From: Pages 214-231
Conservation Biology in Asia (2006) McNeely, J.A., T. M. McCarthy, A. Smith, L. Olsvig-Whittaker, and E.D. Wikramanayake (editors). Published by the Society for Conservation Biology Asia Section and Resources Himalaya, Kathmandu, Nepal, 455 pp. ISBN 99946-996-9-5

CHAPTER 14

USING A "BAGH HERALU" NETWORK TO MAP THE METAPOPULATION STRUCTURE OF TIGERS IN NEPAL

By

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ABSTRACT

Citizen participation was used to assess the potential for tigers to disperse between protected areas in Nepal and to determine if breeding occurred outside of the protected areas. We were interested in breeding and dispersal outside of reserves because: 1) existing reserves are too small to maintain viable tiger populations; 2) the extensive forest lands outside reserves could supplement the land base for tigers and could also serve for dispersal corridors; and 3) it is feasible to improve tiger habitat in these forests because local people are increasingly interested in forest restoration. We chose 30 areas where dispersal might be restricted and a local villager ("Bagh Heralu", Nepali for "tiger guard") was hired in each site to report livestock kills and tiger tracks. Monthly for 3.5 years a research technician went with "Bagh Heralu" to verify all kills / tiger tracks discovered within the past month and locations were geo-referenced. Breeding habitat was identified by presence of co-occurring female and cub tracks. Tigers were recorded near 26 of the 30 chosen sites. Four gaps in tiger distribution were found, and we hypothesized that four discrete tiger populations occur in Nepal and adjacent habitat in India. Evidence of breeding tigers was found at three sites outside protected areas. The "Bagh Heralu" network is a form of citizen science that provides much greater sampling intensity than a team of biologists can accomplish without such help. Additionally, cooperation with villagers has potential to contribute significantly to community support of tiger conservation on a landscape scale.

Key Words: "Bagh Heralu", conservation, corridor, metapopulation, monitoring, Nepal, tiger.

INTRODUCTION

In response to the tiger (*Panthera tigris*) extinction crisis in the late 1960s, a number of national governments used this species as a symbolic rallying point for conservation in Asia. The tiger was considered important as a keystone and umbrella species (Seidensticker & McDougal 1993; Seidensticker 1997), and throughout the 1970s protected areas were created in most tiger range states. Before the advent of population viability analysis (Soulé 1980; Schaffer 1981), many of Asia's most widely known protected areas were created. As a result, no clear biological criteria were used to determine appropriate size of parks. Furthermore, methods used to estimate tiger population size were not rigorous (Karanth *et al*. 2003), and mapping of tiger distribution proceeded slowly (Smith *et al*. 1987; Ahearn *et al*. 1990). As a result, little reliable information on tiger population size and degree of isolation was obtained. In the mid-1990s, Dinerstein *et al*. (1997) mapped tiger distribution across the entire species range. This effort was useful for setting priorities, but was not based on field studies and did not attempt to accurately estimate tiger population sizes within reserves or across entire tiger conservation units. Because of inadequate counting and incomplete mapping efforts, sizes of discrete tiger populations and their geographic extent are still unknown. Therefore, it remains difficult to answer the questions: "are protected areas large enough to conserve tigers?" and "how critical is connectivity among populations for long-term population or species survival?"

No clear answer is yet available to the question of what level of connectivity is adequate to increase population viability. Geneticists have addressed the degree of connectivity needed to prevent local genetic differentiation in the absence of selection. However, for small population viability, connectivity is also demographically important. Pulliam (1988; Pulliam *et al*. 1992) has suggested that sink habitat may function in some circumstances to increase source population size, and similarly that corridor habitat may allow animals from a nearby source population to demographically supplement a population. World Wildlife Fund's ecoregional initiative in Nepal and globally is based on a wide consensus that increasing connectivity is an important conservation issue.

The goals of our research were to determine if barriers to dispersal among tiger populations occur in four protected areas in the sub-Himalayan lowlands or Terai and if any breeding is still occurring outside of these protected areas. This information would help to elucidate the metapopulation structure of tigers in this region and provide managers with information needed to devise a conservation strategy. This site-specific study has important global significance because a great deal of uncertainty remains about how much conservation effort should go to securing existing protected areas versus expanding effort to also include the human dominated landscape that occurs between clusters of regional reserves. This research is a first step to evaluating sink and corridor habitat for tigers.

To ascertain if a dispersal corridor exists is a difficult task because dispersal can be a very rare event. Our approach was to determine if any sites along potential dispersal corridors in Nepal are unoccupied for long enough to conclude that there are barriers to dispersal. To do this we have chosen key sites along potential dispersal corridors, and at these sites we search for tiger sign and ask local villagers to report any tiger sign or livestock kills. Kills are a good indicator of tiger presence because there is a very low density of wild prey throughout potential corridors and thus tigers rely on domestic livestock for food.

We utilized local citizens recruited as "Bagh Heralu" ("BH") to help collect information on distribution of livestock kills and other tiger sign. Specific objectives were to: (1) determine if structural forest corridors that connect protected areas potentially function as dispersal corridors for tigers; (2) determine if tiger breeding occurs in forests outside protected areas; (3) 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; and (4) establish a community-based network of "BH" to accomplish objectives 1 & 2 and to increase citizen knowledge of tiger conservation issues.

METHODS

Study Area

Our study area included 11 Terai districts in seven administrative zones that extend from the Koshi River in the east 722 km to the Mahakali River in the west. The Terai range from 90 to 1000 m in elevation and encompasses the most fertile land in the country. At present, much of the Terai forest has been converted to settlement and agricultural land. It is estimated that about 200,000 ha of the Terai and Siwalik forests were cleared through planned settlement and illegal logging from 1950 to 1985 (Pradhan & Parks 1995). Currently the Terai region has the highest human density in Nepal. Settlement of landless farmers in the regional forests and illegal harvest of trees are still occurring, but community forest plantations and forest restoration are also spreading across the lowlands. In parts of the Terai, particularly in western Nepal, large tracts of forest remain.

Assessing Habitat Connectivity

Our problem was how to determine when we can conclude that tigers are not using a site. There is a growing interest in estimating site occupancy when detection probability is less than one (Mackenzie *et al*. 2002). These statistical approaches, however, could not be applied to our situation because they are based on the assumption that an occupied site remains occupied or if it becomes unoccupied it is because of some ecological covariate. In our case, most sites are not continuously occupied. Furthermore, we assumed that there is connectivity if sites are occupied for a single day. Because we could not develop a statistical approach, we relied on induction. We set our criteria for a dispersal barrier if no tiger sign was found at one or more sites after approximately ½ a tiger generation (Smith & McDougal 1991), roughly 3.5 years.

Sites were selected based on previous tiger reports (e.g. data from old hunting block records, our own past surveys and those of C. McDougal, Personal communication) or at distances of < 30 km along a potential corridor. We did not attempt to sample the entire available habitat because our objective was to determine if there were breaks in tiger distribution, not the full extent of distribution. Isolated forest blocks located a considerable distance from tiger reserves were excluded if no tigers were reported after informally interviewing local people in those areas. A total of 30 survey sites were selected from the known range of tigers in Nepal. Two sites in eastern Nepal were chosen at a distance > 30 km from other sites to determine if tigers had become extirpated from an area where tiger sign had become gradually rarer over the past 30 years. The last observed tiger track in this area was in 1994 (Smith *et al*. 1999), so we included these sites to help confirm that tigers no longer occurred in the area.

We hired “BH” at each of these localities. They informed villagers within a median radius of 6 km from their village that they were seeking information about tiger depredation of livestock or tiger sign. “BHs” held community meetings, sent letters to schools, and asked everyone they contacted to inform their neighbors about reporting livestock depredation and tiger sign. Word spread widely through these communities through causal meetings at tea stalls and local markets. Additionally, “BHs” and research technicians together made reconnaissance surveys (Walsh and White 1999) looking for tiger sign recording distance walked per sign encountered.

When a kill or track was reported, the “BH” and the herder or owner of the dead animal visited the site and the “BH” filled out a data sheet. Tiger tracks lasted for a variable amount of time depending on substrate and weather; some in soft muddy substrate lasted for several weeks. To help preserve tiger sign until the site could be revisited by research technicians, “BHs” covered kills with branches and tracks with flat rocks perched on small pebbles. This technique allowed the research technician to recheck and verify the species, sex and age class of the animals that produced the sign. It is important to note that the ability of “BHs” to recognize sign was tested each time a research technician went to a site with them.

An important part of the site visit was to determine if a tiger or leopard (*Panthera pardus*) made the kill. The following criteria were used to determine if a tiger made the kill: (1) tracks with a pad width > 7.5 cm near the kill (Table 1); (2) kills > 200 kg that were dragged more than 15 m (Seidensticker 1976; Johnsingh 1992; Karanth & Sunquist 1995); (3) broken rib bones of medium and large sized prey (> 100 kg) (leopards do not have a large enough jaw or the strength to break large ribs of cows or buffalos, Personal observation, J.L.D. Smith); (4) large canine tooth holes > 5 cm deep (Personal communication; C. McDougal). Predator identity that was difficult to confirm by the above criteria was recorded as leopard.

Intensity of survey efforts is usually measured as encounter rate per km walked. In our study where reporting of livestock kills or sign were made by villagers and “BHs” we considered sampling effort to be an area of approximately 901 sq km (Table 2) searched for 1268 days. However, additional research technicians (accompanied by “BHs”) conducted tiger surveys in the vicinity of “BHs” villages, only when no tiger kills or tracks were reported within the past one month. On this recce, we recorded the route of survey, distance covered, and location of sign and calculated rate of encounter. Our routes examined likely tiger travel ways (e.g. dry riverbeds, streams, dirt trails and jungle trails for tiger sign) and we noted and measured tracks, kills, and scats. During these surveys tiger scat was discriminated from leopard by scat diameter (i.e. diameter > 4 cm was recorded as tiger). Scat data were important during the summer months to determine tiger presence because scats remained intact for > 2 weeks; tracks were often washed away after a heavy rain. It is important to note that we did not attempt to estimate density and, although we offer meaning of encounter rate, we do not use rate of encounter to make any probabilistic statements.

Extent of Breeding outside Protected Areas

Based on the sex and age class of tiger sign observed at survey sites, an area was classified as "breeding" or "non-breeding habitat". Breeding habitat outside protected areas was defined as habitat > 4 km from protected areas where female tracks co-occurred with cub tracks at the same location.

Establishment and Training of "Bagh Heralu" Network

The "BH" network was established to enlist the help of thousands of villagers in reporting tiger sign and depredation (Figure 1). In addition to help conduct research, we also recognized the potential for this network to increase involvement of local people in regional conservation efforts. "Bagh Heralu" is the title given to a local villager hired to monitor tiger activities in his area. We chose "BHs" who lived in the area year around and were familiar with the forest near their village. Two experienced tiger research technicians verified all information provided by "BHs" by going with them to sites where kills or tiger signs occurred. These researchers had collaborated with McDougal (1999) to formulate criteria for evaluating tiger signs (i.e. using size criteria to accurately distinguish tiger from leopard and male from female tiger tracks).

Four workshops were conducted (December 1999, March 2000, June 2002, March 2003) to train and then to review and evaluate skills of "BHs". The main objective of the first two workshops was to train "BHs" to record data on livestock depredation. At the 2nd through 4th workshop, an ongoing dialogue among the "BHs" and research staff sought to continue to build the capacity of "BHs" and to share research results.

RESULTS

Tiger Presence and Absence at Critical Landscape Points

During the course of the study (October 1999 - March 2003), tiger sign was found on 511 occasions; 354 were tiger sign (e. g. pugmarks, scats), 149 were kills of livestock, 3 were humans killed by tigers and 5 were dead tigers. A total of 457 observations were made in the vicinity of 26 of 30 "BHs"; an additional 54 observations were made while traveling to visit "BHs" (Table 2). By using track size and sexing dead tigers, gender was determined in 436 cases (Table 3). 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 2). The tiger killed 209 animals in 149 occurrences. Single animals were killed 113 times and 2-7 animals were killed 36 times. Adult cattle (N=149) and buffalo (N=47) comprised 94% of tigers kills, whereas, 89% of kills made by leopards were cow calves, pigs and goats (Figure 2).

Of the 354 observations of tiger tracks and scats, 312 were made by "BHs". Out of these 312, 199 were made first by the "BHs" and subsequently confirmed to be correct by research technicians on all occasions; another 42 observations were made by recce surveys where a "BH" and a research technician walked together. On only 71 occasions did "BHs" report sign that we could not confirm because the tracks were washed away or trampled before a research technician visited the site. Based on the "BHs'" verified ability to identify tracks, we accepted their data on the 71 occasions when tracks could not be confirmed. Kills were more difficult for "BHs" to identify to species. Of 149 occurrences of kills "BHs" could not identify the species making the kill on 11 occasions (7%). When we examined these 11 kills, we were able to classify 8 of them.

The total area monitored by the "BH" network was 901 sq km with a mean area of 31 sq km (Table 2) and a median radius of 6 km. The longest distance searched on foot was 15.8 km. This was an overnight trip by a "BH" who was monitoring a site where tigers were never found in 1268 days. This "BH" was in a quandary. There were tigers found to his east, the only feasible source population was to his west and there was no tiger sign in his area. He surmised that there must be another habitat corridor to the south in India.

In India with the help of local villagers he found 3 sets of tiger tracks suggesting that there was another potential dispersal corridor in India (Figure 3). On another occasion a "BH" heard about a kill that occurred 23.7 km from his village so he took a bus to investigate. A total of 250 transects covering 2117 km was walked on the additional survey transects conducted when no tiger presence was reported within the past month in the study area. On average 2 hrs 48 min per km were spent surveying the routes.

Degree of Connectivity between Reserves

Data we obtained with the help of "BHs" demonstrate tigers are widely distributed in forests outside protected areas (Figures 3 and 4). The two easternmost "BHs", located in the Trijuga Forest region, obtained no evidence of tigers during our 42 months study. We conclude that tigers currently do not occur east of the Bagmati River (Figure 4). Records obtained during this study indicate tiger distribution extends from the western border of Nepal to 16 km west of the Bagmati River, a distance of 546 km.

Based on data, four major gaps in distribution separate tigers in Nepal into three populations and isolate these populations from the Dudhwa population in India. The core area of each of these populations is a protected area: Royal Suklaphanta Wildlife Reserve (RSWR) in the far west; Royal Bardia National Park (RBNP) in west central Nepal; Dudhwa Tiger Reserve (DTR) in India; and Royal Chitwan National Park (RCNP) in east central Nepal (Figure 3 and 4).

The isolation of Suklaphanta. From west to east, the first gap in tiger distribution occurs east of RSWR between its northern extension (near the base of the Siwalik Hills) and 22 km to the east (Figure 3). A 3 km wide area is located in the middle of the gap where intensive agriculture appears to create a strong dispersal barrier. The "BH" 7 km south of this east-west gap reported tigers were never observed near his village in the Laljhadi Forest. This forest extends south to within 2 km of DTR where a zone of intensively settled land along the India-Nepal border creates a strong barrier to dispersing tigers. This barrier, supported by lack of tiger records in Laljhadi Forest, provides strong evidence for a 33 km gap in tiger distribution in this area. East of the first gap, tigers were reported by 2 "BHs" along the 75 km forest corridor that extends to RBNP. However, this connection is tenuous because only 2 tiger kills were reported in this corridor (22 km west of Bardia) during the 42 months study period.

Connectivity of Dudwa Tiger Reserve to Bardia National Park. South of the east-west corridor between Suklaphanta and Bardia National Park, 42 km west of Bardia, is a large forest block, Basanta Forest, that forms a north-south corridor providing a potential link from DTR to RBNP. Tiger sign was recorded by "BHs" on 103 occasions in this forest just 9.5 km north of DTR and 56 km southwest of RBNP. South of this area of concentrated tiger sign, Basanta Forest continues to the border with India. Along the border there is an intensely settled 1 km strip of agricultural land and villages similar to the region of settlement on the Nepalese-Indian border at the western end of DTR. However, the Mohana River meanders through this cultivated strip and at one point flows north-south between DTR and Basanta where the forests are separated by only 0.5 km. The river course and riparian vegetation may function as a corridor used by tigers to move from DTR to Basanta Forest (Figure 5). We hypothesize that tigers can move between DTR and Basanta Forest and between Basanta and RBNP. However, the potential corridor from DTR to RBNP is tenuous; therefore, we classify DTR and RBNP as separate populations.

Breaks in connectivity between Bardia and Chitwan. A gap in tiger distribution occurs to the east of Bardia. It extends 34 km between Lamahi and Kapilbastu district in Nepal (Figure 3). Because we found tigers at Kapilbastu, east of this gap, but clearly isolated from Chitwan, we surmise that a corridor between Bardia and Kapilbastu must exist. To investigate this possibility, the field coordinator and "BH" based at Tabdarpur in Dang valley surveyed in India just south of the Siwalik ridges that form the border. They observed male and female tiger tracks, suggesting that a southern dispersal route exists around the Lamahi - Kapilbastu gap. Observations of tigers further west along this southern dispersal corridor (Figure 3) provide additional evidence for this potential southern dispersal corridor. This route, from RBNP to Kapilbastu, 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 RCNP (Figure 3). The city of Butwal, a major lowland urban center, lies at the center of this gap and creates a strong barrier to tiger dispersal. The "BH" based 10 km east of Butwal never observed tigers in his area during the study period.

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 of Bardia to 162 km east of Bardia (Figure 3); the Chitwan tiger population extends 164 km east to west (Figure 4). The widest portion of these populations is 30 km and the narrowest is 1.5 km.

Breeding Habitat outside Protected Areas

Figures 3 and 4 show five areas outside protected areas 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 (Table 3), so we assume the home ranges of these females were primarily within the National Park with part of their home 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.

Development of the "Bagh Heralu" Network

Initially 30 "BHs" were recruited (Figure 1). "BHs" had diverse backgrounds (e.g. 11 farmers, 6 livestock herders, 5 hunters, 6 community leaders, and 2 intelligence informants). As our research progressed, "BHs" became more knowledgeable about basic tiger biology through a series of workshops and visits by field technicians. "BHs" also were recognized in their communities as local tiger experts. Their knowledge of the ecological needs of tigers and strong local interest in the project increased discussions of tiger conservation in local communities throughout the lowlands. This was the first effort in Nepal to conduct formal or informal conservation education beyond the buffer zones of protected areas.

DISCUSSION

The ultimate goal of this research was to map the current metapopulation of tigers in Nepal and to determine extent of breeding outside protected areas. We accomplished this by recruiting local citizens as "Bagh Heralu"; their job was to collect information on distribution of livestock kills and other tiger sign. We are confident that the 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 that the "BH" approach enhances data collection and conservation efforts in several ways. First, because "BHs" were resident members of their community, people were willing to travel 2.5 hours by foot to report kills to the "BH", thus significantly enhancing the database. A second benefit of "BH" 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 "BH" concept facilitated spread of knowledge about the project through local communities, fostering citizen pride in the member of their community who was a tiger expert. We suggest that the activities of "BHs" caused many small rural communities to become more knowledgeable about tiger conservation programs and issues. An obvious potential disadvantage of "BH" is the variable level of skill and ability to collect and report data. We worked to overcome these problems through continuous training and monthly data review by wildlife technicians. These technicians essentially served as "middle managers" who evaluated data collection and provided advanced training in the field.

Tiger distribution and metapopulation structure

In the 1920s, tiger habitat was continuous across the lowlands of Nepal (Survey of India Maps 1924). Tigers were still distributed widely enough in the 1960s to support tiger hunting in most of Nepal's lowland forests (McDougal pers. comm.). However, in the 1950s, malaria eradication and a policy to resettle people into the lowlands of Nepal resulted in progressive habitat loss and fragmentation that has increasingly isolated tiger populations (Gurung 1983). We use the term metapopulation (Hanski and Gaggiotti 2004) to describe the distribution of tigers and define the term broadly as a group of geographically grouped local populations, with the potential for genetic exchange among populations. The concept of metapopulation is heuristically useful for describing the spatial structure of tigers because historically there was adequate connectivity among populations to apply this term to the local complex of tiger populations (Smythies 1942). Although currently the level of gene flow among populations is low or non-existent, a goal of the Nepal Tiger Action Plan (DNPWC 1999) and the Terai Arc Landscape project (TAL) (WWF 2001) is to re-establish connectivity among tiger populations.

This study showed that tigers occur throughout most of the forests from RSWR to east of RCNP in central Nepal. However, there are clear breaks in tiger distribution that must be restored if connectivity is to be re-established. For managers to attempt corridor restoration, they need a description of habitat required by dispersing tigers and criteria to determine if management goals have been achieved. Because determining probability of dispersal is difficult, we suggest criteria for a tiger corridor be continuous forest cover < 5 km (Smith 1993). Unless an animal is photographed or radio located at each end of a corridor, it is not possible to determine if dispersal has occurred. We further suggest that presence of tigers throughout a corridor serves as strong evidence that dispersal is possible and can be used by managers as an indication that the management goal of connectivity has been achieved.

Using these criteria, all populations, except possibly Bardia and Dudhwa, are isolated. Dispersal between Dudhwa and Bardia is most likely to occur because there is no major gap in tiger distribution between these units; the habitat corridor, while tenuous, still exists. The other gaps (Suklaphanta to Dudwa, Suklaphanta to Bardia and Bardia to Chitwan) all need to be restored if historic connectivity among populations is to be reestablished.

In contrast, the Chitwan and Suklaphanta populations are separated from Bardia and Dudhwa by gaps (55 and 22 km respectively) in distribution of tigers and shorter breaks in forest cover created by heavily settled agricultural land. Because the gap in habitat where tigers do not occur is shorter, restoration of connectivity between Suklaphanta and Bardia is more feasible than reestablishment of the link between Bardia and Chitwan. Reconnecting these units will require community forestry and forest restoration at the gap and all along the corridor.

Restoration of a habitat link between Chitwan and Bardia has the added challenge of creating a corridor around the city of Butwal, which lies at the base of the Siwalik Hills. There is no forest cover to the south and a steep gorge lies to the north with cliffs that will likely prevent a tiger from crossing the gorge. At the north end of the gorge a narrow valley exists where the river bifurcates into smaller rivers that are aligned east-west. This valley and its hillsides are intensively settled. Smith (1993) described Butwal and the gorge as a strong barrier to tiger dispersal. Recreating either link requires a careful ecological and economic plan.

As the most modest undertaking to enhance connectivity, we recommend reduction of grazing pressure and establishment of community forestry plantations along the river corridor that connects Basanta Forest to the Dudhwa Tiger Reserve. This project, if successful, will demonstrate the feasibility of TAL's long-term goal of increasing connectivity. This restoration will potentially increase the size of the Dudhwa tiger population by fostering regular exchange of tigers between Basanta Forest and DTR, increase likelihood of dispersal between Dudhwa and Bardia, and develop an alternative to the Baghmara Community Forestry model (Dinerstein *et al*. 1999). The specific conditions leading to success of the Baghmara project are clearly not present in Basanta Forest. However, there is growing interest among local people adjacent to Basanta, and elsewhere in the Terai, to restore the integrity of degraded forests, to undertake community forestry projects at the periphery of national forest lands, to upgrade domestic livestock through breeding programs and stall-feeding, and to establish community user groups.

Breeding Habitat

At three sites outside protected areas there was unequivocal evidence of breeding (e.g. cubs were sighted, and tracks of cubs were observed in association with female tiger tracks). Additional research is needed to study differences in the prey base and other ecological and spatial factors between these breeding and other non-breeding habitats. Research has focused on tigers living in prime habitat either in RCNP or RBNP; 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. Knowledge of the behavior and reproductive success of tigers in these areas may provide insight on how to manage tigers at a landscape scale (Ahearn & Smith 2005). For example, it is likely that breeding areas outside reserves are net population sinks. Nevertheless, Pulliam (1988) suggests that sinks similar to these may be important to the viability of source populations. A slight increase in productivity of a population sink might result in a source-sink dynamic that creates a larger, more stable population than the source population alone. 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.

Wildlife managers and conservation biologists have repeatedly expressed concern about increased risk of extinction as populations become small. Since Soulé (1980) postulated his 50 - 500 rules, there has been significant discussion about minimum viable population size, but lack of adequate population data limits ability to fine-tune population viability analysis for most species. For example, although, Kenney *et al*. (1995) used an extensive data set to demonstrate that populations of 25 breeding tigers have a high probability of surviving 100 years, they had no information on genetic factors (inbreeding depression; loss of genetic variability needed to resist disease) or the magnitude of periodicity of catastrophic environmental events. Faced with similar unknowns, conservation biologists have formulated the precautionary principle (Bodansky 1991). Applying this concept to tigers in Nepal, managers should opt for a large and more connected forested land base to support larger, 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, maintaining these sink habitats is also worthwhile because restoring a weak sink is clearly easier than recovering habitat so degraded that it no longer supports breeding tigers.

"Bagh Heralu": A New Approach to Tiger Monitoring

In summary, the "BH" based approach is useful for determining tiger distribution and documenting breeding in much greater detail than through periodic field surveys conducted by trained biologists. Involvement of local people in monitoring tigers also appeared to increase awareness of tiger conservation in local communities across Nepal's lowlands.

It is important to reflect that the major management recommendations from this research, and much of the conservation literature (USAID 2002), is to better understand human behavior and work more closely with local people to devise new economic endeavors that reduce direct competition for resources between humans and other animals. Our experience indicates the concept of "BHs", and similar efforts, have significant potential to shift some of the responsibility for biodiversity conservation from government agencies to local communities thus enhancing efforts to manage resources sustainably across entire landscapes.

Acknowledgments

This Project was funded by U.S. Fish and Wildlife Service's Rhinoceros, Tiger Conservation Fund, the National Fish and Wildlife Foundation's Save the Tiger Fund, International Trust for Nature Conservation, The Fund For The Tiger, and the University of Minnesota Agricultural Experiment Station. We thank Dr. Tirtha Man Maskey and his colleagues in the Department of National Parks and Wildlife Conservation (Nepal), for support, encouragement and permission to conduct this work. We also acknowledge F. Cuthbert, C. McDougal, and A. Joshi for important intellectual input to this study. Finally, we are grateful to Hari Prasad Choudhary, Indra Bahadur Kumal and all "Bagh Heralus" for their dedicated assistance in collection of field data.

REFERENCES

Ahearn, S.C., and J.L.D. Smith. 2005. Modeling the interaction between humans and animals in multiple-use forests: a case study of *Panthera tigris*. Pages 358-387 in D. Maguire, M. Batty, and M.

Goodchild, (eds.). **GIS, Spatial Analysis, and Modeling**. ESRI Press, Redlands, California, USA.

Ahearn, S.C., J.L.D. Smith, and C. Wee. 1990. Framework for a geographically referenced tabular/visual conservation database: case study Nepal. **Photogrammetric Engineering and Remote Sensing 56**:1477-11481.

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

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. Pages 316-332 in J. Seidensticker, S. Christie and P. Jackson, (eds.). **Riding the tiger: Tiger conservation in human-dominated landscapes.** Cambridge University Press, Cambridge, United Kingdom.

DNPWC. 1999. **Tiger conservation action plan for the Kingdom of Nepal.** WWF Nepal Program, Kathmandu.

Gurung, K.K. 1983. **Heart of the Jungle.** Andre Deutsch, London.

Hanski, I. and O. Gaggiotti (eds.). 2004. **Ecology, Genetics, and Evolution of Metapopulations**. Elsevier, Amsterdam.

Johnsingh, 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., James D. Nichols, J. Seidensticker, E. Dinerstein, J.L. David Smith, C. McDougal, A.J T. Johnsingh, S. Raghunandan, S. Chundawat, and V. Thapar. 2003. Science deficiency in conservation practice: the monitoring of tiger populations in India. **Animal Conservation 6**: 141-146.

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.

Mackenzie, D.I., J.D. Nichols, G.B. Lachman, S. Droege, J.A.Royle, and C.A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. **Ecology 83 (8)**: 2248-2255.

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

Pradhan, A.S., and P.J. Parks. 1995. Environmental and socioeconomic linkages of deforestation and forest land use change in the Nepal Himalaya. Pages 167-179 in S. Hanna and M. Munasinghe, (eds). **Property rights in a social and ecological context,** The World Bank, Washington D.C., USA.

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

Pulliam, R.H., J.B. Dunning, and J. Liu. 1992. Population dynamics in complex landscapes: A Case Study. **Ecological Applications 2 (2)**: 165-177.

Schaffer, M.L. 1981. Minimum population sizes for species conservation. **BioScience 31:** 131-134.

Seidensticker, J. 1976. On the ecological separation between tigers and leopards. **Biotropica 8:** 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:** 6-17.

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

Smith, J.L.D., and C. McDougal. 1991. The contribution of variance in lifetime reproduction to effective population size in tigers. **Conservation Biology 5 (4)**: 484-490.

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

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

Smythies, E.A. 1942. **Big Game Shooting in Nepal.** Thacker, Spink and Co., Calcutta.

Soulé, M.E. 1980. Thresholds for survival: Maintaining fitness and evolutionary potential. Pages 151- 169 in M. E. Soulé and B. A. Wilcox, (eds.). **Conservation Biology: The science of scarcity and diversity.** Sinauer Associates, Sunderland, MA.

USAID. 2002. **Biodiversity conservation program design and management: A guide for USAID staff**. USAID, Washington, D.C.

Walsh, P.D. and L.J.T. White 1999. What will it take to monitor forest elephant populations? **Conservation Biology 13**: 1194-1202.

WWF. 2001. **Terai arc landscape, Nepal.** WWF Nepal Program, Kathmandu.

Table1. Size criteria used to discriminate tiger versus leopard pugmarks (McDougal 1999).

	Pad Width	
	Front	Rear
Adult Male	≥ 9.7 cm	≥ 9.3 cm
Adult Female	> 8.5 cm	7.5 - 8.5 cm
Leopard	< 7.0 cm	< 6.0 cm

Table 2. A total of 511 tiger observations (e. g. tracks, kills, scats) observed by "BAGH HERALUS" from October 1999 - March 2003. Also reported are numbers of months in which tiger and cub sign were observed and area surveyed at each "BH" site.

No.	BH ID	Village	Kills	Tracks	Scats	Dead Tigers	Months Present	Months cub present	Survey Area (km²)
1	101	Kalapani	2	7	0		8	0	22.1
2	102	Singhpur	0	0	0		0	0	40.9
3	103	Jhil	7	5	0		11	0	33.9
4	104	Lakkad	21	42	0		32	2	19.2
5	105	Nak Phoduwa	5	32	0		21	1	22.2
6	106	Jarai Thada	2	0	0		2	0	18.9
7	107	Balchour	8	29	0		23	0	30.1
8	108	Geruwani	3	0	0		3	1	22.7
9	109	Shamshergunj	25	32	0		28	3	17.3
10	110	Agaiya	2	15	0		12	0	21.5
11	111	Kumbhar	3	17	0		15	0	26.9
12	112	Kusum	8	24	0		21	0	16.2
13	113	Hardawa	14	20	0	1	19	0	69.5
14	114	Naya Basti	5	15	0		15	0	28.0
15	115	Tabdarpur	0	3	0		2	0	41.3
16	116	Ramuwadaha	6	4	0		9	0	21.3
17	117	Tikkar	2	2	0		3	0	60.7
18	118	Mormi	6	6	0		10	0	23.8
19	119	Keuli	0	0	0		0	0	22.4
20	120	Sukhaura	0	1	0		1	0	7.7
21	121	Ghaderi Tandi	5	2	0		6	0	30.8
22	122	Siseni	13	14	0		17	0	35.7
23	123	Arunkhola	0	0	0		0	0	17.0
24	124	Piluwa	3	9	0		9	0	32.0
25	125	Ratanpur	3	29	0		18	5	38.3
26	126	Simri	0	2	0		2	0	69.1
27	127	Gaidatar	1	0	0		1	0	72.0
28	128	Phoolbari	0	2	0		1	0	32.5
29	129	Sunderpur	0	0	0		0	0	10.2
30	130	Balahi	0	0	0		0	0	25.9
		Other Areas	8	21	21	4			
		Total=511	152	333	21	5		Total	930.1

Table 3. Breeding and non-breeding areas with numbers of male, female and cub locations reported by "BAGH HERALUS".

No.	BH ID	Village	Male	Female	Cub	Breeding /Non-breeding
1	101	Kalapani	4	4	0	Non-breeding
2	103	Jhil	9	0	0	Non-breeding
3	104	Lakkad	42	15	3	Breeding
4	105	Nak Phoduwa	21	11	1	Breeding
5	107	Balchour	23	12	0	Non-breeding
6	108	Geruwani	0	1	1	Breeding
7	109	Shamshergunj	30	18	6	Breeding
8	110	Agaiya	17	0	0	Non-breeding
9	111	Kumbhar	19	1	0	Non-breeding
10	112	Bairiya Kusum	24	5	0	Non-breeding
11	113	Hardawa	26	4	0	Non-breeding
12	114	Naya Basti	13	6	0	Non-breeding
13	115	Tabdarpur	2	1	0	Non-breeding
14	116	Ramuwadaha	6	3	0	Non-breeding
15	117	Tikkar	3	1	0	Non-breeding
16	118	Mormi	7	0	0	Non-breeding
17	120	Sukhaura	0	1	0	Non-breeding
18	121	Ghaderi Tandi	3	2	0	Non-breeding
19	122	Siseni	5	19	0	Non-breeding
20	124	Piluwa	1	8	0	Non-breeding
21	125	Ratanpur	6	15	8	Breeding
22	126	Simri	2	0	0	Non-breeding
23	128	Phoolbari	2	0	0	Non-breeding
		Other areas	12	11	2	
		Total= 436	277	138	21	

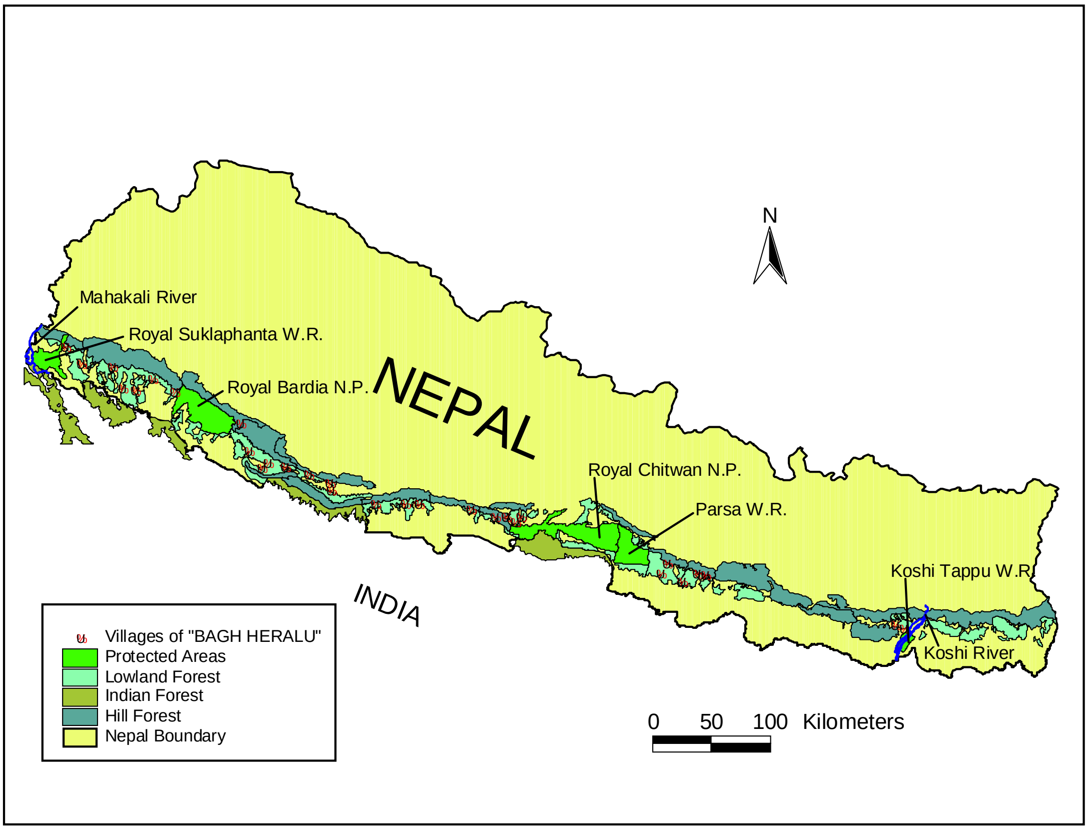

Figure 1. Location of "Bagh Heralus" in Nepal's lowlands.

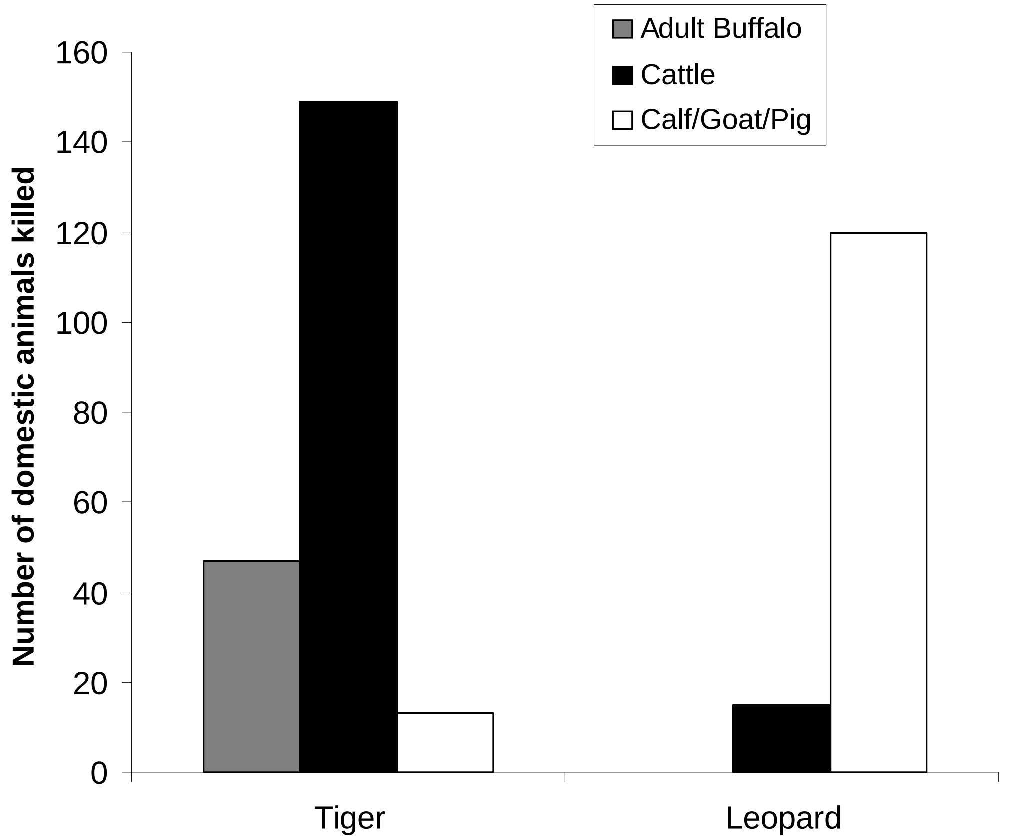

Figure 2. Comparison of size classes of domestic animals killed by tiger and leopard.

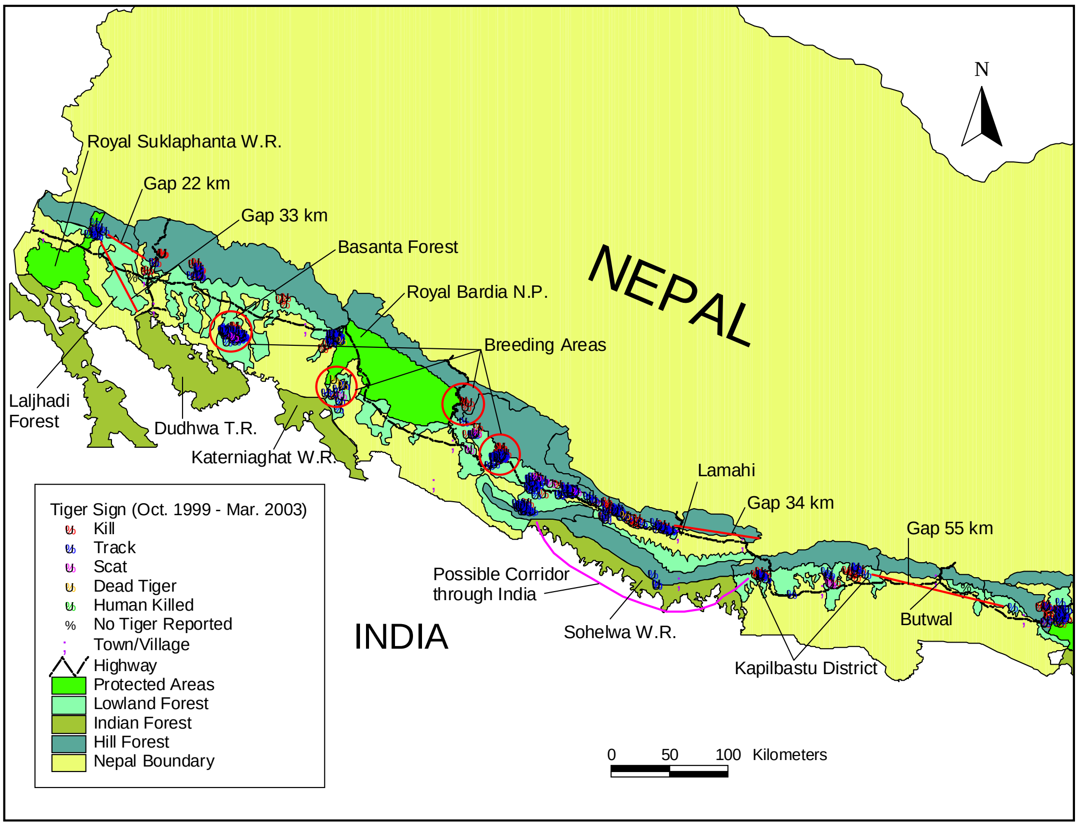

Figure 3. Locations of sign, breeding areas and gaps in tiger distribution between reserves in Western Nepal

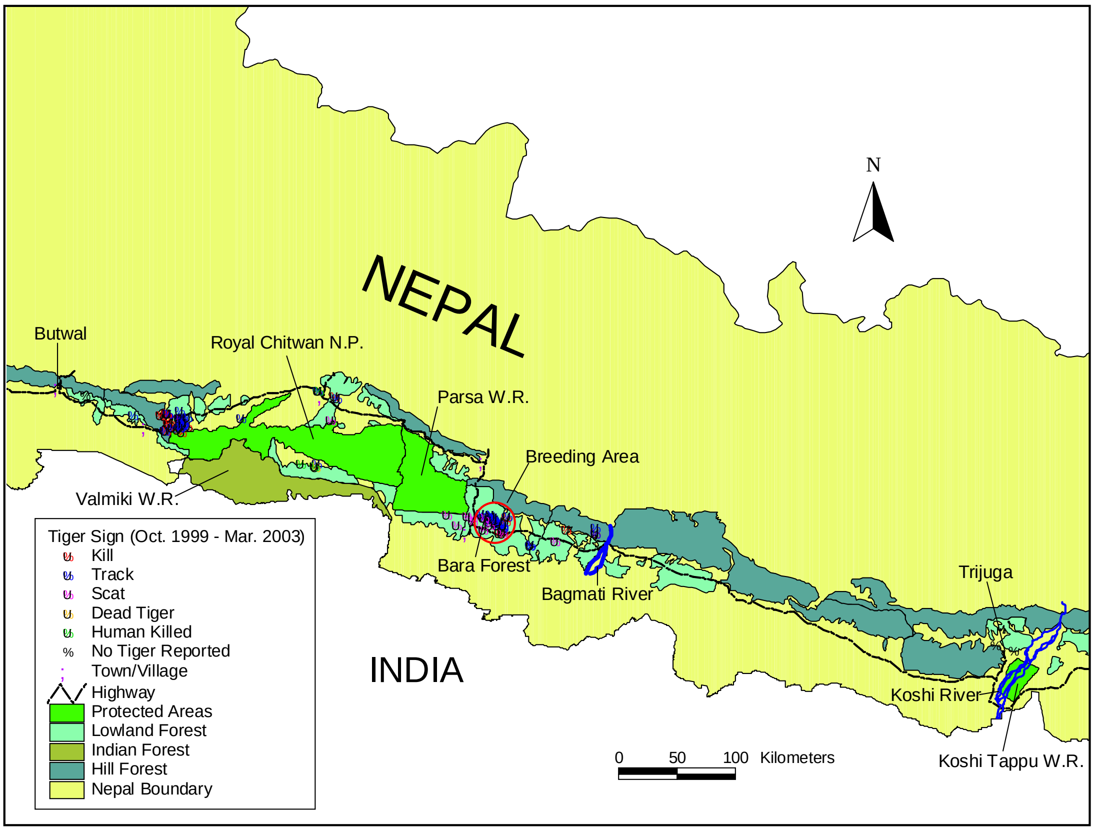

Figure 4. Locations of sign, breeding area and gaps in tiger distribution between reserves in Central Nepal

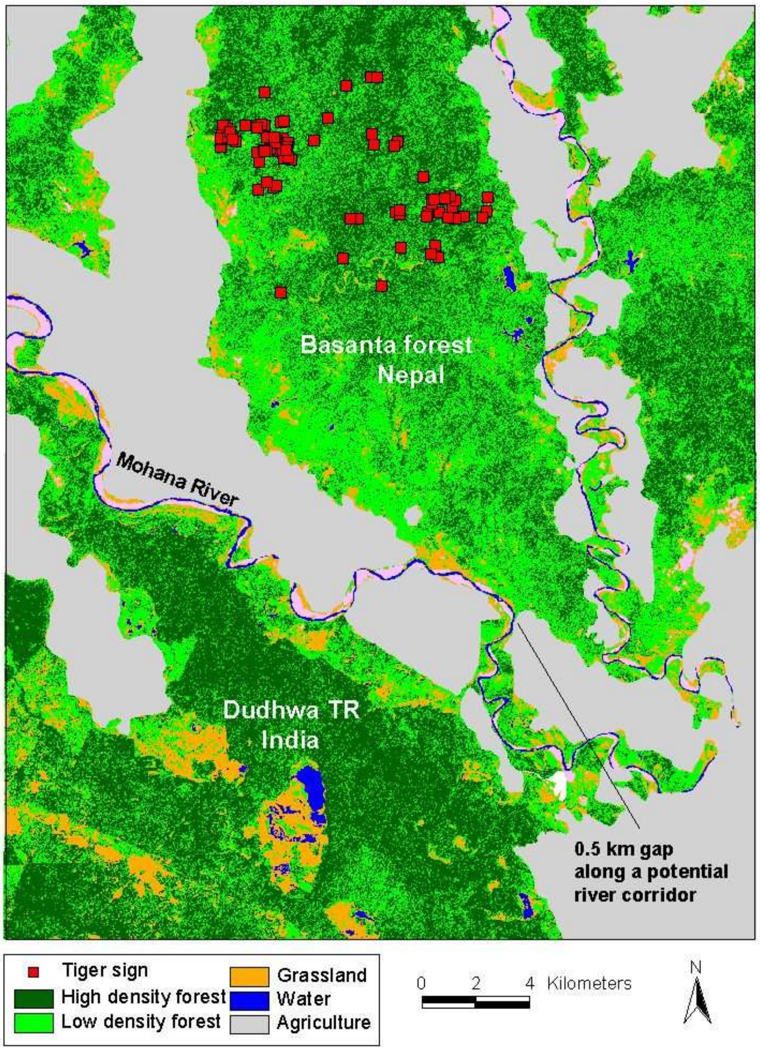

Figure 5. Hypothesized corridor between Basanta Forest and Dudhwa Tiger Reserve that we recommend as a high priority for restoration

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