FINAL REPORT

To:

The National Fish and Wildlife Foundation

Tiger Conservation and Priority Areas for Ecological Restoration
A Landscape Approach
2001-2003

Submitted by:

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BACKGROUND

This report summarizes four sub-projects supported in our original proposal. These projects, undertaken between 2001 and 2003, were delayed or modified because of Maoist activities in the Terai. For example, we had to wait until 2003 to visit all village rangers and recruit new ones because of political disturbances. Despite the challenges of Maoist activities and delays in conducting field work, funding from this proposal supported 2 students who completed M.S. degrees (Bhim Gurung; Adam Barlow) and one student who will complete his Ph.D. in September (Mahendra Shrestha). The projects are listed below:

I. Using a Village Ranger" Network to Map the Metapopulation Structure of Tigers in Nepal.

The primary objective of this project was to determine if there is potential connectivity among populations of tigers that occur in Royal Chitwan National Park, Bardia National Park, Sukla Phanta Wildlife Reserve, and the Dudwa Tiger Reserve. A secondary objective was to recruit local citizens to participate in monitoring tigers.

II. Obtaining base line data on the distribution of wild and domestic prey across the forests of the Terai Arc Landscape (TAL).

These data provide a baseline with which to evaluate management activities undertaken as part of TAL. Analysis of these data in relation to natural ecological variables and human impacts are critical to tiger conservation because abundance of prey is a major determinant of tiger distribution and density.

III. Forest classification of the Terai Arc Landscape (TAL) to identify and analyze tiger and tiger prey habitat.

Forest classification is basic to TAL planning and identification of critical habitat. It also is possibly the most important predictor of prey abundance. Based on this classification and data on where tigers are either absent or breeding has helped WWF identify 8 critical high priority management zones. These high priority areas are either places where tigers are breeding or where habitat fragmentation reduces the probability of genetic exchange among tiger populations.

IV. Collaring tigers to study behavior of tigers living in human dominated landscape.

This project entailed capturing and fitting tigers with GPS collars. We hypothesized that the behavior of tigers living in the human dominated portion of the landscape may differ from tigers in protected areas.

I. Using a "Village Ranger" Network to Map the Metapopulation Structure of Tigers in Nepal

Mapping the potential for tigers to disperse between populations centered in protected areas is difficult because dispersal is a rare event that is difficult to observe. In earlier studies, Smith et al. (1987, 1998) surveyed tiger distribution for approximately 20 days per year. Survey effort for each locality (e.g. watershed) included: 1) a recce route of 5-6 km covered in a single day and 2) an informal survey of villagers near the recce route to determine tiger activity during the rest of the year. This approach was a reasonable first step and successfully identified areas that tigers used extensively. However, it was not adequate to determine extent of habitat connectivity. To more thoroughly assess potential for tiger dispersal, we undertook a project that increased survey effort per year 365 fold; through December 2003, our survey effort encompassed nearly 1500 days.

The goals of our research were to determine if a metapopulation structure existed among a group of tiger populations (core areas are in 4 protected areas in Nepal and an adjacent reserve in India) and if breeding occurs outside protected areas. To accomplish this, we utilized local citizens recruited as "Village Rangers" to collect information on distribution of livestock kills and other tiger sign. Specific objectives were to: 1) establish a community-based network of "Village Rangers" to accomplish objectives 2 and 3 and to increase citizen knowledge of tiger conservation issues, (2) determine if structural forest corridors that connect protected areas potentially function as dispersal corridors for tigers, (3) determine if tiger breeding occurs in forests outside protected areas, and (4) provide information needed by the government to help develop a restoration plan to increase connectivity and the total land base that supports tigers and biodiversity in Nepal.

METHODS

Study Area

Establishment and Training of "Village Ranger" Network

The Village Ranger (VR) network was established in 11 Terai districts in 7 administrative zones that extend from the Koshi River in the east to the Mahakali River in the west. We trained rangers to assess tiger habitat use and breeding areas outside protected areas throughout the Terai. We also recognized the potential for this network to increase involvement of local people in regional conservation efforts. We chose VRs, who lived in the area year around and were familiar with the forest near their village. Two field coordinators were hired to supervise the Village Rangers; both had several years of experience conducting tiger surveys. To provide quality control, these technicians visited each VR monthly. Together the VR and field coordinator traveled to the site of each kill or track to verify it was made by a tiger and to collect a GPS location. These site visits provided VRs an opportunity to improve their professionalism by interacting monthly with a tiger expert.

Four training and evaluation workshops were conducted (Dec 1999, Mar 2000, Jun 2002, Mar 2003). The main objective of the first two workshops was to train VRs to record data on livestock depredation. Expert tiger field technicians from the International Trust for Nature Conservation, the King Mahendra Trust for Nature Conservation and the Department of National Parks and Wildlife Conservation trained the VRs. At the 3rdnd and 4th workshop an ongoing dialogue among the VRs and wildlife technical staff sought to improve our project through an adaptive monitoring process.

Assessing Habitat Connectivity

To choose the location of survey sites we used a satellite image map of the entire Terai region (1:250,000) to delineate forest cover, rivers and road networks, and to identify large forest blocks that might support tigers. Sites were at set distances of < 30 km along a potential corridor. Because we were primarily interested in establishing connectivity, we excluded isolated forest blocks that were not potential corridors if no tigers were reported after we informally interviewed local people in those areas. A total of 28 survey sites were selected from the potential corridor habitat of tigers in Nepal. In addition, 2 non-corridor sites (> 30 km from other sites) were selected in eastern Nepal to determine if tigers were extirpated from the area. At these latter sites, tiger sign had become gradually rarer over the past 30 years.

We hired Village Rangers for each survey area. VRs informed villagers in their village and surrounding areas that they were seeking information about tiger depredation of livestock or tiger sign and asked villagers to report any livestock depredation cases and tiger sign. This system of daily monitoring livestock by villagers and the recce surveys by village rangers, which extended across the terai, increased the probability of observing important rare events such as dispersal and breeding status of tigers over previous survey efforts conducted by tiger researchers making short visits to each locality. This information was collected to determine connectivity of forest corridors. To reduce trampling of tracks, VRs covered them with branches or flat rocks elevated by small pebbles to preserve the tiger sign. These techniques allowed the field coordinator to recheck and verify the species, sex and age class of the animals that produced the sign.

Extent of Breeding outside Protected Areas

Breeding habitat outside protected areas was defined as habitat > 4 km from protected areas where female and cub tracks co-occurred at the same location or where cubs were visually observed. We used a distance of > 4 km from protected areas to define breeding outside protected areas because we did not want to include any locality where there was potential for a breeding female's home range to occur partially within a reserve.

Biodiversity Monitoring by Village Rangers

Beginning 2003, in addition to monitoring tiger depredation and patterns of tiger distribution, VRs helped monitor tiger prey abundance. To expand their professional capacity, we plan to incorporate VRs into our new project to examine patterns of livestock grazing in the Terai. Inclusion of these individuals will increase the role of the VRs as tiger experts within their local communities.

RESULTS

Development of the Village Ranger Network

Initially 30 Village Rangers were recruited; additionally 2 more VRs were included during the course of the project. VRs had diverse backgrounds (e.g. 12 farmers, 6 livestock herders, 5 hunters, 6 community leaders, 3 intelligence informants). As our research progressed, VRs became more knowledgeable about basic tiger biology through a series of workshops and visits by field technicians. At one of their evaluation workshops the Village Rangers realized their group was beginning to function as a conservation education network. At this time they requested we develop brochures on the basic natural history of tigers, the purpose of their monitoring activities and maps showing where tigers occurred. This was the first effort in Nepal to conduct formal or informal conservation education beyond the buffer zones of protected areas.

Tiger Presence

During the course of the study, 26 of 32 VRs recorded presence of tigers on 509 occasions throughout the central and western lowlands of Nepal; 352 reports were tiger sign, 149 were kills of livestock, 3 were human kills and 5 were dead tigers. By using track size and sexing dead tigers, gender was determined in 434 cases.

The area monitored by Village Rangers ranged from 3.6 to 15.8 km from their respective villages except for one case when a Ranger took a bus to investigate a kill 23.7 km from his village. The greatest distance of 15.8 km was reported by a Village Ranger who decided to explore a wider area because he found no tiger sign near his village. He crossed the Siwalik Range, which demarcates the border with India, and searched in

India. The median distance surveyed was 6 km.

Degree of Connectivity between Reserves

Data obtained by Village Rangers demonstrated tigers are widely distributed in forests outside protected areas. Records obtained during this study indicate tiger distribution extends a distance of 546 km from the western border of Nepal to 16 km west of the Bagmati River.

Based on absence of tiger sign at specific sites along potential dispersal corridors, four major gaps in distribution separate tigers in Nepal into three populations and isolate these populations from the Dudhwa tiger population in India.

The isolation of Suklaphanta.— Two gaps in tiger distribution were discovered where the Suklaphanta corridor bifurcated into an eastern corridor and a southeastern corridor. Beginning at the northern extension of Suklaphanta toward the east there was a 22 km gap in tiger distribution. In the middle of this gap was a 3 km wide area where intensive agriculture appears to create a strong dispersal barrier. The southeastern corridor gap in tiger distribution that isolates Suklaphanta from Dudwa is observed in Laljhadi forest. The VR from a village near this forest reported tigers were never observed at this location. This barrier, supported by lack of tiger records in Laljhadi Forest, provides strong evidence for a 33 km gap in tiger distribution between Suklaphanta and Dudwa.

Connectivity of Dudwa Tiger Reserve to Bardia National Park.— South of the east west corridor between Suklaphanta and Bardia, Basanta Forest forms a north south corridor providing a potential link from Dudwa to Bardia. Tiger sign was recorded by VRs on 103 occasions in this forest. The braided Mohana River meanders through this cultivated strip. Separated by only 0.5 km, this river flows north-south between Dudwa and Basanta. The river course and riparian vegetation may function as a corridor used by tigers to move from Dudwa to Basanta Forest. We hypothesize tigers can move easily between Dudwa and Basanta Forest, however, although no gaps in tiger distribution between Basanta and Dudwa were observed, it appears to be a tenuous corridor. Therefore, we classify Dudwa and Bardia as separate populations with some potential for genetic exchange.

Breaks in connectivity between Bardia and Chitwan.— A gap in tiger distribution east of Bardia extends 34 km between Lamahi and Kapilbastu district in Nepal. However, tigers were observed at Kapilbastu, east of this gap, but clearly isolated from Chitwan. The field coordinator and VR based at Tabdarpur in Dang Valley found tiger sign in India just south of the Siwalik ridges that form the border. This observation suggests a southern dispersal route exists around the Lamahi - Kapilbastu gap that passes through the Sohelwa Wildlife Reserve in India.

A major habitat gap between Bardia and Chitwan extends 55 km and separates tigers in Kapilbastu (the Bardia population) from Chitwan. The city of Butwal, a major lowland urban center, lies at the center of this gap and creates a strong barrier to tiger dispersal. In addition, the VR based 10 km east of Butwal never observed tigers in his area during the study period, supporting the conclusion that a major gap in tiger distribution occurs here.

Both the Bardia and Chitwan tiger populations reside within long, narrow strips of forest habitat. The Bardia population extends 288 km from 75 km west to 162 km east of Bardia; the Chitwan tiger population extends 164 km east to west. The widest portion of these populations is 30 km and the narrowest is 1.5 km.

Breeding Habitat outside Protected Areas

Five areas were observed outside parks where female tracks were accompanied by cub tracks. At two of these areas, adjacent to RBNP, cubs were observed in only one month during the study. Therefore, we assumed home ranges of these females were primarily within the National Park with part of their range extending outside. In the other three cases, females resided entirely outside the park and cub tracks were found associated with female tracks at each of these locations on multiple occasions.

DISCUSSION

We are confident that use of local citizens to collect data on a landscape scale has wide application in developing countries, especially when resource managers attempt to implement community participation in resource management. We suggest the Village Ranger approach enhances data collection and conservation efforts in the following ways: Village Rangers were resident members of their community and people were willing to travel 2.5 hours by foot to report kills to the Village Ranger (thus significantly enhancing the database). Another benefit of Village Rangers is that they were “on the job” year around. This is in contrast to rapid assessment teams that obtain information over a very limited time scale. Finally, the Village Ranger concept facilitated spread of knowledge about the project through local communities and fostered citizen pride of community members who were tiger experts.

Our data show that tigers occur throughout most of the forests between Suklaphanta Wildlife Reserve and Royal Chitwan National Park in central Nepal. However, there are clear breaks in tiger distribution that must be restored if connectivity is to be re-established.

As the most modest action to enhance connectivity we recommend reduction of grazing pressure and establishment of community forestry plantations along the gaps and dispersal corridors. This restoration effort, if successful, will demonstrate the feasibility of TAL’s long-term goal of increasing connectivity.

At three sites outside protected areas there was unequivocal evidence of breeding. Additional research is needed to study differences in the prey base and other ecological and spatial factors between breeding and other non-breeding habitats. If connectivity between regions is important for long-term tiger survival in Nepal, and elsewhere, it is important to understand the ecology of tigers living or attempting to live in the human dominated portion of the landscape. For example, it is likely that breeding areas outside reserves are net population sinks. The behavior of tigers in areas classified as population sinks and the dynamics between sources (protected areas) and sink habitat are unknown and need further investigation to provide directors of eco-regional projects with guidelines for habitat management.

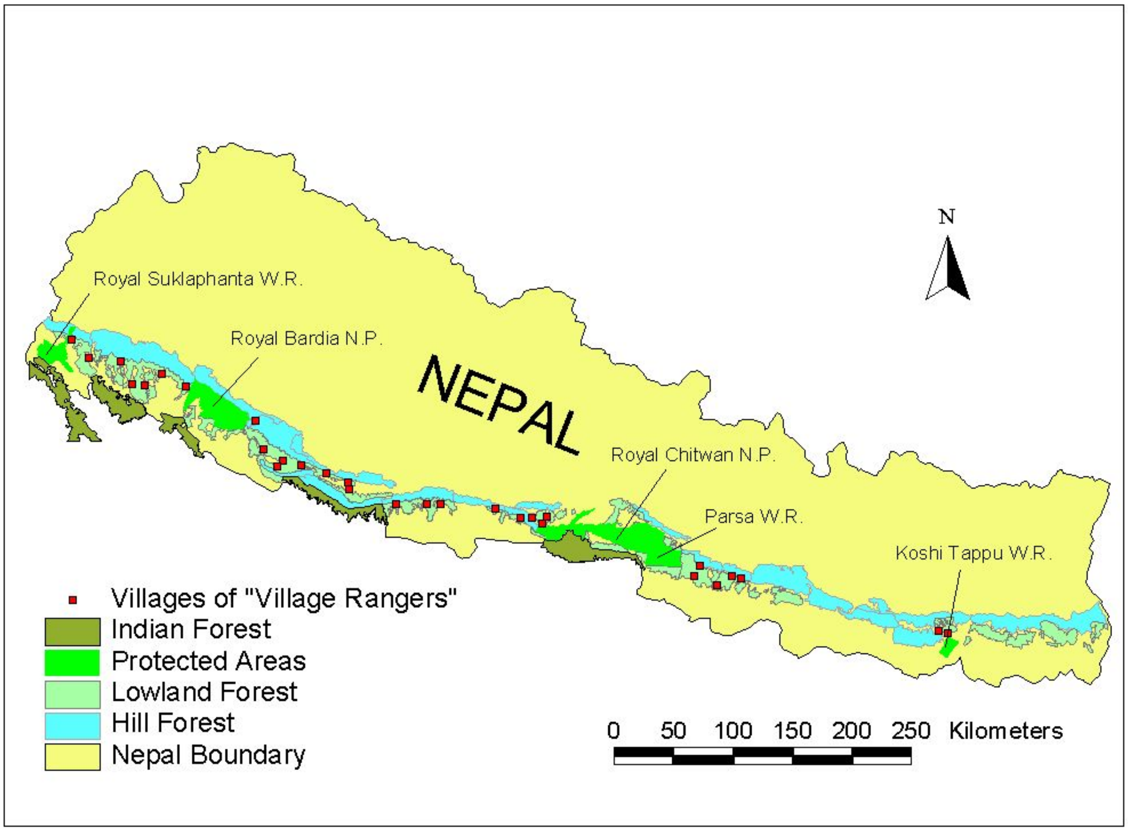


Figure 1. Distribution of “Village Rangers” across the Nepalese lowlands.

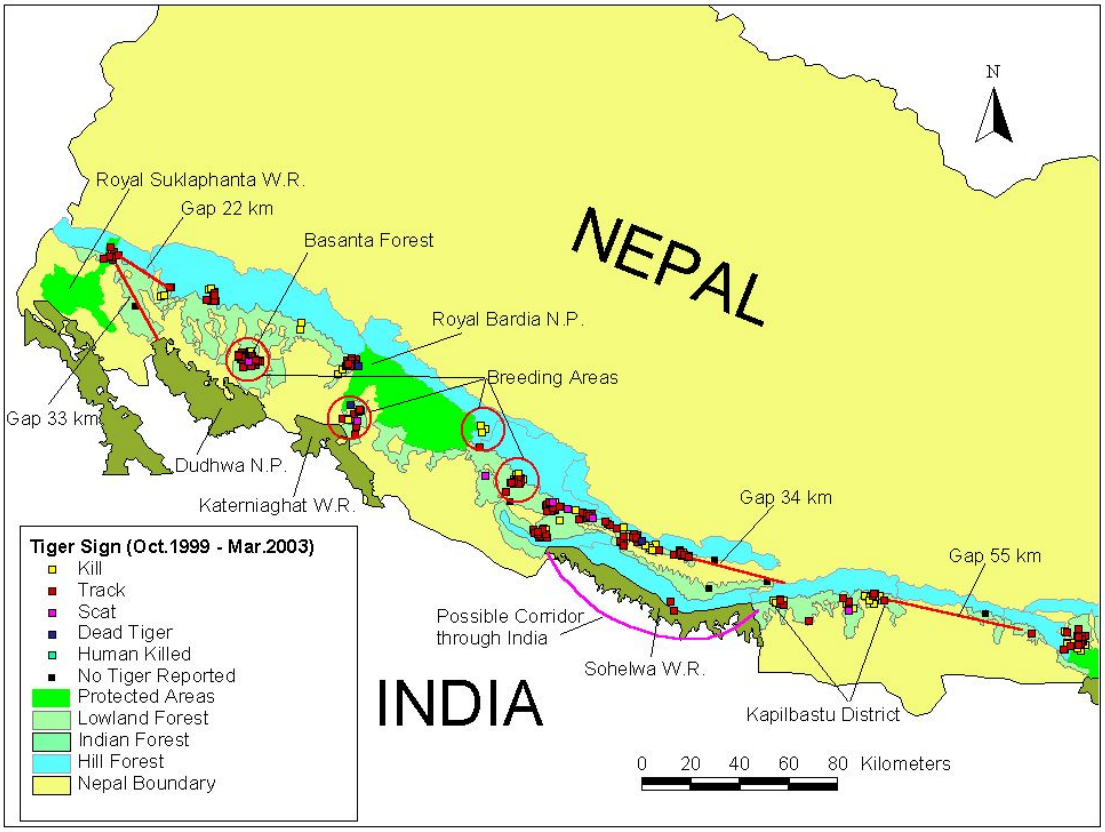


Figure 2. Map of western Nepal that shows gaps in tiger distribution (red lines) where no tiger sign or livestock kills were found in approximately 1500 days of survey effort. Circles are areas where tiger sign is common and cub tracks were observed in close proximity to adult female tracks.

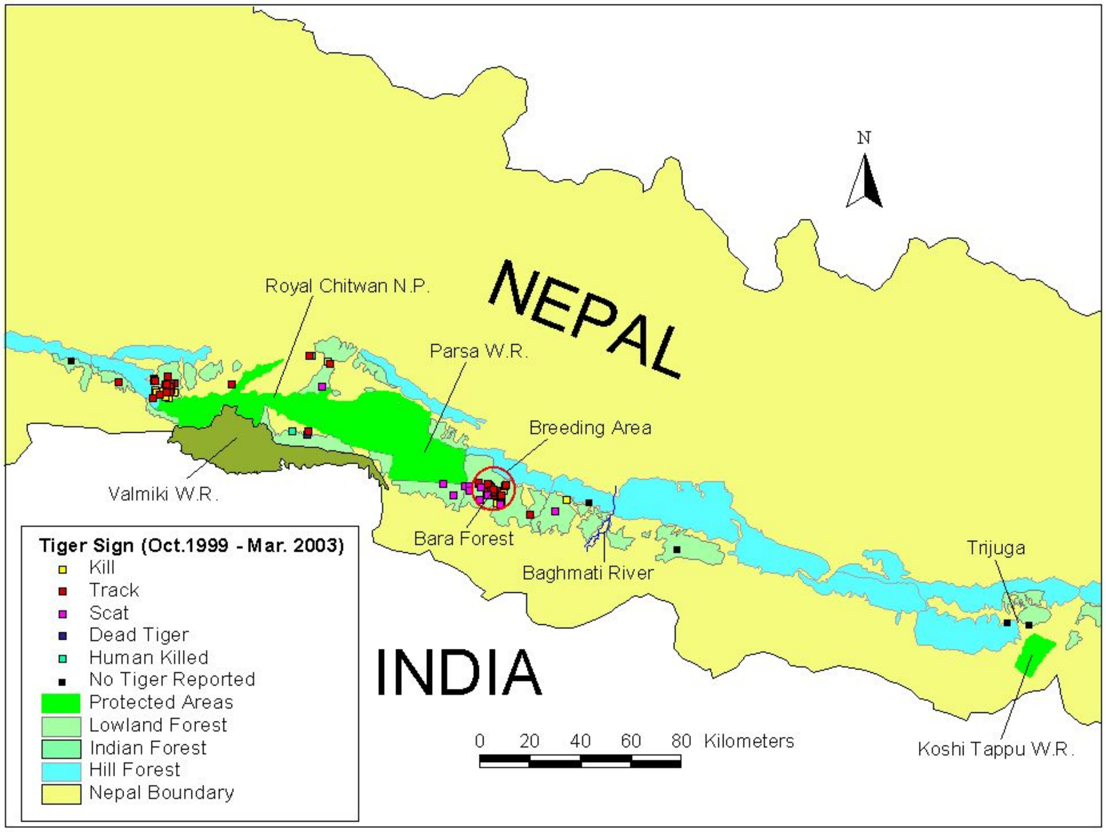


Figure 3. Breeding locality in Bara Forest. This is the only location in central Nepal where breeding tigers occur outside protected areas.

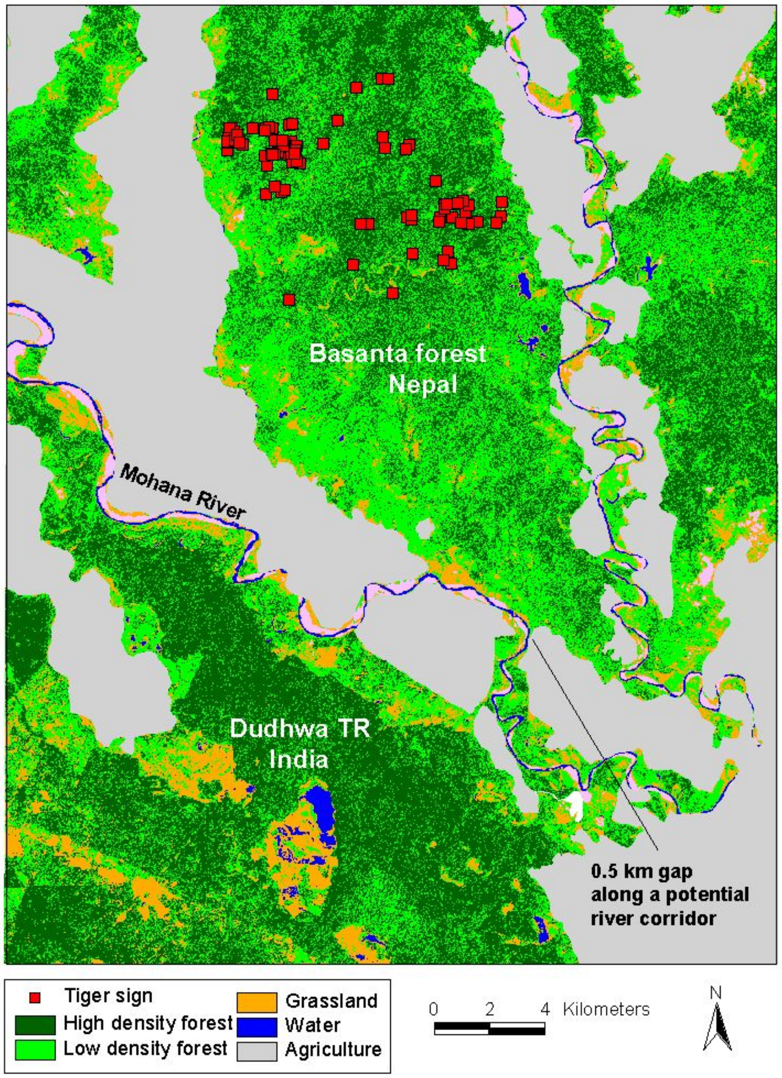


Figure 4. Basanta Forest north of Dudwa Tiger Reserve was identified as an important hotspot for tigers occurring outside protected area. In this area we obtained over 100 observations of tigers; on several occasions cubs or their tracks were observed. A potentially narrow habitat corridor may provide connectivity between this area and Dudwan Tiger Reserve to the south.

II. Relative prey abundance in a fragmented landscape: implications for tiger conservation

Due to their small size, the relatively isolated existing protected areas do not ensure the long term viability of tiger populations (Smith et al. 1987; Dinerstein & Wikramanayake 1993; Smith et al. 1998; Ahearn et al. 2001). Existing forests outside protected areas (national forest) present a great potential to link these tiger populations and increase regional population viability. If these lands are managed under the multiple use system explicitly considering the development of "ecological connectivity" tiger populations will have a higher probability of long term survival. Because the majority of potential tiger habitat is in multiple-use national forest outside protected areas (Ahearn et al. 2001) conservation measures need to be undertaken beyond the boundaries of parks and reserves. Restoring degraded habitat and expanding the land base and connectivity will re-establish the past metapopulation structure of linked population centers that is critical to long term survival of tigers. Smith et al. (1998) advocated shifting to a landscape-wide conservation approach. In response WWF initiated the Terai Arc Landscape (TAL) conservation project to recreate habitat linkage among the 11 protected areas extending from the Bagmati River in the east to theYamuna River approximately 800 km to the west in India. This project was based on the concept that management must occur at the level of landscapes and ecoregions and addressing biodiversity conservation together with socio-economic welfare of local communities.

As management is undertaken to restore forest integrity across the Terai, it is important to monitor and analyze landscape changes and the impact of these changes on tiger prey species. Information on habitat quality, particularly prey abundance, is critical for guiding tiger conservation action from local management interventions to regional conservation planning in the focal landscape (WWF 2002). Tiger density is positively related to prey abundance, wild ungulates in particular (Smith 1984; Karanth & Stith 1999; Sunquist et al. 1999). Establishing protected areas or designating areas for conservation to only secure forest habitats is not enough for tiger conservation but is essential to ensure that they offer a good quality habitat to support tigers (Smith et al. 1998; Smith et al. 1999). In many parts of the tiger's range, ungulate assemblages with no large or medium sized prey (cervids or bovids) support low tiger density and reproduction rates decline in an impoverished habitat with low prey base (Karanth & Stith 1999). Decline in the prey base as a result of habitat degradation and widespread poaching has limited areas that can support tigers. Periodical monitoring of tiger habitat is necessary to prioritize areas for conservation action and assess the effectiveness of management efforts. Moreover, a threshold of prey abundance that determines poor or good quality of habitat reflecting the breeding possibility is important for developing necessary conservation action (Smith et al. 1998; Smith et al. 1999).

Previous quantitative studies of the tiger's prey base in Nepal have been limited to protected areas (Seidensticker 1976; Dinerstein 1980; Mishra 1982; Smith 1984; Dhungel & O'Gara 1991; Stoen & Wegge 1996; Smith et al. 1999). The overall objective of this study was to obtain landscape wide information on the abundance and densities of tiger prey species to prepare a model to predict the tiger prey quality index by determining (1) prey abundance in different habitat types, (2) distribution pattern of prey species, and (3) the effect of human related activities on prey abundance.

The study was conducted across the lowlands of Nepal between 26^0 27’ N to 29^0 05’ N latitude and 80^0 06’ E to 88^0 03’ E longitude covering an aerial distance of about 800 km and approximately 14000 km^2. It included 3 ecological zones on the southern flank of the Himalayas: Siwalik Range, inner Terai composed of “dun” valleys, and the Terai. The Siwaliks and the Terai are the northern extent of the gangetic plain and run almost parallel from east to west across 800 km length. Together they cover 27% of the total land area of Nepal (FRISP 1994). The elevation ranges from 60 m to 1000 m. “Duns” are elongated valleys enclosed between the Siwalik and Midhills range and are flat, similar to the Terai. The Terai together with the dun valleys on the foothills of the Himalayas is characterized by rich alluvial habitat with tall grassland. It is one of the premiere hotspots for large mammal conservation in Asia with the world’s highest density of tigers (Smith et al. 1998).

In the lowlands, wildlife habitat is interspersed with a mosaic of settlement and intensive cultivation. Habitat fragmentation in Nepal that began in the late 1950s shifted the once widespread forest matrix to the current stepping stone structure composed of a series of gradually shrinking forest habitat islands spanning the length of the Terai. Despite the overall decline in forest cover, protected areas in the Terai still contain tigers (*Panthera tigris*), sloth bear (*Ursus ursinus*), gaur (*Bos gaurus*) great one-horned rhinoceros (*Rhinoceros unicornis*), and small population of elephants (*Elephas maximus*). It also supports a dense tiger prey base that includes sambar (*Cervus unicolor*), chital (*Axis axis*), hog deer (*A. prcinus*), barking deer (*Muntiacus muntjak*), wild boar (*Sus scrofa*), and common langur (*Semnopithecus entellus*). Isolated populations of blue bull (*Boselaphus tragocamelus*), four-horned antelope (*Tetracerus quadricornis*), swamp deer (*Cervus duvauceli*), gaur bison (*Bison gaurus*) are also found.

METHODS

Indices of population abundance are frequently used to assess population status and change for many wildlife species that are difficult to census. Pellet-group count is widely used to estimate the abundance of ungulate species (Bennett et al. 1940; Eberhardt & Van Etten 1956; Neff 1968; Bailey & Putnam 1981; Plumptre & Harris 1995a; Barnes et al. 1997; Komers 1997; Vernes 1999; Barnes 2001; Krebs et al. 2001; Marques et al. 2001a; Walsh et al. 2001; Barnes 2002) and their habitat use (Collins & Urness 1984; Loft & Kie 1988; Edge & Marcum 1989; Harkonen & Heikkila 1999) despite some controversies (Van Etten & Bennett 1965; Collins & Urness 1981, 1984; Fuller 1991; Fuller 1992; White 1992). A strong correlation exists between estimates from the pellet group counts and other methods (White 1992; Barnes 2001). Because of the limitation of personnel and the immense size of the study area, we used the standing crop method of pellet group count over the ‘clearance plot’ method despite the difference in accuracy (Plumptre & Harris 1995b; Marques et al. 2001b).

We followed a technique modified from several investigators (e.g. Wegge 1976;

Freddy & Bowden 1983; Smith 1984; Smith et al. 1998; Smith et al. 1999) to assess prey abundance. This allowed me to make comparisons to the old data. Pellet counts in a series of small sized plots along a line transect is considered efficient in terms of power and time required (Neff 1968). Pellet group studies were conducted extensively during the dry season (Jan-March) of 1999 and 2000 and additional data from surveys in 1997 and 2003 from some critical areas were also included in the analysis. Samples were selected across the Terai from topo maps in advance with random starting points. Each sampling unit (SU) consisted of 625 m long straight line transect with 25 plots spaced 25 m apart. Each plot was 10 m^2 in size (Wegge 1976; Smith 1984). The SU was designed to include maximum variability within and between transects. The detection probability was almost 1 as the plots were searched for discrete pellet groups/dung by carefully raking leaf-litter and dry vegetation. Although older pellet groups were fewer in number, all groups were counted equally. A pellet group that was spread out in a line because an animal was moving while defecating was classified as a single group.

Pellet groups were classified by prey size class. The small prey class included barking deer (*Muntiacus muntjak*) and four-horned antelope (*Tetraceros quadricornis*); the medium sized class contained chital (*Axis axis*), hog deer (*Axis porcinus*), and wild boar (*Sus scrofa)*; the large prey class consisted of sambar deer (*Cervus unicolor*), swamp deer (*Cervus duvauceli*), and blue bull (*Boselaphus tragocamelus*). Three other classes of droppings were also classified: primates (*Semnopithecuss entellus* and *Macaca mulatta*), forest bovids (*Bos gaurus*) and domestic livestock (*Bos taurus* and *Bubalus bubalis*). In addition to the data collected at each 10 m^2 plot, animal sign along the transect line and in the vicinity while walking to get to the starting point were also recorded to establish presence of different species in the sampled area. Pellets were identified for species based on their size, shape, habitat where they were found. To give some weight to transects with ungulate sign when no pellet groups were observed, animal tracks in a plot were considered equivalent to one pellet group of that species indicating its presence in that habitat. Deer tracks were considered equivalent to one Chital pellet group regardless of species.

Horizontal cover for each plot was measured by looking at a 122 cm long stick divided into 4 equal colored bands from 25 m distant. A rank of 100% cover was given when all 4 bands were covered up. Type and extent of human use were measured along the transect line in terms of cattle grazing, wood cutting, lopping of tree, shrub branches, livestock dung. Transect were conducted by a team of three-person.

The study area comprised of different levels of protection (and thus the extent of human impact) and other parameters that affect habitat quality. Variations in habitat quality were quantified giving them the different score for the human related activities recorded and comparing the crude index to the best existing habitat in Nepal.

Survey Design and Rules

Sampling was conducted during the dry period of the year, the first in Jan-March 1999 and the second in Jan-April 2000. At the beginning all team members worked together to standardize the field procedures. Transects for sample plots were selected systematically with random start with some pre-determined sampling rules:

a) at least 1-2 km inside the forest from the edge
b) the gap between transects is between 1-5 km
c) steep slopes were avoided
d) a pellet group consisted of ≥5 pellets spread out close together and having similar size, shape, texture, and color for counting purpose (Freddy & Bowden 1983)
e) where overlapping pellet groups occurred, we made a best estimate of the nature of pellet groups based on the varied color, sheen, and level of degradation of pellets

Two to three teams, each composed of 3-persons, were involved in sampling in the field at a time. At the beginning of each field season, the members of all teams did the pellet group survey together to standardize the procedure. The main author switched the teams throughout the survey season to maintain adherence to standards. Each team sampled 2-4 transects/day depending on the field conditions and distance they had to walk. A team consisted of one person measuring the distance between plots by pacing along a fixed bearing, one recorder, and one raker or helper. Horizontal cover for each plot was recorded from 25 m distance looking at a stick divided into 4 color-bands of 30.5 cm each. After recording the horizontal cover, the recorder noted any human related disturbance such as cutting and lopping as he walked to the new plot. The new plot was carefully raked and pellet groups were counted. Pellet groups of different ages were recorded as different groups.

Surveys were done during the dry period (January-April). A pellet group deterioration study indicated that pellets deposited prior to and during the monsoon disappear rapidly. Pellets begin to accumulate in October and pellet groups from October survived through our survey season which extended to April. We divided the survey season into 2 week intervals starting January 1 and applied a correction factor to adjust for the different number of days that pellets accumulate throughout our survey seasons.

We surveyed during the same time of the year to avoid problems of estimating pellet deterioration rate. We assume that there is not difference in defecation and decay rate of pellet groups across the Terai landscape during the same season of the year. Periodic ground fire during the dry period is common all across Terai forest and there is a possibility that some pellet groups get destroyed and were missed during our survey. However, ground fires progress very rapidly on the ground and generally the pellets were partially burnt or still intact.

Mahendra Shrestha is currently analyzing these data and will develop a model to predict the distribution of prey based on the following independent variables: cover type, cover condition, slope, elevation, distance from water, distance from roads, and distance from villages. In his preliminary analysis, cover type and roads are the primary predictors. He is also developing a ruggedness data layer based on slope and elevation to include in his model. He plans to complete his Ph.D. dissertation by September 2004.

III. Forest classification of the Terai Arc Landscape (TAL) to identify and analyze tiger and tiger prey habitat

Success of any conservation and management plan depends on the foundation upon which it is built. It is necessary to understand "Lay of the Land" to design an effective biodiversity conservation plan. Use of modern tools such as Remote Sensing to analyze latest satellite data provides a bird's eye view of the landscape at the present time. Therefore, forest classification of Terai Arc Landscape (TAL) based on satellite data from LANDSAT 7 of 2001 was carried out to assist in building a road map for developing and monitoring tiger and other large mammal biodiversity conservation in addition to developing a management plan for TAL.

This study covers only the Nepalese portion of TAL extending from the Bagmati River (Rautahat district) in the east to Mahakali River (Kanchanpur district) in the west. Therefore references to TAL in the document represent only the Nepalese side of TAL.

Background Information on Terai Arc Landscape (TAL)

The Concept

The TAL concept emerged from efforts to determine metapopulation structure of tigers (Smith et al. 1987, Smith et al. 1998). The goal of this ecoregional project was to link 11 protected areas distributed in Nepal and India to provide space necessary to maintain viable populations of large mammals especially tigers, rhinos, and elephants through next century. A key element of the TAL concept is co-management by the departments of Forests and National Parks and Wildlife Conservation and communities across the Terai landscape. In terms of land use, the project has the dual objectives of providing land needed to support over 3.5 million subsistence farmers living in the TAL region and also providing the land base to support viable populations of large mammals that need corridors between protected areas to maintain gene flow. The apparent competing land use between humans and large mammals is an artificial dichotomy because on a longer time horizon, both humans and large mammals depend on healthy ecosystems that maintain important ecological processes and services essential for all components of the ecosystem.

The TAL

The TAL extends from the Bagmati River (Nepal) in the east to the Yamuna River (India) in the west and covers over 49,000 Km^2. Once covered with contiguous dense forest and tall grassland mosaics, the Terai habitats today are limited to scattered patches of forests in a human dominated landscape, connected only through a narrow band of the Siwalik forest. Nevertheless, protected areas in the TAL still support a wide variety of large mammals including tiger (*Panthera tigris*), elephant (*Elaphus maximus*), rhinoceros (*Rhinoceros unicornis*), sloth bear (*Melursus ursinus*), swamp deer (*Cervus duvauceli*), and sambar (*Cervus unicolor*). Protected areas account for approximately 25% of tiger habitat throughout the world (Smith 1987, Dinerstein et al. 1996); in contrast, 75% of tiger habitat is in forestlands where human activity is a dominant component in the ecological system. The ultimate survival of the tiger and other large mammals such as rhinos and elephants depend on cooperation from local communities in managing habitats outside the protected areas as well as saving them from poaching. However, one shouldn't forget that cooperation from local communities can't be anticipated until they become aware for necessity of saving these animals and also benefited from any national or global initiatives for biodiversity conservation.

The Goal:

The goal of this Remote Sensing analysis to carry out detail forest classification based on 2001 satellite data to develop a baseline forest data for developing conservation and management programs.

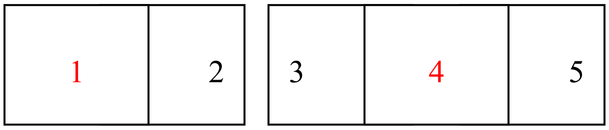
Specific objectives:

The objectives of this study are:

1. To classify the vegetation cover in the forests of the entire Terai including TAL
2. To generate a vegetation data layer as a critical component of a regression analysis to estimate tiger prey density
3. To analyze in detail forest cover in Basanta-Dudwa NP and Bardia-Katarniaghat, 2 potential tiger and elephant dispersal corridors between protected areas in Nepal and India.
4. To develop an algorithm for change detection as a part of monitoring forests in TAL

Methodology

Satellite data from year 2001 (LANDSAT 7) were obtained from the Earth Resource Observation System Data Center of United States Geological Survey. Five satellite scenes were used to cover the major Terai landscape that included TAL. Nepal falls in 2 UTM zones, viz., UTM zone 44N and 45N. The satellite scenes were rectified and projected to UTM zone 44N and WGS 84 datum. Then unsupervised classification was carried out to cluster spectral values into 60 classes. These classes were compared with available aerial photos, topographic maps, satellite maps from 1980's, and expert field knowledge. These sixty classes were merged into 13 classes of which 8 were vegetation classes and 5 non-vegetation classes. Unsupervised classification was done for only two scenes, one at the far-west region (Scene 1) and another one from central part (Scene 4) covering Chitwan for which we have had expert knowledge on forest cover. The signatures for each of the 13 classes from the overlapping zone of the classified scenes were used to classify the adjacent scenes. These signatures were used to classify 3 other scenes using supervised classification algorithm.



The ground verification was done during March-April of 2003 which was during the same season that the data was acquired. During the field verification the classified data were taken in a laptop computer attached to a GPS (Global Positioning System). A GPS was used to navigate to the test plots in the field. Approximately 10 replicates of each vegetation class were obtained per scene. In total 864 sampling plots were surveyed and each plot were georeferenced, photographed on all 4 directions (N, E, S, and W), and measurements of canopy closure, vertical strata, basal area, and species composition were recorded. The analysis of field verification data exhibit over 85% match at the two scenes (scene # 1 and 2) for which unsupervised classification was carried out based on their signature; however, the accuracy level decreased to approximately 70% when we analyzed the 3 adjacent scenes for which signatures were taken from the overlap zones of the 2 scenes. A likely cause for the decrease in the accuracy may have been variation in atmospheric conditions between dates when scenes were acquired. In order to minimize effects of atmospheric variation, later during our final classification process, we converted spectral values into the radiance values and eliminated 2 bands (band1 and band2) which are sensitive to atmospheric variations. Then the classification algorithm was repeated using radiance values instead of spectral values.

The second classification was done based on the information collected from sampling plots during the March 2003 field verification (ground truthing) process. The signatures were developed from the ground data for each of the 5 scenes. Human settlements including agriculture lands were masked out before classification to avoid intermingling of natural grassland with cropland as they carry similar reflectance. Then supervised classification based on the signature was done. The resulting classification with 9 vegetation classes had an overall accuracy of 63% for the vegetation classes. To improve accuracy in discriminating riverine forest and grasslands along the flood plains we stratified the classification by masking out alluvial flood plains along the major rivers and then classified these areas separately. With this modification the overall accuracy increased. We then collapsed 4 categories of high quality forest into a single class, high density forest; we also reclassed 2 low density classes into a single low density forest. The generalized classification consisting of 5 forest classes achieved an 89% overall accuracy.

Results

We present the results of the classification at 2 levels, generalized and detailed, targeting different audience. We also demonstrate use of classification data to develop forest management and restoration plan in combination with other information such as VDC (Village Development Committee) boundaries and population size for 2 priority forest corridors in TAL 1) Bardia-Katarniaghat corridor and 2) Basanta-Dudwa corridor.

I. Generalized classification – This classification is for communicating with general public with little or no forestry background. The classification is presented in a simplified form showing high density (good) forest, low density (low to moderately degraded) forest, degraded forest, short grass (over grazed areas), and tall grass (Fig 1). The classification will be valuable during discussions with stakeholders and policy makers. Current forest cover is presented in Table 1.

Table 1. Generalized forest classification of TAL

	Forest types				
Districts	**High Density**	**Low density**	**Degraded**	**Short grass**	**Tall grass**
Rautahat	18638.1	8482.4	2248.6	731.0	437.0
Bara	27269.3	16976.9	5087.5	491.8	1324.4
Parsa	49776.1	19645.5	4625.5	259.8	1493.4
Chitwan	97227.1	23229.6	13101.1	4139.6	7684.7
Nawalparasi	65545.1	16018.4	19412.3	8669.5	4672.2
Rupendehi	18836.6	5525.3	5839.0	2578.2	265.0
Kapilavastu	42401.9	15152.2	11533.9	3711.7	292.7
Dang	85357.7	75255.1	26791.3	6496.0	873.9
Banke	63694.9	68468.7	10637.8	3697.0	751.3
Bardia	58412.0	33638.9	10132.5	8570.0	7254.8
Kailali	89168.6	80538.0	17252.8	24170.7	6164.5
Kanchanpur	34446.1	43137.1	11075.8	11779.2	7850.9
Total	**650773.6**	**406068.1**	**137738.2**	**75294.4**	**39064.7**

II. Detailed classification – This classification is targeted for more technical people involved in developing biodiversity conservation and management plans or forestry plan for sustainable development programs. The forest has been classified into 9 vegetation classes and 5 non-vegetation classes as following:

Dry Sal forest
Low density Sal
Low density mixed forest
Short grass
Degraded forest (scrub)
Exposed surface
Shadow
Dry Sal forest

High density Sal forest
High density mixed forest
Riverine forest
Tall grass
Water body
Cloud
Settlements (non-forest)
High density Sal forest

Twelve districts lying in the Nepalese side of TAL contains total of 1.3 million hectares of forestland of which 18.6% dry Sal, 19.0% high density Sal, 17.3% low density Sal, 10.1% high density mixed hardwood forest, 13.8% low density mixed hardwood forest, 2.1% short grass mostly over grazed lawns, 3.0% tall grass, and 10.5% degraded forest.

Use of classification data in developing management/restoration plan

Forest classification data in combination with other information such as land use, political boundaries, human demographic, etc. can be used as a powerful tool develop forest management and/restoration plans. We prioritize forest restoration at VDC level in 2 priority forest corridors of TAL 1) Bardia-Katarniaghat and 2) Basanta-Dudhwa based on satellite data and population pressure.

1. Bardia-Katarniaghat corridor

This corridor connects Royal Bardia National Park in Nepal with the Katarniaghat Wildlife Sanctuary of India. The corridor is 25 km long and varies in width from 1-6 km (Fig 15) and falls within administrative boundaries of 5 VDCs (Fig 16). The corridor contains 2,270 ha of high density forest, 3,086 ha of low density forest, 1,514 ha of grasslands, which are mostly overgrazed lawns and 1,249 ha of degraded forest. The forest restoration areas are prioritized based on its role in connectivity there fore degraded forest in the Dodhari VDC which connects with Katarniaghat Wildlife Sanctuary in India received highest priority other VDCs in priority are Suryapatuwa, Thakurdwara, Bagnaha, and Neulapur (Table 2, Figure 2).

Table 2. Forest coverage and population in 5 VDCs of Bardia-Katarniaghat forest corridor.

VDC	High density	Low Density	Grass	Degraded (scrub)	Total House Hold	Total Population	Restoration Priority
Dhodari	369.4	657.4	417.3	452.3	2573	15020	I
Suryapatuwa	318.8	416.2	764.2	403.9	1174	9535	II
Thakurdwara	309.5	397.8	118.3	102.5	1020	7900	III
Baganaha	1006.1	1308.2	131.5	190.5	1502	12756	IV
Neulapur	266.6	306.8	83.3	100.4	1497	11646	V
Total Corridor	2270.3	3086.4	1514.6	1249.6	7,766	56,857	

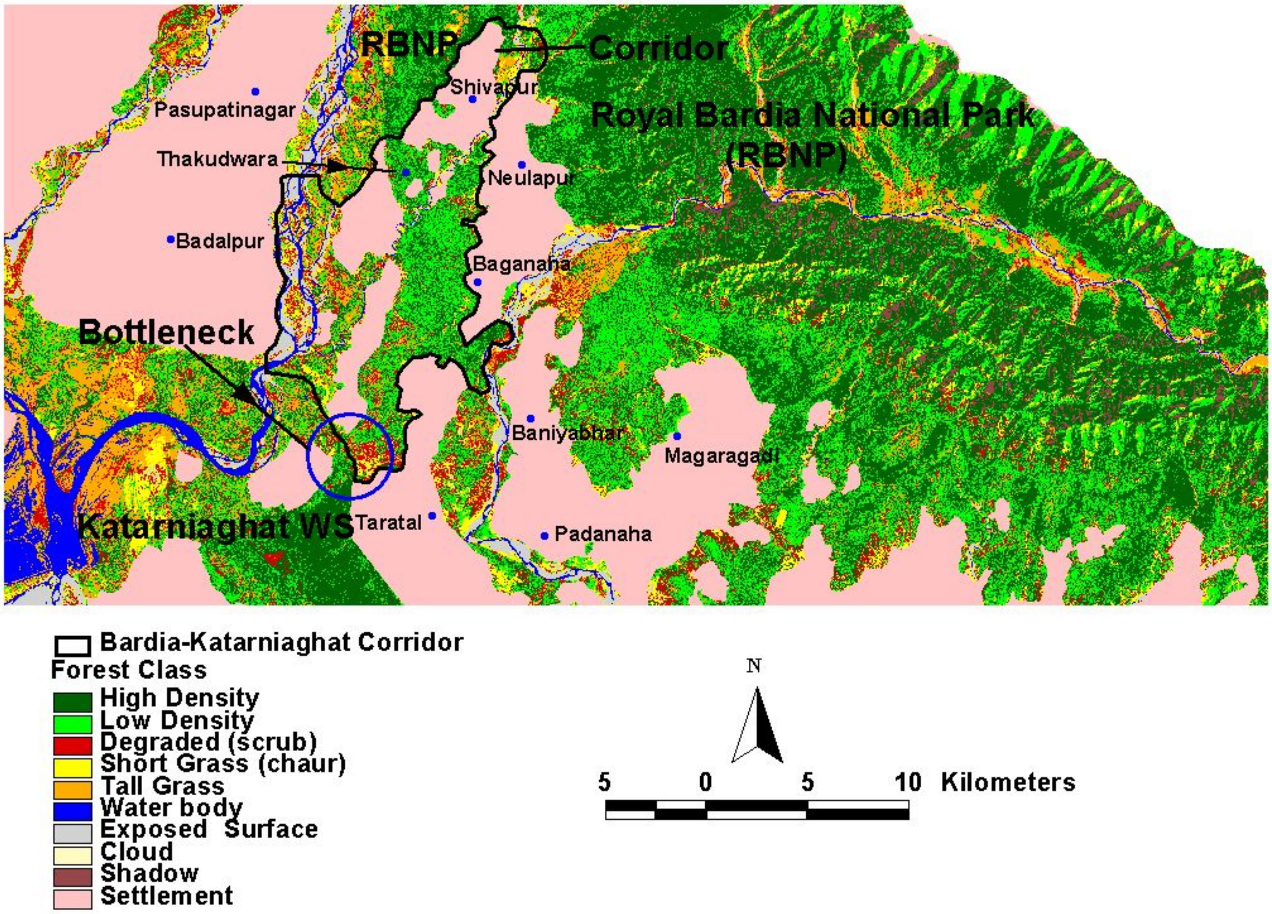


Fig 2. Forest Classification of Bardia-Katarniaghat forest corridor

2. Basanta-Dudhwa Forest Corridor

This corridor connects national forest in Kailali district of Nepal with Dudwa National Park in India in the south (Fig 17). It also connects with Siwalik foothills forest in the north though which it links with Suklaphanta Wildlife Reserve in the west and Bardia National Park in the east. Wild elephants have been known to use this corridor as migratory pathway to move between Dudhwa, Bardia and Suklaphanta. Increasing forest degradation due to land encroachment and over exploitation of the resources has posed a serious threat to the movement of elephants, rhinos, tigers and other wildlife.

The Basanta-Dudhwa forest corridor falls within administrative boundary of six VDCs. Forest composition of the corridor varies from dense Sal forest to highly degraded forest with overgrazed grasslands. There are 9,853 ha of dense forest, 9,729 ha of low density forest, which are low to moderately degraded, 2,030 ha of highly degraded forest and 1,712 ha of grasslands. Grasslands in the corridor are generally overgrazed lawns inside or on the edge of the forest. The corridor is surrounded by very poor subsistence farmers who heavily depend upon forest for their daily resource needs. The forest composition of each of 6 VDCs along with the population size are presented in the table 15.

Because grasslands in the corridor are mostly degraded forest edge for the purpose of identifying priority restoration we combined grasslands and highly d forest into one category called degraded forest. Based on the location and its role in maintaining forest connectivity we rank each of the six VDCs (Table 3). Forest in Lalbhoji VDC which connects Basanta forest with Dudhwa National Park is very tenuous and is in the verge of breaking with width less than 1 km including river course (Fig 3). Therefore Lalbhoji forest is ranked as number I for restoration. Likewise forest in adjacent Ratanpur village was also given rank I due to its importance in connectivity with Dudhwa followed by Udasipur, Khailad, Masuriya, and Pahalmanpur.

Table 3. Forest coverage and population in 6 VDCs of Basanta-Dudhwa forest corridor.

VDC	High density	Low Density	Grass	Degraded (scrub)	Total House Hold	Total Population	Restoration Priority
Lalbojhi	85.9	169.7	88.4	112.7	1599	10548	I
Ratanpur	557.4	1194.3	482.7	329.5	799	8492	I
Udasipur	3416.8	3166.7	538.8	328.8	909	8350	II
Khailad	775.5	991.8	208.2	113.0	957	9000	III
Masuriya	1823.8	1994.2	387.6	519.1	2022	15596	IV
Pahalmanpur	2902.4	1928.1	181.6	127.3	1284	11231	V
Corridor	9852.9	9729.9	2030.6	1711.7	7570	63217	

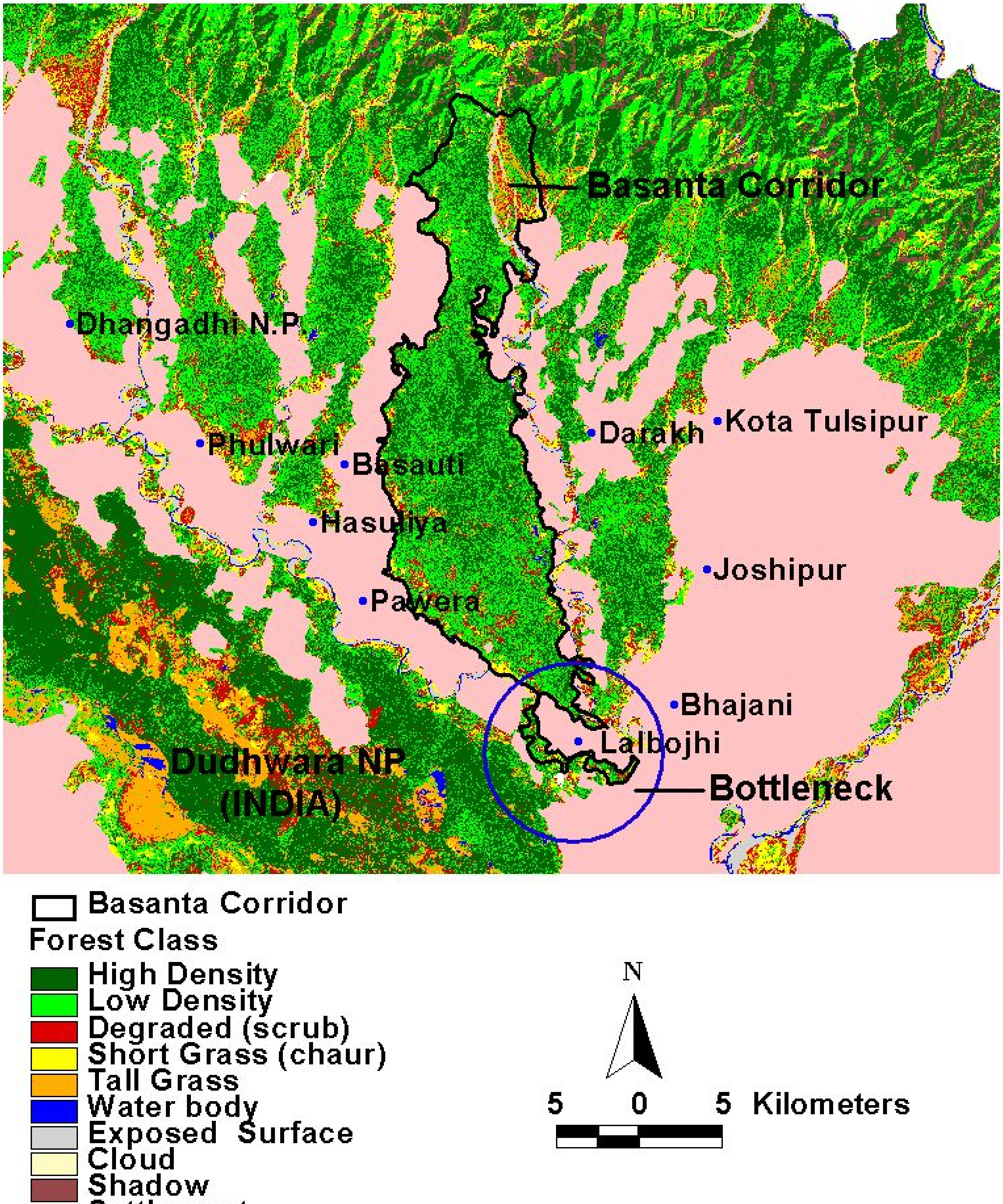


Fig 3. Priority forest restoration areas in Bardia-Katarniaghat corridor

Use of Forest Classification in Monitoring and Evaluation

This forest classification provides most recent and accurate representation of forest coverage in 12 districts in the lowlands of Nepal which fall in the TAL. This classification will help not only in planning biodiversity conservation and natural resource management plans but it will also play equally important role in the monitoring and evaluation of project interventions. With the base line data established it would be easy to monitor and evaluate activities that are directly or indirectly related with forestry such as forest restoration, effectiveness of community forest, livestock improvement programs, alternative source of energy (bio-gas, or solar power), as well income generation through off-farm skill development programs.

Biodiversity monitoring can be done more efficiently with detail forest classification of entire TAL. Vegetation monitoring transects can be laid in the high priority areas to monitor change in habitat quality to prevent further degradation and fragmentation. Likewise efficient wildlife monitoring system can be developed with the knowledge of habitat types.

Monitoring Forest Change at Landscape Level

Satellite data provides an efficient way of detecting change in forest condition over large area. With all algorithms worked out it will be easy to classify future and compare with the current data to measure change in forest cover as well as composition. One way to compare such change is to compare same area between satellite scenes from 2 different time periods. Then using same algorithm new scenes can be classified and cross tabulations models can be used to see transformation of forest types (pixel values) from older scene to newer scene using a transition matrix presented below (Fig 4).

Table 4. A simple transitional matrix to compare change from Time 1 to Time 2.

Classification from Time 1						
		High density	Low density	Short grass	Tall grass	Degraded
Classification from Time 2	High density	90	10	0	0	0
	Low density	20	75	0	0	5
	Short grass	0	0	70	30	0
	Tall grass	0	0	10	70	20
	Degraded	5	20	5	0	70

In the hypothetical example represented by above matrix forest condition seems to be improved from Time 1 to Time 2 because it shows 25 % of degrade forest changed to better quality forest with very little conversion of high and low density forest to degraded or short grass, which generally represent degraded forest edge. This method is good to track changes of higher magnitude such as clear cuttings or plantation of large open areas. Because the values are in categorical it will be hard to measure incremental changes over small area. The better method for measuring such changes will be to develop a continuous model for next level of classification.

Next Step: Advanced classification model for change detection

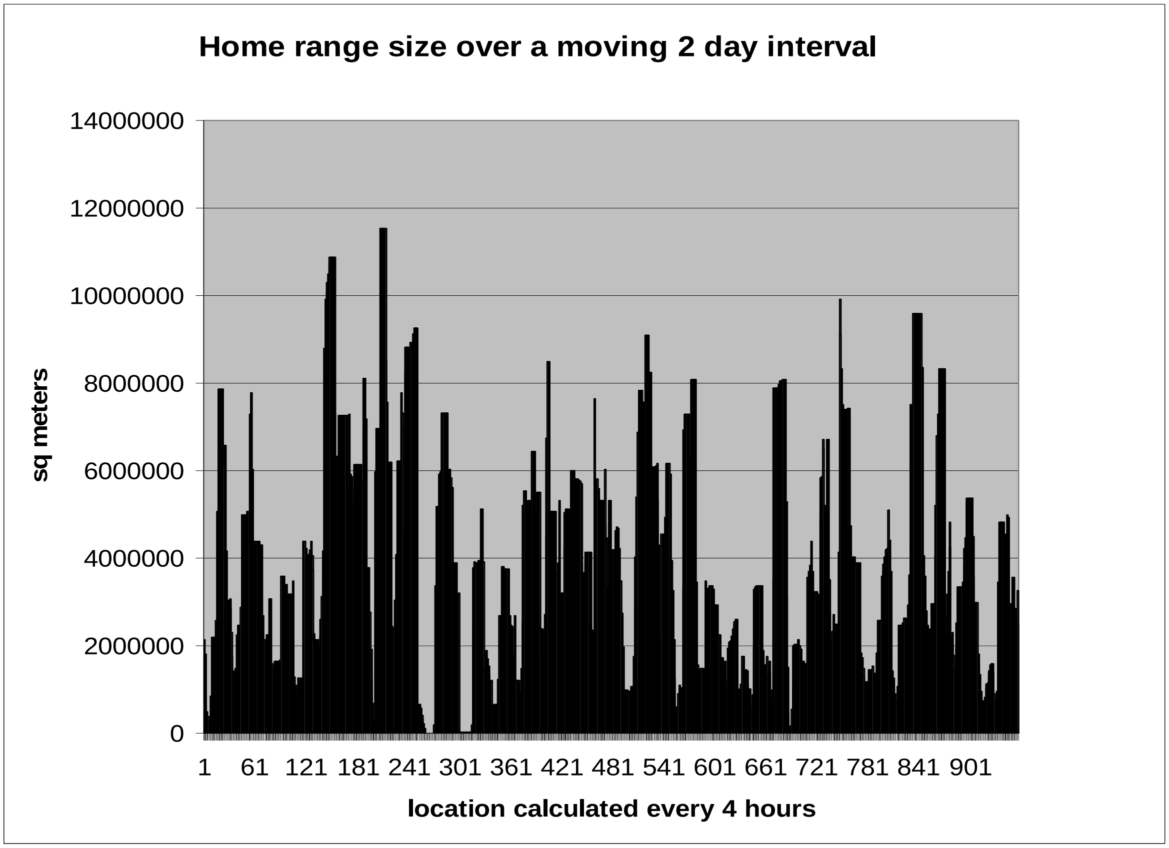
One of the effective methods for building continuous classification model to compare incremental change in forest quality to evaluate and monitor projection interventions will be develop a moving kernel which will give a continuous value to each cell based on the neighboring cells. For example we can develop a model to give value to each cell based on the percentage of different forest types in a matrix of 5 by 5 cells. The classification based on such model would be more homogenous and easier to track small changes.

IV. Collaring tigers to study behavior of individuals living in human dominated landscapes.

Two tigers were radio collared with GPS collars. One was a large female that lived partially inside Royal Chitwan National Park. The other was a female with 4 cubs. We obtained 652 GPS locations over a 5 month period on the second tigress. Her home range was approximately 17 km^2. Considering that she was raising 4 cubs that were 12 months old when she was collared, and 17 months when the collar was recovered, her home range was exceedingly small. In April and May she was feeding 2 male offspring that were considerably larger than she was and 2 female offspring that were only slightly smaller than she was. Based on clusters of locations we estimate that she killed 6 times during the month of April 2001.

Data from this female will help develop a more realistic set of movement rules for a model we have developed to study tiger feeding behavior. Based on our GPS data, after tigers finish a kill they move rapidly away from the kill site and then resume a more meandering movement pattern that may indicate resumption of hunting behavior.

Because GPS data are highly autocorrelated, there is a set of questions that can be asked about tiger movement and home range use that were not easily addressed with data taken at greater intervals. Based on the assumption that long periods of clustered data either represent a kill or mating, we are able to examine shifts in movement patterns. We assume that clustered data from our radioed female represents time she and her cubs spent at the site of a kill (it is unlikely she was mating before the cubs were at least 16 months old). We have created a dynamic movement viewer to help understand movement patterns. We explore shifts in home range size when calculated for a 1, 2, 7, 10 day interval. Figure 1 below shows shifts in home range size for a moving window of 48 hours. There were 27 occasions when home range size was less than a radius of 250 m. We plan to continue this study in the future.


Home range size over a moving 2 day interval
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
sq meters
1
61
121
181
241
301
361
421
481
541
601
661
721
781
841
901
location calculated every 4 hours