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Dr. K Baranidharan
Forest College and Research Institute, Mettupalayam, Tamil Nadu, India

Dr. M Vijayabhama
Forest College and Research Institute, Mettupalayam, Tamil Nadu, India

Vinay JR
Forest College and Research Institute, Mettupalayam, Tamil Nadu, India

Corresponding Author:
Dr. K Baranidharan
Forest College and Research Institute, Mettupalayam, Tamil Nadu, India

Assessment of tiger corridor between Mudumalai tiger reserve and Mukurthi national park in Nilgiri biosphere reserve, India

Dr. K Baranidharan, Dr. M Vijayabhama and Vinay JR

Abstract
Conservation of wildlife corridor is an important management strategy to maintain ecological and genetic connectivity. With this background the present investigation was conducted to study the corridor status in between Mudumalai Tiger Reserve and Mukurthi National Park in Tamil Nadu during the period from August 2014 to July 2015. With respect to herbivore population 11 species of herbivores were recorded through direct and indirect evidence in the study area. Regarding the season, the results revealed that herbivore population were maximum in January and lowest in June. Among the herbivore population, the Sambar deer scored maximum density (6.86/Sq km) followed by Spotted deer (6.56/Sq km) and lowest scored by Elephant (1.63/Sq km). Regarding grids, grid number 28 (45) showed maximum number of herbivore sign and grid number 13 (0) showed lowest through direct and indirect evidence. Regarding distribution of carnivore, Tiger (132) was found to be maximum through indirect evidence than Leopard (58). With respect to season, the result showed that January month showed maximum carnivore population and lowest in June. With respect to grids, the carnivore's population in grid number 21 encountered maximum indirect evidences occurring 19 times. With respect to Tiger population, grid number 23 recorded maximum evidences occurring 14 times and for Leopard, grid number 21 showed maximum evidences occurring 9 times. It was found that Tigers used 17 grids as a corridor, from Mudumalai to Mukurthi. The probability of movement took from grid number 3 → 4 → 7 → 10 → 11 → 14 → 15 → 17 → →18 → 21 → 22 → 23 → 25 → 28 → 31 → 34 → 35 →36. This was the corridor used by Tiger to move from Mudhumalai to Mukurthi. These grid pathways when monitored regularly and given protection from human intervention, we could protect Tiger population and its expansion in Nilgiri Biosphere Reserve.

Keywords: Corridors, grids, direct and indirect evidences

Introduction
Habitat reduction and fragmentation at a variety of spatial scales has been widely acknowledged as a primary cause of the decline of many species worldwide. Habitat fragmentation generally leads to smaller and more isolated animal populations. Smaller populations are then more vulnerable to local extinction, due to stochastic events (Shaffer *et al.*, 1985) and they are more susceptible to the negative effects of inbreeding depression. To reduce the isolation of habitat fragments, many conservation biologists have recommended maintaining landscape "connectivity", preserving habitat for movement of species between remaining fragments. Restoring and protecting existing habitat and providing linkages between fragmented areas are becoming critically important to the continued existence of many species. Wildlife habitat corridors allow populations to interact; interbreed and as climate changes, shift their geographic range. Planning, designing, and implementing wildlife corridors can be difficult, but GIS technology is helping streamline the process. Effective implication of National Tiger Conservation Authority guidelines and management strategies in Mudumalai Tiger Reserve were leads to increase the population of tiger. Due to increasing population and its territories, the tiger starts to move towards one side that was Satyamangalam Reserve forest. Tiger starts moving on the other side of Mudumalai Tiger Reserve, i.e., Mukurthi National Park. This particular corridor between Mudumalai Tiger Reserve and Mukurthi National Park has to be explored to ascertain the condition of habitat. Against this backdrop the present study was designed to resolve the issue.

Materials and Methods

Study area

Assessment of corridor was carried out between Mudumalai Tiger Reserve and Mukurthi National Park located in the Nilgiri District of Tamil Nadu at 11.5454ºN and 11.36533ºN latitiude to 76.5056ºE and 76.48723ºE longitude. It extends over an area of 144 sq km and forms a part of the Nilgiri Biosphere Reserve. The study area is located in the Western Ghats, which is one of the 10 hottest biodiversity hotspots of the world (Mittermeier *et al*., 2000) [5]. Altitude in the study area varies from 908 m to 2428 m above Mean Sea Level (MSL). The study area was surrounded in north by Chamarajanagar District of Karnataka State, in North West by Wayanad District of Kerala State, in the South East by Coimbatore District and the North East by Erode District of Tamil Nadu.

Land use pattern of study area

The total geographical area of the study area is 144 sq km of which41.61 per cent (59.92 sq km) is under forest, the cultivable land was 4.90 per cent (7.06 sq km), the Grassland was 18.07 per cent (26.02 sq km), the Human settlements 9.17 per cent (13.2 sq km) and the tea estate was 26.25 per cent (37.8 sq km).

Forest type in study area

The study area has three major forest types' *viz*., Evergreen forest, Semi Evergreen forest and Shola Forest (Champion and Seth, 1968) and manmade plantation *(Eucalyptus globulus, Eucalyptus grandis, Eucalyptus citridora, Pinus patula, Grevillea robusta* and *Tectona grandis*).

Southern Tropical Evergreen Forest (1A/C_3)

The tropical evergreen is characterised by its luxuriance of vegetation consisting of several tiers, the highest containing tall trees and the lower containing dense shrubby undergrowth. A heavy rainfall, high humidity, and a short dry season are characteristic of this forest type.

Southern Tropical Semi Evergreen Forest (2A/C_2)

These forests always occur in association with the evergreen forest. The mean annual temperature of region, where these forests occur is 26ºC. The mean annual maximum and mean annual minimum temperature are about 30ºC and 22.5ºC respectively the mean annual rainfall varies from 2000-2500 mm.

Southern Montane Wet Temperate Forest (11A/C_1)

The Tropical montane forest is also called Shola forest, found in valleys amid rolling grassland in the higher mountain region, The Shola Forest and Grassland complex has been described as climatic climax vegetation. It occurs between 1600 m-2000 m Mean Sea Level Shola is characteristics of highly branched trees, clothed with mosses and other epiphytes. Woody climbers are few. There is no stratification of trees.

Methods

The study area was divided in to grids of 4 Sq km. By using Qgis Software, a total 36 grid was laid out throughout the study area.

Assessment of Herbivores diversity

Recce-transects were laid out [which was not follow straight line walks but was follow paths (animal and human) and also the most suitable routes and terrain. Such transects were duplicate the way in which animals are likely to move in response to the terrain] of length 2 to 3 km and width of 30 m in each grid it cover maximum area of a grid. The study area was divided into 36 grid, the total length of transect in each of the habitat type was approximately proportional to the area of the habitat type. Each of the transect were covered in the dawn and dusk during the study period, in order to describe and evaluate the herbivores population, each transect were walked between 7.00 am to 9.00 am and 4.00 pm to 6.00 pm. The details of pellet, dung, hoof mark and foot mark were collected in each grid these come in different shapes, sizes, degree of scatter and decomposition.

Assessment the distribution of Tiger

Identification of pug mark, scrape, scat

The pug mark of each individual of species is different from that of other individuals, the pugmark also have certain morphological difference in respect of male, female, as well as cub and therefore it was enumerated as such. Pug mark of adult Tiger have a size of 11.4-14 cm, square in shape, the pugmark length of an adult Leopard is 7-9.5cm and rectangular in shape. The marking scrape on tree and land are specific for each species, Tiger have a scrape up to length 45 cm, width 30 cm and nails marking on scrape, the Leopard have a length of 15 cm and width of 7 cm. Based on the amount of scat and place of scat on the path it will help to identify a species. Tigers scat is more when compared to Leopard. The scat of Tiger can be observed on the side of the path whereas the scat of Leopard can be seen in the center of the road. Carnivore signs will be recorded in terms of number per km length surveyed (Rodgers, 1991 and Umaramakrishnan *et al.*, 2001) [6] in the selected roads and foot paths. In the study area observations were made for indirect evidences, like pug mark, scats, scrape, etc indicating the presence of Tiger was recorded.

Scoring of welfare factor by grid wise

Score was given by the resource found in and around a recce transect, (Schamburger *et al*. (Appendix I).

Table 1: Maximum score of resource

Sl. No.	Resources	Maximum score
1	Water	0.30
2	Food	0.26
3	Cover	0.26
4	Disturbance	0.30
5	Habitat linkage	0.06

Table 2: Habitat suitable for Tiger

Sl. No.	Score	Remarks
1	0 - 0.25	Habitat is not suitable for Tiger
2	0.26 - 0.5	Habitat is less suitable for Tiger
3	0.51 - 0.75	Habitat is moderately suitable for Tiger
4	0.76 - 1.00	Habitat is highly suitable for Tiger

To draw a digitized map of corridor between Mudumalai and Mukurthi in Nilgiris Bio-sphere reserve

Existing maps was checked for accuracy and wherever needed, it was corrected. The reserve forests was digitized from existing records of the forest department. Maps to identify gaps and conflicts overlaps were prepared. Potential movement routes for the respective species was identified and

anthropogenic threats to different areas was also identified. Identification of potential routes was based on forest cover, land use, terrain features and anthropogenic disturbance (based on distance from settlements). All these were verified on the ground based data on identification of locations which were generating some ambiguity in mapping or about their land use/ownership and also critical areas for corridor and its function. Similarly potential threat sites (mostly based on potential human impact areas but also taking terrain features, constrictions, etc.) was also marked during the mapping exercise.

Geometric correction

Geometric distortions were removed by registering the raw image of LISS IV to the (SOI) toposheets with R.M.S. error being 0.008 with 5.8 m pixel size using nearest neighbor re sampling with first order polynomial equation. Image registration for both the datasets was carried out with the following projection - UTM Zone 43N (Spheroid: WGS 1984; Datum: D_WGS 1984). After registration, the dataset was subjected for the extraction of the study area using the boundary map of the protected area.

Database creation

SOI toposheets on 1:50,000 scale were subjected for rectification. They were then further used as base maps and were digitized to generate road map and settlement map. Google Earth tiles of the study area were downloaded with CGUTIL tool and they were mosaiced and geo referenced with the help of Global Mapper software. The imagery is used for generating the cultivated land, tea estate, forest area, water bodies, layer and settlement polygons for updating the toposheet derived layers. The reserve boundary was procured from the Geomatics Cell of Tamil Nadu Forest Department. It was used for extracting the study area from satellite imagery and the Google Earth data. (Fig 1)

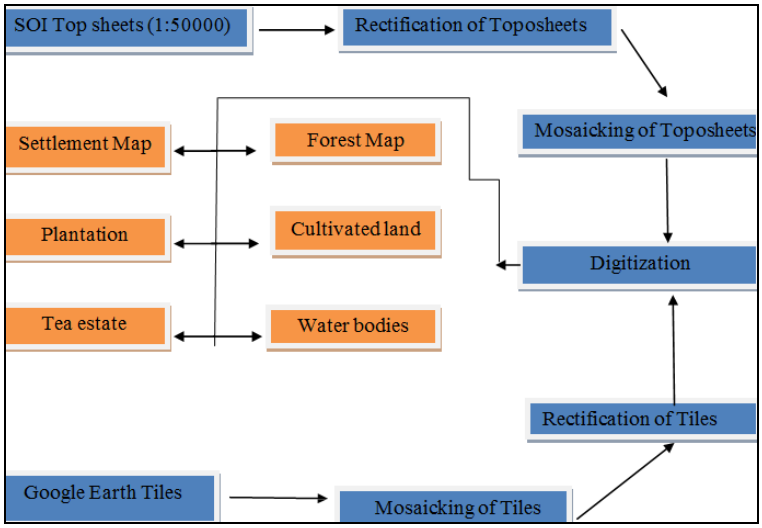

Fig 1: Shows data base creation

Results and Discussion

Direct and indirect observation of herbivores in the study area: With regard to the herbivore diversity, the results revealed that 11 herbivores has been recorded through direct and indirect evidences in the study area. The more number of herbivore diversity might be due to the maximum floral diversity in the study area and this region was having 3 major forest type *viz*., Southern tropical evergreen forest, Southern tropical semi evergreen forest and Southern montane wet temperate forest. The results agree with the earlier findings of Kumaraguru *et al*. (2010) [3] which indicates that because of the floral diversity, density analysis showed a considerable variation with Dindugul forest division (0.76 Elephants/sq km) having more than double the density of Theni forest division (0.26 Elephants/sq km). Regarding the season, the result showed that herbivore population was maximum in January and lowest in June due to maximum rainfall during the month of July and October. Moreover the indirect evidences were washed away in the rain, and animals movement was also restricted during this time. The presence of shola forest provided water throughout the year and hence in January large number of herbivores population could be noticed. The current findings were in accordance with the findings made by Surendra *et al.* (2000) who revealed that variation in number of animals in different seasons may be due to food and water requirements, finding mates and avoiding predators.

Among the herbivore diversity, the Sambar deer had scored maximum density (6.86/Sq km) in the study area which may be due to the presence of more food availability, good habitat, less predation and less human disturbance. This might be the reason for more number of Sambar deer. Baranidharan (2000) [1] also quoted similar results in his study, which revealed that Indian Bison sightings was found to be more in Nochikutai area because of presence of grassy meadows with fragmented forest which were a suitable habitat for them. Regarding the grid, grid number 25 recorded maximum number of herbivores sighted and it was due to the presence of high palatable grass species as undergrowth and the grid had good network of fire lines created on a mosaic opening which was an optimal habitat for Chital along with good resource of water and also less chance of predation. This finding is in line with Schaller (1967) [7] which reveals that herbivores and carnivores will not live together in a particular area.

To assess the distribution pattern of Tiger, its relationship with prey species and welfare factor for Tiger

Carnivore's population in the study area

With regard to the distribution of carnivores in the study area, the result revealed that Tiger was observed to be more (132) than Leopard (58) due to abundance of Sambar deer. Similar result were found by Linkie *et al.* (2003) [4] were Tiger sign

was found to be more when compare to Leopard of 141 location surveyed Tiger sign was found in 126 location and Leopard sign was found in 102 location. With respect to the season, indirect evidence of Tiger and Leopard were observed to be maximum in January due to maximum number of herbivore population, and also due to less rainfall, the movement was high. Surendra *et al.* (2000) who revealed that variation in number of animals in different seasons may be due to food and water requirements, finding mates and avoiding predators. With respect to grid, maximum number of indirect evidence of carnivores were found in grid number 21 (19) which was due to less disturbance from the people and good linkage of forest and the herbivore population was high in the adjacent grids. With respect to Tiger indirect evidence was found highest in grid number 23. Regarding Leopard grid number 21 showed highest evidence, which might be due to the fact that two competitors can't live in the same area and these were immediately adjacent to area where availability of herbivores was maximum.

Food spectrum of Tiger through scat analysis

With regard food spectrum of Tiger, Sambar (33%) was observed to be the principle prey species followed by Spotted deer (26%) due to wide distribution of Sambar and Spotted deer across the study area. This result finding was similar with Karanth *et al.* (1995) [2] reported that Sambar was principal species of Tiger containing 34 per cent of Tiger diet in Nagarhole National Park Karnataka.

Scoring of welfare for Tiger in different grids of the study area

Regarding the Tiger habitat in the study area, score was given based on resources like water, food, cover and disturbance and habitat linkage the grid numbers 4, 7 and 21 good for Tiger and grid numbers 1, 5, 12, 16, 20 and 23 was not suitable for Tiger. With respect to grid wise distribution of resources the water was high in grid number 26, food was high in grid number 3, cover was high in grid number 21 disturbance was low in 21 and habitat linkage was good in grid number 24. With regards to the habitat suitability for Tiger, the area of 12 Sq km was highly suitable, followed by moderately suitable was 56 Sq km. (Table. 3)

Table 3: Scoring of welfare factors for tigers in different grid of the study area

Grid no.	Water	Food	Cover	Disturbance	Habitat linkage	Total
1	0	0.08	0.09	0	0	0.17
2	0.08	0.13	0.17	0	0.03	0.41
3	0.19	0.26	0.17	0.04	0.06	0.72
4	0.15	0.26	0.26	0.04	0.06	0.77
5	0.08	0.13	0.02	0	0	0.23
6	0.15	0.26	0.13	0.04	0.03	0.61
7	0.15	0.26	0.26	0.08	0.03	0.78
8	0.15	0.13	0.13	0.04	0.06	0.51
9	0.18	0.13	0.26	0	0	0.57
10	0.15	0.13	0.22	0.04	0.03	0.57
11	0.15	0.17	0.26	0.04	0	0.62
12	0	0.05	0.02	0.04	0	0.11
13	0.11	0.08	0.02	0.04	0	0.25
14	0.08	0.08	0.04	0.04	0	0.24
15	0.19	0.13	0.08	0.04	0.03	0.47
16	0	0.08	0.04	0.04	0	0.16
17	0.19	0.17	0.17	0.02	0.03	0.58
18	0.07	0.09	0.06	0.02	0.03	0.27
19	0.15	0.13	0.17	0.02	0.03	0.50
20	0.11	0.08	0.04	0.02	0	0.25
21	0.19	0.22	0.26	0.06	0.03	0.76
22	0.15	0.13	0.13	0.02	0.03	0.46
23	0.11	0.08	0.04	0.02	0	0.25
24	0.22	0.22	0.15	0.04	0.06	0.69
25	0.11	0.08	0.04	0.04	0.03	0.30
26	0.11	0.08	0.04	0.02	0.06	0.31
27	0.22	0.21	0.1	0.06	0.03	0.62
28	0.11	0.13	0.08	0.04	0.03	0.39
29	0.22	0.13	0.1	0.04	0.06	0.55
30	0.22	0.13	0.13	0.06	0.06	0.60
31	0.11	0.13	0.13	0.06	0.06	0.49
32	0.22	0.13	0	0.08	0.06	0.49
33	0.26	0.13	0.04	0.08	0.06	0.57
34	0.26	0.13	0.26	0.08	0	0.73
35	0.11	0.13	0.1	0.08	0.03	0.45
36	0.26	0.13	0.19	0.08	0.03	0.69
Average	0.14	0.14	0.12	0.04	0.03	0.48

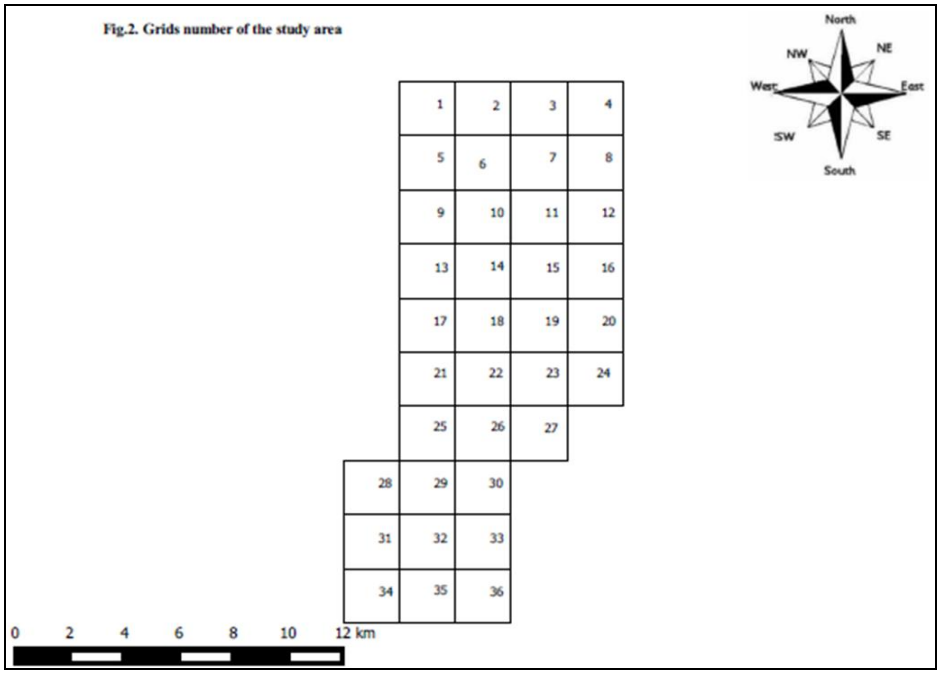

Fig 2: Grids number of the study area

To draw a digitalized map of Tiger corridor

Indirect symptoms and sign of carnivores

Regarding carnivores sign mapping, the result revealed that the symptoms and sign of Tiger and Leopard were found maximum in 23 and 15 grids respectively. Due to Tiger was roaming the large area than Leopard, and Leopard were concentrated more in village boundary.

Probability of corridor through GIS

With respect to Tiger corridor between Mudumalai Tiger Reserve and Mukurthi national park, the Tiger corridor used to moves in 17 grids, which start from grid number 3 in Mudumalai boundary and it reaches grid number 36 in near Mukurthi National Park. The Tiger used to cross this corridor by using following grids number 3 → 4 → 7 → 10 → 11 → 14 → 15 → 17 → →18 → 21 → 22 → 23→ 25 → 28 → 31 → 34 → 35 → 36. This corridor was highly suitable for Tiger movement from Mudumalai Tiger Reserve to Mukurthi National Park due to following reason (Fig.2)

5 High suitable terrain
6 Good prey species
7 Less human disturbances
8 It is only a transition pathway

Conclusion

The study revealed that the Tiger corridor between Mudumalai Tiger Reserve and Mukurthi National Park was highly suitable for Tiger movement. The Mudhumalai Tiger Reserve was having more density of tiger and also having more habitat fragmentation, which lead to inbreeding problems. So connection of these corridors is the need of hour, which can facilitate Tiger movement and expansion of its territory. This corridor was having many land use pattern like Tea estate, Agriculture land and three major types of forests and there were six revenue villages. Even though there was lot of disturbances in the corridor, the present study lime lights that the grid numbering 3 to 36 is a potential tiger movement pathway. This grid pathway when monitored regularly and are given protection from human intervention, we could protect tiger population and its expansion in Nilgiri Biosphere Reserve.

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