



Evaluation of the functional status and quality of
corridors connecting fragmented populations of tiger
in the Indian part of Terai Arc Landscape

**Final Technical Report
(2004-0103-002)**

Funded by
Save the Tiger Fund, National Fish and Wildlife
Foundation, USA

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**भारतीय वन्यजीव संस्थान
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**Part III:
Summary and
recommendation**

Most rare and critically endangered species such as tiger (*Panthera tigris*) exist in human-dominated landscapes as small, fragmented and isolated populations in most part of its range. A prerequisite for conservation efforts and management is to identify the factors which affect the distribution and abundance of the species of interest and connectivity between populations occupying the remaining fragments. Tiger populations have dramatically declined in recent years in the Indian part of Terai Arc Landscape (TAL). This top priority landscape for tiger conservation was once continuous across the

Himalayan foothills but is now highly fragmented and most of the remaining large, intact habitats are located within protected areas. As tigers cannot sustain viable populations in small habitat fragments, an assessment of potential suitable habitat and connectivity among the remaining habitat patches is required to assess possibilities to ensure the creation of a single functioning metapopulation unit for tiger. Therefore, there is a need to monitor condition of tiger's habitat (Smith et al. 1998). The effectiveness of potential corridors depends on the quality of habitat within the corridor, the matrix that surrounds the corridor and redundancy of the corridor network (Collinge, 1998; Haddad et al. 2003). Out of ten corridors identified in TAL (Johnsingh et al., 2004), seven corridors were taken on priority basis for understanding quality and functionality assessment. Five and two corridors exist in Uttarakhand and Uttar Pradesh state of India, respectively. In view of understanding functionality of corridor, the objectives of this study was aimed (i) To describe the functional status (use and intensity) of the corridors with reference to tiger, (ii) To study the biological characteristics (vegetation composition, prey distribution and abundance, and disturbance status) that determines the corridor quality and (iii) To use, and to document the socioeconomic issues affecting the corridor existence and its use.

Under this study, we describe basic data obtained for these seven corridors for their habitat characteristics, use by tiger and level of disturbance under Part I. This would provide base line information for comparison in future. Data analysis undertaken in Part II of this report are use of ecological modeling models to assess functionality of these corridors using remote sensing data and other aspects.

Vegetation communities and structure:

We describe delineation of vegetation communities and woody vegetation as a key features of habitat quality. Highest vegetation communities delineated were ten in Rajaji-Corbett corridor followed by six each in Gola river, Kilpura-Khatima-Surai and Dudhwa-Katerniaghat corridors and five communities each in Kosi river, Nihal-Bhakra and Laggabagga-Sukhlaphanta-Tatarganj corridors. Hajra (2002) also delineated ten vegetation communities including grassland with sparsely distributed trees. Vegetation communities delineated in Rajaji-Corbett corridor is also comparable with that of the study by Singh et al. (1995) in Corbett National Park. Vegetation communities (6) in Dudhwa-Katerniaghat corridor are lower than that of the study by Kumar et al. (2002) where they found ten and this might be because of more plantations in the corridor area.

Total numbers of tree species recorded were 90 in Rajaji-Corbett corridor, 52 in Kosi river corridor, 45 in Nihal-Bhakra corridor, 54 in Gola river corridor, 60 in Kilpura-Khatima-Surai corridor, 49 in Laggabagga-Sukhlaphanta-Tatarganj corridor and 71 in Dudhwa-Katerniaghat corridor. Tree densities among vegetation communities ranges between 1.5 ± 0.1 to 85.8 ± 4.0 (Mean individuals/ha \pm SE) in Rajaji-Corbett corridor, 4.2 ± 0.3 to 85.1 ± 4.1 in Kosi river corridor, 6.1 ± 0.4 to 61.8 ± 5.4 in Nihal-Bhakra corridor, 2.8 ± 0.2 to 68.2 ± 6.5 in Gola river corridor, 4.1 ± 0.3 to 85.8 ± 11.8 in Kilpura-Khatima-Surai corridor, 3.2 ± 0.4 to 100.0 ± 9.5 in Laggabagga-Sukhlaphanta-Tatarganj corridor and 2.6 ± 0.2 to 50.0 ± 7.2 in Dudhwa-Katerniaghat corridor.

The Shanon-Weiner index has been widely used for calculation of diversity. Highest and lowest diversities were of 3.5 and 0.9 in Rajaji-Corbett corridor, 3.0 and 0.6 in Kosi river corridor, 2.7 and 0.7 in Nihal-Bhakra corridor, 2.6 and 0.1 Gola river corridor, 3.1 and 1.1 Kilpura-Khatima-Surai corridor, 2.4 and 1.3 in Laggabagga-Sukhlaphanta-Tatarganj corridor and 3.1 and 0.6 in Dudhwa-Katerniaghat corridor.

Status of prey (wild and prey) distribution and abundance and disturbance levels:

Including the one horned rhinoceros, TAL supports eight species of wild ungulates viz. sambar, chital, nilgai, wild pig, swamp deer, hog deer, goral and barking deer (Johnsingh et al. 2004). Being the major prey base, these species have a key role in the survival of tiger (Seidensticker 1976, Stoen and Wagge 1996). The evidence on evolutionary history suggests the ungulate

communities act as a determinant of tiger distribution and abundance across the distribution range (Seidensticker et al. 1999).

Mean density of pellet groups of wild ungulates were estimated highest among some of the vegetation communities around Gola river corridor in spite of mining in these areas, followed by Nihal-Bhakra, Rajaji-corbett, Lagga-bagga-Sukhlaphanta-Tatarganj, Dudhwa-Katerniaghat, Kilpura-Khatima-Surai corridors and lowest in Kosi river corridor.

Commonly seen domestic ungulates in TAL include cattle (*Bos indicus*), Buffalo (*Bubalus bubalis*), goat (*Capra hircus*), sheep (*Ovis aries*) and pony (*Equus caballus*). Though tiger also preys upon domestic livestock (Bagchi et al 2003), but avoid areas of disturbance, even caused by cattle (Johnsingh et al. 2004). Mean density of pellet groups/dung of domestic ungulates were estimated highest among the vegetation communities in Gola river corridor, followed by Lagga-bagga-Sukhlaphanta-Tatarganj, Rajaji-corbett corridor, Kilpura-Khatima-Surai, Dudhwa-Katerniaghat, Kosi river corridors and lowest in Nihal-Bhakra corridor.

Cutting and lopping of the trees involves human interference hence a disturbance for the tiger. Mean density of cutting of the trees follows the trend as in Lagga-bagga-Sukhlaphanta-Tatarganj > Gola river > Kilpura-Khatima-Surai > Kosi river = Dudhwa-Katerniaghat > Nihal-Bhakra > Rajaji-corbett corridor while lopping of the trees were as Kosi river > Gola river > Dudhwa-Katerniaghat > Nihal-Bhakra > Kilpura-Khatima-Surai > Lagga-bagga-Sukhlaphanta-Tatarganj > Rajaji-corbett corridor trend.

Functional status of the corridor with reference to tiger:

Monitoring the habitat usage of the elusive carnivores in the disturbed areas like corridors where human interference always remain high is difficult on the basis of direct methods. Because of such challenges associated with locating and directly handling carnivores, indirect methods have been in use. Such methods mainly uses animal signs (track and faeces) as indices of abundance and distribution within the given area can be obtained quickly and inexpensively. However, the ability to identify individuals from animal signs remains problematic (Panwar, 1979; Gore 1993; Smallwood and Fitzhugh 1993; Das and Sanyal 1995; Karanth 1995; Riordan 1998; Grigione et al. 1999; Zalewski 1999). To avoid recounting of the signs, size and shape of the track and association with the other tracks were considered. All the counted tracks were digitally photographed. Highest tiger signs were encountered in Kosi river corridor followed by Rajaji-Corbett, Nihal-Bhakra,

Dudhwa-Katerniaghat, Kilpura-Khatima-Surai, Lagga-bagga-Sukhlaphanta-Tatarganj corridor and least in Gola river corridor. Though tiger signs were restricted to the areas of Dudhwa National park and Katerniaghat range of Katerniaghat WLS only. No tiger signs were encountered in the forest patches of corridor area which are surrounded by human matrices. Tiger sign encountered in the Gola range of Gola river corridor was ambiguous because of only a scat was found.

Use of ecological modeling models in assessing functionality of corridors in TAL:

Under Part II section of this report, we identify the factors affecting the distribution of tiger and assess the distribution of suitable habitat patches and the connectivity between these patches for successful dispersal in the Indian part of TAL. We developed GIS probability models for tiger and its prey species and a spatially explicit individual-based dispersal model (SEIBM) for tiger in order to identify and assess the factors which are affecting the occupancy of tiger and subsequently predict potential suitable habitats and estimate the connectivity between the fragmented subpopulations in the Indian as well as between Indian and Nepal part of TAL.

Data were collected on presence/absence of four wild ungulates (sambar *Cervus unicolor*, chital *Axis axis*, nilgai *Boselaphus tragocamelus*, and wild pig *Sus scrofa*), which are important prey species of tiger in two phases during the period between 2002 and 2006. Remote sensing and topographic data were used to develop spatial layers of land use, vegetation characteristics and topography. We integrated the presence and absence information with landscape characteristics and indices of human disturbance.

For tiger, we used an approach based on presence and pseudo-absence data, combining ecological niche factor analysis (ENFA) and GLM. The tiger presence locations were based on the evidences of tiger's scat and pugmark. Data for two most important prey species, chital and sambar, were taken from plots laid for collection of prey species faecal pellet groups. All these data were collected from the Indian part of TAL. All hypotheses yielded models with high prediction accuracy (> 90%). The most parsimonious model supported the "prey species hypothesis" and contained two variables characterizing the amount of two prey species (chital and sambar) habitat suitability within a 37sq.km neighbourhood scale area. The best model of the human disturbances hypothesis suggested that the presence of agriculture land and human habitation and diversity in landuse types had negative effects and presence of protected area had positive effect on tiger distribution. More detailed assessment of the potentially suitable areas using an extended source-

sink approach suggested that most of the habitats outside the protected areas were attractive sink-like habitats, i.e., they showed high “natural” quality but suffered high levels of human disturbance. Potential corridors had generally a low proportion of suitable habitat and showed high levels of human disturbance. In the next step, we developed a SEIBM of dispersing tiger behaviour and assessed the connectivity among the major habitat patches and investigated the effect of potential initiatives to restore corridors in the Indian and between India and Nepal part of TAL. Model clearly showed that connectivity is not solely a function of distance between patches, but an outcome of the interplay between behaviour and landscape configuration, with asymmetric connectivity explained by canalizing or diffusing effects of the landscape, and depending on the landscape context of the starting patch. The most important model parameter determining patch connectivity was the autocorrelation in movement, followed by the daily movement capacity.

The results of this study, in addition to contributing to the knowledge on factors affecting suitable habitat distribution and dispersal of tiger, have many implications for conservation of tiger in the Indian part of TAL. The model predicted that 16% of the study area was suitable for tiger (cut-off $P > 0.5$), out of which only 7% of the area was under PAs in the Indian part of TAL. Our approach also revealed that only 8% of the habitat area was good quality habitat to be considered as source patches, out of which 5% was protected in the study area. Within the PAs, 56% of the area was assigned good quality habitat and only 8% as attractive sink-like habitat, indicating the low level of disturbances in the PAs. However, when considering the remaining habitats outside PAs, only 17% of the habitat was predicted as good quality habitat and 11% as attractive sink-like habitats indicating the high level of human disturbances in the good habitat outside the PAs. Approach used in this study has also revealed large areas of matrix, poor habitats and attractive sink-like habitats as those dominated by forest monoculture plantations of softwood and hardwood, which replaced the mixed forests and grassland habitats in the 1960s to meet industrial needs (Johnsingh & Negi 2003) in the Rajaji-Corbett Conservation Unit. It also exposed the areas of attractive sink-like habitats in the Kosi river and Nihal-Bhakhra corridors (Johnsingh *et al.* 2004) and in the narrow Rajaji-Corbett corridor, which is a vital habitat link between Rajaji NP and Corbett TR (Johnsingh & Negi 2003), especially in the critical areas where disturbance in this narrow corridor arises largely from Kotdwar town and adjacent villages (Johnsingh & Negi 2003). These corridors are currently used by tigers (Johnsingh *et al.* 2004; *personal observations of* R. Kanagaraj & M. Anwar), but the identification as attractive sink-like habitat highlights the importance of reducing

the human disturbance in these areas; failure of this might destroy these corridors and jeopardize the connectivity in this most intact and extensive forest block in TAL with 4053.5km² of potential habitat for tiger in the near future (Johnsingh *et al.* 2004). This sets clear objectives of where to further strengthen conservation actions. This study has also identified critical areas needed for management initiatives for functional unit of tiger conservation in the TAL. Results have consequences for the conservation of tiger populations, since several of the habitat patches are likely to be island-like and already effectively isolated for dispersal. However, most of the patches in India and between India and Nepal could become connected under the simulated scenarios of corridor restoration. Ensuring this may mitigate the genetic consequences of small population size and effective isolation on tiger populations in this landscape. More widely, this study has shown that combining habitat models with individual based and spatially explicit dispersal models is a powerful and robust approach that could be widely applied to quantify patch connectivity even for species with scarce data.

A landscape manipulation in terms of corridor restoration may be a relatively cheap management action. We found that most of the patches in India and between India and Nepal could become connected under this scenario. Moreover, an additional 0.5km buffer around the restored dispersal habitat did not substantially enhance connectivity, which makes this management action even more sensible. Connectivity between protected areas is crucial for effective and sustainable landscape level conservation. Twenty years ago an exercise proposing a network of protected areas connected by corridors as a conservation strategy in India (Rodgers and Panwar 1988; Sukumar 1991) resulted in highlighting the importance of Chilla-Motichur and Rajaji-Corbett corridors for large mammal conservation in the Rajaji and Corbett NP areas (Johnsingh *et al.* 1990; Johnsingh 1992; Sunderraj *et al.* 1995). Despite the fact that the Chilla- Motichur corridor was identified in the early 1980s, its conservation status has constantly declined over time (Johnsingh *et al.* 1990; Johnsingh 1992), subsequently resulting in considerable loss of corridor area (Nandy *et al.* 2007). However, results of this study showed that improving the quality of currently remaining degraded corridor habitats by reducing the anthropogenic disturbances may result in regaining the lost connectivity for tiger in Rajaji NP. Although connectivity in the already good habitat quality Rajaji-Corbett corridor area did not improve under the scenarios, it is

recommended to reduce the anthropogenic disturbance in there to ensure that dispersing tiger reaching the another protected area successfully (Johnsingh *et al.* 2004). By doing so, ensuring connectivity in these corridors would enable to create a single large block of a functioning unit (4052 km²) for tiger in the Indian side of TAL (Johnsingh *et al.* 2004). The three functional trans-boundary dispersal corridors, Pilibhit- Suklaphanta, Dudhwa-Basanta and Katerniaghat-Bardia, between India and Nepal are vital for creating a single landscape level functioning unit of the entire TAL. These corridors connect India's Dudhwa NP, Katerniaghat and Kishanpur WLSs and Pilibhit FD with the Nepal's Bardia NP and Suklaphanta WLR through the Churia foothill forests. Results show that improving the quality of the remaining degraded habitats and adding the 0.5km buffer area in case of Dudhwa-Basanta corridor may create a single functional unit of these fragmented habitats through improved connectivity. Although different habitat blocks showed connectivity under the landscape restoration scenarios, there are no protected areas in the long forest stretch between Corbett NP in India and Sulaphanta WLR in Nepal and Bardia NP and Sukalphanta WLR in Nepal. Further human disturbance and habitat fragmentation in these areas could potentially mitigate the successful dispersal of tiger (Johnsingh *et al.* 2004; Wikramanayake *et al.* 2004). Dispersal model assessed the permeability of the linkage habitat and estimated the connectivity values in the TAL. But it is essential to conduct a future study that considers the functional level of connectivity that not only depends on the permeability of the linkage habitat, but also upon conditions in the source and destination patches, such as the production of sufficient potential dispersers (Kramer-Schadt *et al.* 2005; Crooks and Sanjayan 2006; Revilla and Wiegand, *in press*). Therefore, a spatially explicit population model to assess the functional connectivity by examining the roles of all landscape elements in promoting or hindering effective dispersal is recommended.

On the basis of study findings and field work carried out in the evaluation of the corridors in TAL, following other measures are proposed for the preservation and restoration of the corridors.

Rajaji-Corbett corridor:

Relocation of the Gujjars (pastoral community) should be carried out on priority basis. A total of 34 Gujjar deras (settlements) with 105 families and around 1100 domestic animals (cattle, buffalo, dog, goat/sheep, and pony) were encountered in this corridor through out the field visits. There is a direct competition between wild prey base and domestic animals for drinking water in addition to

fodder. Relocation of Gujjars from the Kolhu-Chaur area of Saneh range would result in potential grassland for wildlife as well as revenue generating tourism zone. Monoculture plantations should not be encouraged in the corridor area and restoration and management of chaur (grassland) should be considered. Cutting and lopping of the trees should be checked among the vegetation communities in the corridor. Awareness campaign should be carried out in villages dependent on the corridors for fodder, fuel wood and other NTFPs. Use of L.P.G. stove and fuel efficient chulas should be promoted to minimize villager's dependency on the forest of the corridor. Culverts and bridges should be plan in such a way to ease the wildlife movement across the Kotdwar-Dugadda metalled road and steeper slopes on the bank of Kho river.

Kosi river corridor:

Relocation of Sunderkhal village would provide disturbance free movements of the tiger as well as its prey base from CTR to Ramnagar forest division and vice-versa. Resettling of Amdanda and Ringora villages should also be considered to free corridor area from disturbances between Ladua chaur to Bijrani gate of CTR. Any further development should be discouraged in these two important tracts of the corridor along both sides of the Kosi river. Shifting of Tedha village near sukha sot would be another milestone in the strengthening of this corridor. Cutting and lopping of the trees should be checked among the vegetation communities in the corridor. Awareness campaign should be carried out in villages dependent on the corridors for fodder, fuel wood and other NTFPs. Use of L.P.G. stove and fuel efficient chulas should be promoted to minimize villager's dependency on the forest of the corridor.

Nihal-Bhakra corridor:

Commercial felling should not be carried out in the width of at least one km along Kaladhungi-Haldwani metalled road in Gadgadia range of Terai central forest division.

There should be a check on the speed of the vehicles running on the Kaladhungi-Haldwani metalled road passing through corridor area. Culverts and bridges should be plan in such a way to ease the wildlife movement (including tiger) across the Kaladhungi-Haldwani metalled road passing through corridor area. Present study shows use of Kaligad nullah by tiger near this road. There is a need of intense eco-development and awareness initiatives in the surrounding villages and villages in the corridor area, to arrest disturbances to the corridor.

Gola river corridor:

Under this corridor, boulder and sand mining should be banned from Gola river and this stretch should be declared as an 'ecologically sensitive zone'. Encroached area in the form of bindukhatta settlement (26.71 km², management plan, Terai east forest division, 1996-2006) under this corridor should be reclaimed and any developmental activity should be discouraged in the corridor area to restore the connectivity. Intensive regeneration of forests on either side of this corridor, particularly of Dauli range and protection from grazing and cutting should also be carried out.

Kilpura-Khatima-Surai corridor:

Resettlement of goths (settlements) from Kilpura range and eviction of encroachments from Khatima range should be carried out on priority basis to maintain the connectivity with the Pilibhit forest division. Access of forest road to villagers in Surai range should be restricted to minimize anthropogenic disturbances. Release of waste water from factories in the nullah (Khara) of Surai range should be checked to maintain drinking water sources for tiger and its prey base. Cross boarder anthropogenic disturbances caused by villages of Nepal should be minimize.

Laggabagga-Sukhlaphanta-Tatarganj corridor:

To maintain the connectivity between Sukhlaphanta Wildlife Reserve and Pilibhit forest division, resettling of Tharu-patti and Gorakh-dipi (settlements) should be carried out at earliest. Pastoral settlements (Gaudi) should be discouraged in this corridor to avoid the competition between domestic and wild ungulates. There is a need of eco-development and awareness activities in the surrounding villages of the corridor area, to arrest anthropogenic pressure to the forests of corridor. Polyculture plantations should be carried out to check the flood water of Sharda river and to increase the green cover of the corridor area.

Dudhwa-Katerniaghat corridor:

In this corridor, encroached forested area (16 km²) should be evicted. Cattle grazing in the parts of Belrayan range of Dudhwa NP and Katerniaghat range of Katerniaghat WS, should be checked. Illegal felling in the corridor area, particularly in the parts of Belrayan range should be arrested. In the corridor area contiguous forest cover along Mohana river and Suheli river should be increased

to ensure the connectivity. Connectivity between Basantha forest and Belrayan range of Dudhwa NP should also be restored through cross boarder cooperation.

Dispersal is a key process for the survival of these spatially structured fragmented tiger subpopulations. Quantitative estimates of dispersal probability between habitat patches and successful production of emigrants can adequately explain whether a given landscape configuration is good enough for the long-term population survival (Jepsen *et al.* 2005). Hence, for future research, it will be important to derive quantitative estimates of connectivity between suitable patches in order to ensure the long term survival of tiger in this fragmented and heterogeneous landscape. More detailed assessment of the potentially suitable areas using an extended source-sink approach suggested that most of the habitats outside the protected areas were attractive sink-like habitats, i.e., they showed high “natural” quality but suffered from high levels of human disturbance. Potential corridors had generally a low proportion of suitable habitat and showed high levels of human disturbance. The key management recommendations for tigers in the TAL stress the importance of reducing the human disturbance outside the protected areas, especially in potential corridors, to maintain connectivity between subpopulations located in India and Nepal.

Additionally, we also suggest for a need to use landscape genetics approach to examine historical and present gene flow among different populations to understand functionality of different corridors.