TO JOHN SEIDENSTICKER

2/26/03

MAPPING THE META-POPULATION STRUCTURE OF TIGERS THROUGHOUT NEPAL BY ESTABLISHING A TIGER MONITORING NETWORK OF "VILLAGE RANGERS"

A THESIS
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA

BY

BHIM B. GURUNG

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

DECEMBER 2002

UNIVERSITY OF MINNESOTA

This is to certify that I have examined this bound copy of a master's thesis

BY

BHIM B. GURUNG

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

Dr. James L. David Smith

Faculty Advisor

James L.D. Smith

Oct 25, 2002

Date

GRADUATE SCHOOL

ACKNOWLEDGEMENTS

This project would not have been possible without the assistance of many organizations, colleagues, family and friends. I am especially grateful to Dr. Tirtha Man Maskey, Director General of Department of National Park and Wildlife Conservation (DNPWC), and the staff at the department, for their support of this research. Dr. Maskey was very helpful in encouraging and assisting the project in numerous ways. I thank Mr. Narayan Poudyal, Deputy Director General of the DNPWC, for his assistance to carry out the project. Also I would like to thank Mr. Shiv Raj Bhatta, warden of Royal Bardia National Park (RBNP), for granting permission, providing facilities and inaugurating the first "Village Rangers" training workshop for the project.

This project was made possible by funding provided by the United States Fish and Wildlife Service (USFWS), National Fish and Wildlife Foundation (NFWF), International Trust for Nature Conservation (ITNC), The Fund for the Tiger and Tiger Mountain. Very special thanks are given to Dr. Charles McDougal, Wildlife Director and trustee of ITNC, who inspired me to start the project and assisted me throughout the duration of project. I would also like to thank Mr. Brian Weirum, chairman of "The Fund for the Tiger" foundation, for providing financial support for field works. I would also like to thank Mr. Pradeep S.J.B.Rana, General Manager of Karnali Jungle Lodge (KJL), Mr. Dushyant Singh, Manager of KJL, for housing and logistic support during my field study. Furthermore, I would like to thank Mr. Sanu Raja Bajracharya and Ms. Gauri Malakar, for their help in coordination and getting field data from field

coordinators and sending it on a monthly basis to the University of Minnesota, USA.

The project would never have reached completion without the invaluable field assistance from field coordinators and "Village Rangers". I express my special thanks to my field coordinators, Mr. Hari Prasad Choudhary and Mr. Indra Bahadur Kumal, for not only traveling continuously each month to all the survey sites but also for their hard work, dedication, patience and commitment to their work, ever under difficult field conditions. Their good natured and friendship made my field trips more memorable. My special thanks to all the "Village Rangers" for committing their time to collect field data with enthusiasms and dedications, without their support this project would never have been accomplished.

I would like to express my special gratitude to my major advisor, Dr. J. L. David Smith, for his support, encouragement, advice, suggestions and assisting me in this project from beginning to the end. He not only provided me an academic guidance, but also supported for accepting me into the Conservation Biology Graduate Program. I would like to thank my advising committee members, Dr. David Fulton and Dr. Francesca J. Cuthbert, for their suggestions and insightful criticisms of this manuscript. Dr. Cuthbert not only provided helpful comments with editing of the final manuscript but also helped to adjust our family life comfortably in the United States.

I benefited greatly from the friendship of my colleagues and fellow graduate students, who helped me throughout the process, which was, at times, difficult and frustrating. I would particularly like to thank Dr. Anup Joshi, for his suggestions and assistance in data analysis and map productions. Similarly, I would like to thank Mr.

Mahendra Shrestha, for his support during the field study and his invaluable suggestions throughout the project. In addition, I thank my fellow graduate students, namely Perry Nacionales for helping me with GIS and others for their patience in listening to my research work and their encouragement to accomplish this project.

I would also like to thank my friends around the globe for their support in encouraging me in this project. Specially, Patricia O'Neill, Max and Thea Kalhamer, Dieter and Liz Gutman, and Pushpa and Nique Maskey, for their support and well wishes.

My family members always encouraged my education in Nepal, India as well as in USA. My special thanks go to my wife Sandhya Gurung who always supported me for my higher education, with love, patient and helped in every possible ways during my study. The cute smile of my newly born son, Suluv, provided me with extra energy during the completion of the project. Finally, I thank my parents and wish to dedicate this thesis to them. They both have never been to school but they have been a source of encouragement, support and love throughout my life. Anything I have accomplished is solely of their blessing and to them, I will always be deeply grateful.

ABSTRACT

This research assesses the extent to which tigers use land outside of protected areas as breeding or dispersal habitat throughout the lowland of Nepal. The premise for working outside reserves is based on the following observations: (1) existing reserves are not large enough to maintain the viable tiger populations, (2) extensive forest lands exist outside reserves, (3) these forest lands may serve as critical tiger habitat, and (4) local people are increasingly interested in forest restoration. Formerly, experienced biologists surveyed the area inadequately. To overcome this problem a network of 30 Village Rangers was established to map the locations of tiger's tracks and livestock kills across the lowlands of Nepal. Tiger kills are recognized by the large sized pugmarks of predators; large sized animal killed; broken rib bones; and large and deep canine tooth mark. Breeding habitat is identified by the presence of female and cub, or hypothesized if both males and females use an area > 6 months a year. Tigers still disperse through even degraded habitat. There is a greater potential for tigers dispersal between Suklaphanta and Bardia than between Bardia and Chitwan. Furthermore, four sites near Bardia were identified as breeding in contrast to only one breeding area near Chitwan. Village Rangers are a forum of citizen monitoring that provides much greater sampling intensity.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The tiger (*Panthera tigris)*, is a globally endangered species (IUCN 1996). Gee (1964) said there were "a possible 40,000" tigers in India 50 years ago, which would have been shortly after the turn of the century. His number of 40,000 has often been repeated (WWF 1998a, Jackson 1993, 1998), but we need to recognize that he was guessing not estimating; he provides no criteria or citation and "50 years ago" he was but a young boy. More recent counts in India are criticized and estimates for Thailand (Rabinowitz 1993) that give population sizes of 2, 2.5, 3, and 4.5 may not stand op to rigorous scientific review. Although estimated numbers of tigers still do not specify the age class of animals being counted and are mostly not based on a rigorous scientific methodology, we do know that three sub-species have become extinct (Caspian, 1970; Bali, 1940; and Java, 1980) (Seidensticker 1987); the South-China tiger is on the verge of extinction (Bangjie 1987) and over much of its range the tiger continue to decline due to poaching and habitat loss.

Until approximately 1990, the primary threat to tigers was habitat loss, fragmentation and degradation (Karanth 1999, Smith et al. 1999, Oza 1986, Wilcox and Murphy 1985) associated with human population growth. Additionally, poisoning of domestic livestock carcasses to reduce livestock losses occurred with widespread use of insecticides in the 1970s (Dorji and Santipillai 1989, Martin 1992). However, beginning about 1990, tiger poaching became a major threat to tiger survival (Kenney et al. 1995, Jackson 1999). Asian markets for tiger products, especially tiger bones, resulted in rapid reduction in tiger numbers in Cambodia, India, Myanmar, Russia and Vietnam and probably elsewhere (Jackson and Kemf 1999, Hean 2000, Novell 2000).

In response to the tiger extinction crisis in the late 1960s, a number of countries governments used the tiger as a symbolic rallying point for conservation in Asia; the species was considered important as both a keystone and an umbrella species (Seidensticker and McDougal 1993, Seidensticker 1997). In 1973 *Project Tiger* was launched (Panwar 1979) to protect tigers globally, and tiger reserves were created in India and many other tiger range countries. Twenty years later, as the conservation paradigm shifted from single species and protected areas to community based, ecosystem and bioregional conservation the tiger remains as an important symbol and a key element defining ecosystem and bioregional conservation units (Grumbine 1994, 1997, Dinerstein et al. 1997, Wikramanayake et al. 1998, Smith et al. 1999).

Tiger Conservation in Nepal

In Nepal, conservation efforts have focused on the establishment of parks and reserves for the protection of tigers as well as other endangered species (Upreti 1992). Concomitant with establishment of protected areas across the tiger's range, research was initiated in Nepal. Early studies focused on behavior and life histories (McDougal 1977), social structure (Sunquist 1981, Smith et al. 1987), impact on prey (Tamang 1982, Seidensticker and McDougal 1993), communication (Smith et al. 1989), lifetime reproduction (Smith and McDougal 1991), dispersal (Smith 1993) and poaching (Kenney et al. 1995). At the same time, management was progressing. Royal Chitwan National Park (RCNP) was expanded in 1977 and adjoining Parsa Wildlife Reserve (PWR) was created in 1984 to encompass more extended habitat for the tiger (Smith 1984). In Nepal, tigers also occur in Royal Bardia National Park (RBNP), Royal Suklaphanta Wildlife Reserve (RSWR) and are distributed sparsely in lowland forest

found between these protected areas. The parks and reserves are administered by the Department of National Park and Wildlife Conservation (DNPWC) and protected by the Royal Nepal Army; other forest habitat is managed by the Department of Forestry (DoF).

Population surveys were conducted between 1994-97 in all tiger reserves in Nepal, and the population was estimated to be approximately 100 breeding tigers (48 in RCNP + PWR, 36 in RBNP and 16 in RSWR) (Smith et al. 1999). Several sources suggested the population in RCNP had reached saturation (DNPWC 1996, McDougal and Tshiring 1998). Nepal's reserves are relatively small and distant from one another; the potential for dispersal between parks is unknown. Kenney et al. (1995) suggested that tiger populations of the sizes estimated in Nepal, and indeed all across south Asia, are inadequate to withstand a combination of demographic and environmental stochasticity for the next 100 years. Periodic bouts of poaching, outbreaks of disease, and the genetic consequences of close inbreeding are difficult to estimate individually, and no one has data to model the combined consequences of all of these factors.

In Nepal there are extensive forestlands outside protected areas. These forests are administered by the DoF, but due to lack of economic resources and personnel, there is no regular monitoring of tigers living in these forests. The extent of poaching and poisoning outside parks is unknown, but both activities clearly occur across tiger habitat. The Department of Forestry is in a period of transition from traditional forest production and extraction to a broader based ecosystem approach that also encompasses community forestry, biodiversity conservation and maintenance of healthy intact ecosystems. Consistent with this new approach, the Tiger Conservation

Action Plan for the Kingdom of Nepal (1999) identifies the conservation of tigers beyond protected areas as its number one priority. The Terai Arc Landscape project was recently initiated to coordinate the efforts of the DNPWC and DoF to implement an ecosystem and community based approach to management (WWF 2001).

Implementation the Tiger Action Plan is not an easy task. The forests outside protected areas are the main resource for fuel-wood, fodder, livestock grazing, and minor forest products that are economically critical to people living in the region. Over-use of forests in many locations has degraded and fragmented the once continuous forests of the Nepalese lowlands. Restoration of degraded forestlands to maintain the landscape corridors (Noss 1987) may be critical to the long-term survival of tigers (Smith 1993, Smith et al. 1998). However, there is still limited information on tiger distribution outside protected areas. Surveys conducted in the past were of short duration and thus inadequate to determine the extent tigers move between reserves (Smith et al. 1999). Short-term survey efforts outside protected areas were also insufficient to determine where tigers are breeding.

Objectives of the study

The goal of my research was to evaluate the role of national forest lands as tiger habitat. The specific objectives were: 1) to assess the connectivity among the protected area populations, 2) to determine the extent of breeding outside of protected areas as a first step to exploring source sink dynamics (Pulliam 1988), and 3) to establish a community- based network of "Village Rangers" to accomplish the above objectives. A secondary, but critically important aspect of using "Village Rangers" was to establish local participation in tiger conservation. Data on the distribution of

tigers and their breeding habitat outside protected areas will help identify important sites for forest restoration that are critical for improving connectivity among reserves. Distribution data will be integrated with prey and habitat quality data to help formulate a Terai-wide biodiversity action plan.

METHODS

Study Area

Nepal extends 885 km east-west from longitude E 80° 45' to 87° 45' and north south 145-193 km from latitude N 26° 15' to 30°30'. The country encompasses approximately 147,181 sq km (Figure 1). Geographically Nepal has three topographic zones: the Himalayan zone includes several of the highest peaks of the world and lies to the north, it is sparsely populated. The Middle Hills, the most densely populated region of Nepal until the 1950s; they range from 1000 to over 3000 m. The lowlands extend from 400 to 1300 m (Staiton 1972) and currently are occupied by Nepal's highest density of human settlements. Because of dense human population and lack of prey in the middle hills, for most of this century, tigers have been found only in the lowlands of Nepal.

The lowlands are composed of an inner and outer terai separated by the Siwalik Hills, which extends across Nepal and the entire length of the Himalayas. The inner terai is a series of separate valleys that are formed where the Siwaliks bend away from the Mahabharat or Middle Hill range. These inner terai "Dun" valleys have rich soils that historically supported some of the tallest grasslands in the world and high

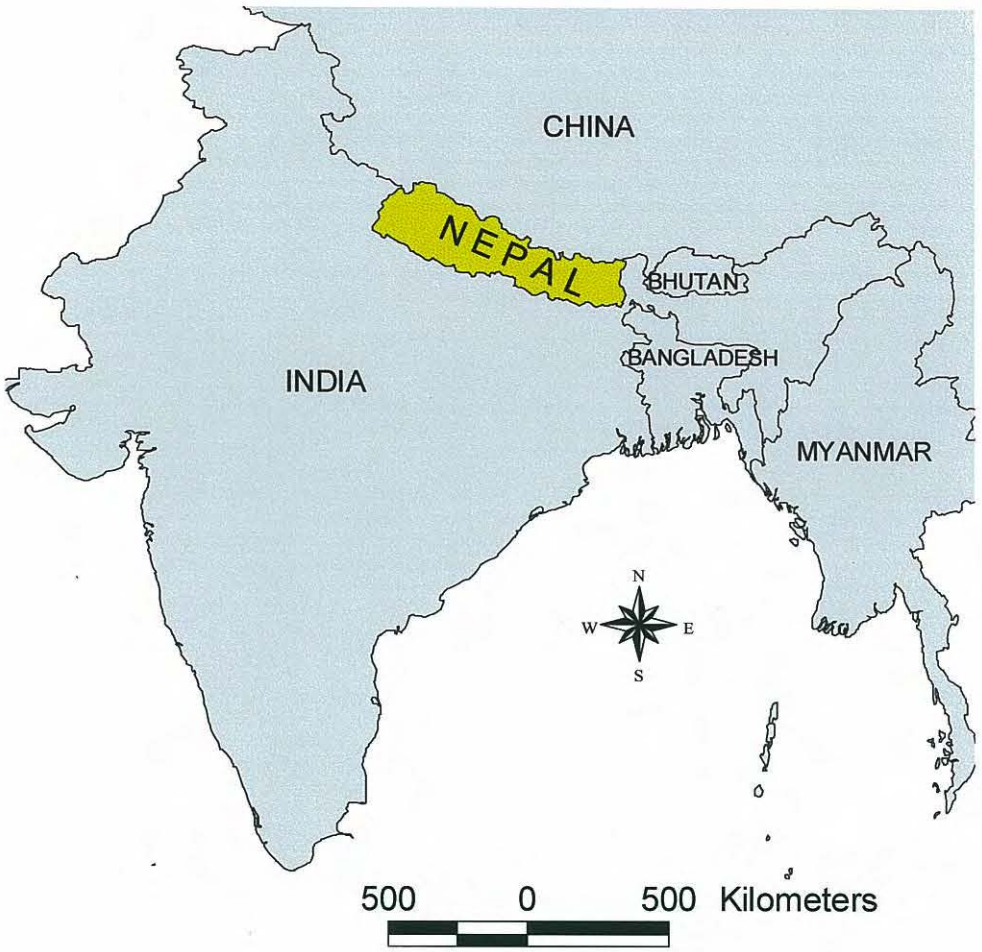


Figure 1. Geographic location of Nepal

densities of several ungulate species including sambar (*Cervus unicolor*), swamp deer *(Cervus duvaucelii*), blue bull (*Boselaphus tragocamelus*), spotted deer (*Axis axis*), hog deer (*Axis porcinus*), barking deer (*Muntiacus muntjak*), four-horned antelope (*Tetraceros quadricorins*) and at higher elevations, the serow (*Capricornis sumatraensis*). This high diversity and abundance of prey species in turn supports and continues to support the highest density of tigers found anywhere else in the world (Smith et al. 1998). Until six decades ago, the entire terai was a continues belt of dense tropical forest (Shrestha 1997) with scattered villages of indigenous ethnic people such as the Tharu who lived in forest villages. Large mammals such as the tiger, Asiatic elephant (*Elephus maximus)*, gaur *(Bos gaurus)*, leopard (*Panthera pardus)*, water buffalo (*Bulalus bulalis)* and greater one-horned rhinos (*Rhinoceros unicornis)* were common.

At present, much of the terai forest has been converted to settlement and agricultural land. It is estimated that about 0.2 million hectares of the terai and Siwaliks forests were cleared through planned settlement and illegal logging from 1950 to 1985 (Pradhan and Parks 1993). Settlement of landless farmers in the terai forests and illegal harvest of trees are still a major problem. However, in a few parts of the terai, particularly in west Nepal, large tracks of forest still survive. My study area included 11 terai districts in 7 administrative zones that extend from the Koshi River in the east to Mahakali River in the west.

Sal forest dominated by *Shorea robusta* occupies 70% of the forest in the terai. Sal reaches > 30 m in height in low areas, but on upper benches where soils are shallow, sal is stunted and forms woodland with a tall grass under-story. Along

streams, dips and gulleys where soils are richer and water more plentiful both mixed deciduous and tropical evergreen forest are present.

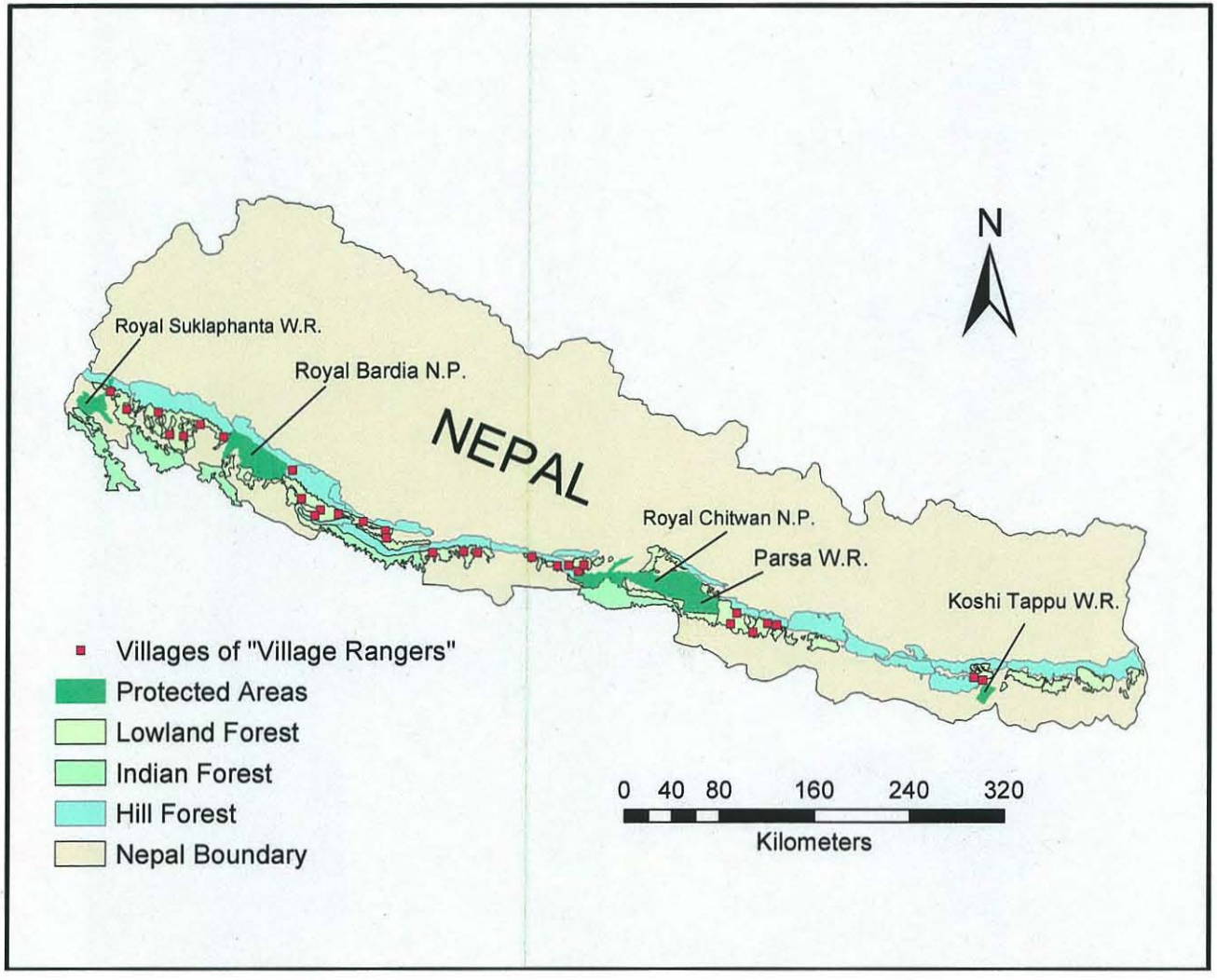
A climax type of sal forest in the vegetation succession does not occur along river side, newly formed alluvium soil or on waterlogged soil. Therefore, along riversides are tropical deciduous riverine forests composed of *Accacia catechu* and *Dalbergia sisso* as common tree species.

Establishing Network of Village Rangers

To assess distribution and habitat use by tigers outside the protected areas of Nepal, I used a satellite image map of entire terai region (1:25,000) to delineate forest cover, rivers and road networks and to identify the large forest blocks that may support tigers. I then selected sites where tigers had been previously reported, e. g. old hunting blocks (pers. comm. C. McDougal), and areas of recent observations (Smith et al. 1999) to identify areas critical to maintaining connectivity among parks. Isolated forest blocks a considerable distance from the tiger reserves were excluded after informally interviewing local people in those areas. A total of 30 survey sites were selected from the known range of tigers in Nepal.

To initiate my research I hired two field coordinators with several years of experience conducting tiger surveys between 1994-97. These coordinators were skilled in reading animal sign and could accurately distinguish tiger from leopard and male from female tiger tracks based on size criteria. I trained these coordinators to use a Global Positioning System (GPS) so they could record the geographic coordinates of livestock kill sites and other tiger sign. These coordinators also helped me select the "Village Rangers".

Figure 2. Location of Village Rangers in Nepal's lowlands


N
Royal Suklaphanta W.R.
Royal Bardia N.P.
NEPAL
Royal Chitwan N.P.
Parsa W.R.
Koshi Tappu W.R.
Villages of "Village Rangers"
Protected Areas
Lowland Forest
Indian Forest
Hill Forest
Nepal Boundary
0 40 80 160 240 320
Kilometers

A local "Village Ranger" (VR) was hired at each survey site. I chose people who lived in the area year around and were familiar with the forested areas near their village. VR were selected from villages that were situated closest to the forest so that they had less distance to travel to the forest to conduct surveys. In October and November 1999, the field coordinator and I hired 30 VRs (Figure 2, Appendix 1). Rangers had diverse backgrounds (e. g. 11 farmers, 6 livestock herders, 5 hunters, 6 community leaders and 2 intelligence informants). The villages where I hired VRs were sites where a high incident of poaching had occurred. When I hired VR I took them to the forest and trained them on the basic field-craft of field surveys.

Capacity Building for Village Rangers

I conducted the training workshop for capacity building of VRs between 30 November and 2 December,1999. The main objectives of the workshop were to train VR to evaluate and record data on livestock depredation (described in section Field Methodology). Technicians from the Tiger Monitoring team from International Trust for Nature Conservation (ITNC), King Mahendra Trust for Nature Conservation (KMTNC), and DNPWC conducted the field training. The training was held at the Research and Training Center for Protected Areas (RTCPA) in RBNP. This site was selected inside the national park because tiger and leopard pugmarks, or paw prints, are easily available. An expert tiger monitoring field technician trained the VRs to discriminate tiger and leopard based on size of the pugmark (Table 1). Many tracks available in different sites provided opportunities to practice multiple measures of tiger and leopard pugmarks for identification. There is a misconception in Nepal of leopards being called tigers. I clarified this misconception by discussing the distinctive

features between the two and by showing photographs and video movies of leopards and tigers.

Upon returning to their villages VRs began surveying the forest up to 3 hours walk (approx. 6 km) from their village at least once a week to determine if tigers occur in their forests. Each VR also informed all villagers, especially livestock herders in his areas, about the project objectives. Villagers were asked to report any information regarding tigers (e.g. observation of pugmarks, information on domestic animals killed).

Each month the field coordinators visited each VR. Together, the VR and field coordinator went to the site of each kill or pugmark to verify that it was made by a tiger and to collect GPS location data. These site visits gave VRs an opportunity to interact with the tiger expert and improve their professionalism on the job. This close association during monthly visits increased rapport between the VR and field coordinator by allowing them to discuss conservation problems and issues together.

Field Methodology

When a kill was reported, the VR visited the site with the owner of the kill or other villagers. A data sheet was filled out while investigating the kill site. The following criteria were used by the VRs to determine if the kill was made by a tiger or leopard (measurements given in units used by VRs).

1. First, they searched for the predator's pugmarks near the kill site. If found, the pugmarks were measured to determine if the kill was made by tiger (male or female) or leopard.

2. Size of the kill was observed. Tigers usually kill large sized animals, (Seidensticker 1976; John Singh 1992; Karanth and Sunguist 1995). However, Seidensticker (1976), Eisenberg and Lochart (1972) report that adult leopard may prey on small adult cattle. In such cases, a criterion 3 was used to identify the predator.
3. Broken rib bones of medium and large sized prey indicated that a tiger made the kill (Figure 3). Leopards do not have a large enough jaws or strength to break large ribs of cows and buffalos (pers. comm. Smith).
4. Large (> 2.5 cm wide) and deep (5 cm) canine tooth mark indicated a tiger made the kill. (pers. comm. C. McDougal).

All the above criteria were used to determine tiger or leopard kill. A kill that was difficult to confirm by the above criteria was classified as a leopard kill.

Figure 3. **Broken rib bone of this buffalo kill made two weeks previous indicates a tiger made the kill.**

Criteria used to identify Tiger and Leopard Pugmarks

A pugmark is a single paw print. Under certain substrate conditions and using rigorous methods it is possible to identify individual animals from these pugmarks (Smith et al. 1999, McDougal 1999); however, I did attempt to distinguish individuals, but simply to distinguish tiger from leopard and the sex and age class of tigers. Pugmarks were measured in compact, hard or moist surfaces, but to avoid error, we did not measure pugmarks in deep large grained sand or mud. Three measurements were made: pad width, total width and total length (McDougal 1999, WWF 1998b). These were recorded for fore and aft pugmarks of each animal if distinct pugmarks occurred in the appropriate substrate. Although tiger and adult leopard pugmarks are similar in appearance, they are significantly different in size (McDougal 1977). Tiger and leopard pugmarks were separated using criteria in Table 1 (McDougal 1999). A tiger cub with a track pad width similar to an adult male leopard size is < 9 months old and would not be moving without its mother so a lone track with a pad width of 7 cm or less is a leopard.

Table 1. Size criteria used to discriminate tiger versus leopard pugmarks (McDougal 1999).

	Pad width		Total Length
	Front	Rear	Rear
Tiger	≥ 8.5 cm	≥ 7.5 cm	>12 cm
Leopard	< 7.0 cm	< 6.0 cm	< 10 cm

Sex Determination of Adult Tigers from Pugmarks

Male and female tigers were identified by the size of pugmarks. I combined McDougal (1999) and (WWF 1998b) (Table 2).

Table 2. Size criteria used to determine male versus female tiger pugmarks (McDougal 1999; WWF 1998b)

	Pad Width		Total Width
	Front	Rear	Rear
Adult Male	≥ 9.7 cm	≥ 8.5 cm	>11 cm
Adult Female	< 9.3 cm	< 8.5 cm	< 11 cm

Determination of Breeding, Potential Breeding and Non-breeding habitat

Based on sex and age class of tiger sign observed at the survey sites, the area was classified as breeding, potential breeding or non-breeding habitat (Table 3). Breeding habitat was defined as an area where a female with cub pugmarks was documented; potential breeding habitat was defined as an area where male and female pugmarks were documented > 50% of the months during the year; and non-breeding habitat was an area where tigers were present < 50% of the time.

Table 3. Scenarios used to determine Breeding, Potential Breeding and Non-breeding habitat.

Sex Status	% Presence	Habitat Classification
Male + Female + Cub	any occurrence	Breeding
Female + Cub	any occurrence	Breeding
Male + Female	> 50% Presence	Potential Breeding
Male + Female	< 50% Presence	Non-breeding
Male or Female	any occurrence	Non-breeding

Data Collection

Once a month field coordinators visited all Village Rangers. Data forms were collected from the VR and each kill site and pugmark location was visited again by the field coordinator and VR; GPS locations were also recorded. Kills were usually clearly evident within a month after they had been made. Tiger pugmarks lasted for a variable amount of time depending on the substrate and weather; some in soft muddy substrate lasted for several weeks. To reduce trampling of pugmarks, VRs covered them with branches or rocks to preserve the tiger sign. This technique allowed the field coordinator to recheck and verify the species, sex and age class of the animals that produced the sign.

Tiger Survey Data

Tiger surveys were conducted outside the protected areas from February 1999 – May 1999. The survey team consisted of highly trained Tiger Monitoring Field

Technicians from KMTNC, ITNC and DNPWC. Dry riverbeds, streams, dirt trails and jungle trails were surveyed to record tiger sign (e.g. pugmarks, kills, scats). Tiger scat was discriminated from leopard by diameter of the scat. Scat diameter > 4 cm was considered to be tiger sign. Scat data were important during the summer months to determine tiger presence because scats remained intact for > 2 weeks.

When no kills or pugmarks were reported at the VR site during a particular month, the field coordinators traveled with VR for a tiger survey in the forest. Therefore, when sign was absent survey efforts were increased.

RESULTS

Presence / Absence Data

During the course of the study (October 1999 to November 2001) 22 of 30 VRs documented presence of tigers in their areas. A total of 336 tiger observations were reported (Table 4); 235 were tiger sign (e. g. pugmarks, scats), 94 were kills of livestock, 3 were human kills and 4 were dead tigers. Tiger kills consisted of large-sized animals (e.g. buffalo, adult cattle); whereas, leopard kills were generally small-sized animals (e.g. cattle calves, goats, pigs) (Figure 4). In 94 observations of tiger kills 137 animals were killed. On 67 occasions, tigers killed a single animal; on the other occasions they killed 2-7 animals. Of the 137 kills made by tigers 93% were cattle (n=88) and buffalos (n=40), whereas, 91% of kills made by leopards were cow calves, pigs and goats.

Table 4. A total of 336 tiger observations (e. g. tracks, kills, scats) observed by village rangers from October 1999 to November 2001. Also reported are the number of months tiger and cub sign were observed at each VR site.

No.	VR ID	Village	Kills	Tracks	Scats	Mo. Present	Mo. cub present
1	101	Kalapani	2	6	2	7	0
2	102	Singhpur (Krishnapur)	0	0	0	0	0
3	103	Jhil	4	3	0	7	0
4	104	Lakkad	16	27	0	19	2
5	105	Nak Phoduwa	4	21	1	13	1
6	106	Jarai Thada	1	0	0	1	0
7	107	Balchour	6	21	1	15	0
8	108	Geruwani	3	0	0	3	1
9	109	Obhari (Shamshergunj)	12	20	0	16	2
10	110	Agaiya	2	8	1	7	0
11	111	Kumbhar	2	11	0	8	0
12	112	Bairiya Kusum	5	14	0	13	0
13	113	Hardawa	8	10	0	11	0
14	114	Naya Basti	2	7	1	9	0
15	115	Tabdarpur	0	3	0	2	0
16	116	Ramuwadaha	4	3	0	5	0
17	117	Tikkar	1	2	0	2	0
18	118	Mormi	5	5	1	8	0
19	119	Keuli	0	0	0	0	0
20	120	Sukhaura	0	0	0	0	0
21	121	Ghaderi Tandi	4	1	0	4	0
22	122	Siseni	2	8	0	8	0
23	123	Arunkhola	0	0	0	0	0
24	124	Piluwa	3	5	0	5	0
25	125	Ratanpur	3	21	0	13	5
26	126	Simri	0	0	0	0	0
27	127	Gaidatar	1	0	1	1	0
28	128	Phoolbari	0	0	0	0	0
29	129	Sunderpur	0	0	0	0	0
30	130	Balahi	0	0	0	0	0
		Other Areas	11	16	17		
		Total = 336	101	210	25		

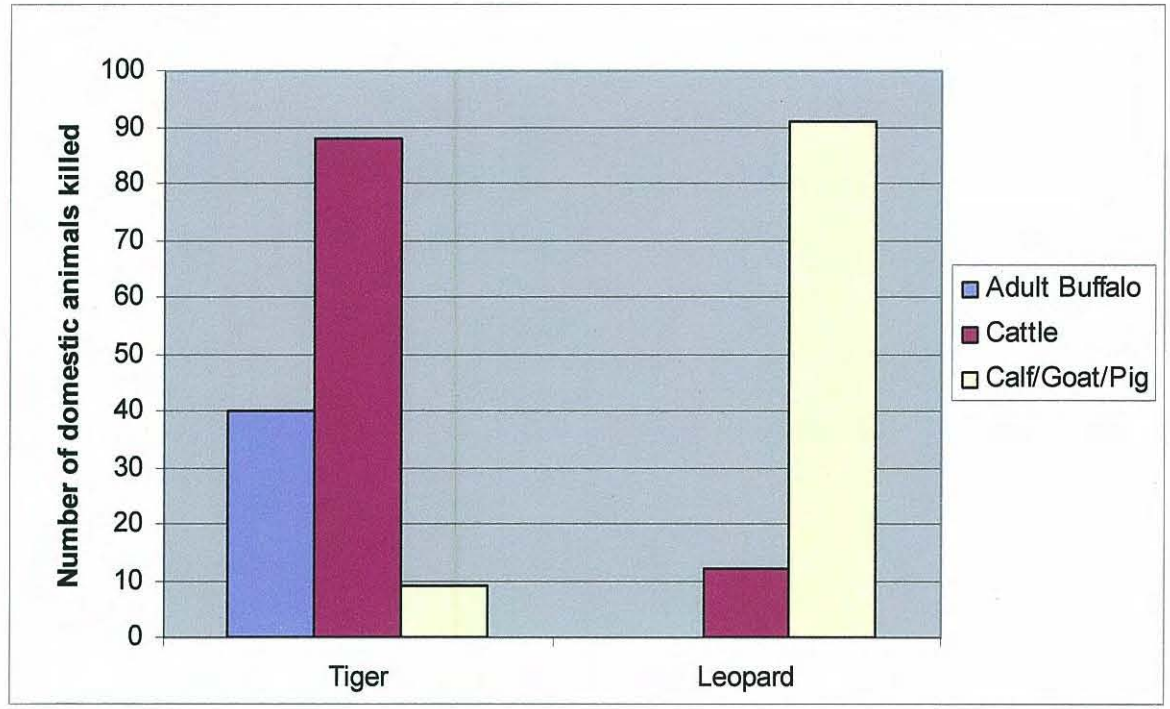


Figure 4. Comparison of tigers and leopards killing domestic animals.

Table 5. Comparison of % occasion versus % animals killed between tiger and leopard

	1 animal killed		2 animals killed		>3 animals killed	
	Tiger	Leopard	Tiger	Leopard	Tiger	Leopard
% of occasions	71	86	19	5	10	9
% of animals killed	49	63	26	8	25	29

In 60 occasions in which I identified that tigers made the kill it was based on the presence of tiger tracks (Table 6).

Table 6. Index of different types of sign found per occasion to identify tiger kills.

Type of sign	Pugmark	Inter-canine Distance	Broken ribs	Total
Pugmark	45	-	-	45
Inter-canine dist.	13	20	-	33
Ribs broken	2	1	13	16
Total	60	21	13	94

Degree of connectivity between reserves

Major gaps in tiger distribution

The data show that tigers are widely distributed in the forests outside protected areas. However, there are two major gaps in distribution, separating the tigers in Nepal into three populations. The Suklaphanta populations is located in far west; in the

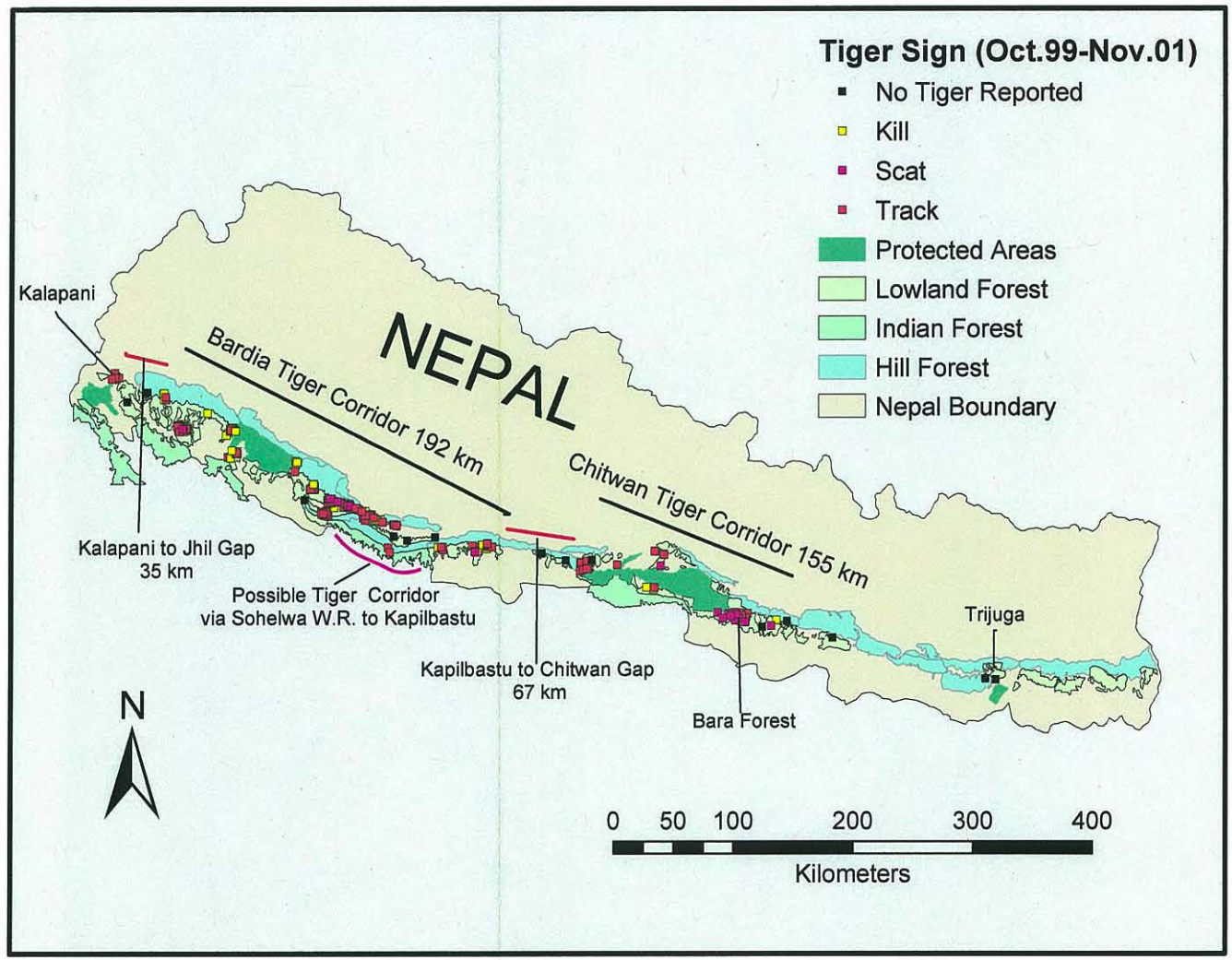
center is Bardia, including RBNP and national forest lands to the east and west; in the east is the Chitwan population which extends from west of RCNP to Bara forest in the east. The gap between the Bardia and the Chitwan populations is 67 km and the gap between Bardia and Suklaphanta is 35 km (Figure 5). These results confirm previous research of Smith et al. (1998). A small remnant population of tigers continued to survive in Trijuga from 1977 to 1994 (Smith et al. 1998). That population appears to have been extirpated around 1994. Two VR obtained no evidence of tigers in Trijuga or east of the Bagmati River during 26 months from October 1999 to November 2001.

Habitat gaps isolate Suklaphanta from Bardia and Dudhwa reserves

The major habitat gap between Suklaphanta and Bardia is between Kalapani and Jhil (35 km) (Figure 5). Tigers were often found at Kalapani, situated near the base of the Siwalik Hills northeast of RSWR. However, the Kalapani forest appears to be a habitat sink or simply unsuitable habitat that is only occasionally visited by tigers; it is used less than 50% of the time (Table 4). The VR based at Krishnapur and Godavari reported that tigers were never observed in these areas. Furthermore, the VR based at Krishnapur, Laljhadi forest, situated between Dudhwa National Park and RSWR, never observed tigers in the corridor between the two areas. So RSWR also appears to be isolated from both Dudhwa Tiger Reserve and Bardia.

East of the gap from Jhil to Bardia, tigers were reported by all the VRs suggesting a Bardia tiger corridor that extends 62 km west of RBNP. This corridor, however, is a tenuous one because at Jarai Thada, 22.1 km west of Bardia we only had one tiger kill during the 26th month study period.

Figure 5 **Locations of tiger kills, pugmarks, scats and tiger gaps between reserves**


Tiger Sign (Oct.99-Nov.01)
No Tiger Reported
Kill
Scat
Track
Protected Areas
Lowland Forest
Indian Forest
Hill Forest
Nepal Boundary
NEPAL
Kalapani
Bardia Tiger Corridor 192 km
Chitwan Tiger Corridor 155 km
Kalapani to Jhil Gap
35 km
Possible Tiger Corridor
via Sohelwa W.R. to Kapilbastu
Kapilbastu to Chitwan Gap
67 km
Bara Forest
Trijuga
N
0 50 100 200 300 400
Kilometers

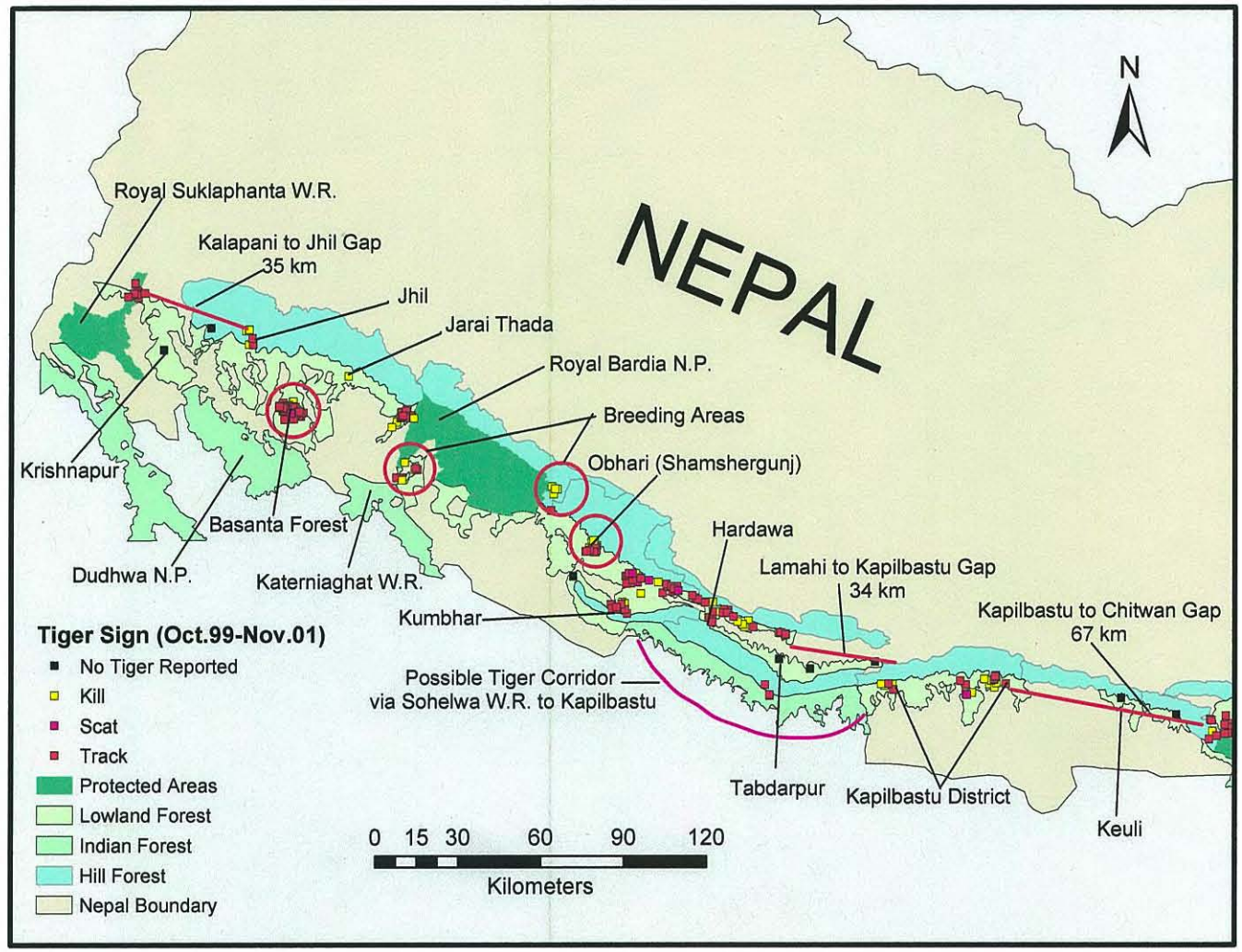
Habitat gaps that isolate RBNP

As described above RBNP is isolated from Suklaphanta; it is also only tenuously connected to Dudhwa Tiger Reserve in India by a narrow strip of forest connecting Basanta Forest and Dudhwa National Park in India. Dispersal of tigers could not be confirmed between Bardia and Dudhwa, but there was no clear habitat barrier to tiger movement (Figure 6).

There appears to be two gaps in tiger distribution between Bardia and Chitwan. The first gap is between Lamahi and Kapilbastu district in Nepal (Figure 6). However, the field coordinator and the village ranger based at Tabdarpur in Dang surveyed a forest at the Indian border and observed male and female tiger tracks suggesting that tigers may disperse eastward through this southern route. Additional evidence of this southern dispersal corridor were observations of tigers south of the Rapti River suggesting the possibility of connections between Bardia and Sohelwa Reserve in India.

The second longer gap, 67 km, occurs between Mormi in Kapilbastu district and Ghaderi Tandi in Nawalparasi district (Figure 5). The city of Butwal, a major tiger barrier, (Smith et al. 1998) lies at the center of the gap. Two VR based at Keuli and Sukhaura in Rupendehi district, east of Butwal never observed tigers in those areas during the study period.

Figure 6. Tiger Breeding Habitats in Western Nepal


NEPAL
N
Royal Suklaphanta W.R.
Kalapani to Jhil Gap
35 km
Jhil
Jarai Thada
Royal Bardia N.P.
Breeding Areas
Obhari (Shamshergunj)
Hardawa
Lamahi to Kapilbastu Gap
34 km
Kapilbastu to Chitwan Gap
67 km
Krishnapur
Basanta Forest
Dudhwa N.P.
Katerniaghat W.R.
Kumbhar
Possible Tiger Corridor
via Sohelwa W.R. to Kapilbastu
Tabdarpur
Kapilbastu District
Keuli
Tiger Sign (Oct.99-Nov.01)
No Tiger Reported
Kill
Scat
Track
Protected Areas
Lowland Forest
Indian Forest
Hill Forest
Nepal Boundary
0 15 30 60 90 120
Kilometers

Habitat gap east of RCNP to Trijuga and Koshi Tappu

Although land ownership is organized into different government units, the forest between Chitwan and Bara is continuous that is 20 - 25 km wide (Figure 7). Tigers still occur in Bara forest; however, they are now rarely found east of Piluwa. Only once was a tiger reported in Gaidatar in the eastern part of Bara; whereas, until 1996 tigers were found fairly common near Gaidatar and Simri village (Smith pers. comm.). A strong barrier to tiger dispersal occurs at the Baghmati River. Tigers were not reported beyond this barrier prior to my study or when I set up my TMN from the Baghmati to Trijuga forest. In summary, tigers now occur regularly as far as the eastern portion of Bara district.

Although tigers occurred in both the Trijuga forest and Koshi Tappu Wildlife Reserve (KTWR) in the early 1970s, they disappeared from KTWR and were becoming rare in Trijuga when Smith (pers. comm.) surveyed the area in 1979. However, there still were tigers in Trijuga forest when it was surveyed in 1994 (Smith et al. 1998). Two Village Rangers were established at Trijuga to monitor tiger activities. During the 26 month study period, no tigers were reported (Table 4). It appears the tiger is extirpated from the Trijuga area.

Bardia tiger population

The Bardia tiger population resides in a narrow 192 km long belt of forest that extends 62 km west and 79 km east of RBNP (Figure 5). I classified two areas east and two west of RBNP as breeding areas (Figure 6). Although there appears to be a break in tiger distribution on the east side of Bardia between Lamahi and Kapilbastu

Figure 7. Tiger Breeding Habitats in Central Nepal


N
NEPAL
Sukhaura
Chitwan N.P.
Parsa W.R.
Bara Forest
Baghmati Bridge
Trijuga
Daune Hills
Simri
Gaidatar
Breeding Area
Koshi Tappu W.R.
Tiger Sign (Oct.99-Nov.01)
No Tiger Reported
Kill
Scat
Track
Protected Areas
Lowland Forest
Indian Forest
Hill Forest
Nepal Boundary
0 15 30 60 90 120
Kilometers

(Figure 6), this gap may be misleading because there may be an alternative dispersal route between Kumbhar, Hardawa and Kapilbastu via a southern corridor that extends through Sohelwa Wildlife Reserve in India along the southern slopes of the Siwalik Hills.

Chitwan tiger population

The entire Chitwan tiger population extends 155 km east to west. To the west of Chitwan the situation is similar to that reported by Smith over the past 25 years (Smith et al. 1987, Smith 1993, Smith et al. (1998). Tigers make forays west of Chitwan into the Daune Hills and northwest to the Binai River; however, a combination of poor habitat, high rate of tiger poisoning, and human disturbance limits tigers use of these areas making them strong population sinks and poor corridors with no reported breeding.

On the east side of Chitwan, tigers occur in PWR and Bara Forest. However, habitat in eastern Bara appears to be shrinking due to habitat fragmentation and intensive illegal hunting pressure. Smith (1999) reported breeding tigers near Simri Village in eastern Bara from 1978 until 1994, but during this study, no tiger sign was recorded at this location. Only one breeding area in the central portion of Bara Forest remains. The lack of tiger locations limited tiger occurrence in the eastern part of Bara, suggests that the habitat quality there has declined (Figure 7).

Areas classified as breeding and potentially breeding habitat

Five areas were identified as breeding habitat based on the presence of cub tracks accompanied by female tracks (Figure 6, 7). Four of the breeding habitats were reported by five of the VRs (Table 7). The fifth breeding area, south of RBNP toward

Katerniaghat in India, was identified during the tiger survey. Basanta Forest was identified as breeding habitat by two VRs at Lakkad and Nak Phoduwa. Although cub tracks were not present, one area was classified as potential breeding areas based on presence of both male and female tracks in the area at least 50% of the year (Table 7). In total 271 tiger locations with gender identifications were documented. Sex was identified based on size of tracks on 267 occasions and by sexing dead tigers 4 times. Distribution of male tigers was wider (19 VRs sites) than female (12 sites) (Table 7).

Table 7: Breeding, Potential breeding and Non-breeding Areas with numbers of male, female and cub locations reported by VR.

No.	VR ID	Village	Male	Female	Cub	Breed / Potential / Non-breed
1	101	Kalapani	4	3	0	Non-breeding
2	103	Jhil	5	0	0	Non-breeding
3	104	Lakkad	28	9	3	Breeding
4	105	Nak Phoduwa	15	6	1	Breeding
5	107	Balchour	16	10	0	Potential breeding
6	108	Geruwani	0	1	1	Breeding
7	109	Obhari	17	9	3	Breeding
8	110	Agaiya	10	0	0	Non-breeding
9	111	Kumbhar	13	0	0	Non-breeding
10	112	Bairiya Kusum	11	2	0	Non-breeding
11	113	Hardawa	18	0	0	Non-breeding
12	114	Naya Basti	6	2	0	Non-breeding
13	115	Tabdarpur	2	1	0	Non-breeding
14	116	Ramuwadaha	6	0	0	Non-breeding
15	117	Tikkar	3	0	0	Non-breeding
16	118	Mormi	6	0	0	Non-breeding
17	121	Ghaderi Tandi	3	0	0	Non-breeding
18	122	Siseni	5	4	0	Non-breeding
19	124	Piluwa	1	5	0	Non-breeding
20	125	Ratanpur	4	10	8	Breeding
		Other areas	11	7	2	
		Total= 271	184	69	18	

DISCUSSION

Biological Importance of Data

Corridors

My data show that tigers occur throughout most of the corridor between Bardia national park and Suklaphanta wildlife reserve and within large stretches of corridor habitat between Bardia and Chitwan national parks. Among the three populations, dispersal between Suklaphanta and Bardia is more likely to occur because the gap where tigers are not known to occur is relatively short, 35 km, compared to the gap of 67 km between Bardia and Chitwan. Furthermore, the city of Butwal is at the center of the gap between Bardia and Chitwan. This city lies at the base of the Siwalik Hills. There is no forest cover to the south; to the north, there is a steep gorge with cliffs that even a tiger might have difficulty negotiating in an attempt to cross the gorge. At the north end of the gorge there is a narrow valley where the river bifurcates into smaller rivers that are aligned east west. This valley and its hillsides are intensively settled. Smith (1984) described Butwal and the gorge as a strong barrier to tiger dispersal. Because no tigers were found in villages 10 and 30 km east of Butwal supports Smith's earlier conclusion that Butwal forms a strong barrier to tiger dispersal.

Breeding Habitat

Five areas were identified where there is evidence of breeding tigers. In each breeding area the evidence is unequivocal. cubs were sighted or tracks of cubs observed in association with female tiger tracks. In other non-breeding areas, the evidence is circumstantial. We concluded, if both male and female tigers are found in the area most of the year there is potential for breeding. Tigers in these breeding areas

need to be the topic of more in-depth ecological and behavioral studies. To date, tiger research has focused on tigers living in prime habitat either in RCNP or RBNP. However, it is critical to understand the behavior and reproductive success of tigers living in the human dominated portion of the landscape.

It is likely that breeding areas outside protected areas are net population sinks. Even if this is true, Pulliam (1988) suggested that, a weak sink population and a strong source population in combination can result in a larger, more stable population than the source population alone. The source-sink dynamics in Nepal are unknown and also need to be further investigated. However, wildlife managers and conservation biologists are often concerned that populations below 50 animals are at an increased risk of extinction. Although, Kenney et al. (1995) demonstrated that populations of 25 breeding animals have a high probability of surviving 100 years given known demographic stochasticity, the probability of survival of a population of this size in response to genetic (inbreeding depression or resistance to disease) factors or environmental stochasticity is unknown. Faced with similar unknowns, conservation biologists have formulated the cautionary principle (Bodansky 1991). Applying this concept to tigers in Nepal suggests that managers should opt for larger habitat less extinction prone populations. To achieve a larger population requires a major effort to conserve forests outside protected areas as corridor and breeding habitat. Regardless of the outcome of future research on source-sink population dynamics in Nepal, one can argue that maintaining these sink habitats might also be worthwhile because restoration of a weak sink is clearly easier than restoring habitat so degraded that it no longer supports breeding tigers. Furthermore, habitat with an adequate prey base to

support breeding is likely to be a higher quality dispersal corridor than one with a lower abundance of prey.

Village Ranger: A new approach to tiger monitoring

My approach of recruiting villagers to serve as Village Rangers was based on a need to monitor tiger activity across the lowlands of Nepal throughout the entire year. In addition, kill and track surveys are less expensive than radio telemetry (Riordan 1998) and involve participation by local people. This approach has potential implications for monitoring tigers over a large habitat that tigers utilize. Furthermore, the Village Rangers are local residents, thus the data on tiger use of forest habitat are obtained in much greater depth and intensity than in previous studies (Smith et al. 1998). In addition to the corridor habitat, we were also able to identify breeding habitats used by tigers. Thus, the important information on tiger use of corridor or breeding habitats outside protected areas is determined with reliable data collected by Village Rangers. This information is of great importance in justifying the restoration efforts to maintain the connectivity between reserves.

With establishment of long-term monitoring of tigers using Village Rangers, information on poaching of tigers or their prey or habitat degradation is obtained. Such information is useful for respective authorities when provided quickly through a good communication network. Rapid information can minimize poaching incidents by allowing law enforcement personal to make quick decisions and immediate actions.

Community based conservation evolved because managers realized that conservation will not be successful using a top down authority approach. Unless human resource needs are met, people will continue to encroach into forests.

Community participation in the restoration of degraded forest habitat in a buffer zone of RCNP has been successful (Dinerstein et al.1999) and has increased local interest in conservation activities. Support of local people (Tilson & Nyhus 1998) and positive attitudes (Simonetti 1995) are important in dealing with human tiger conflicts (Mishra et al. 1987). Because conflicts are more likely to occur in multiple use forests (e.g. buffer zone and national forests) and these forests are critical habitat, it is important to include local participation in conservation programs and conservation education beyond buffer zones of protected areas to a broader landscape. Wildlife and local people share these forests and it is not feasible to convert all tiger habitat into protected areas (Dinerstein & Wikramanayake 1993). However, forests can be managed to meet the needs of tigers and local people through community forestry and the participation of local people in decision making. The Village Ranger system adds an additional component to community-based conservation by seeking help from local people in monitoring tigers. Village Rangers soon learn the needs of tigers and act as local experts who can guide local input to participatory management. This approach is gaining acceptance globally. Mishra (1987) suggested that tigers should be profitable for people surrounding tiger habitat rather a financial burden.

Involvement of local people in our program was both a necessity to accomplish our objective of monitoring tiger habitat use and also met an underlying goal of our project to enlist the help of local people in conserving tigers. Concern for tigers grew as villager Rangers learned more about basic natural history and needs of the species. The VRs take great pride in their tiger conservation work.

The presence of the VR helped reduce tiger poisoning to some extent. One such case was reported from Obhari where tiger poisoning was common in the past. After establishment of the VR, villagers were more cautious about poisoning the carcasses to kill tigers because the VR visits every domestic animal carcass killed by a tiger or leopard to record the data. These visits might reveal poisoning activities. Therefore, there is awareness about poisoning the carcasses and this appears to reduce overall frequency of tiger poisoning.

Another important aspect of the Village Ranger based tiger monitoring approach is the mid level management or field coordinator. Because the coordinator visits Village Rangers each month, the VRs remain motivated all times. Regular meetings help them both individuals to understand each other better and thus promote good relationships, co-operation, and trust. Therefore, exchange of information for capacity building was more smooth and comfortable. Furthermore, re-verification of kills and track data by field coordinator yielded high quality data.

Tiger Conservation Awareness through Village Ranger

With establishment of Village Rangers across the lowlands of Nepal, awareness of tiger conservation is reaching a new audience. Previously, conservation education was focused in urban areas and buffer zones adjacent to protected areas. VRs are local residents of their villages and they have enlisted the help of other villagers not only in their own village, but also in other nearby villages. One of the first things the Village Rangers requested was a simply written brochure describing the natural history of tigers and purpose of their project. Local villagers across Nepal are beginning to feel some pride that they are collecting information about tigers. They

also express very clearly that tigers are a natural heritage of both the nation and the people of Nepal. This is not a utopian situation. Tigers kill livestock and people get angry and poison carcasses to kill problem tigers. It is important in developing conservation programs similar to the VR project to recognize there is often ambivalence in human attitude towards tigers, elephants and bears. However, villagers in Nepal express all the same reasons for saving tigers that conservationists do. Furthermore, villagers across the lowlands of Nepal are helping the Village Rangers collect data. To help local attitudes, we encouraged local conservation non governmental organization, Environmental Camps for Conservation Awareness (ECCA), to start conservation camps for school children in each village where VRs reside.

Similar local participation in monitoring biodiversity is a rapidly spreading phenomenon that was a natural progression from earlier efforts of international rapid assessment teams is a significant accomplishment in conservation because local participation advances community-based conservation.

In summary, the Village Ranger based approach is useful for determining distribution of tigers throughout the lowlands of Nepal in much greater detail than done in previous studies. Furthermore, involvement of local people in the monitoring work created a sense of tiger conservation awareness in their community. However, domestic animals killed by tigers indicate conflicts between tigers and human cannot be ignored. Further assessment of habitat use by livestock and natural tiger prey species is an important topic for future research.

LITERATURE CITED

Bangjie, T. (1987). Status and Problems of Captive Tigers in China, In Tigers of the World: The Biology, Biopolitics, Management and Conservation of an Endangered Species, ed. R. L. Tilson & U. S. Seal, pp 134-148. Park Ridge, New Jersey, Noyes Publications.

Bodansky, D. (1991). Scientific uncertainty and the precautionary principle. Environment, **33 (4-5),** 43-44.

Dinerstein, E. and E. D. Wikramanayake (1993). Beyond "hotspots": how to prioritize investments to conserve biodiversity in the Indo-Pacific region. Conservation Biology, **7 (1)**, 53-65.

Dinerstein, E., E. Wikramanayake, J. Robinson, U. Karanth, A. Rabinowitz, D. Olson, T. Mathew, P. Hedao, M. Connor, G. Hemley, and D. Bolze (1997). A framework for Identifying High Priority Areas and Actions for the Conservation of Tigers in the Wild. Part 1. Washington DC, World Wildlife Fund-US and Wildlife Conservation Society.

Dinerstein, E., A. Rijal, M. Bookbinder, B. Kattel, and A. Rajuria (1999). Tigers as neighbors: efforts to promote local guardianship of endangered species in lowland Nepal, In Riding the Tiger: Tiger conservation in human-dominated landscapes, ed. J. Seidensticker, S. Christie and P. Jackson, pp 316-332. Cambridge University Press, Cambridge, United Kingdom.

DNPWC (1996). Report on a Tiger Census of Royal Chitwan, Parsa, and Bardia National Parks. Kathmandu, Nepal.

DNPWC (1999). Tiger conservation action plan for the Kingdom of Nepal. WWF Nepal Program, Kathmandu, pp 32.

Dorji, D. P. and C. Santiapillai (1989). The status, distribution and conservation of the tiger *Panthera tigris* in Bhutan. Biological Conservation, **48**, 311-319.

Eisenberg, J. F. and M. Lochart (1972). An Ecological Reconnaissance of Wilpattu National Park, Ceylon. Smithsonian Contributions to Zoology, **101**, pp 118.

Gee, E. P. (1964). The Wildlife of India. London, Collins.

Grumbine, R. E. (1994). What is ecosystem management? Conservation Biology, **8**, 27-38.

Grumbine, R. E. (1997). Reflection on "What is Ecosystem Management?" Conservation Biology, **11**, 41-47.

Hean, S. (2000). Status of the tiger and its conservation in Cambodia. University of Minnesota, M. S. Thesis, Minneapolis, MN, USA.

IUCN (1996). Red list of Threatened Animals compiled and edited by Jonathan Baillie and Brian Groombridge, *IUCN*, Gland, Switzerland.

Jackson, P. (1993). Status of the tiger in 1993 and threats to its future. Cat News, **19**, 5-11.

Jackson, P. (1998). Current status of the Tiger. Cat News, **28,** 11.

Jackson, P. (1999). The tiger in human consciousness and its significance in crafting solutions for tiger conservation, In Riding the Tiger: Tiger conservation in human-dominated landscapes, ed. J. Seidensticker, S. Christie and P. Jackson, pp 50-54. Cambridge University Press, Cambridge, United Kingdom.

Jackson, P. and Kemf E. (1999). Tigers in the wild- wanted alive. WWF, Gland, Switzerland. pp 24.

John Singh, A. J. T. (1992). Prey Selection in three large sympatric carnivores in Bandipur. Mammalia, **56.** 517-525.

Karanth, U. K. and M. E. Sunquist (1995). Prey selection by tiger, leopard and dhole in tropical forests. Journal of Animal Ecology, **64,** 439-450.

Karanth, U. K. and B. M. Stith (1999). Prey depletion as a critical determination of tiger population viability, In Riding the Tiger: Tiger conservation in human-dominated landscapes, ed. J. Seidensticker, S. Christie and P. Jackson, pp 100-113. Cambridge University Press, Cambridge, United Kingdom.

Kenney, J. S, J. L .D. Smith, A. M. Starfield and C. McDougal (1995). The long term effects of tiger poaching on population viability. Conservation Biology, **9**, 1127-1133.

Martin, E. B. (1992). The poisoning of rhinos and tigers in Nepal. Oryx, **26**, 82-86.

McDougal, C. (1977). The Face of the Tiger. Rivington Books / Andre' Deutsch, London W. C. 1.

McDougal, C. and K. Tshering (1998). Tiger Conservation Strategy for the Kingdom of Bhutan. Nature Conservation Section. Forestry Service Division. Ministry of Agriculture/WWF.

McDougal, C. (1999). You can tell some tigers by their tracks with confidence, In Riding the Tiger: Tiger conservation in human-dominated landscapes, ed. J. Seidensticker, S. Christie and P. Jackson, pp 190. Cambridge University Press, Cambridge, United Kingdom.

Mishra, H., C. Wemmer and J. L. D. Smith (1987). Tigers in Nepal: Management conflicts with Human Interest, In Tigers of the World: The Biology, Biopolitics, Management and Conservation of an Endangered Species, ed. R.L. Tilson & U.S. Seal, pp 449-462. Park Ridge, New Jersey, Noyes Publications.

Noss, R. F. (1987). Corridors in real landscapes: A reply to Simberloff and Cox. Conservation Biology, **2,** 159-164.

Novell, K. (2000). Traffic Network, Traffic International, Cambridge, UK. pp 100.

Oza, G. M. (1986). Threats to unique wildlife through Indian habitat destruction. Environmental Conservation, **13**, 131-136.

Panwar, H. S. (1979). International Symposium on Tiger. The Indian Forester, **105**, 243-248.

Pradhan, A. S. and P. J. Parks (1995). Environmental and Socioeconomic Linkages of Deforestation and Forest Land Use Change in the Nepal Himalaya, In Property Rights in a Social and Ecological Context, ed. S. Hanna and M. Munasinghe, pp 167-179. The World Bank, Washington D. C., USA.

Pulliam, R. H. (1988). Source, sinks, and population regulation. The American Naturalist, **132,** 652-661.

Riordan, P. (1998). Unsupervised recognition of individual tigers and snow leopards from their footprints. Animal Conservation, **1,** 253-262.

Rabinowitz, A. (1993). Estimating the Indochinese tiger *Panthera tigris corbetti* population in Thailand. Biological Conservation, **65**, 213- 217.

Seidensticker, J. (1987). Bearing witness: observations on the extinction of *Panthera tigris balica* and *Panthera tigris sondaica*, In Tigers of the world: The

Biology, Biopolitics, Management and Conservation of an Endangered Species, ed. R. L. Tilson and U. S. Seal, pp 1-8. Park Ridge, New Jersey, Noyes Publications.

Seidensticker, J. (1976). On the ecological separation between tigers and leopards. Biotropica, **8 (4),** 225-234.

Seidensticker, J. and C. McDougal, (1993). Tiger predatory behavior, ecology and conservation. Symposia of the Zoological Society of London, **65**, 105-125.

Seidensticker, J. (1997). Saving the tiger. Wildlife Society Bulletin, **25 (1),** 6-17.

Shrestha, T. K. (1997). Mammals of Nepal, R. K. Printers, Kathmandu, Nepal.

Simonetti, J. A. (1995). Wildlife conservation outside parks is a disease-mediated task. Conservation Biology, **2**, 454-456.

Smith, J. L. D. (1984). Dispersal, communication, and conservation strategies for the tiger *(Panthera tigris)* in Royal Chitwan National Park, Nepal. University of Minnesota, Ph.D. Dissertation. Minneapolis, MN. USA.

Smith, J. L. D., C. McDougal and M. E. Sunquist (1987). Female land tenure systems in tigers. In Tigers of the World: The Biology, Biopolitics, Management and Conservation of an Endangered Species, ed. R.L. Tilson & U.S. Seal, pp 97-109. Park Ridge, New Jersey, Noyes Publications.

Smith, J. L. D., C. McDougal and D. Miquelle (1989). Scent marking in free- ranging tigers *Panthera tigris*. Animal Behavior, **37**, 1-10.

Smith, J .L. D. and C. McDougal (1991). The contribution of variance in lifetime reproduction to effective population size in tigers. Conservation Biology, **5**, 484-90.

Smith, J. L. D. (1993). The role of dispersal in structuring the Chitwan tiger population. Behavior, **124**, 165-95.

Smith, J. L. D., S. C. Ahearn and C. McDougal (1998). A landscape analysis of tiger distribution and habitat quality in Nepal. Conservation Biology, **12**, 1338-46.

Smith, J. L. D., C. McDougal, S. C. Ahearn, A. Joshi and K. Conforti (1999). Metapopulation structure of tigers in Nepal, In Riding the Tiger: Tiger conservation in human-dominated landscapes, ed. J. Seidensticker, S. Christie and P. Jackson, pp 176-189. Cambridge University Press, Cambridge, United Kingdom.

Staiton, J. D. A. (1972). Forests of Nepal. London, John Murray, Ltd.

Sunquist, M. E. (1981). The social organization of tigers (*Panthera tigris*) in Royal Chitwan National Park, Nepal. Smithsonian Contributions to Zoology, **336**, 1-98.

Tamang, K. M. (1982). The status of the tiger *(Panthera tigris)* and its impact on principal prey population in Royal Chitwan National Park, Nepal. East Lansing, Michigan State University, Ph.D. Dissertation. MI, USA.

Tilson, R. and Philip Nyhus (1998). Keeping problem tigers from becoming a problem species. Conservation Biology, **2**, 261-262.

Upreti, B. N. (1992). Wildlife Protection in Nepal. KMTNC, ACAP Report, Kathmandu, Nepal.

Wikramanayake, E., E. Dinerstein, U. Karanth, A. Rabinowitz, et al. (1998). An ecology-based method for defining Priority for large mammal conservation. The tiger as a case study. Conservation Biology, **12**, 865-878.

Wilcox, B. A. & D. D. Murphy (1985). Conservation Strategy: The effects of fragmentation on extinction. American Naturalist, **125,** 879-887.

WWF (1998a). Tiger Status Report: 1998 the WWF Year for the Tiger. WWF-UK, Surrey, United Kingdom, pp 46.

WWF (1998b). Tiger Manual: Indirect field study techniques for the Kingdom of Nepal, compiled and edited by S. Gnawali and S. Gundersen. WWF Nepal Program, Kathmandu, pp 94.

WWF (2001). Terai arc landscape, Nepal. WWF Nepal Program, Kathmandu, pp 51.

Appendix I.

Part I: Name, age, address, occupation and location of 30 "Village Rangers:

ID	NAME	AGE	VILLAGE	ADDRESS	OCCUPATION	Y	X
101	Chandra Singh Dhami	50 yrs	Kalapani	Jhalari-2, Kanchanpur, Mahakali	Community Leader	2857333	8021729
102	Naththu Ram Choudhary	30 yrs	Singhpur	Krishnapur-7, Kanchanpur, Mahakali	Community Leader	2849070	8029241
103	Krishna Prasad Acharya	56 yrs	Jhil	Choumala-4, Kailali, Seti	Former Hunter	2847585	8043579
104	Ram Prasad Choudhary	45 yrs	Lakkad	Basauti-6, Kailali, Seti	Livestock Herder	2837401	8048875
105	Hori Lal Choudhary	54 yrs	Nak Phoduwa	Pahalwanpur-9, Kailali, Seti	Former Hunter	2836601	8054855
106	Dil Bdr Gautam	38 yrs	Jarai Thadha	Dododhara-9, Kailali, Seti	Farmer / Shop	2841991	8102665

ID	NAME	AGE	VILLAGE	ADDRESS	OCCUPATION	Y	X
107	Sukla Sonaha	40 yrs	Balchour	Baliya-9, Kailali, Seti	Farmer / Fisherman	2836325	8113282
108	Kabiram Budhathoki (Chhetri)	35 yrs	Geruwani	Chhinchu-1, Surkhet, Bheri	Farmer	2820804	8144733
109	Govardhan Oli (Chhetri)	33 yrs	Obhari	Mahadevpur-7, Banke, Bheri	Farmer	2807758	8148632
110	Jalu Ram Choudhary	28 yrs	Agaiya	Kachanapur-1, Banke, Bheri	Former Hunter	2802506	8157490
111	Ali Ram Choudhary	35 yrs	Kumbhar	Baijapur-3, Banke, Bheri	Farmer	2759923	8154716
112	Dambar Bdr Kumal	29 yrs	Bairiya	Khaskusma-2, Banke, Bheri	Farmer	2800645	8205467
113	Bala Ram Pun	46 yrs	Hardawa	Satbariya-9, Dang, Rapti	Livestock Herder	2756986	8216905
114	Aita Ram Baral (Magar)	62 yrs	Naya Basti	Satbariya-3, Dang, Rapti	Former Hunter	2752675	8227003

ID	NAME	AGE	VILLAGE	ADDRESS	OCCUPATION	Y	X
115	Kulbir Choudhary	50 yrs	Tabdarpur	Bela-3, Dang, Rapti	Community Leader	2749485	8227441
116	Ajaya Roka	20 yrs	Ramuwadaha	Shiwagadhi-3, Kapilbastu, Lumbini	Livestock Herder	2742650	8248563
117	Bhui Lotan Tharu	50 yrs	Tikkar	Mahendrakot-5, Kapilbastu, Lumbini	Livestock Herder	2743076	8302551
118	Om Bdr Baral (Chhetri)	58 yrs	Mormi	Motipur-9, Kapilbastu, Lumbini	Livestock Herder	2742719	8308880
119	Parman Thapa	29 yrs	Keuli	Devdaha-3, Rupendehi, Lumbini	Farmer	2740588	8333545
120	Min Bdr Pun	45 yrs	Sukhaura	Dhurkot-7, Nawalparasi, Lumbini	Community Leader	2736638	8345024
121	Mitra Lal Midhun Magar	58 yrs	Ghaderi Tadi	Dumkibas-3, Nawalparasi, Lumbini	Community Member	2736688	8350150
122	Bir Bdr Kumal	42 yrs	Siseni	Dumkibas-8, Nawalparasi, Lumbini	Community Member	2734097	8354720

ID	NAME	AGE	VILLAGE	ADDRESS	OCCUPATION	Y	X
123	Amar Pun	24 yrs	Arunkhola Tadi	Naya Belhani-8, Nawalparasi, Lumbini	Intelligence / Agriculture	2736934	8357106
124	Ashok Sapkota Chhetri	24 yrs	Piluwa	Dumarwana-7, Bara, Narayani	Intelligence / Shop	2709998	8503761
125	Feku Gurau	45 yrs	Ratanpur	Ratanpuri-1, Bara, Narayani	Farmer / Gurau	2714847	8506515
126	Bhagirath Choudhary	37 yrs	Simri	Kanakpur-5, Rautahat, Narayani	Farmer	2706059	8513787
127	Shant Lal Kunwar	36 yrs	Gaidatar	Chandranigahpur-3, Rautahat, Narayani	Farmer	2710199	8520602
128	Indra Bdr Syangtan	42 yrs	Phoolbari	Judibela-1, Rautahat, Narayani	Former Hunter	2709353	8524679
129	Ram Dev Choudhary	36 yrs	Sunderpur	Sunderpur-5, Udayapur, Koshi	Farmer / Shop	2645387	8654335
130	Dev Narayan Choudhary	30 yrs	Balahi	Tapeswori-6, Udayapur, Koshi	Livestock Herder	2644165	8658443

Part 2: Distance from one "Village Ranger" village to another

Sno	Village (ID) to Village (ID)	Distance (km)	Remarks
1.	Kalapani (101) to Singhpur (102)	19.6	
2.	Kalapani (101) to Jhil (103)	39.8	Along the hills
3.	Singhpur (102) to Jhil (103)	23.5	
4.	Jhil (103) to Lakkad (104)	20.8	
5.	Lakkad (104) to Nak Phoduwa (105)	9.9	Basanta Forest
6.	Jhil (103) to Jarai Thada (106)	32.9	Along the hills
7.	Nak Phoduwa (105) to Jarai Thada (106)	16.5	
8.	Jarai Thada (106) to Balchour (107)	20.4	Along the hills
9.	Geruwani (108) to Obhari (109)	25	
10.	Obhari to Park border (RBNP)	22.4	
11.	Obhari (109) to Agaiya (110)	17.5	
12.	Agaiya (110) to Kumbhar (111)	6.7	Towards Indian border
13.	Agaiya (110) to Bairiya (112)	13.4	

14.	Bairiya (112) to Hardawa (113)	20	
15.	Hardawa (113) to Naya Basti (114)	19.1	
16.	Naya Basti (114) to Tabdarpur (115)	5.8	Village and cultivated land
17.	Kumbhar (111) to Tabdarpur (115)	57.4	Along Indian border
18.	Tabdarpur (115) to Ramuwadaha (116)	37.1	Along Indian border
19.	Ramuwadaha (116) to Tikkar (117)	23	
20.	Tikkar (117) to Mormi (118)	10.2	
21.	Mormi (118) to Keuli (119)	40.9	Butwal town in between
22.	Keuli (119) to Sukhaura (120)	20.1	Along the hills
23.	Sukhaura (120) to Ghaderi Tadi (121)	8.4	Over the hills
24.	Ghaderi Tadi (121) to Siseni (122)	8.8	
25.	Siseni (122) to Arunkhola Tadi (123)	6.5	
26.	Piluwa (124) to PWR border	12.8	
27.	Piluwa (124) to Ratanpur (125)	9.9	
28.	Piluwa (124) to Simri (126)	18.3	

29.	Simri (126) to Gaidatar (127)	13.6	
30.	Gaidatar (127) to Phoolbari (128)	6.8	
31.	Phoolbari (128) to Sunderpur (129)	155	Bagmati to Koshi
32.	Sunderpur (129) to Balahi (130)	7.5	