stand 60-70 cm at the shoulder and measure 130-140 cm in total length. Bucks average 43 kg and does weigh 36 kg. Antlers scale 34-36 cm in length.

A deer darted and collared (no. 504) on April 14, 1976 was judged to be a cross between chital and hog deer. It stood 79 cm at the shoulder, measured 172 cm in total length, had 46 cm long antlers and weighed 68 kg. Its coat was reddish-brown with white spots but the spots were not as prominent as in chital. Interbreeding between the two species has also been observed at Gokarna forest, Kathmandu, Nepal, and elsewhere (Prater 1971).

Barking Deer (Muntjac)

The barking deer (*Muntiacus muntjak*) is a widely distributed species in Asia (Prater 1971). The subspecies found in Nepal, Bhutan and northern India is *M. m. vaginalis*.

Its coat is bright chestnut. Of the four deer species in the park, the barking deer is the smallest and weighs 20-23 kg.

Adults stand 53-68 cm at the shoulder and measure 120-103 cm in total length. The antlers are a short 7-8 cm and set on bony hair-covered pedicels that extend down each side of the forehead as bony ridges. The upper canines of the males are well developed and are distinctly visible from a distance.

They occur in a variety of habitat types to an altitude of 3000 m. They inhabit sal and riverine forests and are often seen on meadows. Unlike hog deer, they are not grassland animals.

Wild Boar

The wild boar (*Sus scrofa*) inhabits various forest types in subtropical and temperate regions to an altitude of 3000 m. In Chitawan it is found in sal and riverine forests and grasslands.

Young ones are brown with dark stripes. They lose their stripes in a few months and become dark brown and black as they get older. A few individuals weigh as much as 200 kg or more.

Wild boars are omnivorous. They raid crops in villages and cause quite substantial damages when their densities are high. They also feed on remains of tiger kills.

Drug Dosages

Twenty individual deer of four prey species - 7 sambar, 7 spotted deer, 4 hog deer and 2 barking deer - were immobilized with the Parke-Davis drug CI-744. No adverse reactions were observed but, surprisingly, the dosages required to immobilize ungulates were found to be considerably higher than those required for tigers. Initial doses of 7 - 20 mg/kg were found to be necessary for the hoofed animals in contrast to 4.15 mg/kg of body weight for tigers. Initial drug dosages averaged 7.3 mg/kg for sambar, 13 mg/kg for spotted deer, 20.6 mg/kg for hog deer and 18.6 mg/kg of body weight for barking deer (Table 5). Additional drugs were administered by hand syringe whenever necessary to keep the animals calm during study and tagging. The induction time for the drug (period for the drug to take effect) was approximately 5 minutes.

Population Characteristics

Herd Size and Composition

Herd sizes varied considerably with the season and availability of food, water and cover (Table 6).

Sambars were observed mostly as single individuals or as a hind with young or a hind with yearling. Associations of a stag with hinds occurred in November and December while mating. That the sambar is a typical forest

Table 5. Drug dosages of CI-744 and recovery time for mammals immobilized in the Royal Chitawan National Park, Nepal, 1973-1977.

Species	Number	Mean dosage mg/kg	Mean hours to recover
Tiger	17	4.15	5.4
Sambar	7	7.30	4.9
Spotted deer	7	13.00	3.3
Hog deer	4	20.60	6.0
Barking deer	2	18.60	4.0

Table 6. Relative abundance and herd sizes for large mammals, Royal Chitawan National Park, Nepal, 1975-1977.

Species	Number of herds	Average herd size	Herd sizes - %							
			1	2	3	4	5-10	11-20	21-30	31+
Axis axis	1268	6.1	17	20	13	11	24	11	3	1.5
A. porcinus	814	1.7	51	29	11	4	5	-	-	-
Cervus unicolor	509	1.5	63	26	9	2	4	-	-	-
Muntiacus muntjak	448	1.2	85	13	2	-	-	-	-	-
Sus scrofa	193	2.0	70	12	3	3	9	2	1	-
Bos gaurus	13	8.0	36	-	9	-	19	27	9	-
Rhinoceros unicornis	468	1.9	45	43	6	2	4	-	-	-

animal was indicated by 90 percent of observations being in riverine and sal forest (Table 7).

Chital gathered in large herds after grass areas were burned and new forage became plentiful. Average herd size for chital was six, with maxima of 100-200 animals in February, March and April. Two-hundred and ten animals were tallied in one herd on March 18, 1976 in a short grass meadow. From September to February when most of the chital bucks were in velvet, separate herds of bucks and of does with fawns were observed. Chital like sambar indicated a preference for riverine forests. Over 50 percent of their herds were observed in riverine forest and about 35 percent in grasslands (Table 7).

Eighty percent of the hog deer observed were as one or two individuals, with only a few larger herds occurring in open grasslands from February to April after burning. Hog deer are primarily grassland animals and were seldom seen in forests. Over 95 percent of the hog deer tallied were observed in grasslands and the rest in grassland and forest fringes (Table 7).

Barking deer are solitary animals with a rare association of more than two individuals. Females with young or a male with a female may be found together.

Wild boar populations were at an all-time low during the study period because of an epidemic in 1973-1974. Increased sightings in 1977 indicated it was recovering.

Table 7. Relative abundance of large mammal species by vegetation types. General observations. Royal Chitawan National Park, Nepal, 1975-1977.

Species	Riverine forest	Grassland	Sal forest
Axis axis	3556	2793	1157
Cervus unicolor	559	88	117
Rhinoceros unicornis	483	599	11
Muntiacus muntjak	422	44	74
Sus scrofa	202	157	42
Axis porcinus	41	1485	38
Bos gaurus	0	32	72
Totals	5263	5198	1511

Twelve percent of the total groups tallied were of 5 or more animals.

Sex and Age Composition

The adult sex ratio in all ungulate species was in favor of females (Table 8).

A pronounced disparity of the sexes was found in favor of females in the adult populations of chital, sambar, hog deer, barking deer, wild boar, rhino and gaur. A similar disproportion in sex ratios has been observed for these species also in studies elsewhere (Schaller 1967). An unequal sex ratio at birth, higher mortality in young males and selective predation on adult males may be reasons (Schaller 1967). A preference for males as prey of tigers was shown in this study (see beyond).

Gestation and Birth

The females keep their newborn young hidden for varying lengths of time before joining a herd. When fawns are observed with females in a herd, it gives only a relative idea of the births in any one month. Most chital fawns were born between January and March, the peak fawning period (Table 9). Some fawns were, however, seen every month of the year. The gestation period for chital is 7.5 months (Graf and Nichols 1966, Russ 1973).

Most sambar fawns were born in the rainy season, June to August. This agrees with the rutting season in November to December, since the gestation period is eight months (Kenneth et al. 1953). Some newborn fawns, however,

Table 8. Proportions of adult males and juveniles per 100 adult females for large mammals, Royal Chitawan National Park, Nepal, 1975-1977.

Species	Number	Adult male	:	Young
Axis axis	5915	54	:	48
A. porcinus	1378	40	:	25
Rhinoceros unicornis	806	46	:	60
Cervus unicolor	682	55	:	22
Muntiacus muntjak	517	78	:	13
Sus scrofa	377	93	:	180
Bos gaurus	124	57	:	48

Table 9. Proportions of adult males and juveniles per 100 adult chital at monthly intervals. Royal Chitawan National Park, Nepal, 1975-1977.

Month	Number	Adult Male	:	Young
January	712	74	:	39
February	1381	44	:	52
March	1831	65	:	71
April	895	63	:	61
May	486	62	:	55
June	285	48	:	66
July	280	37	:	34
August	347	57	:	16
September	186	34	:	20
October	280	34	:	16
November	650	45	:	23
December	305	66	:	22

were seen from February to May and also after the main fawning season.

Although hog deer fawns were observed every month of the year, the peak season was March to June. Barking deer appears to breed at all seasons. Most young were seen between May and July.

Wild boar in Chitawan paired in December-January and the young were born in April-May. The gestation period is said to be 3.5 to 4 months and four to six or more young are born in a litter.

The Rutting Season

Antler replacement occurs in an annual cycle for all four species of deer. Bucks shed their antlers yearly. Antlers are lost after the rut and are replaced by "velvet" antlers that develop to full size while covered with fur. These bony structures are said to "turn hard" when they shed the skin at the onset of the next rutting period. Not all bucks are in hard antlers at the onset of rut but most turn hard by the peak season.

Of the 2073 chital bucks seen clearly and classified, the proportion in hard antlers increased from nine percent in January/February, to 79 percent in March/April and 98 percent in May/June (Table 10). The peak rutting season for chital was between April and June.

Sambar males in hard antlers increased from 38 percent in July/August to 92 percent in November/December, their rutting time. Over 90 percent of hog deer males were in hard antlers for their rut in May/June (Table 10). Barking deer breed at all seasons but the main rut takes place in December/January, when about 75 percent of the bucks were in hard antlers.

Numerical and Biomass Density

Estimates of numerical and biomass density were determined from line-transect censuses (Table 11). Actual weights of local animals in Chitawan were used and these were adjusted with respect to percentages of sex and age classes.

Both in terms of numbers and biomass weights, chital were the most abundant of all large mammals in the park as a whole (Table 11). In sal forests, chital represented over 50 percent of ungulate number and biomass. Hog deer accounted for over half of all animals present and more than one-third of the biomass in the grassland-riverine forest vegetation type. Although only 2 to 3 individuals occurred per km^2, sambar ranked high in terms of biomass weight among ungulates in all vegetation types. Largely because of their invididual size, however, rhinoceroses yielded an estimated one-half of the total biomass in the grassland and riverine forest and nearly a fourth in the entire area.

Grassland and riverine forest was the most productive habitat with 5612 kg/km^2 biomass versus 1846 kg/km^2

Table 10. Percentages of male deer in hard antlers at bi-monthly intervals, Royal Chitawan National Park, Nepal, 1975-1977.

	Cervus unicolor		Axis axis		Axis porcinus		Muntiacus muntjak	
Months	Number males	Percent hard	Number males	Percent hard	Number males	Percent hard	Number males	Percent hard
Jan.-Feb.	78	99	539	9	125	31	76	78
Mar.-Apr.	83	98	798	79	172	22	63	90
May-Jun.	24	75	223	98	57	81	21	86
Jul.-Aug.	16	38	121	93	16	100	12	50
Sep.-Oct.	14	43	88	28	9	88	38	45
Nov.-Dec.	24	92	304	6	16	56	38	71

for sal forest (Table 11). The overall crude biomass estimate for the entire park was 2581 kg/km^2. This agrees closely with the biomass of 2362 - 2609 kg/km^2 estimated for the Keoladeo Ghana Sanctuary, Rajasthan, India where rhinos were absent (Schaller and Spillett 1966) but nilgai (*Boselaphus tragocamelus*) were more abundant.

Table 11. Numerical densities and biomass weights (kg) of ungulates per square kilometer, Royal Chitawan National Park, Nepal, 1977.

Species	Average* Weight (kg.)	Grassland and Riverine forest		Shorea (Sal) forest		Combined** Areas	
		Numbers	Weights	Numbers	Weights	Numbers	Weights
Axis axis	54	16.4	886	18.6	1004	16.8	907
Cervus unicolor	198	2.6	515	3.0	594	2.7	535
Axis porcinus	33	33.0	1089	-	-	7.9	261
Muntiacus montjak	17	5.4	92	7.7	131	6.6	112
Sus scrofa	45	5.4	216	2.6	117	2.9	131
Rhinoceros unicornis	1340	2.1	2814	-	-	.48	643
Totals		64.3	5612	31.9	1846	37.38	2589

*Population weights for Chitawan specimens adjusted with respect to percentages of sex and age classes.

**Park area 910 km^2: sal forest 637 km^2, grassland 150 km^2, riverine 60 km^2 and riverbeds and water 63 km^2.

Home Ranges

Altogether twenty deer, seven sambar, seven chital, four hog deer and two barking deer were darted. Of these nineteen were collared and radio-tracked for various periods (Table 12). Visual contacts were made more often in the case of tagged ungulates than was true for tigers. Their transmitted and sighted locations were plotted on the 1:21000 scale aerial photographs of 1973.

Ungulates ranged over relatively smaller areas than tigers. Their movements were influenced by daily and seasonal changes in the availability of food, cover and water. Agricultural crops in neighboring villages also influenced the movements of ungulates in peripheral areas.

All males covered larger areas than females. Wandering among males of all species was considerable, especially during the rut.

Of the seven radio-tracked sambar, four were males and three were females. Two of four marked stags were killed by tigers one fifteen days and the other ten months after being collared. None of the three hinds was known to be preyed upon. Home range sizes varied between 3.2 and 5.5 km^2 for these stags and between 1 and 2.8 km^2 for the hinds (Table 12).

Two chital males (nos. 401 and 402) collared in March and April 1975 moved from village forest at the periphery of the park to the interior during rut. They covered areas of 8 and 16 km^2, respectively. Home range sizes

Table 12. Number of days located and minimum home range size of ungulates. Royal Chitawan National Park, Nepal. 1975-1977.

Species	Serial number	Age/sex	Capture date	Days Located	Home Range km^2	Remarks
Cervus unicolor	301	Ad. M	1.16.75	12	3.2	Killed by tiger 1.30.75
	302	Ad. F	2. 6.75	462	1.0	Transmitter operated till 10.25.76
	303	Ad. M	2.25.75	228	3.2	Killed by tiger 12.11.75
	304	Ad. M	1.23.76	141	5.5	Died 11.29.76
	305	Ad. F	1.28.76	159	2.1	
	306	Ad. M	4. 7.76	88	3.6	
	307	Ad. F	4. 8.76	172	1.5	
Axis axis	401	Ad. M	3.14.75	42	8.0	Transmitter operated till 1.16.76
	402	Ad. M	4. 8.75	194	16.0	Died 3.1.76
	403	Ad. F	4. 9.75	456	2.5	
	404	Ad. M	1.21.76	259	3.0	
	405	Ad. M	4. 7.76	195	4.3	
	406	Ad. M	4. 8.76	194	3.5	
	407	Ad. F	4.15.76	200	2.2	
Axis porcinus	501	Ad. M	3.11.75	466	2.2	
	502	Sub.-Ad.M	4.11.75	-	-	Not collared
	503	Ad. F	4. 9.76	5		Transmitter malfunction.
	504	Ad. M	4.14.76	23	.5	Transmitter malfunction.
Muntiacus muntjak	601	Ad. F	2.28.75	10	.15	Died 3.18.75
	602	Ad. M	3.18.75	15	.23	Attacked by leopard 4.1.75. Died two days later.

of three other adult bucks ranged only from 3.0 to 4.3 km^2, while two does lived in areas of 2.2 to 2.5 km^2.

Of the three hog deer collared, two transmitters did not operate satisfactorly. One adult male was located on 466 days, however, and moved only within 2.2 km^2.

Of two radio-tagged barking deer, one female died after two weeks. The male collared on March 18, 1975 was attacked by a leopard on April 1, 1975 and died after two days. Data collected were inadequate for estimating home range sizes (Table 12).

In summary, grassland and riverine forest was the most productive habitat with 5612 kg/km^2 biomass versus 1846 kg/km^2 for sal forest. The overall crude biomass estimate for the entire park was 2581 kg/km^2. Both in terms of numbers and biomass weights, chital were the most abundant of all large mammals in the park as a whole. In sal forests, chital represented over 50 percent of ungulate number and biomass. Hog deer accounted for over half of all animals present and more than one-third of the biomass in the grassland/riverine forest vegetation type. Although only 2 to 3 individuals occurred per km^2, sambar ranked high in terms of biomass weight among ungulates in all vegetation types. Largely because of their individual size, however, rhinoceroses yielded an estimated one-half of the total biomass in the grassland and riverine forest and nearly a fourth in the entire area.

PREDATOR-PREY INTERACTIONS

Much of the tiger's activities revolve around its food supply (Schaller 1967). Tigers are mostly nocturnal and hunt their prey between dusk and dawn.

On the study area, tigers were most active when their prey also were actively feeding in late afternoon, night and early morning. During the hot part of the day, from mid-morning to mid-afternoon, they usually rested close to water.

Predators, like other animals, require food energy and must forage in such a way that the net rate of energy intake is maximized (Schoener 1971). The ease with which prey animals can be found, killed and consumed differ substantially for different prey species and in their nutritive value to the predator.

Benefits to the tiger should be greatest when the time required to obtain a required amount of food is minimized and the energy gained per unit time is maximized. Optimal foraging theory, in attempting to explain the many aspects of foraging behavior in animals (Emlen 1966; MacArthur et al. 1966; Schoener 1971; Westoby 1974; Charnov 1976a, 1976b; Pyke et al. 1977), assumes that the fitness of an animal's foraging behavior has been maximized by natural selection.

The degree to which the behavior of a predator will affect the abundance of its prey in the future depends in part on the degree to which the predator has exclusive use of an area. If an animal has such exclusive use, it could utilize its resources for sustained yields rather than maximize initial yields at the cost of poorer yields later (Charnov 1973, Charnov et al. 1976 in Pyke et al. 1977). This particularly could be true for the tiger which is harvesting a self-renewing resource.

After a tiger makes its kill, the kill is dragged into dense cover before eating. The distance dragged will depend on the proximity of the cover, the type of terrain and the degree of disturbance by humans or wild animals. First, one or both of the hindquarters are eaten. The viscera then are cleanly removed and the kill dragged again into another cover for further consumption. If the size of the prey permits it to last more than a night, the carcass may be covered with leaves and grass for concealment against daytime scavengers. Feeding is resumed the next evening. An adult sambar may last 3-5 days for one tiger and an adult chital 2 days. Except for skin and bones, all edible meat usually is devoured.

Tiger Kills

A total of 156 large-mammal tiger kills were found. Wild animals comprised about two-thirds and livestock the remainder. The largest percentage (27%) was sambar which together with hog deer, chital, wild boar, barking deer and rhino calves equalled 68 percent of the total. The claws and fur of a sloth bear (*Melursus ursinus*) also were collected from a tiger scat. Twenty-four domestic cows (*Bos taurus*) and twenty-five water buffalos (*Bubalis bubalis*) accounted for almost one-third (32%) of the natural kills. This "cattle lifting" was related to the exposure and close proximity of human habitations all along the Rapti River northern boundary of the park and along the Reu River in the south. Another reason for the large volume of livestock kills is that these were most likely to be found and reported.

The relative importance of various wild ungulates in the tiger diet and prey preference ratings (Petrides 1966, 1975) were determined by species and sex. Prey preference ratings are determined as the ratio between the kill percentage and the percentage abundance of prey.

In the order of total biomass consumed, sambar, chital, hog deer, wild boar and barking deer were the principal prey (Table 11). In the order that they evidently were preferred as prey by tigers, however, was sambar, hog deer, wild boar, barking deer and chital (Table 13). Among wild ungulates, the sambar is evidently highly sought-after as prey while hog deer rank the second. The other deer are not taken as often as their abundance would indicate.

Table 13. Prey preference ratings of wild ungulates in the Royal Chitawan National Park, Nepal, 1973-1977.

Species	Kills		Kills Percentage		Availability Number/km²		Availability Percentage		Prey Preference Ratings	
Sambar	42		39.3		2.7		6.8		5.78	
Male		20		18.7		.9		2.3		8.13
Female		22		20.6		1.3		4.5		4.58
Hog deer	24		22.4		7.9		19.9		1.13	
Male		7		6.5		2.1		5.3		1.23
Female		17		15.9		5.8		14.6		1.09
Wild boar	12		11.2		4.8		12.1		.92	
Male		7		6.5		2.3		5.8		1.12
Female		5		4.7		2.5		6.3		.75
Barking deer	8		7.5		5.4		13.6		.55	
Male		3		2.8		2.6		6.5		.43
Female		5		4.7		2.3		7.1		.66
Chital	19		17.8		16.8		42.3		.42	
Male		9		8.4		5.5		13.8		.61
Female		10		9.3		11.3		28.5		.33
Rhino (calves)	2		1.9		2.1		5.3		.36	
TOTALS	107				39.7					

The tiger's selection of sambar, the largest among wild ungulates and of the large domestic cattle and buffalos as prey agrees with the optimal foraging theory in terms of maximizing the net energy gained per unit time.

Among the wild ungulates killed by tigers, a comparison of kill percentages and availability by sex indicated males of sambar, chital and wild boars were sought out as victims of tiger predation in preference to females.

Food Consumption

The amounts of meat consumed per tiger were calculated in the field from the weights of buffalo baits and natural kills. These varied from 11 kg to a maximum of 34 kg in a day. These amounts varied according to the number of tigers associated with the kills and whether cubs were present.

The amounts of meat consumed by tigers while actually feeding in the wild and the actual amount reported to be needed on a sustained basis do not agree. Schaller (1967) assumed a requirement of 5.4 to 6.8 kg per day on a long-term basis at Kanha National Park. Sankhala (1977) suggested the need to be 10-12 kg of meat per day. Sunquist (1981) suggested 5-6 kg for a tigress and 6-7 kg for a tiger per day. Taking into consideration the normal activities of a free-ranging tiger in the wild which included a number of days when no feeding occurred and the plentiful supply of prey - a requirement of 7 kg of meat per day on an average (Tamang 1979) seems reasonable. Based on experience with domestic buffalo baits and wild prey, 30 percent of the total weight of the prey can be considered inedible. In order to obtain 2555 kg (7 kg x 365 days) of meat per year, a tiger would be required to kill an estimated 3650 kg of large prey biomass in a year. That weight would be equal to 18 sambar or 111 hog deer or 68 chital.

Impact of Tiger Predation on Wild Ungulates

My estimate of the Chitawan tiger population for May 1977 was 5 adult males, 16 adult females and 9 sub-adults of both sexes. The area considered was the whole park (910 km^2), including the eastern and western extensions (Tamang 1979). At that time, there were at least 8 cubs in the northern section of the park (see page 67) and an additional 8 cubs may reasonably be estimated to have been present in the rest of the area. Assuming that a sub-adult requires the same amount of meat as an adult and that a cub eats one-quarter of an adult's requirements, the total food need of the population would be equivalent to that of 34 adult tigers. The combined annual requirement for 34 tigers at 3650 kg/tiger/year would be a total of 124,100 kg of large prey biomass.

It would be realistic to exclude rhinos from our calculations since rhino calves are only occasional prey, rarely taken even though they constituted 25 percent of the total wild ungulate biomass. The crude biomass available to tigers without rhinos would then amount to 1,769,292 kg for the park (Table 11). The total requirement for tigers of 124,100 kg/year, therefore, would account only for 7 percent of the standing crop biomass.

My estimate of the average density of adult tigers in the park was one per 43 km^2. The average weight of a Chitawan tiger was 176 kg (based on actual weights and adjusted to a female:male ratio of 3:1). Therefore, it can be estimated that the Royal Chitawan National Park during the study period supported a crude biomass density of 4 kg of tiger/km^2 and 1 kg of tiger per 475 kg of wild ungulate biomass (excluding rhinos). Schaller (1972) estimated 1 kg of predator (mostly lion, hyenas and leopards) per 250-300 kg of prey in the Serengeti National Park and removal of roughly 9-10 percent of the prey biomass by predators.

The requirement of transient tigers and also that of smaller predators such as leopards and wild dogs has not been taken into consideration at Chitawan. On the other hand, the amount contributed by domestic livestock, gaur and rhinos to the tiger's diet has not be included. Considering total tiger predation as 7 percent of the standing crop, it seems that by no means does tiger predation limit the prey populations in the park.

TIGER MANAGEMENT

The key to the survival of wild tigers in the long run is the maintenance of tiger habitats. These must be sufficiently large to support the number of animals which provides for an adequate genetic diversity. "Buffer area" habitats adjoining park area must be maintained to provide for an adequate and diverse gene pool.

The effect of human population growth with consequent habitat alteration and disturbance over the past generation or two has overwhelmed the tiger populations in Asia. Surviving populations are isolated, scattered and mostly confined to parks, reserves and adjoining forest areas. The Royal Chitawan National Park is an area that holds the typical and natural number of tigers which is characteristic of Nepali dun and terai habitats. The population seems to be stable and maintaining itself under the existing environmental conditions.

Tigers are solitary hunters. Their territorial behavior insures that they are not overcrowded and remain at low density. There is no reasonable possibility, therefore, of large increases in tiger number in any reserve where natural densities prevail. Intraspecific competition keeps their numbers down. Confrontation between individuals and the lack of suitable additional habitat areas for the establishment of new populations after dispersal as individuals approaching maturity are factors that limit tiger density. Mortality as a result of direct conflict with man and his activities, such as the poisoning of livestock killed by tigers, also takes its toll.

At Chitawan, the protection and maintenance of existing forest areas to the east and west of the park as buffer areas is absolutely vital. The existing popular demand for the re-assignment of wildlife habitats for human settlement is bound to grow more intense with the increase in human population in Chitawan and neighboring districts. If the historic, cultural, scientific, recreational and economic benefits of national parks as living museums are to be preserved for future generations, it may be advisable to strengthen the provisions in the national park act against further human encroachments on the domains of tigers and the associated fauna and flora with which they are inextricably linked.

Changes in vegetative stages and successional development induces corresponding changes in the types and abundance of wildlife inhabiting the area. Areas in early stages of vegetative succession are some of the best wildlife habitats. The annual burning of grasslands and riverine forests has helped to maintain this status and high wildlife productivity of these habitats in the park. This fact is well recognized by park authorities and controlled burning of grasslands and other areas have been beneficially carried out in the past. The controlled harvesting of thatch-grass and reeds by local villagers also maintains early-stage vegetation and are presently permitted in the park during prescribed seasons.

Sal forests occupy about 70 percent of the park. Because sal trees tend to become dense, the grasses and other vegetation beneath them decreases whenever the sal canopy becomes closed. As sal forests advance increasingly toward maturity, there is less food and cover for grazing animals and, hence, for the large predators which depend upon them as food. The properly-planned harvesting of mature and overmatureed sal forests in selected areas, under the supervision of Forest Department and park authorities, benefits wildlife by returning such areas to early stages of vegetative and faunal succession.

BIBLIOGRAPHY

Anderson, D. R., K. P. Burnham and B. R. Crain. 1978. A log-linear model approach to estimation of population size using the line-transect sampling method. Ecology 59(1): 190-193.

Anderson, D. R., L. L. Laake, B. R. Crain and K. P. Burnham. 1979. Guidelines for line transect sampling of biological populations. J. Wildl. Manage. 43(1): 70-78.

Beck, C. C. 1972. Chemical Restraint of Exotic Species. J. Zoo. An. Med. 3(3): 3-66.

Bolton, M. 1975. Royal Chitawan National Park Management Plan. FAO/UNDP Document No. 2 FO NEP/72/002, Kathmandu, Nepal. 105 pp.

Boorer, M. 1969. Wildcats. Hamlyn, London. 159 pp.

Burnham, K. P. and D. R. Anderson. 1976. Mathematical Models for Nonparametric Inferences from Transect Data. Biometrics 32: 325-336.

Burnham, K. P.; D. R. Anderson and J. L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monograph No. 72.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy, 24: 346-352.

Calhoun, J. B. and J. U. Casby. 1958. Calculation of Home Range and Density of Small Mammals. Public Health Service Publication No. 592: 1-24.

Caughley, G. 1977. Analysis of Vertebrate Populations. John Wiley and Sons, New York.

Champion, H. G. 1938. A preliminary survey of the forest types of India and Burma. Indian Forest Records. (N.S.), 1.

Champion, H. G. and S. K. Seth. 1968. The Forest Types of India. Government of India Press, Delhi, India. 404 pp.

Charnov, E. L. 1973. Optimal foraging; some theoretical explorations. Ph.D. Thesis, University of Washington.

Charnov, E. L. 1976a. Optimal foraging; attack strategy of a mantid. Am. Nat. 110: 141-151.

Charnov, E. L. 1976b. Optimal foraging, the marginal value theorem. Theor. Pop. Biol., 9: 129-136.

Charnov, E. L., G. H. Orians and K. Hyatt. 1976. Ecological implications of resource depression. Am. Nat., 110: 247-259.

Chowdhury, S. R. 1976. Maiden peak oestrus of Khairi and the omnibus punch card. Unpublished mid-term report on Simlipal Tiger Reserve, Bihar, India.

Corbett, J. 1946. Man-Eaters of Kumaon. Oxford Univ. Press, London. 235 pp.

Craighead, F. C., Jr. 1963. Radio-tracking of Grizzly Bears in Yellowstone National Park, Wyoming. Nat. Geogr. Soc. Res. Reports, 1963 Projects, 59-67.

Craighead, F. C., Jr. and J. J. Craighead. 1966. Trailing Yellowstone's grizzlies by radio. Nat. Geogr. 130(2): 252-267.

Crain, B. R., K. P. Burnham, D. R. Anderson and J. L. Laake. 1978. A fourier series estimator of population density for line transect sampling. Utah St. Univ. Press, 1-25.

Crandall, L. 1964. The management of wild animals in captivity. Chicago.

Dinerstein, E. 1979. An ecological survey of the Royal Karnali-Bardia Wildlife Reserve Nepal. M.S. Thesis, University of Washington.

Doi, T. 1970. Re-evaluation of population studies by sighting observation of whale. Bull.Tokai Reg. Fish. Lab. 63: 1-9.

Ebedes, H. 1972. The Drug Immobilization of Carnivorous Animals. 62-68.

Eberhardt, L. 1968. A preliminary appraisal of line transects. J. Wildl. Manage. 32(1): 82-88.

Eberhardt, L. 1978a. Transect methods for population studies. J. Wildl. Manage. 42(1): 1-31.

Eberhardt, L. 1978b. Appraising variability in population studies. J. Wildl. Manage. 42(2): 207-238.

Eisenberg, J. F. 1981. The Mammalian Radiations: An analysis of trends in evolution, adaptation and behavior. The Univ. of Chicago Press, Chicago.

Eisenberg, J. F. and M. Lockhart. 1972. An ecological reconnaisance of Wilpattu National Park, Ceylon. Smithsonian Contr. Zool. 100: 1-118.

Ellerman, J. and T. Morrison-Scott. 1966. Checklist of Palaearctic and Indian Mammals. 2nd ed. Alden, Oxford. 810 pp.

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

Emlen, J.. and M. G. R. Emlen. 1975. Optimal choice in diet: test of a hypothesis. Am. Nat., 109: 427-435.

Fisher, J. 1978. Tiger! Tiger! International Wildlife. 8(3): 4-10.

Gates, C. E. 1969. Simulation study of estimators for the line transect sampling method. Biometrics 25: 317-328.

Gates, C. E. 1979. Line transects and related issues. pp. 71-154. In R. M. Cormack, G. P. Patil and D. S. Robson (eds.). Sampling biological populations. Internat'l. Co-op. Publ. House, Fairland, MD.

Gates, C. E.; W. H. Marshall and D. P. Olson. 1968. Line transect method of estimating grouse population densities. Biometrics 24: 135-145.

Gee, E. P. 1959. Report on a survey of the rhinoceros area of Nepal. Oryx 5: 51-85.

Gee, E. P. 1963. Report on a brief survey of the wildlife resources of Nepal, including the rhinoceros. Oryx 9: 1-15

Graf, W. and L. Nichols. 1966. The axis deer in Hawaii. J. Bombay Nat. Hist. Soc. 63(3): 629-734.

Gurung, H. 1980. Vignettes of Nepal. Sajha Prakashan, Kathmandu, Nepal.

Hagen, T. 1966. Nepal, the Kingdom in the Himalayas. Kummerly and Frey Geographical Publishers, Berne, Switzerland. 2nd ed.

Harthoorn, A. M.; S. Harthoorn and P. D. Sayer. 1971. Two field operations on the African lion. Vet. Rec. 89: 159-164.

Hayne, D. W. 1949. Calculation of size of home range. J. of Mamm., 30(1): 1-18.

Heezen, K. L. and J. R. Tester. 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. J. Wildl. Manage. 31(1): 124-141.

Hemingway, P. 1971. Field trials of the line transect method of sampling large populations of herbivores. Pp. 405-411 in E. Duffey and A. S. Watts (eds.). The scientific management of animal and plant communities for conservation. Blackwell Sci. Publ., Oxford, England.

His Majesty's Government of Nepal. 1968. Soil survey of Chitawan Division. Forest Resources Survey Publication No. 5. 126 pp.

His Majesty's Government of Nepal. 1978. Climatological records of Nepal. Dept. of Irrigation, Hydrology and Meteorology, Kathmandu, Nepal.

Hornocker, M. G. 1969. Winter territoriality in mountain lions. J. Wildl. Manage. 33(3): 457-464.

Hornocker, M.G. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildl. Monogr. No. 21. 39 pp.

Jackson, P. 1979. The World Wildlife Fund and the Tiger. Tigerpaper 6(2-3): 2-4.

Kelker, G. H. 1945. Measurement and interpretation of forces that determine population of managed deer herds. Unpubl. doctoral dissertation, University of Michigan, Ann Arbor, Michigan.

Kenneth, J. H. and G. R. Ritche. 1983. Gestation periods. 3rd ed. Commonwealth Bur. Animal Breeding and Genetics, Edinburgh, Tech. Comm. 5: 1-39.

Laurie, W. A. 1978. The ecology and behavior of the Greater One-horned Rhinoceros. Unpubl. Ph.D. Thesis. University of Cambridge, Cambridge, England. 426+ pp.

MacArthur, R. H. 1972. Geographical Ecology. Harper and Row, New York. 269 pp.

MacArthur, R. H., and E. R. Pianka. 1966. On the optimal use of a patchy habitat. Amer. Natur. 100: 603-609.

Manville, R. H. 1957. Longevity of captive animals. J. Mamm. 38: 279-280.

McDougal, C. 1977. The face of the tiger. Rivington Books, London. 180 pp.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist, 37: 223-249.

Ngampongsai, C. 1977. Habitat relations of the sambar (Cervus unicolor) in Khao-Yai National Park, Thailand. Unpublished Ph.D. Dissertation, Michigan State University, East Lansing, Michigan. 115 pp.

Palmer Chemical and Equipment Co., Inc. 1970. Catalog of and instructions for use of Cap-Chur equipment for remote injection of any liquid drug. Douglasville, Georgia.

Panwar, H. S. 1979. Population dynamics and land tenures of tiger in Kanha National Park. International Symposium on the Tiger, Delhi, India (Feb. 1979). Unpubl. 30 pp.

Parke-Davis. 1974. Veterinary Medical Summary of CI-744. Chemical Research Information. Parke-Davis & Co., Ann Arbor, Michigan. 150 pp.

Perry, R. 1964. The World of the Tiger. Cassel and Co., Ltd., London. 236 pp.

Petrides, G. A. 1966. Calculation and ecological interpretation of prey preference for large predators in Kruger National Park, South Africa. Typed ms. 15 pp.

Petrides, G. A. 1975. Principal foods versus preferred foods and their relations to stocking rate and range condition. Biol. Conserv. 7: 161-169.

Pocock, R. 1929. Tiger. J. Bombay Nat. Hist. Soc. 33: 505-541.

Pocock, R. 1939. The fauna of British India. Mammalia. London.

Prater, S. H. 1971. The Book of Indian Animals. Bombay Nat. Hist. Soc., Bombay, India. 2nd. ed. 324 pp.

Pyke, G. H., H. R. Pulliam and E. R. Charnov. 1977. Optimal foraging: a selective review of theory and tests. Quart. Rev. Biol. 52(2): 137-154.

Ranjitsinh, M. K. 1979. The tiger in the twenty-first century. International Symposium on the Tiger, Delhi, India (Feb. 1979). Unpubl. 8 pp.

Rao, P. V. and J. A. Ondrasik. 1980. Density estimation using inverse sampling on line transects. University of Florida and Boehringer Ingelheim, Ltd. Tech. Rep. No. 154. Gainesville, Florida.

Russ, W. B. 1973. Reproduction/Population. pp. 53-61 <u>in</u> (E. D. Ables, ed.), The axis deer in Texas. Texas A&M Univ. 86 pp.

Sankhala, K. 1977. Tiger! The Story of the Indian Tiger. Simon and Schuster, New York. 220 pp.

Schaller, G. B. 1967. The Deer and the Tiger: A Study of Wildlife in India. University of Chicago Press, Chicago. 370 pp.

Schaller, G. B. 1972. The Serengeti Lion. University of Chicago Press, Chicago. 480 pp.

Schaller, G. B. and J. J. Spillett. 1966. The status of the big game species in the Keoladeo Ghana Sanctuary, Rajasthan. The Cheetal 8(2): 12-16.

Schoener, T. W. 1969. Models of optimal size for a solitary predator. Am. Nat., 103: 277-313.

Schoener, T. W. 1971. Theory of feeding strategies. Ann. Rev. Ecol. Syst., 11: 369-404.

Seber, G. A. F. 1973. The estimation of animal abundance. Hafner Press, New York.

Seidensticker, J. C., M. G. Hornocker, W. V. Wiles and J. P. Messick. 1973. Mountain lion social organization in the Idaho Primitive Area. Wildl. Monogr. No. 35. 60 pp.

Seidensticker, J. C., K. M. Tamang and C. W. Gray. 1974. The use of CI-744 to immobilize free ranging tigers and leopards. J. Zoo Animal Medicine 5(4): 22-25.

Singh, A. 1973. Tiger Haven. Macmillan, London. 237 pp.

Singh, A. 1979. Introduction of hand-reared leopard and a tigress to free living conditions. International Symposium on the Tiger, Delhi, India (Feb. 1979). Unpubl. 19 pp.

Singh, K. 1959. The tiger of Rajasthan. Jaico Books, Bombay, India. 198 pp.

Smith, J. L. D. 1978. Unpublished Smithsonian Tiger Ecology Project Report No. 13. Kathmandu, Nepal.

Smythies, E. A. 1942. Big game shooting in Nepal. Thacker, Spink & Co., Ltd. Calcutta, India. 174 pp.

Spillett, J. J. and K. M. Tamang. 1967. Wildlife Conservation in Nepal. J. Bombay Nat. Hist. Soc. 63: 557-572.

Srivastava, B. P. 1979. Status of Tiger in India. Tigerpaper 6(2-3): 24-27.

Stracey, P. D. 1968. Tigers. Golden Press, New York. 198 pp.

Sunquist, M. E. 1979. The movements and activities of tigers (<u>Panthera tigris tigris</u>) in Royal Chitawan National Park, Nepal. Unpublished Ph.D. Dissertation. University of Minnesota, Minneapolis, Minnesota. 170 pp.

Sunquist, M. 1981. The social organization of tigers (<u>Panthera tigris</u>) in Royal Chitawan National Park, Nepal. Smithsonian controbution to zoology. No. 336.

Tamang, K. M. 1965. Report on investigation of forest management requirements for the TCN area in Chitawan forest division. Unpublished.

Tamang, K. M. 1979. Population characteristics of the tiger and its prey. International Symposium on the Tiger, Delhi, India (Feb. 22-24, 1979). Unpubl.

Tamang, K. M. and J. L. D. Smith. 1977. Unpublished Smithsonian Tiger Ecology Report No. 12. Kathmandu, Nepal.

Tester, J. R., D. W. Warner and W. W. Cochran. 1964. A radio-tracking system for studying movements of deer. J. Wildl. Manage. 28(1): 42-45.

Upreti, B. N. 1973. Report on the Royal Chitawan National Park. National Parks and Wildlife Conservation Office, unpublished report.

Westoby, M. 1974. An analysis of diet selection by large generalist herbivores. Am. Nat., 108: 209-304.

Willan, R. G. M. 1965a. The Chitawan Wildlife Sanctuary in Nepal. IUCN Bull. 8. Morges, Switzerland.

Willan, R. G. M. 1965b. Rhinos Increase in Nepal. Oryx 8. 2 pp.

Zhu-Jin. 1979. The tiger and its conservation in China. International Symposium on the Tiger, Delhi, India. Unpublished report, 3 pp.