Distribution and population assessment of Striped Hyena (*Hyaena hyaena*), Indian Wolf (*Canis lupus pallipes*), Golden Jackal (*Canis aureus*), Leopard Cat (*Prionailurus bengalensis*) and Wild Boar (*Sus scrofa*) in South West Bengal for conservation and management planning

FINAL PROJECT REPORT

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Executive Summary

The present study was conducted to gather ecological data on distribution and population assessment of Hyena (*Hyaena hyaena*), Indian grey wolf (*Canis lupus pallipes*), Golden Jackal (*Canis aureus*), Leopard Cat (*Prionailurus bengalensis*) and Wild Boar (*Sus scrofa*) in all districts of southern region of the West Bengal State except the Sunderban region. The study made use of all the applications/ tools available in recording and identifying the wildlife, including sign surveys, questionnaire interviews, camera trapping, ecological modeling using remote sensing and GIS, non invasive genetics (DNA analysis of the faecal samples). We successfully generated ecological data on distribution mapping, population assessment, and identified human wildlife conflict hot spot.

The study identified that adjoining area of southern part of Purulia district, South West part of Bankura district and extreme North West portion of Jhargram district (including some areas of Kangsabati South, Bankura South and Jhargram forest division), has high habitat suitability for all the five studied species. While Zone-wise evaluation suggested, higher suitable regions in Bhulaveda followed by Jhilmili and Banspahari ranges. We reported high suitable region in Bankura and West Midnapore having 3,040 Km^2 and 2,557 Km^2 respectively for Indian grey wolf, about 696 km^2 area in Purulia, 580 km^2 in Bankura and 131 km^2 in Jhargram for Golden Jackal. We found wild boar are more generalist and often utilize almost entire forest division and we report almost 589 km^2 area in Purulia district, 479 km^2 in Bankura district and 229 km^2area in Jhargram district was highly suitable for wild boar. In case of hyaena, we obtained high suitable regions in Ajodhya (0.76) followed by Matha (0.69) ranges of Purulia Division.

From sign surveys, we reported highest encounter rate of Indian grey wolf and Striped Hyaena in Puralia, while in Jhargram, West Midnapore, Birbhum, Burdwan, Nadia, Murshidabad, East Midnapore and Hoogly districts, we did not find any evidence of Striped Hyaena. However, in questionnaire surveys, a few respondents of Banshiasol, Shialia, Taldiha, Malam and Nimainagar village reported Striped hyaena conflict. Whereas the Encounter of Golden Jackal and Wild Boar is found to be highest in Hoogly and Bankura district respectively. In Nadia-Murshidabad forest division, Bethuadahari Wildlife Sanctuary represented relatively high abundance of Golden jackal than other places. If we concentrate on the forest division level Encounter Rate, Kangsabati South may have the potential habitat for the survival of Indian

grey wolf followed by Jhargram but contrastively no evidence of Striped Hyena was found in Jhargarm. This poor ER of Golden Jackal in Jhargarm, Rupnarayan, Kharagpur, Birbhum, Durgapur forest division suggests the lower relative abundance of the species, due to habitat degradation, and mainly due to high level of conflict with humans and revenge killing. Despite of high level of hunting, high Encounter Rate of Wild Boar is observed in almost all the forest divisions except Nadia-Murshidabad, Howrah-Hoogly and Purba Midnapore.

The results of surveys and questionnaire interviews for understanding the amount of wildlife conflicts showed a negative attitude towards conservation as the proportion of illiteracy and school dropout in primary level are important factors in shaping the perception in all three forest divisions of Purulia district. In Bankura North and South division near about 50% respondents were illiterate though more than 60% of them are engaged in different type of unskilled works but the huge conflict with the wild animals make them against the wildlife conservation. Though illiteracy percentage is low in Kharagpur forest division and maximum respondents are engaged in agriculture, almost 70% responses are negative for the conservation. Geo-spatial patterns of human-wildlife conflict indicate that almost every forest division is more or less conflict prone. In case of wolf the comparative zonal mean evaluation suggests higher intensity of conflict in Ranibandh with a mean score of (12.01), followed by Bandwan-II (11.81) and Bagmundi (11.43). In Purulia District, high conflict zone fell under the Purulia Division and Kangsabati South division. In case of Golden Jackal the comparative zonal mean evaluation of the ranges suggest higher intensity of conflict in Arsa range with a mean score of (12.20), followed by Bandwan-II (12.09) and Bagmundi (11.57). We obtained wild boar-human conflict concentrates from western to Sothern regions, influencing largest portion of the landscape, compared to the rest of the study species. The comparative zonal mean evaluation of the ranges suggests higher intensity of conflict in Bandwan-II with a mean score of (12.48), followed by Arsa (12.34) and Jamuna (11.92). Unlike other studied species, we found Hyaena conflict restricted to a few ranges due to its restricted distribution. We obtained Hyaena-Human conflict cases in the most south-western portion of the landscape. The forest ranges falling under the higher intensity of conflict

includes Bandwan-II with a mean score of (12.35), followed by Arsa (12.20) and Jamuna (11.80). Based on the statement of the respondents, Indian grey wolf and Golden Jackal attack the livestock most. Indian grey wolf mostly attacks the goats whereas Golden Jackal usually kills the poultry. Moreover, livestock attack is the second most frequently occurring conflict in all these forest divisions.

With three years of extensive and intensive study, we identified major threats i.e. habitat Loss and fragmentation, retaliatory killing of Hyaena, Wolf, Wild boar and Golden Jackal, poor availability of natural prey species of large predators such as hyaena and wolf, killing of study animals during the ShikarUtsab by tribal communities as a annuals cultural practice, lack of awareness among the local communities about the ecology and behavior of the study carnivores species, lethal removal of conflicting individuals to mitigate human-wildlife conflicts. We propose detailed management recommendations to overcome threats or at least cope-up the current threats in framework model with respect to the associated risks for dealing human -wildlife conflicts in South West Bengal. We categorized the degree of problem from low to high and proposed management recommendations which are neutral (no action) to most urgent category (immediate action required), and both wildlife centric and well as human centric. The most urgent action required for the management of wildlife and holding sustainability in the landscape are (1). Intensive monitoring and removal of the conflict animal from the site of conflict. We propose to strategize a rapid action team of the Forest Department to deal with conflicts. (2). Forest department should provide targeted information on avoidance of human-wildlife conflicts to the communities and form team for spreading awareness by campaigning or circulating pamphlets, flyers, animal letters in school etc. to explain causes and possible consequences of the carnivore behaviour on humans, livestock and as well as on wildlife animals.

For long term sustenance of wildlife in the degraded area of South West Bengal, we also proposed detailed plantation model from agro forestry systems, including the expenditure required and the list of species that may be preferred for plantation to achieve the sustainable goals.

1.0. Introduction

Global mammal accounts for more than 5,500 species placed in 154 families and 29 orders, of which India accounts for 422 species placed in 48 families and 13 orders (Wilson and Reeder, 2005). Out of 422 mammalian species 391 species are terrestrial and 31 species are marine form have been reported from India so far belonging to 13 orders and 48 families (Kamalakannan and Venkatraman, 2017). Only two mammalian species (Bengal Marsh Mongoose *Herpestes palustris* Ghose, 1965 and Sombre Bat *Eptesicus tatei* Ellerman& Morrison Scott 1951) are endemics to West Bengal (Mallick 2007, 2009). The Indian Wildlife (Protection) Act, 1972 (as amended up to 2006) includes about 80 mammalian species in Schedule I, which are considered nationally 'threatened' (Anonymous 2003; Saha & Mazumdar 2008). The Red Data List of Threatened Species (2008) of the International Union for Conservation of Nature and Natural Resources (IUCN) records 96 threatened species of mammals in India (Vié *et al*. 2009). According to Nandy (2006a), West Bengal harbours at least 24 globally threatened (eight 'Endangered' and 16 'Vulnerable') mammalian species. However, 70 species of mammals in the West Bengal state require special attention for conservation (Saha *et al*. 1992).

Conservation and management of wildlife species depend on the knowledge we have on their number. The only source for population estimates for many of the wildlife species in India is the seasonally, annually or periodically conducted census operations on them. Estimating population density of animal species, more specifically the mammalian species that attract conservation interest (Krishnan 1972; Ramachandran *et al* 1986) is an important tool for their conservation and population management (Karanth and Sunquist 1992; Varman and Sukumar 1995; Sutherland 1997; Varman 1988). However estimating animal numbers in tropical forest habitat is difficult mainly because of poor visibility and relatively low density of some species resulting in inadequate sample sizes for obtaining statistically precise results (Koster and Hart 1980; Varman and Sukumar 1995). The other important aspect related to this issue is that, except in a few locations, no systematic or scientific approaches have been followed to estimate population densities.

1.1.1. Origin of the proposal

The authorities of West Bengal Forest & Biodiversity Conservation project has approached the Director, Zoological Survey of India, Kolkata by vide letter no: 920/WL/213-281/15, dated April 11, 2018 to submit the project proposal for undertaking population estimation and ecological reconnaissance of the small mammals of South Bengal and hence the present was conducted for the period of two years in the various Forest Divisions of the South Bengal region except sundarban districts of the West Bengal state.

1.1.2. Definition of the problem

The West Bengal Forest and Biodiversity Conservation Project (WBFBCP) has commissioned six biodiversity research projects covering large mammals such as Elephant, Gaur, Tiger, Leopard, besides assessing the impacts of habitat management inventions. However, the mammals of South Bengal are not covered by these studies and there is a glaring gap in knowledge about the species. This absence of adequate knowledge affects the management of the species and the efforts to address the human – wildlife conflicts involving these species. A seminar on human-wildlife conflicts and review of the biodiversity research project organized by WBFBCP in June 2017 expressed concern about the absence of information on the population and distribution of small mammals of South Bengal which hamstring the management of the escalating human-wildlife conflicts and hence decided to conduct this study under the WBFBCP.

1.1.3. Distribution assessment

With the help of remote sensing data the wildlife conservation, natural resource management has become more scientific and realistic, as the data is more reliable and highly accurate, it is now possible to study species-habitat relationship in a better way (Kushwah and Roy 2002). To model the species distribution it is imperative to understand that ecological interactions of the species, species correlations with abiotc and biotic factors (Meier et al. 2010; Wisz et al. 2012; Salazer et al. 2013). The ecological factors with respect to the species niche in a given area can be mapped using the GIS tools. The combination of such factors and the subsequent identification of the area meet the species requirement and in identifying the species distribution range either actual or potential. This basic scheme has been adopted by number of researches to model the distribution of plants and animal species (Raxworthy et al. 2003; Rood et al. 2010; Kushwah et al. 2012; Shilpa et al. 2012). Species distribution prediction modelling has been attempted in number of studies for the conservation and management planning of many important floral and faunal species throughout the range of taxonomic groups. Studies are also available where possible distribution pattern with respect to climate change is reported. Though variety of distribution prediction models are available and has been applied for variety of species ranging from fishes, plant species, invasive species to large mammals. The most commonly used presence based models are applied in programs such as maxent, biomapper, INFA etc. More advance models like Generalized Linear Model (GLM) based models are also available for estimating the distribution of species (Hill et al. 1991; Bakkenes et al. 2002, Guisan et al. 2002). Modelling studies have indicated that different techniques for the same species may give different results and also they tend to vary idiosyncratically across species (Thuiller et al. 2003). The comparative analysis conducted by Manel et al. (1999) with respect to use of different models for species prediction indicated that it may be obscure for non-statisticians or inexperienced users to select a modelling techniques to predict species distribution. Hence method with relatively high predictability, type of dataset, number of variables and the intensity of observation should be a prerequisite for model or method selection for making predictions. Hence, the present study proposes to estimate and map the current distribution of the selected species. The findings of the proposed study will directly help the Forest Department of West Bengal State in identifying the core population areas in the study landscape which will play significant role in minimizing conflict incidences and also to develop adaptive conservation ana management strategy.

1.1.4. Population estimation and abundance

Estimating abundance and monitoring populations are important aspects of species conservation and management and a common goal in ecology (Peters 1991).The spatial and temporal patterns of abundance depict the spatio-temporal patterns of abundance and thus windows into community, ecosystem, and evolutionary processes. The information on abundance and change in abundance is important for the effective management of endangered species (Gibbs et al. 1999). A need of reliable population estimates and trends governed by effective methods to make these estimates is required for the decisions in conservation practices (Sadlier et al. 2004). This fact has been emphasized by an accelerated loss of biodiversity in recent decades which has reinforced the urgent need for monitoring programs and the necessity of studies relating habitat and species occurrence and abundance worldwide.

Carnivores in particular are often considered flagship, umbrella or indicator species and have been used as conservation tools for gauging and preventing loss of biodiversity (Ray 2005). Finding efficient and practical ways to acquire the information of abundance is of wide relevance and increasing urgency in view of globally declining carnivore populations (Treves and Karanth2003) and increasing human–carnivore conflict (Charoo et al. 2011). However, this is a challenging task: carnivores are often solitary, cryptic, nocturnal, or occur at low density, making them inherently difficult and labour intensive to detect (Gompper et al. 2006; Garshelis 1999). The challenges associated with surveying carnivores necessitate methods that are effective at large spatial scales and over a broad spectrum of population densities (Zielinski 1997; Barea-Azcon et al. 2007), particularly in studies addressing landscape-scale questions such as distribution or macro-habitat associations.

1.1.5. Abundance based on sign surveys

All selected species in the proposed study are largely nocturnal and occurring at low densities, often pose difficulties in abundance estimation and population monitoring. Although various techniques are available to provide accurate estimates of abundance and density, however, logistics and funds are the main constrains that makes difficult to use these techniques. On the contrary, using of indirect signs as a tool for abundance estimation has been found to be potential method. Recent studies on comparative methodologies suggest sign surveys a cost effective and rapid method for estimation of animal abundance and has indicated a close fit between sign abundance and density for carnivore species, despite early criticisms about accuracy (Kruuk et al. 1986). Signs and sightings may be used to define distribution (essentially presence-absence), and changes in distribution may signify changes in abundance (Rossell and Litvaitis 1991). The sightings or signs have been used to directly detect changes in animal abundance (Knight et al. 1995) or differences in abundance between areas (Johnson 1990).

1.1.6. Population estimation using camera trap and DNA based analysis

Camera-trapping has been successfully used throughout the world for studying a wide range of elusive animals when compared with more traditional methods (O’Brien et al.2003; Sanderson and Trolle 2005; Bowkett et al.2007; Ríos-Uzeda et al. 2007; Moruzzi et al. 2002; Carbone et al. 2001; Karanth and Nichols 1998). This technique has proven useful in providing detailed species inventories, where it has high detection efficiency and has recorded species that were otherwise undetected (Yasuda 2004; Giman et al., 2007). Elusive species such as hyena have been studied worldwide using this technique (Singh et al., 2014). Traditional presence–absence surveys estimate the proportion of the area occupied by the species of interest within a landscape through direct field observations, often ignoring the key issues of detectability and spatial sampling and thus rendering at best a naïve estimate. A species may not be detected even when it is present and its delectability may vary from site to site. Surveys conducted over large regions are impractical to carry out unless a spatial sampling scheme is followed (Yoccoz et al. 2001). Hence, camera trapping was carried out for species which can be identified using the patterns of the coat and for those species whose individuals cannot be identified DNA based analysis was adopted.

1.1.7. Non-invasive DNA technique for abundance estimation

Due to difficulty in estimating the population of species whose individuals cannot be identified using camera traps the DNA based mark-recapture can be adopted. A number of studies are available where DNA based analysis have reliably estimated the population of such species. Moreover, the recent advancements have led to routinely utilize genetic information in proteins and DNA to addresses questions about the behavior, ecology, life history, and evolution of bear populations. From a biological perspective, molecular genetic analyses have been utilized to uncover important characteristics of natural populations such as patterns of gene flow (Paetkau et al., 1995), reproductive success (Craighead et al. 1995), genetic diversity (Paetkau and Strobeck 1994; Paetkau et al., 1995; Waits et al. 1998), evolutionary history (Taberlet and Bouvet 1992; Waits et al. 1998) and individual identification within a population (Paetkau and Strobeck 1994; Paetkau et al. 1995). However, the DNA based analysis is considered to be the most advance technique at present in the wildlife ecology. Further, the use of a DNA-based population census may eliminate some of the logistical barriers to estimating population numbers. The recent development of using genetic fingerprinting to estimate size of wildlife populations has provided biologists with a more efficient tool to estimate numbers than traditional mark-recapture techniques. Thus, genetic monitoring of free ranging species with non-invasive samples is a process of quantifying temporal changes in a metric of population genetic data generated using standard molecular markers (Schwartz et al., 2007) and it can be divided into two broad categories: Category 1 defines the use of diagnostic molecular markers through the identification of individuals, populations and species; whereas Category 2 focuses majorly on the application of molecular markers to evaluate the changes in the population genetic parameters on a temporal scale (Schwartz et al., 2007). Genetic data can unveil pivotal information like population sizes, ranging patterns, sex ratio, demographic history, which is required to strategise the conservation and management planning. Further, heterogeneity and rapid changes imposed in the landscape often accelerate restriction in the species movement between suitable patches (Katayama et al., 2014; Doherty et al., 2018). This restricted movement may lead to genetic consequences including disruption of gene flow, inflation of inbreeding and loss of rare alleles (Frankham 2010; Haddad et al., 2015; Weeks et al., 2016). Moreover, most populations of threatened mammals reside in small and isolated protected areas (<500 sq. km), thereby increasing high risk of local extirpation due to genetic inbreeding and loss of heterozygosity (Hansen and DeFries 2007; Haddad et al., 2015). Furthermore, conservation priority species requires studying through multidimensional aspects as these species have the significant role in functioning ecosystem through cascade networks and hold a key place in terrestrial ecosystem. Thus, it is important to have complete foundation of genetic variability, inbreeding, population structure and demographic history to frame conservation and management plans for free ranging wildlife.

1.1.8. Human-wildlife conflict

The interaction of humans with wild animals especially large ranging carnivores lead to conflicts worldwide. Conflicts between humans and wildlife in India are escalating due to increasing human population, loss of natural habitats, and in some regions, increasing wildlife populations as a result of successful conservation programs (Rodgers 1989; Saberwal et al. 1994). The intimate interspersion of people in protected areas often results in conflicts between humans and wildlife (Rodgers 1989). Most wildlife protected areas in India support various forms of land use, such as agriculture, livestock grazing, and collection of minor forest produce. Human-wildlife conflicts are acute when the species involved is highly imperiled while its presence in an area poses a serious threat to human welfare (Saberwal et al. 1994). Although humans and carnivores have co-existed for a long time but the frequency of conflicts have increased in recent decades as a result of increased human activities in wildlife areas or on natural habitats (Graham et al. 2005; Bulte and Rondeau 2005).

Multiple studies have shown that carnivore populations are limited by human interventions. The species with conflicts with humans are more prone to extinction. Conflicts with people have lead to extinction and eradication of certain wild species (Woodroffe et al. 2005). In certain cases where local extinctions are not any how possible, the local decline suppressed populations and restricted distribution are the secondary outcomes. Species such as brown bears, lynx and wolves had disappeared from most of Western Europe by the end of the nineteenth century (Woodroffe 2001). Such human-induced mortality affects not only the population viability of some of the most endangered species, but also has broader environmental impacts on ecosystem equilibrium and biodiversity preservation.

Human-wildlife conflicts are not a local, small-phenomenon, but an issue that spans diverse arrays of geographic and human demographic contexts. Carnivore sometimes typically compete directly with humans for resources such as space, food, security and cover and are reported to be involved in interaction with humans throughout their distributional ranges (Garshelis 1989; Huygens and Hayashi 1999; Sathyakumar 2003; Bargali et al. 2005; Fredriksson 2005; Smith et al. 2005; Mordo et al. 2008; Yadav et al. 2009; Charoo et al. 2011). Positive interactions in which animals gain rewards from human food sources can lead them to adapt and utilize human food sources. This behavior has the potential to perpetuate through generations, often resulting in conflicts with humans (Gilbert 1989; Beckmann and Berger 2003). HWC have long existence as humans and wildlife species such as selected in the proposed study overlap much in resource sharing. Almost all species selected in the study kill or injure livestock, damage agricultural or horticulture crops, or otherwise directly compete with people.

For developing an effective strategy to minimize and mitigate man-animal conflict it is imperative to generate high quality data for identifying the conflict hot spots in any study landscape. Hence, the present study will generate quality data to identify conflict zones viz., high, medium and low intensity zones in the study area.

1.1.9. Aims and objective of the proposed study

Aim

The proposed study has been envisaged to generate robust population estimates of the selected species and also to understand the Human-wildlife conflict in the study landscape with an aim to minimize conflict and to under the populations of the study species for adaptive conservation and management planning.

Objectives

Following are the main objectives of the proposed study:

1. To understand the current distribution and status of all five species *viz.*, Striped Hyena, Indian grey wolf, Leopard cat, Golden Jackal and Wild boar in South and Central region of West Bengal.
2. Population estimates of the study species using camera traps and DNA based analysis in the intensive study sites.
3. To generate quality data on landscape genetic parameters (gene flow, population connectivity, fragmentation) of the selected species in the study landscape.
4. Identification of Human-wildlife conflict zones in the study area with reference the four species (Striped Hyena, Indian grey wolf, Golden Jackal and Wild boar).
5. To develop conservation and management plan of the study species

2.0. Study area

As per the discussion and suggestion of senior forest officials of forest department, the study was conducted in South Bengal except Sunderban Biosphere reserve, West Bengal. The study area includes about 13 districts of West Bengal state viz., Murshidabad, Nadia, Birbhum, Bardhaman, Hoogly, Howrah, Kolkata, Part of 24 PGS (N), 24 PGS (S), Purulia, Medinipur, Jhargram and Bankura. The Southern region of West Bengal State of India represents a variety of divergences with the rest of the state because it has a distinct environment and unique faunal and floral assemblage. The landscape lies between 20˚50' to 25˚0' North Latitude and between 85˚50' to 88˚20' East Longitude administratively divided into 13 districts (Fig. 1) with a total area of about 66,045 km^2 (Fig. 1). The study landscape share boundary with the Indian State of Jharkhand on the west, Odisha and Bay of Bengal in the south and in the east it shares a boundary with Bangladesh. The vegetation type of this area broadly categories into major forest types *viz*., tropical moist deciduous forest, humid subtropical, and tropical dry deciduous forest (Champion and Seth, 1968). The average annual rainfall ranges from 125-175 cm, and the mean temperature varies from minimum 10℃ to maximum 39℃. The river Ganga and its tributaries are the primary water sources in the landscape which irrigate agriculture lands. The landscape can be classified into four types of Agro climatic Regions *viz.*, Western Plateau, Old, Coastal and Eastern Alluvial Plain, which supports diverse agriculture crops in much of the landscape, except the Western Plateau region with undulating laterite region and less productive in term of agriculture. The local communities in the landscape are mostly agrarian with small landholding, and their livelihood is mainly dependent on agriculture and animal-based agriculture (Joshi et al., 2004). The Southeastern region of the study landscape has significant populations of tribal communities which are significantly dependent on forest resources for their livelihoods. These tribal are also known to hunt wild animals in the landscape as a traditional ritual they perform in Shikar Utsav, especially in Ayodhya Hills of Purulia district. The traditional hunting by these communities is a major conservation and management challenge in the study landscape, threatening populations of species (Daripa, 2019; Ghosh et al., 2013). The major wildlife species of the region includes *Melursus ursinus, Elephas maximus, Herpestes edwardsii, Canis aureus, Semnopithecus entellus, Felis chaus, Sus scrofa, Axis axis, Hystrix indica, Prionailurus viverrinus* along with *Canis lupus pallipes* and *Hyaena hyaena* (Agrawal et al., 1992; Biswas, 2008).

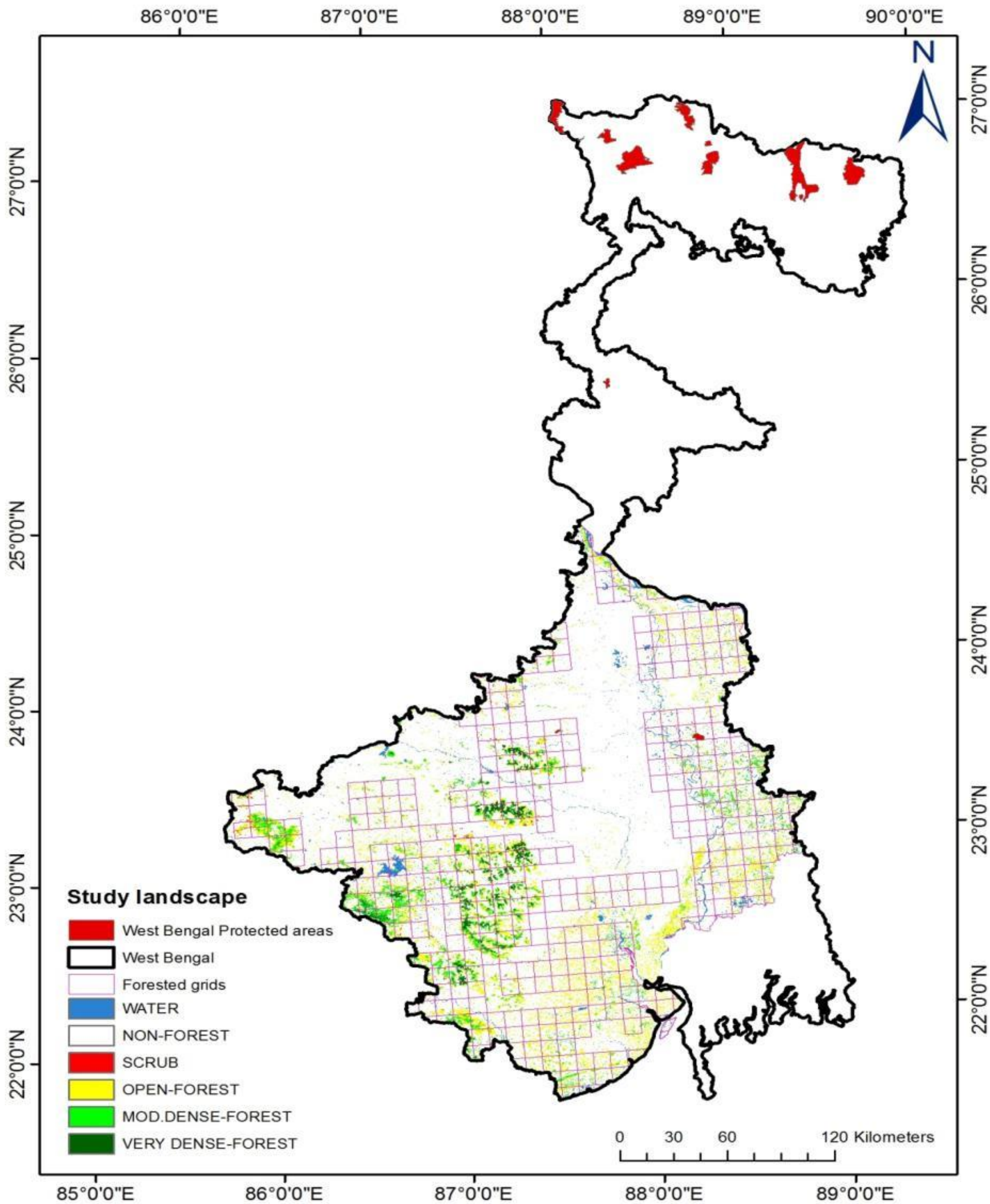


Figure 2.1 - Map showing study area location in West Bengal State

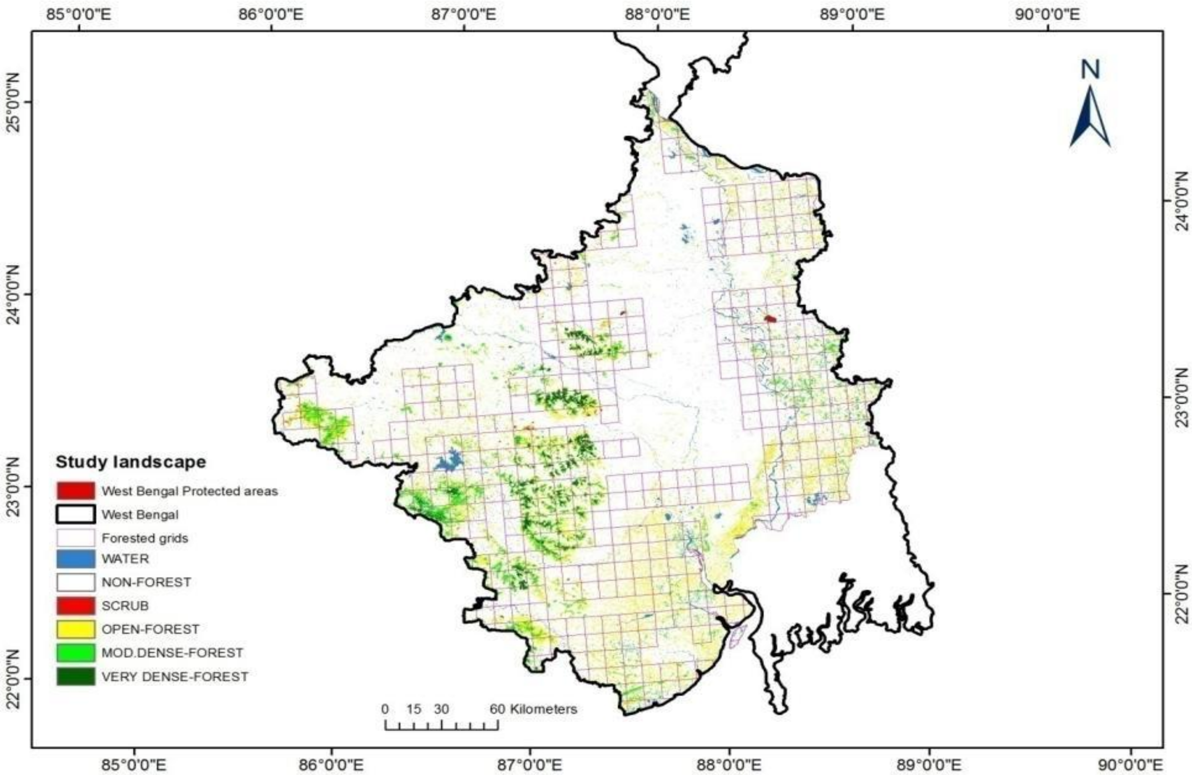


Figure 2.2 - Map showing extensive study area in West Bengal State

3.0. Materials and Methods:

3.1. General field methods

Conservation priorities and strategies are based upon understanding and assessments of general ecology of the concerned species. Selected species in the present study are of great conservation and management concern to the West Bengal at local level and they hold important position in the national as well as global prospective. Although plentiful of literature on the study species are available from other areas, but no information is available from the present study landscape. Hence,, was aimed for studying population, distribution and human-wildlife conflict using the most modern and advance techniques.

3.1.1. Reconnaissance and identification of the intensive and extensive study areas

The study was conducted for the period of two years (2018-2020) and the field reconnaissance surveys were conducted in the study landscape located in Southern and Central region of West Bengal for identifying intensive and extensive study sites (Figure 2.1). The extensive study was conducted with an aim to understand the distribution of the selected five species in the entire region of the West Bengal state. However, the intensive study was conducted after gathering species presence/absence information. Based on the literature review and the field surveys, following strategy was adopted to accomplish the different objectives of the proposed study.

First step was identification and categorization of the study area into extensive and intensive study areas. The extensive study area was defined as agro-forestry landscapes in the study landscape and the areas which are suitable for the study species. The intensive study area was identified as forested habitats including protected areas if any and the territorial forests in the southern and central region of the West Bengal State.

3.1.2. Study design

The most basic carnivore survey consists of surveying an area for the species occurrence. However, for population monitoring surveys were to be conducted repeatedly (Royle and Nichols 2003). For the reliable estimates, the consistency of these surveys is a must. The information about the presence of a species was equally important as of knowing the absence of a species in an area. Regardless of the size of survey area, logic dictates that multiple sites were surveyed because the probability of detecting at least one individual will increase with the number of sites. The most conservative approach to determining the density of sites is to make sure that at least two sites are surveyed within the hypothetical home range of a species. The use of this design reduces the loss of data taking into account the inoperability of the devices/researcher bias/environmental circumstances (Long and Zielinski 2008). Considering all these, a study area was identified and the design was developed and adopted.

Most of the effort in terms of field work was carried out in the intensive study area (Figure 2.2). The intensive study area was divided into 5 x 5 km and 2×2 km grids for intensive camera trapping considering the logistic feasibility and species behavior. Transects/trails of varied length were marked/ laid in the area representing all habitat variability (Figure 2.2). For vegetation sampling circular plots were marked after in each of the grids, a camera trap was deployed.

The entire (intensive) study area was systematically covered twice a month during the study period. Each transect was monitored twice a month for signs and sightings. The camera traps were checked once in three days for replacement of batteries, memory cards in camera traps and in any given area an effort of 15 days camera trapping was carried out in all pre and post monsoon seasons.

3.1.3. Distribution assessment of the study species in the study area

For developing the distribution map of the species in the study landscape Geo-spatial modeling was adopted. The presence locations of all selected species were used during the study duration. A total of 19 bioclimatic variables (BIO1 to BIO19) along with topographic and anthropogenic variables were used for mapping the current distribution of the selected species in the landscape. The environmental data was derived from the WorldClim database (http://www.worldclim.org/bioclim) at a spatial resolution of 30 arc-sec with each cell a square of approximately 1 km by 1 km grid (Hijmans et al., 2005). The thematic maps including altitude, precipitation, temperature and potential distribution map was created using Arc GIS 10.5 (ESRI, Redlands, CA, USA).

Model selection:

Species distribution modelling is a great tool with its simple visualization power and easy to, understand the patterns over geographical as well as environmental space. The observed location for a species can generate the actual distribution of a species in environmental space, with this set of environmental variables it can be predict the other area where the environmental variables more like same. We have used SSDM package in R environment Ver. 3.1 (Schmitt et al., 2017) to evaluate distribution model through multiple modeling algorithms. We have used ensemble approach to build the final distribution model for wolf and hyena. Numerous studies were available highlighting the robustness of the ensemble a modeling approach in predicting the probability of species presence precisely (Franklin, 2009: Peterson et. al. 2011; Elith et al., 2006) (Hutchinson 1957; Phillips et al. 2006, Pearson 2010; Barve 2011).

Simulation procedure

After completing the variables selection procedure we convert the variables for SSDM supported file format to evaluate the probability of maximum suitable habitat of study species. We opt the criteria under Random test percentage to divide the presence data of the species, 30% of the data used for testing the model prediction and 70% data use for build the model. We set the SSDM environment with 50 replications, SES (Sensitivity-Specificity equality) have been used evaluation metric. A total of 8 models have been used for building suitability for all the study species (GLM, GAM, MARS, MAXENT, ANN, SVM, RF and GBM) out of which selection of best fitted model with AUC threshold < 0.75 was set for final ensemble probability surface building. Logistic output format was used to calculate the Sensitivity analysis for each variable. We verified our final ensemble model by generated ROC value, which directed the model evaluation poor when the value is 0.6-0.7, a value with 0.7 – 0.8 is normal, 0.8 – 0.9 is good and best with 0.9 – 1.0, hence if the value is less than 0.6, then the model should be rejected (Swets 1988). Evaluation of the final ensemble model for species have been done using ENMeval (Muscarella et.al., 2014). Variable importance have been evaluated by percentage contribution in the final model using SSDM package.

3.1.4. Identifying suitable habitats

A total of 19 bio climatic variables (BIO 1-BIO 19) along with topographic (elevation, slope and aspect) and linear features (distance to road, distance to river, distance to rail) had been taken into account (Table 3.1).

Table 3.1 - List of selected variables for habitat suitability modelling for the study species

	Code	Full form of the variables
Bioclimatic variables	bio_1	Annual Mean Temperature
	bio_2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
	bio_3	Isothermality (BIO2/BIO7) (×100)
	bio_4	Temperature Seasonality (standard deviation ×100)
	bio_5	Max Temperature of Warmest Month
	bio_6	Min Temperature of Coldest Month
	bio_7	Temperature Annual Range (BIO5-BIO6)
	bio_8	Mean Temperature of Wettest Quarter
	bio_9	Mean Temperature of Driest Quarter
	bio_10	Mean Temperature of Warmest Quarter
	bio_11	Mean Temperature of Coldest Quarter
	bio_12	Annual Precipitation
	bio_13	Precipitation of Wettest Month
	bio_14	Precipitation of Driest Month
	bio_15	Precipitation Seasonality (Coefficient of Variation)
	bio_16	Precipitation of Wettest Quarter
	bio_17	Precipitation of Driest Quarter
	bio_18	Precipitation of Warmest Quarter
	bio_19	Precipitation of Coldest Quarter
Anthropogenic variables	bio_human footprint	Human footprint
	bio_rail	Euclidian distance from Rail
	bio_road	Euclidian distance from Road
LULC type	lulc	Land use land cover
	bio_water	Euclidian distance from Water cover type
Topographic variables	Aspect	Aspect
	Elevation	elevation

3.1.5. Population estimation of study species using Camera traps and DNA based analysis

Camera trapping for estimating the population of Leopard cat and Hyena

The camera trap study was carried out in the second year of implementation after identification of highly suitable habitats of the study species. Camera-trapping has been successfully used throughout the world for studying a wide range of elusive animals when compared with more traditional methods (O'Brien et al.2003; Sanderson and Trolle 2005; Bowkett et al.2007; Ríos-Uzeda et al. 2007; Moruzzi et al. 2002; Carbone et al. 2001; Karanth and Nichols 1998). This technique has proven useful in providing detailed species inventories, where it has high detection efficiency and has recorded species that were otherwise undetected (Yasuda 2004; Giman et al., 2007). Elusive species such as hyena have been studied worldwide using this technique (Singh et al., 2014). Traditional presence–absence surveys estimate the proportion of the area occupied by the species of interest within a landscape through direct field observations, often ignoring the key issues of delectability and spatial sampling and thus rendering at best a naïve estimate. A species may not be detected even when it is present and its delectability may vary from site to site. Surveys conducted over large regions are impractical to carry out unless a spatial sampling scheme is followed (Yoccoz et al. 2001). Hence, camera trapping was carried out for species which can be identified using the patterns of the coat and for those species whose individuals cannot be identified DNA based analysis was adopted.

DNA based population estimation of Wolf, Wild boar and Jackal

Collection of fecal samples for DNA analysis:

The study area was searched for scat samples of all study species and collected scats were stored over silica gel (Wasser et al., 1997) along with GPS location. Age of each samples were determined with respect to freshness and degradation into very fresh, fresh less than a week, old (less than a month) and very old (more than a month). Other qualitative details regarding habitat types, level of disturbance and food resources were noted from the places of fecal samples collection.

Field sampling:

We did not obtain samples from all study sites and the samples which were then identified using genetic analysis to be originated from Indian grey wolf, wild boar and golden jackal were limited and did not represent all sites/ districts. Therefore, we combined all the samples species wise to estimate number of unique genotypes of a species present in South West Bengal. This strategy was not ideal but then followed to identify unique individuals and to investigate genetic make-up of these species.For collection of the faecal samples, we under took transects/ trail surveys and opportunistic surveys, and also the remote camera traps following Joshi et al., 2019; Dalui et al., 2020). During surveys, natural trails, ridges, nullahs, Goths and Dhars were walked on, and information on sightings and evidences of the occurrence of the wildlife were recorded. In the case of any wildlife sighting/sign encountered, information on GPS location, time, number, sighting distance were recorded. The sampling locations were plotted on the map of the study area to represent their distribution across the landscape. Scats were collected in autoclaved plastic bottles with silica gel for further genetic analysis.

Mitochondrial markers:

DNA extraction, PCR amplification and sequencing:

All the faecal samples were processed for DNA extraction using the Qiagen Stool DNA extraction kit following manufacturer recommendations (Qiagen, Germany).Species wereidentified based on the mitochondrial markers using a multigenic approach (cytb/D-loop/ATP8 etc.). We used combination of several mitochondrial markers for species identification (Table 3.2). To amplify the mitochondrial gene, the polymerase chain reactions (PCR) were conducted in 10 µl volume containing 1X PCR buffer, 1.5 mM $MgCL_2$, 0.50 mM of each dNTP, 0.40 µM forward and reverse primer, 0.5 unit of Taq DNA polymerase (Takara), 0.10 µg/µl of Bovine Serum Albumin, 20 to 30 ng DNA. The PCR profile included an initial denaturation step at 95ºC for 5 min followed by 38 cycles at 94ºC for 30 sec, annealing temp. 53-56ºC for 40 sec (gene wise annealing temp Ta mentioned in table), primer extension at 72ºC for 50 sec, and a final extension step at 72ºC for 10 min with holding the cycle at 4 ºC.

Table 3.2 - Details of mtDNA markers used in the present study for species identification

S. No.	Genes	Primer sequences		Amplicon size (bp)	Temp. (^{0}C)	References
		Forward 5 '-3'	Reverse 5 '-3'			
1	d-loop	5'-TACCCG-TACTGTGCTTGCCC-3'	5'-AGCACTTTCGGA-CAGTTGAG-3'	160	56	Jae-Heup et al., 2001
2	Cyt b	5'-TACCATGAGGACAAATATCATTCTG-3'	5'-CCTCCTAGTTTGTTAGGGATTG ATCG-3'	472	55	Verma & Singh 2002
3	ATP6	5'-AACGAAAATCTATTCGCCTCT-3'	5'-TGGATGGACAGTATTTGTTTTGAT-3'	156	53	Hag et al., 2009 and Chaves et al, 2012

The amplified PCR products were cleaned up using Exo-SAP treatment to remove residual oligonucleotides and dNTPs prior to DNA sequencing. Forward and reverse primer of each mitochondrial gene were used for setting up the cycle sequencing PCR using the Big dye terminator cycle sequencing kit version 3.1 (Applied Biosystems, USA). The sequencing products were cleaned up to remove any unbound ddNTPs using alcoholic precipitation method and subjected for sequencing to ABI 3730 Genetic Analyzer (Applied Biosystems, USA). Qualities of sequences were determined using Sequence Analysis v 5.2 software (Applied Biosystems, USA) and validated by Sequencher v 4.7 software (www. gene code. com. Multiple sequence alignment (MSA) was performed using CLUSTAL-W as implemented in BioEdit v 7.0.9.0 software (Hall, 1999).

Microsatellite analysis

A set of nine microsatellite loci for Indian grey wolf and golden Jackal and seven markers for wild boar were selected for individual identification following previous studies (Janssonet al. 2014; Flagstad et al., 2003; Boitani, 2003).Seven porcine (*S. scrofa*) microsatellites were screened across wild suiform DNA, comprised a panel used for PiGMaP genetic diversity studies in *S. scrofa* (Laval et al. 2000; http://www.ri.bbsrc.ac.uk/pigbiodiv/markers. htm; http://www.toulouse.inra.fr/lgc/pig/panel.htm). These microsatellites were selected for their high degree of polymorphism and their wide coverage on the genome. Each locus was individually amplified using the PCR master mix in a 10 µl volumes with the following PCR mix: 4 μl Multiplex master mix (Qiagen, Germany). The amplified products were pooled with different dyes in a single tube and run for genotyping in the ABI 3730 Genetic Analyzer.All the selected markers were first tested in a uniplex independent PCR with 10 known samples of each species and subsequently the primers were pooled to generate multiplexes considering their annealing temperature, dye chemistry and amplicon size. The forward primer of each locus was labelled with one of the fluorescent dye i.e. FAM, VIC, PET, NED at 5' end.

Estimation of nuclear DNA diversity, Hardy Weinberg equilibrium, linkage disequilibrium and relatedness

All population genetic analysis parameters were generated using software GENEPOP version 3.4 (Raymond and Rousset, 1995) and GENETIX version 4.02 (Belkhir et al., 1996-2004) after standardization of analysis method in the second year of the project implementation. We measured the nuclear genetic diversity as the number of alleles per locus, the observed heterozygosity (Ho), and expected heterozygosity (He). These estimates were compared across different population with in the study areas to identify if any population is inbred or there is a loss of genetic diversity. Genetic differentiation was estimated using GENEPOP 3.4 with global Fst (across all population), pair wise Fst (Weir and Cockerham, 1984) and significance in population differential was tested in GENEPOP 3.4 as suggested by Dixon et al. (2006). Pair wise genetic relatedness between pairs of individuals using Wang's estimator (Wang 2002) was estimated in relation to habitat types and level of anthropogenic factors. Extent of gene flow was determined based on commonly used Fst values and defined gene flow as low (≥0.25), medium (0.15 – 0.24), high (0.05 – 0.14) as used in the study of mountain lion (Ernest et al 2003). The subprogram ISOLDE in GENEPOP 3.4 was used to test a relationship between geographic distances and Fst values and Mantel test was used for statistical significance. We understand "isolation by distance by examining spatial use by individuals based on relatedness in relation to geographical distance using GENETIX version 4.02 (Belkhir et al., 1996-2004) and understand dispersal patterns in male and female individuals using Bayesian based approaches in program 'STRUCTURE' (Pritchand et al 2000). Program "STRUCTURE" has been widely used in identifying migrants or admixture of population as has been used by Proctor (2003) for Grizzly bears in south western Canada. In addition, we used Factorial Correspondence Analysis (FCA) which has been deployed for population differentiation and distinction (Pierpaoli et al. 2002).

Non-invasive DNA technique for abundance estimation

Individuals identified using the DNA analysis was subjected to density analysis. Hence, the capture history was constructed for all selected in spatial explicit capture–recapture (SECR) data format for analysis. The SECR approach was used to obtain maximum likelihood density estimates for the study species using the camera-trapping data was adopted. The likelihood SECR models would be implemented in the R package SECR and DENSITY 5.0 (Efford et al. 2009; Efford 2010; www.otago.ac.nz/density).

3.1.6. Studying man-animal conflict

Informal interviews using semi-structured questionnaires were conducted in the study area. Interviews were mostly interaction based; however, the information was recorded in the pre-designed formats. In each village, a stratified sample of households was selected by compiling census data of village households and by adopting participatory rural appraisal (PRA) techniques (Richards et al. 1999). Based on economic status, the government of India the households were classified into 2 groups: below poverty line (BPL) families have annual incomes <20,000 Indian rupees (INR) and above poverty line (APL) families have annual incomes >20,000 INR (Planning Commission of India 2008). Informal interviews were conducted with the villagers to collect information on various parameters such as livestock holdings, livestock grazing patterns and livestock predations incidences (number of livestock killed and place of attack). Information on livestock depredation by large carnivores in the region was collected from the Forest Department. Further, population data on livestock population was also gathered from the departmental records of Animal and Sheep Husbandry Government Departments. Considering the socio-economic condition of the local communities in the study landscape stratified multistage random sampling technique was employed for getting responses of the locals. The first stage-sampling units were the villages and the second stage-sampling units were the households. The first sampling units i.e. villages were stratified based on the population of the villages available as per the human population census 2011 (Census, 2011). After arranging all villages in descending order of population, if n villages were selected then this list of villages were grouped into 10 groups based on population and n/10 villages were selected with simple random sampling without replacement (SRSWOR) from each such group with the help of Fisher's random number table. For documenting response, a minimum of five households or 30% of the total households in a village representing different socio-economic status was interviewed following the method suggested by Cochran, (1997) and Sukhatme & Sukhatme, (1997). Data on types of conflict such as crop damage, livestock depredation and human attacks were generated from primary surveys and also the secondary data was collected from the Forest Department to understand the nature, type and intensity of conflict cases in the study landscape.

Based on the semi structured questionnaire, responses can be classified as dependent variable such as attitude towards wildlife and independent variables, such as education, income, livelihood, grazing, infringement land and land holding. Generalized Linear Model (GLM) is used to interpret the relationship between all these dependent and independent variables, and the variable that positively signifies, can be assumed as factors affecting the attitude wildlife of the community. The generalized linear model is a statistical linear model. It may be written as,

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \ldots\ldots + \beta_n X_n$$

Where X_1 to X_n were the drivers and β_1 to β_n were coefficients of independent variables showing effect (positive or negative) of the unit change in the independent variables on the dependent variables.

3.1.7. Understanding the spatial pattern of Human-wildlife conflict

To understand the spatial distribution of wildlife–human conflicts, the GPS locations of the conflict cases were recorded during the surveys and the study area was divided in to 4x4 km grids. Due to the point nature of the collected data, a point pattern analysis was employed to identify patterns and clustering. Evaluation of the conflict data has been done by fitting GLM (Generalized linear models). Parameters for the primary model selection have been selected based on the expert opinion, and ground truth data collected during the field visit. For determine the spatial pattern of the conflict and its influence, special emphasis has been given for the anthropogenic predictors including Human footprint, Cattle density, Distance to Cropland, Distance to road ways and railways and Night light. The final predictors have been categorized in to 3 classes i.e. Topographic, Anthropogenic, Landuse. Model evaluation and selection of the best fitted model was done by forward step-wise selection based on AIC score of the respective model combinations. The percentage of influence and relation with the species level conflict data was evaluated on Pearson's method. For final conflict map generation, the estimate scores of the significant contributors have been used in raster calculator and spatial analyst tool box in ArcGIS 10.6. The forest rangebased evaluation of the conflict threat for all the study species was evaluated by zonal statistics.

3.1.8. Socio-economic Conditions of the Forest Communities in the Landscapes

Selection of villages

For assessing the socio-economic condition of the forest communities in the landscapes, questionnaire surveys were conducted. The forest fringe villages were selected in view of their close proximity to forests in the landscape. Considering the selected grids, representative sampling was carried out by randomly selected sample villages. The data was collected by visiting the selected houses-holds in each selected village of each study area in all the 13 study districts. The questionnaire household level aimed information about the individual's household profile, social and economic characteristics, questions related to the forest, and priority species etc.

Selection of households

Minimum twelve to fifteen households were selected randomly after stratification for the survey from each selected village (affluent, less-affluent and other class respectively) (NSSO, 2001, FSI, 2011). A number of samples (Sample Size/Intensity) have been derived by the following formula (Cochran, 1997, Sukhatme & Sukhatme, 1997) keeping in view of a large number of households.

$$n = \left(\frac{CV(Y) * t}{\in}\right)^2$$

Where CV = Coefficient of Variation of character under study

Y = Character under study

t = Value of t statistics at 5% level of significance (95% Confidence Interval)

ε = Margin of Error or permissible error, which is generally 5% to 25%, as where the permissible error is increase, the sample size will also increase.

A semi-structured close ended questionnaire formats were used to collect information with respect to the household demography, education, income, livelihood, their dependency on the forest, awareness related to forest conservation and management. The collected data was analyzed using Kuppusamy's socio-economic status scale which is modified considering the 2019year consumer price index for agricultural workers in the three study States (Kuppuswamy, 1981; Kumar et al., 2007).The evaluation of the socio-economic status of the forest community was carried out for categorization of the individual households based on their education, occupation, and family income in the present study. Several methods or scales have been developed for classification of different populations by socioeconomic status (Rahudkar scale, 1970; Shrivastava scale, 1972; Bharadwaj scale, 2001).

Characterization Socio-Economic Status

For the socio-economic characterization of the selected village communities, the information on the socio-economic condition such as education, income, and occupation or (source of livelihood) were collected. Several methods or scales have been developed for classification of thedifferent population by socioeconomic status (Rahudkar scale, 1970; Shrivastava scale, 1972; Bharadwaj scale, 2001). However, the modified Kuppuswamy's socioeconomic status scale for therural area of India using the basic Kuppuswamy's (1967) was used in the present study considering its usefulness in explaining the relative influence of education, occupation, and income (Kuppuswamy, 1981) (Table 3.3). To scale the socio-economic condition of the locals, the Consumer Price Index (CPI) for agricultural laborer given by Central Statistical Organization (CSO), Ministry of Statistics and Programme Implementation, Government of India, CPI-2019 was used because the study was conducted in the rural or forest fringe villages (Mishra and Singh, 2003). The conversion factor for the NUCPI for 1976 (the year when Kuppuswamy's scale was proposed) and 2019 was developed as follows.

NUCPI for 1976 = 15.6 (Base Year: 1995 / 96 = 100)

NUCPI for 2019 = 828 (Base Year: 1995 / 96 = 100)

Study determined the conversion factor between the index of 1976 and 2019: 828 ÷ 15.6 = 53.07. The Income groups of all scales were multiplied to get the modified income scale for

2019 (Table 3.4). All variables were evaluated based on scores given in modified Kuppuswamy's scale 1976 for scaling the respondent's socio-economic contrition (Table 3.5).

Table 3.3 – The Socioeconomic Status Scale of Kuppuswamy's (Urban, 1967).

Scorecard					
Education	**Scores**	**Occupation**	**Scores**	**Income per month (Rs)**	**Scores**
Professional degree	7	Government Job	7	≥ 2000	12
Graduate	6	Medium-Business	6	1000 – 1999	10
Intermediate or Senior Secondary	5	Small-Business	5	750 – 999	6
High-school or Higher Secondary	4	Farmer or Agriculture	4	500 – 749	4
Middle school or Secondary	3	Skilled Laborer	3	300 – 499	3
Primary school	2	Unskilled Laborer	2	101 - 299	2
Illiterate	1	Unemployed	1	≤ 100	1

Table 3.4 - Modified Family Incomes in Indian Rupees of the Kuppuswamy's Socioeconomic Status Scale (modified for 2019)

Original Value	Modified Value for 2019	Score
≥2000	127702 and above	10
2000 – 1999	63851-127701	6
750 - 999	47888-63850	5
500 -749	31925-47887	4
300 - 499	19155-31924	3
101 - 299	6449-19154	2
≤ 100	< 6448	1

Table 3.5 - Socio-economic class

Total Score	Socio-economic class
26-29	Upper
16-25	Upper middle
11-15	Lower Middle
5-10	Upper lower
<5	Lower

4.0. Results

4.1. Field effort

For achieving the objective of the project we systematically covered the grids which possess forest cover (Figure 4.1). After the selection of the study grids we conducted questionnaire surveys and carnivore sign surveys. A total of 1770 questionnaire interviews and indirect sign (scat, pugmark etc.) sampling were conducted in 15(53 ranges: about 50.48% of the total ranges 105) forest divisions of 10 districts (Purulia, Bankura, Jhargram, West Midnapore, Birbhum, Burdwan, Nadia, Murshidabad, Hoogly and East Midnapore). The maximum numbers of interviews were conducted in Purulia district (813) and minimum in Burdwan (50). A total of 200 transects have been surveyed by walking a distance of 900.46 km in all the 53 ranges of fifteen forest divisions (Figure 4.2).

In Medinipur forest division, maximum no. of trails (28) are covered by walking 157.51 km followed by Purulia forest division (19 trails, 77.5 km), Jhargram forest division (18 trails, 49.36km), Bankura South forest division (18 trails, 43 km) and Birbhum forest division (17 trails, 74.34 km). 16 transects are surveyed in both Kharagpur and Kangsabati South forest division with a covered distance of 99.46 km and 73.73 km respectively while 15 transects are surveyed in both Burdwan and Bankura North forest division with a covered distance of 98.57 km and 32 km respectively. In Kangsabati North, Nadia-Murshidabad, Rupnarayan and Durgapur forest division 11, 8, 6, 5 trails have been walked with a distance of 46.77 km, 33.85 km, 33.95 km, 31.04 km respectively whereas both in Howrah-Hoogly and Purba Medinipur forest division, 4trails have been surveyed with a covered distance of 26.5 km and 22.88 km respectively (Figure 4.2).

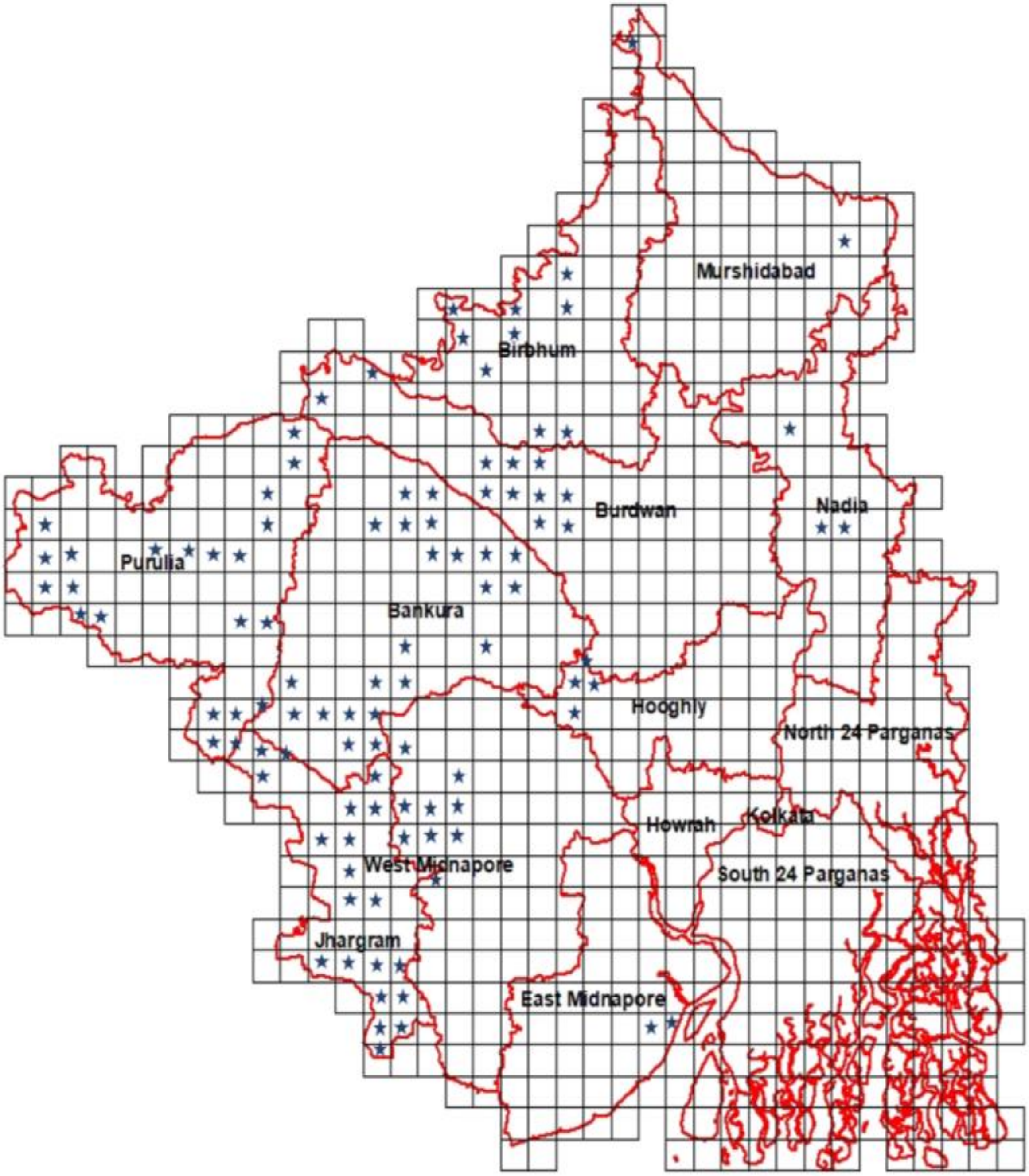


Figure 4.1 - Grid map of study districts showing the grids covered during the survey. Grids sampled are marked with blue color (intensive study area) star.

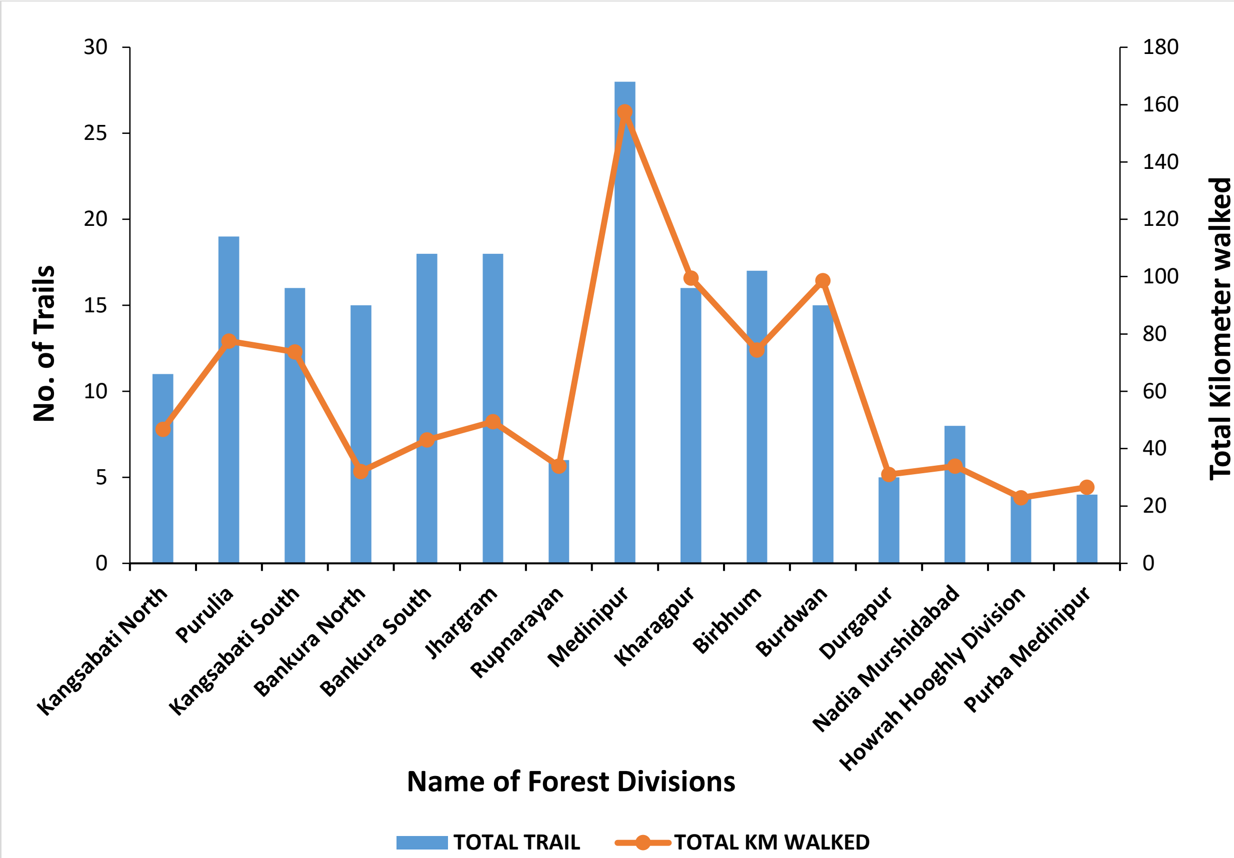


Figure 4.2 - Total number of trails covered along with the total kilometer walked in fifteen forest divisions

4.2. Current distribution and status of all four species in study landscape

All districts of South West Bengal have been covered for presenting the current distribution of study species. Under the species distribution model the areas under these districts were categorized as least suitable, low suitable, moderately suitable and highly suitable habitat and that varied species wise.

Model performance

The final result of the ensemble modeling approach evaluate the AUC value of the Receiver Operating Characteristic (ROC) curve for Golden jackal, Hyaena, Indian grey wolfIndian Indian grey wolf and Wild boar was 0.784, 0.892, 0.819 and 0.823 respectively (Table 5, 7, 9 and 11), which suggest outstanding prediction for all the species.

Selected variables for all the four studied species play differently to configure the suitable habitat apart from elevation and slope. Elevation and slope are the two common highest variables for all the four species. bio_14 (Precipitation of Driest Month) and bio_2 (Mean Diurnal Range) were highest performing variable for Golden Jackal with 11.47 and 9.5 respectively. On the other hand lulc (Land use Land cover) and bio_rail (euclidian distance from rail) were most significant variables with 16.31 and 13.13 respectively for Hyaena, for Indian grey wolf bio_10 (Mean Temperature of Warmest Quarter) and bio_17 (Precipitation of Driest Quarter) were the most important variables with a value of 11.33 and 11.27 respectively and bio_14 (Precipitation of Driest Month) and Human footprint are two major contributor for Wild boar distribution with 12.62 and 11.06 respectively. Furthermore, the mean value of ensemble species distribution model indicates the range wise high probability of distribution of each species. Matha and Ajodhya range of Purulia district have the high probability of Golden Jackal and Hyaena population distribution respectively among the study area. Indian grey wolf and Wild boar population highly suitable in Bhulaveda range of Jhargram district (Table 2). Moreover, the resultant habitat suitability model of the whole studied area classify into binary classes, for evaluating the suitable area for all the studied species, where we found 7913 km^2 area suitable for Golden Jackal, 3586 km^2 area suitable for Hyaena, 7531 km^2 area suitable for Indian grey wolf and 7157 km^2 area suitable for Wild Boar.

4.2.1. Distribution of Indian grey wolf (*Canis lupus pallipes*) in Southern Part of West Bengal

Out of the nine participating models a total of seven models, with more than the threshold AUC>0.75 have been selected for final ensemble building for Indian grey wolf. The final AUC of the selected models was found to be ranged from 0.772 (GLM) to 0.842 (RF) (Table 4.1). Apart from the AUC based model evaluation the respective score of other model evaluation metrics i.e. Sensitivity, Specificity, PCC and Kappa also was found to be above the selection threshold (Table 4.1). The model correlation was found to be highest between GBM and RF with a correlation value of 0.89 (Figure 4.3). Among the topographic predictors, percentage contribution of elevation and slope was found to be highest followed by the relative contribution of bioclimatic variables (Mean Temperature of Warmest Quarter) and (Precipitation of Coldest Quarter) (Figure 4.4). Zonal evaluation of the mean suitability scores suggests, higher suitable regions in Bhulaveda followed by Jhilmili and Banspahari ranges (Figure 4.5). The highest suitable regions for Indian grey wolf was found to reside in Bankura and West Midnapore having 3,040 Km^2 and 2,557Km^2 respectively (Table 4.2, Figure 4.6).

Table 4.1 - Individual model scores along with final ensemble model for evaluating the suitable habitat of Indian grey wolf.

Species	Models	AUC	Omission	Sensitivity	Specificity	PCC	Kappa
Indian grey wolf	**GLM**	0.772	0.227	0.773	0.771	0.771	0.299
	MARS	0.822	0.176	0.824	0.819	0.819	0.391
	GBM	0.826	0.174	0.826	0.826	0.826	0.652
	RF	0.842	0.158	0.842	0.842	0.842	0.684
	MAXENT	0.836	0.164	0.836	0.836	0.836	0.083
	SVM	0.808	0.191	0.809	0.806	0.808	0.615
	ANN	0.828	0.118	0.882	0.774	0.828	0.657
	Ensemble	0.819	0.173	0.827	0.810	0.819	0.483

Note: A total of seven model algorithms were found to be selected with a threshold of <0.75 AUC score, i.e. Maximum Entropy (MAXENT), Artificial Neural Network (ANN), Generalized linear model (GLM), Support Vector Machine (SVM), Multivariate adaptive regression splines (MARS), Random forests (RF) and Gradient Boosting Machine (GBM).

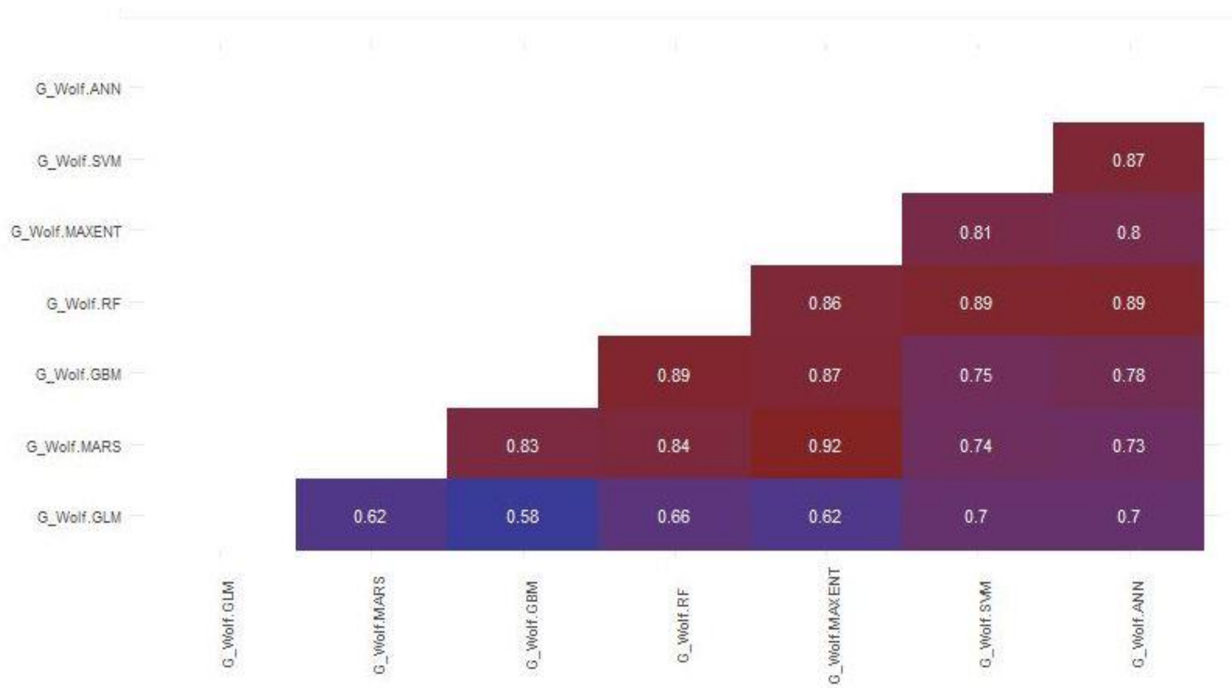


Figure 4.3 - Model algorithm correlation matric of all individual models toevaluating the habitat suitability of Indian grey wolf.

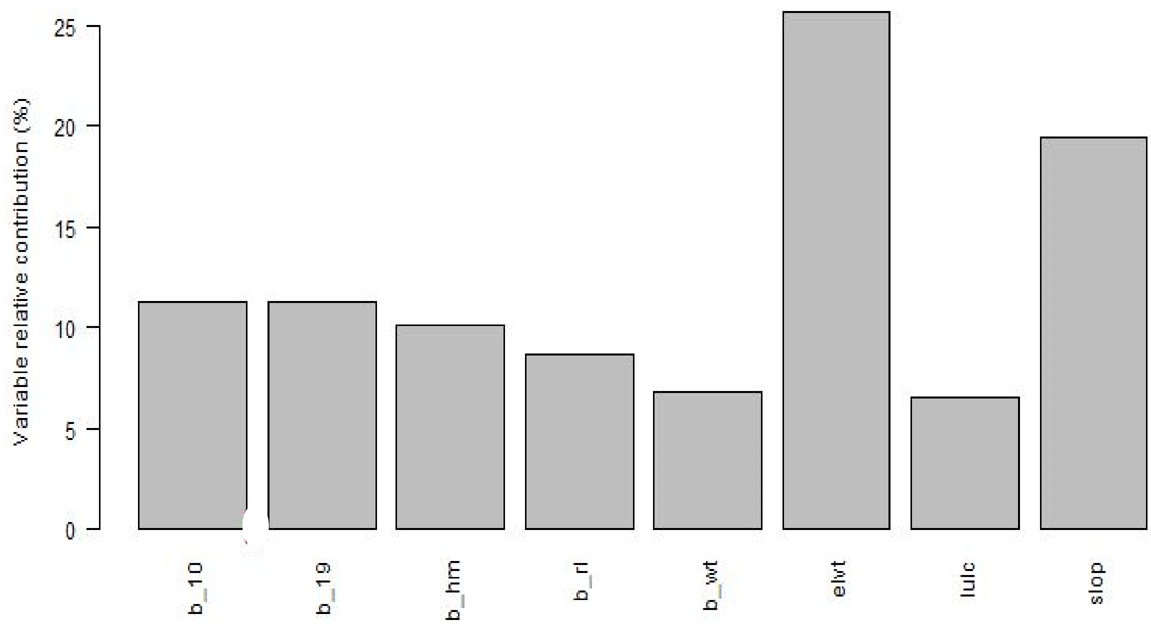


Figure 4.4 - A bar graph showing the Percentage contribution and permutation importance of selected variables to generate the habitat suitability of Indian grey wolf.

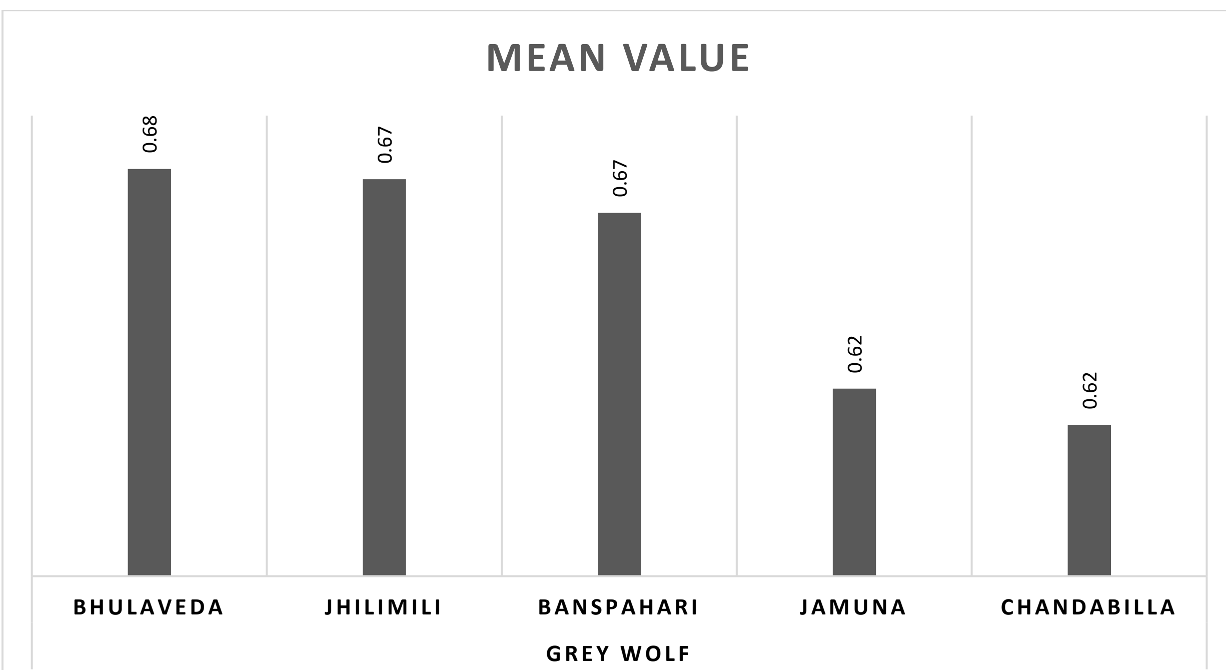


Figure 4.5 - Mean value of ensemble species distribution modeling reveals the high suitable distribution of Indian grey wolf among the ranges, only top 5 ranges with highest suitability.

Table 4.2 - Showing area suitable in three categories (Low, Medium and High) within different district of southern Bengal for Indian grey wolf in Km²

	Suitability/District	Low	Med	High
Indian grey wolf	Purulia	2408	4218	1324
	Bankura	1914	3887	3040
	West Midnapore	6303	3005	2557
	Burdwan	6736	1399	817
	Birbhum	3389	1264	1162
	Murshidabad	6867	29	0
	East Midnapore	4902	2	0
	Howrah	1816	0	0
	Nadia	4973	0	0
	Hooghly	3984	12	0

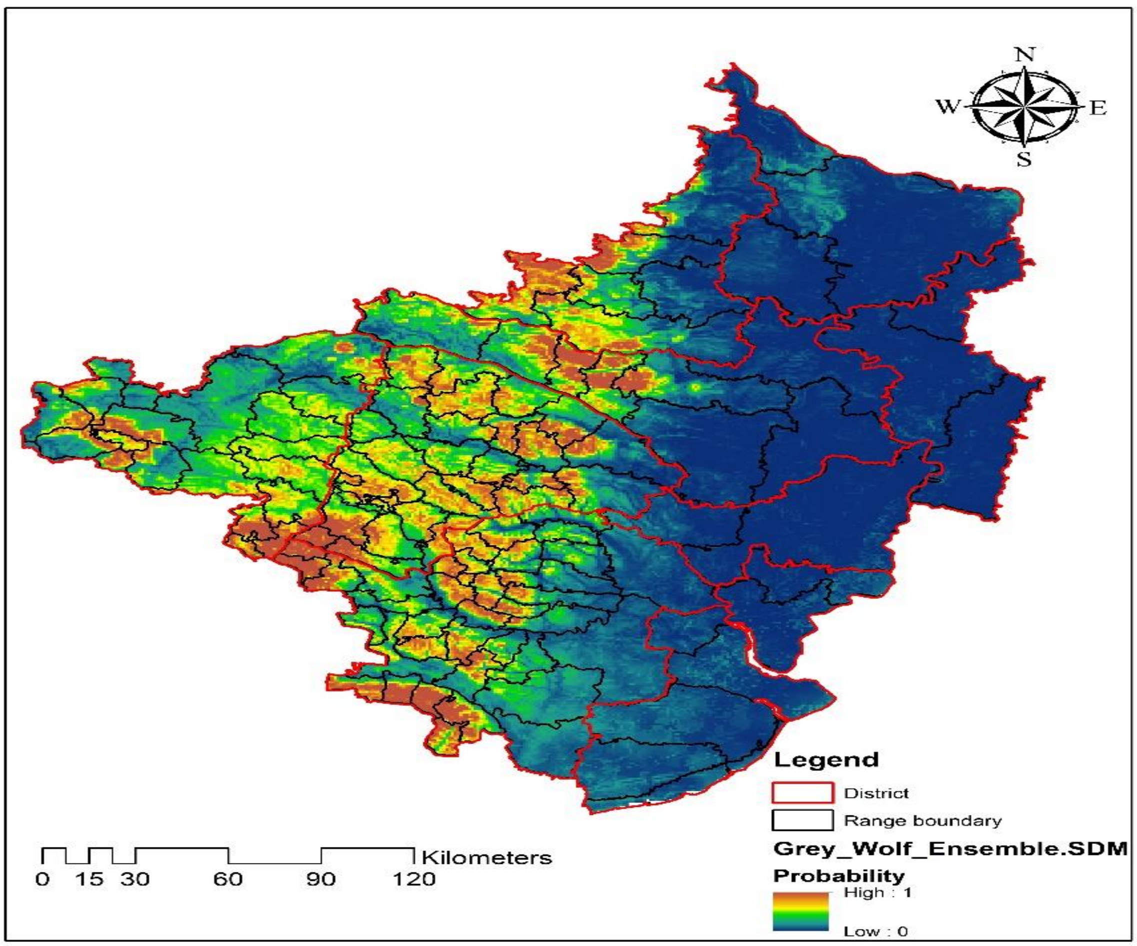


Figure 4.6 - Suitable habitat distribution for Indian grey wolf in Southern region of West Bengal. Maps were generated in ArcGIS Ver. 10.6.

4.2.2. Distribution of Golden Jackal (*Canis aureus*) in Southern Part of West Bengal

The final AUC of the selected models was found to be ranged from 0.765 (ANN) to 0.823 (RF) (Table 4.3). Apart from the AUC based model evaluation the respective score of other model evaluation metrics i.e. Sensitivity, Specificity, PCC and Kappa also had been found to be above the selection threshold (Table 4.3). The model correlation was found to be highest between MARS and MAXENT with a correlation value of 0.87 (Figure 4.7). Among the topographic predictors, percentage contribution of elevation and slope was found to be highest followed by the relative contribution of bioclimatic variables (Precipitation of Driest Month) and (Precipitation of Wettest Quarter) (Figure 4.8). Zonal evaluation of the mean suitability scores suggests, higher suitable regions in Matha (0.57) and Ajodhya (0.57) followed by Chandabilla (0.54) ranges (Figure 4.9). The highest suitable regions for Golden Jackal was found to reside in Bankura and West Midnapore having 2,341 Km^2 and 2,199 Km^2 respectively and East Midnapore, Haora, Nadia and Hugli were found to be less suitable for the species (Table 4.4; Figure 4.10).

Table 4.3 - Individual model scores along with final ensemble model for evaluating the suitable habitat Golden Jackal.

Species	Models	AUC	Omission	Sensitivity	Specificity	PCC	Kappa
Golden Jackal	**SVM**	0.788	0.212	0.788	0.788	0.788	0.576
	ANN	0.765	0.242	0.758	0.773	0.765	0.530
	MAXENT	0.782	0.220	0.780	0.784	0.784	0.055
	RF	0.823	0.178	0.822	0.825	0.823	0.646
	MARS	0.777	0.227	0.773	0.781	0.780	0.312
	GBM	0.791	0.212	0.788	0.794	0.791	0.582
	GLM	0.765	0.242	0.758	0.772	0.770	0.291
	Ensemble	0.784	0.219	0.781	0.788	0.786	0.428

Note: A total of seven model algorithms were found to be selected with a threshold of <0.75 AUC score, i.e. Maximum Entropy (MAXENT), Artificial Neural Network (ANN), Generalized linear model (GLM), Support Vector Machine (SVM), Multivariate adaptive regression splines (MARS), Random forests (RF) and Gradient Boosting Machine (GBM).

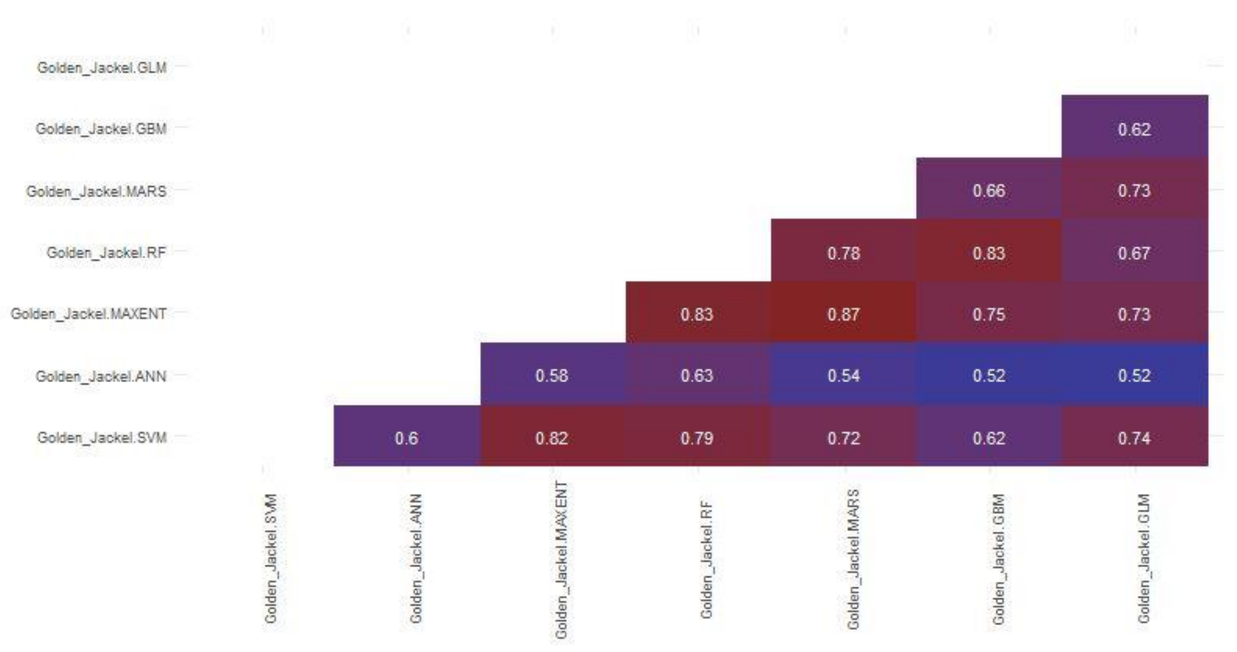


Figure 4.7 - Model algorithm correlation matrix of all individual models to evaluating the habitat suitability of Golden Jackal in the studied area.

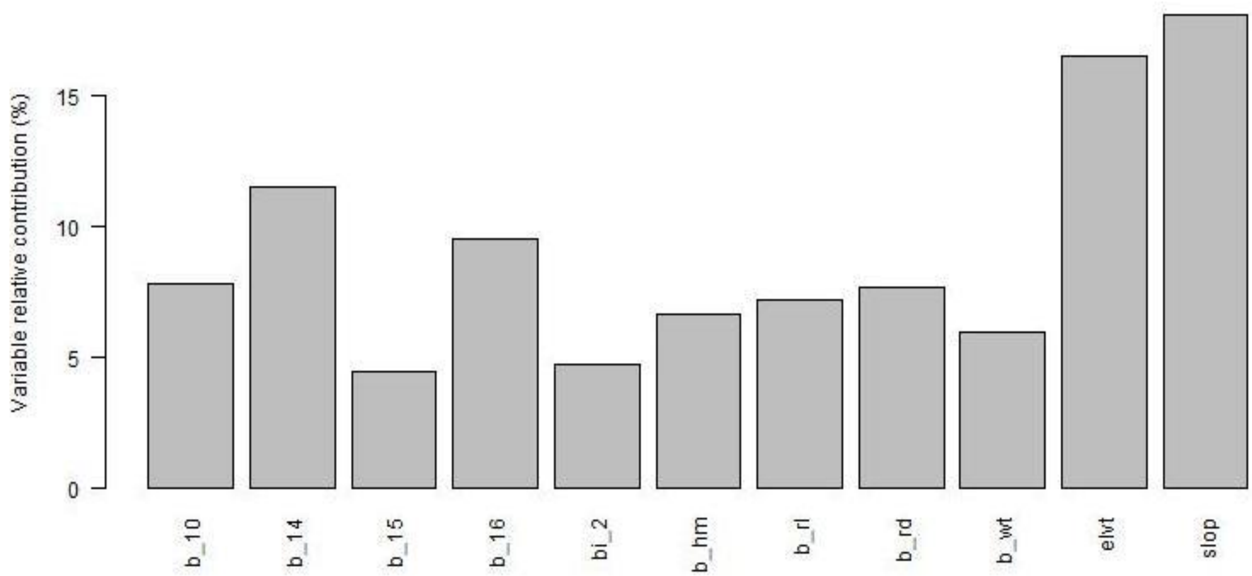


Figure 4.8 - A bar graph showing the Percentage contribution and permutation importance of selected variables to generate the habitat suitability of Golden Jackal.

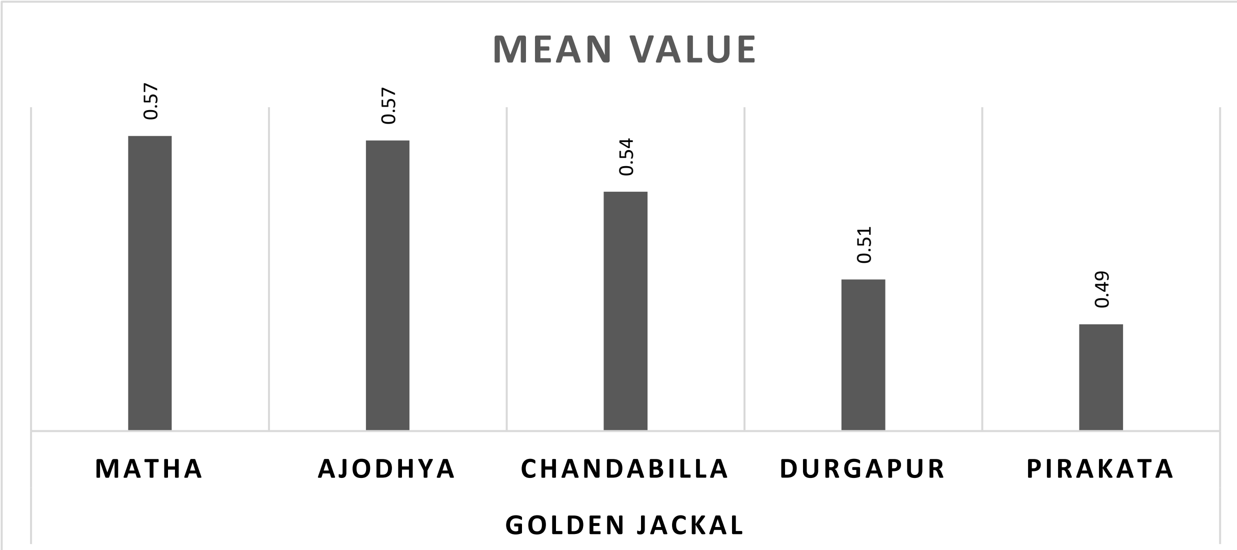


Figure 4.9 - Mean value of ensemble species distribution modelling reveals the high suitable distribution of Golden Jackal among the ranges, only top 5 ranges where high probability of distribution of each species showing below.

Table 4.4 - Showing area suitable in three categories (Low, Medium and High) within different district of southern Bengal for Golden Jackal in Km^2

	Suitability/District	Low	Med	High
Golden Jackal	Purulia	956	4935	2059
	Bankura	1618	4882	2341
	West Midnapore	5566	4100	2199
	Burdwan	6797	1334	821
	Birbhum	3613	1436	766
	Murshidabad	5695	1123	78
	East Midnapore	4070	814	20
	Howrah	1816	0	0
	Nadia	4145	818	10
	Hooghly	3417	573	6

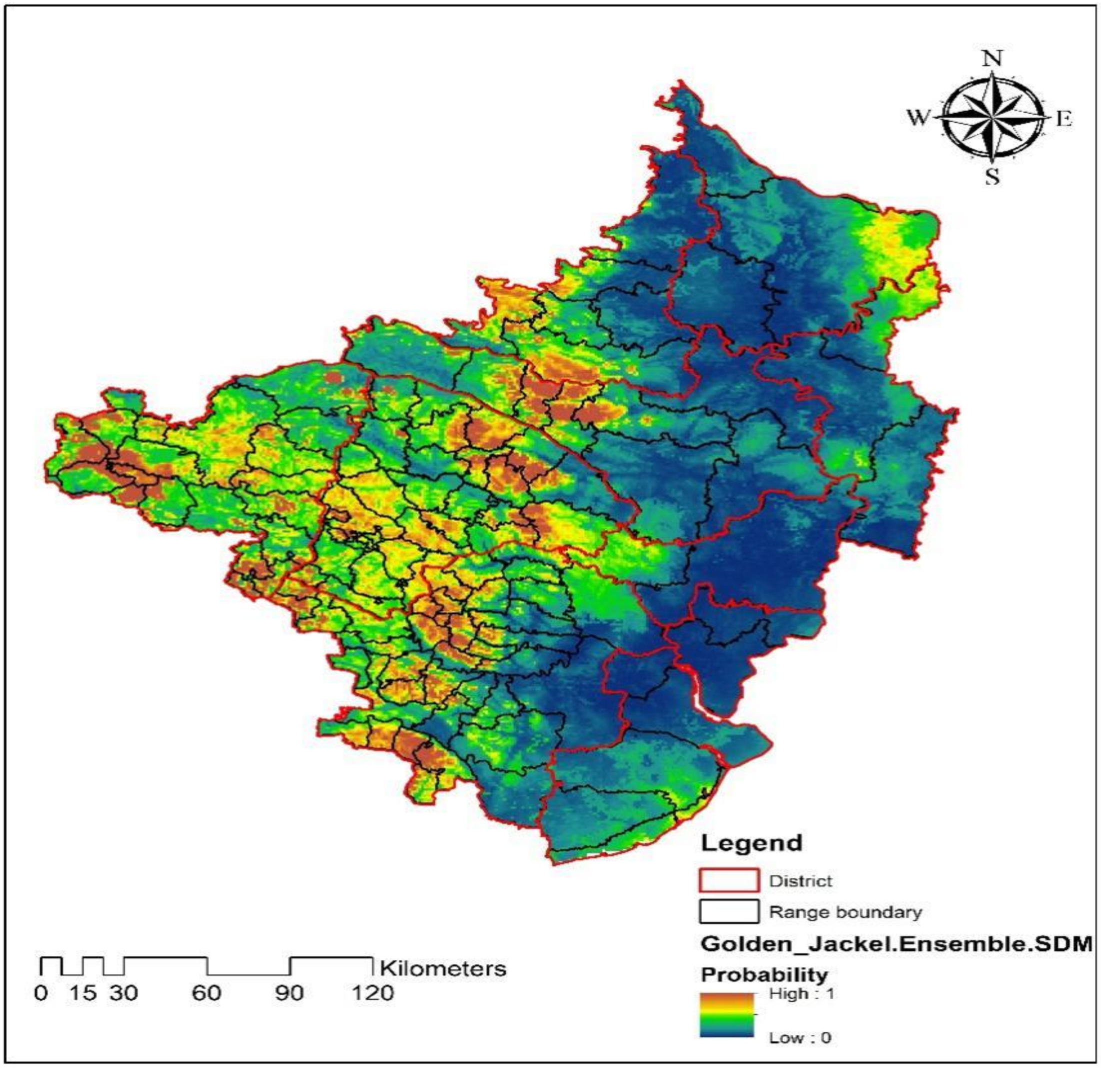


Figure 4.10 - Map Showing the Possible Habitat Suitability of Golden Jackal in present study area of southern region of West Bengal state

4.2.3. Distribution of Wild Boar in Southern Part of West Bengal

The final AUC of the selected models for Wild Boar was found to be ranged from 0.794 (GLM) to 0.865 (MAXENT) (Table 4.5). Apart from the AUC based model evaluation the respective score of other model evaluation metrics i.e. Sensitivity, Specificity, PCC and Kappa also been found to be above the selection threshold (Table 4.5). The model correlation was found to be highest between MARS and MAXENT with a correlation value of 0.91 (Figure 4.11). Among the topographic predictors, percentage contribution of elevation and slope was found to be highest followed by the relative contribution of bioclimatic variables (Mean

Temperature of Warmest Quarter) and (Precipitation of Driest Month) (Figure 4.12). Zonal evaluation of the mean suitability scores suggests, higher suitable regions in Bhulaveda (0.59) and Chandabilla (0.59) followed by Jhilimili (0.57) ranges (Figure 4.13). The highest suitable regions for Wild boar was found to reside West Midnapore having (2,341Km^2) and Bankura (2,532 Km^2). Murshidabad, East Midnapore, Haora, Nadia and Hugli were found to be not suitable for the species (Table 4.6; Figure 4.14).

Table 4.5 - Individual model scores along with final ensemble model for evaluating the suitable habitat of Wild Boar.

Species	Models	AUC	Omission	Sensitivity	Specificity	PCC	Kappa
Wild Boar	**GLM**	0.794	0.209	0.791	0.798	0.798	0.339
	MARS	0.847	0.150	0.850	0.844	0.845	0.441
	GBM	0.797	0.208	0.792	0.802	0.797	0.594
	RF	0.833	0.166	0.834	0.831	0.833	0.666
	MAXENT	0.865	0.134	0.866	0.863	0.863	0.102
	ANN	0.800	0.200	0.800	0.800	0.800	0.600
	SVM	0.828	0.172	0.828	0.828	0.828	0.656
	Ensemble	0.823	0.177	0.823	0.824	0.823	0.485

Note: A total of seven model algorithms were found to be selected with a threshold of <0.75 AUC score, i.e. Maximum Entropy (MAXENT), Artificial Neural Network (ANN), Generalized linear model (GLM), Support Vector Machine (SVM), Multivariate adaptive regression splines (MARS), Random forests (RF) and Gradient Boosting Machine (GBM).

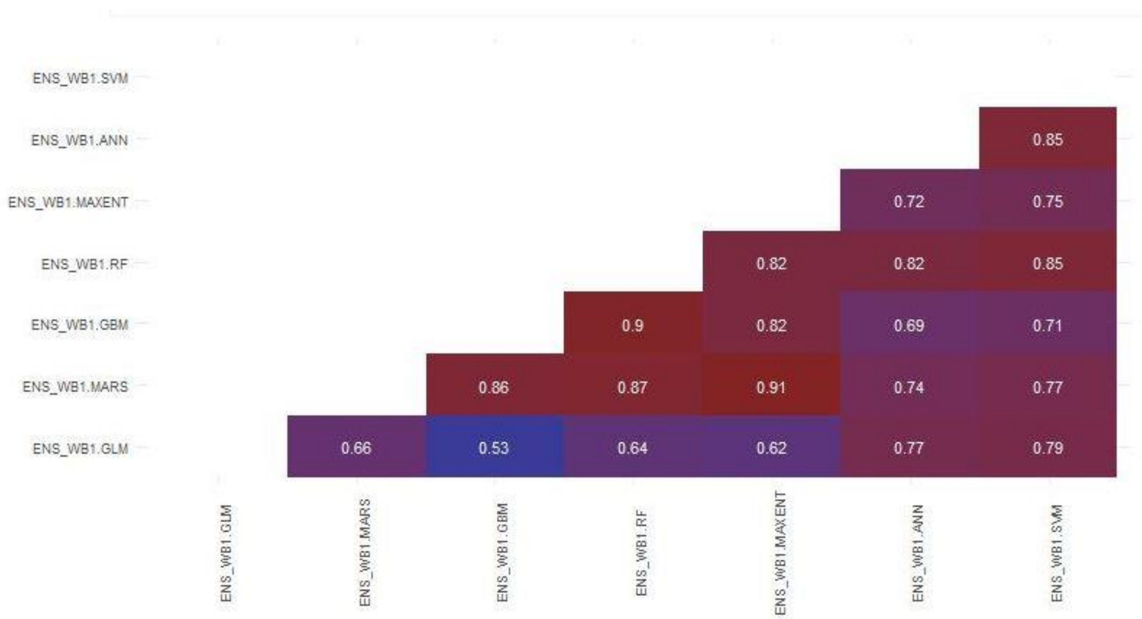


Figure 4.11 - Model algorithm correlation matrix of all individual models to evaluating the habitat suitability of Wild boar.

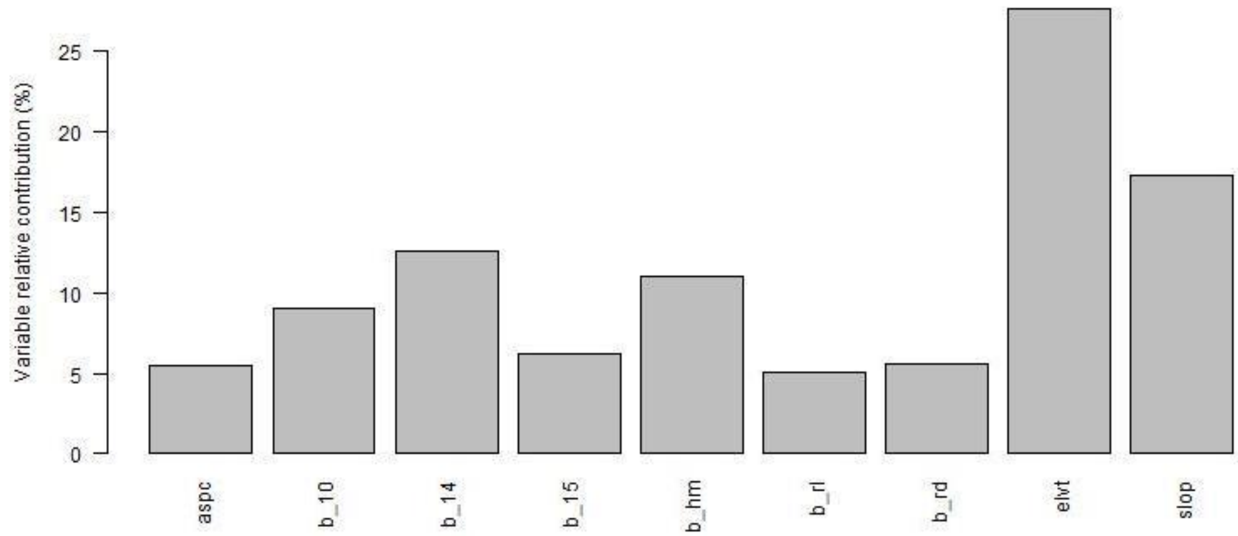


Figure 4.12 -A bar graph showing the Percentage contribution and permutation importance of selected variables to generate the habitat suitability of Wild Boar.

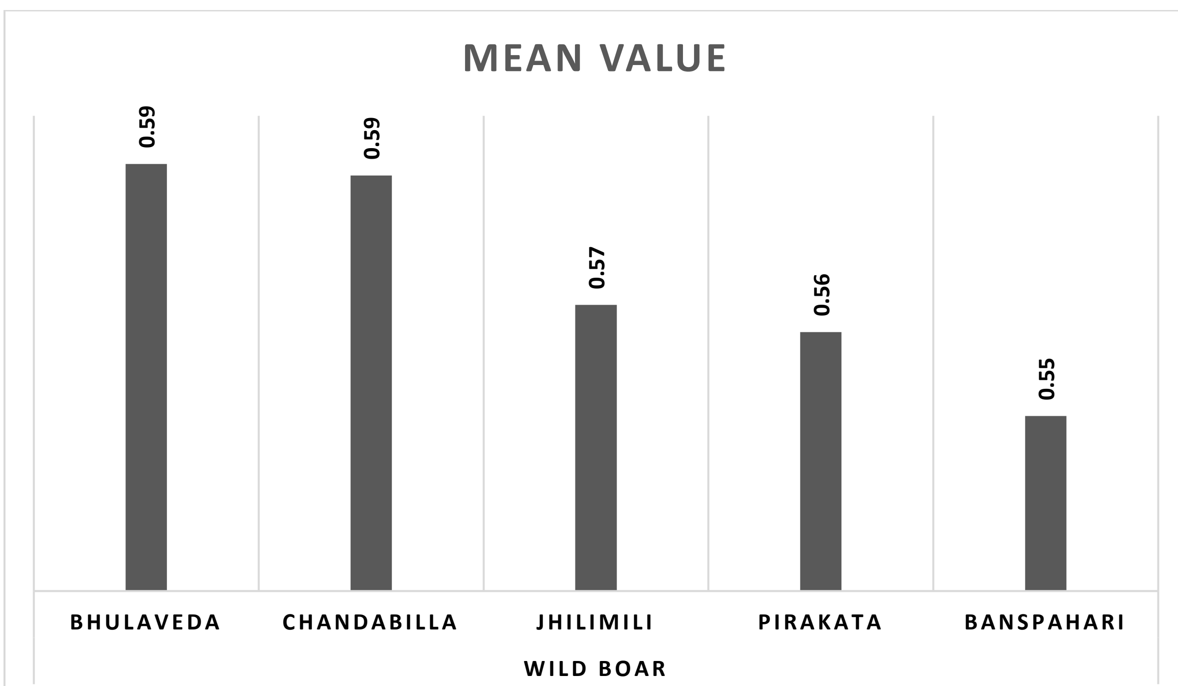


Figure 4.13 - Mean value of ensemble species distribution modeling reveals the high suitable distribution for Wild Boar among the ranges, only top 5 ranges where high probability of distribution of each species showing below.

Table 4.6 - Showing area suitable in three categories (Low, Medium and High) within different district of southern Bengal for Wild Boar in Km^2

	Suitibility/District	Low	Med	High
Wild Boar	Purulia	2787	4029	1134
	Bankura	1911	4398	2532
	West Midnapore	5557	3489	2819
	Burdwan	6618	1486	848
	Birbhum	3323	1422	1070
	Murshidabad	6896	0	0
	East Midnapore	4872	32	0
	Howrah	1815	1	0
	Nadia	4971	2	0
	Hooghly	3991	5	0

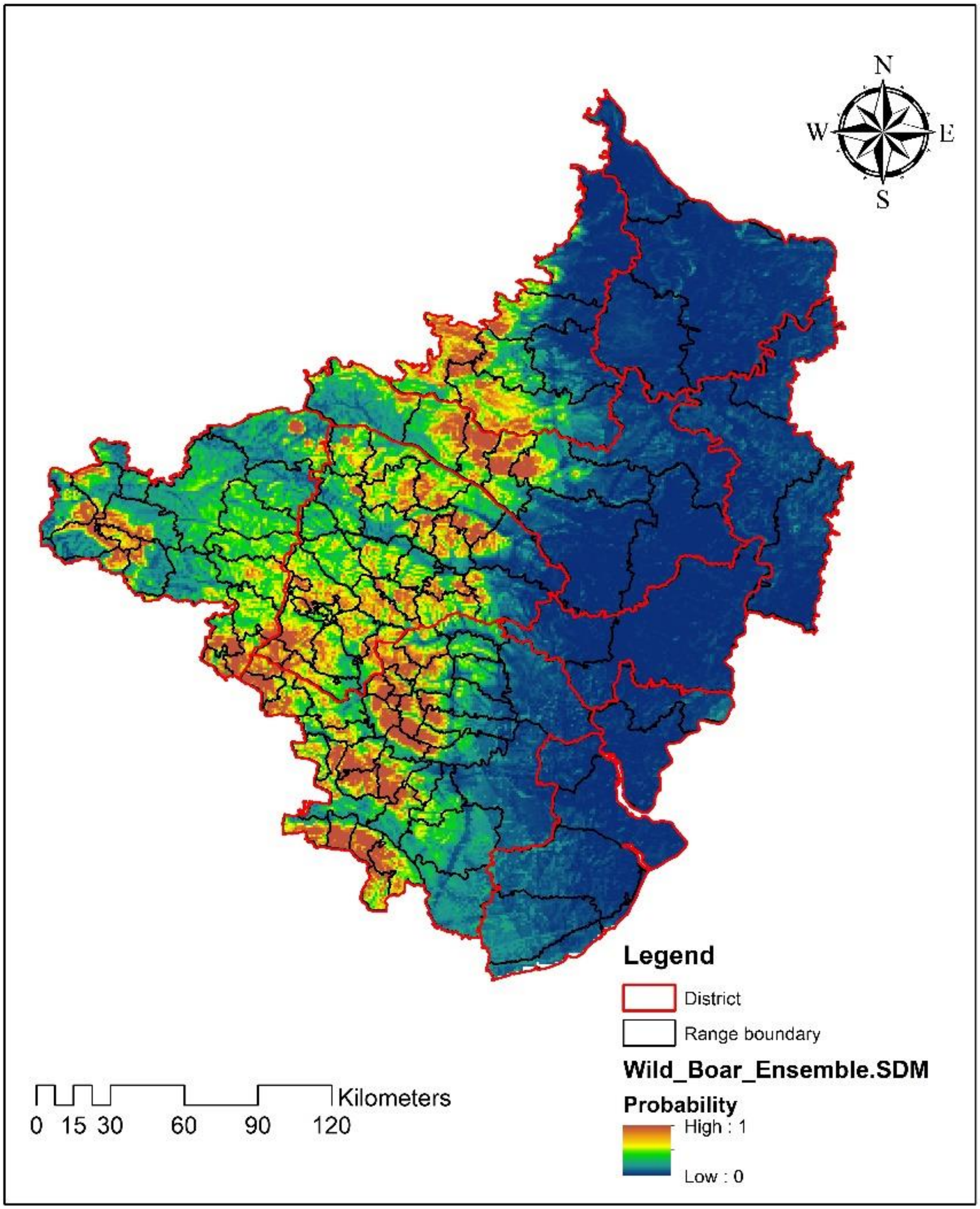


Figure 4.14 - Map Showing the Possible Habitat Suitability of Wild Boar in present study area of southern region of West Bengal state.

4.2.4. Distribution of Striped Hyena in Southern Part of West Bengal

The final AUC of the selected models for Striped Hyena was found to be ranged from 0.860 (SVM) to 0.930 (ANN) (Table 4.7). Apart from the AUC based model evaluation the respective score of other model evaluation metrics i.e. Sensitivity, Specificity, PCC and Kappa also been found to be above the selection threshold (Table 4.7). The model correlation was found to be highest between SVM and MAXENT with a correlation value of 0.9 (Figure 4.15). Among the topographic predictors, percentage contribution of elevation and slope was found to be highest followed by the relative contribution of bioclimatic variables (Precipitation Seasonality (Coefficient of Variation)) was found to be highest (Figure 4.16). Among the anthropogenic predictors the euclidian distance from the railway lines was also found to have significantly contributed in demarcating the spatial distribution of Hyena. Zonal evaluation of the mean suitability scores suggests, higher suitable regions in Ajodhya (0.76) followed by Matha (0.69) ranges (Figure 4.17). The highest suitable regions for Wild boar was found to reside in Puruliya district having 3,022 Km^2 of high suitable area followed by Bankura with only 597 Km^2 area. However, most of the other districts are found to be not suitable for the species (Table 4.8; Figure 4.18).

Table 4.7 - Individual model scores along with final ensemble model for evaluating the suitable habitat of Striped Hyena.

Species	Models	AUC	Omission	Sensitivity	Specificity	PCC	Kappa
Striped Hyena	**SVM**	0.860	0.140	0.860	0.860	0.860	0.720
	ANN	0.930	0.060	0.940	0.920	0.930	0.860
	MAXENT	0.909	0.080	0.920	0.898	0.898	0.041
	RF	0.910	0.080	0.920	0.900	0.910	0.820
	GBM	0.910	0.040	0.960	0.860	0.910	0.820
	MARS	0.859	0.143	0.857	0.860	0.860	0.150
	GLM	0.869	0.100	0.900	0.839	0.840	0.175
	Ensemble	0.892	0.092	0.908	0.877	0.887	0.512

Note: A total of seven model algorithms were found to be selected with a threshold of <0.75 AUC score, i.e. Maximum Entropy (MAXENT), Artificial Neural Network (ANN), Generalized linear model (GLM), Support Vector Machine (SVM), Multivariate adaptive regression splines (MARS), Random forests (RF) and Gradient Boosting Machine (GBM).

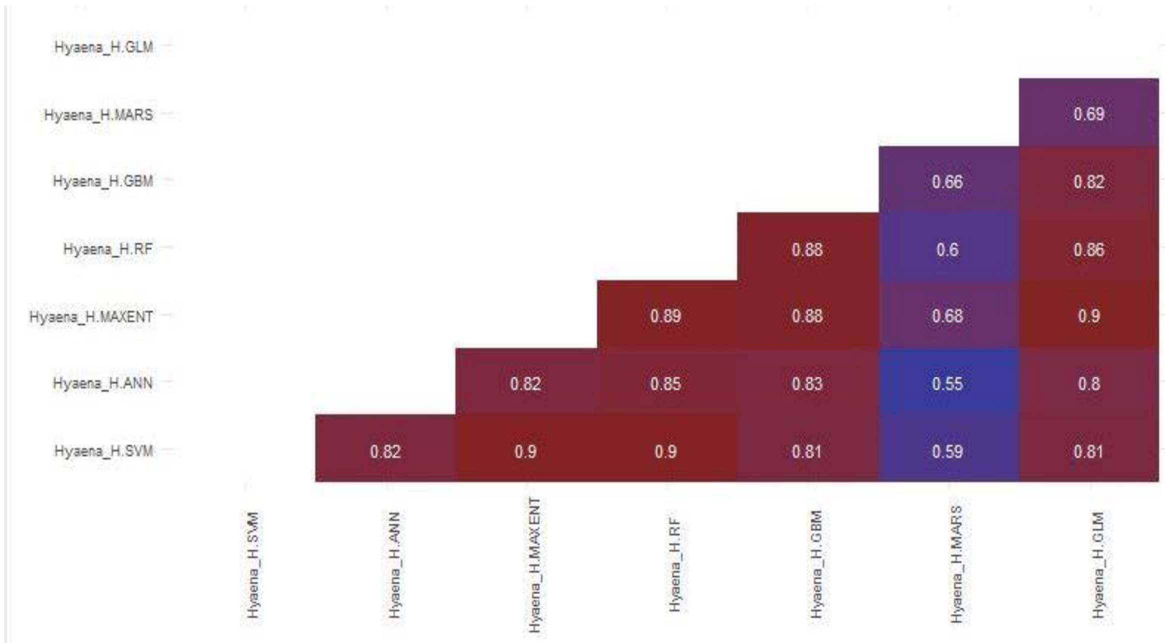


Figure 4.15 - Model algorithm correlation matrix of all individual models to evaluating the habitat suitability of Hyaena.

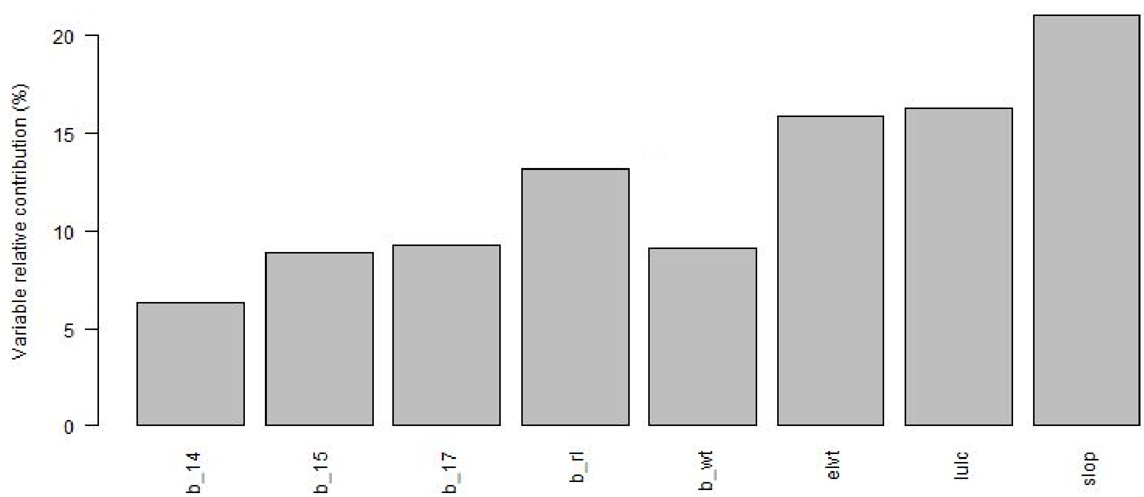


Figure 4.16 - A bar graph showing the Percentage contribution and permutation importance of selected variables to generate the habitat suitability of Striped Hyena.

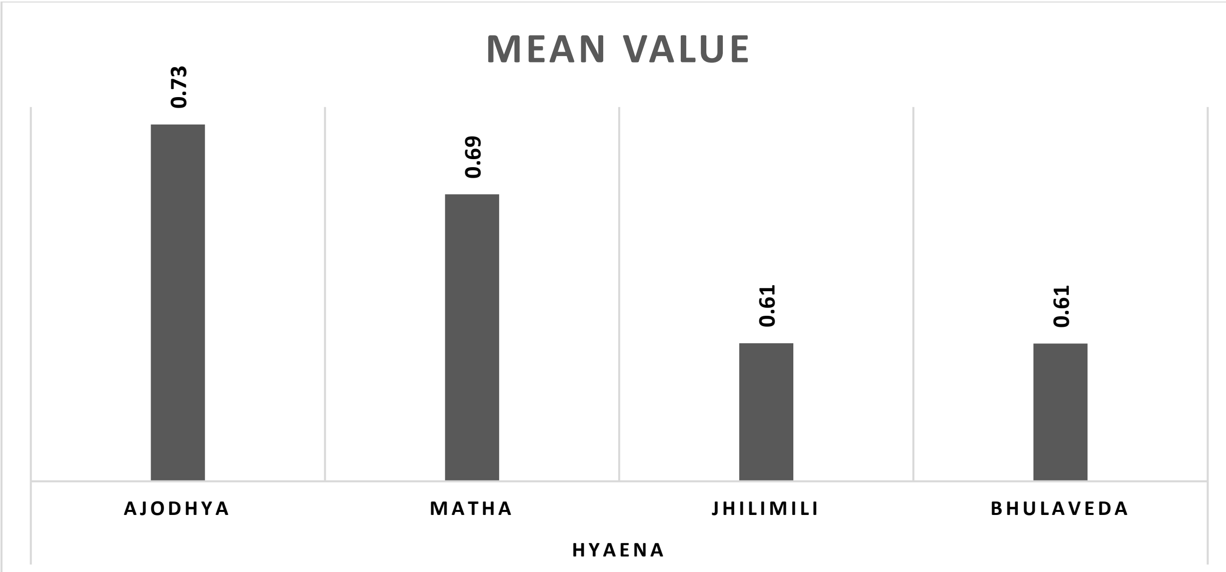


Figure 4.17 - Mean value of ensemble species distribution modeling reveals the high suitable distribution for Hyaena among the ranges.

Table 4.8 - Showing area suitable in three categories (Low, Medium and High) within different district of southern Bengal for Hyaena in Km^2

	Suitability/District	Low	Med	High
Hyaena	Purulia	440	4487	3022
	Bankura	4971	3273	597
	West Midnapore	10713	823	329
	Burdwan	8234	717	1
	Birbhum	5721	94	0
	Murshidabad	6865	31	0
	East Midnapore	4929	8	0
	Howrah	1816	0	0
	Nadia	4973	0	0
	Hooghly	3996	0	0

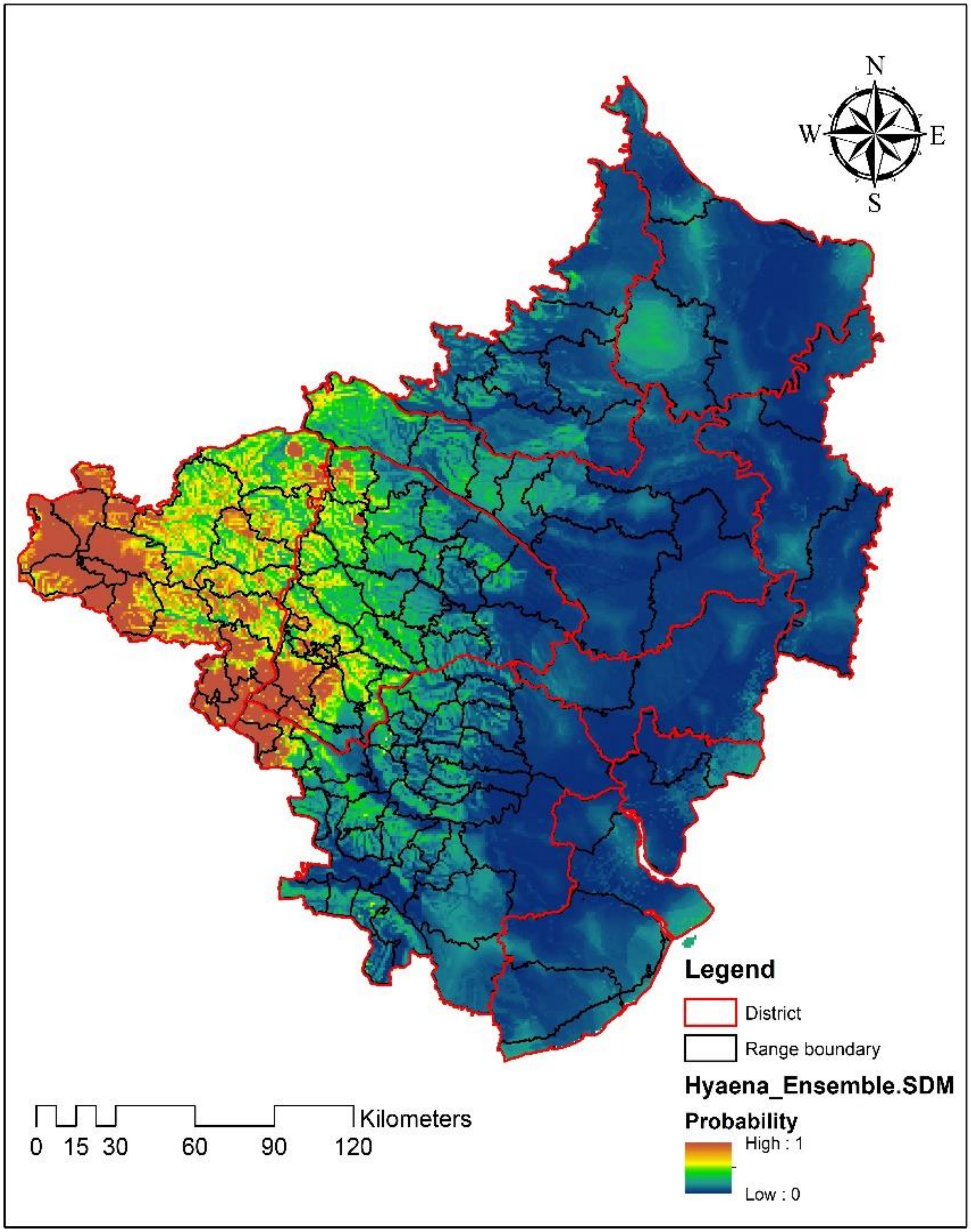


Figure 4.18 - Map Showing the Possible Habitat Suitability of Striped Hyena in present study area of southern region of West Bengal state.

4.2.5. Distribution of Leopard cat in Southern Part of West Bengal

After a effort on about 200 transects, camera trapping and 1770 questionnaire surveys in the entire study landscape we could not detect any single evidence indicating the presence of Leopard Cat in the region. We did not encounter any indirect sign (scat, pug mark) and neither we got any camera capture of the species from all study sites. This suggests the Leopard cat has locally got extirpated from the region.

4.3. Abundance estimates of study species

4.3.1. Indian grey wolf (*Canis lupus pallipes*)

Out of the total ten districts studied, the encounter rate (no. of signs/km) was highest in Purulia (0.25±0.06) and it was lowest in Birbhum (0.19±0.05) (Figure 4.19).While the comparative analysis of the ER among the forest divisions of the districts indicates that the ER was highest in Kangsabati South forest division (0.34±0.12) of Purulia district followed by Kharagpur forest division (0.32±0.08), Burdwan (0.29±0.03), Jhargram (0.28±0.07), Medinipur (0.22±0.04), Purulia (0.22±0.08), Bankura North (0.22±0.06), Bankura South (0.19±0.06), Birbhum (0.19±0.05), Kangsabati North (0.16±0.09), Rupnarayan (0.09±0.06) and Durgapur forest division (0.03±0.03) (Figure 4.20).

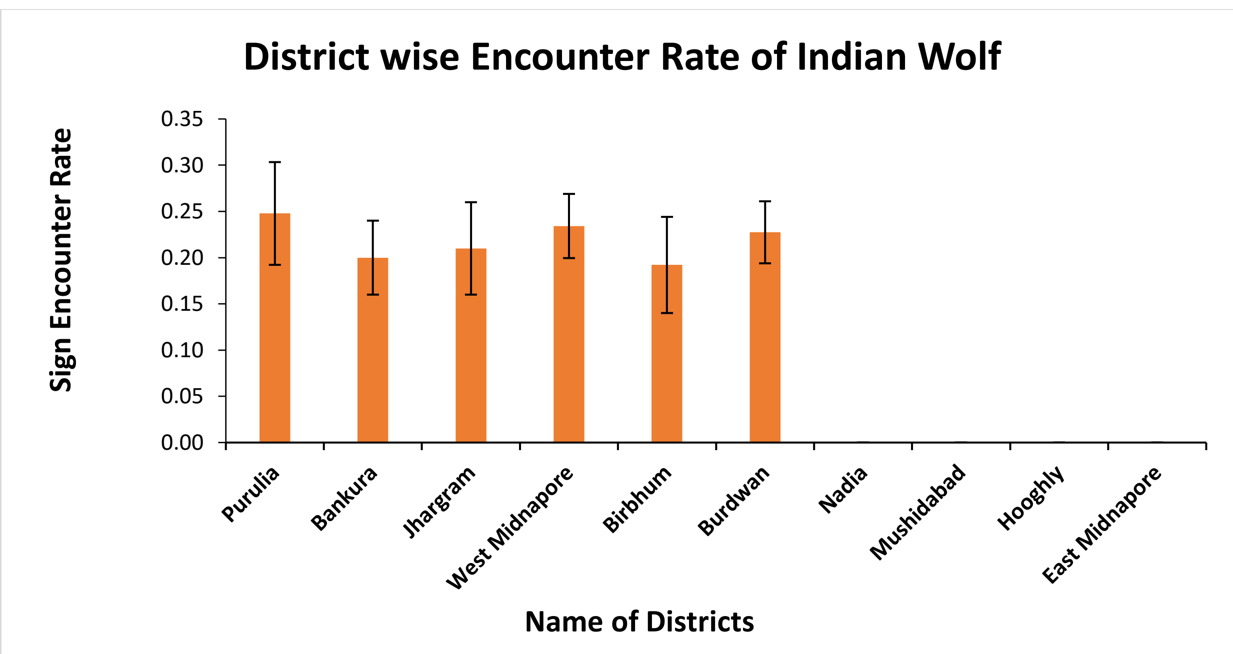


Figure 4.19 - District wise sign encounter rate of Indian grey wolf

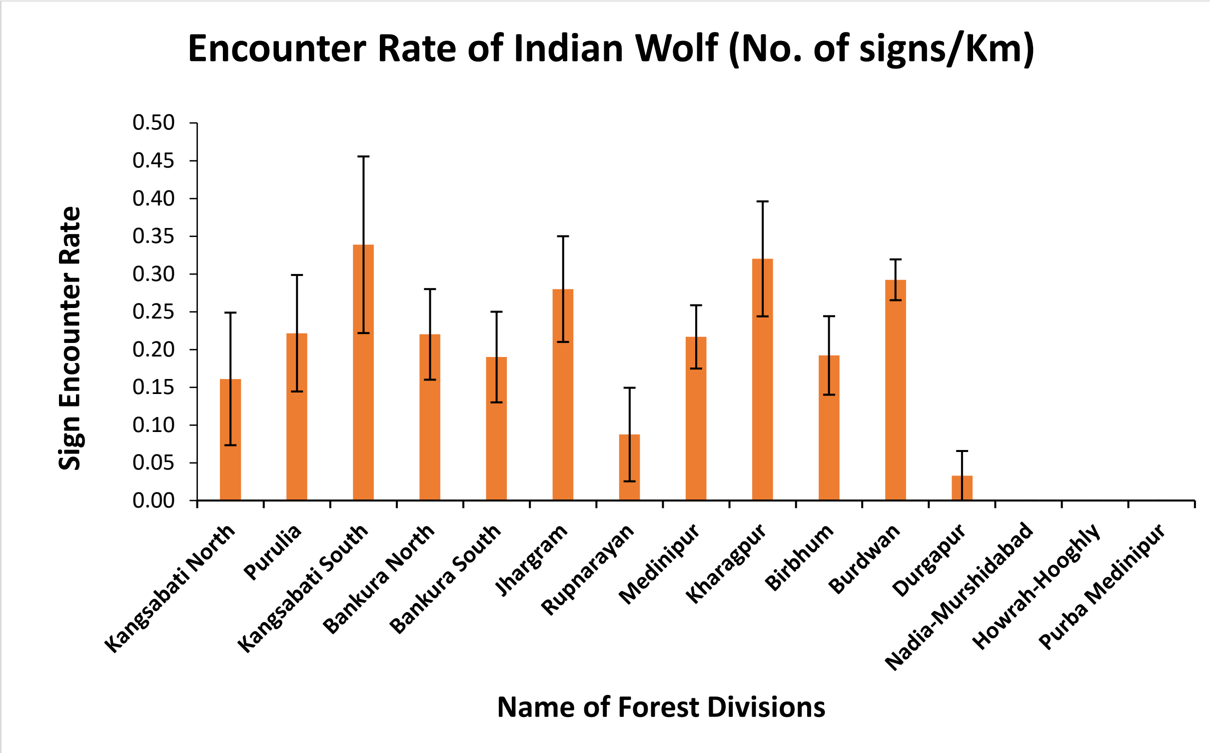


Figure 4.20 - Sign encounter rate of Indian grey wolf in all forest divisions

4.3.2. Golden Jackal (*Canis aureus*)

Among the three districts surveyed, the encounter rate (no. of signs/km) was highest in Hoogly (0.87±0.08) and it was lowest in Jhargram (0.13±0.06) (Figure 4.21).Whereas in all the forest divisions that were surveyed, the ER (no. of signs/km) of Golden Jackal (*Canis aureus*) was highest in Howrah-Hoogly forest division (0.87±0.08) followed by Nadia-Murshidabad (0.81±0.16), Bankura north (0.63±0.12), Purba Medinipur (0.61±0.08), Bankura South (0.42±0.10), Kangsabati North (0.42±0.12), Kangsabati South (0.36±0.08), Purulia (0.33±0.06), Medinipur (0.30±0.06), Burdwan (0.26±0.06), Rupnarayan (0.19±0.10), Kharagpur (0.19±0.05), Birbhum (0.18±0.05), Jhargram (0.13±0.06) and Durgapur (0.06±0.04) forest division (Figure 4.22).

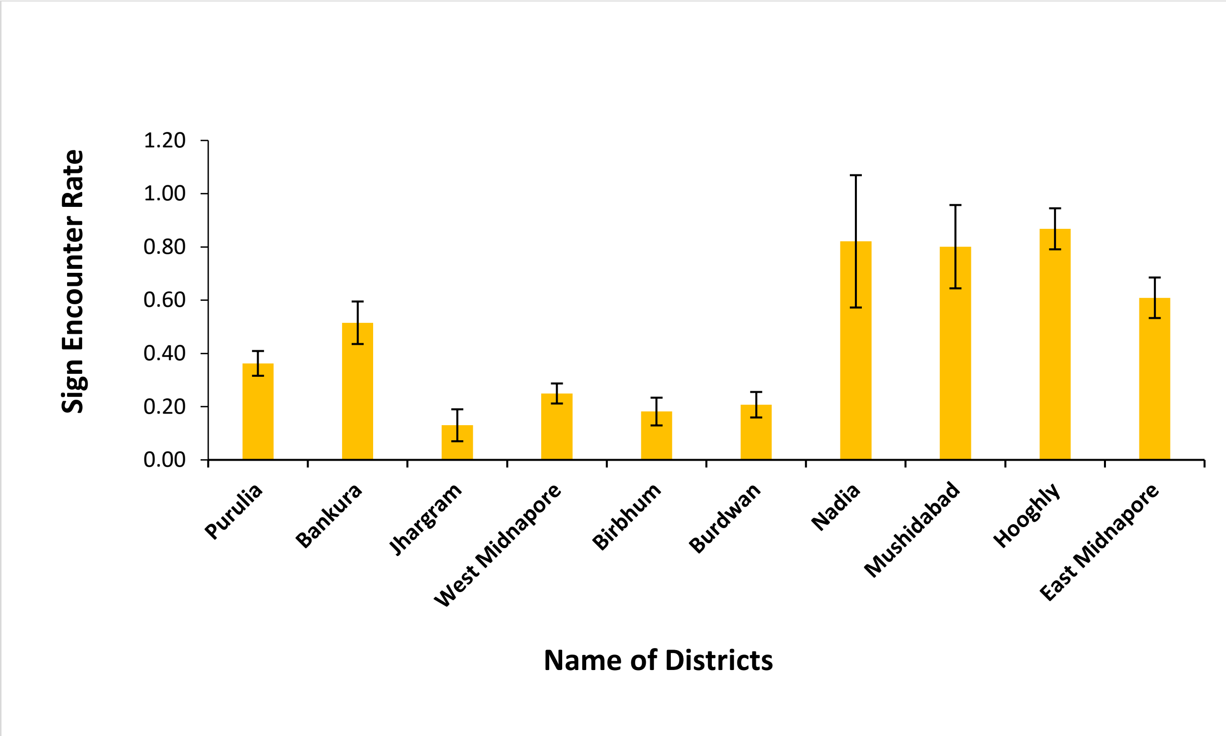


Figure 4.21 - District wise sign encounter rate of Golden Jackal

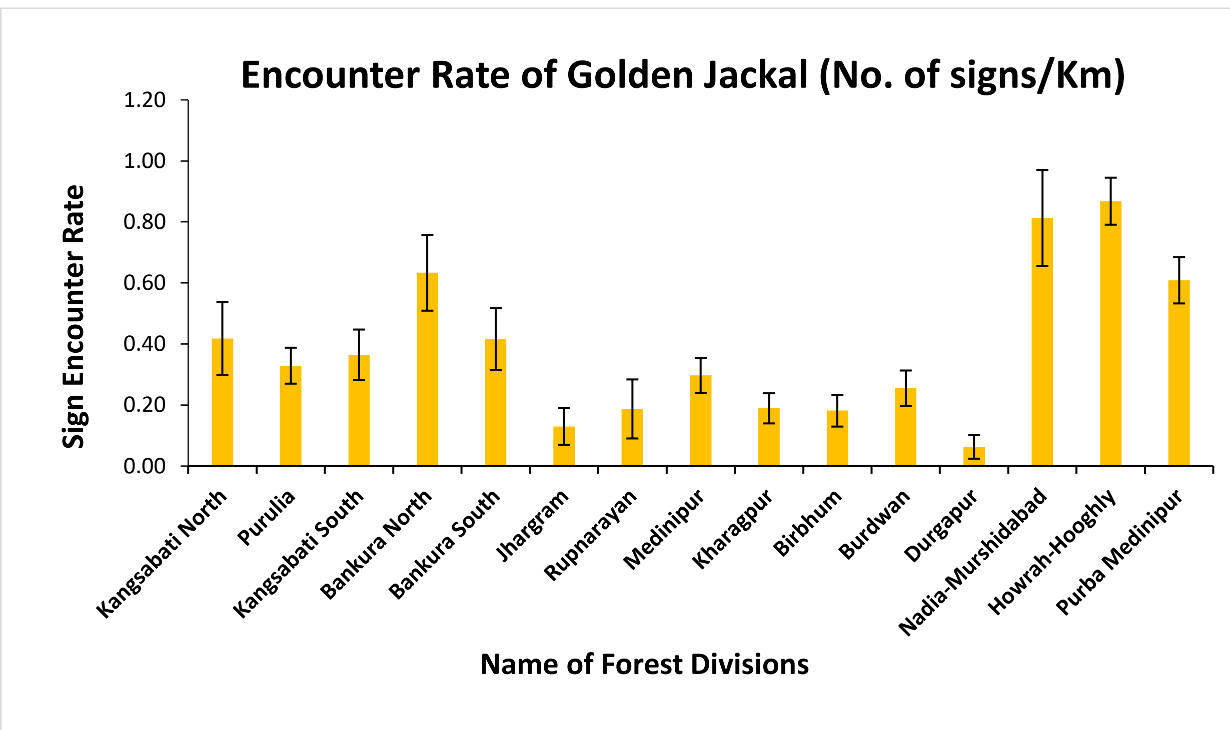


Figure 4.22 - Sign encounter rate of Golden Jackal in all forest divisions

4.3.3. Wild Boar (*Sus scrofa*)

Based on the district, the encounter rate (no. of signs/km) of Wild Boar was highest in Bankura (0.45±0.07) and it was lowest in Nadia district (0.04±0.04) (Figure 4.23). Based on the forest divisions the ER of Wild Boar (*Sus scrofa*) was highest in Bankura North forest division (0.55± 0.11) followed by Medinipur (0.49±0.04), Rupnarayan (0.39±0.15), Bankura South (0.37± 0.08), Kangsabati South (0.36±0.13), Burdwan (0.30±0.04), Purulia (0.28±0.07), Jhargram (0.28± 0.06), Kangsabati North (0.27±0.11), Durgapur (0.26±0.07), Birbhum (0.23±0.08), Kharagpur (0.21±0.05) and Nadia-Murshidabad forest division (0.02±0.02).(Figure 4.24).

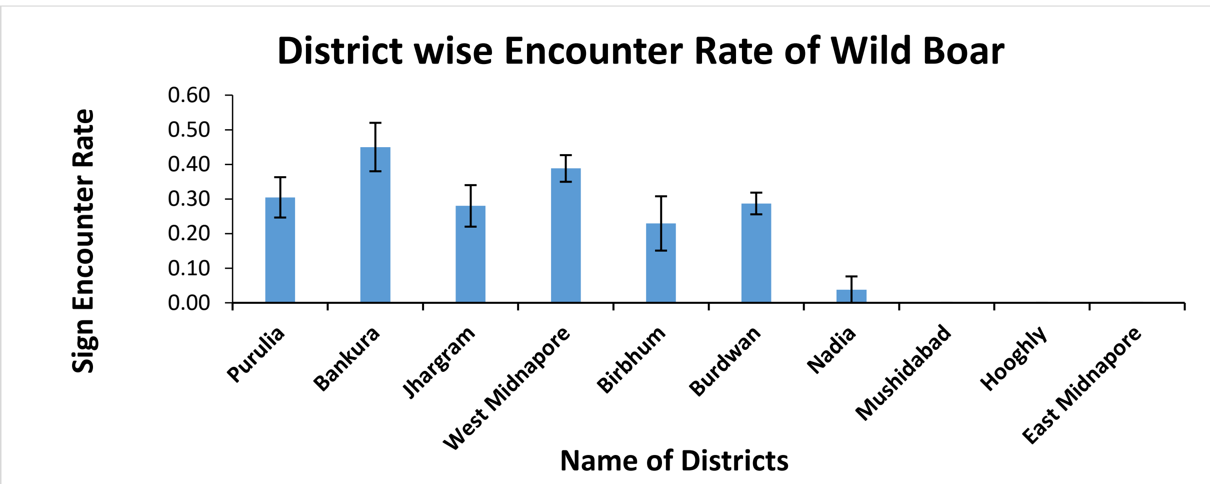


Figure 4.23 - District wise sign encounter rate of Wild Boar

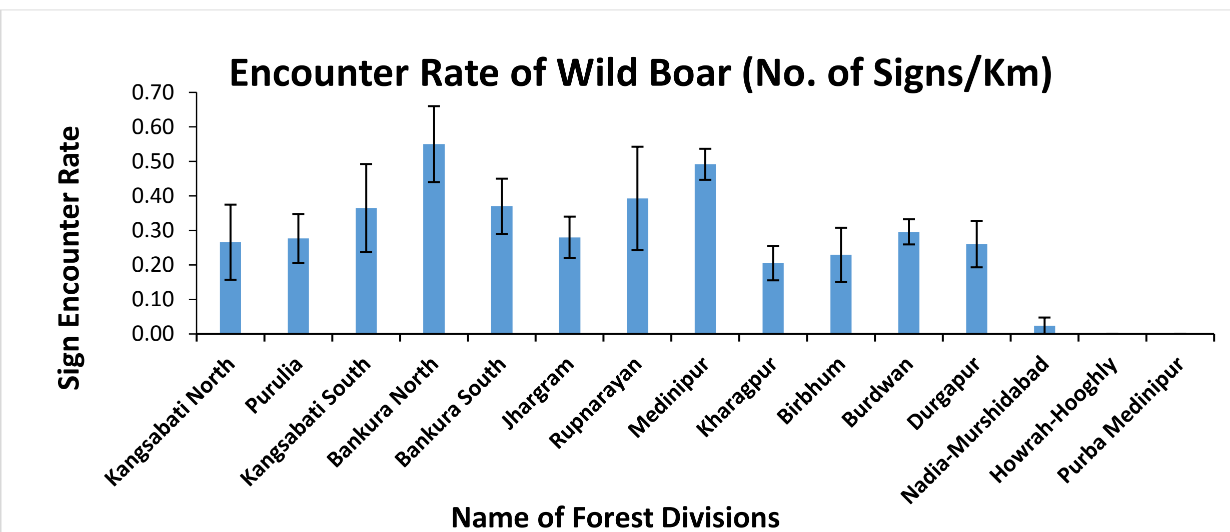


Figure 4.24 -Sign encounter rate of Wild Boarin all forest divisions

4.3.4. Striped Hyena (*Hyaena hyaena*)

Among the ten districts that were surveyed, the highest encounter rate (no. of signs/km) of Striped Hyena was observed in Purulia district and lowest in Bakura district (Figure 4.25). Whereas among the fifteen forest divisions that were surveyed, the highest sign encounter rate of Striped Hyena (*Hyaena hyaena*) was observed in Purulia forest division (0.11±0.04) followed by Bankura South (0.03±0.03), Bankura North (0.02± 0.02), Kangsabati South (0.01±0.01), and Kangsabati North forest division (0.01±0.01). (Figure 4.26).

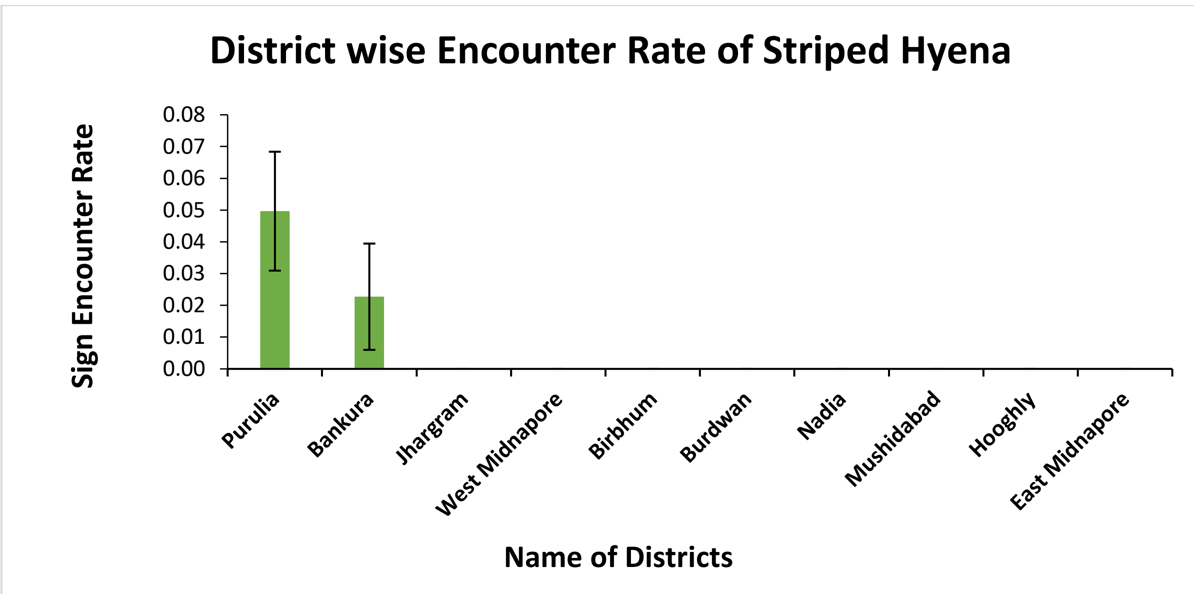


Figure 4.25 - District wise sign encounter rate of Striped Hyena

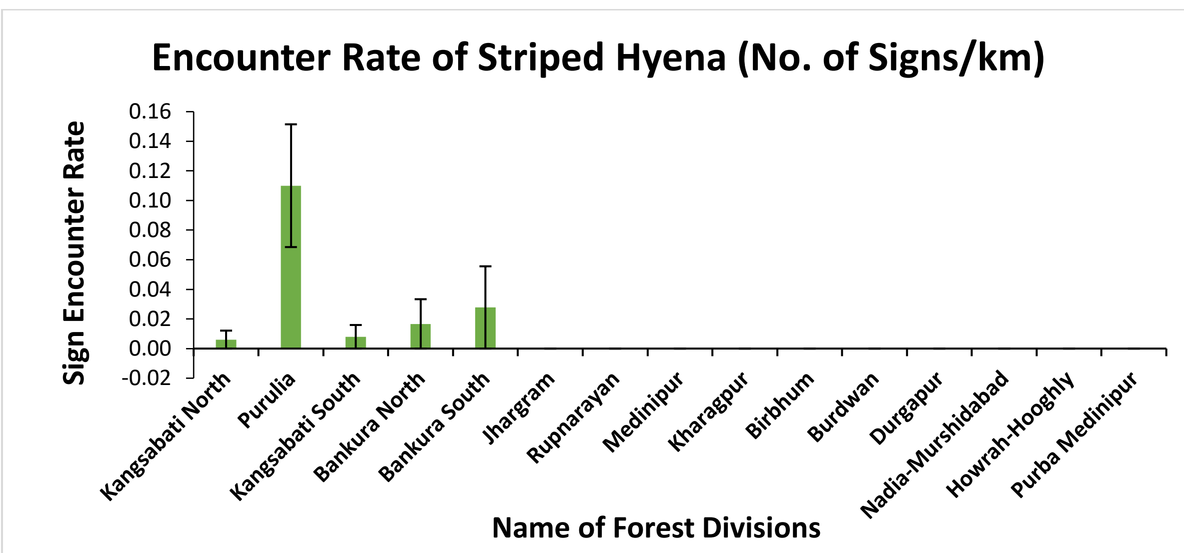


Figure 4.26 - Sign encounter rate of Striped Hyena in all forest divisions

4.4. Photo Capture Rate of the study species in the landscpape

In three districts of South West Bengal, Purulia, Bankura and Jhargram, camera traps were installed into 4×4 Km^2 grids. Based on the species distribution modelling an intensive study area was identified, i.e. one range of Kangsabati North forest division, six ranges of Purulia forest division, four ranges of Kangsabati South forest division, three ranges of Bankura North forest division, six ranges of Bankura South forest division and three ranges of Jhargram forest division were covered for the intensive camera trapping. All the traps were working for 24 hours day-night basis and the 24-hour period was considered as one trap night. For each site capture histories were recorded. All the cameras were considered as functional even if the position of them were changed due to any human activity or animal movement. For the cameras, which stopped functioning due to technical deformities, the non-functional days were counted after the last hour of capture. The photo capture rate of individual species was calculated as per species captured at the interval of 1 hour. In a total effort of 486 camera trap nights, the number of images of captured study species were 20 for Striped Hyena, 7 for Indian grey wolf, 24 for Wild Boar and 56 for Golden Jackal we did not got any camera trap capture of leopard cat during the study duration of two years in the entire study landscape (Table 4.9).

Table 4.9 - Overall Capture rates of the study species in South Bengal

	Kangsabati North	Purulia	Kangsabati South	Bankura North	Bankura South	Jhargram
Camera trap nights	61	254	58	26	50	37
Total Camera traps	15	50	14	5	9	7
Striped Hyena	0.339 ±0.137	00	00	00	00	00
Indian grey wolf	0.012 ±0.011	0.002 ±0.001	00	00	0.083 ±0.066	0.021 ±0.020
Wild Boar	0.101 ±0.014	0.047 ±0.016	00	0.227± 0.112	0.019 ±0.008	00
Golden Jackal	0.023 ±0.003	0.177 ±0.052	00	0.240 ±0.098	0.145 ±0.061	00
Leopard Cat	00	00	00	00	00	00

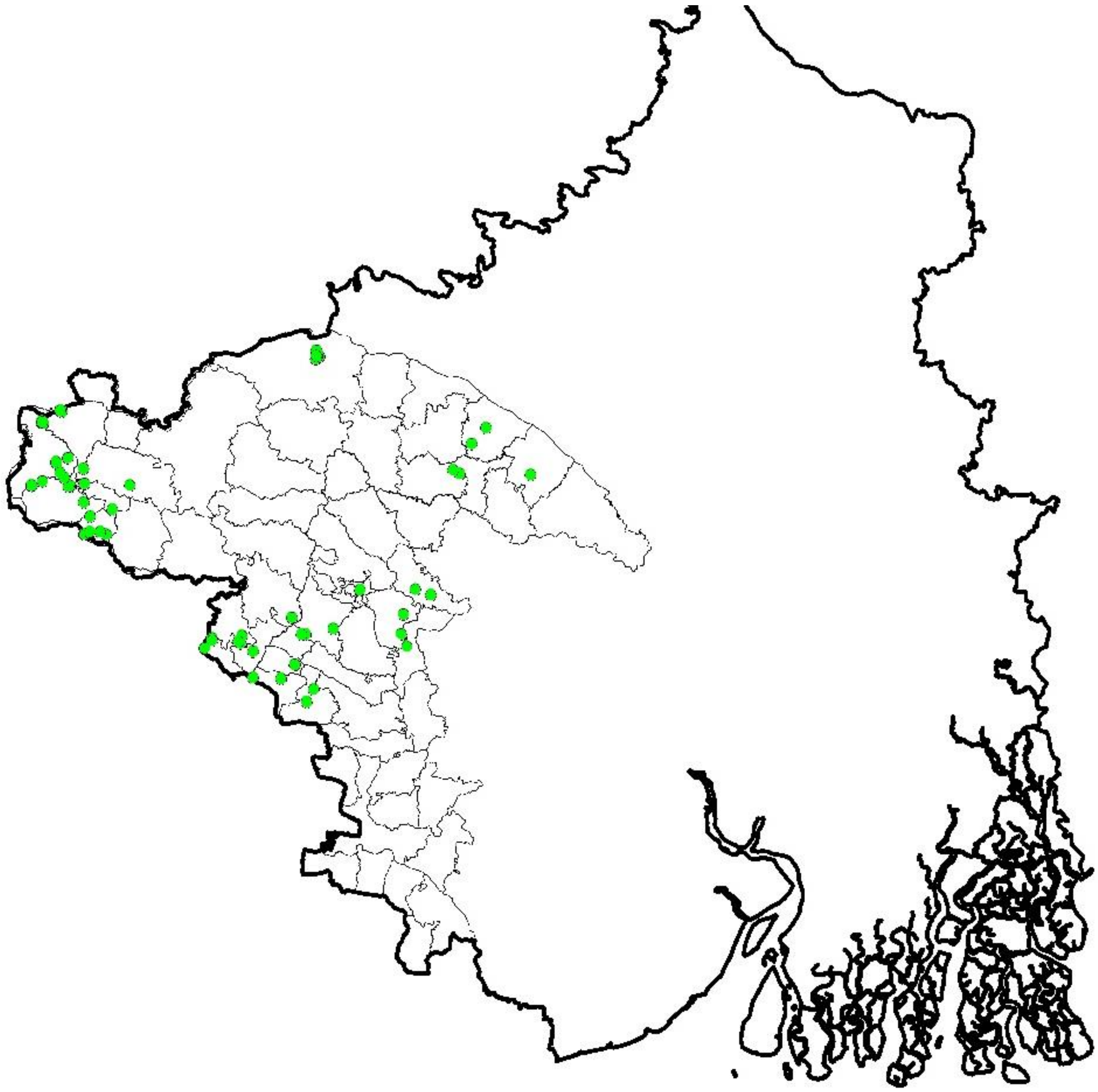


Figure 4.27- Map showing locations of all the Camera traps in different forest ranges of the study landscape.

Among the six forest divisions that were surveyed using camera traps, the highest capture rate (CR) (no. of photos/total trap nights) of Striped Hyena was observed in Kangsabati North forest division (0.338±0.137) (Figure 29; Table 14). For the Indian grey wolf photo capture rate was highest in Bankura South forest division (0.083±0.066) followed by Jhargram forest division (0.021±0.020), Kangsabati North forest division (0.012±0.011) and Purulia forest division (0.002±0.001). In case of Wild Boar (Sus scrofa) CR was highest in Bankura North forest division (0.227±0.112), followed by Kangsabati North forest division (0.101±0.014), Purulia forest division (0.047±0.016), Bankura South forest division (0.019±0.008) (FigureXX). Whereas of Golden Jackal (*Canis aureus*) the CR was highest in Bankura North forest division (0.240 ±0.098) followed by Purulia forest division (0.177±0.052), Bankura South forest division (0.145±0.061) and Kangsabati North forest division (0.023± 0.003) (Figure 4.27).

4.5. Population and landscape genetics of the selected study species

In order to understand the population density of the species we have adopted non-invasive DNA based sampling. However, out of the total five studied species we could able to generate population genetics data for only three species (Indian grey wolf, Golden Jackal and Wild boar). We found a total of 22 individuals of Indian grey wolf, 40 individuals of wild boar and 41 individuals of Golden Jackal and provide genetic diversity and population viability estimates based on the samples analyzed.

4.5.1. Assessment of genetic diversity indices and individual identification of Indian grey wolf

Mitochondrial marker

DNA extraction and PCR amplification success rate

Of the 193 sample collected and presumed to be Indian grey wolf origin, 17 samples did not yield DNA. This was either due to the age of the sample collected or because of the potential degradation of the samples before processing to provide detectable DNA on agarose gel. Of the remaining 175 samples, we got positive PCR amplification from 143 samples (81%) and 137 samples yielded good quality sequences d-loop that we processed for subsequent analysis. We identified species based on the similarity search using BLAST tool in the NCBI. All the generated sequences showed 98-100% sequences similarity with Indian grey wolf (*Canis lupus*).

Microsatellite data analysis

Genotyping success rate

Out of 193 faecal samples, 137 samples were of Indian grey wolf origin. Out of 137 confirmed Indian grey wolf samples, 67 samples did not amplify for majority of the loci, probably because of degraded sample or the potential inhibitors and genotypes of 12 samples were mixed and not easy to score. Thus, we processed 58 samples for fragment analysis with 09 microsatellite loci. We repeated genotyping thrice and only two samples did not produce consensus genotypes, and therefore excluded from the further analysis. In total, we generated 56 genotypes with 09 loci. Nine loci that showed amplification success ≥74% were used in detailed population genetic analysis.

Selection of the microsatellites for individual identification

We utilized three parameters for limiting microsatellites for individual identification, i.e. (1) short amplicon size (assuming shorter amplicon size will yield relatively high amplification success with potentially degraded DNA samples); (2) having no or least genotyping errors and missing values (to avoid overestimation of the individuals as biased count of individuals bound to obtain in the presence of genotyping errors and missing values and (3) a high PID (sibs) value (indicative of high discrimination power of a locus). Following the above criteria, we opted a panel of seven loci from 09 loci genotype data (Table 4.10, Fig. 4.28), having the cumulative probability of identity assuming all individuals were siblings (PID sibs) was 1.2 x 10-3 (1.2 mismatches in 1000 genotypes). Locus wise probability of matching genotypes among unrelated individuals (PID) and siblings (PID sibs) varied from 0.027-0.22 to 0.32-0.52, respectively. Finally, after using the select panel of seven loci we identified 22 unique individuals out of 56 genotypes. Thus we analyzed 22 unique genotypes data of 09 microsatellite loci for the further population genetic analysis (Table 4.11).

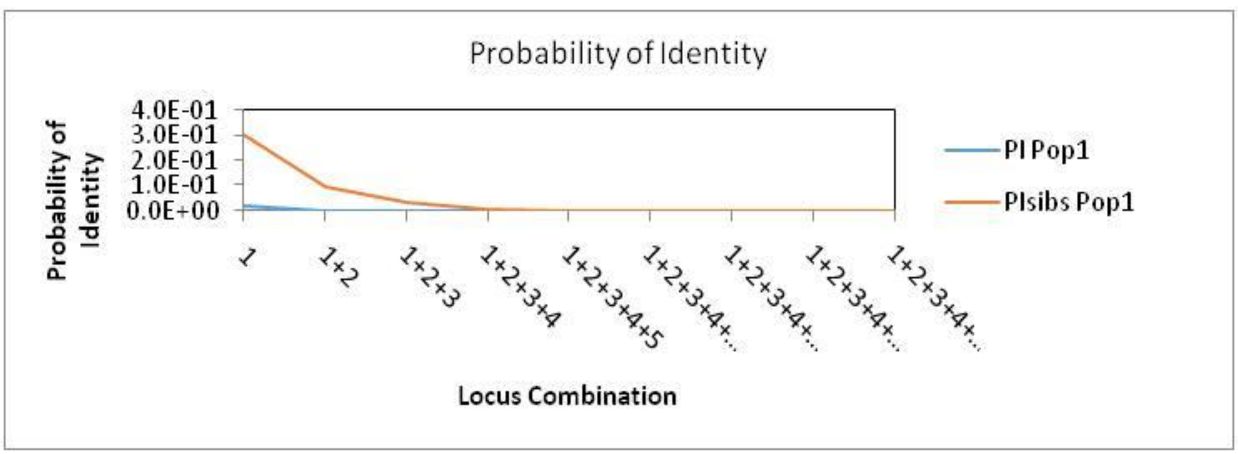


Figure 4.28 - Select panel of seven polymorphic microsatellite loci used for individual identification of Indian grey wolf

Genetic polymorphism

The wild caught samples showed high genetic variation with a mean of 9.889 alleles, ranging from 7 (CPH2) to 12 (CPH12, C09173 and C2096) alleles. The effective number of alleles ranged from 5.378 (CPH2) to 10.083 (CPH12, C09173) alleles with a mean of 7.411 alleles. Observed number of alleles of each locus was higher than the effective number of alleles with no exception. Observed (Ho) and expected heterozygosity (He) ranged from 0.545 (CPH8) to 0.909 (CPH2) and from 0.814 (CPH2) and 0.901 (CPH12, C09173), respectively. The mean observed and expected heterozygosity was 0.737 and 0.859, respectively.

Figure 4.29 - Bubble chart for allele frequencies Allele at each locus in Indian grey wolf population

Table 4.10 - Genetic diversity indices of Indian grey wolf population at nine microsatellite loci

Locus	N	Na	Ne	Ho	He	F
CPH12	22	12.000	10.083	0.818	0.901	0.092
CPH8	22	10.000	8.067	0.545	0.876	0.377
AHT121	22	9.000	5.902	0.818	0.831	0.015
C09173	22	12.000	10.083	0.636	0.901	0.294
CXX279	22	9.000	7.118	0.727	0.860	0.154
AHTH130	22	10.000	6.368	0.727	0.843	0.137
CPH2	22	7.000	5.378	0.909	0.814	-0.117
CPH4	22	8.000	6.368	0.818	0.843	0.029
C2096	22	12.000	7.333	0.636	0.864	0.263
Mean		**9.889**	**7.411**	**0.737**	**0.859**	**0.138**

N- number of Individuals used, Na—observed number of alleles, Ne- effective number of allale, Ho—observed heterozygosity, He—expected heterozygosity, F_{IS}—inbreeding coefficient, PID—probability of identity (locus), PIDsib—probability of identity for sibs (locus).

Table 4.11 - Summary of multilocus matches analysis of Indian grey wolf

Sample	Genotype	No.	Label	Individual
ZSI_027	19420620220896100911031271291001089296g	4	A	1
ZSI_020	19420620220896100911031271291001089296g	0	A	1
ZSI_013	19420620220896100911031271291001089296g	0	A	1
ZSI_003	19420620220896100911031271291001089296g	0	A	1
ZSI_031	1962002062061001029191127127100108102106g	4	B	2
ZSI_024	1962002062061001029191127127100108102106g	0	B	2
ZSI_017	1962002062061001029191127127100108102106g	0	B	2
ZSI_007	1962002062061001029191127127100108102106g	0	B	2
ZSI_026	198204208208961028181125129981029296g	4	C	3
ZSI_019	198204208208961028181125129981029296g	0	C	3
ZSI_012	198204208208961028181125129981029296g	0	C	3
ZSI_002	198204208208961028181125129981029296g	0	C	3
ZSI_028	2022042022121021029310313114710610496106g	4	D	4
ZSI_021	2022042022121021029310313114710610496106g	0	D	4
ZSI_014	2022042022121021029310313114710610496106g	0	D	4
ZSI_004	2022042022121021029310313114710610496106g	0	D	4
ZSI_032	20422221021610011411311512112710811292102g	4	E	5
ZSI_025	20422221021610011411311512112710811292102g	0	E	5
ZSI_018	20422221021610011411311512112710811292102g	0	E	5
ZSI_008	20422221021610011411311512112710811292102g	0	E	5
ZSI_029	2322322222281101121311351451471141186096g	4	F	6
ZSI_022	2322322222281101121311351451471141186096g	0	F	6
ZSI_015	2322322222281101121311351451471141186096g	0	F	6
ZSI_005	2322322222281101121311351451471141186096g	0	F	6

ZSI_030	23223422222211411413313714714711611892102g	4	G		7
ZSI_023	23223422222211411413313714714711611892102g	0	G		7
ZSI_016	23223422222211411413313714714711611892102g	0	G		7
ZSI_006	23223422222211411413313714714711611892102g	0	G		7
ZSI-001	194196212212929685851231231001009494g	1		1	8
ZSI_011	196198204204961028183121125106106921 02g	1		2	9
ZSI_010	2102102002061021048383119125100106961 02g	1		3	10
ZSI_009	22222420420610611411311512312510810810 0106g	1		4	11
ZSI_009	22222420420610611411311512312510810810 0106g	1		4	11
ZSI_009	22222420420610611411311512312510810810 0106g	1		4	11
ZSI_051	200206202208961009110312912910010892 98g	4	A		12
ZSI_051	200206202208961009110312912910010892 98g	4	A		12
ZSI_051	200206202208961009110312912910010892 98g	4	A		12
ZSI_051	200206202208961009110312912910010892 98g	4	A		12
ZSI_052	1982002062061021029191127127100108102104g	4	B		13
ZSI_052	1982002062061021029191127127100108102104g	4	B		13
ZSI_053	198206208208961028181125129981029298g	4	C		14
ZSI_053	198206208208961028181125129981029298g	4	C		14
ZSI_053	198206208208961028181125129981029298g	4	C		14
ZSI_054	200204210212102102931031311471061041 06106g	4	D		15
ZSI_054	200204210212102102931031311471061041 06106g	4	D		15
ZSI_054	200204210212102102931031311471061041 06106g	4	D		15
ZSI_055	21022221021610011411311512112910811292106g	4	E		16
ZSI_056	234236222228112112131135145147114118 6106g	4	F		17
ZSI_056	234236222228112112131135145147114118 6106g	4	F		17
ZSI_056	234236222228112112131135145147114118 6106g	4	F		17
ZSI_057	234238222222114114133137147147116118102108g	0	G		18
ZSI_057	234238222222114114133137147147116118102108g	0	G		18
ZSI-058	194198212212929685871231251001009498g	1		1	19

ZSI-058	194198212212929685871231251001009498g	1	1	19
ZSI-058	194198212212929685871231251001009498g	1	1	19
ZSI-058	194198212212929685871231251001009498g	1	1	19
ZSI-058	194198212212929685871231251001009498g	1	1	19
ZSI_059	19620020420496102818312112510610892106g	1	2	20
ZSI_059	19620020420496102818312112510610892106g	1	2	20
ZSI_061	212212200206102104838311912510010696108g	1	3	21
ZSI_061	212212200206102104838311912510010696108g	1	3	21
ZSI_060	224226204206106114113115123125108108102106g	1	4	22
ZSI_060	224226204206106114113115123125108108102106g	1	4	22
ZSI_060	224226204206106114113115123125108108102106g	1	4	22
ZSI_060	224226204206106114113115123125108108102106g	1	4	22
ZSI_060	224226204206106114113115123125108108102106g	1	4	22

4.5.2. Assessment of genetic diversity indices and individual identification of wild boar

Mitochondrial marker

DNA extraction and PCR amplification success rate

Out of 198 faecal pellets collected to be wild boar origin, we found 107 faecal pellet (55%) yielded amplification success and good quality sequences of d-loop region. We identified species based on the similarity search using BLAST tool in the NCBI. All the generated sequences showed 98-100% with 98-100% sequences similarity with wild boar.

Microsatellite data analysis

Genotyping success rate:

Of the 107 faecal pellets genotyped at seven loci, 39 samples did not yield consensus genotypes and 13 samples showed low amplification success. Finally, we found 55 samples showed relatively high success rate i.e., >70 % and yielded consensus genotypes.

Selection of the microsatellite markers for individual identification

Following the criteria as discussed earlier, we opted a panel of seven loci having the cumulative probability of identity assuming all individuals were siblings (P_{ID} sibs) was 5.4E-03 (5.4 mismatches in 1000 genotypes), we identified 40 unique genotypes (Table 4.13). The locus wise probability of matching genotypes among unrelated individuals (P_{ID}) and siblings (P_{ID} sibs) varied from 0.042-0.51 to 0.34-0.73, respectively (Fig 4.28).

Genetic polymorphism

Seven microsatellite loci were successfully amplified with a mean expected heterozygosity HE 0.877, and a mean observed heterozygosity HO 0.707. The mean number of alleles per locus (Na=15.286) ranged from 11 (S0225) to 18 (S0005 and SW911).The overall estimated inbreeding coefficient (Fis) was high (Fis: 195) and different than zero and suggested that wild boar population was inbred (Table 4.12). The effective number of alleles ranged from 6.362 (SW632) to 12.488 (S0005) alleles with a mean of 8.566 alleles (Fig 4.29). Observed number of alleles of each locus was higher than the effective number of alleles with no exception. Observed (Ho) and expected heterozygosity (He) ranged from 0.564 (SW72) to 0.813 (S0005) and from 0.843 (SW632) and 0.920 (S0005), respectively. The mean observed and expected heterozygosity was 0.707 and 0.877, respectively.

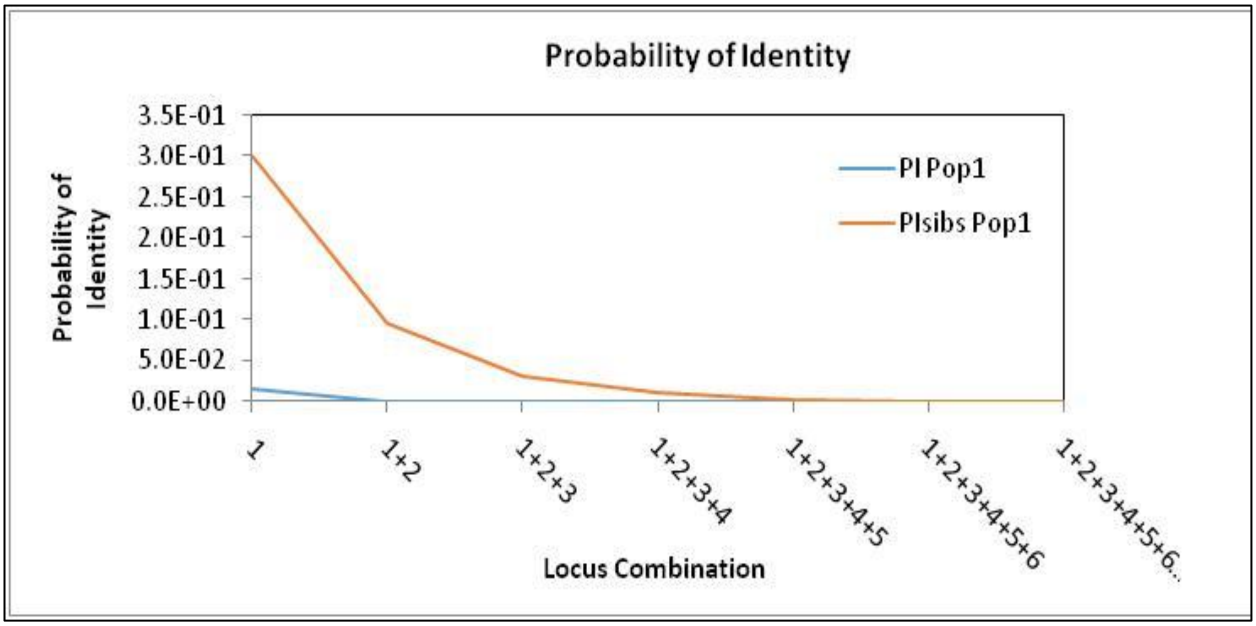


Figure 4.30 - Probability of identity of unrelated individuals (PID) and probability of identity of siblings (PIDsibs) in locus combination using seven polymorphic microsatellite markers with wild boar samples

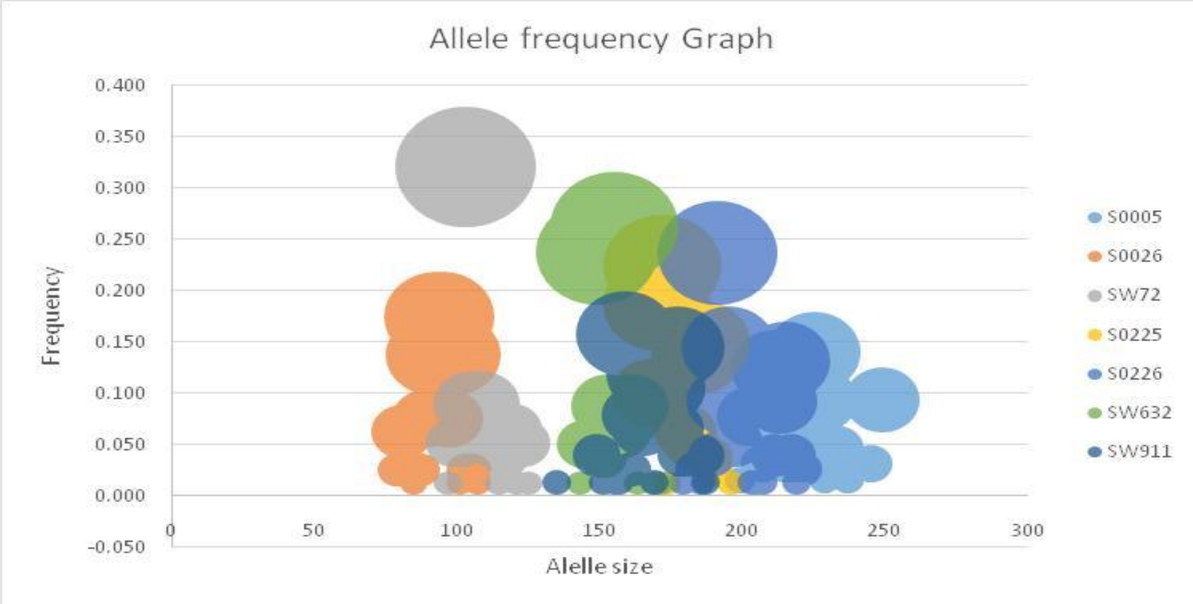


Figure 4.31 - Bubble chart for allele frequencies at each locus in wild boar population

Table 4.12 - Genetic diversity indices of wild boar population at seven microsatellite loci

Locus	N	Na	Ne	Ho	He	F
S0005	32	18.000	12.488	0.813	0.920	0.117
S0026	40	15.000	8.488	0.800	0.882	0.093
SW72	39	15.000	6.867	0.564	0.854	0.340
S0225	40	11.000	6.852	0.575	0.854	0.327
S0226	38	17.000	8.251	0.684	0.879	0.221
SW632	40	13.000	6.362	0.775	0.843	0.080
SW911	38	18.000	10.657	0.737	0.906	0.187
		15.286	8.566	0.707	0.877	0.195

N- number of Individuals used, Na—observed number of alleles, Ne- Number of effective allele Ho—observed heterozygosity, He—expected heterozygosity, F_{IS}—inbreeding coefficient, PID—probability of identity (locus), PIDsib—probability of identity for sibs (locus).

Table 4.13 - Summary of multilocus match analysis of wild boar

Sample ID	Genotype	No.	Label
913	008595107107180180193217149155175175g	3	A
867	008595107107180180193217149155175175g	0	A
867	008595107107180180193217149155175175g	0	A
911	009595117117182182193193151157 00g	3	B

856	00959511711718218219319315115700g	0	B
856	00959511711718218219319315115700g	0	B
915	0099101103103170184191191149157149149g	3	C
905	0099101103103170184191191149157149149g	0	C
905	0099101103103170184191191149157149149g	0	C
360	2112239395103119168168193195145157167177g	3	D
127	2112239395103119168168193195145157167177g	0	D
127	2112239395103119168168193195145157167177g	0	D
908	21122589107103113170170191203145159149159g	3	E
838	21122589107103113170170191203145159149159g	0	E
838	21122589107103113170170191203145159149159g	0	E
362	2112259393109117170172179191145155167179g	3	F
356	2112259393109117170172179191145155167179g	0	F
356	2112259393109117170172179191145155167179g	0	F
909	2112279999103111168172189191147147159187g	3	G
841	2112279999103111168172189191147147159187g	0	G
841	2112279999103111168172189191147147159187g	0	G
914	21321381931211251701700014915500g	3	H
892	21321381931211251701700014915500g	0	H
892	21321381931211251701700014915500g	0	H
912	217227105105103103168172191191153153151177g	3	I
857	217227105105103103168172191191153153151177g	0	I
857	217227105105103103168172191191153153151177g	0	I
358	2172498999113119172180215215149155165177g	7	J
357	2172498999113119172180215215149155165177g	0	J
126	2172498999113119172180215215149155165177g	0	J
125	2172498999113119172180215215149155165177g	0	J
126	2172498999113119172180215215149155165177g	0	J
125	2172498999113119172180215215149155165177g	0	J

101	2172498999113119172180215215149155165177g	0	J
910	2192399397101107182188195213147161157159g	3	K
846	2192399397101107182188195213147161157159g	0	K
846	2192399397101107182188195213147161157159g	0	K
361	2212259193103107170172185195149153179185g	3	L
144	2212259193103107170172185195149153179185g	0	L
144	2212259193103107170172185195149153179185g	0	L
906	22322993979999172188193221143155155159g	3	M
824	22322993979999172188193221143155155159g	0	M
824	22322993979999172188193221143155155159g	0	M
359	2252258393103111172172191197153155175175g	3	N
126	2252258393103111172172191197153155175175g	0	N
126	2252258393103111172172191197153155175175g	0	N
907	2272279191101109184184191191149155163163g	3	O
831	2272279191101109184184191191149155163163g	0	O
831	2272279191101109184184191191149155163163g	0	O
980	0081811031151721841911951491551671175g	1	1
316	008199103111184186183213149155159163g	1	2
359	008391103105172172221145157163163g	1	3
1081	0087870018218819319314915516517 3g	1	4
308	0093951031031841840014915516716 7g	1	5
307	1992499599103109184186213213149155135159g	1	6
319	20321179899999186186211213161161159173g	1	7
314	2032198191105111168186189195149163167177g	1	8
317	2032459599109109186186183195161161159159g	1	9
305	20324995103109109186186191195153171173173g	1	10
306	2032499599103103186186189191149161167173g	1	11
123	2072159193123123168172213215149155173183g	1	12
124	2072159193123123172172213215149155173183g	1	13

823	211211939510710719019019721115915915916 5g	1	14
548	211221899710311917018419519515915917717 7g	1	15
921	213223919710310317018419719714915917717 7g	1	16
914	213239939510110117017019121515515515917 9g	1	17
990	217227799510510517017019121714915518318 5g	1	18
108	225225919110310516817219120515315316318 5g	1	19
549	225227971039710517418419520715515516116 7g	1	20
819	225233919710310516817019119115115715917 7g	1	21
809	233233939510310317017221121514715116116 7g	1	22
318	237245959910311118619619521916116916917 3g	1	23

4.5.3. Assessment of genetic diversity indices and individual identification of golden jackal

Mitochondrial marker

DNA extraction and PCR amplification success rate

Of 79 faecal droppings, we found 48 faeces (60%) yielded amplification success and good quality sequences for the Cytb gene. Sequence similarity was undertaken using the BLAST search tool of NCBI. All 56 sequences showed 98- 100% sequence similarity with golden jackal.

Microsatellite data analysis

Genotyping success rate:

Nine loci amplified with 56 faecal pellets of conformed golden jackal collected from different sites in South West Bengal. Of the 56 faecal pellets genotyped at nine loci, 6 samples did not yield consensus genotypes and three samples showed low amplification success. Finally, we found nine loci showed relatively high success rate i.e. >70 % with 47 samples and yielded consensus genotypes and used for the further analysis.

Selection of the microsatellites for individual identification

Following the set criteria as discussed earlier, we opted a panel of seven loci having the cumulative probability of identity assuming all individuals were siblings (P_{ID} sibs) was 1.6E-03 (1.6 mismatches in 1000 genotypes). The locus wise probability of matching genotypes among unrelated individuals (P_{ID}) and siblings (P_{ID} sibs) varied from0.033-0.29 to 0.31.-0.58, respectively (Fig 4.32). This panel of seven loci identified 41 unique genotypes from faecal pellets DNA extracts (Table 4.15).

Genetic diversity and inbreeding

Nine microsatellite loci were successfully amplified with a mean expected heterozygosity He - 0.713, and a mean observed heterozygosity Ho - 0.778. The mean number of alleles per locus (Na =4.88) ranged from 3 (AHTH130 and C2096) to 7 (CPH8) (Table 4.14). All nine loci used in the present study were significantly deviated from HWE and Five pairs of loci out of 72 pairwise comparisons were in significant linkage disequilibrium ($P<0.05$). The estimated inbreeding coefficient (Fis) was not different than zero (Fis: -0.090) and showed population was not inbred.

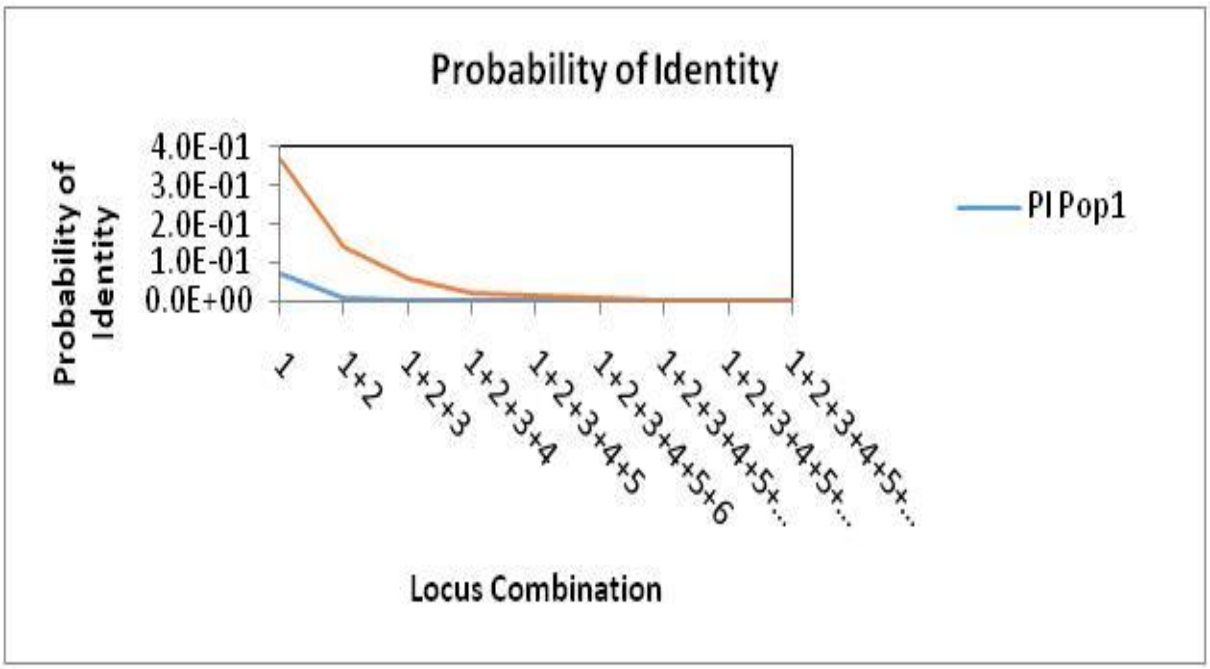


Figure 4.32 - Probability of identity of unrelated individuals (PID) and probability of identity of siblings (PIDsibs) in locus combination using seven polymorphic microsatellite markers with golden jackal samples

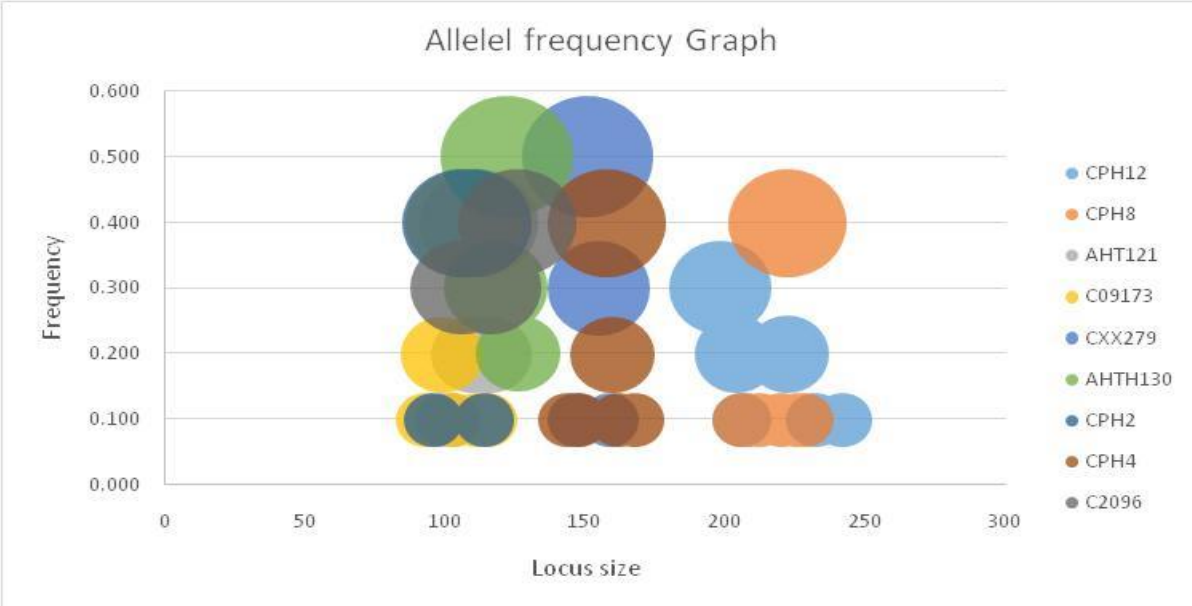


Figure 4.33 - Bubble chart for the allele frequencies at each locus in Golden jackal population

Table 4.14 - Genetic diversity indices of golden jackal population at nine microsatellite loci

Locus	N	Na	Ne	Ho	He	F
CPH12	41	6.000	5.000	0.800	0.800	0.000
CPH8	41	7.000	4.545	1.000	0.780	-0.282
AHT121	41	5.000	3.846	0.800	0.740	-0.081
C09173	41	6.000	4.167	0.800	0.760	-0.053
CXX279	41	4.000	2.778	0.800	0.640	-0.250
AHTH130	41	3.000	2.632	0.600	0.620	0.032
CPH2	41	4.000	2.941	0.600	0.660	0.091
CPH4	41	6.000	4.167	0.800	0.760	-0.053
C2096	41	3.000	2.941	0.800	0.660	-0.212
Mean		**4.889**	**3.669**	**0.778**	**0.713**	**-0.090**

N- number of Individuals used, Na—observed number of alleles, Ne-number of effective alleles, Ho—observed heterozygosity, He—expected heterozygosity, F_{IS}—inbreeding coefficient, PID—probability of identity (locus), PIDsib—probability of identity for sibs (locus).

Table 4.15 - Summary of multilocus match analysis of golden jackal

Sample	Genotype	No.	Label	Individual
ZSI_GJ_011	198198220222100102939914715111812296106g	3	A	1
ZSI_GJ_006	198198220222100102939914715111812296106g	0	A	1

ZSI_GJ_001	198198220222100102939914715111812296106g	0	A	1
ZSI_GJ_012	198206222226110112991071511511221261061O6g	3	B	2
ZSI_GJ_007	198206222226110112991071511511221261061O6g	0	B	2
ZSI_GJ_002	198206222226110112991071511511221261061O6g	0	B	2
ZSI_GJ_014	2042222062121101161071071511551181181 10114g	3	C	3
ZSI_GJ_009	2042222062121101161071071511551181181 10114g	0	C	3
ZSI_GJ_004	2042222062121101161071071511551181181 10114g	0	C	3
ZSI_GJ_013	204222208222112116103107151155122122106110g	3	D	4
ZSI_GJ_008	204222208222112116103107151155122122106110g	0	D	4
ZSI_GJ_003	204222208222112116103107151155122122106110g	0	D	4
ZSI_GJ_015	232242222228112112111115155159122126110110g	3	E	5
ZSI_GJ_010	232242222228112112111115155159122126110110g	0	E	5
ZSI_GJ_005	232242222228112112111115155159122126110110g	0	E	5
ZSI_GJ_011	198220220222100102939914715111812296108g	3	A	6
ZSI_GJ_011	198220220222100102939914715111812296108g	3	A	6
ZSI_GJ_011	198220220222100102939914715111812296108g	3	A	6
ZSI_GJ_011	198220220222100102939914715111812296108g	3	A	6
ZSI_GJ_007	206206222226110112991071511511221261061 10g	0	B	7
ZSI_GJ_007	206206222226110112991071511511221261061 10g	0	B	7
ZSI_GJ_007	206206222226110112991071511511221261061 10g	0	B	7
ZSI_GJ_007	206206222226110112991071511511221261061 10g	0	B	7
ZSI_GJ_009	198222206212110116107107151155118118110110g	0	C	8
ZSI_GJ_009	198222206212110116107107151155118118110110g	0	C	8
ZSI_GJ_009	198222206212110116107107151155118118110110g	0	C	8
ZSI_GJ_018	198204220222100102939914715111812496102g	3	A	9
ZSI_GJ_018	198204220222100102939914715111812496102g	3	A	9
ZSI_GJ_018	198204220222100102939914715111812496102g	3	A	9
ZSI_GJ_019	198210222226110112991071511551221261061O8g	3	B	10
ZSI_GJ_019	198210222226110112991071511551221261061O8g	3	B	10
ZSI_GJ_020	204222206214110116107109151155118118110112g	3	C	11
ZSI_GJ_020	204222206214110116107109151155118118110112g	3	C	11
ZSI_GJ_020	204222206214110116107109151155118118110112g	3	C	11

ZSI_GJ_021	2082222082221161161031071531551221221 08110g	3	D	12
ZSI_GJ_021	208222208222116116103107153155122122108110g	3	D	12
ZSI_GJ_022	234242222228114114111115155159122126118108g	3	E	13
ZSI_GJ_022	234242222228114114111115155159122126118108g	3	E	13
ZSI_GJ_022	234242222228114114111115155159122126118108g	3	E	13
ZSI_GJ_022	234242222228114114111115155159122126118108g	3	E	13
ZSI_GJ_023	198222220222100100939914715112012296108g	3	A	14
ZSI_GJ_023	198222220222100100939914715112012296108g	3	A	14
ZSI_GJ_024	20621022222611011299107151153122126108110g	0	B	15
ZSI_GJ_024	20621022222611011299107151153122126108110g	0	B	15
ZSI_GJ_024	20621022222611011299107151153122126108110g	0	B	15
ZSI_GJ_025	196220206212110116107107151153118118110112g	0	C	16
ZSI_GJ_025	196220206212110116107107151153118118110112g	0	C	16
ZSI_GJ_025	196220206212110116107107151153118118110112g	0	C	16
ZSI_GJ_026	198220206212110116105107151155118120110112g	0	C	17
ZSI_GJ_026	198220206212110116105107151155118120110112g	0	C	17
ZSI_GJ_027	198226206212110118107107151155120120110112g	0	C	18
ZSI_GJ_027	198226206212110118107107151155120120110112g	0	C	18
ZSI_GJ_028	220220220222100102959914715111812296110g	2	F	19
ZSI_GJ_028	220220220222100102959914715111812296110g	2	F	19
ZSI_GJ_029	20620822222811011299107151153122126106110g	3	G	20
ZSI_GJ_029	20620822222811011299107151153122126106110g	3	G	20
ZSI_GJ_029	20620822222811011299107151153122126106110g	3	G	20
ZSI_GJ_030	198202220222100102939314715111812496104g	2	A	21
ZSI_GJ_030	198202220222100102939314715111812496104g	2	A	21
ZSI_GJ_031	236240222228114114311115155159122126118110g	1	E	22
ZSI_GJ_032	198200220222100102959914715111812296106g	1	A	23
ZSI_GJ_033	210224206212110116107107151155118118310114g	1	H	24
ZSI_GJ_033	210224206212110116107107151155118118310114g	1	H	24
ZSI_GJ_034	200202206212110116105107151157118120110114g	0	G	25
ZSI_GJ_034	200202206212110116105107151157118120110114g	0	G	25
ZSI_GJ_035	198220206212110116107107151173118118110114g	0	C	26

ZSI_GJ_035	1982202062121101161071071511731181181101114g	0	C	26
ZSI_GJ_036	2002222062121101161071071511551181181101114g	1	K	27
ZSI_GJ_036	2002222062121101161071071511551181181101114g	1	K	27
ZSI_GJ_036	2002222062121101161071071511551181181101114g	1	K	27
ZSI_GJ_037	2062222082221121161031071511551221221061114g	3	D	28
ZSI_GJ_039	20021222222811011299107151155122126106108g	3	B	29
ZSI_GJ_040	2102222082221161161031071531551221221101110g	3	D	30
ZSI_GJ_041	2002222202221001009399147151120122961110g	3	F	31
ZSI_GJ_041	2002222202221001009399147151120122961110g	3	F	31
ZSI_GJ_041	2002222202221001009399147151120122961110g	3	F	31
ZSI_GJ_042	2002102062121101161071071511551181181101112g	0	C	32
ZSI_GJ_042	2002102062121101161071071511551181181101112g	0	C	32
ZSI_GJ_043	2002202202221001029399147151118122961110g	3	A	33
ZSI_GJ_044	2002202062121101161071071511531181181121112g	0	C	34
ZSI_GJ_044	2002202062121101161071071511531181181121112g	0	C	34
ZSI_GJ_044	2002202062121101161071071511531181181121112g	0	C	34
ZSI_GJ_044	21021022222611011299107151153122126108108g	0	B	35
ZSI_GJ_044	21021022222611011299107151153122126108108g	0	B	35
ZSI_GJ_044	21021022222611011299107151153122126108108g	0	B	35
ZSI_GJ_045	2102182062141101161071091511551181181121112g	3	C	36
ZSI_GJ_045	2102182062141101161071091511551181181121112g	3	C	36
ZSI_GJ_046	2222222082221121161031071511551221221061106g	3	D	37
ZSI_GJ_047	1982002202221001029399147151118122961108g	3	G	38
ZSI_GJ_047	1982002202221001029399147151118122961108g	3	G	38
ZSI_GJ_047	1982002202221001029399147151118122961108g	3	G	38
ZSI_GJ_048	2222222082221161181051051531551221241101114g	3	K	39
ZSI_GJ_048	2222222082221161181051051531551221241101114g	3	K	39
ZSI_GJ_048	2222222082221161181051051531551221241101114g	3	KD	39
ZSI_GJ_049	21021022224611011099107151153122124108110g	0	B	40
ZSI_GJ_049	21021022224611011099107151153122124108110g	0	B	40
ZSI_GJ_050	2002042202241001049399147151118124961104g	3	M	41
ZSI_GJ_050	2002042202241001049399147151118124961104g	3	M	41

4.6. Identification of Human-wildlife conflict zones in the study area

4.6.1. Human Wildlife Conflict in all study forest divisions:

The analysis specifies that the human wildlife conflict cases by these study species were varied significantly in all forest divisions ($\chi2= 137.975$, and $p <0.001$). Among the total 187 conflict cases reported by the respondents of Kangsabati North forest division who had been facing wildlife conflicts, 37.97% conflict was with the Wild boar while 26.20%, 22.99% and 12.83% conflict was caused by Indian grey wolf, Golden jackal and Striped hyena (Figure 4.34). Out of total 599 conflict cases informed by the respondents in Purulia forest division, about 50.75% was considered wild boar conflict, while Golden jackal, Indian grey wolf and Striped hyena considered by about 20.03%, 25.88% and 3.34% conflict respectively. In Kangsabati South forest division total 462cases were reported by the respondents, out of which 43.94% was wild boar conflict followed by Indian grey wolf conflict (30.52%), Golden jackal conflict (25.54%) (Figure 4.34). Among the total 272 respondents of Bankura North forest division, about 58.82% reported conflict with the wild boar followed by Indian grey wolf (25.74%), 15.07% and 0.37% conflict instances with Golden jackal and Striped hyena respectively. Out of total 289 wildlife conflict cases in Bankura South forest division, about 47.40% conflict was by Wild boar while30.10%, 20.76%and 1.73% were by Indian grey wolf, Golden jackal and Striped hyena respectively. In Jhargram forest division most of the conflict was by Wild boar (48.03%) followed by Indian grey wolf (40.94%) and Golden jackal (11.02%) (Figure 4.34). In both Rupnarayan, Medinipur and Kharagpur forest division most of the conflict cases reported, were by the Wild boar. In Rupnarayan and Medinipur conflict cases by Indian grey wolf were higher than the conflict caused by Golden jackal. In Kharagpur 33.78% cases were by Golden jackal, 20.27% and 9.19% conflict cases were caused by Indian grey wolf and Striped hyena respectively. Whereas in Birbhum most of the conflict cases were by Indian grey wolf, followed by Wild boar and Golden jackal. In Burdwan forest divisionWild boarconflict was very high (52.94%) while both Golden jackal and Indian grey wolf conflict percentage were same i.e. 23.53%. A very few conflict cases in Durgapur were caused by Wild boar and Indian grey wolf. In Howrah-Hoogly only Golden jackal conflicts were reported.

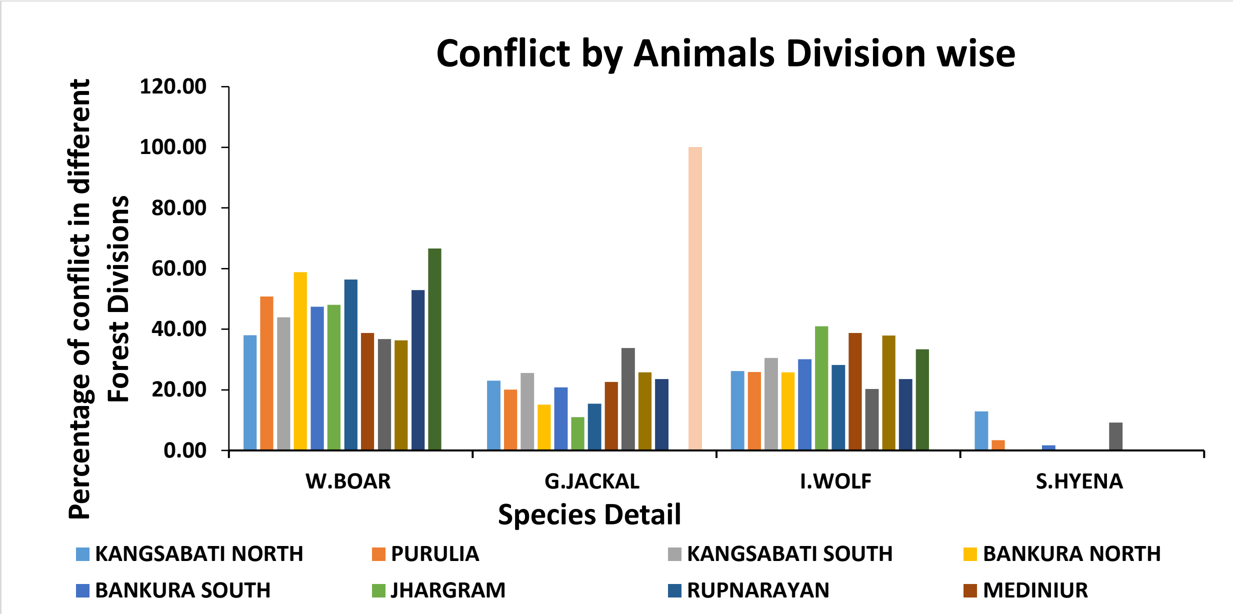


Figure 4.34 - Number of conflict locations in the forest divisions based on the study species

4.6.2. Different types of conflict in all study forest divisions

Human wildlife conflict cases were classified into three different types, crop damage mainly caused by Wild Boar, livestock attack by Indian grey wolf and Golden Jackal, and human attack which was less frequent (Figure 4.35). The analysis indicates that all three type of human wildlife conflict cases were varied significantly in all forest divisions ($\chi 2= 90.772$, and $p <0.001$).Among 377 respondents in Purulia and 27 respondents in Rupnarayan forest division more than 80% interviewee faced crop damage by Wild boar. In Kangsabati South,Bankura North, Bankura Southand Kharagpur forest division more than 60% of respondents suffered crop damage. Whereas in Kangsabati North, Jhargram and Medinipur forest division crop damage was reported by 58.68%, 56.48% and 54.55% of the respondents. In Birbhum and Burdwan more than 50% interviewee faced crop damage while in Durgapur the percentage is very low. Livestock attack is the most common type of wildlife conflict in each forest division. In Medinipur and Kharagpur Forest Division the percentage of respondents facing livestock attack were highest followed by Kangsabati North, Kangsabati South, Bankura South, Rupnarayan, Birbhum and Jhargram. In case of Purulia, Bankura North, Burdwan and Durgapur less than 50% of respondents faced this type of conflict and in Howrah-Hoogly forest division lowest percentage of respondents stated about livestock attack. A very few percentage of people were directly attacked by the concerned species i.e. 6.48% in Jhargram, 3.90% in Kharagpur and 2.63% in Burdwan Forest Division.

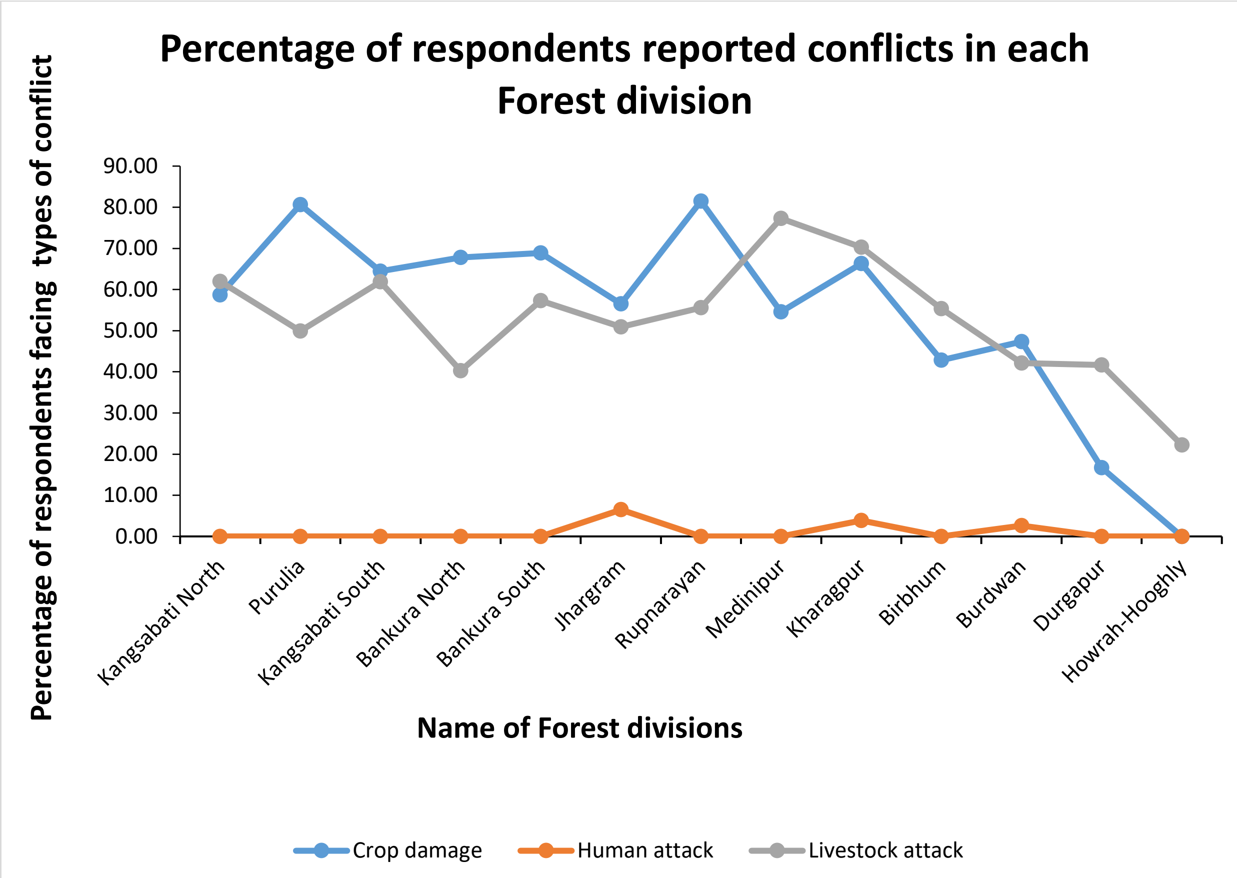


Figure 4.35 - Different type of conflict in all study forest divisions of South Bengal region

4.6.3. Geo-spatial patterns in human-wildlife conflicts with respect to the study species

i). Indian grey wolf-human conflict zones

Spatial pattern of Human-Indian grey wolf conflict indicates that most of the conflict hotspots were located in the far western regions of the study landscape (Figure 4.36). Stepwise model evaluation base on AIC based model suggests higher accuracy with lowest score of (AIC=831.75) with a total of eight predictors variable being selected for the best fitted linear model (Table 4.16; Figure 4.37). The influence of Distance from mixed forest was found to be highest with an estimate score (β= -1.11289) with highest significance value (p= 2e-16), also suggesting the negative relation with the predictor (Figure 4.37, 4.38 and Table 4.17). Among the topographic predictors elevation was found to have a positive correlation with the spatial distribution of human-Wolf cases, within the study area with contribution (β= 0.34668). Among the anthropogenic predictors, distance to road and the cattle density was found to be the most influential variable s with higher significance p=1.10E-08 and 1.91E-05 respectively (Figure 4.37). Results from the comparative zonal mean evaluation within the forest ranges suggests, higher intensity of conflict in Ranibandh with a mean score of (12.01), followed by Bandwan-II (11.81) and Bagmundi (11.43) (Figure 4.39).

Table 4.16 - Evaluation of conflict risk predictive model for Indian grey wolf.

Model	AIC	No. of Parameters
Ψ(Mix + CV + BU + RD + Drain + Ele + NL + CA)	831.95	7
Ψ(Mix + CV + BU + RD + Drain +Rail + Ele + NL + CA)	832.27	9
Ψ(Grass + Mix + CV + BU + RD + Drain +Rail + Ele + NL + CA)	832.66	10
Ψ(Grass + Mix + CV + BU + Crop + RD + Drain +Rail + Ele + NL + CA)	833.49	11
Ψ(Grass + SV + Mix + CV + BU + Crop + RD + Drain +Rail + Ele + NL + CA)	834.88	12
Ψ(Grass + SV + Mix + Water + CV + BU + Crop + RD + Drain +Rail + Ele + NL + CA)	836.58	13
Ψ(Grass + SV + Mix + Water + CV + BU + Crop + RD + Drain +Rail + Ele + HFP + NL + CA)	838.45	14

Note: Model selection by lowest AIC value.Ψ= degree of conflict cases by Indian grey wolf; Grass = Distance from grassland; Mix = Distance from mixed forest; CV = Distance from Cropland/Natural Vegetation Mosaics; Crop = Distance from cropland; SV= Distance from savannas, BU = Distance from built up areas; Water = Distance from water areas, RD = Distance from roads; Drain = Distance from drainage, Ele = Elevation, NL = Night light data; CA = cattle data; Rail = Distance from Rail lines; HFP = Human footprint data

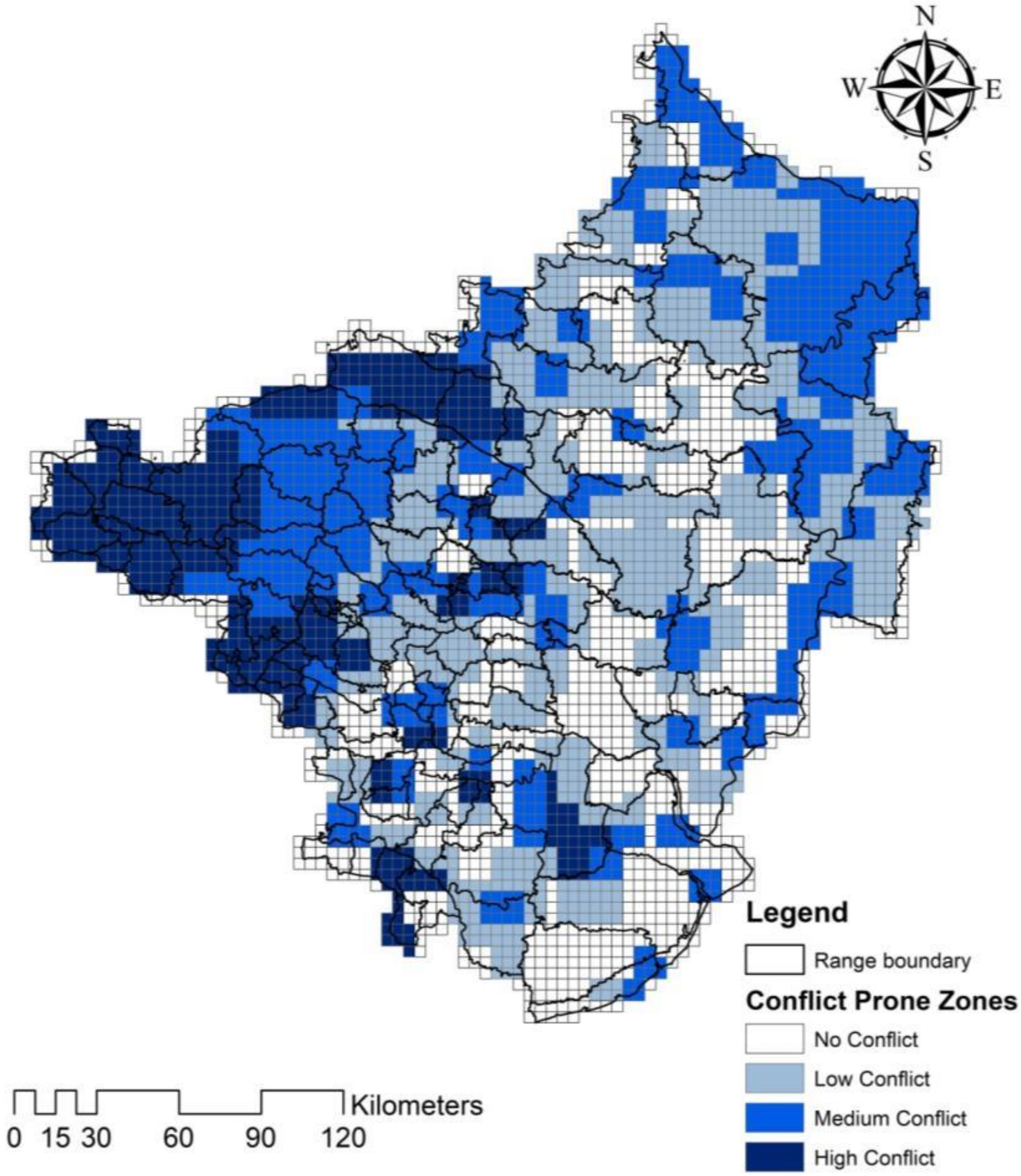


Figure 4.36 - Conflict zones by Indian grey wolf in the present study area, colour scale denoted the range of conflict reported by local people

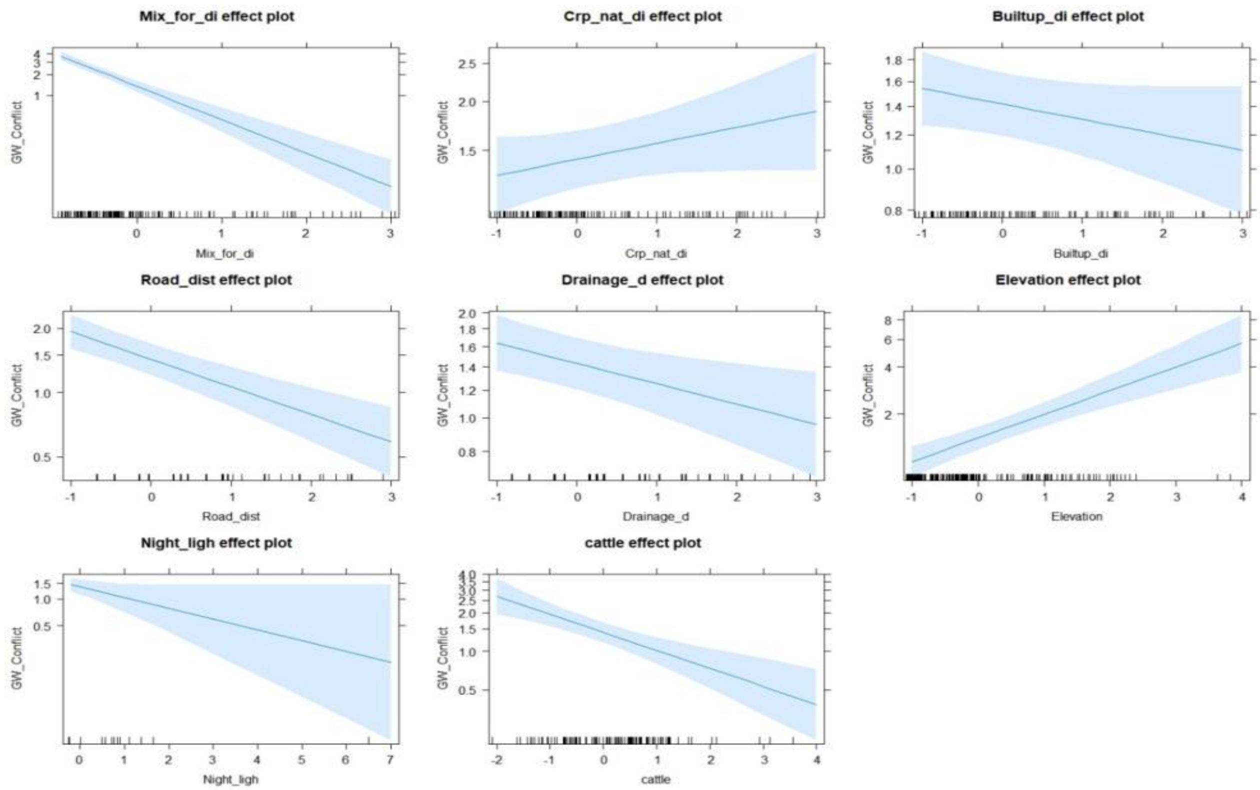


Figure 4.37 - The effects of predictor variables with the conflict risk induced by Indian grey wolf. (Mix_for_di = Distance from mixed forest, Crp_nat_di = Distance from crop and natural vegetation mosaic, Builtup_di = Distance from Builtup areas, Road_dist = Distance from roads, Drainage_d = Distance from drainage, Elevation, Night_ligh = Night light, cattle)

Table 4.17 - The evaluated β coefficients values of predictor variables of best model for the conflict probability.

	Coefficients	Estimate	Std. Error	z value	Sig(p<0.05)
Conflict Risk Prediction model output for Indian grey wolf	(Intercept)	0.26899	0.0929	2.895	0.00379
	Mix_for_di	-1.11289	0.13001	-8.56	< 2e-16
	Crp_nat_di	0.09426	0.05822	1.619	0.10542
	Builtup_di	-0.08267	0.05077	-1.628	0.10347
	Road_dist	-0.29721	0.05201	-5.714	1.10E-08
	Drainage_d	-0.13421	0.0483	-2.779	0.00545
	Elevation	0.34668	0.05468	6.34	2.29E-10
	Night_ligh	-0.27882	0.14273	-1.954	0.05076
	cattle	-0.324	0.07579	-4.275	1.91E-05

Note: (Mix_for_di = Distance from mixed forest, Crp_nat_di = Distance from crop and natural vegetation mosaic, Builtup_di = Distance from Builtup areas, Road_dist = Distance from roads, Drainage_d = Distance from drainage, Elevation, Night_ligh = Night light, cattle).

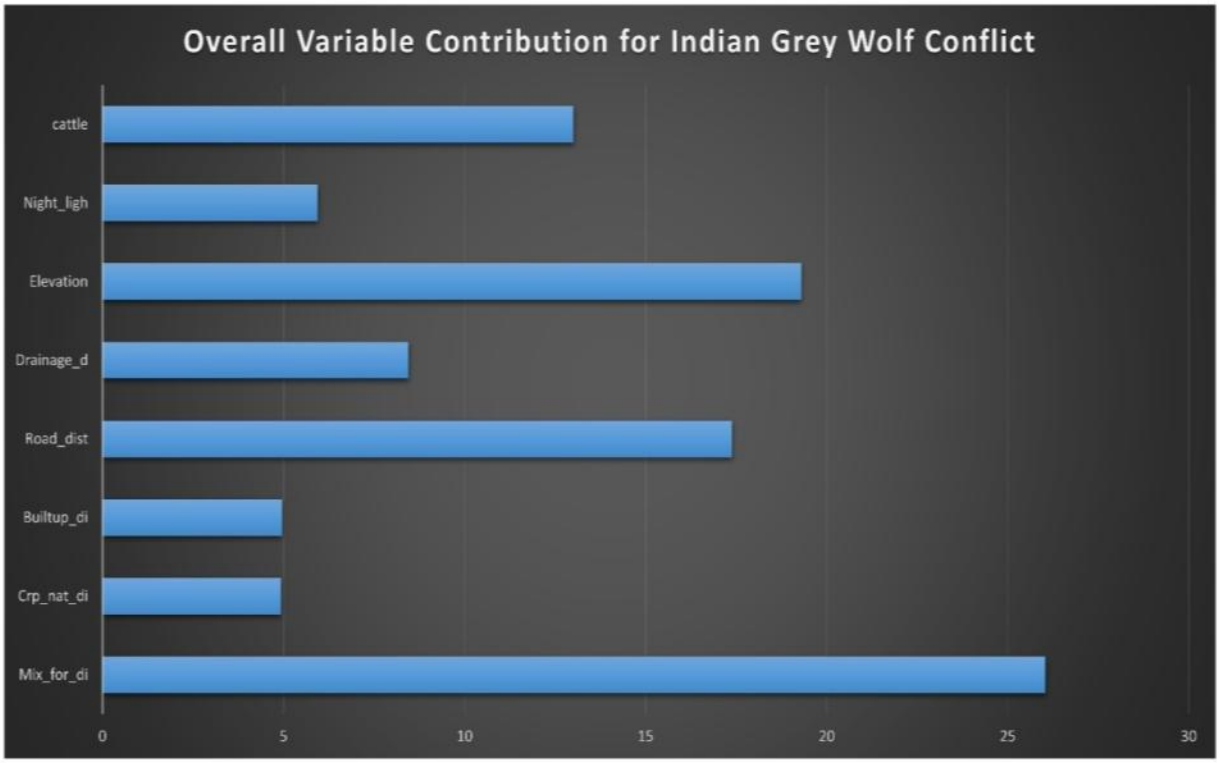


Figure 4.38 - Shows the overall variable contribution in the final Generalize Linear Model for Indian grey wolf conflict risk prediction, where the data was trained by 70% of the crude data.

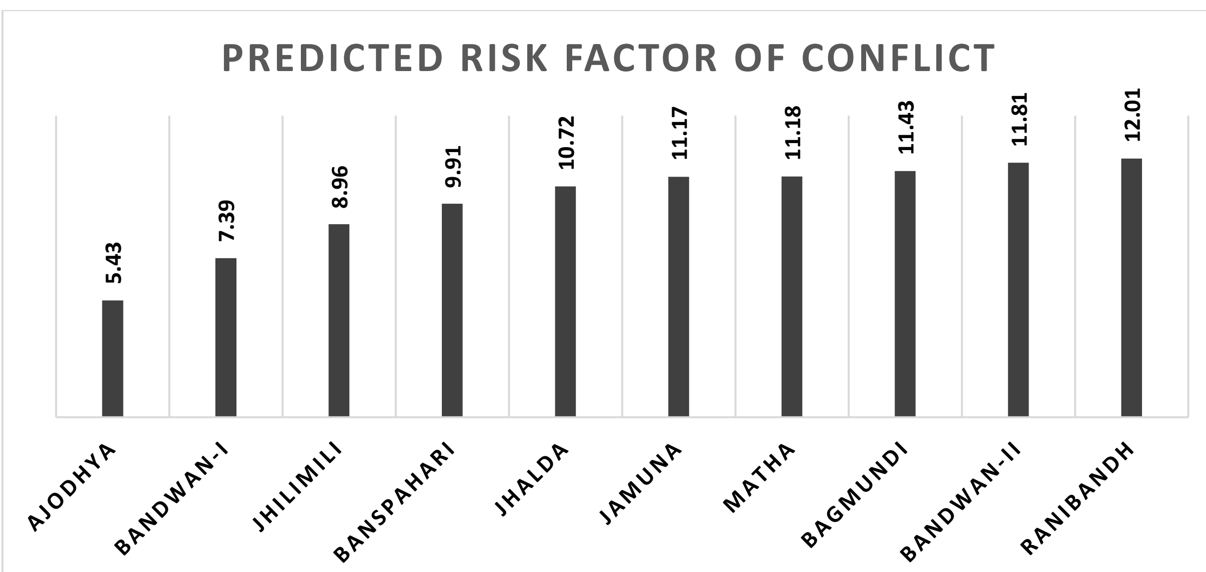


Figure - 4.39 - Predicted risk factor of conflict by Indian grey wolf in forest ranges of South Bengal landscape.

ii). Golden Jackal-human conflict zones

Spatial pattern of Golden Jackal-human conflict indicates that most of the high intensity conflict zones were located in the far western regions with some medium level of conflict zones in the southern portion of the study landscape (Figure 4.40). Stepwise model evaluation base on AIC based selection suggests higher accuracy with lowest score of (AIC=727.26) with a total of ten predictors variable being selected for the best fitted linear model (Table 4.18). The influence of elevation was found to be highest with an estimate score (β= 0.60162) with highest significance value (p=1.17E-09), also suggesting the positive relation with the predictor (Table 4.18; Figure 4.40, 4.41). Among the anthropogenic predictors, Human foot print was found to be the most influential variable s with higher significance 9.07E-09, followed by the contribution of euclidian distance from railway line (p=.37E-08), Night light (p=0.000201) and cattle density (0.000187) (Table 4.19; Figure 4.42). The cattle density, railway lines and human footprint in the region also found to have a positive relation with the conflict (Figure 4.42). Results from the comparative zonal mean evaluation within the forest ranges suggests, higher intensity of conflict in Arsa with a mean score of (12.20), followed by Bandwan-II (12.09) and Bagmundi (11.57) (Figure 4.43).

Table 4.18 - Evaluation of conflict risk predictive model for Golden Jackal.

Model	AIC	No. of Parameters
Ψ(Grass + SV + Mix + Water + RD + Drain + Rail + Ele + HFP + NL + cattle)	727.26	10
Ψ(Grass + SV + Mix + Water + Crop + RD + Drain + Rail + Ele + HFP + NL + cattle)	728.1	12
Ψ(Grass + SV + Mix + Water + CV + Crop + RD + Drain + Rail + Ele + HFP + NL + cattle)	729.49	13
Ψ(Grass + SV + Mix + Water + CV + BU + Crop + RD + Drain + Rail + Ele + HFP + NL + cattle)	730.85	14

Note: Model selection by lowest AIC value. Ψ= degree of conflict cases by Golden Jackal; Grass = Distance from grassland; Mix = Distance from mixed forest; CV = Distance from Cropland/Natural Vegetation Mosaics; Crop = Distance from cropland; SV= Distance from savannas, BU = Distance from built up areas; Water = Distance from water areas, RD = Distance from roads; Drain = Distance from drainage, Ele = Elevation, NL = Night light data; CA = cattle data; Rail = Distance from Rail lines; HFP = Human footprint data.

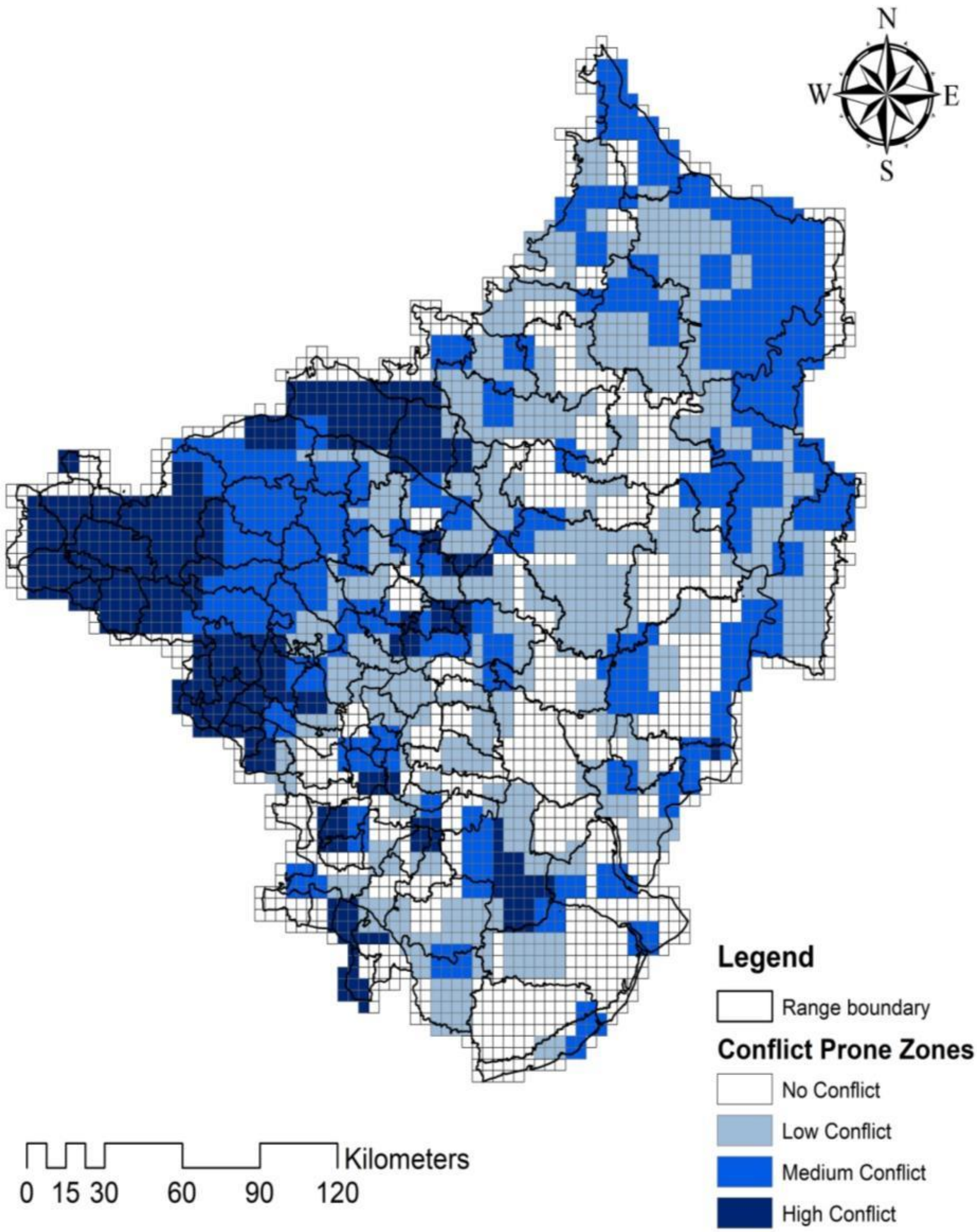


Figure 4.40 - Conflict issues by Golden Jackal in the present study area, colour scale denoted the range of conflict reported by local people

Table 4.19 - The evaluated β coefficients values of predictor variables of best model for the conflict probability evaluation. (

	Coefficients	Estimate	Std. Error	z value	Sig(p<0.05)
Conflict Risk Prediction model output for Golden Jackal	(Intercept)	0.23238	0.10559	2.201	0.027748
	Grassland	0.16267	0.08138	1.999	0.045606
	Savva_dist	0.25457	0.06637	3.836	0.000125
	Mix_for_di	-0.71793	0.16037	-4.477	7.58E-06
	Water_dist	-0.1831	0.09143	-2.003	0.045214
	Road_dist	-0.24322	0.0691	-3.52	0.000432
	Drainage_d	-0.20488	0.05811	-3.526	0.000422
	Rail_dist	0.34304	0.06266	5.475	4.37E-08
	Elevation	0.60162	0.09888	6.085	1.17E-09
	HFP	0.45341	0.07889	5.747	9.07E-09
	Night_ligh	-0.35199	0.09468	-3.718	0.000201
	cattle	-0.33843	0.09059	-3.736	0.000187

Note; Grassland = Distance from Grassland, Savva_dist = Distance from Savanna, Mix_for_di = Distance from mixed forest, Water_dist = Distance from water, Road_dist = Distance from roads, Drainage_d = Distance from drainage, Rail_dist = Distance from Rail lines, Elevation, HFP = Human foot print, Night_ligh = Night light, cattle)

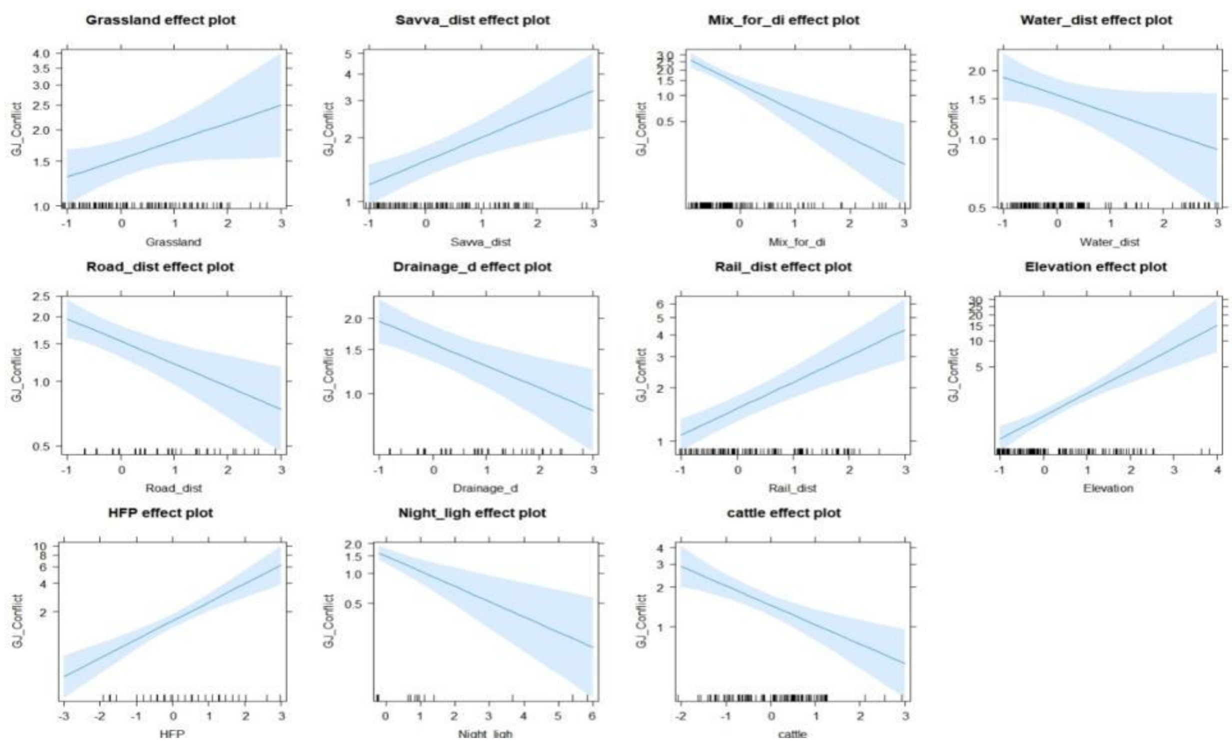


Figure 4.41 - The effects of predictor variables with the conflict risk induced by Golden Jackal. (Grassland = Distance from Grassland, Savva_dist = Distance from Savanna, Mix_for_di = Distance from mixed forest, Water_dist = Distance from water,Road_dist = Distance from roads, Drainage_d = Distance from drainage, Rail_dist = Distance from Rail lines, Elevation, HFP = Human foot print, Night_ligh = Night light, cattle)

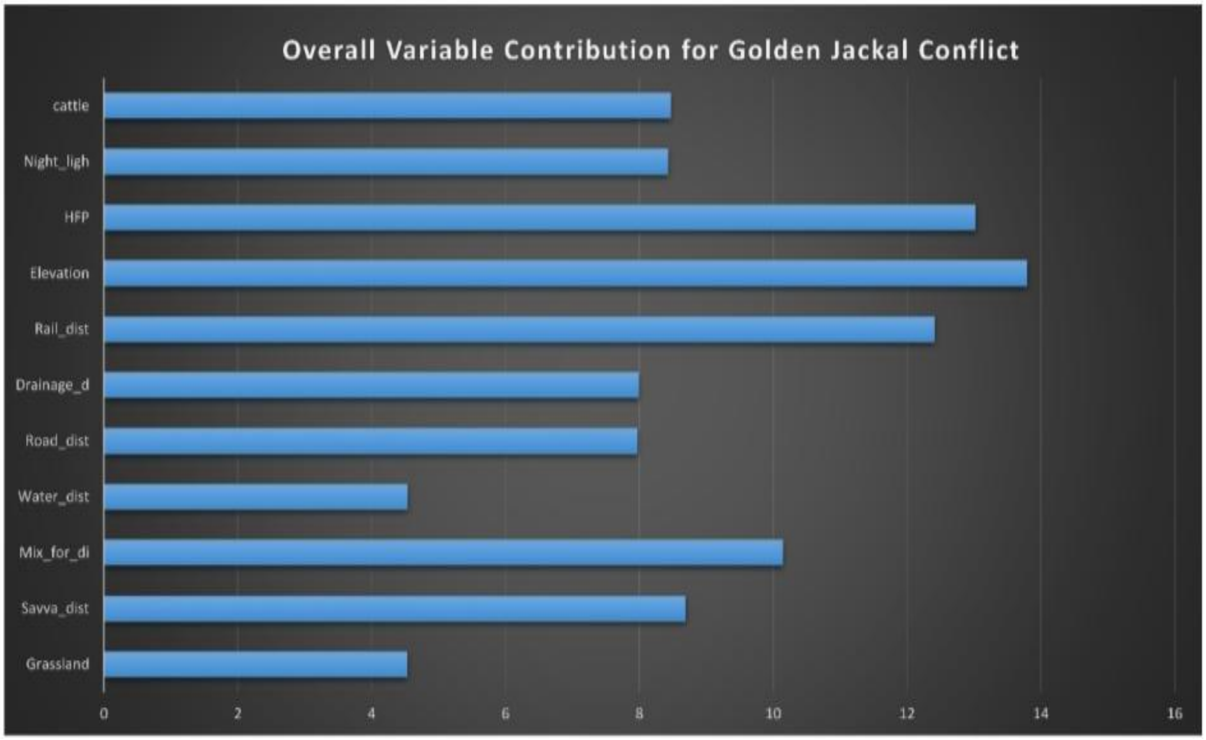


Figure 4.42 - shows the overall variable contribution in the final Generalize Linear Model for Golden jackal conflict risk prediction, where the data was trained by 70% of the crude data.

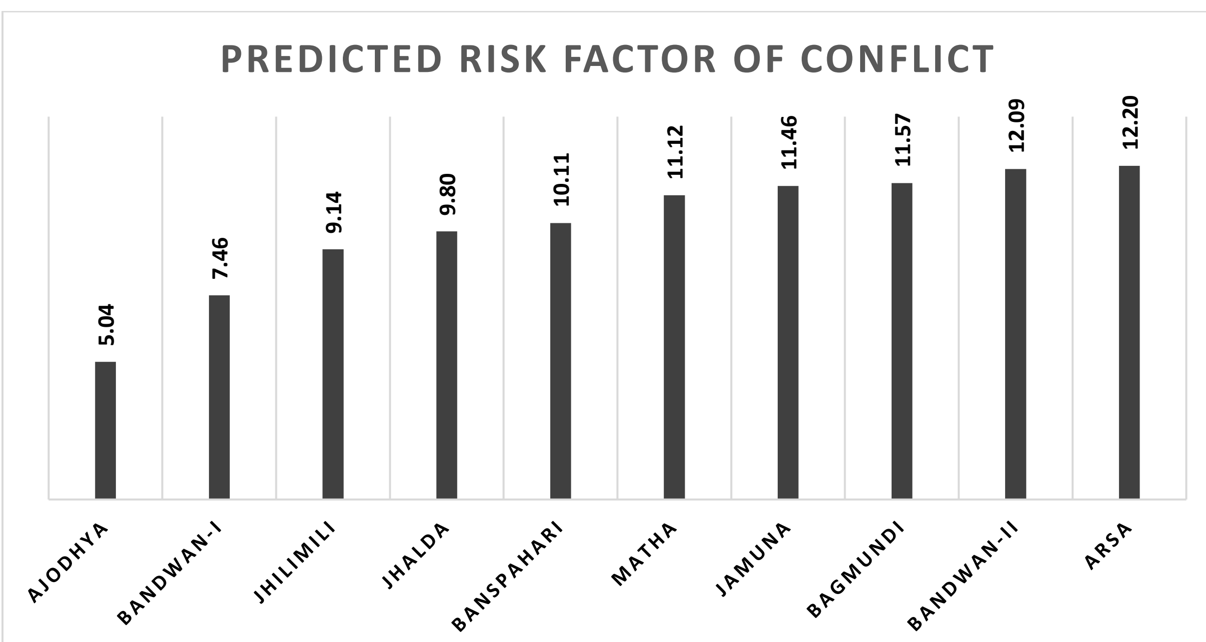


Figure 4.43 - Predicted risk factor of conflict by Golden jackal in forest ranges of South Bengal landscape.

iii). Wild Boar-human conflict zones

Being a generalist species the spatial pattern of Wild Boar -human conflict indicates that most of the conflict hot sports were located in the western regions to Sothern regions, influencing largest portion of the landscape, compared to the rest of the study species (Figure 4.44). Stepwise model evaluation base on AIC based model suggests higher accuracy with lowest score of (AIC=1132.55) with a total of nine predictors variable being selected for the best fitted linear model (Table 4.20). Distance from mixed forest was found to be highest with an estimate score (β= -1.09563) with highest significance value (p=< 2e-16), also suggesting the negative relation with the predictor (Table 4.21; Figure 4.45, 4.46). Among the topographic predictors elevation was found to have a positive correlation with the spatial distribution of Wild Boar -human cases, within the study area with contribution (β= -0.26092). Among the anthropogenic predictors, distance to road, cattle density and night light was found to be the most influential variables with higher significance p=5.54E-13, 0.021705 and 0.000249 respectively. The influence of anthropogenic predictors i.e. distance from build-up areas was found to be one of the major positive influencer for increasing conflict in the region (Figure 4.46). Results from the comparative zonal mean evaluation within the forest ranges suggests, higher intensity of conflict in Bandwan-II with a mean score of (12.48), followed by Arsa (12.34) and Jamuna (11.92) (Figure 4.47).

Table 4.20 - Evaluation of conflict risk predictive model for Wild Boar.

Model	AIC	No. of Parameters
Ψ(SV + Mix + Water + BU + Crop + RD + Drain + Ele + NL + cattle)	1132.55	9
Ψ(SV + Mix + Water + BU + Crop + RD + Drain + Ele + HFP + NL + cattle)	1133.87	11
Ψ(Grass +SV + Mix + Water + BU + Crop +RD + Drain + Ele + HFP + NL + cattle)	1135.02	12
Ψ(Grass +SV + Mix + Water + BU + Crop + RD + Drain + Rail + Ele + HFP + NL + cattle)	1136.92	13
Ψ(Grass +SV + Mix + Water + CV + BU + Crop + RD + Drain + Rail + Ele + HFP + NL + cattle)	1138.78	14

Note: Model selection by lowest AIC value.Ψ= degree of conflict cases by Wild Boar; Grass = Distance from grassland; Mix = Distance from mixed forest; CV = Distance from Cropland/Natural Vegetation Mosaics; Crop = Distance from cropland; SV= Distance from savannas, BU = Distance from built up areas; Water = Distance from water areas, RD = Distance from roads; Drain = Distance from drainage, Ele = Elevation, NL = Night light data; CA = cattle data; Rail = Distance from Rail lines; HFP = Human footprint data.

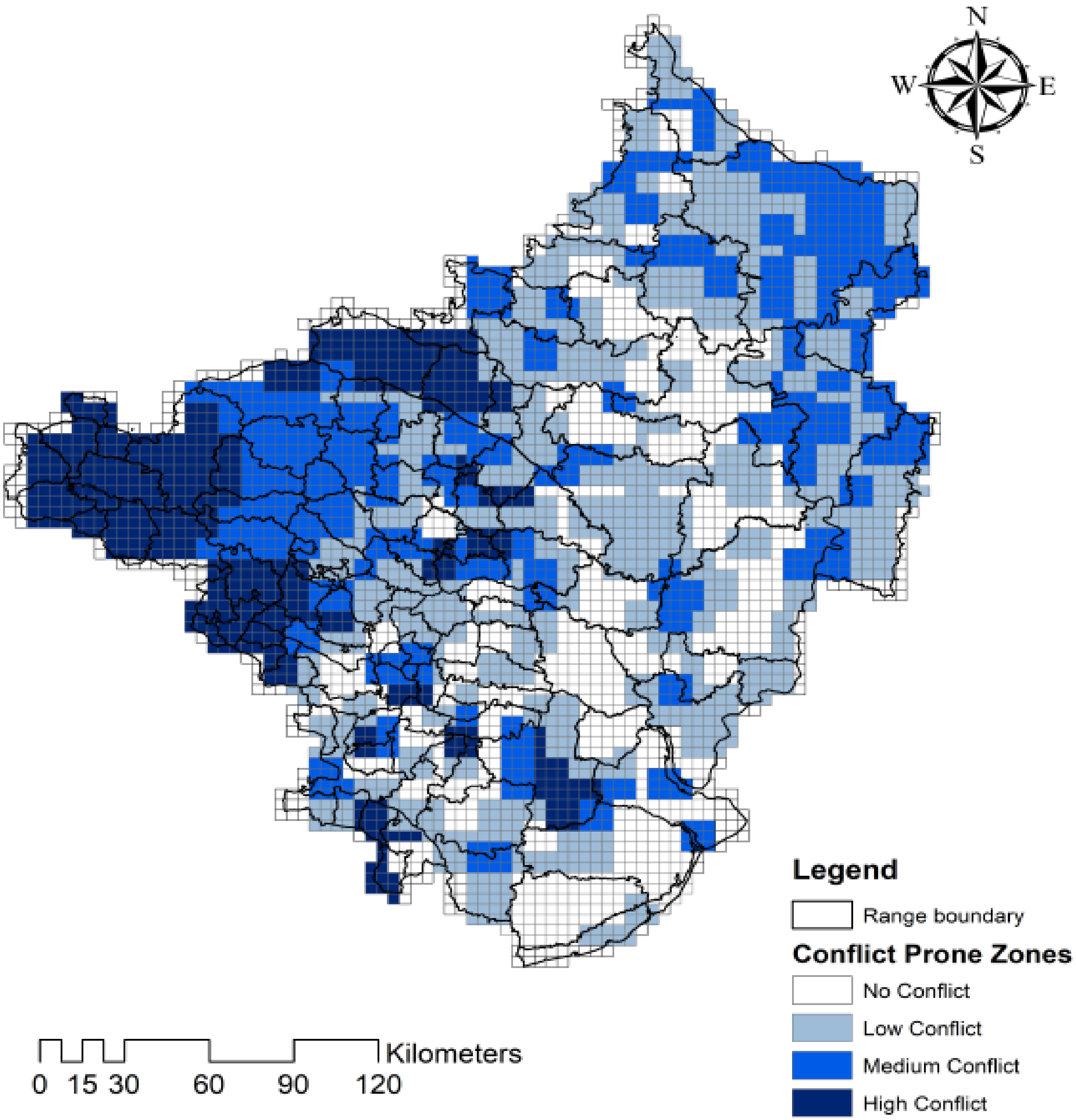


Figure 4.44 - Conflict issues by Wild Boar in the present study area, colour scale denoted the range of conflict reported by local people

Table 4.21 - The evaluated β coefficients values of predictor variables of best model for the conflict probability evaluation.

	Coefficients	Estimate	Std. Error	z value	Sig(p<0.05)
Conflict Risk Prediction model output for Wild Boar	(Intercept)	0.71935	0.07468	9.632	< 2e-16
	Savva_dist	-0.1191	0.05145	-2.315	0.020612
	Mix_for_di	-1.09563	0.10734	-10.207	< 2e-16
	Water_dist	-0.15001	0.05268	-2.848	0.004403
	Builtup_di	0.20175	0.04467	4.517	6.28E-06
	Cropland_d	-0.20526	0.04636	-4.428	9.53E-06
	Road_dist	-0.30019	0.04163	-7.211	5.54E-13
	Drainage_d	-0.10037	0.03846	-2.61	0.009067
	Elevation	0.47472	0.07086	6.7	2.09E-11
	Night_ligh	-0.26092	0.07123	-3.663	0.000249
	cattle	-0.13954	0.06079	-2.295	0.021705

Note: (Savva_dist = Distance from Savanna, Mix_for_di = Distance from mixed forest, Water_dist = Distance from water, Builtup_di = Distance from Builtup areas, Cropland_d = Distance from Cropland, Road_dist = Distance from roads, Drainage_d = Distance from drainage, Elevation, Night_ligh = Night light, cattle).

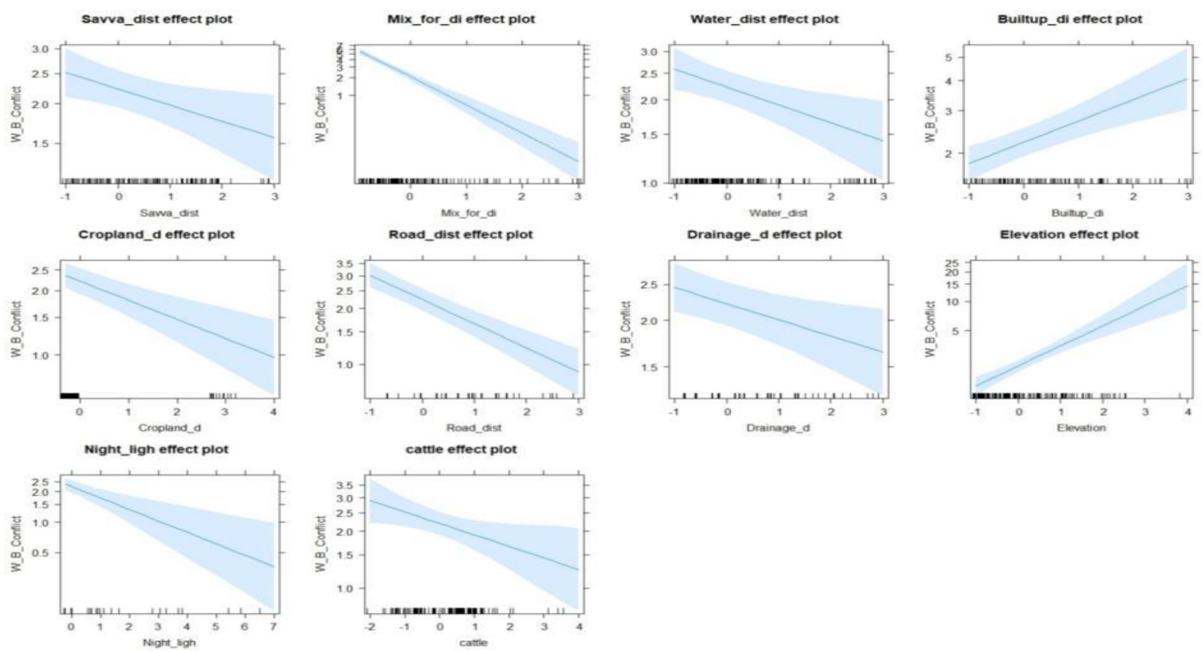


Figure 4.45 - The effects of predictor variables with the conflict risk induced by Wild Boar. (Savva_dist = Distance from Savanna, Mix_for_di = Distance from mixed forest, Water_dist = Distance from water, Builtup_di = Distance from Builtup areas, Cropland_d = Distance from Cropland, Road_dist = Distance from roads, Drainage_d = Distance from drainage, Elevation, Night_ligh=Nightlight,cattle)

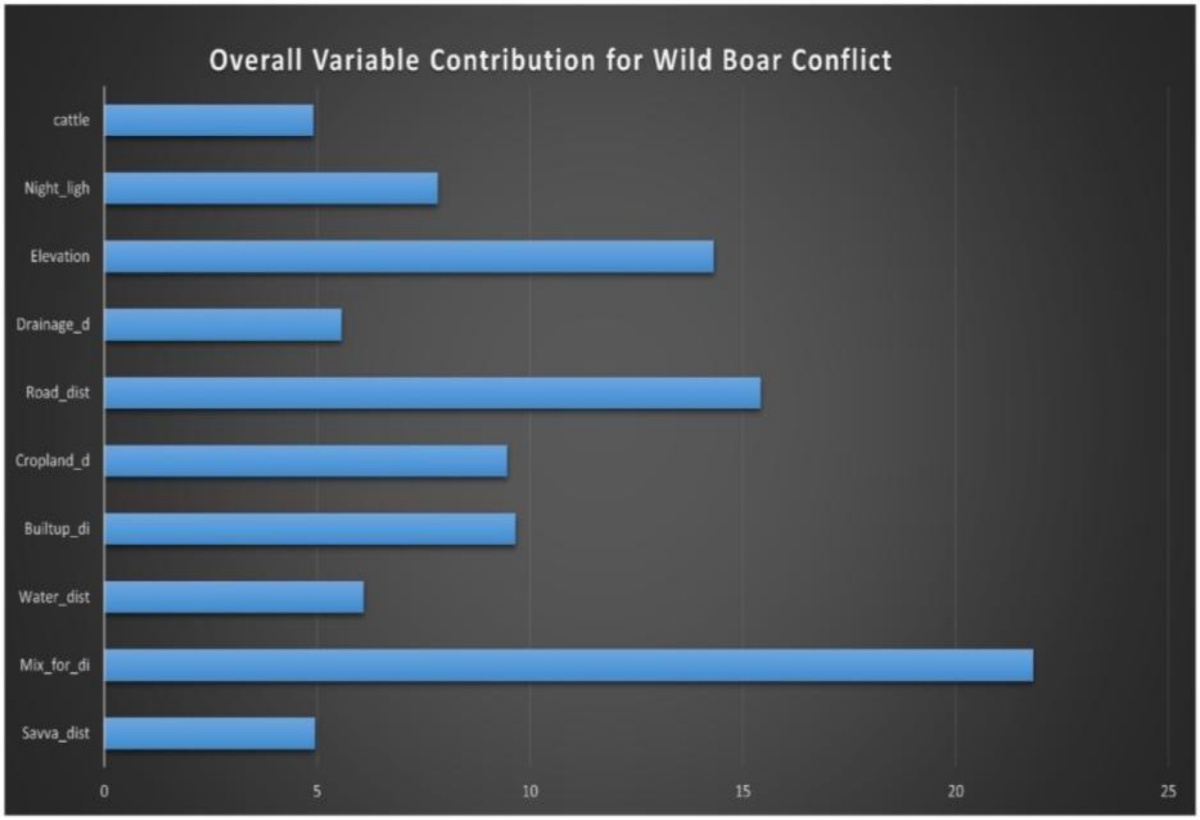


Figure 4.46 - Shows the overall variable contribution in the final Generalize Linear Model for Wild Boar conflict risk prediction, where the data was trained by 70% of the crude data.

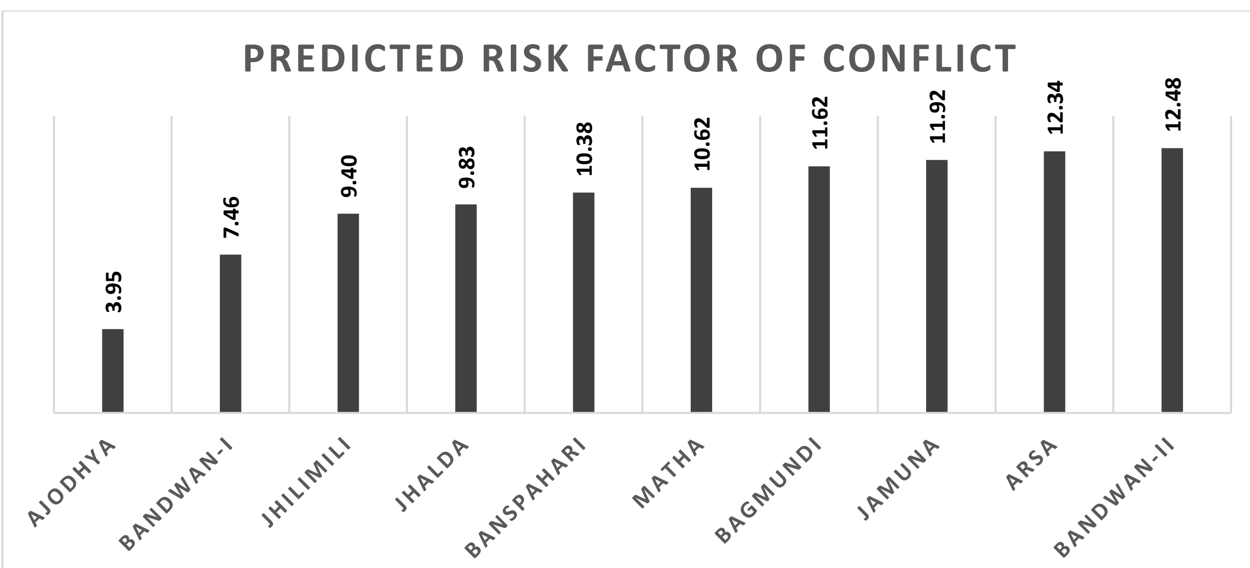


Figure 4.47 - Predicted risk factor of conflict by Wild Boar in forest ranges of South Bengal landscape.

iii). Hyaena-human conflict zones

Restricted by the limited distribution, within the landscape, Hyaena-Human conflict cases in the study area was only being observed in the most south-western portion of the landscape (Figure 4.48). Stepwise model evaluation base on AIC based model suggests mid accuracy with lowest score of (AIC=104.9) with a total of nine predictors variable being selected for the best fitted linear model (Table 4.22). However, it can be noted that due to poor abundance of the species and low distribution points of conflict cases the comparative result suggests low dependency with predictors. Distance from mixed forest was found to be highest with an estimate score (β= -6.024) with highest significance value (p=0.000874), also suggesting the negative relation with the predictor (Table 4.23, Figure 4.49). Among the topographic predictors elevation was found to have a negative correlation with the spatial distribution of Hyaena -human cases, within the study area with contribution (β= 1.6581) (Table 4.23, Figure 4.50). Among the anthropogenic predictors, cattle density and human foot print were found to be the most influential variables with higher significance p=0.007627 and 0.151631 respectively. The influence of anthropogenic predictors i.e. distance from railway lines and build-up areas was found to be one of the major positive influencer for increasing conflict in the region (Figure 4.49). Results from the comparative zonal mean evaluation within the forest ranges suggests, higher intensity of conflict in Bandwan-II with a mean score of (12.35), followed by Arsa (12.20) and Jamuna (11.80) (Figure 4.51).

Table 4.22 - Evaluation of conflict risk predictive model for Stripped Hyaena.

Model	AIC	No. of Parameters
Ψ(Grass +SV + Mix + Water + BU + Crop + Rail + Ele + HFP + cattle)	104.9	9
Ψ(Grass +SV + Mix + Water + BU + Crop + Rail + Ele + HFP + NL + cattle)	105.04	11
Ψ(Grass +SV + Mix + Water + CV + BU + Crop + Rail + Ele + HFP + NL + cattle)	106.54	12
Ψ(Grass +SV + Mix + Water + CV + BU + Crop + Drain + Rail + Ele + HFP + NL + cattle)	108.35	13
Ψ(Grass +SV + Mix + Water + CV + BU + Crop +RD + Drain + Rail + Ele + HFP + NL + cattle)	110.33	14

Note: Model selection by lowest AIC value. Ψ= degree of conflict cases by Stripped Hyaena; Grass = Distance from grassland; Mix = Distance from mixed forest; CV = Distance from Cropland/Natural Vegetation Mosaics; Crop = Distance from cropland; SV= Distance from savannas, BU = Distance from built up areas; Water = Distance from water areas, RD = Distance from roads; Drain = Distance from drainage, Ele = Elevation, NL = Night light data; CA = cattle data; Rail = Distance from Rail lines; HFP = Human footprint

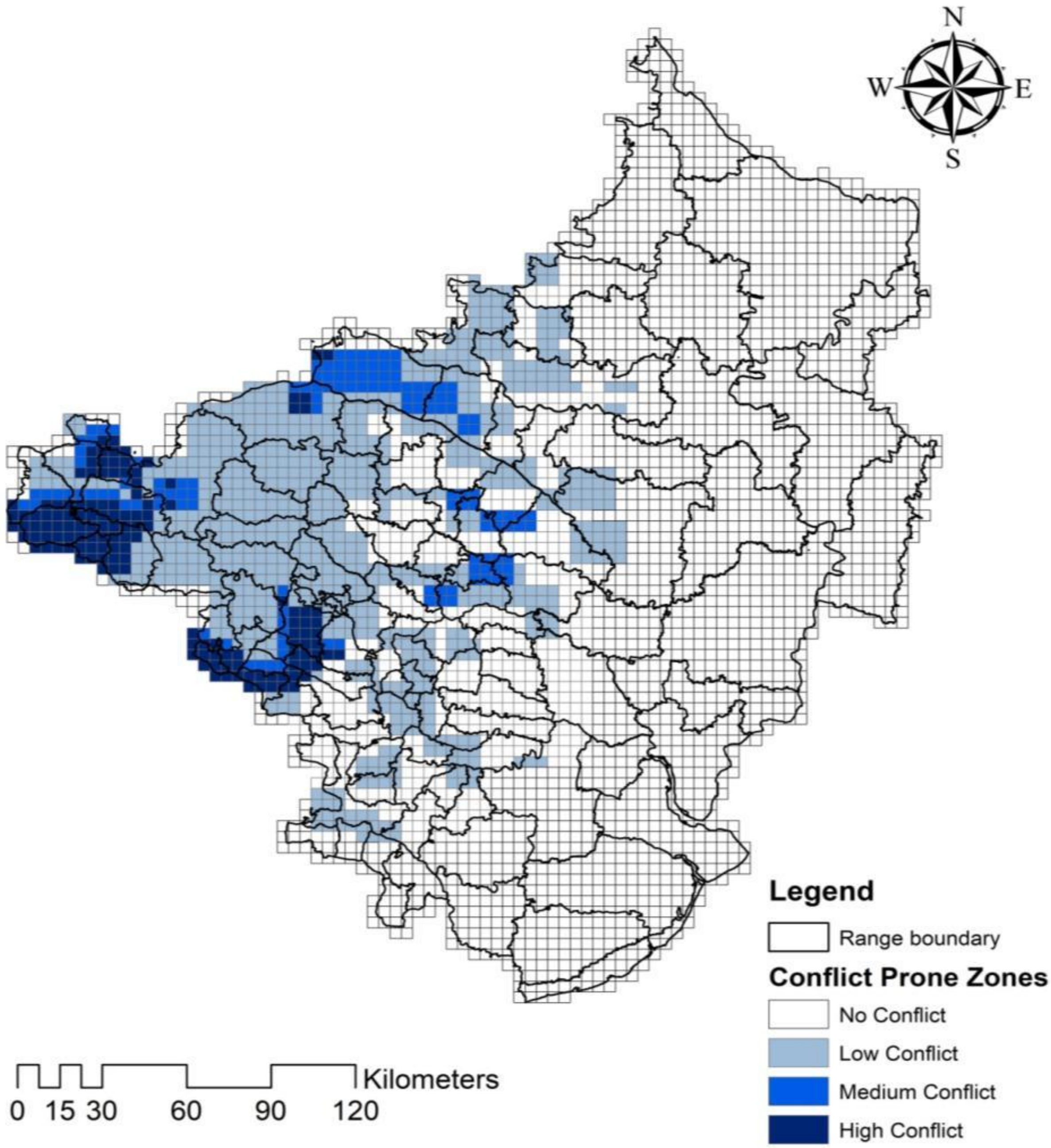


Figure 4.48 - Conflict issues by Hyaena in the present study area, colour scale denoted the range of conflict reported by local people

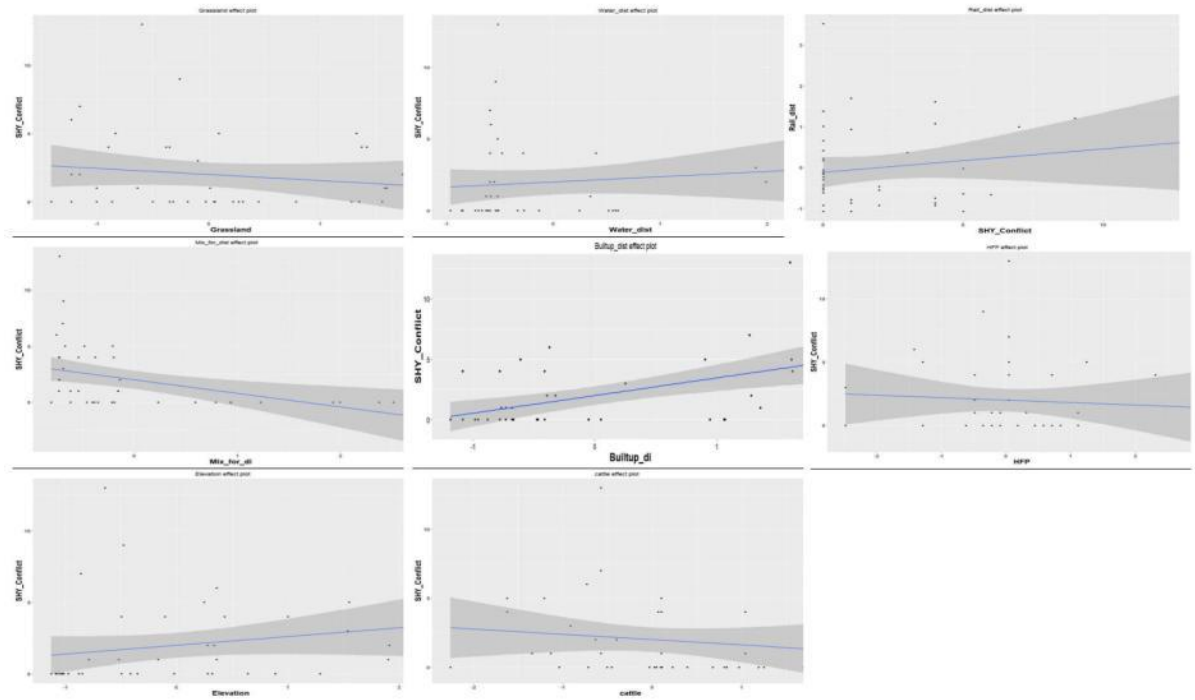


Figure 4.49 - The effects of predictor variables with the conflict risk induced by Stripped Hyaena. (Grassland = Distance from Grassland,Mix_for_di = Distance from mixed forest, Water_dist = Distance from water, Builtup_di = Distance from Builtup areas, Rail_dist = Distance from Rail lines, Elevation, HFP = Human foot print,cattle)

Table 4.23 - The evaluated β coefficients values of predictor variables of best model for the conflict probability evaluation.

	Coefficients:	Estimate	Std. Error	z value	Sig(p<0.05)
Conflict Risk Prediction model output for Stripped Hyaena	(Intercept)	-4.7994	347.9483	-0.014	0.988995
	Grassland	1.255	0.5041	2.49	0.01279
	Savva_dist	-2.0125	1.0874	-1.851	0.064199
	Mix_for_di	-6.024	1.8099	-3.328	0.000874
	Water_dist	-2.9868	1.2852	-2.324	0.020126
	Builtup_di	1.7107	0.6474	2.642	0.00823
	Cropland_d	-7.9637	1101.168	-0.007	0.99423
	Rail_dist	1.156	0.6716	1.721	0.085194
	Elevation	1.6581	0.7726	2.146	0.031868
	HFP	0.3342	0.2331	1.434	0.151631
	cattle	-0.4766	0.1786	-2.668	0.007627

Note: (Grassland = Distance from Grassland, Savva_dist = Distance from Savanna, Mix_for_di = Distance from mixed forest, Water_dist = Distance from water, Crp_nat_di = Distance from crop and natural vegetation mosaic, Builtup_di = Distance from Builtup areas, Cropland_d = Distance from Cropland, Road_dist = Distance from roads, Drainage_d = Distance from drainage, Rail_dist = Distance from Rail lines, Elevation, HFP = Human foot print, Night_ligh = Night light, cattle)

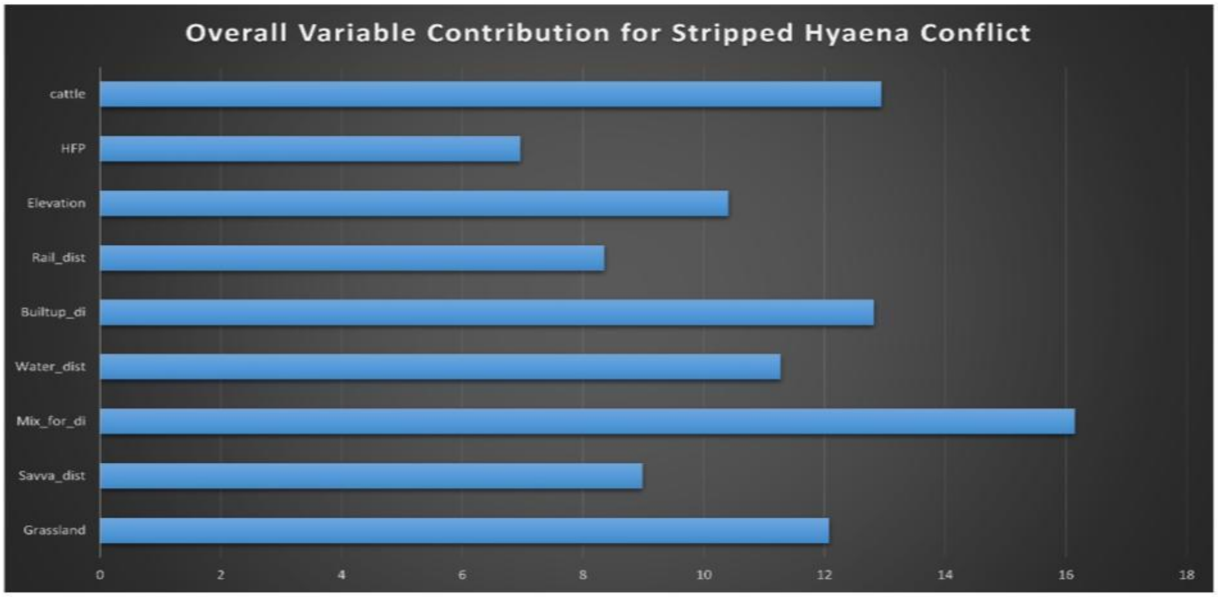


Figure 4.50 - Shows the overall variable contribution in the final Generalize Linear Model for Stripped Hyaena conflict risk prediction, where the data was trained by 70% of the crude data.

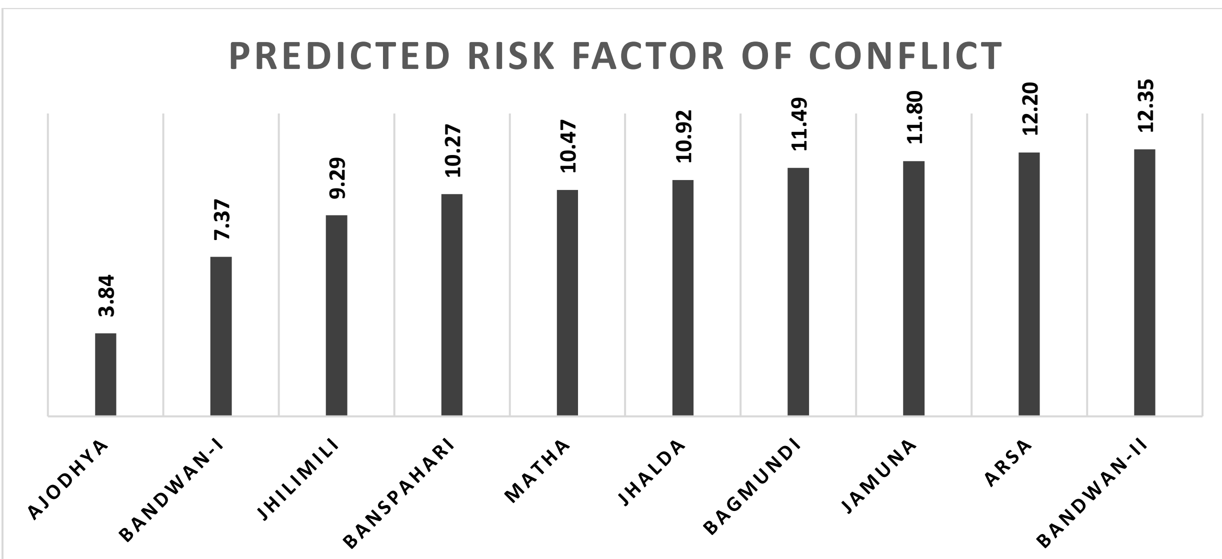


Figure 4.51 - Predicted risk factor of conflict induced by Stripped Hyaena in forest ranges of South Bengal landscape.

4.7. Socio-economic status of respondents in all study districts

The socio-economic analysis indicates that in Purulia majority of the respondents belonged to upper lower class while in other districts (Bankura, Jhargram, West Midnapore, Birbhum, Burdwan and Hoogly) majority of the respondents were falling under lower and upper lower class. In all the study districts not a single respondent was belonging to upper socio-economic class. In Purulia district, 92.62% respondents belong to the upper lower class but the proportion of lower (4.55%) and lower middle (2.83%) respondents were very low. Whereas in Bankura district, higher proportion of respondents belong to the upper lower class (56.78%) followed by the lower (41.15%) and lower middle (2.07%) class. In Jhargram West Midnapore and Birbhum district most of the respondents were from upper lower class i.e. 56.48%, 81.89% and 53.57% respectively. In Burdwan district the proportion of the respondents belonging to the lower and upper lower class were same i.e. 48% while in Hoogly district 61.11% respondents were from lower category and 38.89% were under upper lower class (Figure 4.52).

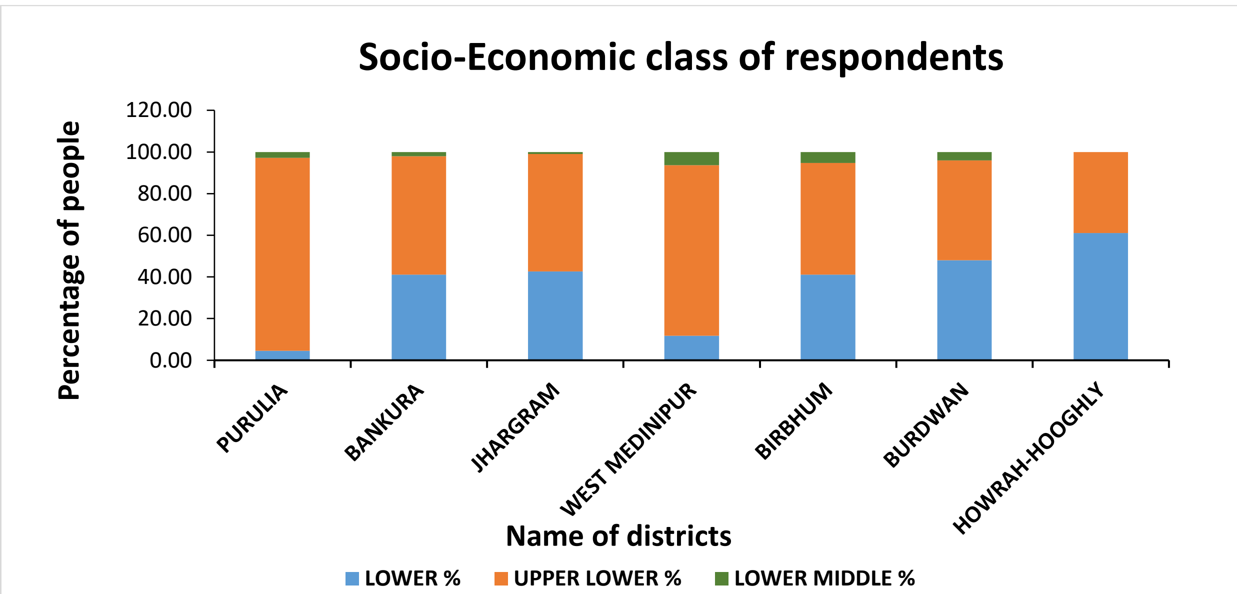


Figure 4.52 - Socio-economic class of respondents in all the surveyed districts

4.7.1. Socio-economic class status of the communities among all study forest divisions

In Purulia district, three forest divisions have been surveyed namely Kangsabati North, Purulia and Kangsabati South forest divisions. Maximum number of respondents was from Purulia forest division and minimum number of interviews was conducted in Kangsabati North forest division. In Kangsabati North Forest Division n=121 respondents were interviewed. As per the Kuppuswamy's socioeconomic status scale, about 93.39% villagers were falling under upper lower category followed by lower middle (4.13%) and lower (2.48%).Whereas, in Purulia forest division out of total n=377 respondents, 87.53% were classified as upper lower class and 8.75% respondents were from lower class followed by very less proportion of lower middle (3.71%). A total of n=315 respondents were interviewed in Kangsabati south forest division. In this division, 98.41% respondents were classified as the upper lower class but the proportion of lower middle (1.27%) and lower (0.32%) class respondent was very low.

In Bankura district, two forest divisions have been surveyed- Bankura North and Bankura South forest divisions. The total number of respondents were n=236 in Bankura North forest division. Respondents were falling under upper lower class (58.05%), lower class (40.25%)and lower middle class (1.69%).A total of n=199 respondents were interviewed in Bankura South forest division where upper lower, lower and lower middle class respondents accounted for 55.28%, 42.21% and 2.51% respectively (Figure 4.53). The Jhargram forest division has been surveyed in Jhargram district. n=108 respondents were interviewed, out of which 56.48% came under upper lower category whereas 42.59% represent the lower class and 0.93% were from lower middle category (Figure 4.53).

In West Midnapore district, three forest divisions have been surveyed- Rupnarayan, Medinipur and Kharagpur forest divisions. The total number of respondents were n=27 in Rupnarayan forest division. In this division respondents were categorized as upper lower class (62.96%) and lower class (37.04%). A total of n=22 respondents were interviewed in Medinipur forest division. Upper lower, lower and lower middle class respondents account for 72.73%, 22.73% and 4.55% respectively n=205 respondents were interviewed in Kharagpur forest division, out of which 85.37% came under upper lower category whereas 7.32% represent both the lower and lower middle category (Figure 4.53).

In Birbhum division. n=56 respondents were interviewed, out of which 53.57% came under upper lower class followed by lower (41.07%) and lower middle category (5.36%) (Figure 4.53). In Burdwan division, two forest divisions have been surveyed- Burdwan and Durgapur forest divisions. The total number of respondents were n=38 in Burdwan forest division and the respondents were falling under upper lower class (52.63%), lower class

(42.11%) and lower middle class (5.26%). A total of n=12 respondents were interviewed in Durgapur forest division where lower and upper lower class respondents accounted for 66.67% and 33.33% respectively (Figure 4.53). In Howrah-Hoogly forest division n=54 respondents were interviewed, out of which 61.11% came under lower category followed by upper lower class (38.89%) (Figure 4.53).

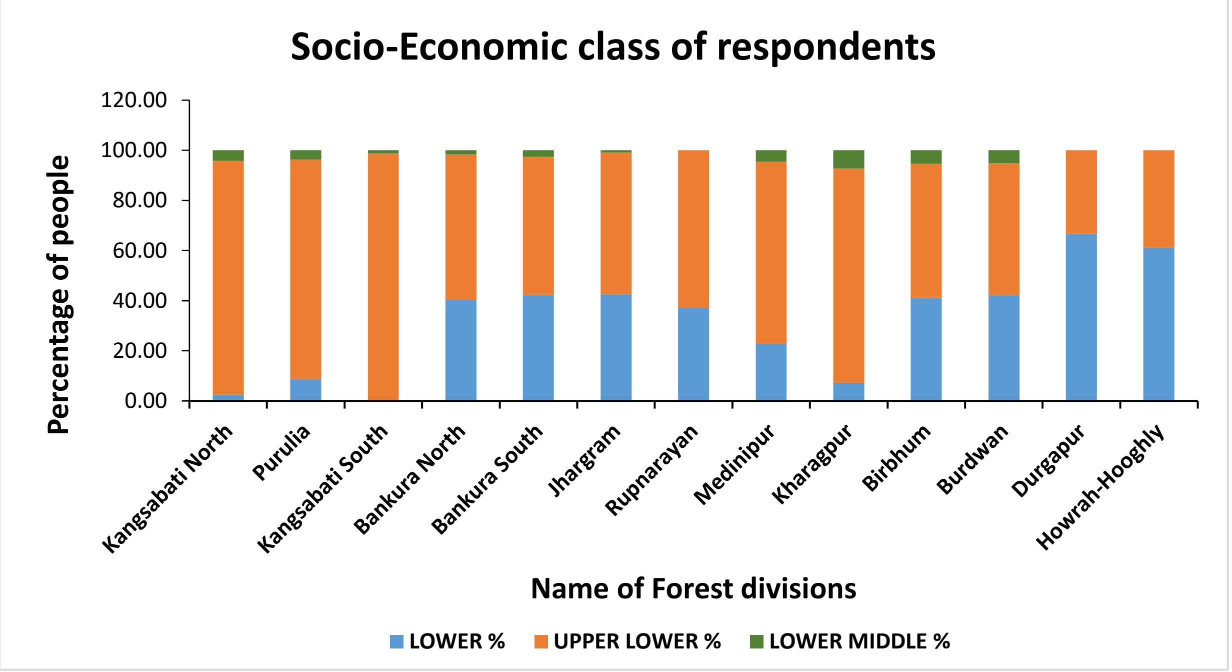


Figure 4.53 - Socio economic class of respondents based on the forest divisions

4.8. Understand the factor influencing the attitude of the local communities towards wildlife conservation

Among the 1770 people surveyed in Purulia, Bankura, Jhargram, West Midnapore, Birbhum, Burdwan and Hoogly district where 72.5% respondents were male and female accounted for 27.5% of the total respondents. Very few proportions of respondents (18%) had positive attitude towards wildlife conservation and rest 82% had negative attitude towards conservation. The age of the interviewees ranged from 18 to 90 years. Regarding literacy, maximum proportion of respondents was Illiterate (44.9%). About 23.9% respondents were Primary School Certificate holder followed by 17.9% Middle School Certificate holder and 8.8% High School Certificate holder. A very few proportion of respondents had Intermediate education i.e. 2% while 2.5% of respondents were Graduate and 0.1% interviewee had Professional degree. The land holding of the respondents ranged from 0 to 2.4 Hectare and a higher proportion of respondents (65%) faced the problem of crop damage. The majority of the respondents took agriculture as their main source of livelihood; hence Semi-field worker (58.3%) while 1.1% were unemployed. Among the respondents 34.1% and 4% interviewee were unskilled worker and skilled worker respectively. Small business holder respondents accounted for 1% and Professionals were 1.5%. Out of the total villagers interviewed, the higher proportion of respondents (75.9%) belonged to Upper Lower class followed by 21% lower class. While a smaller proportion of interviewee belonged to Lower Middle (3.1%).

Generalized Linear Modeling (GLM) was done for tasting the attitude of the respondents towards wildlife conservation which included nine independent variables: Socio-Economic Class, Education, Land Holding, Income, Age, Family Member, Occupation, Crop Damage and Total Livestock. The GLM results showed that out of the nine covariates, socio-economic class, education, occupation, income, family member and total no. of livestock were the main factors that shaped the attitude of respondents towards wildlife conservation. Among these significant parameters except socio-economic class and family member, rest of the parameters was negatively impacting the people's perception. The other factors did not play significant role in predicting the attitude of the respondents. Higher proportion of female (90.34%) respondents had negative attitude towards wildlife conservation than the males (78.88%). Socio-Economic class (β= 0.871, p=0.000), formal education (β= -0.579, p=0.000), occupation (β= -0.222, p=0.010), income (β= -0.277, p=0.000) and family member (β= 0.160, p=0.026) played significant role, as it drives the attitude. The perception also differs with total no. of livestock (β= -0.138, p=0.028) as, most of the respondents were facing the problem of livestock attack by wild animals (Table 4.24).

Table 4.24 - Table provides beta-coefficient of the variables used for understanding the relationship

	Estimate	SE	Wald	Significance	
(Intercept)	1.925	.2971	41.979	.000	
Socio-Economic class	.871	.2488	12.252	.000	*
Education	-.579	.0667	75.350	.000	*
Occupation	-.222	.0863	6.623	.010	*

Crop Damage	.122	.1625	.564	.453	
Land holding	.097	.0766	1.605	.205	
Income	-.277	.0596	21.554	.000	*
Age	-.056	.0713	.619	.431	
Family member	.160	.0716	4.978	.026	*
Total no. of livestock	-.138	.0628	4.842	.028	*

Chapter 5. Discussion

5.1. Discussion

The geo-spatial analysis for assessing the distribution of the study species indicates that an adjoining area of southern part of Purulia district, South West part of Bankura district and extreme North West portion of Jhargram district that includes some areas of Kangsabati South, Bankura South and Jhargram forest division, has high habitat suitability for all the concerned species. Zonal evaluation of the mean suitability scores suggests, higher suitable regions in Bhulaveda followed by Jhilmili and Banspahari ranges (Figure 4.5). The highest suitable regions for Indian grey wolf was found to reside in Bankura and West Midnapore having 3,040 Km^2 and 2,557Km^2respectively (Table 4.1, Figure 4.6).

Out of total 1407 km^2 most suitable habitat of Golden Jackal in Purulia district was found to be696 km^2 followed by Bankura and Jhargram having 580 km^2 and 131 km^2 respectively. Study depicts that majority of the areas of Jhargram district, have poor habitat for Golden Jackal except the extreme North Western part (Figure 4.10).

Being comparatively generalist species Wild Boar found to utilize almost entire forest division. Total 1297 km^2 area can be considered as highly suitable habitat for Wild Boar with 589 km^2 in Purulia district, 479 km^2in Bankura district and 229 km^2area in Jhargram district. Result from the present study suggest that Purulia forest division of Purulia district, Bankura North and Bankura South forest division of Bankura district can be considered as highly suitable habitat for Wild Boar (Figure 4.14).

In case of Golden Jackal the zonal evaluation analysis of the mean suitability scores suggests, higher suitable regions in Matha (0.57) and Ajodhya (0.57) followed by Chandabilla

(0.54) ranges (Figure 4.9). The highest suitable regions for Golden Jackal was found to reside in Bankura and West Midnapore having 2,341Km^2 and 2,199 Km^2 respectively and East Midnapore, Haora, Nadia and Hugli were found to be less suitable for the species (Table 4.6; Figure 4.10). Whereas for Wild boar the higher suitable regions are distributed in Bhulaveda (0.59) and Chandabilla (0.59) followed by Jhilimili (0.57) ranges (Figure 4.13). The highest suitable regions for Wild boar were found to reside West Midnapore (2,341Km^2) and Bankura (2,532 Km^2). Murshidabad, East Midnapore, Haora, Nadia and Hugli were found to be not suitable for the species (Table 4.5; Figure 4.14).

In case of hyaena the zonal evaluation of the mean suitability scores suggests, higher suitable regions in Ajodhya (0.76) followed by Matha (0.69) ranges of Purulia Division (Figure 4.17). The highest suitable regions for Wild boar was found restricted largely to Purulia district with about 3,022 Km^2 of high suitable area followed by Bankura with only 597 Km^2 area. However, most of the other districts are found to be not suitable for the species (Table 4.7; Figure 4.18). Considering the fact that hyena suitable habitats are very restricted in few ranges it becomes imperative to enhance the protection as well as there is a need to adopt best ways to improve the habitat quality in the areas identified and mapped in the present study. As study by Sharma *et.al.*, (2019) in a large landscape indicates that Chottanagpur plateau region situated in Purulia district, lower Gangetic Plane covering Bankura and Jhargram district has potential biological corridors which wolf may be using. Further, the present results are in consonance with the earlier published study. Previous studies from the study regions also with an opinion that there is a need to enhance awareness among the local communities about the ecological significant of large and meso-carnivores in the study landscape (Sharma *et.al.*,2019). Results from the sign survey indicates that Purulia district has the highest sign encounter rate of Indian grey wolf and Striped Hyaena while in Jhargram, West Midnapore, Birbhum, Burdwan, Nadia, Murshidabad, East Midnapore and Hoogly districts, no evidence of Striped Hyaena is found although based on the questionnaire and field survey in other rest of the forest divisions. However, few respondents of Banshiasol, Shialia, Taldiha, Malam and Nimainagar village reported Striped hyaena conflict. Whereas the Encounter Rate (based on the signs per km) of Golden Jackal and Wild Boar is found to be highest in Hoogly and Bankura district respectively. In Nadia-Murshidabad forest division the sign survey for Golden jackal had been conducted in Bethuadahari Wildlife Sanctuary and the analysis indicates higher abundance of Golden jackal than other places. If we concentrate on the forest division level Encounter Rate, Kangsabati South may have the potential habitat for the survival of Indian grey wolf followed by Jhargram but contrastively no evidence of Striped Hyena was found in Jhargarm. This poor ER of Golden Jackal in Jhargarm, Rupnarayan, Kharagpur, Birbhum, Durgapur forest division suggests the lower relative abundance of the species, due to habitat degradation, and mainly due to high level of conflict with humans and revenge killing. Despite of high level of hunting, high Encounter Rate of Wild Boar is observed in almost all the forest divisions except Nadia-Murshidabad, Howrah-Hoogly and Purba Midnapore.

We used two mitochondrial genes (control region and cytochrome) for identifying species from the collected faecal samples. Of the presumed samples of 193 of grey wolf, 198 samples of wild boar and 79 sample of golden jackal, we generated around 300 good quality sequences i.e. 137 for grey wolf, 107 for wild boar and 56 for golden jackal, and we generated around 158 consensus genotypes i.e. 56 fro grey wolf, 55 for wild boar and 47 for golden jackal. Assigning unique individuals from the non-invasive samples has been the most challenging aspect of the study as many times DNA extracted from faecal samples was often limited or contained potential inhibitors which affected downstream processing required for multiplexing of microsatellite loci and calling of alleles. Since, microsatellite genotyping requires several time PCR optimizations before yielding the final consensus genotypes to be used for scrutinizing the panel of loci for individual identification and population genetic analysis. We experienced many times exhaustion of the template DNAs or the DNAs that we obtained, were either sheared or contained secondary metabolites, plant pigments (in case of wild boar), prey DNAs (in case of wolf and jacakl) or mixed sequences on DNA analysis. These potential hiccups and challenges are often obvious and universally faced by scientists dealing with the non-invasive samples for population genetic monitoring. Thus, we kept an account for all these challenges and standardized PCRs accordingly and generated multiplexes for all studied species. The most important observations on population genetic analysis of three species are as follows:

Indian grey wolf- We generated 137 sequences of control region of Indian grey wolf and at microsatellite analysis, we obtained 22 unique consensus genotypes following the select panel of seven loci (PID sibs= 1.2 x 10-3). The grey wolf population showed relatively adequate genetic polymorphism (Mean He: 0.859; Na: 9.889) and low inbreeding (Mean FiS"0.138). Wild boar - We generated 107 sequences of control region of wild boar from the 198 samples collected, and identified 40 unique individuals from the 55 consens genotype data based on the seven loci having the cumulative probability of identity assuming all individuals (P_{ID} sibs 5.4E-03). The overall estimated inbreeding coefficient (Fis) was high (Fis: 195) and suggested that wild boar population was inbred. There have been a few earlier observations from India, that highlighted hybridization of wild boar with the domestic pig. However, with the limited samples we analyzed, we cannot over rule the hybridization. Golden jackal - We generated 56 sequences of cytb gene of golden jackal and at microsatellite analysis, we obtained 47 consensus genotypes and identified 41 individuals using a select panel of seven loci (P_{ID} sibs= 1.6E-03). The overall diversity estimates suggested that golden jackal population is doing well (mean He - 0.713, and mean Ho - 0.778). The population also did not show any signature of genetic inbreeding.

Genetic monitoring and assessment allow us to identify the risk of extinction in wild population by estimating inbreeding, genetic diversity loss and sub-structuring of the species (Thakur et al., 2015a; Thakur et al., 2015b). In conclusion, genetic assessment and long term non-invasive monitoring of the wildlife may provide great insights and lay foundation for the further conservation and management of the species in wild. So, if manager considers the present study a baseline genetic data of the standing population of three species, we propose the same may be monitored by means of non-invasive genetic approach on a five-year time interval and investigate the similar genetic parameters in order to quantify the loss or gain of the effective population size, assessment of the functionality of corridors that keep the free ranging populations genetically viable and proliferating in degraded landscape.

For making the effective management planning in order to mitigate human-wildlife conflict and for conservation of these species, questionnaire surveys have played a crucial role. In the present study we assess the present scenario of conflict by study species, local people of the forest adjacent villages were interviewed and their point of view on the presence and the conflict caused by these species were recorded. Based on the Kuppuswamy Socio Economic Scale (Kuppuswamy, 1981) analysis the result indicates that the highest proportion of upper lower class respondents are from Kangsabati South forest division of Purulia district, where the maximum proportion of respondents were field worker and semi-skilled. In Howrah-Hoogly forest division though the illiteracy percentage (81.5%) is quite high and most of the respondents are unskilled worker (more than 70%), the willingness among the respondents to conserve the wildlife is high (83.3%) may be because they are relatively less conflicts and majority of reported were associated with Golden jackal only. Among the very few people interviewed in Durgapur forest division, most of them are not agreed to protect wildlife may be due to higher illiteracy percentage. In all the three forest divisions of Purulia district maximum percentage of respondents shows negative attitude towards conservation as the proportion of illiteracy and school dropout in primary level are important factors in shaping the perception. In Bankura North and South division near about 50% respondents are illiterate though more than 60% of them are engaged in different type of unskilled works but the huge conflict with the wild animals make them against the wildlife conservation. Illiteracy might be an important factor behind the very high proportion of negative attitude of respondents in Jhargram, Burdwan and Birbhum, Medinipur and Rupnarayan forest division. Though illiteracy percentage is low in Kharagpur forest division and maximum respondents are engaged in agriculture, almost 70% responses are negative for the conservation.

The Generalized linear model analysis (GLM) was performed to assess the factors associated with the attitude of respondents towards wildlife conservation. The analysis indicates that the most significant contributing variables behind the attitude of the respondents include educational qualification, occupation and income. Educational background of the respondent's plays a major role in Kangsabati North, Purulia and Kharagpur forest division. Occupation was considered as the significant contributor in controlling the attitude of the respondents in Purulia, Bankura North and Jhargram forest division. However in case of Kangsabti South, Bankura South and Jhargram forest division, income of respondents was found to be a significant variable. In Bankura North and Kharagpur forest division land holding was also a significant covariate whereas crop damage and total no. of livestock are the significant factors in Purulia and Bankura North forest division respectively.

The geo-spatial patterns of human-wildlife conflict indicate that almost every forest division is more or less conflict prone. In case of wolf the comparative zonal mean evaluation suggests higher intensity of conflict in Ranibandh with a mean score of (12.01), followed by Bandwan-II (11.81) and Bagmundi (11.43). It can be considered through this geo-spatial pattern, that in Purulia District, maximum high conflict zone are falling under Purulia Division and Kangsabati South division. In case of Golden Jackal the comparative zonal mean evaluation of the ranges suggest higher intensity of conflict in Arsa range with a mean score of (12.20), followed by Bandwan-II (12.09) and Bagmundi (11.57).

Being a generalist species the spatial pattern of Wild Boar-human conflict indicates that most of the conflict hot sports were located in the western to Sothern regions, influencing largest portion of the landscape, compared to the rest of the study species. The influence of anthropogenic predictors i.e. distance from build-up areas was found to be one of the major positive influencer for increasing conflict in the region. The comparative zonal mean evaluation of the ranges suggests higher intensity of conflict in Bandwan-II with a mean score of (12.48), followed by Arsa (12.34) and Jamuna (11.92) (Figure 4.46).

The Hyaena conflict is restricted to few ranges only because of its restricted distribution. Hyaena-Human conflict cases in the study area were only being observed in the most south-western portion of the landscape. Based on the present model it can be noted that due to poor abundance of the species and low distribution points of conflict cases the comparative result suggests low dependency with predictors. The forest ranges falling under the higher intensity of conflict includes Bandwan-II with a mean score of (12.35), followed by Arsa (12.20) and Jamuna (11.80) (Figure 4.50). Based on the statement of the respondents, Indian grey wolf and Golden Jackal attack the livestock most. Indian grey wolf mostly attacks the goats whereas Golden Jackal usually kills the poultry. Moreover, livestock attack is the second most frequently occurring conflict in all these forest divisions.

From the present study, we also assessed the patterns of HWC based on the interviews with villagers living near the forest lands in all the districts of South West Bengal. In these districts most of the surveyed villages are located in and around the forest land along with the agricultural fields. So, these crop lands and human habitation become very prone to wildlife attack because of the high resource availability. Indian Wolves and Golden Jackals were known to prey on livestock, resulting in economic loss of local communities. Sometimes they also keep cows, goats, buffaloes, poultry and sheep for selling purposes and to supplement their income. Our surveys suggest that villagers on a regular basis enter the forest for collection of firewood and non-timber forest products. Though villagers are involved in tree cutting and lopping, they also worship Shal tree (*Soria robusta*), Karam tree (*Nauclea parbifolia*), Banyan tree (*Ficus benghalensis*) and Ashwatha tree (*Ficus religiosa*) during Gram Puja. Moreover villagers also took their livestock to the forest for grazing which increase the probability of direct attack by wild animals. In our present study, HWC have been categorized as crop damage, human attack and livestock attack.

In our present study timeframe, crop damage was reported to be the most common type of wild boar-human interaction. Food attraction might be the primary reason behind the wild boar-human conflict. Agricultural lands that are adjacent to forest lands were the main attraction of wild boars because it serves as a high quantity of instant food. Almost all agricultural land located within and near the forests, was raided by wild boars. As the villagers are mainly dependent on the agriculture, crop depredation by wild boars results high economic losses for farmers. During interviews local respondents claim that wild boars are mostly active during late evening and night and although they are present almost every time of the year but particularly during paddy ripening season, the frequency of conflict increases. They usually feed on paddy, potatoes, tomatoes and tubers. Human attack by wild animal is only reported from Jhargram Forest Division (Shimulganga village) by Indian grey wolf. The active resource sharing between humans and wildlife leads to close HWC (Charoo et al., 2011). Economic losses in the form of livestock depredation and crop damage, influence the negative of local people towards wildlife conservation. According to Aiyadurai 2011, the practice of Wildlife hunting is responsible for Population declination and extinction of some species. Wildlife hunting is being practiced among group of indigenous people in some areas through generations. Wildlife resources are exploited either as food, income, sport or as rituals or cultural practices. Hunting is not allowed legally in India and after enactment of Wildlife Protection Act in 1972, any kind of destruction of wild life is unlawful (Anonymous 1994). But the link between hunting practices and socio-economic needs of local communities is a major cause behind the wildlife hunting. In several districts of South West Bengal "Shikar Utsab" is a ritual practiced annually by the local tribal people during the summer time, which is considered as a traditional right. In this ritual people are involved in the retaliatory killing of animals especially Wild Boar. Wild Boars are killed either to maintain the rituals or as the adequate food for the total village. Many of the villagers have the Perception about wildlife, that it is a never ending resource that cannot undergo extinction. Sometimes in spite of having knowledge about the penalty for killing the wild animals, they become involved in this illegal practice. Moreover, we have also recorded that the local remove wildlife species which are involved in HWC during the Shikar Utsab to minimize economic losses caused by the wildlife species in terms of crop damage and livestock depredation.

The presence of Striped Hyena was reported from the very few places such as Muraddi, Shyampur, Shiulibari, Nanduara, Aakhduara, Keliabali of Kangsabati North Forest Division, Baghbinda, Chaitanyadih, Rangamati, Gopalpur, Nischintapur of Purulia Forest Division, Hurhure of Bankura North and Kansachora, Sidhagora of Bankura South Forest Division. No signs of Leopard cat are found during the present time frame of the survey. However, village communities of villages namely Nanduara of Kangsabati North Forest Division, Gopalpur, Baghbinda, Murguma, Khirabera, Tahadri of Purulia Forest Division and Nanna of Kangsabati South Forest Division, reported the presence of the species in their locality. Based on intensive camera trap study, Indian Wolves were captured in all three districts where camera traps were installed based on the reconnaissance survey. The wolf camera captured from Panchet hill, Raghunathpur Range of Kangsabati North Division; Ona, Jhalda Range of Purulia Forest Division; Kansachora, Simlapal range and Borapocha, Ranibandh range of Bankura South Forest Division; Kodopal, Belpahari Range of Jhargram Forest Division.

A good number of captures of Golden Jackal were recorded from Purulia district under Kangsabati North Division, Panchet hill of Raghunathpur Range under Purulia Forest division, Ichakota and Khoirabera of Baghmundi Range; Kudlung, Rangamati, Matha of Matha Range; Gobria of Ajodhya Range; Ona, Khamar, Hensla, Kiribera of Jhalda Range and Jabar of Kotshila Range. Further in Bankura North golden jackal was also camera captures from Sonamukhi forest of Sonamukhi Range, Markha and Dhabani of Beliatore Range. Whereas in Bankura South Forest Division jackal was also recorded by our camera traps from Krishnapur and Kansachora of Simlapal Range, Chetiashol, Tilbari of Pirorgari Range and Borapocha of Ranibandh Range. The Wild Boar was camera captured from Panchet hill, Raghunathpur Range, Kangsabati North Division; Gobria, Ajodhya Range; Ona, hensla, Kiribera, Jhalda

Range; Gojraidi, Jabar; Kotshila Range of Purulia Forest Division; Barjora and Paboya, Barjora Range; Markha, Beliatore Range of Bankura North and Chetiashol, Pirorgari Range of Bankura South Forest Division. Whereas, the Striped Hyaenas were camera captured from Panchet hills of Raghunathpur Range, Kangsabati North Division.

Chapter 6: Management plan

The present study was conducted in all the districts of southern region of the West Bengal State except the sunderban region. The study successfully generated data on distribution mapping, population assessment, human wildlife conflict hot spot identification and also to under the factor responsible for increasing human-wildlife conflicts in the region.

Identification of threats to study species

Based on the data collected in the present study we have identified a number of threats to the study species given below:-

1. **Habitat Loss and fragmentation:** The landscape configuration analysis implemented for mapping the suitable habitats and biological corridors in the landscape indicates that majority of the suitable habitats of the species are fragmented and are highly vulnerable to loss (Mukjerjee et al. 2021).
2. **Retaliatory killing of Hyaena, Wolf, Wild boar and Golden Jackal**: During the household surveys the respondents have reported the killing/lethal removal of these study animals by them to minimize the economic losses resulted because of the animals. The antagonistic behavior of local communities towards these species is largely because of serious economic losses caused by these species.
3. Poor availability of natural prey species of large predators such as hyaena and wolf.
4. Killing of study animals during the ShikarUtsab by tribal communities as a annuals cultural practice.
5. Lack of awareness among the local communities about the ecology and behavior of the study carnivores species
6. Lethal removal of conflicting individuals to mitigate human-wildlife conflicts.

In a Human dominated resource-poor landscape of south west Bengal, wild animals such as Indian grey wolf, Golden Jackal, Striped Hyena and Wild Boar live in close proximity with humans. The human settlements may serve as the food resources for them because of insufficient natural prey base in forested habitats. In the districts of South West Bengal, crop damage and livestock depredation are major issues which makes human wildlife conflict management a challenging task. The continuous monitoring of the populations and adoption of strategies which are both human as well as wildlife centric is provital for mitigating conflicts and long term viability of the species. Hence, for dealing with carnivore human conflict situations a logical framework is developed which can be used for taking up necessary action with respect to the risk to human and human property from wildlife. The framework classifies the problem into four categories based on the degree of problem and urgency of desired actions (Table 6.1).

Table 6.1 - A framework providing actions with respect to associated risks for dealing with human-wildlife conflict situations in South Bengal region of West Bengal.

Degree of problem	Urgency of action	Individual carnivore behaviour	Recommended management actions	Recommended public communication actions
	no action	The carnivore unaware of your presence is continuing its natural behaviour.	no action	Seasonally provide general information on avoidance of human-carnivore conflict to the local communities.
		If any of the study species is causing damages in human dominated areas (Cropland, human settlements, grazing lands)	damage prevention and basic monitoring to assess the effectiveness of existing damage prevention mechanism	Provide targeted information on why damages happen and how to prevent them including where to get help.
		If any of the study species present in forested area and aware of humans and livestock presence but is not running away and ignoring the presence in the forested habitat	No action, damage prevention is any and also stringent monitoring and patrolling in the area	Provide targeted information to local communities to avoidance human wildlife interactions.
	no hurry	Carnivores are	intensive	Provide targeted

		repeatedly coming close and continuously/ regularly in to human habitations	monitoring, remove attractants and cover (damage prevention), enhance deterrence	information to increase understanding of habituation and food conditioning processes and its consequences; information on avoidance of human-wildlife conflicts
		Provoked carnivores may results in attack (e.g. approaching towards the animal, etc.)	monitoring, damage prevention	Provide targeted information on avoidance of human-wildlife conflicts to the communities and explain causes and possible consequences of the carnivore behaviour on humans, livestock and as well as on wildlife animals.
		Study animal is searching for food or is causing damages close to houses and in croplands	monitoring, damage prevention (remove attractants), deterrence, removal of the unwanted vegetation (cover for the species)	Provide targeted information on avoidance of human-wildlife conflicts to the communities and explain causes and possible consequences of the carnivore behaviour on humans, livestock and as well as on wildlife animals.
	urgent	Carnivore attacks a human after being provoked	Intensive monitoring the trend in population of the conflicting species. If needed in growing population removal of conflicting individuals may be considered.	Provide targeted information on avoidance of human-wildlife conflicts to the communities and explain causes and possible consequences of the carnivore behaviour on humans, livestock and as well as on wildlife animals.

		Carnivore attacks livestock in cattle sheds	The removal of attractants, intensive monitoring and deterrence is preferred in for small populations of conflicting species. But in growing populations 0removal may be considered as the first option.	Provide targeted information on avoidance of human-wildlife conflicts to the communities and explain causes and possible consequences of the carnivore behaviour on humans, livestock and as well as on wildlife animals. The existing compensatory payments for the loss may should be used with procedural ease.
	most urgent	If any of the study species cannot be deterred successfully from residential areas	Intensive monitoring, removal of the study species is most important. A rapid action team of the Forest Department to deal with conflict should be positioned in the area of incidence.	Provide targeted information on avoidance of human-wildlife conflicts to the communities and explain causes and possible consequences of the carnivore behaviour on humans, livestock and as well as on wildlife animals.

Management Goals

A millions of the communities live in close proximity to large carnivores without conflict. However, where human-wildlife conflicts exists the forest management agencies, and other stakeholders should take actions which not only reduce conflict but also reduce the chances of future reoccurrence of the problem. Hence, a useful strategy should address the root cause of conflicts by adopting an integrative strategy accounting the needs and behavior of both humans and wildlife. The strategies may involve direct, indirect interventions or a combination of both the approaches. Therefore, based on the present study we herewith provide human focused and wildlife focused conflict resolving strategies.

1. Human - focused methods to mitigate Human wildlife conflicts

Improve knowledge/ awareness - The data indicates that there is a need to create awareness among the communities about the ecology and behavior of the species. Since, changing human behavior is often necessary to reduce conflicts and it can be achieved by bring the local communities onboard for conservation and management of wildlife in their locality. They develop a sense of ownership when involved in process of actions and planning strategies. Moreover, their involvement in such actions improves their understanding about the species and importance of conservation.

Removal of attractants and avoiding negative encounters - Removal of attractants such as waste, unsecured garbage, livestock carcasses, etc should be the integral part of any action at a fine scale or a village level. This can be done by involving the panchayti raj institutions and the Joint Forest Management Committees of the area. Further negative encounters can be avoided by understanding the behavior of wildlife species and by following the principles of living, working and recreating in carnivore populated areas.

Development planning in landscape- Development of new roads, conversion of forest land to other land use type and any other large scale planned degradation driver should be based on the knowledge about the existing habitats and corridors in the landscape.

Compensation - Ex-gratia payment should be implemented with minimum procedural requirements. The communities should be made aware about the compensation schemes of the government in case of damage and loss done by the wildlife species. Moreover, these ex-gratia payments should be given along with other mitigation efforts. Rewarding the landowner who protect wildlife and its habitat or resolve conflicts non-lethally can effectively contribute towards wildlife conservation.

2. Wildlife - focused methods to mitigate Human wildlife conflicts

Habitat improvement - Large carnivores and other wildlife species moves out of the forested habitats in search of food when enough food resources are not available in their natural habitat. Moreover, easy and high nutritional human food can easily motive and habituate the wildlife species. Hence, there is a need to improve the food resources availability in their habitat and the food attractants in the human habitations should be made wildlife proof or protected. Further, studies indicates that enhancement of key feeding areas far away from human may reduce the attractiveness of food sources near human habitations.

The large carnivores such as wolf are generally a very long ranging species for which they are dependent of corridors which connects their habitats. These corridors are provital for mentioning the genetic viability as well as protect the species from environmental stochasticity.

Aversive conditioning and removal of conflict animals -

The conflict animal found regularly involved in conflicts should be release after aversive conditioning. Such treatments generally involve giving repeated negative (threatening, uncomfortable) stimuli to make their experience bad so the animal will avoid similar situations/interactions. However, removal if necessary can also be done by capturing them and releasing them far from the conflict area after aversive treatment.

6.1. Management action plan

To mitigate human wildlife conflicts and for effective conservation planning a set of recommendation are provided below:-

1. Management action to reduction of livestock depredation by Indian grey wolf, Golden Jackal and Striped Hyena in the study landscape

The present study indicates that livestock depredation is a serious conservation and management issue in the study landscape. Since the wildlife species are occupying forests which are anastamozed with the villages with agro-forestry landscape. Hence the forest fringe communities should be actively involved in implementing any conservation as well as conflict management plan. They are facing economical losses due to the attack of these carnivores on their livestock and hence the willingness for conserving these species reduces among them. Based on the conflict zonation model, some forest ranges are very prone to Human-Wildlife conflict in the form of livestock depredation by Indian grey wolf, Golden Jackal and Striped Hyena. In Ranibandh range of Bankura South forest division, the observed predicted risk factor for Human-Indian grey wolf conflict was highest. Bandwan-II and Jamuna range of Kangsabati South forest division along with the Baghmundi, Matha and Jhalda range of Purulia forest division were also very susceptible to the conflict possibility by the Indian grey wolf. The Arsha, Baghmundi, Matha and Jhalda range of Purulia forest division, Bandwan-II, Jamuna range of Kangsabati South forest division and Banspahari, Jhilimili range of Bankura South forest division accounted for most of the conflict risks by Golden Jackal. On the basis of questionnaire survey in the forest nearby villages, few forest ranges are very vulnerable to Striped Hyena conflict namely Sona mukhi under the Bankura North forest division, Shimlapal, Ranibandh of Bankura South forest division, Raghunathpur of Kangsabati North forest division, Kotshila, Jhalda, Matha and Baghmundi of Purulia forest division. More specifically in these forest ranges supervised livestock grazing is recommended (Chauhan 2003, Charoo et al. 2011). Villagers should be in a group while going to the forest for livestock grazing to reduce the direct conflict probability. However, group grazing might be practices in few areas but it is imperative to motivate the communities to adopt grazing in clusters in agro-forestry landscapes falling under the high conflict zones in the region. The JFMCs/ FPC or other community organizations should be involved in popularizing group grazing in identified or grazing allocated areas.

2. Management action to reduction crop damage from Wild Boar

Wild Boars are one of the most important crop raiders and they are able to thrive in areas which are highly influenced with human activities (Geisser and Bürgin 1998). Agricultural lands are more vulnerable to Wild Boar attack and crop damage is one of the most predominant type of conflict in the forest nearby areas of South West Bengal. This omnivore species usually damages the crop lands while being in a herd especially during paddy ripen seasons. They also feed upon potatoes, tomatoes and other tuber type of vegetables. The conflict zonation model indicated that Bandwan-II of Kangsabati South forest division along with the Bandwan-I and Jamuna range, Arsha, Baghmundi, Matha and Jhalda of Purullia forest division, Banspahari and Jhilimili Bankura South forest division, are at a high risk. In these regions, specifically the most vulnerable crop fields situated in the forest fringe areas, local villager's especially the Forest Protection Committee (PFC) members should be involved in night patrolling to guard the agricultural fields during the paddy ripen seasons.

3. **Creation of Conflict Management Team**

The formation of the proper 'Conflict management team' can mitigate different arrays of human wildlife conflict at forest division levels. The team should comprise of well-trained and well-equipped forest staffs, veterinarians, staff of related departments along with the sincere Forest Protection Committee (FPC) members. Efficient forest guards should be provided with proper arms and amenities for safety purpose. Wireless devices should be given to the members of the management team for instant communication among each other during the conflict events, for taking suitable actions. In these outside protected areas, for monitoring of different conflict areas and different conflict cases, rescue of wild animals (if necessary) and relocation of any captured animals, the establishment of control room is required.

Constitution of Division (Rapid Relief Team) and village level committee: The RRT can be formed to handle the conflict situation, if any conflicting animals attacked or entry reported in the village/town and city. The RRT should be formed with at least seven persons one lead person with the rank of Assistant Conservator of Forests (ACF) or DFO, one veterinary doctor and 5 trained support staff of respective forest division and that too familiar with local area. Whereas, the village level committee (also known as Local Wildlife Squad) need to be formed which respond the village level conflict, and respond for the time being until RRT reach at the site to ensure initial mitigation measures like keeping peoples inside their home, manage crowd and keep animal undisturbed. Further in case, human attack attempted by the problem animal then make an arrangement to send injured person to the hospital. These LWS should be composed of volunteers as per the suggestions of the village head of respective area along with forest department official of the region.

The RRT should be equipped with following items given to deal with HWC.

1) **Tools and equipment's:** While handling the HWC, RRT should be equipped with latest and functional equipment suggested in NTCA's SOP (2013) to mitigate the conflict
   - I. A field van/mini-truck with built in rails for accommodating a trap cage, with space for equipment, attendants and staff.
   - II. A tranquilization kit with drugs for chemical immobilization.
   - III. Taser gun for instant immobilization of the animal.
   - IV. 2 mobile phones for continued communication with the authorities.
   - V. 4 wireless handsets.
   - VI. 2 GPS sets.
   - VII. 1 long ranging night vision for seeing objects in the dark.
   - VIII. A digital camera.
   - IX. 4 trap cages (2 for tiger and 2 for leopard).
   - X. 1 mini-tractor for transporting the cage in rugged terrain.
   - XI. 2 search lights.
   - XII. 2 portable tents.

XIII. Portable hides – which can be set up fast, to be used for persons with tranquilizers

XIV. 2 folding chairs with table.

XV. Hand held audio system.

XVI. Rope and net.

XVII. First aid kits

The ADS should carry a stretcher for moving chemically immobilized animals

2) **Uniform and Protective Gear**: All team member of the RRT staff should be provided with special uniform to make them identifiable during the operation. The RRT staff should also carry special protective gear in case they are likely to deal with big carnivores.

3) **Insurance Cover**: The Forest Department should arrange insurance cover for each member (permanent or contractual) of the RRT against death or injury.

4) **Chemical Immobilization Team:** Chemical immobilisation has now become a requirement for HWC management. Chemical immobilisation is a safe, quick, and painless method of capturing and moving problem animals. One team of expert doctors and field staff should be included in for the chemical immobilisation in case it required. The team will handle the process of capturing animals and safely translocation of animals to wildlife habitat or transit.

5) **Capacity building:** After establishing the RRT each member of team should be trained in handling the conflict issues. These training programmers can be conducted with the support of the National level research Institute and NGOs. Further, the trained RRT should be responsible to trained the local level team and should make the local aware about how to deal in the conflict situation. These staff should have equipped with latest tools, equipment's and updated with all the prevention measurements.

6) **Duty List of the RRT**

I. To remove the problem animals from human habitations, croplands and other sensitive areas by managing the local people, or by driving/ scaring the animal away, or by capturing/ trapping/ translocating/ eliminating the animal—in accordance with the merit of the individual case and in keeping with the provisions of law.

II. To rescue wild animals stranded in human habitations.

III. To identify wild animals indulging habitually in human-killing/ crop-raiding/ cattle-killing/ house-breaking; maintain their dossiers; and submit proposals to the DFO / DLC for hunting them under S.11(1).

IV. To help the authorised hunter / trapper /chemical immobilization expert in tracking and locating the problem animals proclaimed by the CWLW / AO under S.11(1).

V. To help the victims of wildlife depredation in getting ex-gratia relief from the competent authority.

VI. To provide first aid to the persons injured by wild animals and help them in receiving medical care.

VII. To conduct inquiry in each case of human-death caused by a wild animal and submit a report to the DFO / DLC.

VIII. To conduct inquiry in each case of wild animal killed during conflict and submit a report to the DFO / DLC.

IX. To supervise fences, trenches and other barriers set up to prevent HWC and inform the appropriate authority about their maintenance.

X. To oversee the status of the recognised wildlife corridors once in a quarter and submit a report to the DLC.

XI. To provide training in conflict-management techniques to Local Wildlife Squads and other stakeholders

4. Habitat improvement in selected sites/ ranges through adopting agro-forestry models.

For the improvement of habitat or modification necessary provisions should be made in the working plan or may be implemented through the other mechanism. During the study we found that there are areas in the landscape which are on the fringe of forest and found suitable for the species based on the model. Such areas (forest land, community lands) should be takeup for habitat improvement by following agroforestry model suitable for the landscape. However a simple example is provide below for the reference.

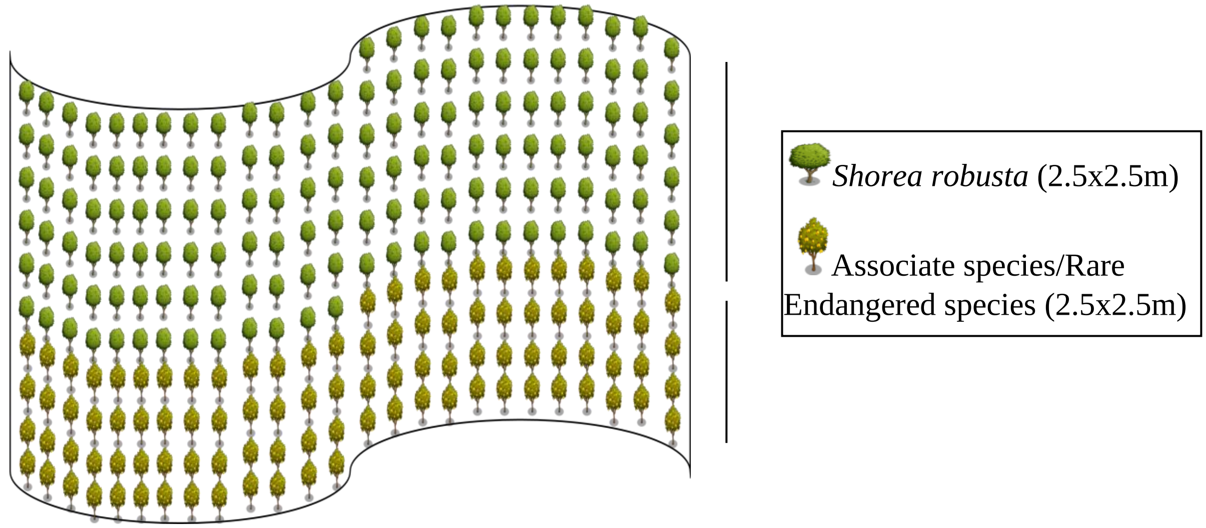
Plantation model 1: South Bengal plantation model for degraded areas

This will involve development of a mixed plantation, *Shorea robusta* (sal) or other prominent species being the main constituent with other natural associates. Sal will be planted in blocks comprising 60% area and miscellaneous spp. to be planted in blocks comprising 40% area. 1,600 plants per ha at spacing 2.5 m x 2.5 m to be followed. The species mixture shall be in strips of 6 lines of Sal alternating with strips of 4 lines of miscellaneous hardwood species. Associates to be planted in groups (preferably 160 – 400 plants per species in each block of 4 lines). For ease of management, number of miscellaneous species in a particular plantation area to be restricted between 6 to10. For *ex-situ* conservation of rare and endangered species a small sub-block (not more than 10% of the area of miscellaneous species) may be planted within the miscellaneous block containing at least 160 plants. The seedlings for this purpose should be supplied by reliable sources in the SFD. The pit dimensions will be length 60 cm at top, 45 cm at bottom, width 45 cm and depth 45 cm.

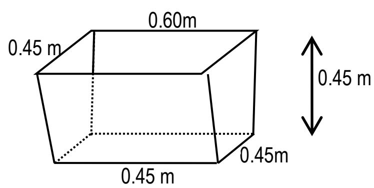
List of illustrative species for plantation

Shorea robusta, Pterocarpus marsupium, Ougeinia oojeinensis, Dalbergia latifolia, Anogeissus latifolia, Syzygium cumini, Buichanania spp.*, Schleichera oleosa, Terminalia arjuna, Terminalia blerica, Aegle marmalos, Ficus bengalensis, Dellenia indica, Ficus hispia, Artocarpus integrifolia, Bauhina perpura, Phoenix spp., Schlerichera trifuga, Diospyros melanoxylon, Bassia latifolia, Butea frondosa, Shorea robustia, Dulbergia spp., Lagerstroemia parvifolia, Tamarindus indica, Calotropis gigantia, Eupatorium odoratum, Ipol1zia cornea, Ocimum camum, Madhuca indica, Terminalia chebula, Acacia auriculiformis, Mangifera indica,* and *Emblica officinalis.*

For providing shade to sal plants, plants of arhar (*Cajanus cajan*) or any local legume species should be sown on the dug up soil of the contour trenches. Boundary demarcation, by planting some species of local bamboo (*Dendrocalamus* spp., *Bambusa* spp.), khejur (*Phoenix* spp.) etc. and even sowing of suitable plants in thick lines, should be carried out.



Plantation Pattern Sal and Associates Species



Plantation pit

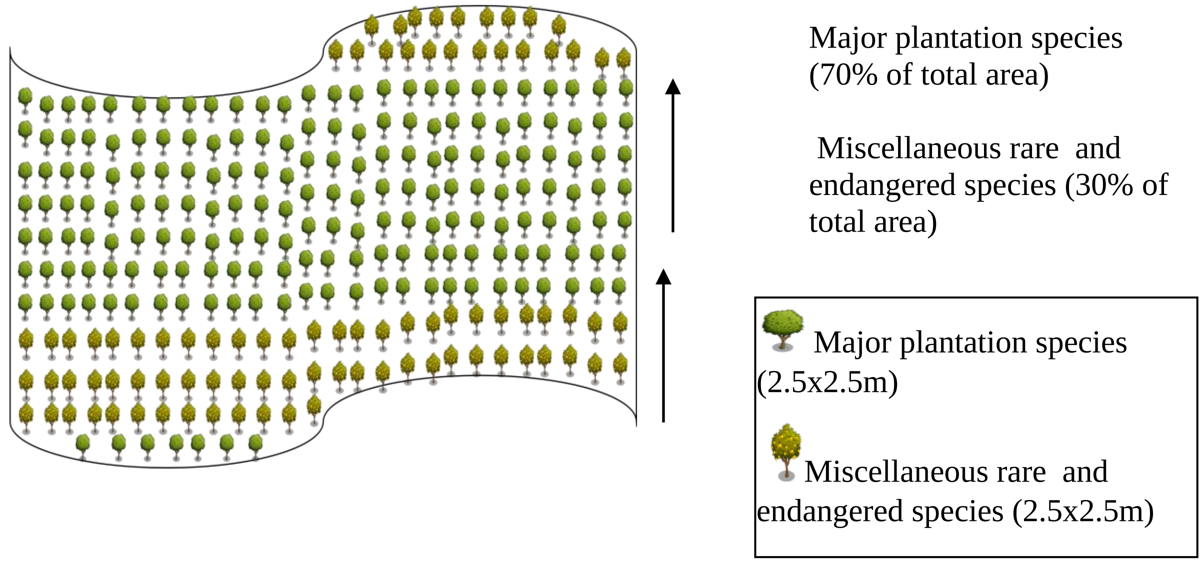
Estimated cost for adopting the model

Model Name				**Miscellaneous species plantation**
Labour rate (Rs./Mandays)				225
Number of plants (/ha)				1600
Establishment	**Advance works**	**Survey & alignment of planting lines**	**Mandays**	3.5
			Cost (Rs.)	**787.5**
		Cleaning of site & making of inspection path	**Mandays**	15
			Cost (Rs.)	**3,375**
		Advance soil work (pit digging)	**Pit size**	
			Mandays	40
			Cost (Rs.)	**9,000**
		Fencing		
		Live Hedge	**Mound**	12
			Cost (Rs.)	**7595**
	Creation		**Cost of plant @ Rs. 40 per plant**	**64,000**
		Carriage of seedlings from nursery to planting site	**Material**	1,600 Seedlings
			Cost (Rs.)	**1,200**
		Transplanting of potted seedlings in pits	**Mandays**	20
			Cost (Rs.)	**4,500**

		Vacancy filling	**Mandays**	4
			Cost (Rs.)	**900**
		Associated activities	Supply of arha seeds	
		Cultural operations (Mulching, weeding, cleaning) (three times/ year)	**Mandays**	34
			Cost (Rs.)	**7,650**
		Cost, Carriage & application of cowdung manure, fertilizers (once a year)	**Mandays**	2
			Cost (material & transportation)	**1450**
			Cost (Rs.)	**1,900**
		Watch & ward (1md/10ha for 6 months)	**Mandays**	18
			Cost (Rs.)	**4,050**
		Contingency	**Cost (Rs.)**	**678**
Establishment Total				**105,636**
Maintenance	**1st year**		**Cost (Rs.)**	**15,884**
	2nd year		**Cost (Rs.)**	**14,884**
	3rd year		**Cost (Rs.)**	**13,884**
	4th year		**Cost (Rs.)**	**12,884**
Maintenance Total				**57,536**
G. total				**163,172**

Plantation model 2: Fast Growing Small Timber, Fuel and Fodder Plantation

This type of plantation strategy will be useful in identified corridors of large carnivores species in the present study. The model involve development of a mixed plantation of fast growing species in blocks, the major plantation species will comprise 70% area and miscellaneous species will be planted in distinct blocks comprising 30% area. The blocks (major species and miscellaneous species) should, however, be contiguous and should not be at a different location. 1,600 plants per ha will be planted at spacing of 2.5 m x 2.5 m. Within the block of miscellaneous spp., pure sub-blocks of each species comprising 160 to 400 individual plants to be planted. For ease of management, number of miscellaneous spp. in a particular plantation area should be restricted to 6. For *ex-situ* conservation of rare and endangered species a small sub-block (not more than 5% of the area of the miscellaneous block) may be planted within the miscellaneous block containing at least 160 plants of a species. The seedlings for this purpose should be supplied by reliable sources in the SFD. Boundary demarcation, by planting some species of local bamboo (*Dendrocalamus* spp., *Bambusa* spp.), palm (*Borassus flabellifer*), khejur (*Phoenix* spp.) etc. and even sowing of suitable plants in thick lines, should be carried out. The pit dimensions will be: length 60 cm at top, 45 cm at bottom, width 45 cm and depth 45 cm.



Fast growing small timber, fuel and fodder plantation

List of illustrative species for plantation

Terminalia bellirica, Terminalia arjuna, Azadirachta indica, Cassia siamea, Holoptelea integrifolia, Calotropis gigantia, Ipomia cornea, *Ficus* spp., *Acacia spp.* etc any other locally abundant food and fodder plant species.

Estimated cost for the Models

Model Name	**Grass and Fodder Tree Plantation**	**Underplanting with Bamboo**
Labour rate (Rs./Manday)	Rs. 216	Rs. 216
Number of plants (/ha)	Grass slips 10,000 plants/ha fodder tree seedlings 100 plants/ha	Bamboo 625plants/ha Fruit plants (if applicable) 100 plants/ha
Total	Rs. 85,700	Rs. 91,700/ha

Estimated cost for model on sal and quick growing plantations

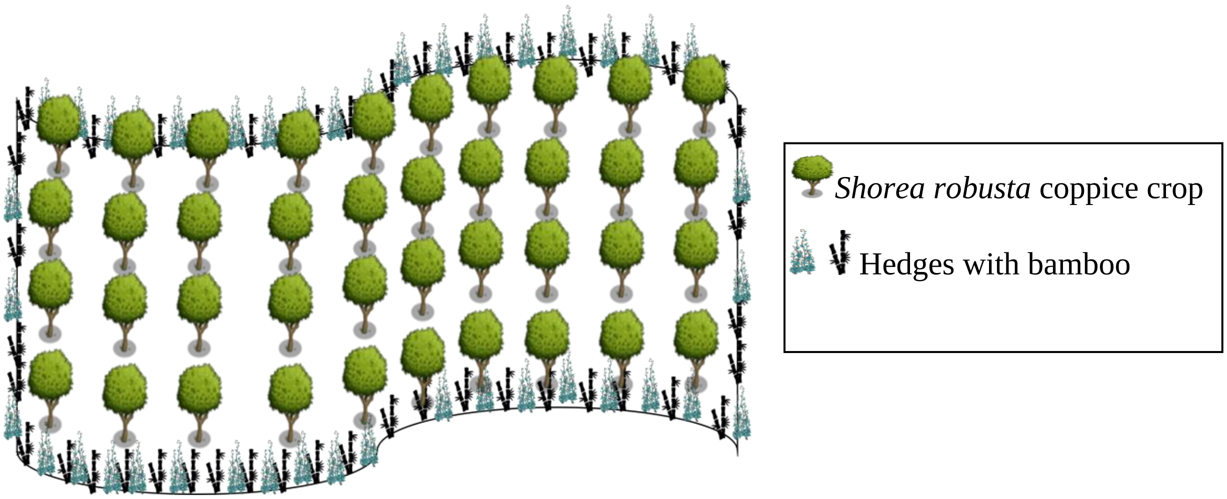
Model Name				**Sal & Associate Plantation**	**Quick growing small timber, fuel & fodder plantation**
Labour rate (Rs./Mandays)				225	225
Number of plants (/ha)				1600	1600
Establishment	**Advance works**	**Survey & alignment of planting lines**	**Mandays**	2	2
			Cost (Rs.)	**450**	**450**
		Cleaning of site & making of inspection path	**Mandays**	15	15
			Cost (Rs.)	**3,375**	**3,375**

		Advance soil work (pit digging)	**Pit size**		(.60+.45)/2X.45X.45 at 2.5X 2.5m spacing (1600 No.)
			Mandays	40	40
			Cost (Rs.)	**9,000**	**9,000**
		Fencing			
		Live Hedge	**Mound**	12	12
			Cost (Rs.)	**7592**	**7,592**
	Creation		**Cost of plant @ Rs. 40 per plant**	**64,000**	**64,000**
		Carriage of seedlings from nursery to planting site	**Material**	1,600 Seedlings	1600 Seedlings
			Cost (Rs.)	**1,600**	**1,200**
		Transplanting of potted seedlings in pits	**Mandays**	20	20
			Cost (Rs.)	**4,500**	**4,500**
		Vacancy filling	**Mandays**	3	
			Cost (Rs.)	**675**	
		Associated activities	Supply of arha seeds	5 kg	
			Cost (Rs.)	**500**	
			Sowing of seeds for nurse crop (500 rmt)	2	
			Cost (Rs.)	**432**	
			Cutting fireline 3 m wide (500 rmt)	4	
			Cost (Rs.)	**864**	
			Digging dug well/ shallow tube well (Labour & material)	30	
			Cost (Rs.)	**6,480**	
			Planting, sowing on boundary including supply & carriage of all material	4	
			Cost (Rs.)	**864**	
			Filling of planting pits with dug up pulverized soil	216	
			Cost (Rs.)	**3,456**	
			Cutting fireline 3 m wide (250 rmt)	2	
			Cost (Rs.)	**432**	
			Planting, sowing on boundary including supply	1	

			& carriage of all material		
			Cost (Rs.)	**216**	
		Cultural operations (Mulching, weeding, cleaning) (three times/ year)	**Mandays**	50	12
			Cost (Rs.)	**11,250**	**2700**
		Cost, Carriage & application of cowdung mauure, fertilizers (once a year)	**Mandays**		
			Cost (material & transportation)	**4,500**	**2,250**
			Cost (Rs.)	**4,500**	**2,250**
		Watch & ward (1md/10ha for 6 months)	**Mandays**	18	18
			Cost (Rs.)	**4,050**	**4,050**
		Contingency	**Cost (Rs.)**	**280**	**594**
Establishment Total				**124,516**	**99,711**
Maintenance	**1st year**		**Cost (Rs.)**	**15,884**	**15,884**
	2nd year		**Cost (Rs.)**	**14,884**	**14,884**
	3rd year		**Cost (Rs.)**	**13,884**	**13,884**
	4th year		**Cost (Rs.)**	**12,884**	**12,884**
Maintenance Total				**57,536**	**57,536**
G. total				**182,052**	**157,247**

Plantation model 3: Restoration of degraded forest in biological corridors of the species

Rehabilitation of degraded forest patches in the suitable habitats of the species will be imperative for maintaining the landscape connectivity as well as it will improve the patch configuration of the landscape which is vital for movement of species. Under the model ut is envisaged to cut the dead, dying, moribund, bent and suppressed coppice shoots of sal, the ground may be hoed around the basal portion of living stump, and mulch, manure and insecticide should be applied. Organic manures and insecticides may be used. Live hedge of *Ipomoea*, *Vitex* and thorny species can be raised along with fence of bamboo posts to protect the young coppice shoots from grazing. This will help restore the sal forests to develop into a more productive forest.



Fencing with bamboo for restoration of degraded forests

Illustrative species for treatment: *Shorea robusta*

Plantation model 4: Multiple shoot cutting for improving the growth of healthy shoots in selected forest management units

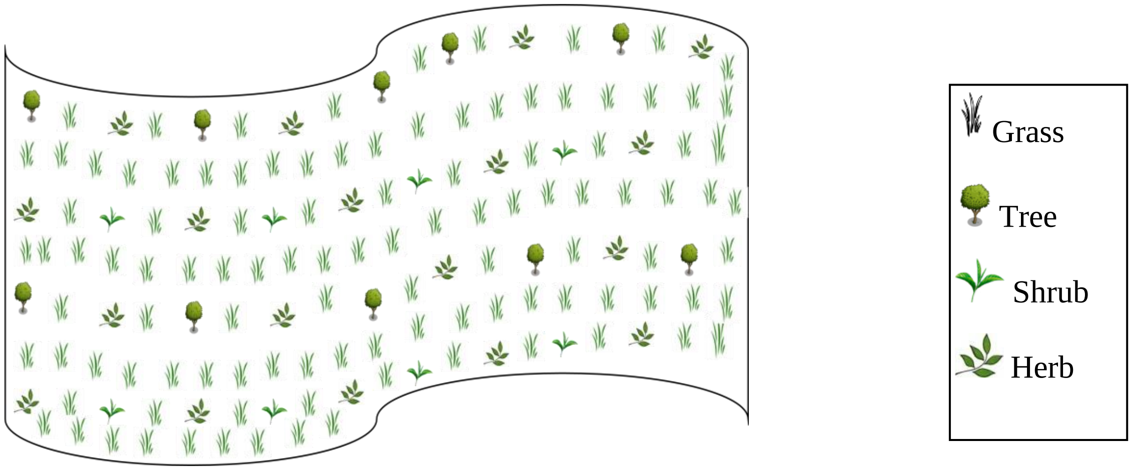
Under this model, the best 2-3 shoots on a stump should be marked and the remaining shoots should be removed. Removal of excess shoots may produce healthy and better quality shoots which may lead to development of trees with better form and improve wood quality of the stand.

Illustrative species for treatment: *Shorea robusta*

Plantation model 5: River or canal side plantation for improving the habitat and creating wildlife refugia.

This model envisages plantation on rivers, rivulets and canals to stabilize the bank by protecting it from soil erosion. In this model, multi-tier planting methods may be used which will utilize the land economically and efficiently. Water loving and soil-binder species should be used. At the ground surface, grasses or surface growers will be allowed to cover and bind the surface soil. At the second layer of vegetation, small to medium sized herbs and shrubs will be accommodated. At the third layer of canopy, small to medium sized trees or larger shrubs, i.e. mainly sunlight loving plants, will be accommodated to cover the crown area. The top canopy should have strong light demanding species like teak (*Tectona grandis*), sal (*Shorea robusta*), neem (*Azadirachta indica*), mahogany (*Swietenia mahagoni*), sisoo (*Dalbegia sissoo*), khair (*Acacia catechu*), jamun (*Syzygium cumini*), arjun (*Terminalia arjuna*), babul

(*Acacia nilotica*), sal (*Shorea robusta*), *Saccharum* spp., bamboo species (*Dendrocalamus* spp., *Bambusa* spp.) etc. which are the dominant species in such areas.



Design for river bank afforestation (multi-tier planting)

List of illustrative species for plantation

Large trees: *Azadirachta indica, Terminalia bellirica, Terminalia arjuna, Syzygium cumini, Pongamia pinnata, Albizia lebbeck, Lagerstroemia speciosa, Grewia asiatica*

Dwarf tree/shrubs/bamboos: *Acacia nilotica, Cassia fistula, Thespesia populnea, Dendrocalamus strictus, Bauhinia purpurea, Nerium oleander, Sesbania grandiflora, Cocos nucifera*

Herbs: *Adhatoda vasica, Ocimum sativum, Wedelia trilobata, Ipomea sp., Stylosanthes* sp.,

Grasses: *Arundo donax, Axonopus campressus, Saccharum munja, Saccharum spontaneum*

5. Habitat improvement in selected sites/ ranges through adopting agro-forestry models.

Considering the fact that much of the area in the landscape is agriculture dominated and forests are patchy in distribution there is a need to adopt agro-forestry plantation models in such areas (forest fringe, common property resource lands) which have been identified as important biological corridors for the species based on our study. The local communities can be convinced for adopting tree based agriculture which will yield multiple benefits to communities and also the forest management. There are established models for the same which are pertinent to the present landscape. Some of them include Anola plantation, sunflower, and Citrus plantation which are reported to be deterrent to animal species such as elephant. Moreover, the plantation of Anola in degraded crop lands is found useful in improving the livelihood of the local coomunities. These types of plantations should be promoted among the local communities which are located on the forest fringe. Importantly citrus plantations found to be useful as elephant repellent and hence can be used in combination with other crops in the identified elephant corridor areas in the study landscape.

Indian Gooseberry known as Aonla *(Emblica officinalis)*, occupying an area of more than 80,000 ha, is an indigenous fruit plant grown in semi-arid regions throughout the country. It is a hardy, low water requiring plant, which can also be grown on marginal and salt affected saline/sodic lands. Aonla can be grown successfully as a sole crop but more profitably in agro-forestry system in the States of Rajasthan, Maharashtra, West Bengal, Gujarat, Madhya Pradesh, Uttar Pradesh and Tamil Nadu. Further, it can be planted in marginalized lands along with other crops to improve the productivity of degraded lands in the study area. There are waste lands in the study region and with the help of Wasteland development corporation such lands can be prioritized with an aim to improve the forest connectivity.

Case study:

Agro-techniques of Aonla Cultivation: Grafted or budded Aonla plants can be planted at a spacing of 10m × 10m (100-110 plants per hectare)using the Pits of 1m × 1m × 1 m size are dug two months prior to planting. In each pit, 3-4 baskets of farmyard manure and 1 kg neem cake or 500 gm bone meal are mixed with soil before filling the pits. A suitable termite control pesticide should be used and the plantation Pits should be watered if there is no rain. The Chakaiya, Banarasi, NA6, NA7 and NA5 are suitable for the region. Though Aonla is hardy and low water needing plant however young plants need watering at 15-20 days interval during winter and at 8-10 days interval during the peak summer.

	
Fertilization of Aonla after harvest of Kharif Bajara	**Mixed plantation of Aonla in agroforestry**

Potential for Up-Scaling the Practice: Aonla cultivation has wide scope of applicability in the semi arid region, salt affected soils and ravines, where crops are unlikely to give sustainable production. In aonla based agro-forestry cereals and pulses can be grown as inter crops up to 5-6 years successfully, which are an attractive preposition for up-scaling the Aonla cultivation in semi-arid regions. This will also help in generating more employment opportunity for the local persons specially women/youth in the region. Also this horticulture crop along with citrus will not be damaged by elephants. The aonla plantations are prescribed in dry regions specially in identified wastelands in the study landscape. A large tract of land patches are available in the study districts such as Bankura, Purulia, West Medinipur which are identified as wasteland. The lands can be prioritized for plantation with an aim to improve the productivity and income generation among the local communities. It is imperative to improve the socio-economic status of the local communities in the study landscape for the long term viability of species and to mitigate human-wildlife conflicts.

6. Fine scale mapping of biological corridors in the landscape for improving habitat and developing alternative corridors in human-wildlife conflict affected areas.

The wildlife populations throughout the country and elsewhere are threatened due to increasing pressure on forested habitats which is leading to destruction of natural biological corridors. The loss of wildlife corridors is resulting in fragmentation of populations and making them vulnerable to further shrinkage and ultimately extinction due to increased likelihood of edge effects and genetic depression. The majority of researchers have attributed species extinction and biodiversity loss to habitat loss and fragmentation which is caused by increasing development activities and expanding human settlements. The planned drivers of degradation including development of road, rail network etc may result in degradation of existing natural biological corridors hence, efforts should be made urgently to map such vital biological corridors which will facilitate in safe guarding the wildlife habitats while developmental activity planning. The biological corridors are vital for the long term survival of species as these corridors facilitate gene flow and provide space for the species for fulfilling their nutritional demands etc. Our results reveal significant overlap between Indian Indian grey wolf and Striped Hyaena suitable habitats in the study landscape, because the Schoener’s D value (0.612) and the Hellinger's-based I value (0.858), are close to 1 and the space use is more or less same.

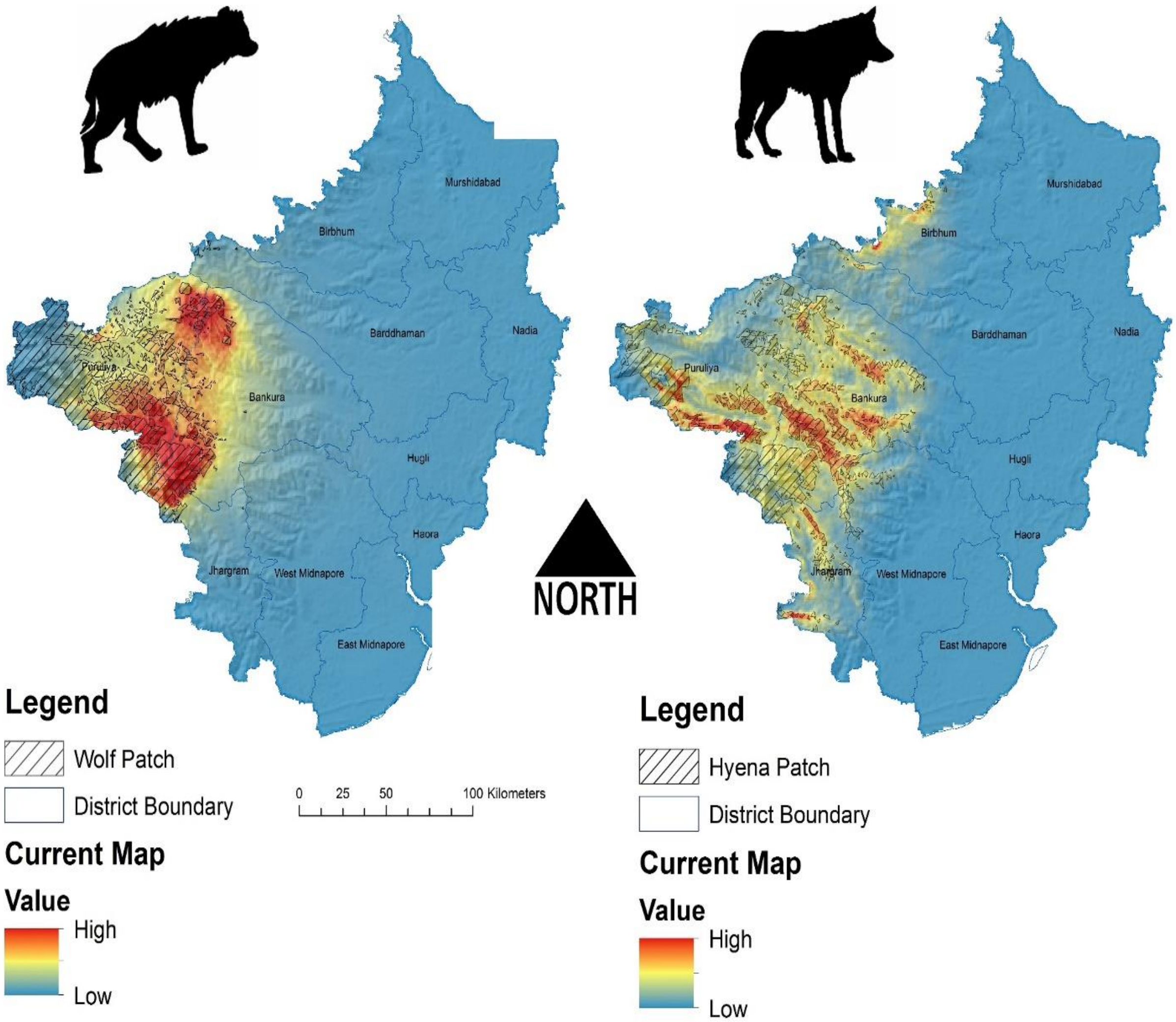


Figure 5.1 - Biological corridor for Hyaena on the left and Wolf on the right side. Colour scale depicting the value of cumulative currect flow between the suitable patches of Hyaena and Wolf, respectively, with Higher connectivity (Red) and Lower connectivity (Blue).

Our model also brought out that much of the suitable habitat of both the species lies within the human – modified lands. Moreover, highest level of biological connectivity resides between the conjunction of Purulia and Bankura district indicating the species negotiates human dominated landscape for movement among suitable habitat patches (Figure 56). Hence, we recommend radio telemetry-based study in the study landscape to better understand landscape utilization and the feeding behavior of both the species.

7. Mass awareness creation among the local communities (nuked natak, distribution of printed material, short videos, school visits).

Through the field study we brought out that there is a need to enhance awareness among the local communities about the importance of wildlife species for their sustenance in the landscape. Creating mass awareness is an important component of wildlife conservation. Sensitizing the public on the importance of wildlife and the role they have to play in conservation and management of wildlife is an inseparable activity of forestry wherein three major objectives are set for awareness creation. Firstly, awareness creation among the public is necessary to make them aware of activities that contribute towards habitat degradation and loss of wildlife. Secondly, it is significant to make the people aware of their role in conservation and management of the nature and its components. The third objective of awareness creation aims at envisaging public support and co-operation for execution of forestry interventions in the landscape.

Awareness activities will be directed towards two target groups - educational institutions and general public. Provisions for awareness campaigns at different levels have to be made, adopting various approaches, tools, mechanisms, and media. The SFDs can adopt various methods like video shows, awareness camps, posters, brochures, pamphlets and booklets, hoardings & sign boards, display vans, advertisements, celebration of important days like World Forestry Day, Wildlife Week, Wildlife Day, Wetlands Day, etc. and wide publicity techniques through mass media communication.

The forest management unit shall conduct awareness campaigns in schools and colleges through Eco-clubs, NSS, NCC or any other mechanism approved by the school authorities both in Government and Private institutions. The CSOs (*Mahila Mandals* etc.) are expected to play vital roles in this priority activity. A video documentary on the ecosystem services provided by the forest and wildlife will be useful in convincing the communities. The video documentary should be developed which will elaborate the socio-ecological significance of the animals, the threats it faces and solutions for conservation and management.

Cost of Awareness Programmes in entire South Bengal region

Particulars	Cost per annum (Lakh Rs.)	Cost for five years (Lakh Rs.)
Awareness campaigns	8	40
Awareness activities for general public	8	40
Publishing pamphlets, brochures, booklets, signages, boards & hoardings	5	25
Publicity through mass media	9	45
Total		**150**

8. Increase the social carrying capacity

To achieve the conservation goal and increase the local tolerance towards the wildlife presence in the areas there is a need to enhance the bidirectional cooperation, through providing incentive, lucrative livelihood opportunity and adequate compensation allocation if any damage caused by the wildlife species. Further, local need to be inform about the importance of wildlife presence and make them aware that the conservation of nature is not only the responsibility of forest department but locals inhibiting near to wildlife habitats have to actively play role in conservation of wildlife and their habitat. Aside from using various conflict-resolution tools such as fence, deterrent, guarding, and scientific management, boosting social tools is also necessary for enhancing social carrying capacity. Furthermore, economic compensation might be utilized to compensate for the economic harm caused by a conflict. It's crucial to focus on social mitigation by lowering the unpleasant consequences of contacts. Furthermore, to increase the tolerance of locals to wildlife species there is a need to provide some sort of relief when such incidences happened without any delay.

Relief to the victims and support

The families that are victim of the human wildlife conflict need to support financially and other ways of which few of them are mentioned below:

I. Compensation scheme and ex-gratia payments: The loss occurred due to human-wildlife conflict either as livestock and crop depredation, paying compensation to cover the loss of livestock and crop loss (Ogra, and Badola, 2008) will help to conservation and effective mitigation of Human wildlife conflicts. If adequate incentives and compensation amount will be paid against livestock and crops depredation it will increase the tolerance of locals towards the wildlife species. In view of this, the existing compensation schemes need to make smooth, reachable with lucrative amount to cover the losses. During the questionnaire survey, we found that the local peoples at many instances were not aware about available compensation schemes provided by forest department. While some of respondent admitted that application process of compensation sachems is complex and lengthy and they believe that when they go to the divisional headquarters to take advantage of this type of scheme, sometimes their expenditure is more than what they get from the scheme. Thus, considering both time and expenditure involved they do not claim for compensation if their livestock killed by animal. Therefore, it is suggested that the application process and other formalities regarding the compensation claims need to be cleared at range level and other formalities can be completed by the forest department. Furthermore, existing compensation amount need to be revised according to the market price of livestock so victim can make offset with economic losses due to depredation and awareness programme need to conduct in the different villages about the application process and available compensation schemes.

II. Self-insure compassion through insurance for livestock and crop: There are various NGOs (e.g., Tata trust etc) provided the insurance for the livestock in the areas need to be identified. Some of the scheme also available from the government of India under Pradhan Mantri Fasal Bima Yojana (PMFBY) that insured the crops for natural calamities, pests & diseases. However, there will be limitation to consider depredation by wildlife species to consider under the damage by pests. Whereas for livestock (cattle/buffalos) loss the West Bengal Government can provide the livestock insurance in which 60% insurance premium cost for the APL families shared by the government and 40% shared by beneficiaries and in case of the BPL families the amount share is 80% and 20% under the mission of the National livestock mission. Further, human medical/life insurance need to be promoted in the areas under the Ayushman Bharat Scheme of government of India to avail the medical facilities in the such condition.

III. Medical treatment during the human attack: Person who is victim of the Human wildlife attack should be provided supported in terms of treatment cost. Further, some instant relief to the victim can be aided:

a) If any villager is lost due to an attack by a wild animal:

1) As quickly as practicable, appropriate economic compensation should be paid in accordance with state regulations.

b) If any villager is injured due to attack of wild animal:

1. He/she should be transported by ambulance to the nearest hospital while receiving first-aid treatment.

2. Innovative insurance policies that recognize the medical necessity of such victims should be encouraged.

c. In case of damage to property.

1. In case the only available house to the family is lost, they should be provided with alternative shelter in the same village.

2. In case, a commercial property was damaged, innovative subsidies should be encouraged that guarantees the economic compensation of such loss.

d) In case of damage to crop.

1. The owner should be compensated as per the clause of state for any damage come across through the wild animals.

iv. Community involvement: To mitigate conflict local communities need to be involved in conservation activities, conservation mitigation and other livelihood activities. Lucrative incentive plans, hiring people for the various conservation related activities and adopt manpower from locals in conflict mitigation. Furthermore, people from the villages can be hired for the village chaukidar or guard for the live guarding and appropriate amount can be paid to them for sustaining the livelihood of locals and also for developing positive attitude among them towards wildlife conservation.

9. Other remedies as per the local communities may be considered for the management plan.

Most of the agricultural lands that are intruded by Wild Boars come under the high conflict zones. Medicinal plants such as *Ocimum tenuiflorum, Andrographis paniculate, Azadirachta indica, Justicia adhatoda* can be grown to the surroundings of these cropfields, so that visibility of the crops such as paddy, tomato etc. can be reduced. The crop lands become less vulnerable to the Wild Boar attack as they naturally avoid feed upon these medicinal plants. Besides, the areas which are not suitable for growing medicinal plants, can be fenced by barbed wire. It is recommended that, the setting up of the electric fencing should be done in supervision of the management team. Based on the questionnaire survey done among the local villagers, we found that the income of the respondents has a pivotal role in describing their perspectives towards wildlife conservation. The villagers having willingness to save wildlife and who have comparatively higher income should contribute for the electric fencing. If 10% money of the fencing costing will come from the villager's side, their responsibility and liability towards the maintenance and protection of fencing will be maintained. The discussion between the Forest Department of West Bengal and the local communities can evolve several strategies to raise financial resources for building night shelters and proper fencing at highly affected villages.

After crop damage the second most prominent type of conflict is livestock depredation in the districts of South West Bengal. Most of the attacks on goats and sheep occur either during grazing time or the wild animals capture them directly from the courtyard at night time almost everyday. To overcome this problem, a proper night shelter should be constructed which must have metal doors, firm and durable walls with appropriate locking system. In village sides, livelihood of many people depends on poultry farming. But the poultry farms are more prone to attack by Golden Jackals and Jungle Cats. To evade this problem the cages should be made very strong and surrounded by double layered metal net.

Although Striped hyenas are confined to some particular areas but there are several cases can be found where they are injured or sometimes killed by road accidents. Being a tourism area, the roads adjacent to Panchet Conservation Reserve are always busy with traffic which increases the probability of road accidents especially at night as Hyenas are nocturnal in nature. If the connection between Panchet hill and the nearby roads are fenced with barbed wires then the movement of wild animals can be restricted to some extent. Proper road lighting in this stretch is needed along with the widening of the road. A specific speed limit of the cars should be enforced in this particular area and strict actions must be taken against the rule breakers. Local people as well as tourists are seen to enter into the forest any time between early morning to late evening which increase disturbance in forest areas. From the camera trap data, it is evident that Hyenas are mostly active from the early evening, hence it increases the probability of direct conflict. So, there should be a particular timing between the entry and exit from the forest.

There are many instances of direct human attack by wild animals (such as Indian grey wolf, Striped Hyena, Wild boar). These incidents have negative impacts on villager's outlook which often drive them to harm or kill the animals. If the concerned department will take the responsibility of the treatment of local villagers who are wounded by the wild animals, the magnitude of agitation among them can be reduced.

Unemployment is a common problem in most of the village areas, especially among the young generation. If some young people having atleast the basic school education and willingness to save the wildlife, are included in the conflict management team, it can serve the purpose of their employment also.

According to N. Behdarvand et al. 2014, Indian wolves prefer to live in close proximity with human settlements. It is seen that in most of the cases the wild animals intrude into the human settlement because of the scarcity of the natural prey within their wild habitat. So some prey species can be introduced to these forest areas. As in our study area most of the forests are fragmented it can raise the risk of habitat degradation, hence a proper planned afforestation can improve the habitat quality.

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Plates from field

CAMERA TRAP IMAGES OF STRIPED HYENA

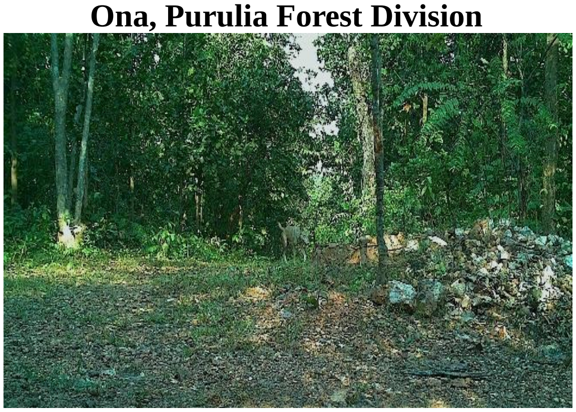
Panchet, Kangsabati North Forest Division, Purulia

CAMERA TRAP IMAGES OF INDIAN GREY WOLF


Panchet,Kangsabati North Forest Division

Ona, Purulia Forest Division

Kansachora, Bankura South




Borapocha, Bankura South Forest Division


Kodopal, Jhargram Forest Division

CAMERA TRAP IMAGES OF WILD BOAR

Panchet, Kangsabati North

Barjora, Bankura North

CAMERA TRAP IMAGES OF GOLDEN JACKAL

Ichakota, Purulia Forest Division

Krishnapur, Bankura South

CAMERA TRAP IMAGES OF OTHER SPECIES FOUND

Barking Deer, Jabar, Purulia FD

Barking Deer, Matha, Purulia FD

Porcupine, Panchet, Kangsabati North

Ruddy Mongoose, Hensla, Purulia FD

Jungle Cat, Jabar, Purulia FD

Small Indian Civet, Barjora, Bankura N

Palm Civet, Sialpahari, Bankura South

Rhesus Macaque, Aamjharna, Jhargram

FIELD ACTIVITIES

Camera Trap installation at Purulia Forest Division

Camera Trap installation and data collection

Questionnaire data collection

Scat sample collection

STUDY LANDSCAPE

Gondhudih at Purulia Forest Division

Pitidiri at Purulia Forest Division

Popo at Kangsabati South Forest Division

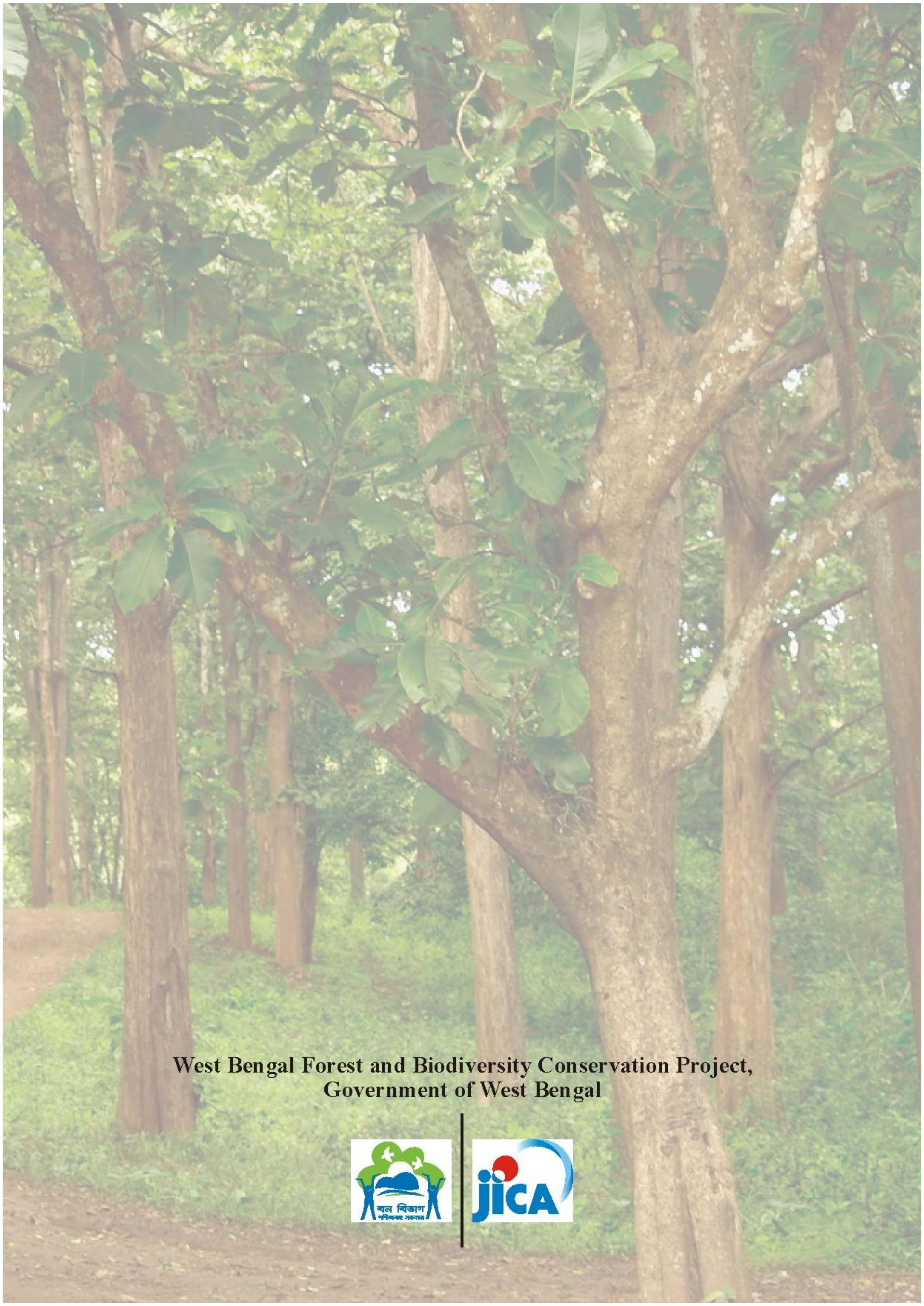
Panchet at Kangsabati North FD

Ranibandh at Bankura South FD

Amjharna at Jhargram Forest Division

Lalgarh at Medinipur Forest Division

Nijkasba at East Medinipur FD


West Bengal Forest and Biodiversity Conservation Project,
Government of West Bengal